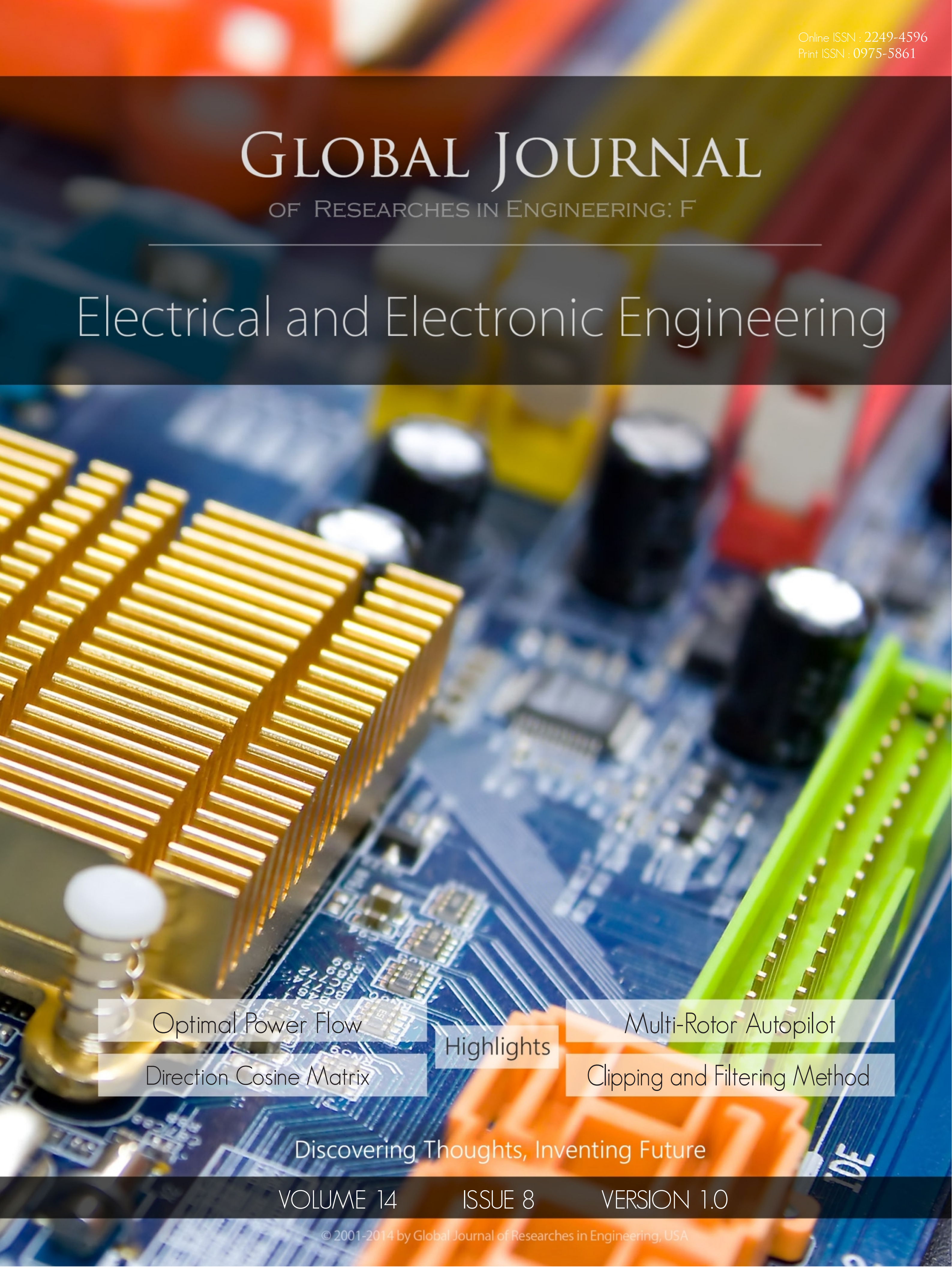

Online ISSN : 2249-4596
Print ISSN : 0975-5861

# Global Journal
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VOLUME 14 ISSUE 8 VERSION 1.0

Global Journal of Researches in Engineering: F
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Global Journal of Researches in Engineering: F
Electrical and Electronics Engineering
Volume 14 Issue 8 Version 1.0 Year 2014
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)
Online ISSN: 2249-4596 & Print ISSN: 0975-5861

