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# Droop based Control Strategy for a Microgrid

By Soha Mansour, Mostafa I. Marei & Ahmed A. Sattar
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*Keywords: distributed generation, droop control method, microgrid, smooth transition, voltage control.*

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# Droop based Control Strategy for a Microgrid

Soha Mansour [α], Mostafa I. Marei [σ] & Ahmed A. Sattar [ρ]

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*Keywords: distributed generation, droop control method, microgrid, smooth transition, voltage control.*

## I. Introduction

The implementation of distributed generation (DG) has been highly increasing. Compared to the conventional centralized power generation, DG units have many advantages such as higher energy utilization efficiency, flexibility in installation location, and less power transmission losses. Nowadays microgrid is one of the most up-to-date and important topics in the scope of power systems [1]. The microgrid concept was first proposed in the USA by the Consortium for Electrical Reliability Technology Solutions [2].

A microgrid is defined as a cluster of DG units and loads, serviced by a distribution system, and can operate in 1) the grid-connected mode, 2) the islanded (stand-alone) mode, and 3) ride-through between these two modes [3].

Islanding; which is the separation of the microgrid from the main grid, may be either planned or accidental. Appropriate detection of such incident is essential to be able to operate the microgrid properly, as well as tracking the changes in both steady state and dynamic characteristics of the microgrid to successfully implement the adopted control technique. The basic functions of a microgrid are [4]:

1. Regulating the microgrid's voltage magnitude and frequency within their normal ranges during autonomous mode.
2. Controlling active power and reactive power flow from DG units to loads while working in autonomous mode.
3. Managing power flow between microgrid and the main grid during grid-connected mode.
4. Providing a smooth transition between islanded mode and grid-connected mode.

Most DG units are connected to the microgrid through DC/AC inverter interface. Thus, by proper control of those inverters, microgrid energy management is sufficiently accomplished. The fundamental control variables of a microgrid are active power, reactive power, voltage, and frequency. In grid-connected mode, the microgird frequency and the voltage at the Point of Common Coupling (PCC) are predominantly dictated by the main grid. In this case, the major function of the microgrid control is to manage both active and reactive powers produced by the DG units and the load requirements. Injecting reactive power into the main power grid can be used to provide ancillary services such as power factor correction, elimination of harmonics, or voltage control. In some cases, the utility may not permit voltage control at PCC by DG units to prevent interfering with similar actions provided by the utility.

In islanded mode, the microgrid works totally independent. Therefore, this situation is more difficult than being connected to the main grid, as maintaining load-supply equilibrium necessitates the application of precise load sharing mechanisms to adjust and equlibrate any unexpected power mismatches. Neither Voltages nor frequency of the microgrid are still determined by the main grid, thus they must be controlled by the DG units. Power balance is guaranteed either by local controllers using local data, or using a centralized controller that calculates and sends set points to local controllers of various DG sets and controllable loads ensuring that all DG units share in feeding the load in a pre-determined way. Any deviation in the magnitude, phase shift or frequency of the output voltage of one of the DG units can lead to severe circulating currents [5].

For microgrid control, two unique opposite approaches are recognized: centralized or decentralized. In centralized control methodology vast communication among the central controller and local controllers is required. Any loss of communication link or faulty operation of the master unit can shut down the

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entire system [6]. However, in the decentralized control methodology, each unit is controlled using its local controller that receives only local measurements without considering other system variables or other controllers' actions.

Various techniques have been adopted to parallel inverters [7]. They have different architectures and modes of operation. In master/slave techniques, a voltage controlled inverter is used as a master unit to maintain proper output sinusoidal voltage and generate a distributive current command to be tracked by the current controlled slave inverters [8]. Another technique is the current/power sharing where the total load current is measured then divided by the number of inverters to get the mean inverter current. Subsequently, the difference between the actual unit current and the average one is used to derive the control signal for load sharing [8]. The frequency/voltage droop based technique has been accepted as the most popular decentralized control strategy [9]. In this method the inverters operate in parallel with no auxiliary interconnections as the above methods. This technique allows the independent inverters to share the load in proportion to their capacities. In this paper, droop control method is adopted for the proposed microgrid with smooth transition capability between the grid-connected and islanded modes of operation.

## II. Overview of Droop Control Method

The droop control method is based on locally measured data, does not depend on communication signal, accordingly eliminating the difficulties imposed by physical location. The droop method has other advantages such as great flexibility, high reliability, simple structure, easy implementation, free laying, and different power ratings [10].

In power grids, the active power and the reactive power have strong coupling with the frequency and the voltage, respectively [8]. Accordingly, the relationship between the active power/frequency and the reactive power/voltage can be expressed as:

$$f = f_o + K_{Pf}(P_o - P) \tag{1}$$

$$V = V_o + K_{QV}(Q_o - Q) \tag{2}$$

where $f_o$ and $V_o$ are the rated values for the system frequency and voltage, respectively, where f and V are the measured frequency and voltage of the DG unit, respectively, and $P_o$ and $Q_o$ are the momentary set points of the active and reactive power references of the inverter, respectively, and P and Q are the measured active and reactive powers, respectively, $K_{Pf}$ and $K_{QV}$ symbolize the droop coefficients which are chosenrelying on steady state performance criteria [5],[11],[12]. The droop coefficients are calculated from:

$$K_P = \frac{\Delta f}{P_{max}} \tag{3}$$

$$K_Q = \frac{\Delta V}{Q} \tag{4}$$

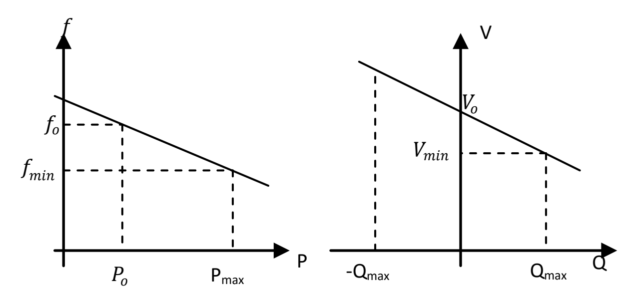
where $P_{max}$ and $Q_{max}$ are the maximum active and reactive powers delivered by the inverter, respectively, $\Delta f$ and $\Delta V$ are the maximum allowable frequency and voltage magnitude deviations, respectively. According to the EN 50160, $\Delta f$ should be within ± 2% of the nominal frequency, while $\Delta V$ should not exceed ± 10% of the nominal voltage magnitude [13], [14]. A conventional P-f and Q-V droop characteristics are shown in Fig. 1(a) and Fig. 1(b), respectively. At nominal voltage operating conditions, the DG units are supposed not to deliver any reactive power to the main grid, which means supplying active power at unity power factor in this working condition. In Fig. 1, $f_{min}$ and $V_{min}$ identify the minimum acceptable frequency and voltage of the DG unit, respectively [14].

For several DG units connected in parallel constituting a microgrid, the load power sharing depends on the slope of the droop characteristics. The main idea is that when there is an increase in the load, the frequency reference is decreased. Similarly, reactive power is shared using the droop characteristic of the voltage magnitude. The mechanism of active power sharing based on droop control is [11]:

$$\Delta P_1 K_{P1} = \Delta P_2 K_{P2} = \cdots = \Delta P_n K_{Pn} \tag{5}$$

Similarly, the mechanism of reactive power sharing using droop control is:

$$\Delta Q_1 K_{Q1} = \Delta Q_2 K_{Q2} = \cdots = \Delta Q_n K_{Qn} \tag{6}$$




3(a) 3(b)

*Figure 1:* Conventional droop characteristics (a) P-f droop (b) Q-V droop

## III. The Proposed Control Systems

Two control technique approaches are used to operate the inverter; active/reactive power (PQ) control mode and voltage-frequency (VF) control mode [12]. The inverters are usually operated in PQ mode when the micorgrid works in grid connected status. The references of active and reactive powers for each inverter may be predetermined by several ways, for example using a microgrid central controller or by a local Maximum Power Point Tracking (MPPT) based control strategy. On the other hand, during islanded mode of operation, at least one inverter must be operated in VF mode and synchronized with the main grid, while the other DG units can still be controlled in PQ mode. When the microgrid moves to the islanded mode, the system will be unstable if all the inverters operate in PQ control mode because we have to set up the system frequency/voltage using this VF operated inverter, as well as properly share the load power among all the parallel inverters.

*a) PQ control mode*

The PQ controlled inverter operates by injecting into the grid a pre-specified power defined locally or centrally. Fig. 2 illustrates the block diagram of the droop based control system for the VF inverter to share the load power. The droop equations can be written as:

$$P = P_o + K_{fP}(f_o - f) \tag{7}$$

$$Q = Q_o + K_{VQ}(V_o - V) \tag{8}$$

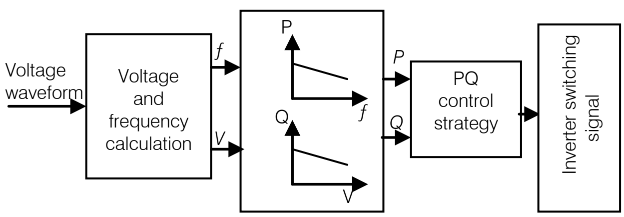



*Figure 2:* Droop based control system for the PQ inverter

The actual voltage and frequency are passed to the droop unit to generate the reference signals for the active and reactive power, P and Q. These references are compared with their actual values and the errors are processed through PI controllers to generate reference direct axis and quadrature axis currents, Idrefand Iqref, respectively, as shown in Fig. 3. The three-phase reference currents, Iaref, Ibref, and Icref, are obtained using the inverse Park transform, dq/abc. The Hysteresis Current Control (HCC) technique is used to produce the appropriate switching signals for the inverters. The HCC is characterized by its fast dynamics, high bandwidth, simple structure, tight and accurate control of current, and excellent transient response [15].

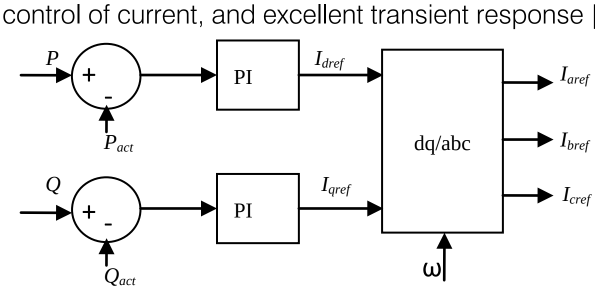



*Figure 3:* Block diagram of PQ inverter control system

*b) VF control mode*

In this case, the reference signals of voltage and frequency are extracted directly from the droop characteristics. The block diagram of the droop control system for the VF inverter is shown in Fig. 4. Inverter output voltage and current are measured, thus calculating active and reactive powers of the inverter and processing them through the inverter droop characteristics represented by (1) and (2) to obtain the voltage and frequency reference, V and F.

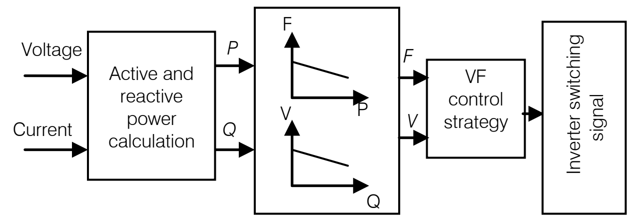



*Figure 4:* Droop based control system for the VF inverter

Fig. 5 displays the block diagram of the VF inverter control strategy. The voltage reference, V, is compared with the actual bus voltage, Vact, and the error processed by a PI controller to produce the modulation index, M. This modulation index along with the reference frequency, F, and appropriate phase shift, δ, are used to generate the three-phase reference voltage for the inverter Varef, Vbref, and Vcref. The SPWM is used due to its simplicity and easy implementation. The reference voltages waveforms are compared with the carrier signal to generate the switching signals for the inverter.

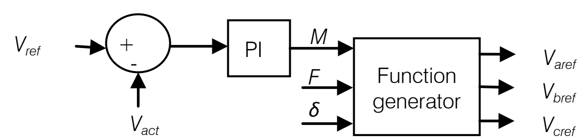



*Figure 5:* Block diagram of VF inverter control system

A smooth transition between grid-connected mode and autonomous mode is required for the reliability of the autonomous microgrid. Smooth transfer implies that the voltage phase, amplitude and frequency of the microgrid do not change abruptly at the transition moment. Accordingly, transient currents are eliminated and the load receives uninterrupted high quality power. To achieve smooth transfer, one DG unit is controlled in VF mode during the grid-connected and islanded mode of operations to set the microgrid voltage, while the other DG units are controlled in PQ mode.

## IV. The Microgrid Under Study

Fig. 6 portrays the single line diagram of the proposed microgrid system with three electronically interfaced DG units. The three DG units are assumed identical. A base load and a switched load are connected to a common ac bus. The microgrid is connected to the utility through a STS. For the sake of simplicity, the DC bus voltage of each unit is assumed constant and equal. The system parameters are listed in Table 1.

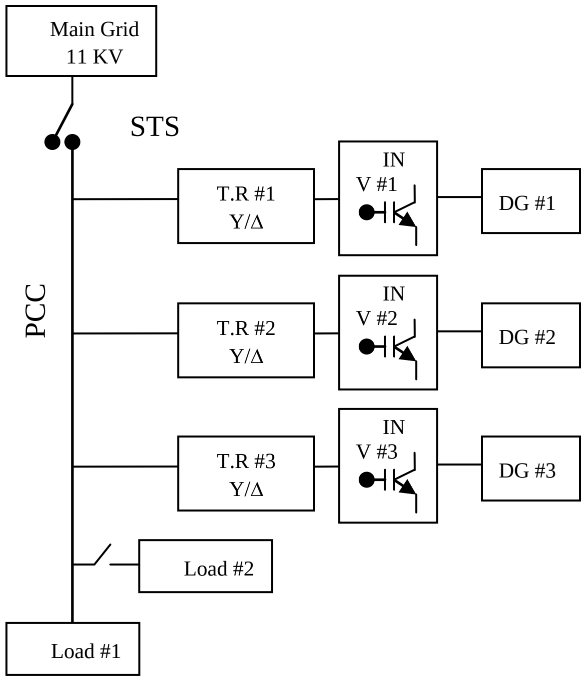



*Figure 6:* Single line diagram of the proposed system.

*Table 1:* System parameters

| Nominal voltage Vo | 11 KV |
|---|---|
| Nominal frequency $fo$ | 50 Hz |
| $K_{Pf1}$ | 10 Hz/MW |
| $K_{QV1}$ | 1.6667 pu voltage/MVAR |
| $K_{fP2,3}$ | 0.1 MW/Hz |
| $K_{VQ2,3}$ | 0.6 MVAR/pu voltage |
| Active power setting Po | 0.1 MW |
| Reactive power setting Qo | 0.03 MVAR |
| Switching frequency | 2000 Hz |
| Filter capacitance | 2 μF |

Inverter one operates in VF control to generate the reference voltage to be followed by the other DG units in the microgrid. Allowing this inverter to work as grid forming in both grid-connected and islanded operation provides the smooth transition required between the two operation modes of the microgrid. On contrary, inverters two and three operate in PQ control during the grid-connected and the islanded operation modes of microgrid.

## V. Simulation Results

The microgrid system presented in Fig. 6 is simulated using the PSCAD/EMTDC software package. The droop characteristics of each unit are adjusted to supply rated active power at rated frequency and zero reactive power at nominal voltage. The dynamic performance of the proposed control strategy is tested under different modes of operations and dynamic load change.

### a) *Grid-connected mode*

In this mode, the main grid dictates its voltage and frequency while the microgrid simply exchanges real and reactive powers. When the load requirement is less than the rated capacity of DGs units, the excess power flows into the main grid. While when the load requirement is greater than the rated capacity of DGs units, the grid feeds the deficit power.

Initially, the microgrid supplies a load of about 300 KW and 150 KVAR as illustrated in Fig. 7(a) and Fig. 8(a), respectively. Figs. 7(c), (d), and (e) indicates that the proposed control system succeeds to equally share the active power among the three DG units of the microgrid. Since the load power equals to the nominal power of the micrgrid, zero active power exchange with the main grid is demonstrated in Fig. 7(b). At t= 1.8 sec, a sudden load increase to 415 KW and 165 KVAR occurs and lasts for 1.2 seconds. Fig. 7(c) illustrates the frequency reference F1ref, obtained from the droop characteristics, of the first DG unit. It is obvious that the actual frequency follows its reference signal. Moreover, the high frequency ripples are reflected in the generated active power P1, exhibited in Fig. 7(c). As the frequency is set by the main grid, each DG unit is supposed to deliver its rated active power regardless the loading condition.

On the other hand, the load reactive power is mainly supplied by the main grid and the filtering capacitors of the microgrid inverters. Fig. 8(c) shows the reactive power fed from the first DG unit, controlled in VF mode. Due to the drop in the grid impedance, the pu voltage at the PPC is lower than unity as indicated in Fig. 8(f). The little PCC voltage drop excites the V-Q droop characteristics of the second and third DG units, controlled in PQ mode, to feed the grid with restraint amounts of reactive power as illustrated in Fig. 8(d) and (e), respectively. Moreover, the reactive powers supplied from the second and third DG units are increased when the load is raised due to the increased drop in the PCC voltage.

These results reveal the success of the proposed droop based control strategy in providing accurate performance for the DG units during grid-connected mode.

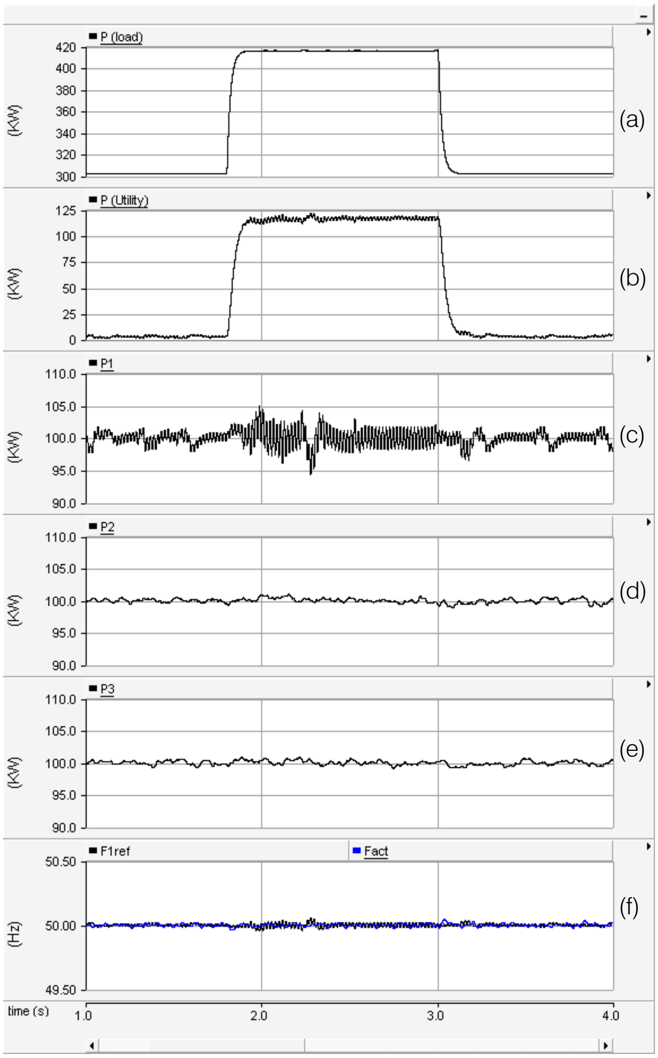



*Figure 7:* Active power of: (a) load, (b) utility, (c) first DG unit, (d) second DG unit, (e) third DG unit, and (f) frequency of the microgrid during the grid-connected mode.

*b) Transition from gird-connected mode to islanded mode*

At t = 4 sec, the static transfer switch disconnects the microgrid from the main grid. Consequently, the microgrid transits to islanded mode. Figs. 9 and 10 show the active and reactive powers of different DG units in the microgrid during transition incident. As seen, the VF control of inverter one during both grid connected and islanded modes of operations offered a smooth transition without the need for detecting the islanding incident. This action provides reliable and continuous operation of the autonomous microgrid.

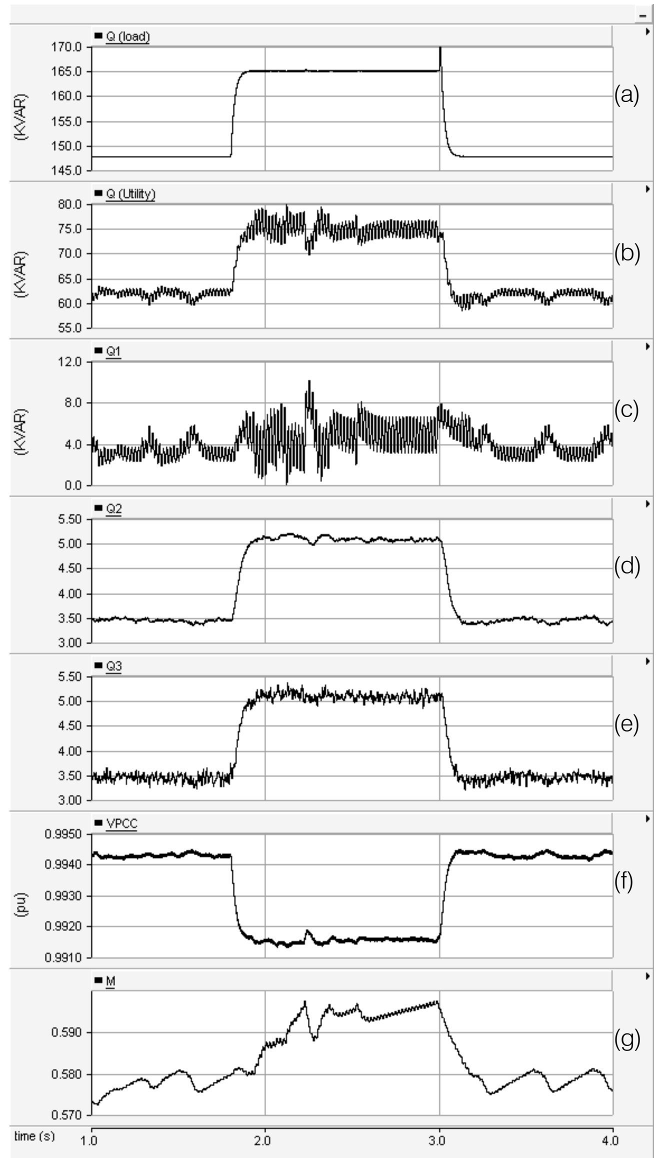



*Figure 8:* Reactive power of: (a) load, (b) utility, (c) first DG unit, (d) second DG unit, (e) third DG unit, (f) PCC voltage, and (g) modulation index of the first DG inverter during the grid-connected mode.

*c) Islanded mode*

In islanded mode, the total power demand of the load has to be supplied by the DG units while regulating the system frequency and voltage. Figs. 11 and 12 illustrate the dynamic behavior of the different DG units in the microgrid. Since the PCC voltage decreases after islanding, as indicated Fig. 10(f), the droop based controllers of the three DGs units increase their reactive power injection to the microgrid as depicted in Fig. 12. In addition, the reduction in PCC voltage results in a little reduction of the load power as shown in Fig. 11(a). In proportional, the injected active power from the DG units are decreased as demonstrated in Fig. 11(c), (d), and (e). In turn, the frequency is lightly increased above 50Hz as shown in Fig. 10(f) and Fig.11(f).

To evaluate the dynamic performance of the proposed microgird system, the load is suddenly increased, at t=6.5 s, similar to that of the grid-connected case and last for two seconds. As shown in Figs. 11 and 12, the system is succeeded again to track the dynamic load change by increasing the DG units output power while maintaining system frequency and voltage within their permissible limits. In addition, equal power sharing between the DG units is demonstrated from the results. Finally, the system smoothly returns back to its initial operating conditions when the sudden load is removed.

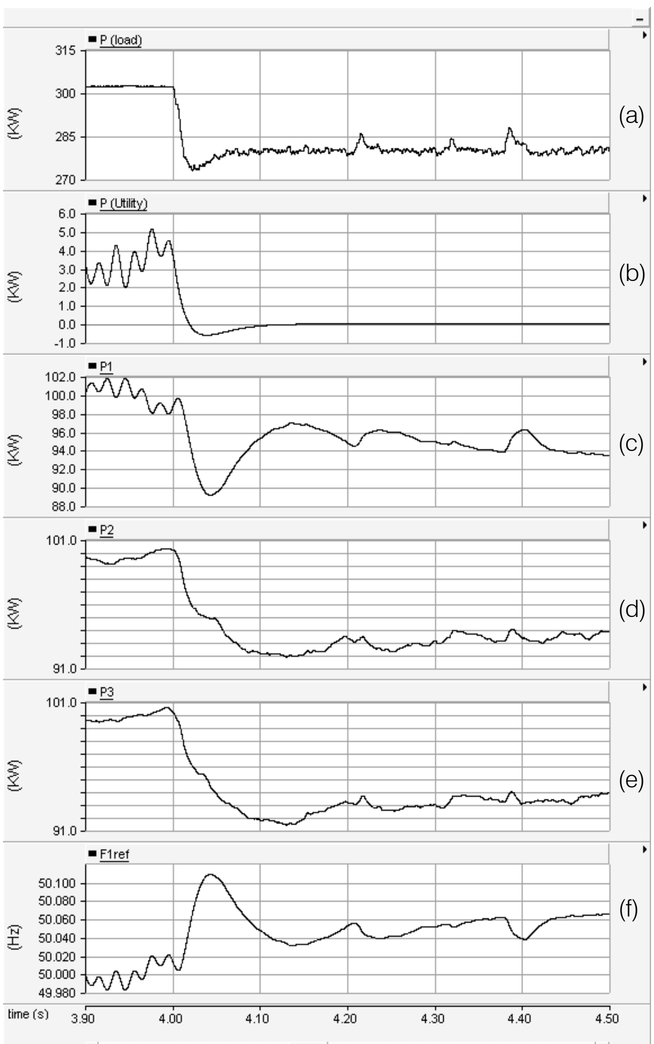



*Figure 9:* Active power of: (a) load, (b) utility, (c) first DG unit, (d) second DG unit, (e) third DG unit, and (f) frequency of the microgrid during the transition to islanding mode.

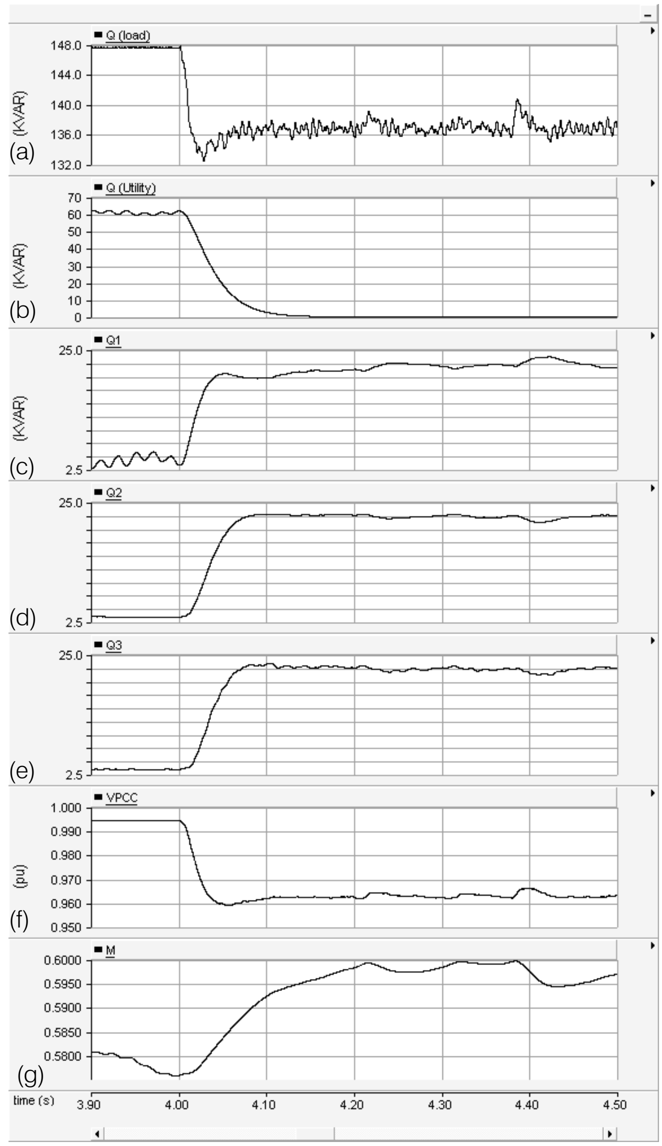



*Figure 10:* Reactive power of: (a) load, (b) utility, (c) first DG unit, (d) second DG unit, (e) third DG unit, (f) PCC voltage, and (g) modulation index of the first DG inverter during the transition to islanding mode.

## VI. Conclusion

The control strategy of the DG interface system greatly influences the microgrid performance. In this paper, the droop characteristics of frequency-versus-active power and voltage-versus-reactive power are adapted to control three identical DG units in a microgrid. One inverter is set to operate in VF control mode, while the other two inverters are controlled by PQ mode during grid-connected and islanded operation of the microgrid. The VF controlled DG unit of the proposed microgrid system has the capability of providing smooth transition from grid-connected to islanded mode without the need to wait for the islanding detection signal or mode switching. This action results in autonomous operation of the microgrid and enhancing the system reliability. Computer simulations using PSCAD/EMTDC are carried out to study the effectiveness of the proposed control approach under dynamic loading conditions during both islanded and grid-connected modes. Simulation results show that the proposed system succeeded in regulating the voltage and the frequency of the microgrid while, preserving the required load sharing among DG units.

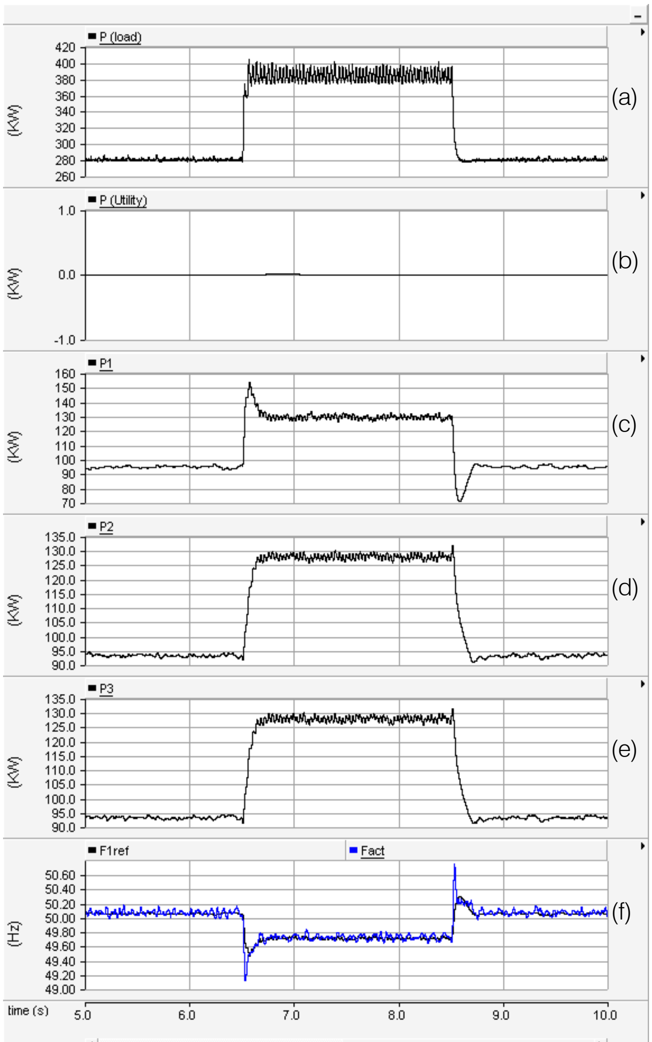



*Figure 11:* Active power of: (a) load, (b) utility, (c) first DG unit, (d) second DG unit, (e) third DG unit, and (f) frequency of the microgrid during the islanding mode.

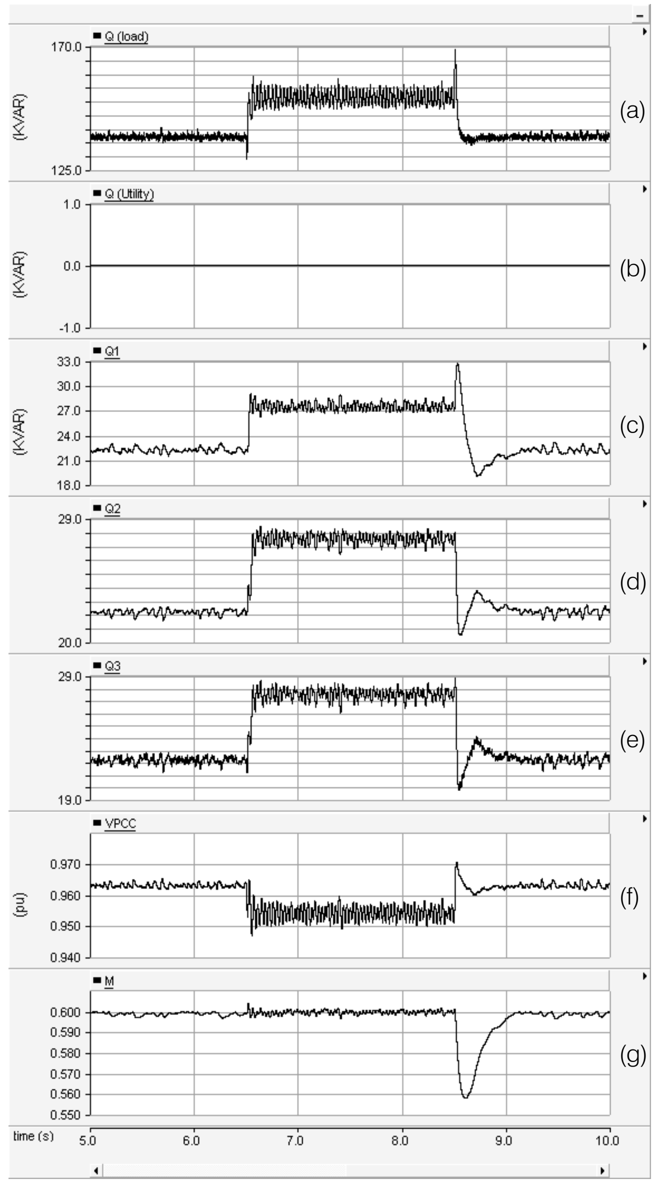



*Figure 12:* Reactive power of: (a) load, (b) utility, (c) first DG unit, (d) second DG unit, (e) third DG unit, (f) PCC voltage, and (g) modulation index of the first DG inverter during the islanding mode.

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# A Semi Blind Watermarking Technique for Copyright Protection of Image Based on DCT and SVD Domain

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*Abstract-* With the rapid use of digital data in information technology and multimedia, piracy and malicious manipulations have become a common concern, thus it is inevitable that the digital content is protected. Hence copyright protection has become a vital issue. Digital watermarking has emerged as a solution to this problem. In this paper, a watermarking technique is proposed and implemented. In which the original image is sorted out to another form by applying zigzag process followed by DCT and SVD. Watermark is then embedded by modifying the singular values and extraction of watermark is the inverse process of embedding. The deliberated algorithm gives good Peak Signal to Noise Ratio (PSNR) which ensures good imperceptibility and Normalized Cross Correlation (NCC) which ensures more robustness against different kinds of noise such as Histogram equalization, JPEG compression, Speckle noise, Gaussian noise, Salt and Pepper noise, Cropping, Rotation, Sharpening and so on.