# Implementation and Experimental Validation of a Real-Time Discontinuous PWM Technique for VSI Fed IM Drives

By P. Senthilkumar & N. P. Subramaniam
*PRIST University, India*

*Abstract-* Adjustable speed drive system requires variable voltage and frequency supply which is invariably obtained from a three-phase voltage source inverter (VSI). A number of Pulse Width Modulation (PWM) schemes are used to obtain variable voltage and frequency supply from an inverter. The most widely used PWM schemes for a three-phase VSI are carrier-based sinusoidal PWM and space vector PWM (SVPWM). This paper develops discontinuous PWM (DPWM) techniques for a voltage source inverter (VSI). Performance is evaluated in terms of total harmonic distortion (THD) in the output phase voltages. A significant reduction in switching losses is observed by adopting the proposed PWM schemes. The simulation and experimental results are provided to validate the concept.

*Keywords:* *space vector, PWM, voltage source inverter, discontinuous PWM.*

*GJRE-F Classification :* *FOR Code: 090699*

IMPLEMENTATIONANDEXPERIMENTALVALIDATIONOFAREALTIMEDISCONTINUOUSPWMTECHNIQUEFORVSIFEDIMDRIVES

# Implementation and Experimental Validation of a Real-Time Discontinuous PWM Technique for VSI Fed IM Drives

P. Senthilkumar [α] & N. P. Subramaniam [σ]

*Abstract-* Adjustable speed drive system requires variable voltage and frequency supply which is invariably obtained from a three-phase voltage source inverter (VSI). A number of Pulse Width Modulation (PWM) schemes are used to obtain variable voltage and frequency supply from an inverter. The most widely used PWM schemes for a three-phase VSI are carrier-based sinusoidal PWM and space vector PWM (SVPWM). This paper develops discontinuous PWM (DPWM) techniques for a voltage source inverter (VSI). Performance is evaluated in terms of total harmonic distortion (THD) in the output phase voltages. A significant reduction in switching losses is observed by adopting the proposed PWM schemes. The simulation and experimental results are provided to validate the concept.

*Keywords: space vector, PWM, voltage source inverter, discontinuous PWM.*

## I. Introduction

Three phase DC/AC Voltage Source Inverters (VSI's) are now used extensively in motor drives, active filters and unified power flow controllers in power systems and uninterrupted power supplies to generate controllable frequency and AC voltage magnitudes using various pulse-width modulation (PWM) strategies. Of the possible PWM methods, the carrier-based PWM is very popular due to its simplicity of implementation, defined harmonic waveform characteristics and low harmonic distortion. Two main implementation techniques exist for PWM: the direct digital method and the sine-triangle intersection scheme. In the traditional sine-triangle intersection PWM (SPWM) technique, three reference modulation signals are compared with a triangular carrier signal and the intersections define the switching instants of the controllable devices. PWM strategies are required for switching the devices in a VSI appropriately to generate variable voltage, variable frequency, 3-phase AC required for the variable speed induction motor drive. The performance of the drive strongly depends on the Pulse width Modulation (PWM) technique employed. At high power levels, the inverter distortion is quite high. Hence, PWM strategies for high-power drives must aim in reducing the inverter switching losses, harmonic distortion, subject to low switching frequencies of the inverter.

This zero sequence waveform is used to alter the duty cycle of the inverter switches. Adding the same zero sequence waveform to each of the three reference phase voltages does not change the inverter output line-line voltage per carrier cycle average value; however, if the waveform is properly selected, one can achieve any of the followings: switching losses can be drastically reduced, the waveform quality may be improved, the linear modulation range can be extended, and common mode voltage of motor drives can also be drastically diminished. These potentials have been explored leading to investigations into and determination of various zero sequence waveforms, resulting in a large number of published carrier-based PWM methods. When the augmenting zero sequence waveform is continuous, the continuous PWM (CPWM) scheme is produced; however when the zero sequence signal is discontinuous with a potential for the modulator to have phase segments clamped either to the positive or negative rails, the scheme is called the discontinuous PWM (DPWM).