*Keywords: watermarking, zigzag process, sorted out image, DCT, SVD.*

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ASEMIBLINDWATERMARKINGTECHNIQUEFORCOPYRIGHTPROTECTIONOFIMAGEBASEDONDCTANDSVDDOMAIN

*Strictly as per the compliance and regulations of :*

# A Semi Blind Watermarking Technique for Copyright Protection of Image Based on DCT and SVD Domain

Md. Maklachur Rahman [α], Md. Shale Ahammed [σ], Md. Rishad Ahmed [ρ] & Mohammed Navid Izhar [Ѡ]

*Abstract-* With the rapid use of digital data in information technology and multimedia, piracy and malicious manipulations have become a common concern, thus it is inevitable that the digital content is protected. Hence copyright protection has become a vital issue. Digital watermarking has emerged as a solution to this problem. In this paper, a watermarking technique is proposed and implemented. In which the original image is sorted out to another form by applying zigzag process followed by DCT and SVD. Watermark is then embedded by modifying the singular values and extraction of watermark is the inverse process of embedding. The deliberated algorithm gives good Peak Signal to Noise Ratio (PSNR) which ensures good imperceptibility and Normalized Cross Correlation (NCC) which ensures more robustness against different kinds of noise such as Histogram equalization, JPEG compression, Speckle noise, Gaussian noise, Salt and Pepper noise, Cropping, Rotation, Sharpening and so on. The human eyes are more sensitive to noise in lower- frequency band than higher frequency. The zigzag scanning process is implied for energy distribution from high to low frequency as well as from low to high frequency with the same manner.

*Keywords: watermarking, zigzag process, sorted out image, DCT, SVD.*

## I. Introduction

Digital watermarking is the method of embedding data into digital multimedia content without changing the content of original information. This is used to verify the credibility of the content as well as to recognize the identity of the digital content's owner. In digital image watermarking procedure, the inserted watermark should not degrade the visual perception of an original image and must be robust. So, it must endure the attacks such as, gamma correction histogram equalization, cropping and so on.

Digital Image watermarking is implemented in two ways - spatial domain and frequency domain. In spatial domain, the pixel intensity value of the image is directly modified like LSB is modified to achieve high visual perception. The spatial domain techniques have proven to be less robust against attacks like cropping, JPEG compression. In frequency domain the signal or image is transformed into discreet coefficients which are then modified to insert the watermark. Inverse transformation is used to get back the modified coefficients from original signal or image. Insertion, in transformed domain proves to be more robust against attacks like cropping, JPEG compression. Commonly used frequency-domain transforms are the Discrete Cosine Transform (DCT), Discrete Wavelet Transform (DWT), Discrete Fourier Transform (DFT) and Singular Value Decomposition (SVD). Of the frequency domain transforms, DCT and SVD increase the factor result that helps to achieve effective watermarking. In watermarking, there are some factors that measure the quality of watermarking. These are robustness, imperceptibility and Capacity. Robustness is a measurement which indicates how difficult is to remove or destroy watermark from watermarked image. Normalized Cross Correlation (NCC) is used to measure the similarity and difference between the original watermark and extracted watermark which actually measure the robustness. If NCC value is greater, then it is more robust. This value is generally plotted from 0 to 1. Imperceptibility is related to the quality of host image in presence of the watermark. If we cannot distinguish between host image and watermarked image, it is called imperceptibility. Basically imperceptibility depends on similarity between host image and watermarked image. Imperceptibility is measured by PSNR (Peak signal to Noise Ratio). Capacity indicates how much information is embedded into a digital content. In the proposed method, firstly zigzag process is applied to sort out the image to another form. Then DCT is applied on sorted out image to compress the size of image and SVD is applied on DCT compressed image to get singular values which is used to add watermark image. Finally embedding algorithm is implemented. The paper is organized by: Section 2, focuses on overview of terminologies. Section 3, gives details the proposed methodology, watermark embedding and extraction algorithms. In section 4, gives experimental performance results and comparison. Finally conclusion is given in section 5.

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## II. Overview of Terminology

The theories which are related with the proposed method is described here shortly.

### a) Discrete Cosine Transformation (Dct)

The DCT is the most popular transform function used in signal processing. It transforms a signal from spatial domain to frequency domain. Due to good performance, it has been used in JPEG standard for image compression. It is a technique applied to image pixels in spatial domain in order to transform them into a frequency domain in which redundancy can be identified. The one-dimensional DCT is useful in processing one-dimensional signals such as speech waveforms. To analyze two-dimensional (2D) signals such as images, we need a 2D version of the DCT. The 2D DCT and 2D IDCT transforms is given by the equation 1 and 2.

Two Dimensional (2D) DCT:

$$F(x,y) = C(x)C(y)\sum_{i=0}^{N-1}\sum_{j=0}^{N-1} f(i,j)\cos\left[\frac{\pi(2i+1)x}{2N}\right] * cos\left[\frac{\pi(2j+1)x}{2N}\right] \tag{1}$$

Two Dimensional (2D) IDCT:

$$f(i,j) = C(x)C(y)\sum_{i=0}^{N-1}\sum_{j=0}^{N-1} F(x,y)\cos\left[\frac{\pi(2i+1)x}{2N}\right] * cos\left[\frac{\pi(2j+1)y}{2N}\right] \tag{2}$$

Where, $f(i,j)$and $F(x,y)$are respectively the pixel value and the DCT coefficient and

$$C(x),C(y) = \begin{cases} \sqrt{\frac{1}{N}}, & x,y=0 \\ \sqrt{\frac{2}{N}}, & otherwise \end{cases}$$

### b) Singular Value Decomposition (Svd)

The Singular Value Decomposition (SVD) is one of the most important matrix decomposition technique used in computer vision. A very powerful set of techniques dealing with sets of equations or matrices that are either singular or numerically very close to singular. SVD allows one to diagnose the problems in a given matrix and provides numerical answer as well. Any m x n matrix A (m >= n) can be written as the product of an m x n column-orthogonal matrix U, an n x n diagonal matrix with positive or zero elements, and the transpose of an n x n orthogonal matrix V. SVD matrix can be represented by the equation:

$$A = U.S.V^T$$

Where,

$$S = \begin{bmatrix} s_1 & 0 & . & 0 & 0 \\ 0 & s_2 & & . \quad 0 & 0 \\ . & . & . & . & . \\ 0 & 0 & . & s_{n-1} & 0 \\ 0 & 0 & . & 0 & s_n \end{bmatrix}$$

And

$$U^T U = V^T V = I$$
$$VV^T = I$$
$$s_1, s_2, \ldots \ldots . s_{n-1}, s_n \geq 0$$

The diagonal elements of matrix **S** are the singular values of matrix **A** and non-negative numbers.

### c) Zigzag Process

A zigzag array is a square arrangement of the first $N^2$ integers, where the numbers increase sequentially as you zigzag along the anti-diagonals of the array. The zigzag scanning process is applying for energy distribution from high to low frequency as well as from low to high frequency with the same manner. The zigzag process gives a sorted out matrix from original matrix. For a graphical representation of zigzag scanning process is shown in fig. 1.

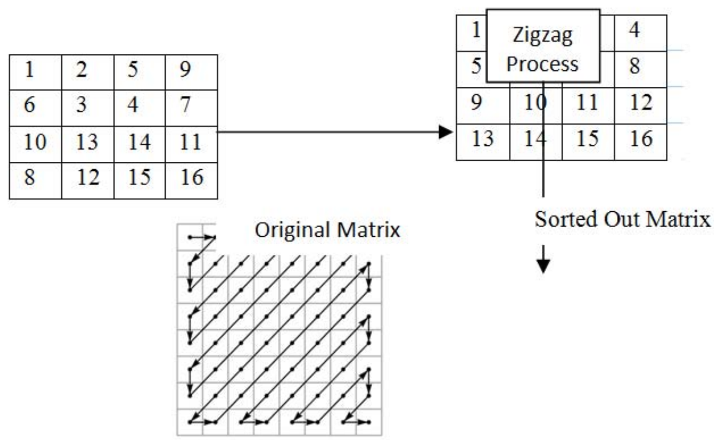



*Figure 1:* Zigzag scanning process

## III. Proposed Methodology and Algorithm

*a) Embedding Process*

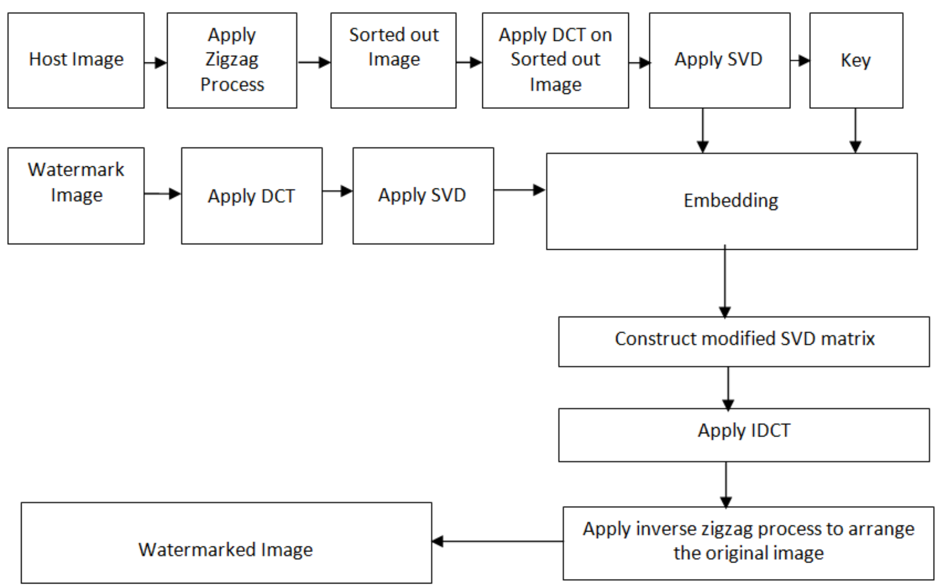



*Figure 2:* Watermark Embedding process

*b) Extraction Process*

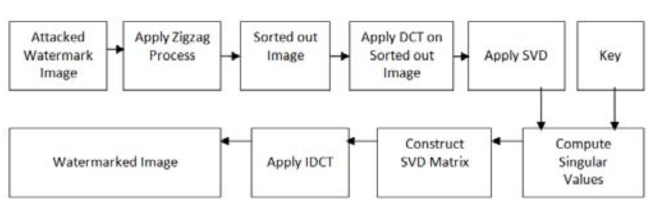



*Figure 3:* Watermark Extraction process

*c) Watermark Extraction Process*

1. Input host image HI and apply Zigzag sequence to sort out the image SI.
2. Apply DCT on Sorted out image SI to compress it.
3. Apply SVD to produce U, S singular values and V matrix.
4. Input watermark wi to embed with host image.
5. Apply DCT on watermark image.
6. Apply SVD to produce Uw, Sw singular values and Vw matrix.
7. Modifying singular values of host image with watermark image by using $S_{wi} = S_i + \alpha * S_w$
8. Construct Modified SVD matrix to produce SW.
9. Apply inverse DCT on SW get SD.

10. Apply inverse zigzag process on SD to order the original position of image and finally get watermarked image WI.

*d) Watermark Extraction Algorithm*

1. Input watermarked image WI and apply Zigzag sequence to sort out the image si.
2. Apply DCT on Sorted out image si to reduce the redundant signal.
3. Apply SVD to produce singular values S.
4. Apply SVD to produce Uw, Sw singular values and Vw matrix.
5. Modifying singular values of watermarked by using $S_w = (S_{wi} - S_i)/\alpha$
6. Construct the SVD matrix to produce sw.
7. Apply IDCT on SW to get watermark image wi.

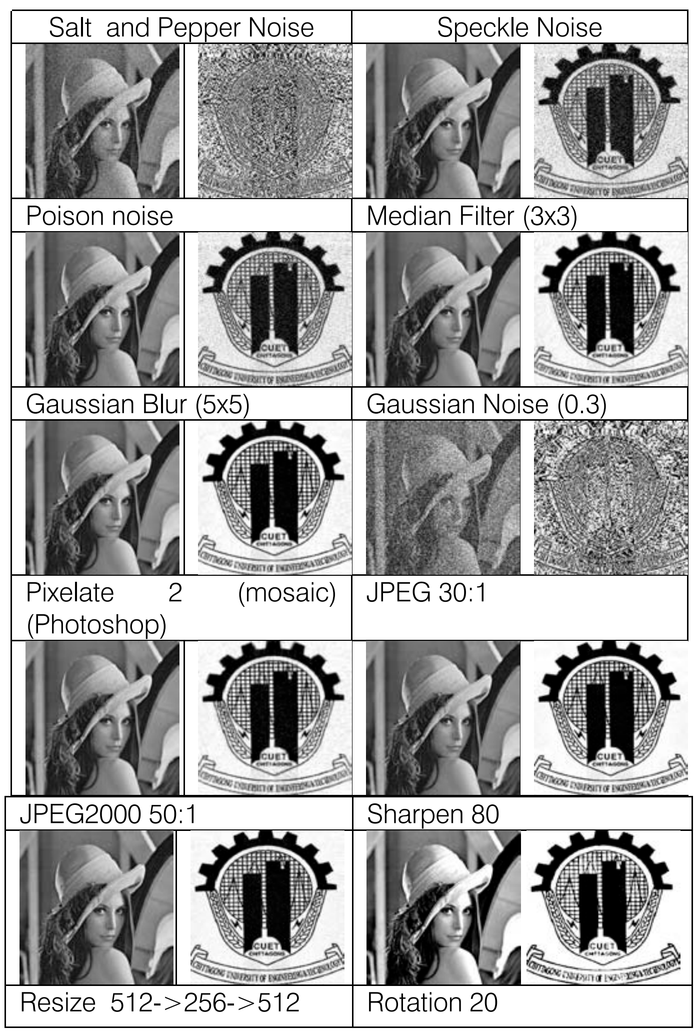
## IV. Experimental Results

The proposed method is simulated using MATLAB 9 with Processor Intel core 2 duo 2.2 GHz, RAM 2 GB and it tested for the various host and watermark images. Here some experimental results are given. With the host image Lena and watermark image CUET logo are described broadly that helps to analysis the proposed method properly.

*Table 1:* PSNR and NCC Values of Different Images Without Applying Attack

| Host image | Watermark image | PSNR | NCC |
|---|---|---|---|
| Lena | CUET logo | 31.4550 | 0.9976 |
| Living room | CUET logo | 31.4114 | 0.9959 |
| Baboon | Copyright image | 30.4195 | 0.9906 |
| Birds | Cameraman | 35.0406 | 0.9829 |
| Boat | CUET Logo | 30.0704 | 0.9980 |
| Fruits | Copyright image | 30.5127 | 0.9945 |

*Attacked watermarked image and corresponding extract watermark image.*

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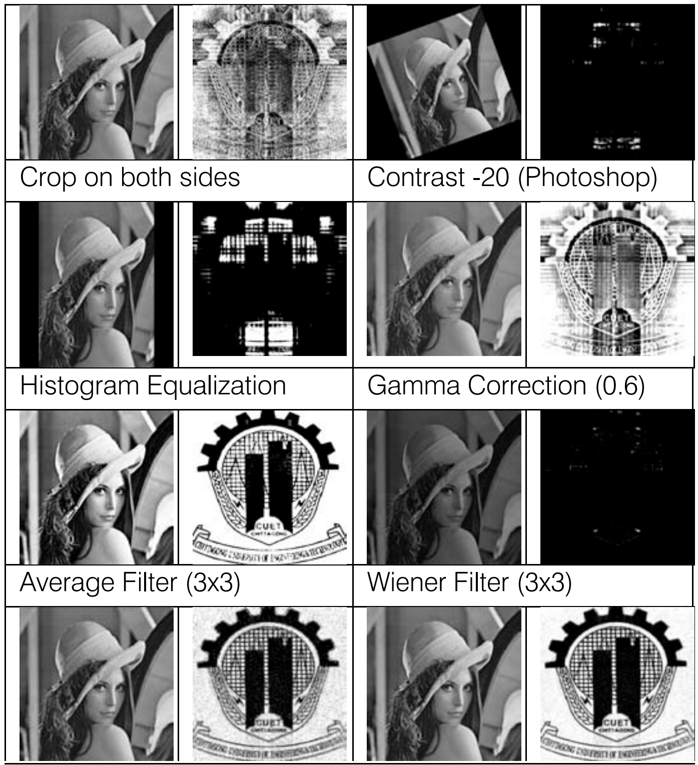


To evaluate the performance of the proposed method we need to compute PSNR (Peak Signal to Noise Ratio) and NCC (Normalized Cross Correlation) values. Normally, PSNR is used to measure imperceptibility between the original image and watermarked image. PSNR is defined by the eqn. (4). And NCC is used to measure robustness i.e. how similar the original and extract watermark image. NCC value can be calculated by the defined eqn. (5).

$$PSNR = 10\log_{10}\left(\frac{255^2}{MSE}\right) \tag{4}$$

Where,

$$MSE = \frac{1}{M \times N}\sum_{m=1}^{M}\sum_{n=1}^{N}[I(m,n) - I_w(m,n)]^2$$

And

$$NCC = \frac{\sum_i \sum_j w(i,j)\, w'(i,j)}{\sum_i \sum_j |w(i,j)|^2} \tag{5}$$

*Table 2:* Performance results comparison in terms of NCC values

| Attacks | Existing Method DWT-SVD (ref : 6 ) | Proposed Method DCT-SVD |
|---|---|---|
| Gaussian Blur (5x5) | 0.8850 | 0.9845 |
| Sharpen 80 | 0.6990 | 0.9179 |
| Average Filter (3x3) | Not given | 0.8428 |
| Median Filter (3x3) | Not given | 0.9233 |
| Wiener Filter (3x3) | Not given | 0.9528 |
| Contrast-20 (Photoshop) | 0.7380 | 0.3529 |
| Gaussian noise 0.3 | 0.8650 | 0.2186 |

| | | |
|---|---|---|
| Speckle noise | Not given | 0.6395 |
| JPEG 30:1 | 0.9930 | 0.9976 |
| JPEG2000 50:1 | 0.9890 | 0.9509 |
| Pixel-ate 2 (Photoshop) | 1.0000 | 0.9640 |
| Salt & Pepper noise | Not given | 0.2569 |
| Resize 512->256->512 | 0.9400 | 0.1928 |
| Rotation 20 | 0.9630 | 0.3567 |
| Crop on both sides | 0.9850 | 0.4188 |
| Poisson noise | Not given | 0.7168 |
| Histogram Equalization | 0.8230 | 0.9449 |
| Gamma correction 0.6 | 0.9970 | 0.3808 |

## V. Conclusion

In this paper, a DCT-SVD watermarking method using zigzag scanning sequence to sort out image is proposed that gives good PSNR and NCC values to ensure the imperceptibility and robustness. From Table 1 and 3, it is observed that the proposed method gives good PSNR and NCC values that fulfill the algorithmic requirements. The proposed method is superior to the existing method for Gaussian blur, sharpening, JPEG compression, histogram equalization and different kinds of filtering attacks. But in some geometric attacks such as rotation, resizing, cropping and in pixilation the proposed method dose not gives improved results. In future the proposed algorithm can be improved against different kinds of geometric attacks and will try to combine DWT, DCT and SVD domain to ensure better performance and further it can be extended to color images.

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# Thermal Effect in Underfill Encapsulation of Ball Grid Array

By Fei Chong Ng, Aizat Abas, MHH Ishak & MZ Abdullah

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*Abstract-* Current trend in the industry has seen multi-stacks ball grid array (BGA) being introduced to fulfill the increasing demands of the customer to includes both high performance and smaller size chip package. Conventional underfill encapsulation process on multi-stack BGA to to enhance the reliability of the package is still prone to undesired drawbacks of prolonged encapsulation time and incomplete filling. Accordingly, thermal energy is introduced by preheating the chip prior the underfill process is seen as a viable option to solve the slow filling time issue. A comparative experimental study is conducted on a scaled-up multi-stack BGA model for the cases at two distinct setups; at room temperature of 25°C and pre-heated at 70°C respectively. Decisive data has concluded that the setup with elevated temperature has prominently increase the filling rate by 75.2% with shorter completion filling time achieved. This justified the necessity of conducting the underfill process at an elevated temperature as a future operating procedure in the encapsulation process.

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## I. Introduction

Ball Grid Array (BGA) is a type of surface-mount packaging for integrated circuits (IC) in which the chip device at the printed circuit board (PCB utilizes the connection of square grid array of solder balls. Generally, BGA is much more advantageous compared to Pin Grid Array (PGA) and Chip-scale Package (CSP), in terms of reliability, durability and manufacturability [1].In contrast, Multi-stack BGA device is a renovated design of conventional BGA flip chip, aimed to multiply the performance of device by slightly sacrificing its height while still retaining its small compact structure. Various researches on the structural and underfilling flow aspects in the multi-stack chip device have been extensively conducted [2 – 5].

The underfill encapsulation process is of utmost important to enhance the package reliability as well as serve as protection to the flip chip device. Moreover, it may also act as heat sink to dissipate thermal stress away from the solder joints [6].The manufacturing process involving underfill process must be properly considered and designed to achieve highest state of reliability. In achieving this target, the underfilling process of multi-stack BGA or generally the BGA flip chip devices usually suffer problems relating to extended filling time and incomplete filling. These defects are generally undesirable which critically impart the quality of the encapsulation process. Subsequently, this will lengthen the lead time and incur additional manufacturing costs. The optimization studies of underfilling flow through BGA device have been comprehensively studies by Aizat et al., from various aspects namely encapsulant dispensing methods, bump orientation and sizes [7 – 9]. They concluded that the U-type dispensing method and perimeter bump arrangement yields the shortest filling time.

It is usually a practice in industry to pre-heat the chip device at about 60°C – 80°C prior to the underfilling process. The aim however is to ensure the encapsulant does not solidify before the curing process [6]. Several experimental and numerical simulation researches have been carried out to investigate the thermal properties of the stacked chip device, from the perspective of heat power dissipation [10], effective thermal coefficient [11] and heat distribution in the package [12]. These studies have emphasized the particular importance of temperature in optimizing the underfill encapsulation process.

Previous literatures showed that the underfill process can to be optimized through proper introduction of heat to the different layers of the package. Therefore, a simple comparative study is required to justify the influence of temperature on the underfill flow for multi-stack BGA device based on scale-up experimental model. This scaled-up BGA model has been utilized by various researchers [3 – 5, 7 – 9] and proven viable in improving the visualization of the encapsulant flow through the solder bumps that is similar to the actual industrial setup. To date, no comparative study has been carried out to identify the contribution of thermal energy to accelerate the encapsulant flow in multi-stack BGA device using experimental approach. Essentially, this paper is aimed to provide useful information for the manufacturer in an attempt to optimize the underfill process using thermal approach.

## II. Methodology

A scale up model of multi-stack BGA was constructed using clear Perspex and plastics beads. Several considerations were made during the design process of the experimental setup and after countless of

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iterations and improvements, the final design of the experimental setup will rely on four walls that is confined around the multi-stacked BGA. This setup will mimic industrial barrier used in encapsulation process to prevent spillage of the fluid outside the integrated chip (IC) package. The advantages of such barrier set up is to ensure simultaneous flow of fluid into all layers of the multi-stacked BGA model, as well as to minimize the waste of underfilling fluid due to spillage and overflow [13]. The barrier and three BGA plate models were constructed using clear Perspex and plastic beads that is jointed together using super glue. Excess glue strains on the Perspex were removed for better appearance and smoother surface to eliminate future possible sources of error. Figure 1 depicts the schematics diagram of the experimental setup being used to study the flow of the underfill fluid across a multi-stacked BGA model.

*Figure 1:* Multi-stack BGA model confined inside a barrier.

Each BGA model plate is then immersed in hot water bath at 70°C for around 20 seconds to reach thermal equilibrium. After being soaked in hot water, a dry cloth is used to remove some of the excess water from the BGA plate. The heated plates were then carefully put into the barrier that is stacked on top of each other. Two videos cameras were used to record the flow of fluid across the multi-stack BGA in both top and side views simultaneously. Later, non-Newtonian fluid with similar fluid properties was used to mimic the industrial encapsulant. The encapsulant were carefully poured into the inlet of barrier to enable it flows into the multi-stack BGA. The replacement fluid is poured thoroughly at constant rate so that it is able to flow in at each layers without any spillage or bubble formation inside the encapsulant. Afterwards, the videos obtained were analyzed and the filling times for the encapsulant to attain filling of 20%, 40%, 60%, 80% and finally the completion 100% at each layers were tabulated and presented in suitable graphical forms.

Similar procedures were being used to study the encapsulant flowin the BGA at normal conditions without introducing heat energy. This experiment is repeated with a pre-arranged three layers of BGA layers at room temperature without adding heat on it.

## III. Results and Discussions

There are total of two distinct sets of experiments with varying parameter scarried out to justify the impact of thermal on the underfill encapsulant flow through the BGA. The main difference between these set sis depicted as follow:

*Set A:* Reference set with all three layers at room temperature of 25°C

*Set B:* Pre-heated set with all three layers at 70°C

The video recordings of the underfill flow through the BGA are analyzed and subsequently the results of the filling time at certain filling percentage for both experimental sets A and B were tabulated in Table 1(i) and Table 1(ii) respectively. Subsequently, a corresponding filling time plot is constructed and presented in Figure 2.

*Table 1:* Filling time at different filling percentage for each layer for experimental (i) set A and (ii) set B.

| (i) Set A at room temperature of 25°C | | | | | |
|---|---|---|---|---|---|
| Layers | Filling time at different filling percentages (s) | | | | |
| | 20% | 40% | 60% | 80% | 100% |
| Top | 14 | 42 | 78 | 120 | 170 |
| Middle | 12 | 26 | 53 | 94 | 125 |
| Bottom | 8 | 17 | 35 | 63 | 98 |

| (ii) Set B at elevated temperature of 70°C | | | | | |
|---|---|---|---|---|---|
| Layers | Filling time at different filling percentages (s) | | | | |
| | 20% | 40% | 60% | 80% | 100% |
| Top | 10 | 25 | 43 | 70 | 99 |
| Middle | 7 | 16 | 36 | 53 | 71 |
| Bottom | 4 | 11 | 22 | 38 | 56 |

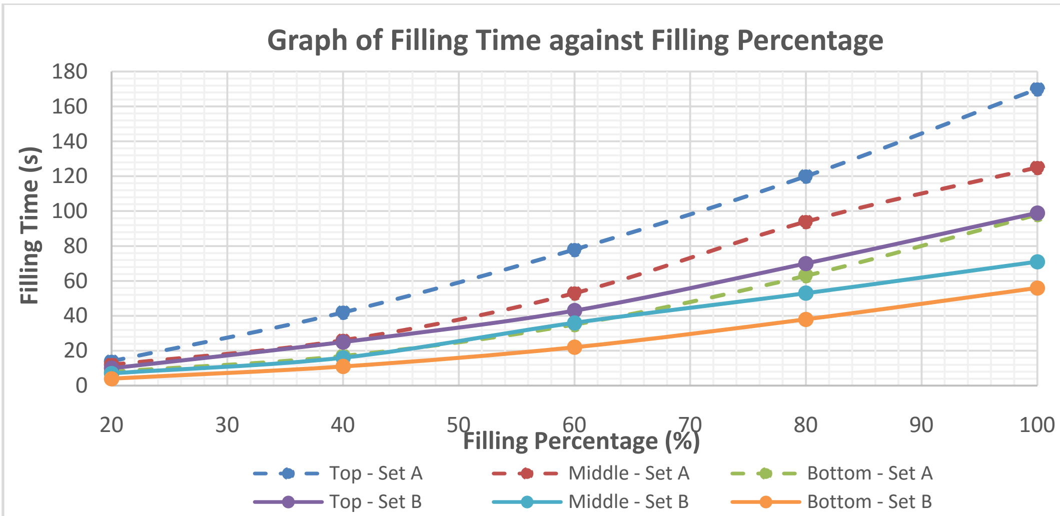


*Figure 2:* Comparison plot of filling time for experiment set A (dashed line) and set B (solid line).

By comparing the filling times for both experimental sets in Table 1(i) and Table 1(ii), it appeared that the flow tends to be faster a tall three layers of Set B. Thus, the filling time gap between top and middle layers were reduced and all three layers appeared to have almost similar flowing rate. So it is deduced that the increase in underfilling temperature willincreases the flow rates of the underfilling mold.

The underfillflow rate appeared to be inconsistent throughout the whole underfilling process. From Figure 2, the encapsulant generally flows faster at the beginning and the flow rate reduces near completion. This is essentially due to the cumulative solder bump resistance that gradually built up as the encapsulant advances. Nonetheless, it can be approximated that the average flow rate of the underfilling process can be approximated through gradient calculation for the whole segment of the graph. The average flow rate, $\bar{q}$ is in fact inversely proportional to the gradient of the graph and can simply be approximate dusing the formula:

$$\bar{q} = \frac{0.8}{T},$$

with$T$ being the time taken for the encapsulant flow from 20% filling until 100% filling.

*Table 2:* Comparisons of encapsulant flow rates at different layer for both experimental sets A and B.

| Layer | Average Flow Rate, $\bar{q}$ ($s^{-1}$) | |
|---|---|---|
| | Set A (At 25°C) | Set B (At 70°C) |
| Top | $5.128 \times 10^{-3}$ | $9.091 \times 10^{-3}$ |
| Middle | $7.080 \times 10^{-3}$ | $12.50 \times 10^{-3}$ |
| Bottom | $8.889 \times 10^{-3}$ | $15.38 \times 10^{-3}$ |
| Average | $7.032 \times 10^{-3}$ | $12.32 \times 10^{-3}$ |

Figure 3 depicts the comparison of the flow front advancement for both Set A and Set B at specific filling intervals of 20%, 40%, 60% and 80% based on the encapsulant flow at the top layer. It appeared that the encapsulant flow fronts are similar across both setups inferring that it is invariant to the under fill temperature condition. Upon careful consideration, based on the encapsulant flow from the side view, the increase in temperature produces a more uniform flow along the multi-stack BGA across all three layers.

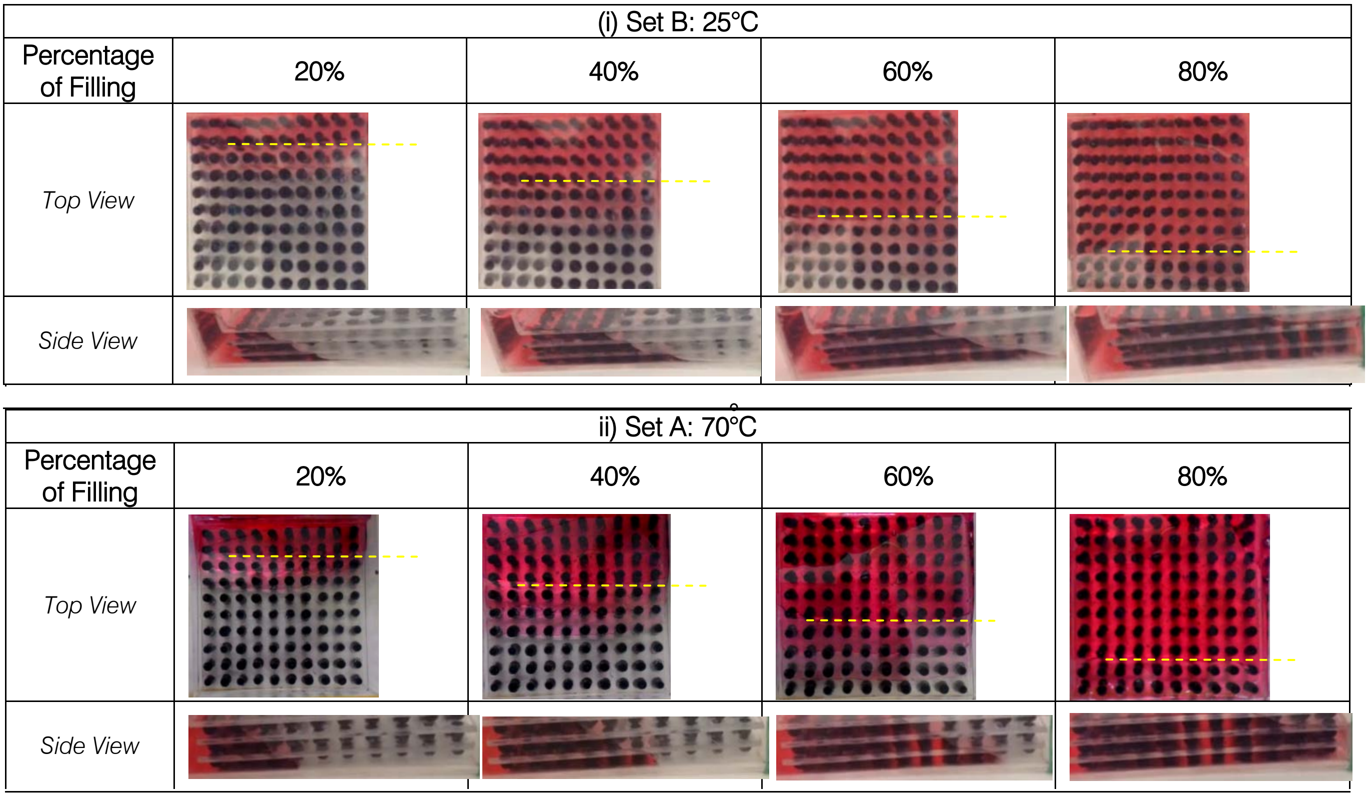


*Figure 3:* Comparison of the encapsulant flow as seen from top and side views for experiment (i) Set A and (ii) Set B based on the filling percentage of flow at the top layer.

## IV. Conclusion

Based on the comparative experimental study conducted, it was shown that the introduction of thermal energy had increased the overall encapsulant flow rate across all layers of the multi-stack BGA with an averagely of 75.2% upon comparison with the standard setup at normal condition. Therefore, it is justified that the temperature has played a significant role in accelerating the underfill encapsulation process. The BGA flip chip is required to be heated to a sufficient high temperature prior the commencement of underfilling process. This will ensure substantial filling rate and prevent the solidification of the underfill mold. Additionally, this research has also provided some insights regarding the trend of underfill flow across multi-stack BGA regardless of its thermal source. The encapsulant tends to flow faster at the bottom layer followed by middle layer and lastly the top layer. It was also shown that the underfill flow also gradually decelerates as it progresses through the array of solder bumps towards the outlet vent.

## V. Acknowledgments

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# Smart Distribution System Design: Automation for Improved Reliability

By Ahmed R. Abul'Wafa
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*Keywords: reliability, smart grid, sectionalizers, ACR, and sectionalizing switches, GA optimization.*

*GJRE-F Classification: FOR Code: 290903*

SMARTDISTRIBUTIONSYSTEMDESIGNAUTOMATIONFORIMPROVEDRELIABILITY

*Strictly as per the compliance and regulations of :*

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## I. Introduction

In utilities, achieving Power distribution reliability has been very challenging issue due to various shortcomings of legacy distribution network: Radial distribution system is vulnerable to faults, supply and demand imbalance occurs, aging of system equipment and time taking fault locating mechanism. Such vulnerability of the system to disturbance has caused frustration in daily activity of the customer. Unpredic*table* and non-programmed power outage, and long outage duration has affected customer electricity consumption patterns. Hence, the reliability issue is still the basic challenge for power utility to meet the customers need. Upgrading of the legacy distribution system to smart distribution system to alleviate existing problems is the proposed solution of this paper.

Being reliability one of the core advantages of smart grid system, its implementation makes visible change in the system's reliable power delivery and operation. Implementation of smart distribution is not one step work but continual improvement. The aim of this paper is to study some of the features of smart grid to step up the legacy distribution system with an incremental step towards the smart distribution.

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### a) *Objective*

A feeder, which has high rate of interruption, is selected as case study, for reliability improvement measures. This feeder, having two sectionalizing switches with calculated reliability indices: SAIDI of 0.23774 hr/customer/yr and SAIFI of 0.11887 int/customer/yr. The corresponding cost of energy not served plus discounted cost of sectionalizing switches is 1698.581 US$/yr.

The study looks into the current system's reliability issues, challenges and possible effective improvement areas and explore the implementation of smart grid features for alleviating the existing distribution problems.

A genetic algorithm optimization technique is developed and used to improve automation, reclosing and switching capacity of the feeder. The optimization resulted in new design of a sectionalizer, an ACR, and three sectionalizing switches integrated with the existing two sectionalizing switches. SAIDI value of 0.25001hr/customer /yr and SAIFI of 0.12301int/customer/yr for the feeder have been achieved. The corresponding cost of energy not served plus discounted cost of automation, reclosing and switching is 4598.100 US$/yr. Reliability improvement by each new device is also calculated.

### b) *Methodology*

For this particular problem in power distribution reliability, the study goes through literature survey on smart grid reliability solution and come up with ideas of mitigating the problems.

Reliability investigation of the feeder, selected as case study area highlighted a highly pronounced interruption problems. Then, the study identified reliability solutions in smart grid environment. Finally, simulation for the identified solutions is made in Matlab R2016a environment using genetic algorithm optimization.

### c) *Literature Review*

#### i. *Smart Grid on Distribution System*

The smart grid resources [1, 2] such as renewable resources, storage devices, demand response and electric transportation have impact on the distribution network load profile. Ultimate use of these resources reduces peak demand but the system will be operated near to peak demands overtime. This increases system's failure susceptibility. The congestion in grid interconnection with large number of line transfers reduces reliability margins. During failure, the system will be subjected to high tensions as it is almost operating at peak demand. At the peak demand, the fault correction time and tolerable error margins are very small leading to volatility of the system. Moreover, storage system, distributed resources are coordinated to achieve flat load profile almost near to the peak load demand which push maximum asset utilization [3, 4].

Though such kinds of effects occur, the reliability of distribution system is improved for sure with implementation of smart distribution system [5]. Reliability modeling and analysis of the system can reveal how power exchange between utility and customer side is enhanced. Modeling of distribution system helps to undergo reliability analysis, risk analysis, contingency analysis and sensitivity analysis. Only reliability analysis [5] is the concern of this study.

ii. *Reliability Analysis*

Reliability of distribution system can be expressed numerically using reliability indices: System Average Interruption Duration Index (SAIDI), System Average Interruption Frequency Index (SAIFI), Customer Average Interruption Duration Index (CAIDI) and Average System Availability Index (ASAI).These quantities reveal the sustained interruption frequency and duration of interruption on monthly basis or annual calculations. Moreover, reliability analysis can also be conducted using failure rates and outage duration of system components [6, 7]. The reliability data can be illustrated using geographical maps and histograms to have better visualization of distribution portions with good or bad outage experience.

SAIDI and SAIFI are the best known reliability measures [6]. They are calculated to display general reliability characteristics of a distribution system.

$$SAIDI = \frac{\sum U_i N_i}{\sum N_i} \tag{1}$$

$$SAIDI = \frac{\sum \lambda_i N_i}{\sum N_i} \tag{2}$$

where,

$\lambda_i$ is average failure rate of load point *i*

$U_i$ average annual outage time of load point *i*

$N_i$ number of customers connected to load point *i*

CAIDI and ASAI are directly obtained from SAIDI and SAIFI as:

$$CAIDI = {}^{SAIDI}/_{SAIFI} \tag{3}$$

$$ASAI = 1 - {}^{SAIDI}/_{8760} \tag{4}$$

According to IEEE Standard 1366-1998 [8] the median value for North American utilities SAIFI is approximately 1.10 interruptions per customer, SAIDI is approximately 1.50 hours and CAIDI is approximately 1.36 hours per customer.

But the problem with such reliability measures is that the load loss during outage is neglected. Moreover, a calculation of these indices is inconsistent. They don't show particular reliability measure in a bus but the system. For same number of interruptions in two systems, the reliability of the systems is affected by the number of customers. The more the number of customers, the lesser the reliability numeric value is obtained. Reliability measurement is also conducted from customer point of view. Therefore the reliability indices Average System Expected Energy Not Supplied (EENS) and Average System Expected Outage Cost (ECOST) are introduced.

$$EENS = \sum_i \sum_k L_k \, t_i \, \lambda_i \tag{5}$$

$$ECOST = \sum_i \sum_k L_k \, C_{ik}(t_i) \, \lambda_i \tag{6}$$

where

*i* Outage source (line, transformer, switch, etc.)

*k* Load point

$L_k$ Average load at load point *k*

$t_i$ Interruption duration by outage source *i*

$\lambda_i$ Failure rate by outage source *i*

iii. *Reliability Improvement Methods*

Reliability of distribution system can be improved by increasing distribution system protection, decreasing equipment failure, system automation, installment of reclosing and switching devices and system configuration [9, 10]. System automation shorten interruption duration. Restoration time of momentary outage event will be small [11, 12, 13]. Similarly system configuration [14] produces effective improvement in reliability. Additionally, reclosing and switching devices provide patterns to help to localize fault points and disconnect faulted lines. This achieves pushing a fault event affect fewer numbers of customers only. Sectionalizing devices also enable way of choosing supplying path during contingency. The study considers automation, installment of reclosing and switching devices for reliability improvement.

One of the methods of reliability enhancement is increase in level of protection of distribution system. Increase in protection device gives option of selective protection system; thus, any failure in some part of distribution network may not affect other part of distribution portion [6]. Selective automation of distribution system can also improve the reliability of distribution system by more than half by placing automatically controlled switch mid-way in the distribution system; any downstream fault away from the switch cannot affect customers in the upstream [15].

For momentary faults occurring in distribution system, installation of ACR in overhead lines can avoid sustained interruption by reconnecting outage line after self-clearing of the fault [12, 6], and if the fault persists, it ensures power delivery to upstream part of the feeder. The reclosing device helps faults to self-clear before affecting upstream customers.

As explained above, network reconfiguration capability of a system enables customers' power access and reduction in un served energy of the system. Sectionalizing and tie switch system option create power path searching alternative with the existing laterals. This improves supply reliability and power availability. It's also related to fault searching mechanism with remote control capability to identify which line to connect and disconnect. The resulting reconfigured network can have multi-objective function such as achieving maximized reliability and reduced power loss [14].

iv. *Reliability Analysis Methods and Optimization*

Depending on the complexity of distribution system, reliability can be analyzed using various methods. Fault tree analysis and Markov analysis [16] method are two examples that have been used in reliability analysis for many years. The preference of one with respect to the other depends on how complex and time consuming the analysis could be [6, 16]. In this study the reliability is evaluated in cut set level, based on Markov analysis.

a. *Genetic Algorithm*

The optimization Genetic Algorithm (GA) is used in this study to locate optimal placement of new automating, reclosing and sectionalizing devices for reliability improvement. GA is a technique of optimization based on natural selection of Darwin's theory of evolution. The theory lies in that selected initial random population with member individuals (chromosomes) can give new population with better fitness and selectivity. These individuals (chromosomes) are represented with binary string [17, 18, 19]. GA has the following main components: Representation, Selection, Recombination (Crossover and Mutation), and Fitness function.

The algorithm searches a location of automating devices (sectionalizing switches, ACR and sectionalizers) where reliability of distribution network can be improved. It carries out such optimization under reliability constraints targets. Every line segment in the distribution line is treated as candidate for placement of automating device. By evaluating the reliability of the system for different locations, an optimal point is obtained.

v. *Contribution*

For reliability improvement, optimized locations for new switches installment are achieved under reliability constraint. Simulation results for the effect of the new devices are tested for reliability improvement. Reliability indices of the identified reliability improvement are be evaluated. Sectionalizer, automatic circuit recloser (ACR), and sectionalizing switches are integrated in the new design combined with existing sectionalizing switches. Objective function is composed of the combined cost of energy not served (ECOST) plus discounted cost of automation devices.

## II. Current State of Study Distribution System

A site substation having five outgoing feeders at 15kV voltage level is selected. Out of these, the study feeder has the highest installed capacity as shown Table 1. The whole distribution system has a minimum power factor of 0.8 and the outgoing line are drawn as uniformly sized conductors for analysis convenience. It is connected to other feeder in the substation and to feeders in neighboring substations through open tie switches.

*Table 1*: Feeder capacity

| Capacity (MVA) | Active power (MW) | Reactive power (MVAR) | No of transformers | No of customers |
|---|---|---|---|---|
| 16.085 | 12.868 | 9.651 | 50 | 11235 |

The paper assesses reliability improvement measure taken on the feeder, which can bring fair improvement in reliability of both to the feeder and to the substation. The feeder single line diagram with existing main CB and two sectionalizing switches is shown in *Fig. 1*. The feeder is radiated from the substation (node number 1).

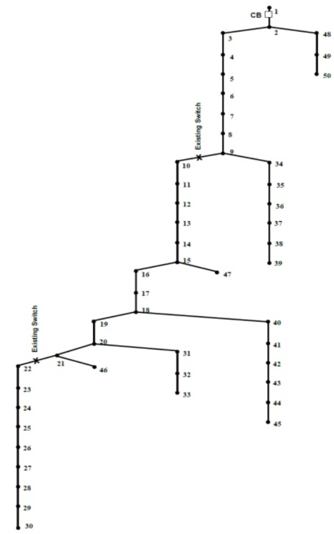


*Fig. 1:* One line diagram of the study feeder

Substation feeders have no standby networks through which alternative power supply mechanism can be reconfigured. If any fault occurs, loads downstream of the fault remain de-energized until fault is cleared. During fault occurrence, because absence of remote control mechanism and automated equipment, manual restoration is common practice which takes long time to reenergize disconnected lines. Additionally, the feeders has high frequency of interruption and it supplies the largest part of the energy from the substation. This is the reason why the reliability improvement study has focused on this feeder.

The interconnection with neighboring feeders has to be supported with adequacy and good reliability of the feeder, as any fault at it affects the other feeders as well. Making the feeder distribution mechanisms smart enhances power availability in the feeders, as neighboring feeders can share power with this feeder during contingency. This improves definitely the substations reliability.

## III. Solution Options with Smart Grid Environment

### a) Objective

Smart grid uses technologies that have high performance in communication with control centers. They are remotely controlled. This feature has high importance in automation. The smart distribution is an evolution towards smarter power distribution with high flexibility towards controllability, monitoring and protection. The smart technology devices are superior in performance of communicating with system equipment, working reliably and making logical decisions in power system.

Examples of smart technology are Intelligent Electronic Device (IED), Phase Measurement Unit (PMU), Automatic Sectionalizer, Smart Re closer, and Sectionalizing and Tie Switches. IED, unlike the traditional devices such as remote control unit (RCU) and the general purpose programmable logic controller (PLC), they can adapt to the working environment [20].

Automatic Sectionalizers operate with added intelligence from IEDS. They are applied as part of Fault Detection Isolation and Reconfiguration (FDIR). Like automatic sectionalizer, ACR are remotely operable with the help of IEDs. ACR can be coordinated to substation circuit breaker to isolate fault on a feeder. Sectionalizing switches are used for immediate restoration of power to healthy part of distribution system. Similarly, the tie switch is normally open switch applied for network reconfiguration. The sectionalizing and Tie switches can improve the SAIDI and CAIDI of a feeder.

### b) Distribution Automation as Base Line for Smart Grid

Automation of distribution, reclosing and switching capabilities reduce the time duration an interruption lasts. If a fault persists for long time, auto-sectionalizing and auto-isolation of fault is carried out using switching and sectionalizing capabilities.

The automated switch avoids interruptions of customers due to faults in down streams of the switch. It being automated means momentary fault can't cause sustained outage and the switch can be operated from control centers. Installment of new devices for automation is important. Automation in distribution for this case is done either in the existing switch or placing new switch. Solution Options with Smart Grid Environment optimized location and connecting automating devices with it.

Placement of automating device is done using genetic algorithm assuming the line segments of the system as chromosomes of the algorithm. For each location, the feeder's reliability indices are evaluated to insure improvement in reliability. Reliability improvement in this section is assumed to be achieved by installment of suitable device from either of sectionalizer, ACR or sectionalizing switch. The reliability of candidates is evaluated according to equations (1), (2) and to equations (5), (6).

*Fig. 2* is flow chart of algorithm solution. The algorithm starts by obtaining lines in mutual effect (cut sets). Mutual effect lines are segment of a feeder where any fault occurrence in some part the feeder affects customers of other mutually connected segments. Then, the algorithm puts devices in candidate segments. Reliability indices are calculated for the whole feeder with the new devices in the candidate segments. The resulting Reliability indices are compared to target reliability indices. The cost minimization process continues by placing either of sectionalizer, ACR or sectionalizing switch as long as SAIFI and SAIDI are within target limits. There are fifty candidate segments for device placement. Optimization of Reliability improvement with lower total cost of devices is simulated within reliability constraints. If the resulting SAIFI and SAIDI violate target limits, a new location for placement of devices and/or interchanging the type of devices is tested for better solution under the required reliability, the cost of installment is also minimized. In such a process, optimal solution of new device placement location is achieved. This flow chart algorithm is written into Matlab R2016a programming code and simulated.

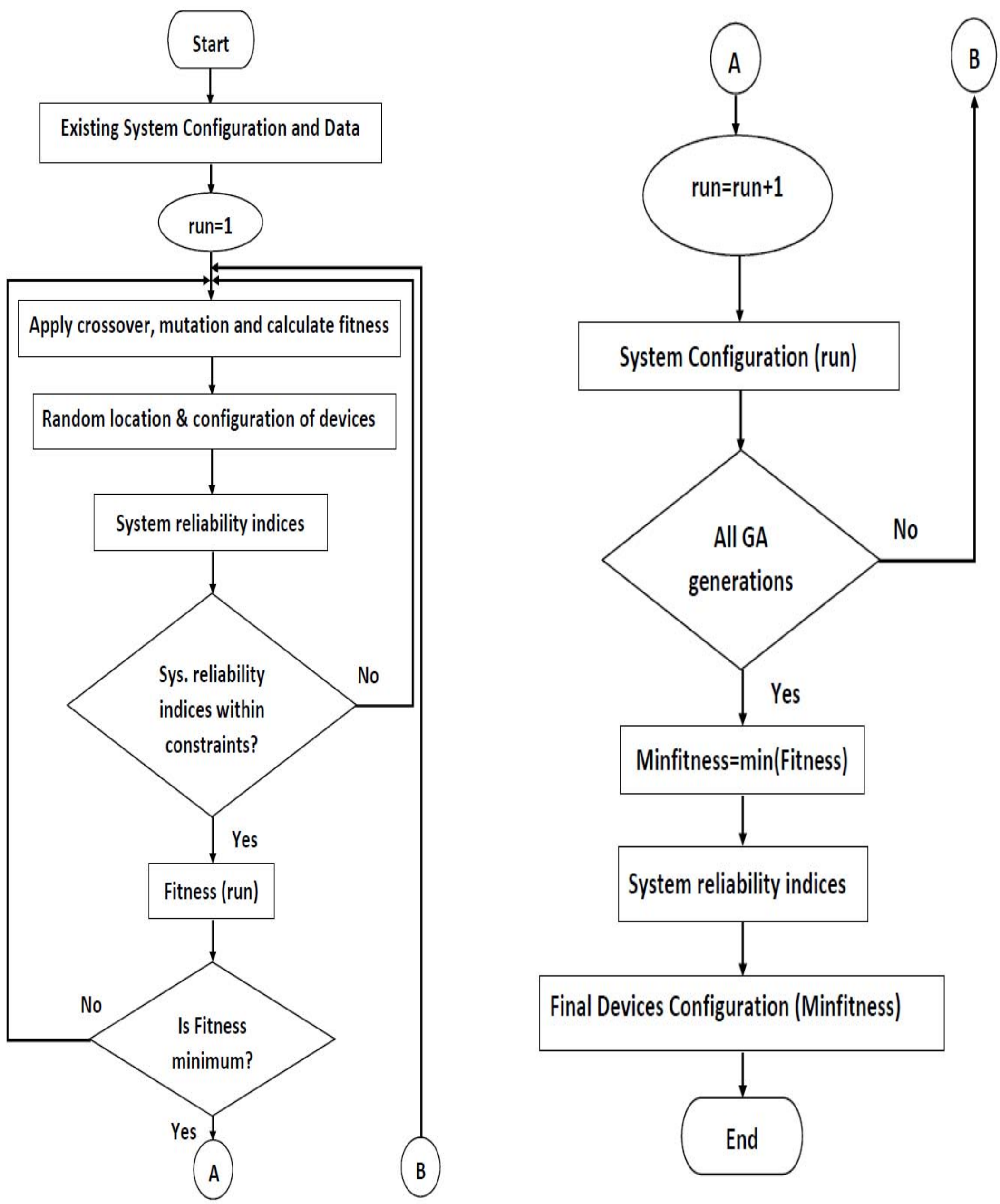


*Fig. 2:* Automation, reclosing and switching flow chart for genetic algorithm optimization

## IV. Simulation and Results Discussion

The objective of this simulation is to evaluate the redesigned distribution networks of the feeder for reliability improvement. It's to validate the design and test its implementation with software based analysis. Sectionalizers, ACR or sectionalizing switches placement optimization is simulated. The network design optimization and effectiveness is simulated subjected to reliability constraints. The simulation is implemented in Matlab R2016a version software using genetic algorithm.

### *a) Automation and Switching*

In the existing network of the feeder, automation and switching capabilities are limited to substation circuit breaker and few (two) sectionalizing switches. The need for better reliability demands installment of recent technologies which can enhance system flexibility for quick restoration capability. In this section, placement of new devices is simulated to locate which line segments give best options to minimize the objective function subjected to reliability constraints. The target line segments are treated as candidate locations for reliability improvement test. Hence, any line segment resulting in system SAIFI and SAIDI indices that lies within the reliability target is chosen to placement of new device. Labeling of line segments starts from the substation and goes downstream. Line lengths of segments are measured from the smaller digit numbered node to the higher neighboring node. For instance, line segment $L_2$ is the length of line segment between nodes 2 and 3.

This simulation considers placement of sectionalizer, ACR or sectionalizing switch. Placement of Automating devices is made to either the newly placed switches or existing ones. Automation of switches helps to advance use of remote control capability by dispatch centers.

The problem of improving reliability by the use of reclosing and switching capability is subjected to cost of installation of new devices. The cost optimization is done under reliability target constraints to achieve reliability targets. The more devices used to reclosing and switching are placed in a feeder, the higher the reliability of the feeder will be, but the cost of installing new devices increases. ECOST is an item of optimization objective and cost of existing switches are deducted from the corresponding costs of the optimized solution.

### *b) Defined Genetic Algorithm Components*

- Initial population: Fifty line segments are assumed as initial population for this optimization. These chromosomes are test points where new devices are placed randomely. 50x9 matrix of line segment make up the initial population. Line segment one is location of the circuit breaker. Therefore, other locations are in searching space of the optimization algorithm for placement of sectionalizers, ACR or sectionalizing switches.
- Representation of line segments: Line segments of the feeder are represented in binary string. Nine digits are used to number the location and the type of device that will be installed. The maximum line number is 50 and it can be represented in six binary digits. The whole string represents a chromosome of the population in the generation. Therefore, Single chromosome is made up of nine genes.

$$B_1B_2B_3B_4B_5B_6B_7B_8B_9 \tag{7}$$

The six digits, $B_1$ to $B_6$, represent the line segment number in the feeder. $B_7$ stands for the installment of new device. Value of $B_7$ is one implies new device is placed in the line segment (chromosome) and value of zero means no device is placed. B8 represent if the installed device is switch or ACR. $B_8=1$ means ACR is placed and $B_8=0$ indicates the newly installed device is a switch. If the switch installed has an automating device or not is represented using the nin$^{th}$ digit of the chromosome. $B_9$ $=1$ indicates automating device installment.

1. $B_7=1$, $B_8=0$, $B_9=1$ represent the new device placed as sectionalizing switch that has automating equipment connected with it. If there is previously an existing switch, only automating equipment is required.
2. For $B_7=1$, if $B_8=1$, it represents new ACR is installed. $B_9$, automating equipment, is required to enable remote-control capability of sectionalizing switches. It's not required if the installed device is an ACR. Therefore, in this case, the value of $B_9$ doesn't represent anything.
3. $B_7$ $=0$ shows that the status of $B_8$ and $B_9$ has no effect in the process. It means no device is installed. However, if an existing switch is there no matter the value of $B_7$, the value of $B_8=0$, $B_9=1$ implies the existing switch is automated.

This way of representation is used for all of the fifty line segments. Line sections or chromosomes that have existing switch have initially $B_7=1$ value. If no switch exists, $B_7=0$. But after recombination, the value of $B_7$ can be changed, i.e., it can have value zero though a switch exists initially.

- Recombination
- ✓ Crossover combination

The way of combination of individuals in the population is based on one-point crossover. One portion genes of a chromosome are exchanged with another mate that gives rise to new chromosome. The combination assumes that variation in the last three genes can lead to the optimal solution. The crossover at this point enables alternative approach to installment of device at different location (chromosome).

*Parent-1:* 0 0 1 0 0 1 | 1 0 0

*Parent-2:* 0 0 1 0 1 0 | 0 0 0

*Child-1:* 0 0 1 0 0 1 | 0 0 0

*Child-2:* 0 0 1 0 1 0 | 1 0 0

*Form of recombination:*

Child-1 = |geneparent1 geneparent2 |
Child-2 = |geneparent2 geneparent1 |

where, the abbreviations stand for

Geneparent1 - Genes from parent-1
Geneparent2 - Genes from parent-2

Six genes from parent one is placed in the first offspring and same from parent two in the second offspring. Gene exchange occurs after the sixth digit. The last three of the first parent is put into the second offspring and vice versa. Such combination is applied to consecutive chromosomes in the population. At first the initial population gives 50 new individuals and using selection function fittest ones are promoted to the next era. Matlab user defined function in m-file programming is developed for this recombination.

✓ Mutation

In this optimization, a mutation probability of 0.08 is applied in the offspring. Alteration of genes brings about different placement location opportunity. This enables alternative way of checking reliability improvements due to installments of new devices. In each generation, the application of such mechanism develops chromosome fitness value to reach into the optimal locations of new candidate sections.

- Fitness function

The objective of this optimization is to minimize the cost of installing new devices in the feeder. Cost optimization is done under reliability constraints. The objective function (8) for this optimization is taken for the cost values of installment of new devices stated as in [6] plus corresponding expected cost of interruption ECOST. The program analyzes the fitness value of only individuals whose $B_7=1$ in their chromosomes. Sections having existing switch before this optimization are only provided to automating equipment installment. Hence for chromosome having $B_7=1$, $B_8=0$ and $B_9=0$, for existing switch is deducted from the total sum of the optimized cost.

$$Minimize\ y = CRF\,(C_s N_s + C_r N_r + C_a N_a) + ECOST \quad (8)$$

Subjected to

$$SAIFI \leq 0.15\ int/cudt/yr \quad (9)$$

$$SAIDI \leq 0.25\ hr/cudt/yr \quad (10)$$

where,

$$CRF = {i(1+i)^n}/{((1+i)^n - 1)} \quad (11)$$

| | |
|---|---|
| *CRF* | Capital recovery factor |
| *i* | Interest rate = 0.08 pu |
| *n* | Life time = 20 yr |
| $C_s$, $N_s$ | Cost and number of new sectionalizing switches installed |
| $C_r$, $N_r$ | Cost and number of new ACR installed |
| $C_a$, $N_a$ | Cost and number of new sctionalizers installed |
| *cust* | Customer |
| *yr* | year |

This optimization considers failure rate of lines, ACRs, sectionalizing switches and sectionalizers. For every generation, the reliability of the feeder is evaluated to see any improvement of the cost minimization process. Because of different individuals represent different line segments in a generation, it is the cumulative reliability of the system that corresponds to the cost minimization process. Hence by improving fitness values of chromosomes in a particular generation, the average reliability value of that generation can be improved. Therefore, a generation is considered instead of individuals. Reliability indices are evaluated for each generation to minimize the cost within the constraint.

To evaluate reliability of the system, the line failure and the portion of the feeder it affects is considered. *Fig. 1* shows feeder line segments and labels of candidates for recruitment to new device installment.

The failure rates of newly installed devices are also assumed in each line segment. Failure rate data of new devices installed is assumed according to data values stated in [18]. Line sections and load points affected by upstream and downstream failure are exclusively and mutually grouped.

$$X_1 \begin{Vmatrix} 1\ 2\ 3\ 4\ 5\ 6\ 7\ 8\ 9\ 34\ 35\ 36\ 37\ 38\ 39\ 48\ 49\ 50 \\ 1\ 2\ 3\ 4\ 5\ 6\ 7\ 8\ 34\ 35\ 36\ 37\ 38\ 39\ 48\ 49\ 50\ 0 \end{Vmatrix}$$

First row of $X_1$ is the line segments in the feeder and the second row is load points (cut set) interrupted by any failure occurring in line segments. Because these load points are isolated using sectionalizing switch at line $L_9$. It's to estimate the reliability of this portion according to how many customers are affected for each lines failure.

The same is true to node points between L9 and L21. Any failure in the upstream of these loads and within the section of L9 and L21 interrupts power to the section from substation to L21. Second row of $X_2$ is the load points (cut set) interrupted by any failure occurring in line sections in the first row. It shows failure in the upstream affects loads in the downstream but the reverse is not true.

$$X_2 = \left\| \begin{matrix} 10 & 11 & 12 & 13 & 14 & 15 & 16 & 17 & 18 & 19 & 20 & 21 & 31 & 32 & 33 & 40 & 41 & 42 & 43 & 44 & 45 & 44 & 47 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 & 9 & 10 & 11 & 12 & 13 & 14 & 15 & 16 & 17 & 18 & 19 & 20 & 21 & 31 & 32 & 33 & 34 & 35 & 36 & 37 & 38 & 39 & 40 & 41 & 42 & 43 & 44 & 45 & 46 & 47 & 48 & 49 & 50 \end{matrix} \right\|$$

However lines sections downstream of $L_{21}$, given by $X_3$, are affecting all loads in the feeder.

$$X_3 = \|22\ 23\ 24\ 25\ 26\ 27\ 28\ 29\ 30\|$$

*Table 2:* Line Segments Candidates for New Device Installment Simulation Result

| Serial No. | Candidate Device | Line Segment No. |
|---|---|---|
| 1 | Sectionalizing Switch | 1 |
| 2 | Sectionalizer (Automated Sectionalizing Switch) | 6 |
| 3 | Sectionalizing Switch | 8 |
| 4 | Sectionalizing Switch | 11 |
| 5 | Automatic Circuit Recloser | 15 |
| 6 | Automatic Circuit Recloser | 23 |
| 7 | Sectionalizing Switch | 27 |
| 8 | Sectionalizing Switch | 36 |
| 9 | Sectionalizing Switch | 41 |

This optimization problem result shows line candidates for automation, reclosing and switching as shown in *Table 2*. The rest line segments are same as in the existing feeder. The simulation result indicates the installment of a new sectionalizer in line segment $L_6$. A new switch placed in line segment $L_1$ is not economical since the feeder main circuit break is in this line segment. Therefore, a switch placed in this line segment is not considered in the total cost of the optimization. Similarly because of the existing sectionalizing switch in $L_9$, placement of new sectionalizing switch in lines $L_8$ and $L_{11}$ is of no technical value. Additionally, the simulation program places an ACR in middle point of the feeder (line segment $L_{15}$) and in line segment $L_{23}$. The reliability improvement is tested by placing a single ACR (the middle point ACR is considered), as ACR is an expensive device. The devices in the remaining line segments $L_{27}$, $L_{36}$ and $L_{41}$, beside existing Sectionalizing Switch in line segments $L_9$, $L_{21}$ are considered in the reliability improvement studies. The cost of placement of these new devices is calculated. The all-generations fitness score and the selected devices installed diagram are shown in *Fig. 3* and *Fig. 4*.

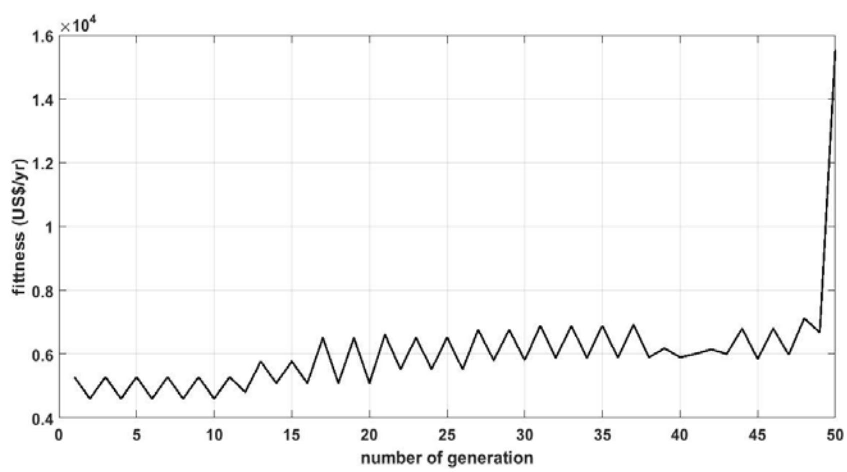


*Fig. 3:* Fitness values of chromosomes of all generations for automation, reclosing and switching optimization

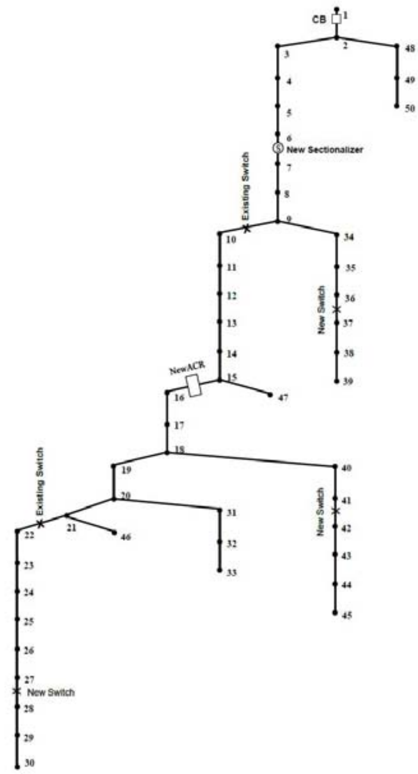


*Fig. 4:* New installed devices in the feeder: *Circled S- a* sectionalizer, *rectangular-* ACR and *X-* a newly installed sectionalizing switch

## V. Summary and Conclusion

Distribution reliability improvement for the study feeder in smart grid environment is achieved by applying switching, automation and reclosing in the existing distribution system. Reliability data is analyzed to illustrate potential unreliability in terms of frequency and duration of interruption. Potential causes of interruption are identified which helped to select what feature of smart grid in distribution system can tackle these problems. Reliability indices SAIDI, SAIFI, CAIDI, ASAI. EENS and ECOST are used to evaluate the reliability of the distribution system. Besides, System Fault assessment is made in terms of how many delivery points are affected during outage event and the number of customers affected by the fault.

Reliability improvement ideas are identified to reduce frequency of interruption and the time an interruption lasts. Utility reliability requirement is taken as bench mark to improvement, automation upgrade are designed using genetic algorithm as optimization tool. Reliability Improvements are designed under constraints of feeder reliability indices SAIDI and SAIFI. The study feeder is chosen for this implementation because of its high installed supply capacity and high record of interruption.

The design considered cost minimization while improving reliability. A sectionalizar, an ACR and three sectionalizing switches are installed. The automation, reclosing and switching optimization simulation results are achieved at low annual extra cost. However resulted reduction in SAIFI and in SAIDI are not significant. This is because Substation feeders have no standby networks through which alternative power supply mechanism can be reconfigured. If any fault occurs, loads downstream of the fault remain de-energized until fault is cleared. This simulation took into consideration existing sectionalizing switches.

Genetic algorithm optimization is applied to search for optimal automation configuration for the network. The genetic algorithm is selected for this design because of its effective combinational searching and representation of potential candidates is easy. Type and location of automation devices (candidates) are represented only by binary coding. Besides, searching space of design candidates are improved through generations enabling rapid arrival to optimal targets using Matlab R2016a version software.

Genetic Algorithm can be implemented in reliability improvement of vast and complex distribution networks.

## VI. Future Works

Distribution reliability improvement for the study feeder in smart grid environment is achieved by applying switching, automation and reclosing in the existing distribution system. Reliability data is analyzed to illustrate potential unreliability in terms of frequency and duration of interruption. Potential causes of interruption are identified which helped to select what feature of smart grid in distribution system can tackle these problems. Reliability indices SAIDI, SAIFI, CAIDI, ASAI. EENS and ECOST are used to evaluate the reliability of the distribution system. Besides, System Fault assessment is made in terms of how many delivery points are affected during outage event and the number of customers affected by the fault.

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Genetic Algorithm can be implemented in reliability improvement of vast and complex distribution networks.

## List of Acrynoms

| | |
|---|---|
| ACR | Automatic Circuit Rrecloser |
| ASAI | Average System Availability Index |
| CAIDI | Customer Average Interruption Duration Index |
| DG | Distributed Generation |
| DLOL | Distribution Line Overload |
| DPEF | Distribution Permanent Earth Fault |
| DPSC | Distribution Permanent Short Circuit |
| DTEF | Distribution Temporary Earth Fault |
| DTSC | Distribution Temporary Short Circuit |
| ECOST | Expected Interruption Cost, US$/yr. |
| FDIR | Fault Detection Isolation and Reconfiguration |
| GA | Genetic Algorithm |
| IED | Intelligent Electronic Device |
| ITS | Information Technology System |
| KVA | Kilo Voltage Ampere |
| MVA | Mega Voltage Ampere |
| PLC | Programmable Logic Controller |
| PMU | Phase Measurement Unit |
| RCU | Remote Control Unit |
| SAIDI | System Average Interruption Duration Index, hr/customer /yr. |
| SAIFI | System Average Interruption Frequency Index, int/customer/yr. |
| SG | Smart Grid |

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# FPGA Implementation of High Speed Radar Signal Processing

By Dr. R. Murali Prasd & Mr.J.Pandu
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*Abstract-* Electronic support measure (ESM) system or Electronic Warfare Support (ES), is the subdivision of EW involving actions tasked by, or under direct control of, an operational commander to search for, intercept, identify, and locate or localize sources of intentional and unintentional radiated electromagnetic (EM) energy for the purpose of immediate threat recognition, targeting, planning, and conduct of future operations. To test an ESM system field environment is created by using various equipment and design tools.Testing a system is important part of designing and manufacturing a system and it is necessary in any field. To test an ESM system, it is difficult to test it near the theater of war. Testing an ESM system in the theater of war may result in expose of our information to the opponent nations. Therefore, in order to test an ESM system an artificial environment is created by using various equipment and design tools.

*Keywords: dielectric resonator oscillator (DRO), acknowledgment (ACK), electronic counter measure (ESM), electronic counter counter measure (ECCM), pulse repetition interval (PRI).*

*GJRE-F Classification: FOR Code: 090609*

FPGAIMPLEMENTATIONOFHIGHSPEEDRADARSIGNALPROCESSING

*Strictly as per the compliance and regulations of :*

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## I. Introduction

The Real time threat environment in the battle field is different and dangerous. In the battle field to test an ESM system there are large number of Radars which monitor or surveillance the signals emitted by the enemies. These Radars identify or trace the signals and transmit to the large group of monitors and equipment. These equipment monitors the data and the Radar parameters such as pulse width, pulse repetition interval, direction of arrival, time of arrival, frequency, type of pulse repetition of time, angle of arrival, distance of the object, pulse repetition of the frequency.

These Radars parameters are identified by the ESM the system and convert into the form of pulse descriptor word format which is of 128 bits. To take the measures in order to protect from the enemy attacks the counter measures are taken with the help of Electronic Counter Measure (ECM) system. These system uses the data captured and create the counter pulses to attack the enemy Radar signal to protect the country. In order to protect from counter signals, the data is captured and transmitted to the advanced system called Electronic Counter Counter Measure (ECCM) System.

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## II. Modeling of Threat

The field is created using Dielectric Resonator Oscillator (DRO) to generate various frequencies ranging from 1 GHz to 40 GHz. To generate higher frequencies, Voltage Control Oscillator (VCO) is used. These frequencies are given to mixer as an input. The mixer can be used as a switch to select the desired frequency by programming the FPGA control signal line. The inter pulse modulation generator is enabled using enable line to generate desired pulse. The desired frequency and pulse modulated signal is given to the programmable attenuator. The Antenna radiated pattern generated signal is also given to programmable attenuator. The output of programmable attenuator is desired signal, which is used to test the Electronic Support Measure (ESM) systems.

### *a) Generating Different types of Pulses*

Radar system uses a Radio frequency electromagnetic signal reflected from a target to determine information about that target. In any Radar system, the signal transmitted and received will exhibit many of the characteristics Radars pulse signal parameters are pulse width, pulse repetition interval, Frequency, Direction of arrival ( DOA), Time of arrival (TOA).The carrier is an RF signal, typically of microwave frequencies, which is usually modulated to allow the system to capture the required data. In simple ranging radars, the carrier will be pulse modulated and in continuous wave systems, such as Doppler Radar, modulation may not be required. Most systems use pulse modulation, with or without other supplementary modulating signals. Note that with pulse modulation, the carrier is simply switched on and off in sync with the pulses the modulating waveform does not actually exist in the transmitted signal and the envelope of the pulse waveform is extracted from the demodulated carrier in the receiver.