The zero-voltage injection has been fully exploited but to different purposes: adding a zero-voltage sequence can serve not only to linearity extension, but also to reducing switching losses. In order to reduce switching losses the simplest method is not to switch: the idea was possible using zero-voltage sequences that saturate one of the modulation wave of the three phases.

There are about six variations reported in the literature under the name Discontinuous Pulse Width Modulation (DPWM) viz., DPWM0, DPMW1, DPWM2, DPWM3, DPWMMAX and DPWMMIN. The basic idea behind all these variations are employing discontinuous modulating signal instead of basic sinusoidal signal while carrier remains the triangular function. DPWM modulation techniques have the advantage of eliminating one switching transition in each half carrier interval, which allows the switching frequency to increase by a nominal value of 3/2 accordingly for the same inverter losses. This may improve the harmonic performance of the inverter by virtue of the reduced influence of higher frequency switching harmonics.

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Global Journal of Researches in Engineering ( F ) Volume XIV Issue VIII Version I Year 2014

The proposed carrier-based non-sinusoidal and discontinuous modulation schemes are experimentally implemented with an TMS320F2812 DSP Processor, intelligent power modules and used to modulate a three-phase inverter feeding a three-phase induction machine.

## II. Principle of Dpwm and its Variants

*a) 120° Discontinuous Modulation*

In this type of modulation, each phase leg in turn is now continuously locked to the upper or lower DC rail (whichever is chosen) for one-third of the fundamental cycle ($120°$).DPWMMAX and DPWMMIN strategies come under this category. In DPWMMAX, each phase around the peak is locked to the upper DC rail for one-third of the fundamental cycle (120°) as shown in Figure 1(a) and hence the name. Each phase in DPWMMIN, is locked to the lower DC rail for one-third of the fundamental cycle (120°) as shown in the Figure 1(b).Due to the asymmetry in line-to-line voltage , it has been expected that the harmonic performance of $120°$ discontinuous PWM will be suboptimal compared to continuous modulation strategies. However, it has been identified that to maintain the same effective phase leg switching frequency as for continuous modulation, the space vector calculation frequency (i.e. twice the carrier frequency) should be increased by approximately 50%, since each phase leg only switches during two-thirds of each fundamental cycle. It is trade-off between these two effects that offers potential advantages for $120°$ discontinuous PWM under some modulation conditions. A further limitation with this strategy is that one device of each phase leg is always turned off during its $120°$ unmodulated region, while the other device is always conducting. Hence conduction losses are not shared equally across the two devices in each phase leg.

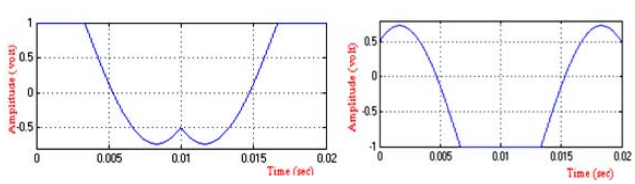



*Figure 1 :* Modulating waveform for phase 'a' (a)DPWMMAX (b) DPWMMIN

However, this limitation can be avoided by clamping to alternate DC buses every half cycle (i.e. cycle between the DPWMIN and the DPWMMAX strategies).

*b) 60° and 120° Discontinuous Modulation*

Another improved discontinuous modulation strategy in which each phase leg is now unmodulated for only $60°$ at a time (alternately switched to the upper or to the lower DC rail).It has the particular benefit that the line-to-line switched voltages are symmetrical. This type of discontinuous switching pattern is termed as DPWM1 and centers the non-switching periods for each phase leg symmetrically around the positive and negative peaks of its fundamental reference voltage. This is the best position for resistive load, since the peaks of the line currents follow the peaks of the fundamental voltages. Therefore each phase leg does not switch just when the current is at its maximum value, and this obviously minimizes switching losses. The modulating waveform for DPWM1 is as shown in the Figure 2(a).