Although obvious when described, this point is often missed when pulse transmissions are first studied, leading to misunderstandings about the nature of the signal .The pulse width ($\tau$) of the transmitted signal is to ensure that the Radar emits sufficient energy to allow that the reflected pulse is detectable by its receiver. The amount of energy that can be delivered to a distant target is the product of two things; the output power of the transmitter, and the duration of the transmission.

Therefore, pulse width constrains the maximum detection range of a target.

It also determines the range discrimination that is the capacity of the radar to distinguish between two targets fairly close together. At any range, with similar azimuth and elevation angles and as viewed by a Radar with an un modulated pulse, the range discrimination is approximately equal in distance to half of the pulse duration. The pulse width of a signal is shown in Fig 2.1 it also determines the dead zone at close ranges. While the Radar transmitter is active, the receiver input is blanked to avoid the amplifiers being swamped or damaged.

All this means that the designer cannot simply increase the pulse width to get greater range without having an impact on other performance factors. As with everything else in a Radar system, compromises have to be made to a Radar systems design to provide the optimal performance for its role.

*b) Pulse Repetition Interval*

Pulse Repetition Interval is commonly known as PRI. It is the time difference between start time of pulse1 to start time of pulse2 . The difference gives the Pulse Repetition Interval (PRI) as shown in Fig 2.1.

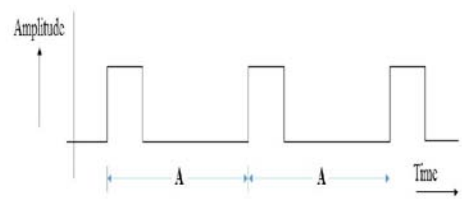


*Fig. 2.1:* Pulse Repetition Interval (PRI)

The pulse changes in PRI are less than plus or minus one present or measured jitter is believed to be incidental. Most nominally constant signals have less then plus or minus one $\mu$second of Jitter. Desired measures are Mean PRI, Peak-to-peak incidental jitter Drift, Basic Clock Interval Range and type of Count downs.

*c) Optimum PRI for Medium PRF Radar*

Fraction of targets Eclipsed in Range = PD/PRI

Fraction of targets Eclipsed in Velocity = $B_e$/PRF

Fraction of Range Velocity combinations visible = [1-PD/PRI] [1- Be/PRF]

$\partial$ (fraction visible)/ $\partial$ PRI = PD/(PRI)$^2$ –$B_e$ = 0

PRI = $\sqrt{PD/Be}$ optimum duty factor

## III. Implementation

The main objective of this paper is to create Radar like parameters to test an ESM system. For this we need a circuitry that generate such pulses and also a modulation mechanism which facilitates to introduce many variations in a continuous waveform. The circuitry which is mentioned for the aforementioned purpose is as shown in Fig 3.1

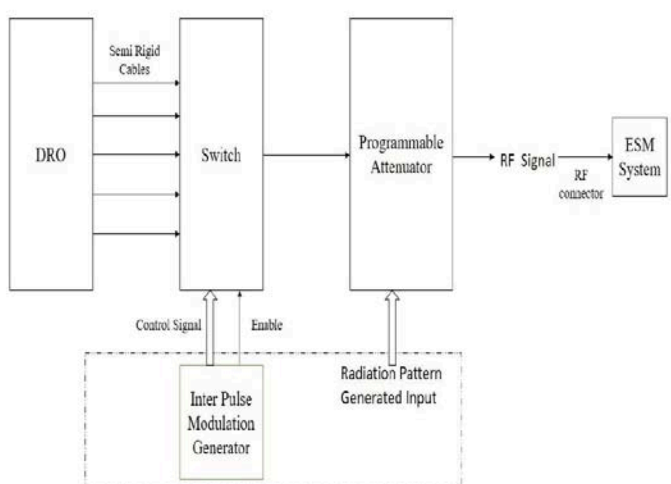


*Fig. 3.1:* Block Diagram of EW Threat Emulator

*a) ESM System*

The Radar like signal generated at the output of programmable attenuator is given to an electronic support measure system. The system measures the Radar parameters and show it on the display. Thus the accuracy of the generated Radar signal can be verified. The overlapping discipline, signals Intelligence (SIGINT) is the related process of analyzing and identifying the intercepted frequencies. The SIGINT is broken into three categories: ELINT, COMINT, and FISINT.

The Parameters of Intercepted Transmission are communication equipment Frequency, Bandwidth, Modulation, Polarization etc. The distinction between Intelligence and Electronic warfare support (ES) is determined by tasks or controls the collection assets, what they are tasked to provide, and for what purpose they are tasked. Electronic warfare support is achieved by assets tasked or Controlled by an Operational commander. The purpose of ES tasking is immediate threat recognition, targeting, planning and conduct of future operations, and other tactical actions such as threat avoidance and Homing. However, the same assets and resources that are tasked with ES can Simultaneously collect Intelligence that meets other Collection Requirements. The ESM System is shown in Fig 3.2.

*Fig. 3.2:* ESM System

With the increase in Technology the Electronic Warfare has been more significant. Counter measuring and Counter Counter measuring has become very important for the security of a Nation and this has lead to various new techniques such that identifying the Radar parameters has become more and more complicated. This is generally done by using various Intra Modulating techniques on FPGA some of them are introducing a Stagger and Jitter levels and Dwell and Switch method.

*b) Protocol & Equipment*

The variations in the pulses such as constant, Stagger levels, Jitter and Dwell and Switch can be introduced in the Radar parameters by modulating the continuous wave output from the DRO with the generated pulse in the Inter pulse modulation block which is shown as below in Fig 3.3

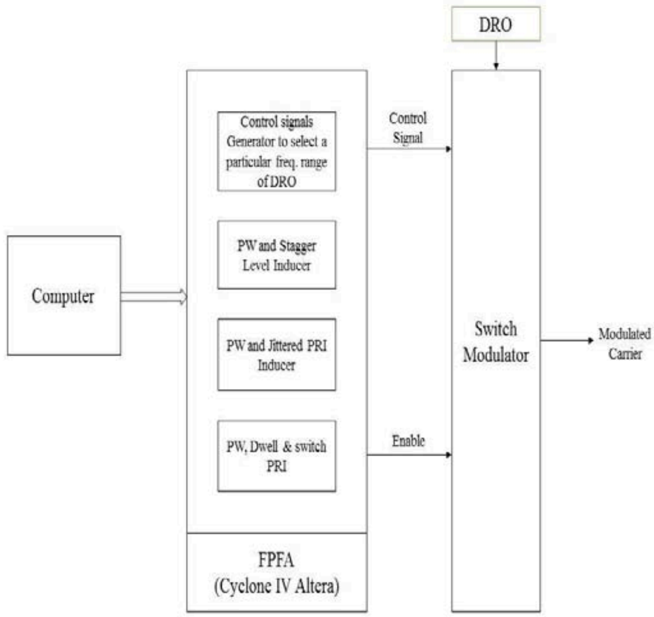


*Fig. 3.3:* Block Diagram of Inter Pulse Modulation

A computer with a LabVIEW and a Graphical User interface (GUI) is required which relates the inputs to the FPGA . LabVIEW panel has provision to specify the type of pulses and levels that are required and these inputs are sent to FPGA by ASCII sliding Window Protocol. Sliding window refers to an imaginary box that hold the Frames on both Sender and Receiver side. It provides the upper limit on the number of Frames that can be Transmitted before acquiring an acknowledgment. Frames may be acknowledged by Receiver at any point even when window is not full on Receiver side. Frames may be transmitted by source even when window is not yet full on Sender side. The windows have a specific size in which the Frames are numbered modulo- N, which means they are numbered from 0 to N-l . For example if N = 8, the Frames are numbered 0, 1,2,3,4,5,6, 7, 0, 1,2,3,4,5,6, 7, 0, 1.

The size of window is N-1. For example in this case it is 7. Therefore, a maximum of N-1 Frames may be sent before an acknowledgment. When the Receiver sends an ACK, it includes the number of next Frame it expects to receive. For example, in order to acknowledge the group of Frames ending in Frame 4, the Receiver sends an ACK containing the number 5. When sender sees an ACK with number 5, it comes to know that all the Frames up to number 4 have been Received.

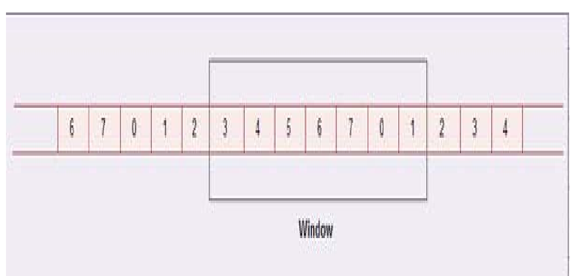


*Fig. 3.4:* Sliding Window

c) *Sliding Window on Sender Side*

At the beginning of a Transmission, the sender's window contains N-1 Frames as shown in Fig 3.5 . As the Frames are sent by source, the left boundary of the window moves inward, shrinking the size of window. This means if window size is w, if four Frames are sent by source after the last acknowledgment, then the number of Frames left in window is (w-4). When the receiver sends an ACK, the source's window expands right boundary moves out words to allow in a number of new Frames equal to the number of Frames acknowledged by that ACK. For example, if the window size is 7, if Frames 0 through 3 have been sent and no acknowledgment has been received, then the sender's window contains three frames - 4, 5 ,6. Now, if an ACK numbered 3 is received by source, it means three frames (0, 1, 2) have been received by receiver and are undamaged.

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The sender's window will now expand to include the next three Frames in its buffer. At this point the sender's window will contain six frames 4, 5, 6, 7, 0, 1

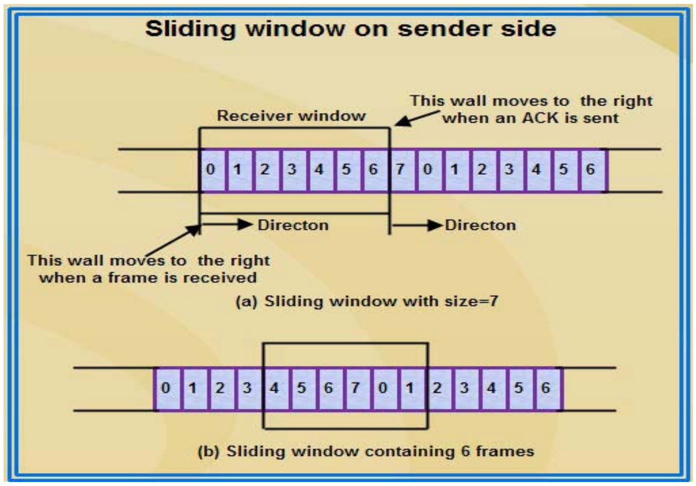


*Fig. 3.5:* Sliding Window on Sender Side

*d) Sliding Window on Receiver Side*

At the beginning of transmission, the receiver's window contains n-1 spaces for frame but not the frames as shown in Fig 3.12. As the new frames come in, the size of window shrinks. Therefore the receiver window represents not the number of frames received but the number of frames that may still be received without an acknowledgment ACK must be sent. Given a window of size w if three frames are received without an ACK being returned, the number of spaces in a window is w-3. As soon as acknowledgment is sent, window expands to include the number of frames equal to the number of frames acknowledged. For example, let the size of receiver's window is 7 as shown in diagram. It means window contains spaces for 7 frames.

With the arrival of the first frame, the receiving window shrinks, moving the boundary from space 0 to 1. Now, window has shrunk by one, so the receiver may accept six more frame before it is required to send an ACK. If frames 0 through 3 have arrived but have DOC been acknowledged, the window will contain three frame spaces. As receiver sends an ACK, the window of the receiver expands to include as many new placeholders as newly acknowledged Frames. The window expands to include a number of new frame spaces equal to the number of the most recently acknowledged frame minus the number of previously acknowledged frame. For example If window size is 7 and if prior ACK was for frame 2 & the current ACK is for Frame 5 the window expands by three 5-3=2

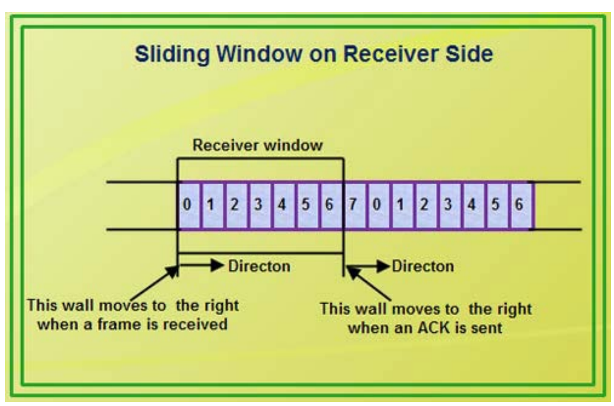


*Fig. 3.6:* Sliding Window on Receiver Side

Therefore, the sliding window of sender shrinks from left when frames of data are sending. The sliding window of the sender expands to right when acknowledgments are received. The sliding window of the receiver shrinks from left when Frames of data are Received. The sliding window of the receiver expands to the right when acknowledgement is sent.

In the ASCII sliding window protocol there are total 32 Frames. Again each frame is further divided into 7 frames. These seven frames are intended to preform seven different tasks namely Start of frame, Frame number, Data length, Command ID, Data width, Check sum, End of frame or Break of frame. If the command ends in that frame, then End of frame comes into play. If the command still exists even after completion of the frame, then the command is passed on to the next frame through the Break of frame accordingly.

## IV. Analysis and Output

Consider we have three segments Continuous Radar (CW) signals are generated by the DRO's as the input in the Range of Ghz. These high frequency signals are observed in the spectrum analyser. A certain Band of frequencies can be selected by either using a binary selector given to a control line or directly give the frequency in lab view software and GUI mode. As DRO's generate high frequency signals, they can be only sending through semi rigid cables with minimal loss of signal. The frequency received can be observed in the spectrum analyser. These received signals will be send to a switch which acts as input. Each DRO is powered with a 5V dc supply voltage.

Pulse generators are also sent into the switch which act as input they are namely Stagger, Jitter, constant and Dwell & switch. Only one kind of pulse generators can be sent at a time. Each different pulse generators have different pulse width (PW) and pulse repetitive index (PRI). Pulse width is width of pulse, generally measured in micro seconds (us) and pulse repetitive index (PRI) is the time duration between two consecutive pulses, generally measured in microseconds (mus). Each pulse generator has its own pulse width and PRI. These values can be manually given by the user in the GUI interface of lab view Software. Now these pulse generators and CW radar signals from the DRO are inter pulse modulated inside switch. Enable pin determines the Ton and Toff of a pulse. Modulation occurs when enable pin is set to high.

Now arises the Hardware connections. The FPGA used in this is Cyclone 3. NIOS is the software used to program the pins of FPGA. Quartus is a software which is used as a Hardware programming language. It acts as medium between FPGA and Computer. These two devices are connected using JTAG USB cable. Quartus contains lots of tools in it, here we use Eclipse as tool for programming the FPGA. NIOS acts as processor of the system.

The Verilog code is dumped inside the FPGA as discussed earlier and executed. Once the code is executed the output is given to an attenuator .A programmable attenuator is used for attenuating the signal amplitude. The received signal is of very high frequency and it is difficult to identify the maximum amplitude of the signal. So to differentiate the signals a programmable attenuator is used. It is used in such a way that the first pulse is attenuated to its maximum and the next consecutive pulse is attenuated a little less, this continues until the pulse which has highest frequency. Once it reaches the pulse with a maximum frequency, it is very easy to identify the pulse which has the maximum frequency, as it has the minimum attenuation. A detector is used to convert the signal from frequency domain to time domain.

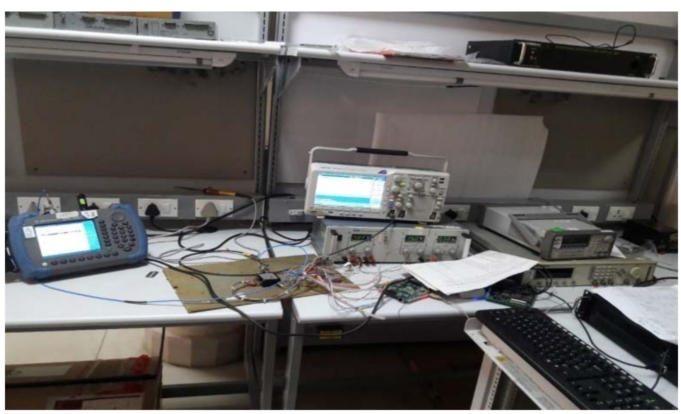

*Fig. 4.1:* EW Threat Emulation Kit

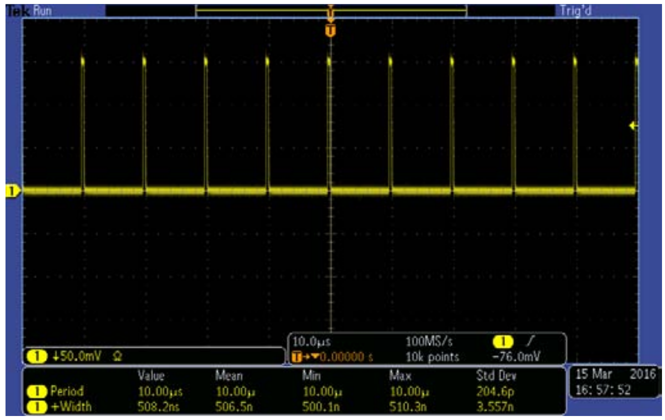


*Fig.4.2:* Oscilloscope Output [Carrier 5GHz]

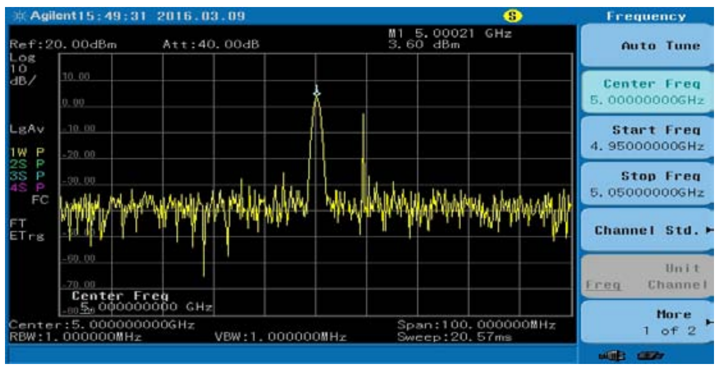


*Fig.4.3:* Staggered PRI

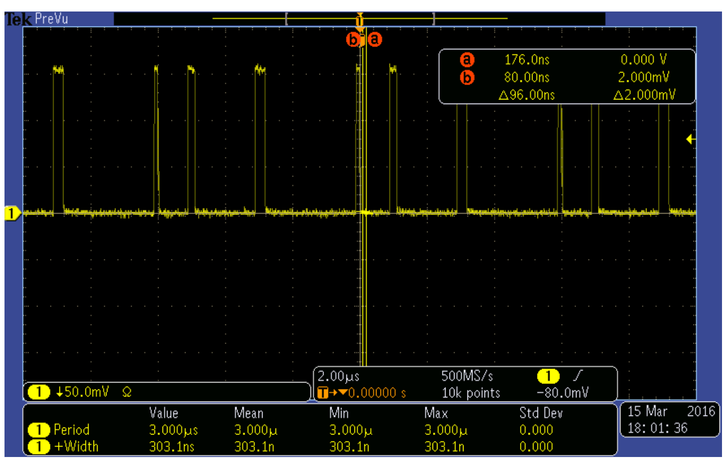


*Fig.4.4:* Oscilloscope Output[ Carrier 8GHz ]

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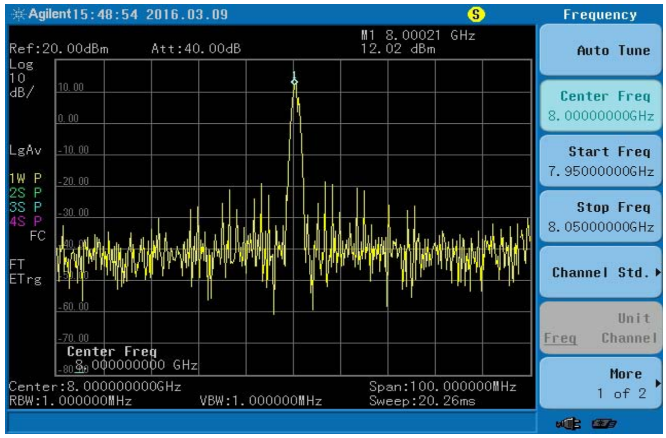


*Fig.4.5:* Dwell & Switch PRI

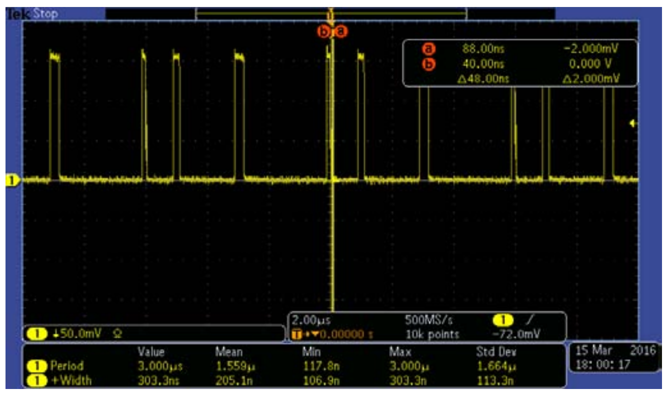


*Fig.4.6:* Oscilloscope Output [ Carrier 8GHz ]

*Synthesis Report*

| S No | |
|---|---|
| Top-level Entity Name | Neo315_Qsys |
| Family | Cyclone III |
| Total logic elements | 5,391 |
| Total combinational functions | 4,335 |
| Dedicated logic registers | 3,290 |
| Total registers | 3290 |
| Total pins | 116 |
| Total virtual pins | 0 |
| Total memory bits | 204,736 |
| Embedded Multiplier 9-bit elements | 4 |
| Total PLLs | 0 |

## V. Conclusion & Future Scope

Modern EW threat Emulation systems are combining advanced materials, SOPC'S, solid-state modules, digital signal processors, and complex A-D converters to give a better look to military and civilian users who need the best possible capability in small, compact, and efficient packages. Recent EW threat emulation systems often have imaging capability, can yield digitized signals quickly and easily for use with graphical overlays, can be networked together so the total system is greater than the sum of its parts, and can serve several different functions such as wide area search, target tracking, fire control, and weather monitoring where previous generations of Radar technology required separate systems to do the same jobs.

Most important, however, is the relative ease and speed with which modern analog Radar signals can be converted to digital information. Not only does this open wide variety of signal processing options, but it also enables Radar information to be made available in Real time or near Real time on Internet type networks for inclusion in the digital battle field and Global Information Grid visions of the future. The Emulation system developed in this paper is used to test the ESM Receiver with most of the mathematically defined signals. Two thousand levels of variation can be implemented in the case of Stagger and constant which is definitely an advancement which is possible using SOPC as implemented.

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# Barriers and Opportunities for Residential Solar PV and Storage Markets – A Western Australian Case Study

By Dev Tayal & Vanessa Rauland
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*Abstract-* Residents and businesses around the world are increasingly installing solar photovoltaic (PV) panels and battery storage systems, satisfying not just their interest in clean energy, but also taking advantage of reduced technology costs and mitigating against future electricity price rises.

Solar PV panels coupled with storage systems present an opportunity to move towards a resilient, affordable, flexible and secure electricity network.

Western Australia provides a unique set of conditions (isolated network, high solar radiation, and rising electricity prices), which has contributed to the rapid uptake of solar PV's in the state. Yet, a number of issues are still obstructing the transition to renewables.

Using Western Australia as a case study, this paper investigates the barriers inhibiting the network transformation and explores the role that solar PV and storage can play as a disruptive threat to the incumbent, centralised service model of electricity utilities.

*Keywords: solar; storage; energy; electricity; barriers; network.*

*GJRE-F Classification: FOR Code: 290903p*

BARRIERSANDOPPORTUNITIESFORRESIDENTIALSOLARPVANDSTORAGEMARKETSAWESTERNAUSTRALIANCASESTUDY

*Strictly as per the compliance and regulations of :*

# Barriers and Opportunities for Residential Solar PV and Storage Markets – A Western Australian Case Study

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*Abstract-* Residents and businesses around the world are increasingly installing solar photovoltaic (PV) panels and battery storage systems, satisfying not just their interest in clean energy, but also taking advantage of reduced technology costs and mitigating against future electricity price rises.

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Western Australia provides a unique set of conditions (isolated network, high solar radiation, and rising electricity prices), which has contributed to the rapid uptake of solar PV's in the state. Yet, a number of issues are still obstructing the transition to renewables.

Using Western Australia as a case study, this paper investigates the barriers inhibiting the network transformation and explores the role that solar PV and storage can play as a disruptive threat to the incumbent, centralised service model of electricity utilities.

These barriers are identified and qualified through a series of interviews with several Western Australian energy market participants.

If policy makers intend to enable widespread adoption of solar PV and storage, they will need to address barriers to support these emerging technologies. In parallel, market participants must work with policy makers to drive flexibility in regulatory frameworks and progress the evolution towards innovative and sustainable electricity networks of the future.

*Keywords: solar; storage; energy; electricity; barriers; network.*

## I. Introduction

Western Australia (WA) has inadvertently become a central player in addressing the universal challenges that are inherent in the transition to a renewable, distributed model of electricity networks. The WA Government has traditionally subsidised the centralised model of fossil fuel generation as a political offering to consumers. But this has only artificially reduced prices, and taxpayers ultimately face the impact of non-cost-reflective pricing. As a result, the state is now faced with some of the highest increases to electricity costs in the world, has discovered this subsidy is unsustainable, and is thus seeking to benefit from the some of the best renewable resources available (Nahan, 2015; Bromley, 2015; Sayeef, 2012).

Coupled with these changing economics is the structure of WA's electricity market itself: still highly regulated, dominated by Government-owned entities and currently undergoing a major reform program. Although the WA market is relatively late in considering initiatives such as full retail competition and flexible pricing (Australia's Eastern States implemented similar reforms through the nineties), the industry is now open to consider major structural reforms and market re-design - not just economic improvements to existing models (CSIRO, 2009; Sharma, 1997). For example, WA is now in prime position to consider the impact of increasing penetration of solar PV on the grid and unlock the potential of increasingly cost-competitive battery storage systems. The technology innovations driving battery costs lower will only increase the challenges for utilities and Government, more so for WA's isolated electricity network relative to other states in Australia, or around the world. As such, the authors predict that WA's energy sector and market will become a demonstration site for energy authorities around the world looking for guidance on how to manage the transition (Parkinson, 2015a).

Whilst other markets are also beginning to contend with the pressures of solar disruption (most notably Hawaii, California and Germany), WA has a unique confluence of economic affluence, market reform, network isolation, high solar radiation and consumer demand that has driven enough Government impetus to recognise the urgency in addressing its impacts (Parkinson, 2015; Bromley, 2015).

While change is imminent, there are still a number of barriers. This paper explores what barriers are preventing renewable energy technologies (specifically residential solar PV and battery storage) from transforming the current energy markets of WA to deliver across the priority outcomes of a low cost, low-carbon, and secure energy network.

Through conducting an extensive literature review and analysing a series of interviews with industry stakeholders, key barriers relating to the development and integration of residential solar PV and battery storage in WA are identified. To assist in the

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identification process, this paper classifies these barriers into three groups: institutional, technological and financial.

It is hoped that this research can be used in practice to encourage energy businesses and utilities operating in WA (and those in similar energy markets around the world), to utilise solar PV and storage systems in a strategic fashion, in order to reduce grid congestion, and/or to remove (or at least defer) the need for network investments, thereby creating value for all stakeholders. This research should also provide valuable insights and recommendations to policymakers currently grappling with an electricity service and delivery model in a state of flux. The authors note that ultimately, all electricity grids share a common goal of achieving a safe, secure, sustainable and affordable service of electricity to customers, and in order to achieve this, leveraging and integrating new technologies into existing grid structures and business models will be inevitable.

## II. Background

### a) The WA energy transition

Energy markets are inherently complex structures. They have numerous stakeholders constantly lobbying for industry and regulatory reform. In WA, the complexity is made even more apparent by the state's geographical isolation, preventing any feasible prospect for WA's networks to be connected to neighbouring systems. However, within this challenging environment, WA's unique isolation also presents an opportunity to study the extent to which renewable energy technologies and distributed generation can be utilised to disrupt the conventional, centralised model of our existing systems.

In WA, the energy sector (retail, distribution and generation of electricity and gas) accounts for around three-quarters of the state's greenhouse-gas emissions, with just over 40 per cent of this attributed to electricity generation (EPA, 2007; ABS 2012). Resource availability, and the associated politics and economics of fossil fuel supply (with an abundance of gas, oil and coal resource in the state), are major factors that will shape energy market reform and policy going forward (Martin, 2015; Commonwealth of Australia, 2012; Tongia, 2015).

The WA Government has remained relatively silent on the issue of climate change, and in particular, its interactions with electricity generation. Meanwhile, the underlying economics of renewable generation have already shifted in favour of the decentralised models of clean technology - as afforded by solar PV and storage, and concerns are already being raised with regards to future industry investment and business decisions for WA energy companies (COAG, 2014; Allen et al., 2009; Grace, 2014).

Recognising the inevitable impact of a changing environment, on 6 March 2014 the Minister for Energy in WA launched a broad based review of the structure, design and regulatory regime of the electricity market in the south west interconnected system (SWIS) of WA. The Minister reflected industry wide-concerns that the electricity market was not functioning as expected and was susceptible to high network costs and the need for significant subsides to maintain downward pressure on costs, contributing to high (and rising) electricity prices (Government of WA, 2014).

These assessments were made against a 'business as usual' view for the government's electricity businesses. However, when considered in the context of the changing landscape – driven by the need for clean energy to address climate change and the surge in distributed generation, particularly in the form of solar PV systems plus storage (Denholm, 2007; Katiraei, 2011; Yip, 2013) – this new wave of technical innovation is set to disrupt WA's electricity utility business models, dramatically affect the availability of capital in the industry, and further intensify the issues with the State's electricity market.

In January 2016, an additional impetus for distributed energy systems was (unfortunately) provided by a destructive fire that damaged or destroyed 873 power poles, 77 transmission poles, 44 transformers and up to 50 kilometres of overhead power lines (Western Power, 2016). In response to criticism of the high expenses involved in restoring the grid, the Minister for Energy in WA outlined that distributed energy options, such as the use of solar and storage micro-grids, were being considered by Western Power (Parkinson, 2016A).

As market dynamics force the hand of electricity utilities globally, changing the business model away from a conventional, grid-based system towards a grid plus distributed solar model across the entire network is forming as a likely solution for WA electricity businesses. Utilities undertaking future business planning and strategy development should be proactively looking to energy efficiency, solar PV and energy storage as growth opportunities rather than an existential threat, and acknowledging that their place in the energy system will only grow (Poudineh &Jamasb, 2014; Klose et al, 2010). The question then remains as to why electricity businesses have not already embraced this change, and what barriers are preventing this transition from occurring.

## III. Methodology

### a) Interviews

A review of existing literature was carried out over six months to gain a broad understanding of barriers to the increased adoption of solar PV and residential storage systems in electricity networks around the world. This research helped to inform the design of a series of semi-structured interviews held with several stakeholders in the WA electricity industry, to ascertain the specific barriers, obstacles and potential solutions within the Western Australian context. Semi structured interviews are based on a protocol and were identified as the most relevant method to use to ensure consistency of topic and discussion (Robson, 2002).They involve priming interviewees for responses based on a set of formulated questions (see Table 1), but also provide flexibility for the discussion to involve topics beyond the structured questions.

*Table 1:* Semi Structured Interview Questions

| No. | Question |
|---|---|
| 1 | What are your thoughts on the speed of the energy [revolution/evolution] process occurring? |
| 2 | Where do you see your businesses' role in the solar PV and/or residential storage market?<br>Are you already/planning/exploring/advising product and service offerings in this space? |
| 3 | Energy st orage is often quoted as the most 'disruptive technology', but to what extent is it an opportunity or a challenge for your business?<br>Do these technologies pose any challenges in maintaining the service of traditional electricity networks? (e.g. expectation for 1 in 10 year service interruptions?), and related to this, what do you see as the biggest threats over the next 2 – 5-10 year time horizons? |
| 4 | Are you also considering large-scale solar projects? i.e. once base-load coal and gas generation retires? If not, why not? (UBS released a very optimistic report on the growth prospects of large-scale solar projects for Utilities) |
| 5 | How else is your business model changing? Would you consider splitting off 'traditional' energy from renewables (e.g. E.ON in Europe?) |
| 6 | What are the remaining barriers, if any, for residential solar PV and storage markets and will the rapidly evolving landscape drive potential opportunities specific to WA? |
| 7 | How can existing barriers be overcome? Through regulation and policy change? Technological innovation? Capital investment? Business Model adaptation? |
| 8 | Any active measures you and your company are employing over the short term to address these barriers? |
| 9 | How will the continued uptake of solar PV and storage affect cost and revenues for utilities and what are the likely impacts for consumers? |
| 10 | What is your view on the tariff reform needed going forward?<br>Would you support a demand based network tariff being passed through retailers to more accurately reflect the cost of the system?<br>How should technologies such as solar and storage best be rolled out at the consumer level, and what role will tariffs play in helping this? |
| 11 | Where do you see WA's energy market relative to the east coast?<br>Other places in the world? |
| 12 | What is the best means to transition the grid, as it is now, to one best placed for the future? |

Interviewee responses helped to identify how important, in practice, these barriers are in the adoption decision and to gain a greater understanding of the challenges that participants in the electricity industry are having to grapple with, particularly during this disruptive period in the energy sector.

Although the interviews were primarily conducted with Western Australians regarding the local barriers faced, it is expected that they could be considered indicative of issues faced globally across energy markets worldwide. It is also noted that under normal circumstances, this information is often difficult to acquire – as business challenges and potential innovations remain in-house and are rarely published in public material. By framing the interviews as a contribution to research, without unduly impacting any competitive advantages the participants and their respective companies may otherwise be protecting, the interviews were able to achieve a rare level of candor to benefit the study.

*b) Selection process*

Various methods were used to identify candidates. These included online databases (e.g. LinkedIn), industry magazines, conferences, news articles, academic literature, and recommendations. They were contacted via email and in total, 40 people were asked to take part in the interviews, of which 45% accepted.[1]

The open nature of semi-structured interviews also allowed for new topics to be discussed, and the guide was tailored to suit the interviewee's experience and background and adapted 'live', depending on what the interviewees said.

Interviewees were identified on the basis of their knowledge and expertise in this area, primarily within the WA electricity sector. Interviewees were predominantly senior executives and directors and represented an

[1] Homogeneity of interview content, structure and participants, and a high degree of expertise of participants offers comprehensive information from smaller interview samples (Guest et al., 2006).

eclectic mix of organisations, including: state and local governmental bodies, network generation and retail electricity utilities, private energy companies, energy consulting firms, associations, non-governmental organisations, academics, and several industry professionals from legal, economic and political backgrounds. The importance of a wide ranging selection across public, private and individual viewpoints was identified in order to obtain more of a balanced and objective account of the current challenges related to distributed generation and barriers being faced in residential solar PV and storage markets.

A summary table of interviewees and their affiliation is included below, which also corresponds as a reference to particular comments and views expressed throughout the text that follows.

*Table 2:* Interview Participant Summary

| Interviewees | Affiliation |
|---|---|
| Participant 1 | Senior Manager - Energy Consulting Firm |
| Participant 2 | Managing Director – Independent WA Electricity Retailer |
| Participant 3 | Manager – Network Utility |
| Participant 4 | Manager – Government Electricity Retailer |
| Participant 5 | Director – Government Energy Policy Office |
| Participant 6 & 7 | Directors – WA Local Government |
| Participant 8 | Director – Energy Consulting Firm |
| Participant 9 & 10 | Analysts – Australian Energy Market Operator |
| Participant 11 | Director – Energy Consulting Firm |
| Participant 12 | Director – Non-Government Organisation |
| Participant 13 | Director – Local Electricity Regulatory Authority |
| Participant 14 | Partner – Professional Services Firm |
| Participant 15 | Manager – Metering Firm |
| Participant 16 | Manager – Distribution Network Utility |
| Participant 17 | CEO – Solar Energy Firm |
| Participant 18 | General Manager - Independent WA Electricity Retailer |

All interviews were recorded on a phone microphone recording application, with the majority occurring in person. The interviews were largely informal, typically lasting between 45to 60 minutes.

## IV. Results

### a) *Overview of barriers*

Research on increasing the adoption of solar PV systems has a long heritage, beginning in the 1980s and with research literature continuing today, profiling the advancement of PV technologies from socio technical (Müggenburg et al, 2012; Dewald &Truffer, 2012), economic (Lund, 2011) and political perspectives (Jacobsson & Lauber, 2006).This research shows that the barriers to increased uptake of solar PV typically relates to a similar set of areas including socio technical, management, economic, or policy (Karakaya & Sriwannawit, 2015; Balcombe et al, 2014). Although specific research investigating the barriers from a WA context was not found, barriers are expected to be similar, albeit with varying levels of priority, and encompassing issues including cost, environmental concerns, self-generation, policy uncertainty, inertia and inconvenience and aesthetic impacts (Ratinen, 2014; Strupeit, 2015; Balcombe et al, 201 4; Sandberg & Aarikka-Stenroos, 2014; Suzuki, 2015; Luthra et al, 2014).For ease of classification, barriers have been re-grouped under three main headings: technological, institutional, and financial.

A summary of the barriers under these three classifications (as reported by stakeholders in interviewees and identified in literature) has been included in Figure 1:


*Figure 1:* Summary of barriers to solar PV and storage uptake

Each barrier is discussed in more detail below.

*b) Technological*

i. *Fore casting capability*

Forecasting inaccuracies are infamously known to drive poor decision-making across any industry, but forecasting has become embedded into the centralised model of electricity provision. In WA, actual demand growth has been far below forecasts made at the time the Wholesale Electricity Market in WA was designed. As a result there is now a substantial excess of capacity in the market, imposing a significant cost to electricity consumers as there is a Capacity Market that pays for the capacity of all generators, even if they simply provide back-up services and are rarely if ever called on to generate electricity. In conjunction, the market mechanism designed to reduce this cost over time is not functioning at all – failing to incentivise generators to mothball or retire redundant capacity. Poor forecasting by the Independent Market Operator (as WA's system operator), Government authorities, and the Economic Regulation Authority, has now resulted in a situation where consumers have to pay for the costly errors and un-needed infrastructure investments in the market (Government of WA, 2015; Parkinson, 2015B).

Whilst the impact of additional costs imposed by poor forecasting might provide residents with additional incentive to go 'off-grid' or install solar PV and storage units, at a business level, electricity generators, networks and retailers have a reduced need for additional capacity and can already secure long term power contracts at long-term average costs (Participant 1, 2016).

ii. *Constraints of existing technology*

The transformation of electricity systems requires technological innovation in order to implement services and products to consumers in an affordable and accessible way (Suzuki, 2015).The quality and reliability of solar PV and storage systems is therefore critical for their increased adoption and barriers exist relating to the uncertainty of the technical performance of solar and storage systems (Zahedi, 2011; Luthra et al, 2014). Adoption rates in China provide an example where high levels of dissatisfaction with the low performance of solar home systems (whether caused by improper usage or not) has reportedly prevented other potential adopters from purchasing systems ( Karakaya & Sriwannawit, 2015; Yuan et al, 2011). Similarly, studies in the US indicated that consumers were also likely to hesitate from adopting solar PV systems due to the perceived risks of unknown technologies and associated complexities (Drury et al, 2012).

As part of the Government led electricity market reforms in WA, the local network utility responsible for grid connections for the SWIS, Western Power, has begun reviewing its processes and technical standards for distributed generation connection in order to reduce system connection costs (Government of WA, 2015).

WA will also require the adoption of smart meters, sensors and advanced communication networks in order to realise the full benefits of new technology such as solar PV and storage systems. For example, new control systems will have to be developed to deal with the bi-directional power flows inherent in a fully developed distributed market. As existing networks evolve to become 'smart grids', utilities will also need to grapple with the complexities of data ownership, cyber security and data privacy (Luthra et al, 2014).

Market participants and smart-meter provider sinter viewed for this research noted that engaging with incumbent utilities in WA was still a slow and often unsuccessful process, with network utilities (Western Power and Horizon Power) and Government owned retailer (Synergy), still applying existing centralised business models (Participant 15, 2016). Trials being conducted by both companies (e.g. at the Alkimos Beach energy storage trial, a fringe of grid development on the outskirts of Perth)[2], and removal of regulatory barriers may assist in alleviating these technology constraints.

[2] For information on this, see https://www.synergy.net.au/Our-energy/Energy-Storage-Trial-at-Alkimos-Beach

iii. *Network capacity and access*

Integrating solar PV systems (with or without storage) also raises technical challenges in regards to network stability, reliability and power quality. Western Power is responsible for following technical rules and regulations in order to safeguard and maintain its network assets. Therefore, as the gatekeeper to network access, Western Power is extremely interested in the potential impacts of new connections. While individual residential solar PV customers introducing 1 or 2kW into the system may have only a minor impact, when aggregated across the interconnected system, or when concentrated in areas with existing network constraints or older infrastructure, network impacts may be more pronounced (Participant 3, 2016).

Given the rapid uptake of solar PV that has already occurred across the state, network access barriers appear to have been minimal over the last few years. Going forward may present a different situation, however, particularly as the penetration rates rise from less than 20 per cent of customers on the network to estimates far above 50 per cent in the next decade. The unknown disruptive component in all of this is of course the impact that residential storage systems will play across both supply and demand side management. Although the connection of small-scale residential batteries received a promising start in 2015, when the WA Energy Minister facilitated the removal of regulations prohibiting homes with battery storage from feeding electricity back into the grid (Participant 4, 2016).

c) *Institutional*

i. *Psychological will –increasing motivation to embrace innovation*

A 2013 study of the German energy market by Richter (2013), found that not only were German utilities yet to react to solar, but the majority of managers interviewed saw no future for solar PV within their organisations (at that time). This was driven by the view of solar PV as a relatively small-scale technology, with relatively high costs and therefore a strong reliance on government subsidies to remain competitive (Richter, 2013). This view may be particularly prevalent for companies without established capabilities in solar or storage technologies (most incumbents), who have a greater reluctance to embrace these technologies than comparable companies with some previous experience (Markard & Truffer, 2006; Stenzel & Frenzel, 2008; Luthra et al, 2014).This places most incumbent electricity utilities (particularly the dominant government-owned entities in WA) in a position where they may be inclined to rely more on their beliefs than facts when formulating business strategies and predicting future market outcomes (Henderson & Clark, 1990).Alternatively, as Storbacka et al. (2009) note, companies may just be 'stuck' in their mindset and identify the structures and players of the energy market as being "given and unchangeable".

In contrast, and three years on, all WA stakeholders interviewed now see solar PV as a 'disruptive innovation' given its potential (particularly in combination with residential storage systems) to challenge the entrenched, centralised models of electricity generation and the opportunities it presents to the electricity market going forward (Participant 1-18, 2016).

Further, the growth potential in the expanding solar market and building new customer relationships would be additional opportunities for utilities; and long-term contracts for solar PV provided by the utility would also facilitate customer retention. Within this new perspective, solar PV could then be viewed as a stepping stone into promoting other 'green energy' initiatives, such as energy efficiency and battery system offerings (Richter, 2013). In the WA context, many stakeholders agreed with the vast opportunities that 'new energy' offerings provide, but various views were expressed on the timing of when these opportunities would be pursued (Participant 1-18, 2016).

ii. *Organisational management - is listening to customers a bad thing?*

Interviewees also cited a general belief that lack of management expertise has acted as a central barrier to increasing adoption of solar PV and storage systems in WA. Unlike the conventional type of value chains in the centralised energy industry (i.e. generators wholesale to distributors and retailers), in the distributed generation model, participants need to develop different types of business models that cooperates across multiple fronts with multiple actors (Karakaya & Sriwannawit, 2015; Participant 1-18, 2016). The question then becomes how these new models will be developed.

Research on disruptive technology's impacts on existing markets has highlighted the inability for incumbent firms to recognise the true nature of threats to existing business models (Christensen, 1997). A study by Christensen and Raynor (2013) found that the primary reason incumbent firms are resistant to innovating product sis because of an over-reliance on listening to what customers are asking for. According to the study, the average customer is blind to any potential benefits from new and innovative products prior to their commercialisation, and therefore rather than driving any form of radical innovation, customer preferences simply lead businesses to make gradual improvements on existing products and services (Christensen and Raynor, 2013).

Apajalahti et al. (2015) identified a further institutional barrier; the inherent complexity faced by utilities attempting to unbundle and split their business units along service offering lines.

Two interviewees also raised the important issue of culture for utility businesses (Participants 8 and 14, 2016),and suggested that whilst in Government hands, WA utilities such as Horizon Power and Western Power would be more resistant to embrace innovation and would inhibit any form of lasting institutional change. One interviewee argued that unless Government-owned enterprises continued to provide secure and stable returns via traditional business models, they would be acting outside their mandate as they could then be seen as first movers and take on the risks of unproven technologies(Participant 14, 2016).

iii. *Government led decision making*

Another challenge for WA's state-owned electricity companies cited by market participants is overcoming inhibitions to adapt to changing market conditions and surmounting the barriers inherent in bureaucratic decision making processes. As government-owned entities, Synergy, Western Power and Horizon Power have a requirement to obtain not just Board approval, but Ministerial sign-off for all major strategic initiatives. This can be a slow and cumbersome process. Should these businesses remain as public corporations going forward, these restrictive remits will need to be flexible enough to adapt the company's functions and objectives to encourage innovation and repositioning, not hinder it(Participants1, 4,18, 2016).

Levi-Faur (2003), argues that this relationship with policy makers is so pervasive, that even following privatisation, bundling of interests and ties between government and utilities continues to permeate through all levels of the policy-making process. These ties slow down both the ability for utilities to change their business models, and the innovations occurring across the sector as a whole (Levi-Faur, 2003).

Indeed, utilities across Australia have been primarily interested on protecting their traditional sources of revenue, and several have gone so far as to publicly announce proposals for higher fixed tariffs, specific solar 'charges', and attempt to introduce market rules and regulations to prevent the sale of generation from battery storage connected households – all efforts to dampen the attractiveness of new technologies for customers (Parkinson, 2016B).

Further, the dominant government-owned electricity utilities of WA have previously sought to slow renewable energy development and influence state energy policies (through politically driven point scoring or otherwise), and have taken limited or lagging actions to address or benefit from its increasing relevance to energy markets and networks (Bromley, 2015; Mitchell, 2000; Pehle, 1997; Participants 1, 4, 12, 18, 2016).

Ultimately, these incumbent entities will have to adapt and compete with new services and products entering the market, or face increasing redundancy in an increasingly competitive energy market.

A renewable energy expert and active advocate in WA summarised it as follows:

> *"As long as government retains ownership of those facilities, we will not see innovative suppliers or price competition at market. As a consumer…I had no choice of another retailer to go to who might have offered me a new product, a different product. That is an example of where the lack of the competitive market and the lack of consumer choice means that I am stuck with the decision that one retailer makes."*

(Participant 12, 2016)

iv. *Government policy and reform*

The Government is often the vilified target for impeding change, and according to energy market participants interviewed, this is arguably justified in the case of policy for renewable energy technologies. The feed-in-tariff policy controversy, whereby the WA Government attempted to remove payments to solar PV customers for surplus electricity exported back to the grid, is a prime example of political uncertainty. It also led to a great deal of scepticism and added to the perception of Government introducing barriers to the adoption of solar PV (Balcombe et al, 2014; Participant 1-18, 2016).

At the federal level, confusing and complicated legislative frameworks and a lack of long term policy certainty is acting as a barrier to renewable energy investment and introducing unnecessary regulatory 'red tape' (Karakaya & Sriwannawit, 2015). Australia has had significant volumes of legislation, regulations, policies and commitments that apply to renewable energy – large and small scale renewable energy targets; renewable energy certificates, carbon pricing schemes, direct action mechanisms – all while enduring competitive pressures of relatively cheap, thermal coal plants (Martin, 2015).

The need to overcome barriers to the adoption of new technologies through the development of "clear and consistent frameworks" was also noted at the meeting of the Council of Australian Governments Energy Council (COAG, 2015).

Removing regulatory barriers was the most consistent theme and highest priority barrier identified by interviewees. As it stands in WA, there is still no reference in the overarching market objectives to any environment effects of energy supply. The WA Government has also remained notably silent on proposing any tariff reform to specifically encourage innovation and consumer investment in renewable or 'clean' technology such as solar PV– citing a preference only to remove market distortions such as eliminating subsidies given to the Government owned electricity retailer, Synergy (WA Government, 2015; Participant 3-5, 2016).

Of course, the issue then becomes how you regulate an evolving area with several unknowns. Comments from an experienced representative of the regulatory environment in Australia hypothesised that unknowns are not necessarily a barrier: "regulations are an iterative process" (Participant 13, 2016). The interviewee used the case of existing electricity market regulations, highlighting that at their early stages, the frameworks were short and concise documents, and as issues were raised, evolved in their level of detail and complexity. A similar evolution is likely already underway for regulatory flexibility to incorporate distributed generation on the WA networks.

Tariff reform was also a central theme that interviewees suggested underpinned the transformation of electricity markets (Participant 9-10, 2016). The current flat-rate electricity tariffs do not incentivise consumers to reduce demand for electricity at peak times, nor do they accurately reflect the true cost of service. Once tariff structures can leverage the capabilities of smart meters and reflect dynamic pricing structures, then the full value of solar PV and battery storage will be unlocked ((Participant 9-10, 2016).

v. *Consumer inertia and information blocks*

Related to government involvement is insufficient consumer information contributing to consumer inertia in adopting solar PV and storage systems. UK studies even highlighted a lack of trust for micro-generation system suppliers and installers due to the sharing of previous poor experiences online, or as a result of aggressive marketing and sales promotions (Taylor, 2013).

Other consumer related barriers include uncertainty and information gaps with regards to access requirements and regulations to use and connect solar and storage into the grid. This has prevented many customers from undertaking the required efforts associated with installation of these systems (Strupeit, 2015). Coupled with these uncertainties for consumers is the growing confusion surrounding local council treatment of building aesthetics (i.e. visual impact of panels), strata issues and shading complications resulting from roof-top solar PV panels being effected by neighbouring buildings and trees. These individual issues combined are likely to provide an overall threshold of inconvenience for potential adopters. While interviews with local council planners (Participant 6-7, 2016)re-enforced that there are no local council obstacles in installing the vast majority of residential solar PV or storage systems (as long as they can be considered part of the dwelling structure), the media dramatisation of the rare cases that cause problems can still feed consumer perception (Participant 6-7, 2016).

Arguably, these constraints are less evident in the WA market, where high solar resource and rising electricity prices are driving consumers through any initial or historic inertia and motivating adopters to face the risks, complexities or uncertainties anyway. Further, the expansion of solar PV providers has risen dramatically in WA over recent years, assisting with consumer education regarding price, visual impacts, maintenance requirements, PV reliability and simplifying the installation process (Faiers and Neame, 2006).

d) *Financial*

i. *Sunk network costs- network design inertia*

Sunk costs in existing network infrastructure are a significant hurdle that is central to the transformation of centralised grids towards more sustainable, distributed platforms for energy trading. A Commonwealth of Australia Governmental led investigation, the Senate's Select Committee on Electricity Prices (Select Committee, 2012), found that network design, connection and cost barriers were the main impediments to increasing embedded generation in Australia's electricity grids.

As per the current design model, customers pay for the sunk costs of electricity poles and wires (whether they want to use them or not) based on levels of spending pre-approved by economic regulators (in Western Power's case, this has been the Economic Regulation Authority). This model has provided very limited incentive to shift these electricity utilities away from their reliance on the regulated asset base (which allows for a more certain revenue stream). In effect, this model propagates old, centralised electricity service business models which are framed to see residential solar and storage generation units as a threat, rather than as an opportunity for new business (Parkinson, 2015B).

One interviewee suggested the immediate focus should be on:

> *"Applications where it already makes more economic sense to have solar and storage technologies, particularly when considering any large capital heavy projects on the electricity network - such as fringe of grid, new developments, undergrounding power lines, or replacing damaged power lines (e.g. following bushfires).*"

(Participant 1, 2016)

Indeed, for the WA context, this appears to be the approach now being followed by the Government and government-owned utilities. The aforementioned trial in Alkimosbeach, combines community scale battery energy storage, high penetration solar PV and energy management, and will test the feasibility of new energy retail models (ARENA, 2016).

ii. *Upfront system costs*

The high cost of solar PV systems is usually cited as the most common (and largest) economic barrier to increased adoption – specifically the high initial capital costs, high repair costs, and long payback period (Zhang et al, 2012; Balcombe et al, 2014; Allen et al, 2008; Ravindranath and Balachandra, 2009). It should also be noted that it is important to consider this cost in relation to the cost of substitutable energy sources available (Karakaya & Sriwannawit, 2015; Sarzynski et al, 2012).

However, significantly cheaper levelised cost of energy[3] for solar and storage systems will not automatically result in strong increases in the uptake for solar PV and storage systems (even if this cost falls below the level of the retail price of electricity), as other cost barriers are likely to continue to impinge on the attractiveness of the investment (Elliston, 2010). These barriers include, for example, investment uncertainty and risk, high rates of return, or a lack of access to debt or equity financing, which can all inhibit "an economically rational decision to install PV once prices provide agood rate of return" (Elliston, 2010: pg 8).

This view was confirmed in research by Mountain (2014), who looked at applying traditional project finance analysis to investigate the value that recent renewable energy policies (feed-in tariff payments and renewable energy target certificates) has had on the uptake of solar in Australia from 2010 to 2012. Combining these government incentives with retailer payments and avoided energy purchases, Mountain's (2014) findings suggested that, on average, households that invested in rooftop PV over the period achieved similar returns to what a utility could have reasonably expected for the same investment. In other words, without these Government incentives in the form of feed-in tariffs and renewable energy certificates, returns would have been strongly negative (Mountain, 2014). Of course, as residential solar and storage technologies continue down the cost curve, these findings will continue to be challenged.

## V. Discussion

In all interviews undertaken with stakeholders, it was implicit that whilst barriers were often discussed in isolation, it is in fact their interaction and combined impact, which has the most significant effect on the deployment and uptake of solar PV and storage systems in Western Australia (Participant 1-18, 2016).

Further, some of the barriers identified do not fit neatly into just one category and feed into multiple themes. For example, one interviewee provided a unique insight into a potential barrier that straddles both financial and technological classifications, relating to Australia's relatively small size in the global markets. In their view, since Australia offers a significantly smaller market than those found in Asia, North America and Europe, Australian consumers with strong preferences for solar and storage products will likely be left waiting in line behind the larger markets(Participant 2, 2016). This is likely to be more noticeable in relation to storage products, which have limited supply chains.

Of course, as these products become commoditised (like our mobile phones), then this limiting factor will no longer be an issue for Australian consumers. This 'maturity' of markets is already seen for solar PV systems, which have all but eroded their high capital costs through mass production and technological improvements.

This research highlighteda common occurrence of attributing general market frustrations on a particular entity - a need to blame someone for a lack of progress, regardless of whether the barriersare actual impediments or simply perceived. In the case of impediments to solar PV and storage uptake in WA, the scapegoat appears to be Government and regulators. A common theme that emerged throughout all interviews was the importance of "flexible and forward looking regulatory frameworks". The example of 'uber' and the taxi industry was often cited as a likely and comparable scenario for the energy industry, whereby customers override regulators and established regulatory frameworks once presented with an affordable, efficient and favourable alternative to the status quo.

On the other hand, despite these barriers, there are still enough commercial incentives for new and existing market participants to take risks and conduct trials. The opportunitiesin WA have already been identified by global technology and energy service companies (e.g. storage providers: Enphase, Tesla and Red flow), who are working with local governments and electricity businesses to pilot projects such as battery technology trials, innovative pricing structures, demand side management studies and long-term capacity planning methodologies. As the diffusion of these technology innovations grows in the WA energy market, new opportunities will continue to arise for both existing and emerging businesses, and importantly consumers are in line to benefit.

Lastly, the timing uncertainties and the speed at which the energy (r) evolution may occur was a topical theme brought up by most interviewees. The full spectrum of rates of change were voiced across the interviewees, from "yesterday" to "decades away", with the common understanding that forecasting the speed of innovation is an inherently complex task. Although in relation to timing, one respondent (Participant 1, 2016) highlighted the interesting dynamic of late-movers to storage systems potentially benefiting substantially, arguing that once electric vehicle uptake is at a reasonable level (e.g. in 2030), the secondary market for the vehicle's batteries to be used as conventional, stationary batteries in residential applications will likely

[3]Levelised cost of energy is a common summary measure of the overall competitiveness of a particular technology and includes capital and fuel costs, operating and maintenance costs, and financing costs, as well as the assumed rate of utilisation.

be over supplied and lead to significant downward pressure on battery prices (Participant 1, 2016).

It is outside the scope of this paper to examine in depth the solutions needed to overcome the myriad of barriers inhibiting greater uptake of solar and batteries in the market. Nevertheless, based on the barriers identified in this paper, some potential solutions, which will require further research, may include:

- Improved regulatory frameworks that remove economic and political barriers at the same time as promoting necessary capital investment;
- Customer involvement and education;
- Development of infrastructure – e.g. upgrade to smart grids and bi-directional communication systems;
- Changes to licensing requirements (to allow power purchase agreements) and revision of customer protection frameworks;
- Increased transparency, introduction of performance reporting, and lower cost connection requirements for distributed generation; and
- Exploration of new utility *business models* (e.g. partnership with technology providers and third-party ownership products to shift financial and performance risks away from customers).

## VI. Conclusions & Policy Implications

This paper focused on the existing barriers to increased penetration of residential solar PV and storage in WA. Three broad groups of barriers were identified and discussed: technological, institutional and financial. A range of issues were identified under each of these groups, both from existing literature, as well as from interviews with key stakeholders working within the WA energy market.

The main barriers identified within the technological barrier include: forecasting capability; constraints of existing technology; and network capacity and access. Institutional barriers include: psychological will of people and the reluctance to embrace the new; organisational management and issues associated with listening too closely to customers; the need for Government lobbying and policy reform; and consumer inertia& information blocks. The main financial barriers discussed include: how to deal with sunk network costs; as well as inertia around network design and how to cover the upfront system costs of solar PV and batteries. A collective view of the discussions suggests that the adoption of solar PV and storage systems is still a challenging process and one that requires all stakeholders in the sector – whether they are industry stakeholders, policy makers, local communities or consumers – to participate in the transition towards a more innovative and sustainable electricity networks of the future. Results also suggest that regulatory and policy reform is what will underpin the removal of other financial, institutional and technological barriers. Without cohesive collaboration and dedicated support for this regulatory and policy reform, the barriers to wider adoption of technology innovations will not be easily overcome.

While many countries worldwide are yet to fully embrace or acknowledge the forthcoming disruption to global electricity markets by solar PV and battery storage technology, the WA stakeholders interviewed clearly recognise these as a disruptive innovation that is already having a significant impact on the WA energy network and market.

The unique set of conditions within WA (i.e. economic affluence, imminent market reform, network isolation and increased consumer demand for solar and, increasingly, batteries) has created a situation and issue which the WA Government can no longer ignore. For this reason, it is expected that WA's isolated electricity network and energy market will become a demonstration site for energy authorities around the world looking for guidance on how to manage the transition and adapt their own regulatory frameworks for the future.

Given the technological and political uncertainty that remains, this paper highlights the importance of firstly creating regulatory transparency to empower a robust, yet flexible policy design, that can then be used to underpin the energy markets that are essential to the sector. Over the long-term, it is the efficiency of markets that will drive competition, rather than regulators. For example, removing barriers to entry for solar PV and storage will facilitate uptake, which will in turn drive innovation and customer choice across retail, network and wholesale markets. Policy makers must recognise the importance of not only identifying and removing any existing regulatory barriers, but creating adaptable and flexible frameworks so that any future barriers can be easily identified, navigated, or mitigated.

Further research is needed to examine the specific solutions that WA may require to address and minimise the negative impact on the network and the market.

*Highlights:*

- Several barriers to residential solar PV and storage remain in Western Australia
- Barriers are qualified through a series of interviews with Western Australian energy market participants
- Common scapegoat appears to be Government and regulators
- Flexible and adaptable regulatory frameworks are important for innovation

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# A Critical Analysis on Electro-Mechanical Works of Public Works Department Based on Key Performance Indicators to Comply PPA 2006 & PPR 2008

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*DESCO*

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*Keywords:* *PPA, PPR, KPI and PWD.*

*GJRE-F Classification:* *FOR Code: 290901p*

ACRITICALANALYSISONELECTROMECHANICALWORKSOFPUBLICWORKSDEPARTMENTBASEDONKEYPERFORMANCEINDICATORSTOCOMPLYPPA2006PPR2008

*Strictly as per the compliance and regulations of :*

# A Critical Analysis on Electro-Mechanical Works of Public Works Department Based on Key Performance Indicators to Comply PPA 2006 & PPR 2008

Kanij Fatema [α], Avizit Basak [σ], Sobuj Kumar Ray [ρ] & M. M. Israfil Shahin Seddiqe [ω]

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The research has been designed under the questions if PWD's electro-mechanical works are following PPR 2008 completely or not; and if not, then the causes behind that. The main objectives of the present study are to find out the extent of compliance of PPR 2008 by PWD and to find out the gap of compliance and scope of improvement for implementation. The related literatures and reports, particularly from PWD and SRGB, have been thoroughly reviewed before conducting the main research work. The key findings of these reports have been compared and analyzed which helped to draw important conclusion of the study.

*Keywords: PPA, PPR, KPI and PWD.*

## I. Introduction

### *a) Background and Context*

"Procurement" means the purchasing or hiring of Goods, or acquisition of Goods through purchasing and hiring, and the execution of Works and performance of Services by any contractual means. When procurement is done with public money, then it is called public procurement.

Until 2003, there was no standard and legal framework for public procurement in Bangladesh and General Financial Rules (GFR) had regulated public procurement procedures and practices in Bangladesh. These rules were originally issued during the British period and slightly revised in 1951 under the Pakistani rule. After Bangladesh's independence, few changes were made to these rules in 1994 and 1999 respectively (Islam, 2011).

To ensure transparency and accountability in the procurement of goods, works or services using public funds, and ensuring equitable treatment and free and fair competition among all persons wishing to participate in such procurement, the Government of the People's Republic of Bangladesh has enacted Public Procurement Act 2006 (hereinafter called PPA 2006) on 06 July 2006. Under the framework of PPA 2006, the government issued Public Procurement Rules 2008 (hereinafter called PPR 2008) which has come into effective on January 31, 2008. All these were the outcomes of the reform process taken by the government to streamline the public procurement. Earlier in 2003, Public procurement Regulations 2003 which was effective till the PPR 2008 was issued (Hoque, 2010).

Upon issuance of the PPA 2006 and PPR 2008, the government agencies are bound to follow the Act and Rules in the day to day procurement activities of their own. The Central Procurement Technical Unit (CPTU) of the Implementation Monitoring and Evaluation Division (IMED) of the Ministry of Planning have been established for carrying out the purposes of Section 67 of PPA 2006 which states as follows:

*Section 67: For carrying out the purposes of the Act, the Government shall, through a Central Procurement Technical Unit or any other unit established by it relating to procurement monitoring, coordination and management, perform the following responsibilities, namely –*

a. Providing for monitoring compliance with and implementation of this Act through the authority as

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designated by the Government;

b. Arranging for performance of the necessary functions and responsibilities incidental thereto, through the authority as designated by the government and
c. Performing any other responsibilities as prescribed.

*b) Statement of the Problem*

Procurement of Goods, Works, and Services are also covered by the IMED's existing way of undertaking implementation monitoring and evaluation tasks but not monitored and evaluated on the basis of any key performance monitoring indicators. That's why CPTU of IMED is monitoring procurement performance through the PPRP-II project. CPTU has appointed a Project Implementation Support Consultant for each of the four target agencies. These consultants are submitting the procurement performance report of each agency on quarterly basis. Also, a consultancy firm, Survey Research Group (SRG) Bangladesh, appointed by CPTU, is submitting quarterly the reports to CPTU based on KPIs. Though it is reported that procurement performance of the target agencies are improving day by day, it would be wise enough to have an independent study to ascertain the procurement performance of the target agencies.

*c) Significance of the proposed research*

The procurement performance of the target agencies have been described and classified in terms of transparency, efficiency, competitiveness and compliance of government procurement rules and procedures. Among the four different categories, compliance of PPR 2008 is considered as the vital one. It is generally considered that if compliance is ensured, then the government purpose for ensuring value for money in the public procurement will be possible.

Among the four target agencies, PWD has a significant quantity of budget allocation against the projects in the Annual Development Program me (ADP).

*d) Research Questions*

This study is aims to know the extent of compliance of PPR 2008 by PWD procurement activities. Also it is intended to know the hindrances which have been faced by PWD while complying with the rules of PPR 2008. Thus, the research questions for the present study are:

i. Is PWD following PPR 2008 completely?
ii. If NO, then what are the causes behind this?

*e) Objectives of the Study*

The objectives of the present study are as follows:

i. To find out the extent of compliance of PPR 2008 by PWD.
ii. To find out the gap of compliance and scope of improvement for implementation of PPR 2008 in PWD.
iii. How to streamline the electro-mechanical works of PWD on the basis of KPIs set by PPA 2006 & PPR 2008.

*f) Scope of the Study*

Under the supervision of the Project Implementation Support Consultant appointed to PWD on behalf of CPTU, the procuring entity (PWD) is carrying out the monitoring and evaluation of their procurement performance in accordance with the set KPIs. But an independent study is intended from the concerned authorities to find out the gap of compliance of PPR 2008 in PWD. This study is such an approach for ascertaining the facts in PWD.

*g) Limitations of the study*

The limitations of this study have come from both its scope and its methodology. Survey was confined to electro-mechanical works of PWD Head Quarter and Dhaka. The respondents were selected mainly from the organization's head office and Sher-e-Bangla Nagar office of Dhaka city. On the other hand, officers were selected on the basis of researcher's convenience. Key informant interview was conducted on few senior officers and with the consultant engaged in PWD from CPTU. Time constraint was also one of the major limitations of the study. Most of the respondents had gathered different types of experiences in different projects; sometimes experiences were not generalized rather project-specific. This issue had come across during the interviews. Also the officers were requested to give answers based on their own perception. As the perceptions on situation varied from person to person, this may have been a major limitation of the study.

## II. Methodology

*a) Methods of collecting data/Sampling method*

A questionnaire survey was adopted for this study. Survey method was used as this is considered as the best method available to the social scientists interested in collecting original data. It gives a clear idea about the actual facts. A quantitative method was followed in this study.

*Table 1:* Name of work: - Revised DPP for Vertical Extension of BCC Bhaban under the project "Strengthening of BCC by Development of structure, 4th floor to 10th floor

| | | | Taka in Lac. |
|---|---|---|---|
| | A. Electrical (Internal Electrification ) | | |
| | i) Internal Electrification of main building | (Area=10551sq.mx1420/-) | 149.82 |
| | ii) Special fittings fixture | L.S | 20.00 |
| | iii) Internal Electrification for Auditorium | L.S | 20.00 |
| | iv) Normal & Emergency MDB.SDB.DB control | L.S | 20.00 |
| | B. Electrical (External Electrification ) | | |
| | i) 400 KVA Generator including cables | 1 Set. | 70.00 |
| | ii) 2000KVA sub-Station equipment & HT. LT cable | 1 Set. | 180.00 |
| | iii) Compound security garden light * facade light | L.S | 15.00 |
| | iv) Earthing with lighting arrester system | 1 Set. | 23.00 |
| | C. Mechanical | | |
| | i) Split type Air-cooler and Split ducted type air cooler system | 600 Ton | 600.00 |
| | ii) Passenger lift ( 2Nos x1600 kg.24 person 11 stop) | 2Nos x 1600 kg. | 90.00 |
| | iii) Pump motor (For lifting water ) | 1 No | 16.00 |
| | iv) Fountain i/c pump control & cable | L.S | 15.00 |
| | D. IT Environment and support | | |
| | i) Computer Networking system (LAN) | L.S | 50.00 |
| | ii) Telephone & PABX system | L.S | 20.00 |
| | iii) Access control system and entry scanner & security post | L.S | 15.00 |
| | iv) PVC pipe laying | L.S | 10.00 |
| | v) PA& Conference system | L.S | 30.00 |
| | vi) Sound and stage lighting system | L.S | 60.00 |
| | E. Renewable energy | | |
| | i) Solar energy plant (14KW) ( 14x3.00 Lac) | | 42.00 |
| | F. Building Automation (E/M works ) safety and security | | |
| | i) Fire Detection protection & Alarm system | L.S | 140.00 |
| | ii) CCTV system | L.S | 30.00 |
| | iii) Building Automation (Occupancy. sensor, light dimmer intelligent & energy saving automation | L.S | 150.00 |
| | iv) Consultancy for building Automation, computer net working system, | L.S | 5.00 |
| | G. Other related works. | | |
| | i) DESA/DESCO security fee | L.S | 20.00 |
| | ii) Preparation of tender documents, honorium for TEC, TOC, Advertisement free etc. | L.S | 5.00 |
| | | Total Tk: | 1795.82 |

A questionnaire survey was adopted for collecting primary data from different stakeholders related to procurement activities of PWD and having an acquaintance with PPA 2006 and PPR 2008. For the in-depth study on compliance issues of PPR 2008, Questionnaire was given to all Division of PWD that are closely related to Electro-mechanical works with a general introduction of the research. Among them 20 (Twenty) Divisions replied with the procurement data of single project. Here both only closed ended questions were stipulated for getting the in-depth essence of procurement activities.

Before asking for filling the questionnaire, the general idea of the research objectives were exchanged with them. After the exchange of general idea of the research objectives, the questionnaire was given to them. They were requested to fill the questionnaire based on the actual data of a specific project under his/her territory. Some electronics means was also used to collect feedback from some of the PWD persons affiliated with the project.

*b) Selection of Study Area*

PWD Head Quarters and District offices were selected for collection of data in the questionnaire. Due to time constraint of the present study, it was not possible to collect data from all the districts. The study was mainly focused on the BCC Bhaban's Electro-mechanical works; As the implementation of work from the ministry wise project progress report has been attached in Appendix C, from where we get the idea that most of the works of the project have been completed and some of them are ongoing and a few of them are not yet started as work order has recently been placed against those works. Especially those which are in the middle stage of their implementation were considered for the study, but some procurement information from the rough estimate of the works as stated bellow-

*Table 2:* Name of work:- Rough Estimate for Vertical Extension of BCC Bhaban under the project " Strengthening of BCC by Development of structure, 3rd phase (11th floor to 14th floor)

| | | | Taka in Lac. |
|---|---|---|---|
| | A. Electrical (Internal Electrification ) | | |
| | i).Internal Electrification(Non Residential Building ) | (Area=6677sq.mx1420/-) | 94.81 |
| | ii). Special fittings fixture and metering system and safety control device | L.S | 20.00 |
| | iii) Normal & Emergency MDB.SDB.DB control in/c L.T cable etc. | L.S | 50.00 |
| | B. Electrical (External Electrification ) | | |
| | i) 400 KVA Generator including cables | 1 Set. | 60.00 |
| | ii) Extension of Earthing with lightening arrester system | 1Set. | 15.00 |
| | iii) Compound lighting from roof | L.S | 5.00 |
| | C. Mechanical | | |
| | i) Split type Air-cooler and Split ducted type air cooler system | 350 Ton | 400.00 |
| | ii) Passenger lift (1600 kg 24 person 15 stop with AVR) | (1No x50.0) | 50.00 |
| | iii) Observation /capsule lift.(1000Kg) 15 person 15 stop with AVR | 1 No | 90.00 |
| | D. IT Environment and support | | |
| | i) Computer Networking system | L.S | 40.00 |
| | ii) Telephone & PABX system | L.S | 20.00 |
| | iii) PA& Conference system | L.S | 30.00 |
| | vi) CCTV | L.S | 20.00 |
| | v) PVC pipe laying (For Telephone, PABX, Intercom CCTV, internet etc. | | 8.00 |
| | vi) Access control system and entry scanner & security post | L.S | 8.00 |
| | E. Renewable energy | | |
| | i ) Solar energy plant | 8Kw x3.00 | 24.00 |
| | ii) Shifting of solar energy plant from 10th floor to 14th floor roof top | L.s | 2.00 |
| | F. Building Automation (E/M works ) safety and security | | |
| | i) Fire Detection protection & Alarm system | L.S | 50.00 |
| | ii) Building Automation (Occupancy. sensor, light dimmer intelligent & energy saving automation | L.S | 50.00 |
| | iii) Consultancy for building Automation, computer net working system, Fire protection and detection system etc. | L.S | 5.00 |
| | G. Other related works. | | |
| | i) Preparation of tender documents, honorium for TEC, TOC, Advertisement free etc. | L.S | 5.00 |
| | | Total Tk: | 1046.81 |

We get the original approved official estimate on which the Project work was performed.