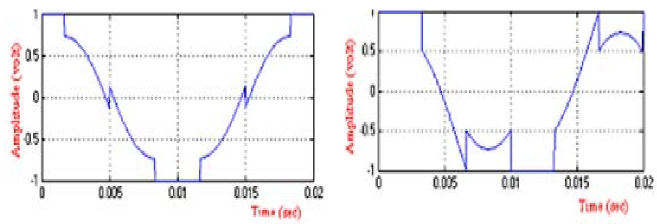
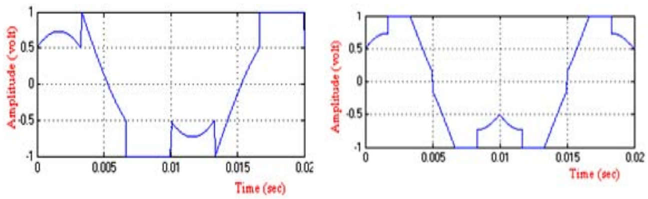



*Figure 2 :* Modulating waveform for phase 'a' (a)DPWM1 (a) DPWM2

It is viable to place each $60°$ non-switching period anywhere within the $120°$ region where the appropriate phase leg reference voltage is the maximum/minimum of the three-phase set. For example, the $60°$ "clamp to $+V_{dc}$ "non switching period for phase leg '**a**' can be placed anywhere in the region $-\frac{\pi}{3} \leftrightarrow \frac{\pi}{3}$, since the 'a' phase reference voltage is more positive than the other two phase reference voltages during this period. Similarly, the "clamp to $-V_{dc}$" non-switching period for phase leg 'a' can be placed anywhere in the region $\frac{2\pi}{3} \leftrightarrow \frac{4\pi}{3}$, since this is the region where the 'a' phase fundamental voltage is more negative than the other two-phase reference voltages. This freedom allows alternative $60°$ discontinuous PWM strategies to be considered which minimize the switching losses for loads which are not unity power factor.

For a lagging power factor (pf) load, it is clearly preferable to retard the non-switching period by up to a maximum of $30°$ (pf of 0.866 lag), depending on the load current power factor. This is the discontinuous modulation strategy DPWM2 and its modulating waveform is as shown in figure 2(ii).For a leading power factor load, the non switching period can be advanced by up to $30°$ (pf of 0.866 lead).This is discontinuous modulation strategy DPWM0 and its modulating waveform is shown in Figure 3(a). It should be noted however, that incorporating this advance/retard of the non switching period reintroduces asymmetry into the line-to-line voltage as shown in the figure 3(b).

The final variation is to clamp the phase legs to the opposite DC rails in each $60^\circ$ segment as shown in the figure. This strategy is referred as $30^\circ$ discontinuous modulation-DPWM3, since it requires the clamping phase leg to change every $30^\circ$ as shown in figure 3(ii).




(a) (b)

*Figure 3 :* Modulating waveform for phase 'a' (a)DPWM0 (b) DPWM3

In DPWM, the modulating signal is discontinuous in nature comprised of different functions for each section of time reference. There are six functions which are substituted in various sections of time reference. The differences among the DPWM schemes are just interchange of these sections. Table 1, 2, 3, 4, 5 and 6 details the expressions for the modulation waves of various DPWM variants for one complete cycle.

In all the cases, it has been understood that the phase leg reference segments are in fact sections of the required line-to-line voltage, referenced to the phase leg which is clamped to either the upper or the lower DC rail. The variation of M does not have any effect in the saturation region of the modulating wave.