*c) Study Period*

Survey was conducted at different Division offices of PWD, Planning Commission, IMED, and TEC members of PWD from Roads and Highways Department (RHD) and Public Works Department (PWD) Dhaka, Bangladesh from December 2015 to May 2016.

*d) Sample Size*

For Questionnaire, the respondents were categorized in four different types namely i) PWD's employee, ii) TEC Members, iii) Persons who are dealing with PWD's projects iv) Others. As there are numerous people are concerned with PWD's procurement activities of Electro-mechanical works, a total of 28 different officers given their data.

Projects for the study were randomly selected as PWD does not do a lot of Electro-mechanical Project work every year, and due to the time constrain of the dissertation.

*e) Data processing and Analysis/Analytical Fram*

*Table 4:* KPI_6

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | Neutral | 4 | 14.3 | 14.3 | 14.3 |
| | Good | 13 | 46.4 | 46.4 | 60.7 |
| | Very Good | 11 | 39.3 | 39.3 | 100.0 |
| | Total | 28 | 100.0 | 100.0 | |

*Table 5:* KPI_11

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | Neutral | 2 | 7.1 | 7.1 | 7.1 |
| | Good | 10 | 35.7 | 35.7 | 42.9 |
| | Very Good | 16 | 57.1 | 57.1 | 100.0 |
| | Total | 28 | 100.0 | 100.0 | |

As a means of processing, collected data have been cleaned, edited, arranged and coded before statistical analysis. The main statistical analytical tool used in this study was Statistical Package for Social Science (SPSS) to analyze and interpret the subject matter of the study and for preparing the frequency table & other tables and for constructing pie charts. 5-point Likert scale was used in the questionnaire to categorize the answers for easy analysis.

Microsoft Excel has been used for preparing Some of the tables related to the BCC Bhaban Project. Microsoft Word has been used for preparing the report.

## III. Result & Discussion

Aim of this study is to find out the level of compliance of PPR 2008 by BCC Bhaban in its procurement activities. This study is specifically aimed to assess the gap of compliance and scope of improvement for implementation of PPR 2008 in BCC Bhaban vertical extension 3rd phase.

*a) Demographic overview of the respondents*

Questionnaire survey has been conducted among officers mainly responsible for Vertical Extension of BCC Bhaban under the project "Strengthening of BCC Bhaban by Development of structure". These officers are from PWD and involved in the project in various engineering activities. Also the respondent holds different ranking and all of them are well acquainted with procurement process of BCC Bhaban extension 11th floor to 14th floor.

Below is a summary of demographic information of respondents,

*Table 3:* Summary of demographic information of the respondents

| Respondent's | Frequen | Percent |
|---|---|---|
| *Organization* | | |
| PWD | 28 | 100.0 |
| Total | 28 | 100.0 |
| *Designation* | | |
| Assistant Engineer | 9 | 32.1 |
| Senior Assistant Engineer | 6 | 21.4 |
| Executive Engineer | 3 | 10.7 |
| Administrator/Consultant | 6 | 21.4 |
| Project Director | 4 | 14.2 |
| Total | 28 | 100.0 |
| *Relevancy with PWD* | | |
| Employee | 9 | 32.1 |
| TEC Member | 5 | 17.8 |
| Dealing with BCC Bhaban | 12 | 42.8 |
| Others | 2 | 7.1 |
| Total | 28 | 100.0 |
| Education Level | | |
| Masters' | 3 | 10.7 |
| Bachelor | 24 | 85.7 |
| Others | 1 | 3.6 |
| Total | 28 | 100.0 |
| Training on PPA/PPR 2008 | | |
| Yes | 25 | 89.3 |
| No | 3 | 10.7 |
| Total | 28 | 100.0 |
| | | |

b) *Overview of survey questionnaire*

The respondents were asked Seventeen (17) questions regarding compliance of PPR 2008 in BCC Bhaban's procurement activities for the Vertical extension from 11$^{th}$ floor to 14$^{th}$floor. Questionnaire were asked to the respondents on compliance KPIs in a 5-point Likert scale where as 1 for "Very Poor", 2 for "Poor", 3 for "Neutral", 4 for "Good" and 5 for "Very Good". Frequency distributions of response are shown in Table 2 and Table 3 respectively

*Table 6:* KPI_13

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | Neutral | 2 | 7.1 | 7.1 | 7.1 |
| | Good | 9 | 32.1 | 32.1 | 39.3 |
| | Very Good | 17 | 60.7 | 60.7 | 100.0 |
| | Total | 28 | 100.0 | 100.0 | |

*Table 7:* KPI_14

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | Very Poor | 1 | 3.6 | 3.6 | 3.6 |
| | Poor | 3 | 10.7 | 10.7 | 14.3 |
| | Neutral | 4 | 14.3 | 14.3 | 28.6 |
| | Good | 8 | 28.6 | 28.6 | 57.1 |
| | Very Good | 12 | 42.9 | 42.9 | 100.0 |
| | Total | 28 | 100.0 | 100.0 | |

*Table 8:* KPI_19

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | Very Poor | 1 | 3.6 | 3.6 | 3.6 |
| | Poor | 2 | 7.1 | 7.1 | 10.7 |
| | Neutral | 4 | 14.3 | 14.3 | 25.0 |
| | Good | 10 | 35.7 | 35.7 | 60.7 |
| | Very Good | 11 | 39.3 | 39.3 | 100.0 |
| | Total | 28 | 100.0 | 100.0 | |

*Table 9:* KPI_20

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | Poor | 1 | 3.6 | 3.6 | 3.6 |
| | Neutral | 7 | 25.0 | 25.0 | 28.6 |
| | Good | 9 | 32.1 | 32.1 | 60.7 |
| | Very Good | 10 | 35.7 | 35.7 | 96.4 |
| | 53.00 | 1 | 3.6 | 3.6 | 100.0 |
| | Total | 28 | 100.0 | 100.0 | |

*Table 10:* KPI_21

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | Poor | 1 | 3.6 | 3.6 | 3.6 |
| | Neutral | 11 | 39.3 | 39.3 | 42.9 |
| | Good | 7 | 25.0 | 25.0 | 67.9 |
| | Very Good | 9 | 32.1 | 32.1 | 100.0 |
| | Total | 28 | 100.0 | 100.0 | |

*Table 11:* KPI_25

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | Poor | 1 | 3.6 | 3.6 | 3.6 |
| | Neutral | 10 | 35.7 | 35.7 | 39.3 |
| | Good | 10 | 35.7 | 35.7 | 75.0 |
| | Very Good | 7 | 25.0 | 25.0 | 100.0 |
| | Total | 28 | 100.0 | 100.0 | |

*Table 12:* KPI_31

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | Very Poor | 1 | 3.6 | 3.6 | 3.6 |
| | Poor | 4 | 14.3 | 14.3 | 17.9 |
| | Neutral | 3 | 10.7 | 10.7 | 28.6 |
| | Good | 14 | 50.0 | 50.0 | 78.6 |

| | | | | | |
|---|---|---|---|---|---|
| | Very Good | 6 | 21.4 | 21.4 | 100.0 |
| | Total | 28 | 100.0 | 100.0 | |

*Table 13:* KPI_33

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | Very Poor | 2 | 7.1 | 7.1 | 7.1 |
| | Poor | 1 | 3.6 | 3.6 | 10.7 |
| | Neutral | 7 | 25.0 | 25.0 | 35.7 |
| | Good | 9 | 32.1 | 32.1 | 67.9 |
| | Very Good | 9 | 32.1 | 32.1 | 100.0 |
| | Total | 28 | 100.0 | 100.0 | |

*Table 14:* KPI_35

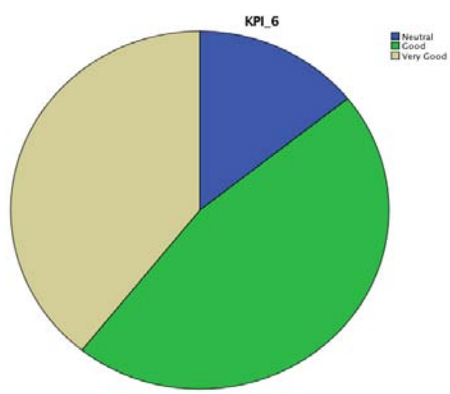
| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | Very Poor | 6 | 21.4 | 21.4 | 21.4 |
| | Poor | 2 | 7.1 | 7.1 | 28.6 |
| | Neutral | 4 | 14.3 | 14.3 | 42.9 |
| | Good | 8 | 28.6 | 28.6 | 71.4 |
| | Very Good | 8 | 28.6 | 28.6 | 100.0 |
| | Total | 28 | 100.0 | 100.0 | |

*c) Overview of the Key Informant Interview*

Key informant interview has been conducted with several engineers involved in strengthening of BCC Bhaban by development of structure, 3rd phase (11th floor to 14th floor). Most of the key informants mentioned that before PPR, General Financial Rules (GFR) was applied for the procurement of goods, works and services. The monitoring and evaluation of the then procurement activities were not so structured. These all were streamlined with the introduction of PPR 2003 and strengthened after PPR 2008.

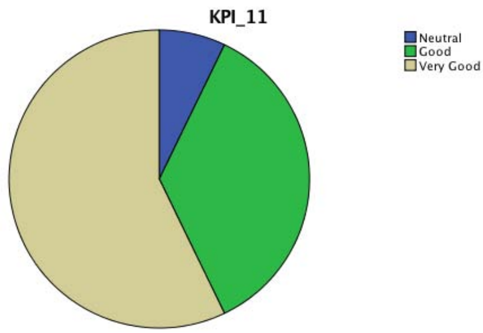
All key informants were asked about the compliance of KPIs and in-depth opinion was expected for a clear view of the issue, understanding the same and concluding thereof. Also, the key informants were asked about the problems of compliance of PPR 2008 in their respective procurement activities. The opinion of the key informants were noted down and used for analyzing the findings of the questionnaire survey.

*d) Findings of the questionnaire survey, analysis and discussion*




*KPI 6:* BCC Bhaban is maintaining time for 'publishing Advertisement and Tender submission deadline'

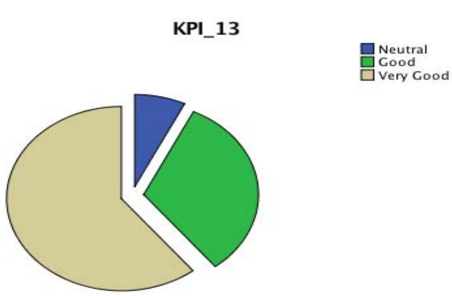
The perception of the respondents varied for this question where 14% respondent encircled 'neutral' option of the questionnaire. 46% marked it it as 'good', and 39% said its 'Very Good'. It is assumed that BCC Bhaban is fairly following the rule, as the standard deviation yield small dispersion in responses. The mean, median, and mode of the responses are 4.25, 4.00 and 4.00 respectively.




*KPI 11:* In BCC Bhaban, TOC consist of at least one member from TEC

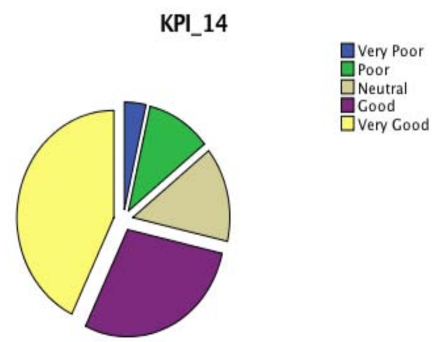
Majority respondents selected two options: 'Very good' and 'Good'. 57.1% of respondents answered the question as 'Very good' and 37.7% answered it as 'Good'. Only 7.1 % answered it as 'neutral', no 'poor' or 'very poor' were being recorded. This express that BCC Bhaban is fairly complying to the Rule 7 of PPR 2008 where Tender Opening Committee (TOC) is always consisted of at least one member from TEC. The standard deviation of the response is 0.63828 which means a small effect on the study result. The mean, median and mode of the responses are 4.50, 5.00 and 5.00 respectively.

According to Schedule II [Rule 7] of PPR 2008, Tender Opening Committee (TOC) must include one (1) member from Tender Evaluation Committee (TEC). From the perceptions of the respondents of questionnaire survey and responses of the key informants, it can be said that BCC is complying the Rule 7 of PPR 2008 as the responses are highly positive to this issue.



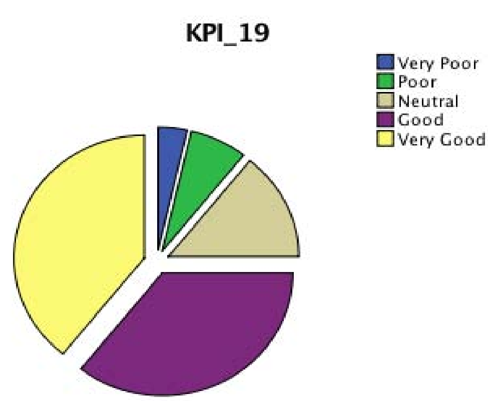

*KPI 13:* BCC Bhaban followed the rule of including Two external members for TEC

60.7% of the respondents have chosen 'Very good' while 32.1% verdict 'Good' on that question. 7.1% of the respondents remained 'neutral'. No one selected 'poor' or 'very poor' option. The standard deviation of the response is 0.63725, which means small effect on the study result. It indicates that BCC Bhaban is complying the Rule 8 of PPR 2008 very fairly and two external members are included in the Tender Evaluation Committee in general. The mean, median and mode of the responses are 3.97, 4.00 and 5.00 respectively.



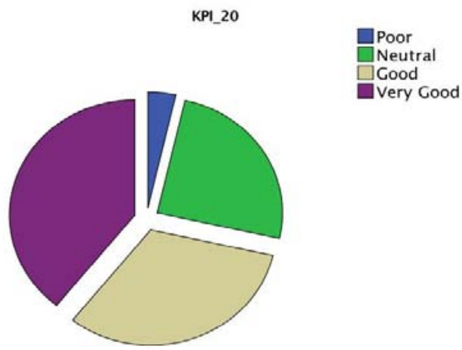

*KPI 14:* BCC Bhaban followed standard time between tender opening and tender evaluation

In response to this question, 42.9% of the respondent have given their opinion as 'Very Good' while 28.6% opted for 'Good',14.3% opted for 'Neutral' response to the question. 10.7% & 3.6% opted for 'poor' or 'very poor' respectively. The mean, median and mode of the responses are 3.964, 4.00 and 5.00 respectively. The standard deviation of the response is 0.63725 which means a small effect on the study result is present. It indicates that BCC Bhaban is complying to the Rule 36 of PPR 2008 keenly following standard time between tender opening and tender valuation. Key informant interviews also reflected in the similar manner.



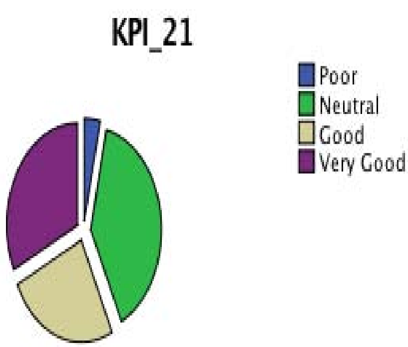

*KPI 19:* BCC Bhaban followed standard time between submission and approval of Tender Evaluation Report (TER)

In this question, 39.3% respondents choose 'Very good' while 35.7% reported as 'Good' and 14.3% shown 'Neutral' response to the question. 7.1% marked it as 'poor' while 3.6% said its 'very poor'. The mean, median, mode and standard deviation of the responses are 4.00, 4.00, 5.00 and 1.088 respectively.



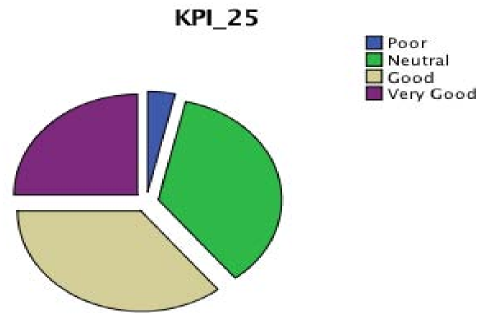

*KPI 20:* In BCC Bhaban, tenders are approved by proper CAA with DFP

In response 35.7% of the respondent have given their opinion as 'Very good' while 32.1% reported as 'Good' and 25% ticked 'Poor' as response. 3.6% gave verdict for 'poor' none opted for 'very poor'. The mean, median, mode and standard deviation of the responses are 4.77, 5.78, 4.00 and 5.00 respectively. Similar results were found among the opinions of the interviewee while conducted the key informant interview. A standard deviation of 9.294 also indicates a significant effect on the study.



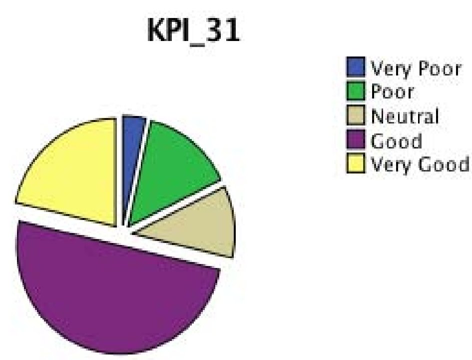

*KPI 21:* In BCC Bhaban, TEC submits TER directly to the CAA

The perceptions of the respondents on this question in this question were also very scattered, 32.1% of the respondent opted for 'very good' while the minimum 3.6% ticked 'Poor'. The other 25% respondents chose 'Good' and 39.3% remained 'Neutral' in their opinion. However, no 'Very poor' answer was received. The mean, median, mode and standard deviation of the responses are 3.857, 4.00, 3.00 and 0.9315 respectively. Though majority of the respondent's perception is 'Very good', but it can be said that BCC Bhaban is complying this rule in a fairly basis as there some respondents choose 'Poor' option.




*KPI 25:* In BCC Bhaban, timeline between approval of TER and issuance of NOA is followed properly.

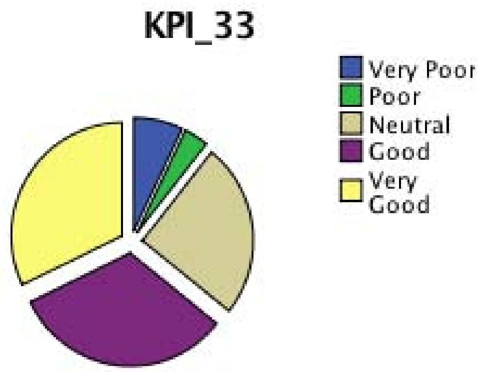
In response to this question, respondents' choices were also scattered. 25% of the respondents (60%) answered the question as 'Very Good' and 35% answered it as 'Good'. 35.7% marked as 'neutral', and 3.6% respondents went for poor'. The mean, median, mode and standard deviation of the responses are 3.82, 4.00, 3.00 and 0.862 respectively. According to the responses regarding this requirement of PPR 2008, the present study indicates that BCC is fairly comply with this timeline.




*KPI 31:* In BCC Bhaban, liquidated damage clause is imposed in the contracts where applicable as per Rule 39 (27)

In response to this question also, respondents' choices were also scattered majority of the respondents 50% answered the question as 'Good', while 21.4% opted for 'Very Good', 'Neutral' 10.7%, 'Poor' 14.3% and 'Very poor' 3.6%. Thus, there is an overall positive response to the question meaning. The mean, median, mode and standard deviation of the responses are 3.71, 4.00, 4 and 1.083 respectively.

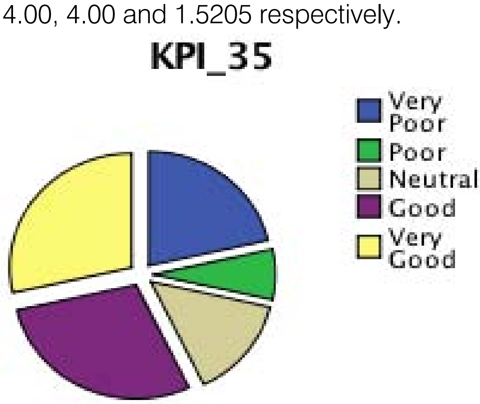
As per Rule 39 (27) of PPR 2008, it is compulsory to include the liquidated damage clause in the contracts where applicable. Though the present questionnaire survey indicates an overall positive result towards imposing liquidated damage clause in the contract but the key informants' does not validate this.




*KPI 33:* In BCC Bhaban, contractor payment is timely disbursed as per Rule 39 (22)

In response to this question, the respondents had shown a mixed response of their perceptions. 32.1% of the respondents opted for 'Very Good' while the same number of respondents for 'Good'. Among others, 25% opted for neutral, poor 3.6% & very poor 7.1%.shown their perception as 'Poor' while the rest 2.9% only replied as 'Very good'. There was no one answered the question as 'Very poor'. This has been shown in Table 3 and graphically expressed in Chart 10. The mean, median, mode and standard deviation of the responses are 3.11, 3.00, 3 and 0.676 respectively. While talked with the key informants, there found a perception that contractor's payment is timely disbursed.

In this question equal number of respondents 28.6% marked it 'Very poor' and 'Good'. While 14.3% remain 'Neutral' in their perception 7.1% was in favor of the 'Poor' opinion. However, 21.4% stated their perception to this question as 'Very Poor'. The mean, median, mode and standard deviation of the responses are 3.35, 4.00, 4.00 and 1.5205 respectively.




*KPI 35:* In PWD, interest is paid for delayed payment regularly

Payment of interest for delayed payment is a mandatory requirement of PPR 2008. However, from the present study, it can be said that BCC Bhaban is not paying any interest for a delayed payment. While conducting key informant interview, the respondents expressed their opinion candidly that as there no provision of sufficient fund in the contract, the contractors never paid for a delayed payment.

## IV. Conclusion

Compliance checking of PPR 2008 is a crucial issue for insuring good standards and value for money in the public procurement. The PPRP II has added a new dimension in the field of monitoring in the sense that it envisages to assess the compliance of the provisions of PPA-2006 and PPR-2008. This has made a shift from the existing approach and methods in dealing with procurement using public funds. Though awareness to some extent about PPA 2006 and PPR 2008 has already been developed within the officials and staffs of BCC Bhaban through mandatory application of PPR 2008 in practice and training, it will certainly take some time to get momentum of the reform activities.

The present study result shows an adherence to the rules of PPR 2008 in BCC Bhaban in carrying out most of the compliance related KPIs. Though varied in different quarters of the years, however it shows a gradual improvement since starting of monitoring.

In respect of KPI 6 (Average number of days between publishing of advertisement and Tender submission deadline), KPI 11 (Percentage of cases TOC included at least ONE member from TEC), KPI 13 (Percentage of cases TEC included Two external members outside the Ministry or Division), KPI 14 (Average number of days between Tender opening and completion of evaluation), KPI 19 (Average number of days taken between submission of Tender Evaluation Report and approval of contract) and KPI 20 (Percentage of Tenders approved by the proper financial delegated authority) and KPI 25 (Average number of days between final approval and Notification of Award (NOA)), BCC Bhaban is fairly following the rules. There is great scope and need for improvement in these areas as to have a 100% compliance of PPR 2008. However, BCC Bhaban's performance in the areas of KPI 21 (Percentage of cases TEC submitted report directly to the Contract Approving Authority where Approving Authority is HOPE or below), KPI 31 (Percentage of Contracts having liquidated damage imposed for delayed delivery/completion), KPI 35 (Percentage of Contracts where interest for delayed payments was made) are not satisfactory and needs to improve these to a great extent. Moreover, compliance of KPI 33 (Average number of days taken to release payment from the date of certificate of PM/ Engineer) need to investigate more as there are ambiguity among the findings of present study.

# IV. Recomendation

From the present study, in BCC Bhaban Project, PPR 2008 is being complied around 70%. This is seen from the viewpoint of compliance of KPIs which are only 17 out of 45 key procurement performance indicators. For further improvement, following recommendations are drawn based on the study:

- Instead of traditional procedure, submission of TER directly to the Contract Approving Authority where Approving Authority is HOPE or below, should be practiced properly to ensure the compliance of Rule 36(3) of PPR 2008. The TEC should be empowered and every member of the TEC should have an understanding of this regulatory requirement. Proper mechanism should be developed within BCC Bhaban Project so that it can be complied.
- Tender should be floated only after having sufficient fund. This would ensure the timely payment to the contractor [Rule 39 (22)]
- Liquidated damage clause to be properly applied as per Rule 39 (27) of PPR 2008. The amount of liquidated damage per day or per week should be calculated on the basis of approximate real monetary loss for delay. Compensation event needs to be properly incorporated in the tender document so that contractors can get appropriate compensation if the situation arises so.
- Provision for payment of interest in case of delayed payment should be kept in the contract and implemented accordingly so that the rights of the contractor are protected.
- More collaborative engagement of the key stakeholders of the project has been recommended for the improvement of the requiring body satisfaction.
- Analyzing the **Appendix C**, we observe that most of the works have been completed, some of them are in progress and a few work orders are still in queue to be processed, that's why the contract value and cost overrun (if any) have not yet been calculated. As the study was based on PPR 2008, a comparatively new project was selected which was started after 2009. But some necessary steps can also be recommended to control the cost, quality and time constraint of BCC Bhaban Project.
- Intensive training programs should be arranged on Electronic Government Procurement as we know that e-GP follows PPA @006 & PPR 2008 in an effective and efficient way

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# Power Conversion Improvement of Fuel Cell Based DG's with ANFIS Controller

By Durgam Kumaraswamy & B.V. Sanker Ram
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*Keywords: fuel cell (FC), renewable energy sources, conversion losses, adaptive nero fuzzy interface system (ANFIS).*

*GJRE-F Classification : FOR Code: 090699*

POWERCONVERSIONIMPROVEMENTOFFUELCELLBASEDDGSWITHANFISCONTROLLER

*Strictly as per the compliance and regulations of :*

# Power Conversion Improvement of Fuel Cell based DG's with ANFIS Controller

Durgam Kumaraswamy [α] & B.V. Sanker Ram [σ]

*Abstract-* This paper defines a novel ANFIS based controller is used for enhance power conversion efficiency of renewable energy source. Hear fuel cells are chosen among different types of renewable energy sources. Here a new converter topology is proposed to minimize conversion losses of devices used for power conversion. The input passive elements of rectifier reduce the circulating currents. The transformer and mutual inductors used to reduce stress on the power electronic conversion devices to improve conversion efficiency and voltage regulation. The ANFIS controller will enhance the power conversion efficiency by improving the switching speed and accuracy of in reference generation and it give extended stable operation.

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## I. Introduction

Fuel Cells (FC) are power sources that convert electrochemical energy into electrical energy with high efficiency, low emissions, and quiet operation. A basic proton exchange membrane (PEM) single-cell arrangement is capable of producing an unregulated voltage below 1V and consists of two electrodes (anode and cathode) linked by electrolyte [1]. The output current capability of a single cell depends on the electrode effective area, and several single cells are connected in series to form a FC stack. Due to the mechanical challenges associated with stacking several single cells, FC are typically low-voltage, high current power sources and can continuously run while reactant is fed into the system [2].

Several approaches to realize DC-DC isolated power conversion for FC power sources have been proposed based on full bridge, push–pull, and current-fed topologies. Some of the key contributions in the area include the study outlined in the following. An FC power converter based on a controlled voltage doubler was introduced, which uses phase-shift modulation to control the power flow through the transformer leakage inductance [3]. This interesting topology proved to be less efficient than other traditional topologies [4], but presents the advantage of the low component count. An FC inverter based on a traditional push–pull DC–DC converter was presented featuring low cost, low component count, and DSP control [5]. Based on the push–pull topology, a modular architecture was presented to enhance scalability and reliability [6]. An innovative current-fed version of the push–pull topology has been reported as part of a grid connected inverter system [7]. A similar current-fed push–pull topology was employed in a step-up resonant converter, presenting a high voltage-conversion ratio [8]. A full-bridge forward DC–DC converter with a full-bridge rectifier was presented [9]. This is a very robust topology when operated with zero-voltage switching (ZVS) technique and represents an industry standard in many applications, such as telecom power supplies (high input voltage). A three-phase version of the full-bridge forward converter was recently proposed [10], based on Δ-Y transformer connection and a clamp circuit to reduce the leakage inductance and circulating currents. A new family of phase-shift ZVS with adaptive energy storage was also proposed to increase soft switching operating range using auxiliary circuits [11]. As well, topologies based on current-fed full-bridge topologies were proposed featuring low-input ripple current and reduced stress on the input-side switches [12].

Successful power conditioning for FC systems requires dealing with poor voltage regulation, high input current, and a wide range of output loading conditions while maintaining high efficiency and low switching stress. When exposed to these stringent requirements, full-bridge ZVS, push–pull, and current fed topologies are confronted with several technical challenges. For example, maintaining ZVS (full-bridge) is difficult due to the poor voltage regulation of the FC and the wide range of loading conditions, which creates excessive conduction losses due to circulating current in the primary. The push–pull topology reduces transformer utilization (primary center tap), compromises magnetizing balance as the power rating increases (winding asymmetry and excitation imbalance), as well as limiting the possibilities for soft-switching operation. Current-fed-based topologies need bulky input inductors (high current), present oscillations produced by the interaction between parasite (leakage inductance, intra winding capacitance, and the input inductor), and could present excessive degrading high-frequency ripple current in the output capacitors due to the absence of filter inductor. While the trend for high-input-

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voltage converters (e.g., connected to the line) has been to minimize switching losses and deal with relatively small line regulation, FC power conversion presents the opposite scenario with low input voltage, poor regulation, and very high input current. Unlike applications with high input voltage, achieving ZVS with low voltage does not lead to substantial efficiency gains, given the small energy stored in the MOSFETs output capacitance (Coss). The power dissipated in a MOSFET due to the output capacitance during turn on is a function of the square of the FC voltage $v_{fc}^2$ . Since FC are low-voltage, high-current power sources, the relative importance of switching losses can be outweighed by conduction losses in the MOSFETs that are a function of $i_{fc}^2$ .

The ANFIS set theory is also used to solve uncertainty problems. The key benefit of ANFIS logic is that its knowledge representation is explicit, using simple "IF-THEN" relations. All situations that are not characterized by a simple and well defined deterministic mathematical model, can be more easily handled in terms of the ANFIS-set theory, in which simple rules and a number of simple membership functions are used to derive the correct result.

In general, ANFIS sets are efficient at various aspects of uncertain knowledge representation and are subjective and heuristic, while neural networks are capable of learning from examples, but have the shortcoming of implicit knowledge representation.

The ANFIS-logic system is inflected in three basic elements: fuzzification, ANFIS inference, and de fuzzification. Degrees of membership in the fuzzifier layer are calculated according to IF-THEN rules. They base their decisions on inputs in the form of a linguistic variable derived from membership functions

Which are formulas used to determine the ANFIS set to which a value belongs and the degree of membership in that set. The variables are then matched with the specific linguistic IF-THEN rules and the response of each rule is obtained through ANFIS implication. To perform compositional rule of inference, the response of each rule is weighted according to the impedance or degree of membership of its inputs and the centroid of the response is calculated to generate the appropriate output.

This paper addresses the challenges 1) to 5) by proposing a set of soft-switching techniques in a full-bridge forward topology. For this purpose, a special modulation sequence is developed to minimize conduction losses while maintaining soft switching characteristics in the MOSFETs and soft transitions in the output rectifiers. Auxiliary elements in the primary, such as series inductors and capacitors that are impractical to realize due the extreme input current are avoided by reflecting them to the secondary of the circuit to minimize circulating current and generate soft transitions in the switches. These variations are conceptually depicted in Fig. 1 indicating three major modifications suited for FC power conversion. The proposed combined techniques have the ability to maintain high efficiency in the entire operating range of the FC (wide input voltage) and under any loading condition. Detailed analysis of the techniques for efficiency gains is presented and a phase-shift ZVS topology is employed as a reference topology to highlight the mechanisms for performance enhancement and the advantages in the use of the special modulation. Experimental results of a 1-kW power converter are presented to validate the efficiency gains, illustrate the benefits of the special modulation, and demonstrate the soft-switching transitions.

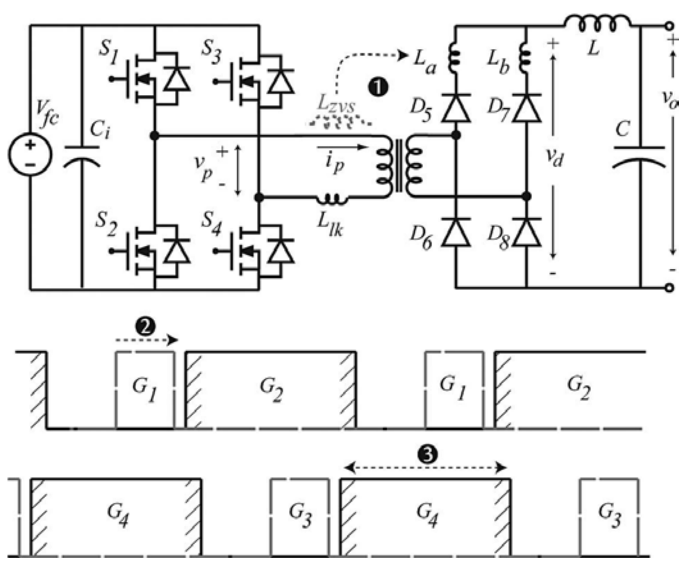


*Fig.1, 2 & 3:* Basic schematic for test system & pulse generation

## II. Fc Voltage Regulation

This section briefly revisits the regulation characteristic of a polymer-electrolyte FC under different operating conditions, providing the basis for successful design of power conditioning stages. Both PEMFC and direct methanol FC (DMFC) belong to this category. The factors that mainly contribute to the output voltage behavior in a DMFC are fuel (methanol concentration), fuel flow rate (supplied to the anode), air/oxygen flow rate (supplied to the cathode), and operating temperature [1]. As well, the output current is a significant factor that affects the output voltage and, hence, its output power. It is interesting to note how the output voltage of this DMFC is greatly affected by its operating temperature and output current (fuel and oxygen flow rates are close to optimal in this case). This results in a significant change of the available output power, the area under the polarization curve. Therefore, in order to obtain a desired output power, it is first necessary to modify the operating conditions to increase the area under the polarization curve (for example, by increasing the operating temperature). It should be pointed out that the transition from a given polarization curve to another through variation in operating conditions is very slow. The main reasons for this behavior are the high heat capacity of the cell, and the slow mass transport processes in the flow fields and electrodes (fuel distribution in the flow channels and electrode assembly) [2], [23]. However, a fast dynamic response exists when the output current changes in fixed operating condition. As a result of this example, the poor voltage regulation, high current and low-voltage characteristics are highlighted. The same principle follows for larger electrode areas required to produce high currents, and a number of singles cells in series to conform a FC stack.

## III. Right-Aligned Modulation and Primary Inductor Elimination in the Full-Bridge Topology

This section presents in a sequential and conceptual manner the steps taken to fulfill the requirements toward increasing the efficiency of the full-bridge forward converter in FC power conversion. A description of the power-loss mechanisms in the input stage is first presented, followed by the analysis of the output rectifier. Each design goal is addressed by the combined effects of the proposed soft-switching techniques.

### a) *Full-Bridge Input Stage*

The conduction losses in the MOSFETs due to circulating current [design goal (a)] and the high-current bulky inductor in the primary are eliminated by removing the traditional *Lzvs* inductor in the primary and by forcing a right-aligned sequence of pulses in the upper switches as illustrated in Fig. 1 (modifications ① and ②). In order to illustrate the gains of the two changes with a practical example, Fig. 3 presents the conduction losses of a commercial MOSFET with low *R*dsON as a function of duty cycle for the voltage polarization curve of a commercial hydrogen FC. It can be seen that the total conduction losses un-der phase-shift ZVS (+ curve that includes circulating current) are considerably higher than losses only associated with power transferred to the secondary. The losses have been calculated using the rms value of the current through switch*M*1 and the MOSFET ON-resistance *R*dson , which is a function of the device temperature

$$P_{losscon} = R_{dson}\, i_{M1}^{2} \quad (1)$$

For example, the IRFB4110 has 3.7 mΩ at $25^{0}$ C and 6 mΩ at $100^{0}$ C (typical), resulting in 35 W conduction losses under 75 A rms at $100^{0}$ C. When the switching losses are analyzed, the same power device experiences less than 6.5 W during the turn- ON transition due to its output capacitance *C*oss when switching at 40 kHz with *v*fc = 22 V as given in the following:

$$P_{losscoss} = \frac{1}{2} C_{oss} F_{sw} v_{fc}^{2} \quad (2)$$

Therefore, it can be inferred that in this particular low-voltage high-current application, the efficiency gain resulting from reducing circulating current in four switches outweighs those of switching losses, especially under heavy loading conditions. When the lower switches are considered, the scenario is even more favorable, as *M*2 and *M*4 not only benefit from lower conduction losses, but also operate in ZVS due to the modification ③in the modulation (+50% duty cycle). In addition, the reduction in the conduction interval also helps to reduce copper losses in the transformer windings and favors the use of planar magnetic with their inherent low leakage inductance to increase power transfer.

### b) *Output Rectifier Stage*

The output rectifiers contribute to conversion losses due to conduction and reverse recovery. Since the output voltage of the power converter is high (i.e., 220 V to supply a single-phase inverter), the conduction current is typically a few amperes per kilowatt of output power (i.e., 4.54 A), making the reverse-recovery losses the dominant factor. Reverse-recovery charge is a function of the forward conduction current (*IF*) and the rate of change of current (*di/dt*), as well as operating temperature of the device. The reverse-recovery losses can be estimated by using the recovery charge, switching frequency (*F*sw), and reverse applied voltage (*VR*), including the peak ringing value as follows

$$P_{loss} = Q_{rr} V_R F_{sw} \quad (3)$$

As a simple review of this combined effects, a conceptual relationship among *di/dt*, the *IF* , and *Qrr* in which the initial forward current is given by *IF* 3 > *IF* 2 > *IF* 1. As indicated in (3) the reverse-recovery losses can be reduced by means of controlling *di/dt* [design goal (c)] and by reducing the reverse peak voltage *VR* produced by transformer oscillations [design goal (d)]. For this purpose, the *Lzvs* inductor is reflected to the secondary and placed at the output of each upper rectifier *D*5 and *D*7 (modification③). This technique limits the *di/dt* in the upper rectifiers, eliminates reverse recovery in the lower diodes *D*6 and *D*8, and reduces significantly the transformer oscillations by preventing a zero-voltage state at the secondary. As will be seen, the technique avoids simultaneous conduction of *D*5 , *D*6 , *D*7, and *D*8, thus reducing undesirable ringing that occurs when the primary current matches the inductor output current, which results in a severe voltage step in the secondary that creates ringing, and therefore, electromagnetic interference (EMI). In the following section, the operation of the full-bridge forward converter and the effect of the proposed modifications for efficiency improvements are presented in detail over the various switching intervals.

## IV. Analysis of Anfis Controller

Proposed system consists of ANFIS to limit error in minimum range based on rules written and its membership functions. The proposed method is as shown in fig4. The simulation has been done on a DFIG system integrating the proposed FLCs for the vector control as shown in Fig. 4. The parameters of induction machine are influenced from Refs. [17] and are indexed in Tables 2 and 3.The vector control performance of proposed ANFIS controller is contrasted with a vector control utilizing fuzzy logic controllers. The wind speed is set at 6 m/s in accordance with a angular speed of 78 rad/s (Fig. 5(d)).

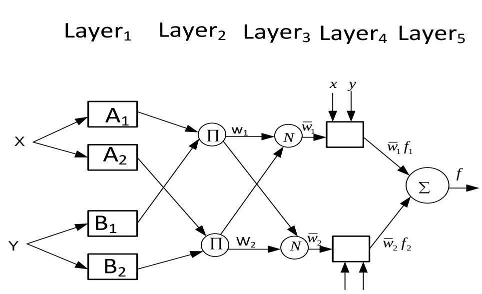


*Fig. 4:* The architecture of the ANFIS

## V. Operation Intervals and Loss-Reduction Effects

The combination of the proposed techniques, *Lzvs* inductor reflection to the output of the rectifier (①), right-aligned gate signals for the upper switches (②), and +50% duty cycle in the lower switches (③) are investigated in detail in this section. Fig. 5 shows the switching sequence for MOSFETs *M*1, *M*2, *M*3, and *M*4 along with the main waveforms for the techniques under study. Transition intervals have been exaggerated for clarity.

### a) *Detailed Analysis of the MOSFETs Waveforms*

The waveforms for MOSFETs *M*1 and *M*4 and their respective body diodes *D*1 and *D*4 are shown in Fig. 7 during a full-cycle period, including the gate signals *G*1 and *G*4, drain to-source voltages *vM*1 and *vM*4 , currents for the MOSFETs n-channel *iM*1 and *iM*4 , and the body diodes *iD*1 and *iD*4.

As can be seen, unlike phase-shift ZVS or resonant converters, the proposed techniques prevent unnecessary circulating current in the transformer and through the MOSFETs, and allows power transfer during the conduction interval. This is a key requirement in low-voltage, high-current applications, where the conduction losses are substantial and outweigh switching losses at moderate switching frequencies. As well, the +50% duty-cycle modulation sequence ensures zero-voltage transitions in MOSFETs *M*2 and *M*4. The gains described in this section are further enhanced in the output rectifier as described in the following section.

### b) *Output Rectifier Waveforms*

In order to complete the analysis of the waveforms and efficiency gains, the output rectifier should be investigated. The current and voltage waveforms for *D*7 (upper) and *D*8 (lower) diodes are presented in Fig. 8, where both conduction losses and reverse-recovery instants can be identified.

In summary, the waveforms for the proposed soft-switching techniques reveal the following improvements.

1. The auxiliary inductors *La* and *Lb* shape the current waveforms of *D*5 and *D*7 during reverse recovery. Therefore, the inductor values can be selected to achieve a desired *Qrr* in the upper diodes and, hence, control the total reverse recovery conversion losses.
2. Diodes *D*6 and *D*8 experience negligible reverse-recovery losses, unlike the phase-shift ZVS topology, which is ex plained by near-zero forward current when the reduced reverse voltage is applied.
3. The presence of *La* and *Lb* reduce oscillations and the peak reverse voltage applied to *D*6 and *D*8 that result from transformer ringing.

Transformer oscillation results in undesirable effect, such as high maximum reverse voltage rating for the diodes, EMI, over voltage between windings, and conversion losses in auxiliary snubber circuits. The concept of avoiding a zero-voltage condition on the transformer secondary is addressed by preventing simultaneous conduction of *D*5 , *D*6 , *D*7 , and *D*8 . As a result, the turn-ON pulse is partially reflected to the secondary of the transformer as if the converter were operating in discontinuous conduction mode. Hence, the oscillations are reduced under any loading condition.

*c) Frequency Response and Dynamic Behavior*

The frequency response of the control-to-output characteristic of the full-bridge topology, which is a buck-derived topology, is dominated by the transfer function of the output filter (*L* and When the converter is operated in phase-shift ZVS, a series inductance is required to limit the current rate of change in the primary to generate soft transitions in the switches [24]. This limitation, reduces the effective duty cycle reflected to the secondary, therefore, affecting the control-to-output characteristic. As a result, an artificial dumping effect is created in the frequency response by the series inductance, which softens the control-to-output characteristic peak at the resonant frequency of the filter [25]. In closed-loop operation using traditional compensation (small signal), the artificial dumping does not have any noticeable effect in phase and gain margins. A similar behavior is experienced when the proposed techniques are employed using traditional compensators, therefore, showing a dynamic response similar to that of a phase-shift ZVS.

In this study, in order to facilitate the efficiency evaluation process, multiple measurements were performed with a closed loop controller (small-signal) in steady-state operation. The controller was realized with an inner current loop (inductor current) and an outer voltage loop. Validation of the waveforms and comparative efficiency measurements are presented in the following section.

## VI. Simulation Results

*Table 1:* Converter Parameters

| Parameters | Value limits |
|---|---|
| $V_{fc}$ | 18-40V |
| $V_o$ | 220V |
| L | 1.33mH |
| $D_a$, $L_b$ | 10uH |
| C | 680uF |
| $C_i$ | 4400Uf |
| $F_{sw}$ | 40-100kHz |
| T/f primary turns $N_p$ | 2 |
| T/f secondary turns $N_s$ | 26 |

*a) Validation of the Waveforms*

A complete switching cycle in *M*1, *M*4, *D*7, and *D*8 was measured under medium loading condition to validate the waveforms. In order to facilitate the visualization, the switching frequency was set to 40 kHz. Fig. 9 shows the waveforms of MOSFET *M*1, including gate and drain-to-source voltages, and the secondary transformer current. It can be seen that the MOSFET current starts at zero (ZCS) at the beginning of *T*1 and slowly ramps up until it reaches the current level of the output-filter inductor at the beginning of *T*2. The MOSFET turns off during *T*3, limiting the conduction interval to *T*1–*T*2. The body diode *D*1 conduction interval can be seen in *T*11, which returns the energy of the leakage inductance to the input dc bus and avoids circulating current in the primary. The small energy in the leakage is absorbed and clamped by the input capacitors of the converter. The lowerMOSFET*M*4 waveforms are shown in Fig. 10, where the zero-voltage transition during turn-ON can be seen at the beginning of *T*11. Thereafter, at the beginning of *T*4, *M*4 turns off. As well, *D*4 has a soft-switching transition during *T*5. The conduction interval in *M*4 is similar to that of *M*1, showing reduced conduction losses.

In order to evaluate the converter operation under phase shift ZVS, the inductor *Lzvt* was included and *La* and *Lb* were removed. Fig. 11 shows MOSFET *M*1 drain-to-source voltage (Ch1) and gate-to-source (Ch2) signals along with the secondary current waveform *is* (Ch4). It can be seen that the turn-ON transition occurs during (*T*1 ) interval and the conduction is extended until the end of (*T*6 ). As described by the analysis of conduction losses, the conduction interval presents unnecessary circulating current. MOSFET *M*4 (lower side switch) presents a similar behavior with circulating current.

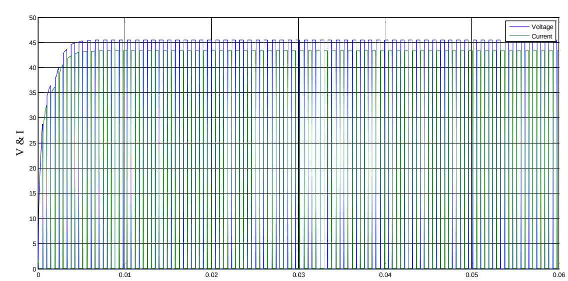


*Fig. 5:* Upper MOSFET Voltage and Current

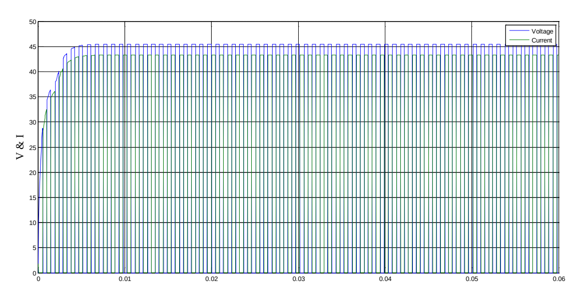


*Fig.6 :* Lower MOSFET Voltage and Current

Focusing on the rectifier stage, the upper output-rectifier *D7* waveforms with the proposed techniques are shown in Fig. 12. The turn-OFF transition from forward-biased to blocking is illustrated in interval

*T*1. The effect of *Lb* and *Ll*k can be seen in the current transition, resulting in moderate reverse-recovery losses at the beginning of *T*2. The end of the interval *T7* corresponds to the instant when the current in *Lb* matches the current in the output-filter inductor *L*. During *T*8 , the slope of *iD*7 is mainly due to *L*. The conduction interval is defined from *T*7 to *T*1 of the next switching cycle. As can be seen, the transformer oscillation are small and experience a fast damping beginning at *T*2 (no snubber have been included in the prototype). Only an initial peak is experienced due to the effect of the stray inductance in the current path (hall effect sensor measurement path) and *Lb*. This provides a clear indication that the proposed arrangement only requires a small local snubber connected from *D*7 cathode to *L* input terminal, as opposed to the well-known bulky snubber circuit in ZVS circuits.

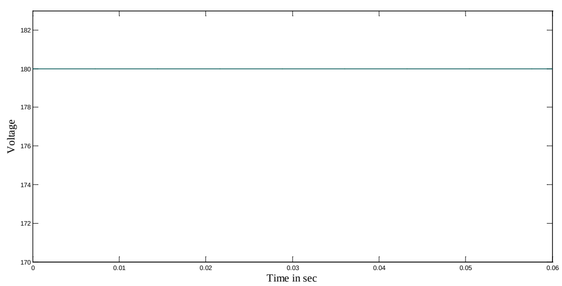


*Fig. 7:* Upper side diode Voltage Medium Loading.

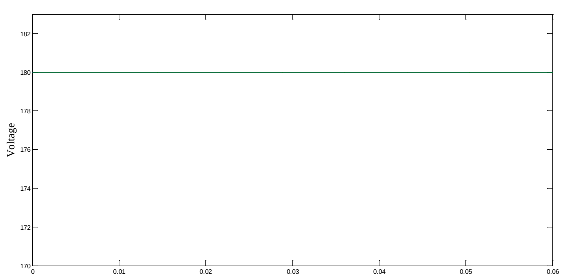


*Fig. 8:* Upper diode voltage under proposed controller

The improvement that results from the proposed modifications is better appreciated in the experimental waveforms for *D*8 depicted in Fig. 13. Due to the interleaving effect of *La* and *Lb* during *T*3–*T*5 interval, diode*D*8 experiences a fast transition from high conduction current to near-zero current. At the beginning of *T*7, the converter input voltage is partially reflected to the secondary and blocks *D*8 immediately with a transition that produces negligible reverse-recovery losses in *D*8. As well, the blocking transition presents moderate ringing at the beginning of *T*7 while the upper diode current *iD*7 ramps up.

When this is compared to the behavior under phase-shift ZVS, which is presented in Fig. 14, diode *D*8 presents undesirable reverse-recovery losses at the beginning of interval *T*8, where a small negative-current peak can be seen due to the effect of *Q*rr . As predicted by the analysis, the ringing peak voltage in *D*8 is high, increasing the reverse-recovery losses and requiring a bulky snubber.

Finally, in order to verify that the input current is positive, a fundamental requirement in FC power conversion, Fig. 15 presents the input current of the converter and the transformer input voltage operating under medium loading condition. As predicted by the analysis, the current remains positive during all the switching intervals.

*b) Comparative Efficiency Measurements*

The combined switching and conduction losses for the proposed soft-switching techniques are presented in this section. A phase-shift ZVS is employed as a reference topology for comparative evaluation. The same power devices, power transformer, drivers, dead-time insertion, heat sink and fan, and output filter were employed in both cases to ensure a fair comparison (see Table I). Note that the objective of the experimental efficiency measurements is to illustrate the efficiency gains with the proposed modifications rather than performing an absolute measurement of the converter efficiency. The efficiency measurement accounts for the power switches, printed circuit board, connections, and magnetic parts and does not include losses in the controller and drivers. For ZVS operation, the auxiliary *L*zvt inductor and snubbers were included, while removing *La* and *Lb*. Several tests were performed for various input voltages *v*fc = 18, 25, and 30 V under variable loading conditions (50–1000 W range) for both power converters. The results are shown in Fig. 16, illustrating the efficiency as a function of output power and input voltage in a 3-D plot. It is important to highlight that even though efficiency characterization in power converters is traditionally performed using fixed input voltage, FC power conversion requires the use of a polarization curve (variable input) to account for the lax voltage regulation that is characteristic in these power sources. Therefore, a surface efficiency measurement provides a better means for comparison, as presented in Fig. 16. The efficiency profile achieved with the proposed soft-switching techniques, referred to as Modified in the figure is depicted with circle markers, while the phase-shift ZVS is illustrated with star markers. It can be seen that the proposed modifications present a significant efficiency gain under any operating condition. For example, an efficiency gain of 3%–4% in a power converter with an overall efficiency of 90% provides an improvement close to 30%–40% in the thermal management of the power stage and allows the use of lower cost power semiconductors/ Heat sinks. This can be considered as an excellent improvement toward power density and cost of the power conversion stage, while maintaining the simplicity of a full-bridge topology. As well, the efficiency gains result in cumulative fuel savings (i.e., hydrogen or methanol) under any operating condition (light, medium, and heavy) by employing the proposed soft-switching techniques.

## VII. Conclusion

The ANFIS based new control topology will reduces the power conversion losses. The transformer utilized conversion network can minimizes stresses on power electronic devices used for conversion. stress less devices can give better performance gives to reduces the losses. The ANFIS based controller can works fast and accurately in pulse generation compared to conventional Fuzzy Logic controller.

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# Design and Development of Automated Electronic Switching System for Energy Regulation

By Vinyl Ho Oquino, Tadesse Hailu Ayane, Temesgen Bailie Workie & Simegnew Yihunie Alaba

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Abstract- Electricity was one of the most important discoveries of science. Humanity in these generations depends much on the usage of electricity. The modern technology cannot exist without this electricity. Energy consumption was higher with manual controllers as compared to automated controllers. Around 300% increased when the said manual controllers were not managed carefully, especially during weekends. Study shows that during weekend some of the employees leave the room forget to check the switch status especially when the power failure occurs during the last hour of office time. The use of automated controllers was more efficient as compare to manual controllers. The design consideration of automated controllers includes the power management of the controller itself was necessary in order to minimized fires caused by appliance.

Keywords: *microcontroller, automated switch, electronic switch, energy saving, automated switching system, solid state relay.*

GJRE-F Classification: *FOR Code: 290903p*

DESIGNANDDEVELOPMENTOFAUTOMATEDELECTRONICSWITCHINGSYSTEMFORENERGYREGULATION

*Strictly as per the compliance and regulations of :*

# Design and Development of Automated Electronic Switching System for Energy Regulation

Vinyl Ho Oquino [α], Tadesse Hailu Ayane [σ], Temesgen Bailie Workie [ρ] & Simegnew Yihunie Alaba [ω]

*Abstract-* Electricity was one of the most important discoveries of science. Humanity in these generations depends much on the usage of electricity. The modern technology cannot exist without this electricity. Energy consumption was higher with manual controllers as compared to automated controllers. Around 300% increased when the said manual controllers were not managed carefully, especially during weekends. Study shows that during weekend some of the employees leave the room forget to check the switch status especially when the power failure occurs during the last hour of office time. The use of automated controllers was more efficient as compare to manual controllers. The design consideration of automated controllers includes the power management of the controller itself was necessary in order to minimized fires caused by appliance. Most of the available design of the automated controllers in the market had a standby power that may cause electrical power consumption and fire. As the appliance become older some of the parts may produce heat and when this heat were accumulated this generate fire. [3] For this reason, most of the consumers unplug their appliances from wall outlet. The main objective of this research project was to develop an automated electronic switch that can be used to disconnect the appliance load automatically when the room was not occupied to minimize the cause of fire and save energy. The specific objective of the research project includes assessment of the existing electrical system in the room, designing the electronic circuit for the automated control switch, simulating the design model circuit, developing the prototype hardware circuit, testing the efficiency of the automated electronic switch, calculating the energy saving with the automated electronic switch and the efficacy of the system. The project was very significant in reducing fire hazard caused by electrical appliance, reducing energy consumption losses due to unawareness of the status of manual controllers, automate the control for all electrical power within the specified room, and the minimal implementation cost of the project due to locally available materials were used.

*Keywords: microcontroller, automated switch, electronic switch, energy saving, automated switching system, solid state relay.*

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## I. Introduction

Ethiopia is Africa's oldest independent country and it is second largest in terms of population.[2] Some advance countries like USA, Germany, Britain, Korea and even China starts introducing different technologies to improve the lifestyle of the people. And most people in this country are adopting these technologies. But this technology requires power in order to operate. Due to these requirements of technologies, people around the country in the offices or even homes plugin the appliances unattended. Most people around the country have different appliances in home or even in the offices. Some office workers both in private and government left their lights and electrical appliance switch-on even when they are not using it.

One of the biggest challenges of electrical engineers of the country is designing a system that disconnects the appliances connected from the line in absence of consumers in the area. Many automated switches are available in the market today, but these available automated switches consume power even when the appliances are already turned off. Thus, these switches consume a standby power. The most common switch is the occupancy switches. This switch detects the presence of people inside the room and turn on the appliance automatically. Using this type of switches are not 100% safe in terms of fire because it always requires power in order to detect the presence of consumers inside the room. According to the fire protection agency (FPA), the most causes of fire in the building or homes are those appliances which are unattended. Thus leaving the appliances connected to the line while the users are not present.

According to MekonnenKassa of the Ethiopian Rural Energy Development and Promotion Center, there are lots of energy losses based on the un-attended uses of electricity. [1] Most people may leave the room or offices without switching off the lights or other electrical consuming devices. In order to ensure that all lights are switch off and the appliances are disconnected from the outlet, an automated switches are used to control the lights and appliances. Research shows that most common available automated controls in the market require power in order to sense the occupancy of the certain room. The aim of this study is to design an automated switch that will also switch off all the lights and disconnect the appliances from the outlet in the room including the controller. Thus, in this way all the loads in the room are totally disconnected from the power source.

## II. Materials & Methods

### a) *Hardware and Software Components of Automated Electronic Switching System*

The block diagram of automated electronic switching system is shown in figure 1. The microcontroller was the heart of the circuit. Embedded programs were stored in the controller. Any microchip product microcontroller can be used in the study. A 16 pin microcontroller was preferred in the study in order to minimize the size of the hardware. The controller controls the solid state relay by giving some voltage across its control input. The solid state relay (SSR) used to connect from the power source to the load and to power the controller. The low voltage power supply gives power to the controller. The SSR supply power from the source to the controller via low voltage power supply. Room sensor was used to detect whether the room was occupied or not. The sensor gives signal to the controller to activate the SSR. It was known that the only way to access the room at normal procedure was through the door. The sensing of the occupancy of the room was based on the opening of the door. Power sensor detects the presence or absence of the power from the system. The power sensor activates the other SSR when the circuit was turned off. These give an alternative power for the controller during the total shutdown period of the system and regain the power from the power source. The two SSR are form of logical OR in the system. The operation of the said SSR follows the logical OR gate function in the digital system.

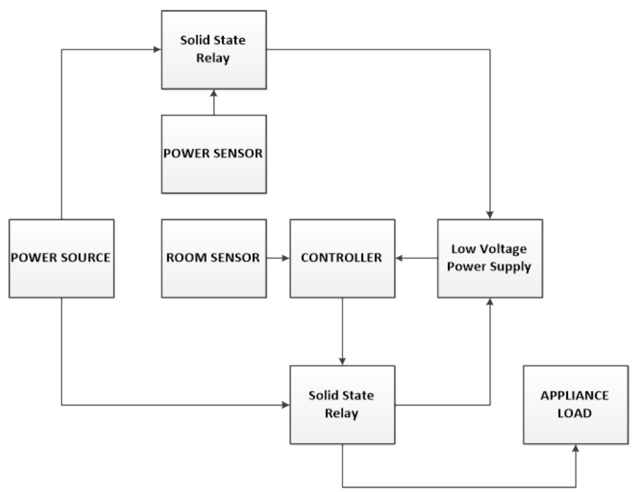


*Figure 1:* Block Diagram of Automatic Electronic Switching System

#### i. *Controller Circuit*

The hardware design of the controller circuit was shown in figure 2. The circuit uses PIC16F84A as main controller. The circuit design uses 4 MHz crystal oscillator. And based from the datasheet of PIC16F84A, the manufacturer recommends a 22 pF ceramic capacitor as filter capacitor in the crystal oscillator, and 10 kilo ohm resistance for the pull down resistor in the input side of the microcontroller.

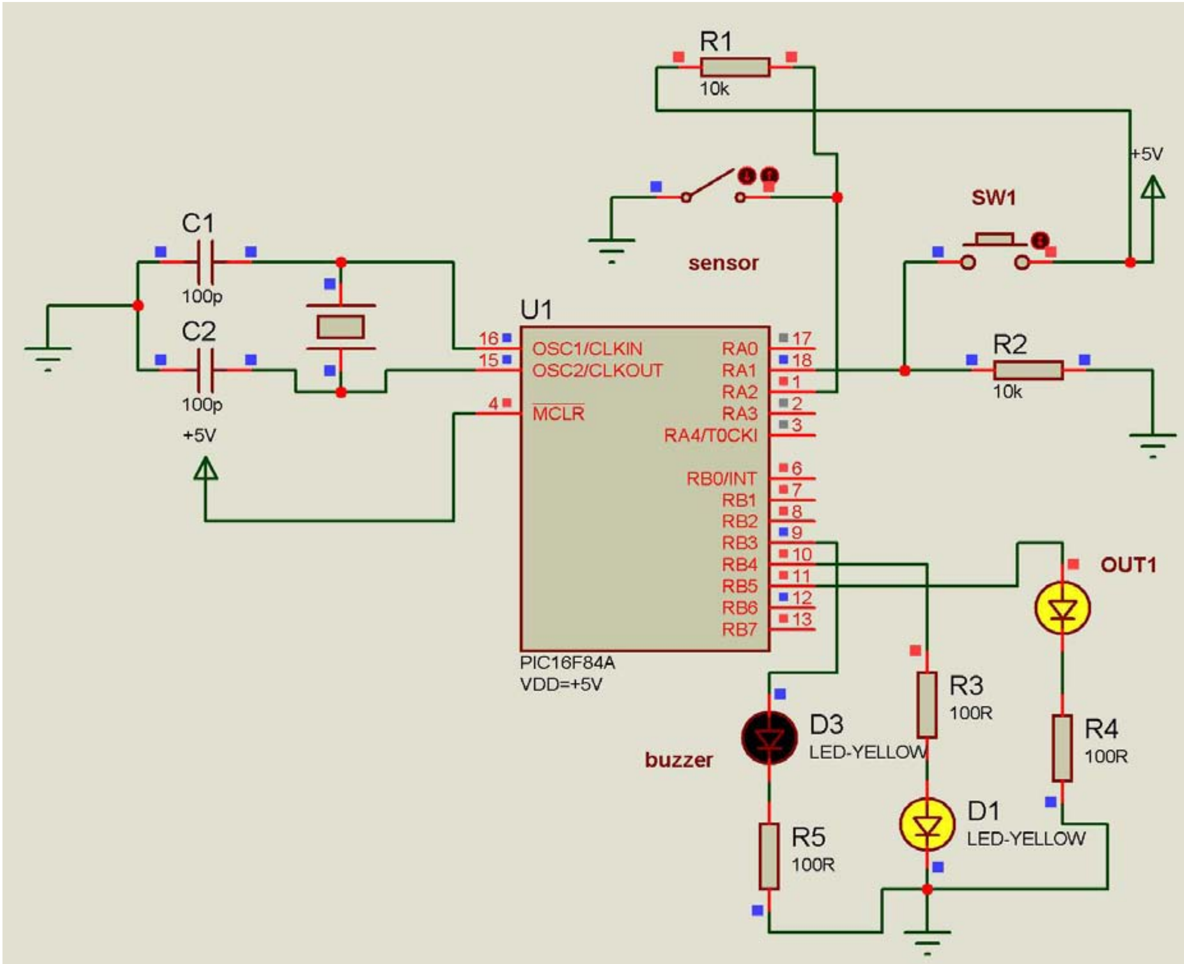


*Figure 2:* The controller circuit

The sensor used in the design was a reed switch. The reed switch reacts with magnet. Thus, the reed switch was used as occupancy sensor for the room. The reed switch was place in the door of the room. And the other side of the door was a small magnet. The reed switch detects the door status. The normal procedure of entering the room was using the door. Thus, the proponent decided to use the door also to monitor the occupancy of the room. The buzzer in D3 was used to trigger the alarm informing the occupant that the door was open and closed. The SW1 was used as the reset switch to turn off the alarm. The output of the microcontroller was connected directly to the SSR driver circuit.

ii. *Solid State Relay*

The SSR circuit was shown in figure 3.

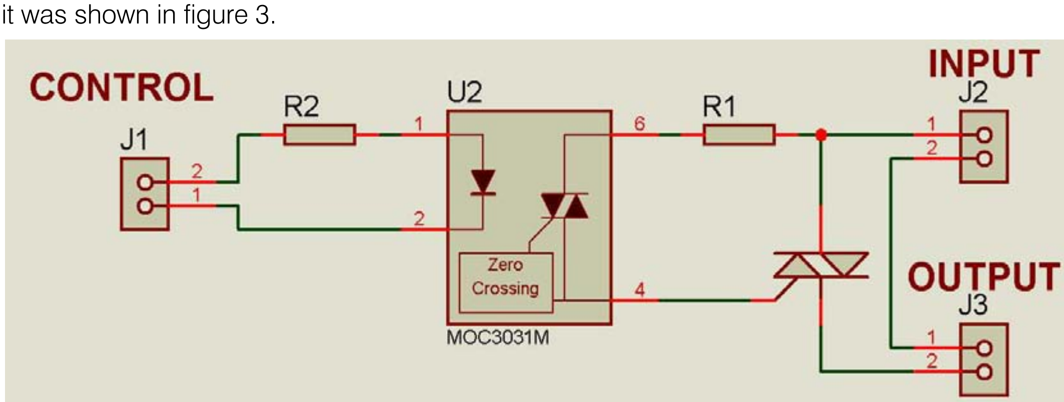


*Figure 3:* Solid State Relay (SSR)

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The SSR was used to minimize the arcing effect of the electromagnetic relay. The proponent design uses the MOC3041 as the driver to the triac. The triac serves as the switching mechanism in turning on and off the loads. The value of R1 was based on the datasheet of the manufacturer. The value of R1 was 180 ohm as per recommendation of the manufacturer. The input side was directly connected to 220Vac and gives an output of 220Vac likewise. The value of R2 was computed using the equation below.

$$R= (E-Vd)/Id$$

Where:

R = the series resistance of the opto-coupler

E= the source voltage, normally the voltage output of the microcontroller which was 5v

Vd = the maximum voltage of the LED inside the opto-coupler, normally it was found out equal 1.7 V

Id = the current for the LED inside the opto-coupler, basically the design uses 10 mA as the working current of the opto-coupler.

Using the above equation, the value of R2 is equal to 330 ohms.

*b) Embedded Program*

The embedded software was written in C, and then compiled to machine language using mikroC compiler.

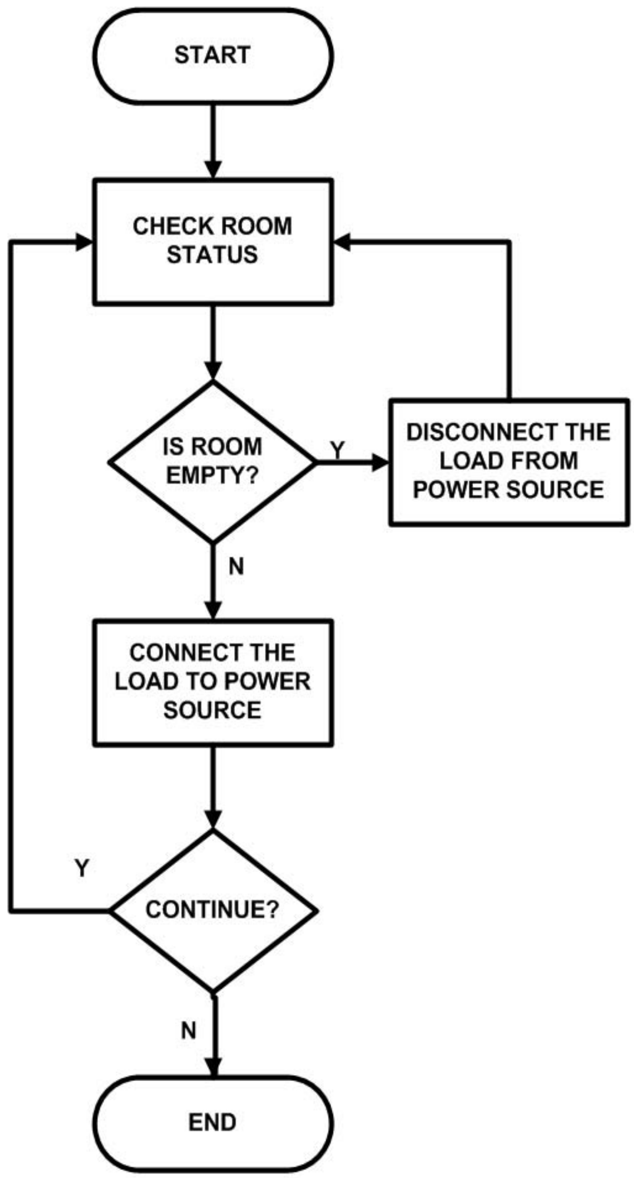


*Figure 4:* The Program Flow Chart

Figure 4 shows the program flow chart for the automated switch. The primary aim of the program was to determine wither the room was vacant or not. And when it was vacant it automatically disconnects the load and including the system from the power source. And it continues until the user terminates the system.

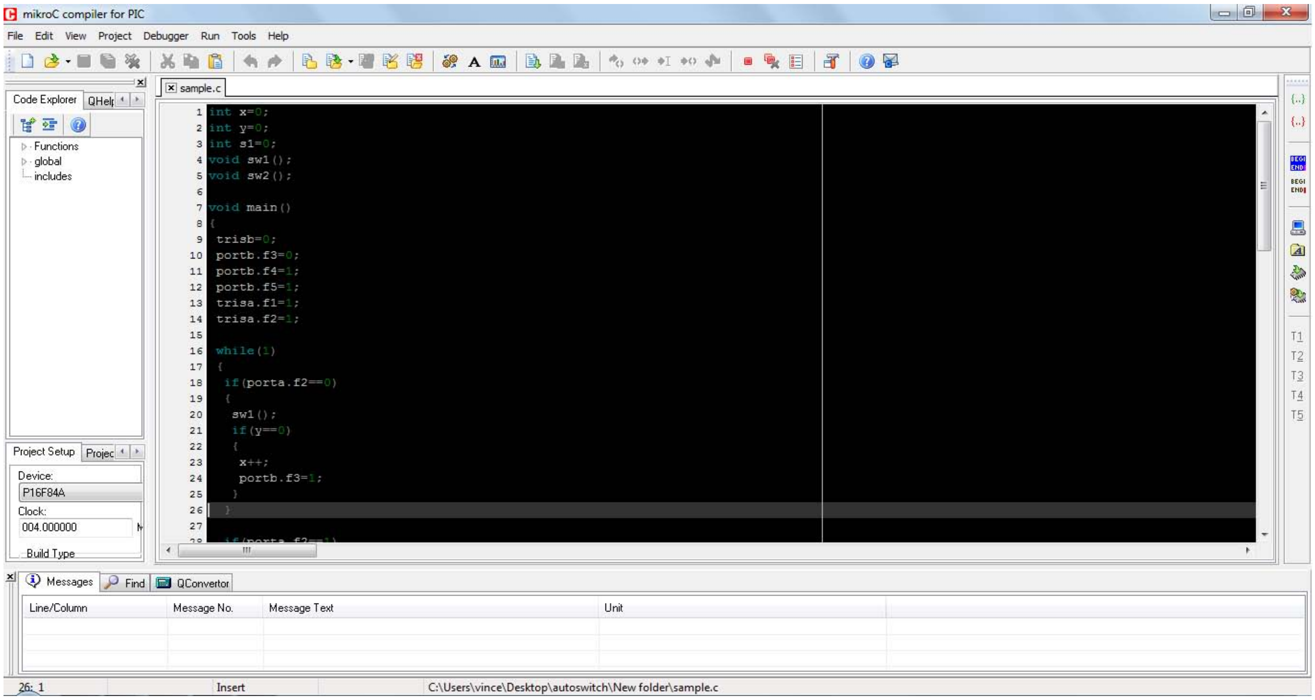


*Figure 5:* The MikroC Environment

Figure 5 shows the mikroc compiler environment. The software automatically compiled the output program to hex files. This hex file was used in the microcontroller.

*c) Simulation of the Hardware and Software*

The design hardware and software were simulate din PROTEUS. And the results show in figure 6 below.

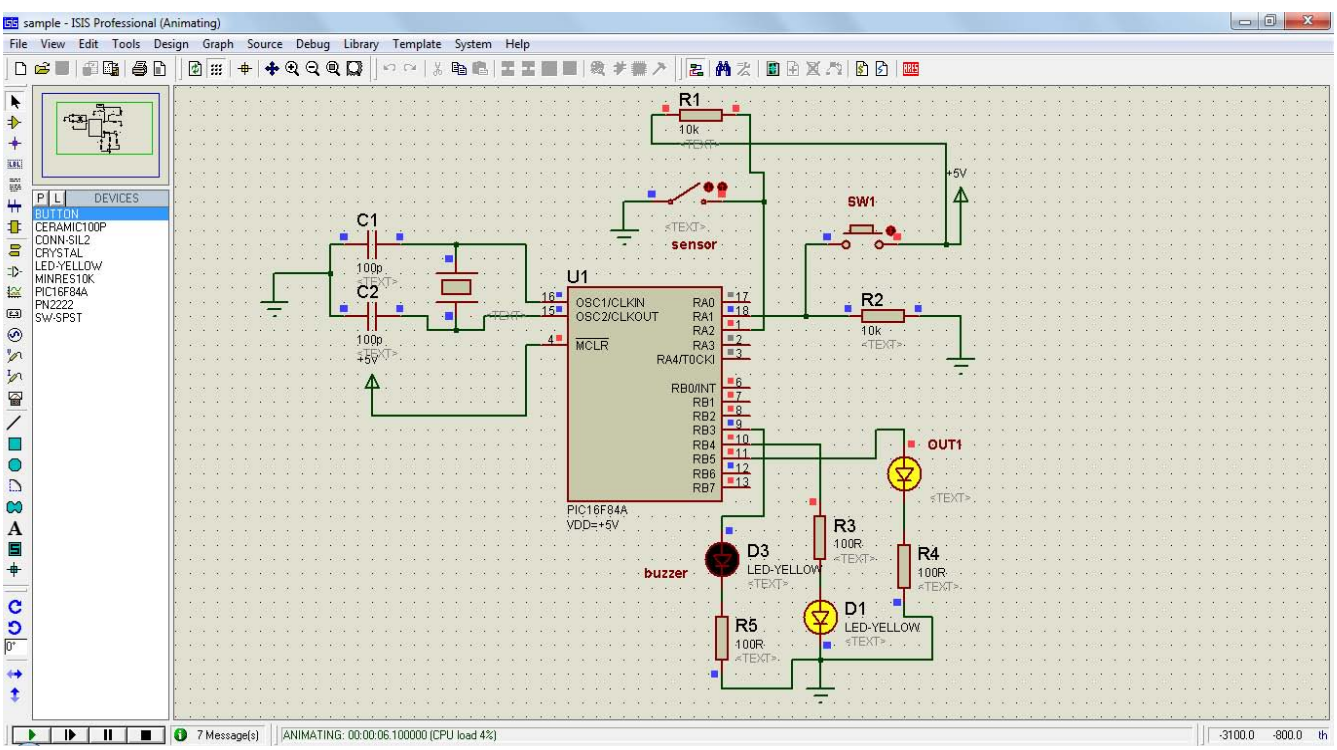


*Figure 6:* Simulation of the Circuit Model

The simulation works as it was expected. The switch sensor works after some debugging in the embedded program.

*Table 1:* The Output of the Controller

| Sensor | Sw1 | Alarm | Output |
|---|---|---|---|
| 0 | 0 | 0 | 1 |
| 1 | 0 | 1 | 0 |
| 0 | 1 | 0 | 1 |
| 1 | 1 | 0 | 1 |

Table 1 shows the logic output of the controller. The '1' and '0' represents the on and off state of the controller. The sensor represents the opening and closing of door. This also identifies the occupancy of the room. The value '0' from the sensor means that the room was open and there is a person inside the room. The value '1' from sensor means that the room was closed and there is nobody inside the room. The $SW_1$ represents the reset switch. This allows the microcontroller determine that the room was not empty. The value of '0' from the SW1 means that nobody inside the room. The value '1' from the SW1 means that someone inside the room. The alarm was only activated when the door was closed and nobody inside the room. The alarm turns on for 10 seconds and turn off. The output value of '1' means that the microcontroller trigger the SSR and '0' means turn off the SSR. This allows the load be connected and disconnected from the power source.

*d) The development of the prototype hardware circuit*

After simulating the circuit using PROTEUS software, the circuit board was prepared. The layout was developed using ARES software. It uses single sided PCB.

The prototype controller circuit was shown in figure 7. The board size of the controller circuit was 1.3 in x 1.7 in. The PIC16F84A was used in the controller. The LED 3.5mm was also used as the power indicator for the circuit.

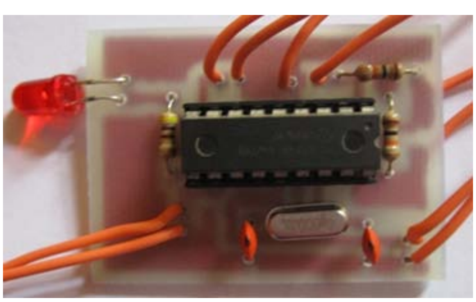

*Figure 7:* Prototype of Controller Circuit

The prototype hardware of the SSR was shown in figure 8. The board size was 1 in x 1.15 in. The circuit uses a zero crossing opto-isolator to interface with the AC source. The TRIAC was controlled by the opto isolator.

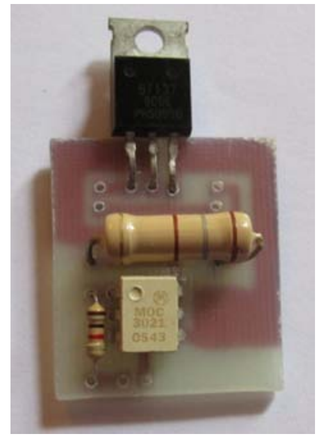

*Figure 8:* Prototype of Solid State Relay

The TRIAC was connected directly to the power source and the load. The power going to the load was being controlled by the TRIAC as per instruction of the controller.

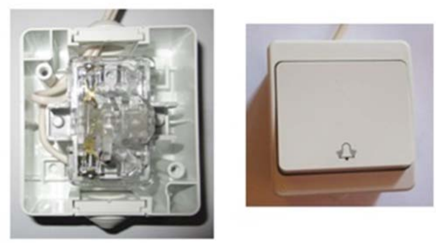

*Figure 9:* The Reset Switch

Figure 9 shows the reset switch. The reset switch was developed by modifying internal structure of the push button switch. The push button switch used was a normally open type. A 10 KΩ resistor was connected in the switch as pull down resistor. The other terminal of the switch was directly connected to the +5V supply on the controller.

*Figure 10:* Prototype of the Controller Switch

The final prototype of the controller was shown in figure 10. The box was made of the electronic chime which was available in the area. All the parts and components in this project were locally available. The box was modified in order that the other modules can be placed.

## III. Implementation Results

*a) The test of functionality and efficiency*

The prototype hardware was tested for two months. And it was found out that it works as what it was expected. During the testing stage, the project seems to work on and off. There are cases that the output seems intermittent fault occurs.

The hardware was operated for 24/7 without interruption. The hardware was also experienced the power failure due to power interruption in the area. This was used to test its functionality even in most critical cases.

And it was found out that during the first three days of operation, it works fine. The sensor and the output works as it were expected. But after three days, the sensor and the output were not working. It was found out that the sensor had a thermal breakdown. This was the cause of transient effect of the load. Since the load was an inductive load, a transient current was very high. This current was being absorbed by the sensor. The correction was made by using a sensor that can handle 80 per cent of the current passing to it.

$$Is = \frac{Imax}{0.8}$$

The current rating for the sensor was increase by 80 per cent of its maximum current. This was made in order to protect the sensor. According to some experts, all components must have a safety factor as an allowance of its current carrying capacity. In this case, 80 per cent safety factor was used.After the correction was made, the output still not working as it was expected. Until the ten days testing was conducted. It was found out that the solid state relay was not working as it was expected. The solid state relay composed of opto-coupler and TRIAC. The TRIAC input and output connection was being interchange. That causes the TRIAC thermal break down. The calculation of the TRIAC current missed the safety factor of the component. The 80 per cent safety factor was also applied on the TRIAC current carrying capacity. After all the adjustment the project works as being expected. The hardware was been continuously connected and operated until this day. The operating current of the system was measured 1 mA. And when it shut down the load, the system also automatically shut off with the load. The input current to the hardware was measured 1.001 mA.

Eff= (Power Output)/ (Power Input) x 100

The equation for calculating the efficiency was used. And it was calculated that the efficiency of the hardware was 99 per cent.

*b) The energy saving*

The energy saving of a certain load was computed based on the equation.

Energy saving = Total Energy Consumption - Energy losses

The energy loses was the term used as the energy consumption that was not actually used by consumer. But still the consumers pay for that consumption. Not all of the total consumption was the actual used by the consumer. Most cases the energy losses were higher as compared to the used energy. One specific sample was the room that has a manual control and the room that had an automated control. It was found out that the said room had 4 sets of 40W fluorescent lamp and a corresponding ballast of 40W. Each set had 2 lamps with corresponding ballast. The each set had a total power consumption of 320 watts. The total power consumption of the said room per official day was calculated of 1280 watts for lighting alone. The total energy per week based on the official time was calculated 256 kW-Hr. This was only based on the official time of the office.

*Figure 11:* Office Room in ASTU

Figure 11 shows one of the office rooms that uses manual control for the lightings. Most cases power interruption occurs in the buildings and all the rooms in those particular buildings had no power. The staff assigned to that room suddenly leave the room without checking the switch if it was already turned off.

One building was randomly checked and records the instances on the total number of hours of lighting operation in every room. One of the rooms had a greater number of utilization of lighting. The said room was not merely switched off the lights when there was no power within the week. There were cases that every Friday the power failures mostly occurs around 3:00 pm or sometimes 4:00 pm. The staff usually went out during that time. They usually don't checked the switch wither it was turned off. When they don't switch off the light before going out, and the power came back after 2 hours and the room was already empty, the tendency the lights were switch on for 24 hours on Saturday and Sunday. In this case it was known based from the study. One office room was constantly observed that during Saturday and Sunday all the lights in that particular room were switched on. Since the room was locked, it can't be switch off unless the staff member who was assigned in that room came and do that turning off the lights.

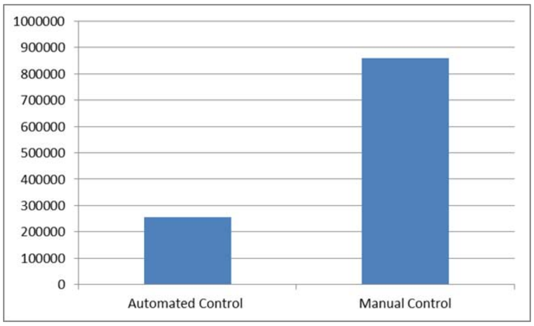


*Figure 12:* Automated Control vs. Manual Control

Figure 12 shows the comparison of the power consumption with the used of automated control and manual control. The graph shows that the losses for 2 days had a great effect on the power consumption on the room. With the automated control the losses were minimized and it was found out that almost the same with the official time power consumption. While for manual control it was found out that more than 300% of the power consumption in two days losses.

## IV. Conclusion

Intensive research shows that using manual controls when the switch was forgotten to switch off especially during weekends in the office, can increase the energy consumption up to 300% of its total energy consumption with the official expected power consumption. And it was found out that using automated electronic switch power utilization in the room was more secured in terms of fire safety. And it was concluded that the design of automated control hardware and software were based on the requirement on the national electrical code. The switching off the power in the room including the system controller itself was included in the designed. The availability of all the parts and components of the hardware were included in designing of the hardware. The prototype of the hardware was tested for many days more two months and it was found out after series of adjustment and modification it was successfully working based on the requirements. And the efficiency of the project was calculated after the series of test conducted and it was found out that the hardware has 99 per cent efficiency. Using automated electronic switch was more energy efficient as compared to manual control in terms of managing the energy consumption and fire safety.

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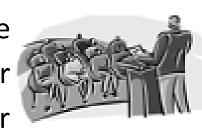

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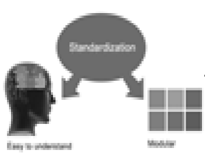

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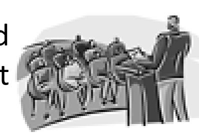

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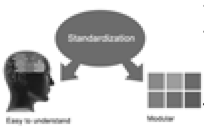


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A major linchpin in research work for the writing research paper is the keyword search, which one will employ to find both library and Internet resources.

One must be persistent and creative in using keywords. An effective keyword search requires a strategy and planning a list of possible keywords and phrases to try.

Search engines for most searches, use Boolean searching, which is somewhat different from Internet searches. The Boolean search uses "operators," words (and, or, not, and near) that enable you to expand or narrow your affords. Tips for research paper while preparing research paper are very helpful guideline of research paper.

Choice of key words is first tool of tips to write research paper. Research paper writing is an art.A few tips for deciding as strategically as possible about keyword search:

- One should start brainstorming lists of possible keywords before even begin searching. Think about the most important concepts related to research work. Ask, "What words would a source have to include to be truly valuable in research paper?" Then consider synonyms for the important words.
- It may take the discovery of only one relevant paper to let steer in the right keyword direction because in most databases, the keywords under which a research paper is abstracted are listed with the paper.
- One should avoid outdated words.

Keywords are the key that opens a door to research work sources. Keyword searching is an art in which researcher's skills are bound to improve with experience and time.

Numerical Methods: Numerical methods used should be clear and, where appropriate, supported by references.

*Acknowledgements: Please make these as concise as possible.*

References

References follow the Harvard scheme of referencing. References in the text should cite the authors' names followed by the time of their publication, unless there are three or more authors when simply the first author's name is quoted followed by et al. unpublished work has to only be cited where necessary, and only in the text. Copies of references in press in other journals have to be supplied with submitted typescripts. It is necessary that all citations and references be carefully checked before submission, as mistakes or omissions will cause delays.

References to information on the World Wide Web can be given, but only if the information is available without charge to readers on an official site. Wikipedia and Similar websites are not allowed where anyone can change the information. Authors will be asked to make available electronic copies of the cited information for inclusion on the Global Journals Inc. (US) homepage at the judgment of the Editorial Board.

The Editorial Board and Global Journals Inc. (US) recommend that, citation of online-published papers and other material should be done via a DOI (digital object identifier). If an author cites anything, which does not have a DOI, they run the risk of the cited material not being noticeable.

The Editorial Board and Global Journals Inc. (US) recommend the use of a tool such as Reference Manager for reference management and formatting.

Tables, Figures and Figure Legends

*Tables: Tables should be few in number, cautiously designed, uncrowned, and include only essential data. Each must have an Arabic number, e.g. Table 4, a self-explanatory caption and be on a separate sheet. Vertical lines should not be used.*

*Figures: Figures are supposed to be submitted as separate files. Always take in a citation in the text for each figure using Arabic numbers, e.g. Fig. 4. Artwork must be submitted online in electronic form by e-mailing them.*

Preparation of Electronic Figures for Publication

Even though low quality images are sufficient for review purposes, print publication requires high quality images to prevent the final product being blurred or fuzzy. Submit (or e-mail) EPS (line art) or TIFF (halftone/photographs) files only. MS PowerPoint and Word Graphics are unsuitable for printed pictures. Do not use pixel-oriented software. Scans (TIFF only) should have a resolution of at least 350 dpi (halftone) or 700 to 1100 dpi (line drawings) in relation to the imitation size. Please give the data for figures in black and white or submit a Color Work Agreement Form. EPS files must be saved with fonts embedded (and with a TIFF preview, if possible).

For scanned images, the scanning resolution (at final image size) ought to be as follows to ensure good reproduction: line art: >650 dpi; halftones (including gel photographs) : >350 dpi; figures containing both halftone and line images: >650 dpi.

*Figure Legends: Self-explanatory legends of all figures should be incorporated separately under the heading 'Legends to Figures'. In the full-text online edition of the journal, figure legends may possibly be truncated in abbreviated links to the full screen version. Therefore, the first 100 characters of any legend should notify the reader, about the key aspects of the figure.*

**6. AFTER ACCEPTANCE**

Upon approval of a paper for publication, the manuscript will be forwarded to the dean, who is responsible for the publication of the Global Journals Inc. (US).

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The corresponding author will receive an e-mail alert containing a link to a website or will be attached. A working e-mail address must therefore be provided for the related author.

Acrobat Reader will be required in order to read this file. This software can be downloaded

(Free of charge) from the following website:

www.adobe.com/products/acrobat/readstep2.html. This will facilitate the file to be opened, read on screen, and printed out in order for any corrections to be added. Further instructions will be sent with the proof.

Proofs must be returned to the dean at dean@globaljournals.org within three days of receipt.

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Before start writing a good quality Computer Science Research Paper, let us first understand what is Computer Science Research Paper? So, Computer Science Research Paper is the paper which is written by professionals or scientists who are associated to Computer Science and Information Technology, or doing research study in these areas. If you are novel to this field then you can consult about this field from your supervisor or guide.

## TECHNIQUES FOR WRITING A GOOD QUALITY RESEARCH PAPER:

**1. Choosing the topic:** In most cases, the topic is searched by the interest of author but it can be also suggested by the guides. You can have several topics and then you can judge that in which topic or subject you are finding yourself most comfortable. This can be done by asking several questions to yourself, like Will I be able to carry our search in this area? Will I find all necessary recourses to accomplish the search? Will I be able to find all information in this field area? If the answer of these types of questions will be "Yes" then you can choose that topic. In most of the cases, you may have to conduct the surveys and have to visit several places because this field is related to Computer Science and Information Technology. Also, you may have to do a lot of work to find all rise and falls regarding the various data of that subject. Sometimes, detailed information plays a vital role, instead of short information.

**2. Evaluators are human:** First thing to remember that evaluators are also human being. They are not only meant for rejecting a paper. They are here to evaluate your paper. So, present your Best.

**3. Think Like Evaluators:** If you are in a confusion or getting demotivated that your paper will be accepted by evaluators or not, then think and try to evaluate your paper like an Evaluator. Try to understand that what an evaluator wants in your research paper and automatically you will have your answer.

**4. Make blueprints of paper:** The outline is the plan or framework that will help you to arrange your thoughts. It will make your paper logical. But remember that all points of your outline must be related to the topic you have chosen.

**5. Ask your Guides:** If you are having any difficulty in your research, then do not hesitate to share your difficulty to your guide (if you have any). They will surely help you out and resolve your doubts. If you can't clarify what exactly you require for your work then ask the supervisor to help you with the alternative. He might also provide you the list of essential readings.

**6. Use of computer is recommended:** As you are doing research in the field of Computer Science, then this point is quite obvious.

**7. Use right software:** Always use good quality software packages. If you are not capable to judge good software then you can lose quality of your paper unknowingly. There are various software programs available to help you, which you can get through Internet.

**8. Use the Internet for help:** An excellent start for your paper can be by using the Google. It is an excellent search engine, where you can have your doubts resolved. You may also read some answers for the frequent question how to write my research paper or find model research paper. From the internet library you can download books. If you have all required books make important reading selecting and analyzing the specified information. Then put together research paper sketch out.

**9. Use and get big pictures:** Always use encyclopedias, Wikipedia to get pictures so that you can go into the depth.

**10. Bookmarks are useful:** When you read any book or magazine, you generally use bookmarks, right! It is a good habit, which helps to not to lose your continuity. You should always use bookmarks while searching on Internet also, which will make your search easier.

**11. Revise what you wrote:** When you write anything, always read it, summarize it and then finalize it.

**12. Make all efforts:** Make all efforts to mention what you are going to write in your paper. That means always have a good start. Try to mention everything in introduction, that what is the need of a particular research paper. Polish your work by good skill of writing and always give an evaluator, what he wants.

**13. Have backups:** When you are going to do any important thing like making research paper, you should always have backup copies of it either in your computer or in paper. This will help you to not to lose any of your important.

**14. Produce good diagrams of your own:** Always try to include good charts or diagrams in your paper to improve quality. Using several and unnecessary diagrams will degrade the quality of your paper by creating "hotchpotch." So always, try to make and include those diagrams, which are made by your own to improve readability and understandability of your paper.

**15. Use of direct quotes:** When you do research relevant to literature, history or current affairs then use of quotes become essential but if study is relevant to science then use of quotes is not preferable.

**16. Use proper verb tense:** Use proper verb tenses in your paper. Use past tense, to present those events that happened. Use present tense to indicate events that are going on. Use future tense to indicate future happening events. Use of improper and wrong tenses will confuse the evaluator. Avoid the sentences that are incomplete.

**17. Never use online paper:** If you are getting any paper on Internet, then never use it as your research paper because it might be possible that evaluator has already seen it or maybe it is outdated version.

**18. Pick a good study spot:** To do your research studies always try to pick a spot, which is quiet. Every spot is not for studies. Spot that suits you choose it and proceed further.

**19. Know what you know:** Always try to know, what you know by making objectives. Else, you will be confused and cannot achieve your target.

**20. Use good quality grammar:** Always use a good quality grammar and use words that will throw positive impact on evaluator. Use of good quality grammar does not mean to use tough words, that for each word the evaluator has to go through dictionary. Do not start sentence with a conjunction. Do not fragment sentences. Eliminate one-word sentences. Ignore passive voice. Do not ever use a big word when a diminutive one would suffice. Verbs have to be in agreement with their subjects. Prepositions are not expressions to finish sentences with. It is incorrect to ever divide an infinitive. Avoid clichés like the disease. Also, always shun irritating alliteration. Use language that is simple and straight forward. put together a neat summary.

**21. Arrangement of information:** Each section of the main body should start with an opening sentence and there should be a changeover at the end of the section. Give only valid and powerful arguments to your topic. You may also maintain your arguments with records.

**22. Never start in last minute:** Always start at right time and give enough time to research work. Leaving everything to the last minute will degrade your paper and spoil your work.

**23. Multitasking in research is not good:** Doing several things at the same time proves bad habit in case of research activity. Research is an area, where everything has a particular time slot. Divide your research work in parts and do particular part in particular time slot.

**24. Never copy others' work:** Never copy others' work and give it your name because if evaluator has seen it anywhere you will be in trouble.

**25. Take proper rest and food:** No matter how many hours you spend for your research activity, if you are not taking care of your health then all your efforts will be in vain. For a quality research, study is must, and this can be done by taking proper rest and food.

**26. Go for seminars:** Attend seminars if the topic is relevant to your research area. Utilize all your resources.

**27. Refresh your mind after intervals:** Try to give rest to your mind by listening to soft music or by sleeping in intervals. This will also improve your memory.

**28. Make colleagues:** Always try to make colleagues. No matter how sharper or intelligent you are, if you make colleagues you can have several ideas, which will be helpful for your research.

**29. Think technically:** Always think technically. If anything happens, then search its reasons, its benefits, and demerits.

**30. Think and then print:** When you will go to print your paper, notice that tables are not be split, headings are not detached from their descriptions, and page sequence is maintained.

**31. Adding unnecessary information:** Do not add unnecessary information, like, I have used MS Excel to draw graph. Do not add irrelevant and inappropriate material. These all will create superfluous. Foreign terminology and phrases are not apropos. One should NEVER take a broad view. Analogy in script is like feathers on a snake. Not at all use a large word when a very small one would be sufficient. Use words properly, regardless of how others use them. Remove quotations. Puns are for kids, not grunt readers. Amplification is a billion times of inferior quality than sarcasm.

**32. Never oversimplify everything:** To add material in your research paper, never go for oversimplification. This will definitely irritate the evaluator. Be more or less specific. Also too, by no means, ever use rhythmic redundancies. Contractions aren't essential and shouldn't be there used. Comparisons are as terrible as clichés. Give up ampersands and abbreviations, and so on. Remove commas, that are, not necessary. Parenthetical words however should be together with this in commas. Understatement is all the time the complete best way to put onward earth-shaking thoughts. Give a detailed literary review.

**33. Report concluded results:** Use concluded results. From raw data, filter the results and then conclude your studies based on measurements and observations taken. Significant figures and appropriate number of decimal places should be used. Parenthetical remarks are prohibitive. Proofread carefully at final stage. In the end give outline to your arguments. Spot out perspectives of further study of this subject. Justify your conclusion by at the bottom of them with sufficient justifications and examples.

**34. After conclusion:** Once you have concluded your research, the next most important step is to present your findings. Presentation is extremely important as it is the definite medium though which your research is going to be in print to the rest of the crowd. Care should be taken to categorize your thoughts well and present them in a logical and neat manner. A good quality research paper format is essential because it serves to highlight your research paper and bring to light all necessary aspects in your research.

## Informal Guidelines of Research Paper Writing

**Key points to remember:**

- Submit all work in its final form.
- Write your paper in the form, which is presented in the guidelines using the template.
- Please note the criterion for grading the final paper by peer-reviewers.

**Final Points:**

A purpose of organizing a research paper is to let people to interpret your effort selectively. The journal requires the following sections, submitted in the order listed, each section to start on a new page.

The introduction will be compiled from reference matter and will reflect the design processes or outline of basis that direct you to make study. As you will carry out the process of study, the method and process section will be constructed as like that. The result segment will show related statistics in nearly sequential order and will direct the reviewers next to the similar intellectual paths throughout the data that you took to carry out your study. The discussion section will provide understanding of the data and projections as to the implication of the results. The use of good quality references all through the paper will give the effort trustworthiness by representing an alertness of prior workings.

Writing a research paper is not an easy job no matter how trouble-free the actual research or concept. Practice, excellent preparation, and controlled record keeping are the only means to make straightforward the progression.

**General style:**

Specific editorial column necessities for compliance of a manuscript will always take over from directions in these general guidelines.

To make a paper clear

· Adhere to recommended page limits

Mistakes to evade

- Insertion a title at the foot of a page with the subsequent text on the next page
- Separating a table/chart or figure - impound each figure/table to a single page
- Submitting a manuscript with pages out of sequence

In every sections of your document

· Use standard writing style including articles ("a", "the," etc.)

· Keep on paying attention on the research topic of the paper

· Use paragraphs to split each significant point (excluding for the abstract)

· Align the primary line of each section

· Present your points in sound order

· Use present tense to report well accepted

· Use past tense to describe specific results

· Shun familiar wording, don't address the reviewer directly, and don't use slang, slang language, or superlatives

· Shun use of extra pictures - include only those figures essential to presenting results

**Title Page:**

Choose a revealing title. It should be short. It should not have non-standard acronyms or abbreviations. It should not exceed two printed lines. It should include the name(s) and address (es) of all authors.

**Abstract:**

The summary should be two hundred words or less. It should briefly and clearly explain the key findings reported in the manuscript--must have precise statistics. It should not have abnormal acronyms or abbreviations. It should be logical in itself. Shun citing references at this point.

An abstract is a brief distinct paragraph summary of finished work or work in development. In a minute or less a reviewer can be taught the foundation behind the study, common approach to the problem, relevant results, and significant conclusions or new questions.

Write your summary when your paper is completed because how can you write the summary of anything which is not yet written? Wealth of terminology is very essential in abstract. Yet, use comprehensive sentences and do not let go readability for briefness. You can maintain it succinct by phrasing sentences so that they provide more than lone rationale. The author can at this moment go straight to shortening the outcome. Sum up the study, with the subsequent elements in any summary. Try to maintain the initial two items to no more than one ruling each.

- Reason of the study - theory, overall issue, purpose
- Fundamental goal
- To the point depiction of the research
- Consequences, including definite statistics - if the consequences are quantitative in nature, account quantitative data; results of any numerical analysis should be reported
- Significant conclusions or questions that track from the research(es)

Approach:

- Single section, and succinct
- As a outline of job done, it is always written in past tense
- A conceptual should situate on its own, and not submit to any other part of the paper such as a form or table
- Center on shortening results - bound background information to a verdict or two, if completely necessary
- What you account in an conceptual must be regular with what you reported in the manuscript
- Exact spelling, clearness of sentences and phrases, and appropriate reporting of quantities (proper units, important statistics) are just as significant in an abstract as they are anywhere else

**Introduction:**

The **Introduction** should "introduce" the manuscript. The reviewer should be presented with sufficient background information to be capable to comprehend and calculate the purpose of your study without having to submit to other works. The basis for the study should be offered. Give most important references but shun difficult to make a comprehensive appraisal of the topic. In the introduction, describe the problem visibly. If the problem is not acknowledged in a logical, reasonable way, the reviewer will have no attention in your result. Speak in common terms about techniques used to explain the problem, if needed, but do not present any particulars about the protocols here. Following approach can create a valuable beginning:

- Explain the value (significance) of the study
- Shield the model - why did you employ this particular system or method? What is its compensation? You strength remark on its appropriateness from a abstract point of vision as well as point out sensible reasons for using it.
- Present a justification. Status your particular theory (es) or aim(s), and describe the logic that led you to choose them.
- Very for a short time explain the tentative propose and how it skilled the declared objectives.

Approach:

- Use past tense except for when referring to recognized facts. After all, the manuscript will be submitted after the entire job is done.
- Sort out your thoughts; manufacture one key point with every section. If you make the four points listed above, you will need a least of four paragraphs.

- Present surroundings information only as desirable in order hold up a situation. The reviewer does not desire to read the whole thing you know about a topic.
- Shape the theory/purpose specifically - do not take a broad view.
- As always, give awareness to spelling, simplicity and correctness of sentences and phrases.

**Procedures (Methods and Materials):**

This part is supposed to be the easiest to carve if you have good skills. A sound written Procedures segment allows a capable scientist to replacement your results. Present precise information about your supplies. The suppliers and clarity of reagents can be helpful bits of information. Present methods in sequential order but linked methodologies can be grouped as a segment. Be concise when relating the protocols. Attempt for the least amount of information that would permit another capable scientist to spare your outcome but be cautious that vital information is integrated. The use of subheadings is suggested and ought to be synchronized with the results section. When a technique is used that has been well described in another object, mention the specific item describing a way but draw the basic principle while stating the situation. The purpose is to text all particular resources and broad procedures, so that another person may use some or all of the methods in one more study or referee the scientific value of your work. It is not to be a step by step report of the whole thing you did, nor is a methods section a set of orders.

Materials:

- Explain materials individually only if the study is so complex that it saves liberty this way.
- Embrace particular materials, and any tools or provisions that are not frequently found in laboratories.
- Do not take in frequently found.
- If use of a definite type of tools.
- Materials may be reported in a part section or else they may be recognized along with your measures.

Methods:

- Report the method (not particulars of each process that engaged the same methodology)
- Describe the method entirely
- To be succinct, present methods under headings dedicated to specific dealings or groups of measures
- Simplify - details how procedures were completed not how they were exclusively performed on a particular day.
- If well known procedures were used, account the procedure by name, possibly with reference, and that's all.

Approach:

- It is embarrassed or not possible to use vigorous voice when documenting methods with no using first person, which would focus the reviewer's interest on the researcher rather than the job. As a result when script up the methods most authors use third person passive voice.
- Use standard style in this and in every other part of the paper - avoid familiar lists, and use full sentences.

What to keep away from

- Resources and methods are not a set of information.
- Skip all descriptive information and surroundings - save it for the argument.
- Leave out information that is immaterial to a third party.

**Results:**

The principle of a results segment is to present and demonstrate your conclusion. Create this part a entirely objective details of the outcome, and save all understanding for the discussion.

The page length of this segment is set by the sum and types of data to be reported. Carry on to be to the point, by means of statistics and tables, if suitable, to present consequences most efficiently.You must obviously differentiate material that would usually be incorporated in a study editorial from any unprocessed data or additional appendix matter that would not be available. In fact, such matter should not be submitted at all except requested by the instructor.

Content

- Sum up your conclusion in text and demonstrate them, if suitable, with figures and tables.
- In manuscript, explain each of your consequences, point the reader to remarks that are most appropriate.
- Present a background, such as by describing the question that was addressed by creation an exacting study.
- Explain results of control experiments and comprise remarks that are not accessible in a prescribed figure or table, if appropriate.
- Examine your data, then prepare the analyzed (transformed) data in the form of a figure (graph), table, or in manuscript form.

What to stay away from

- Do not discuss or infer your outcome, report surroundings information, or try to explain anything.
- Not at all, take in raw data or intermediate calculations in a research manuscript.
- Do not present the similar data more than once.
- Manuscript should complement any figures or tables, not duplicate the identical information.
- Never confuse figures with tables - there is a difference.

Approach

- As forever, use past tense when you submit to your results, and put the whole thing in a reasonable order.
- Put figures and tables, appropriately numbered, in order at the end of the report
- If you desire, you may place your figures and tables properly within the text of your results part.

Figures and tables

- If you put figures and tables at the end of the details, make certain that they are visibly distinguished from any attach appendix materials, such as raw facts
- Despite of position, each figure must be numbered one after the other and complete with subtitle
- In spite of position, each table must be titled, numbered one after the other and complete with heading
- All figure and table must be adequately complete that it could situate on its own, divide from text

**Discussion:**

The Discussion is expected the trickiest segment to write and describe. A lot of papers submitted for journal are discarded based on problems with the Discussion. There is no head of state for how long a argument should be. Position your understanding of the outcome visibly to lead the reviewer through your conclusions, and then finish the paper with a summing up of the implication of the study. The purpose here is to offer an understanding of your results and hold up for all of your conclusions, using facts from your research and generally accepted information, if suitable. The implication of result should be visibly described. Infer your data in the conversation in suitable depth. This means that when you clarify an observable fact you must explain mechanisms that may account for the observation. If your results vary from your prospect, make clear why that may have happened. If your results agree, then explain the theory that the proof supported. It is never suitable to just state that the data approved with prospect, and let it drop at that.

- Make a decision if each premise is supported, discarded, or if you cannot make a conclusion with assurance. Do not just dismiss a study or part of a study as "uncertain."
- Research papers are not acknowledged if the work is imperfect. Draw what conclusions you can based upon the results that you have, and take care of the study as a finished work
- You may propose future guidelines, such as how the experiment might be personalized to accomplish a new idea.
- Give details all of your remarks as much as possible, focus on mechanisms.
- Make a decision if the tentative design sufficiently addressed the theory, and whether or not it was correctly restricted.
- Try to present substitute explanations if sensible alternatives be present.
- One research will not counter an overall question, so maintain the large picture in mind, where do you go next? The best studies unlock new avenues of study. What questions remain?
- Recommendations for detailed papers will offer supplementary suggestions.

Approach:

- When you refer to information, differentiate data generated by your own studies from available information
- Submit to work done by specific persons (including you) in past tense.
- Submit to generally acknowledged facts and main beliefs in present tense.

Please carefully note down following rules and regulation before submitting your Research Paper to Global Journals Inc. (US):

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- To guard yourself and others from possible illegal use please do not permit anyone right to use to your paper and files.

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| Topics | Grades | | |
|---|---|---|---|
| | **A-B** | **C-D** | **E-F** |
| ***Abstract*** | Clear and concise with appropriate content, Correct format. 200 words or below | Unclear summary and no specific data, Incorrect form<br><br>Above 200 words | No specific data with ambiguous information<br><br>Above 250 words |
| ***Introduction*** | Containing all background details with clear goal and appropriate details, flow specification, no grammar and spelling mistake, well organized sentence and paragraph, reference cited | Unclear and confusing data, appropriate format, grammar and spelling errors with unorganized matter | Out of place depth and content, hazy format |
| ***Methods and Procedures*** | Clear and to the point with well arranged paragraph, precision and accuracy of facts and figures, well organized subheads | Difficult to comprehend with embarrassed text, too much explanation but completed | Incorrect and unorganized structure with hazy meaning |
| ***Result*** | Well organized, Clear and specific, Correct units with precision, correct data, well structuring of paragraph, no grammar and spelling mistake | Complete and embarrassed text, difficult to comprehend | Irregular format with wrong facts and figures |
| ***Discussion*** | Well organized, meaningful specification, sound conclusion, logical and concise explanation, highly structured paragraph reference cited | Wordy, unclear conclusion, spurious | Conclusion is not cited, unorganized, difficult to comprehend |
| ***References*** | Complete and correct format, well organized | Beside the point, Incomplete | Wrong format and structuring |

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