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*Table 1 :* Composite modulating function- DPWM1

| Alpha (degree) | Phase A | Phase B | Phase C |
|---|---|---|---|
| 0-30$^0$ | +1 | $+1-\sqrt{3}*M*\cos(\theta+\frac{\pi}{6})$ | $+1+\sqrt{3}*M*\cos(\theta+\frac{5\pi}{6})$ |
| 30$^0$-90$^0$ | $-1-\sqrt{3}*M*\cos(\theta+\frac{5\pi}{6})$ | $-1+\sqrt{3}*M*\sin(\theta)$ | -1 |
| 90$^0$-150$^0$ | $+1+\sqrt{3}*M*\cos(\theta+\frac{\pi}{6})$ | +1 | $+1-\sqrt{3}*M*\sin(\theta)$ |
| 150$^0$-210$^0$ | -1 | $-1-\sqrt{3}*M*\cos(\theta+\frac{\pi}{6})$ | $-1+\sqrt{3}*M*\cos(\theta+\frac{5\pi}{6})$ |
| 210$^0$-270$^0$ | $+1-\sqrt{3}*M*\cos(\theta+\frac{5\pi}{6})$ | $+1+\sqrt{3}*M*\sin(\theta)$ | +1 |
| 270$^0$-330$^0$ | $-1+\sqrt{3}*M*\cos(\theta+\frac{\pi}{6})$ | -1 | $-1-\sqrt{3}*M*\sin(\theta)$ |
| 330$^0$-360$^0$ | +1 | $+1-\sqrt{3}*M*\cos(\theta+\frac{\pi}{6})$ | $+1+\sqrt{3}*M*\cos(\theta+\frac{5\pi}{6})$ |

*Table 2 :* Composite modulating function- DPWMMAX

| Alpha (degree) | Phase A | Phase B | Phase C |
|---|---|---|---|
| 0-60$^0$ | +1 | $+1-\sqrt{3}*M*\cos(\theta+\frac{\pi}{6})$ | $+1+\sqrt{3}*M*\cos(\theta+\frac{5\pi}{6})$ |
| 60$^0$-180$^0$ | $+1+\sqrt{3}*M*\cos(\theta+\frac{\pi}{6})$ | +1 | $+1-\sqrt{3}*M*\sin(\theta)$ |
| 180$^0$-300$^0$ | $+1-\sqrt{3}*M*\cos(\theta+\frac{5\pi}{6})$ | $+1+\sqrt{3}*M*\sin(\theta)$ | +1 |
| 300$^0$-360$^0$ | +1 | $+1-\sqrt{3}*M*\cos(\theta+\frac{\pi}{6})$ | $+1+\sqrt{3}*M*\cos(\theta+\frac{5\pi}{6})$ |

*Table 3 :* Composite modulating function- DPWM2

| Alpha (degree) | Phase A | Phase B | Phase C |
|---|---|---|---|
| $0\text{-}60^0$ | +1 | $+1-\sqrt{3}*M*\cos(\theta+\frac{\pi}{6})$ | $+1+\sqrt{3}*M*\cos(\theta+\frac{5\pi}{6})$ |
| $60^0\text{-}120^0$ | $-1-\sqrt{3}*M*\cos(\theta+\frac{5\pi}{6})$ | $-1+\sqrt{3}*M*\sin(\theta)$ | -1 |
| $120^0\text{-}180^0$ | $+1+\sqrt{3}*M*\cos(\theta+\frac{\pi}{6})$ | +1 | $+1-\sqrt{3}*M*\sin(\theta)$ |
| $180^0\text{-}240^0$ | -1 | $-1-\sqrt{3}*M*\cos(\theta+\frac{\pi}{6})$ | $-1+\sqrt{3}*M*\cos(\theta+\frac{5\pi}{6})$ |
| $240^0\text{-}300^0$ | $+1-\sqrt{3}*M*\cos(\theta+\frac{5\pi}{6})$ | $+1+\sqrt{3}*M*\sin(\theta)$ | +1 |
| $300^0\text{-}360^0$ | $-1+\sqrt{3}*M*\cos(\theta+\frac{\pi}{6})$ | -1 | $-1-\sqrt{3}*M*\sin(\theta)$ |

*Table 4 :* Composite modulating function- DPWM0

| Alpha (degree) | Phase A | Phase B | Phase C |
|---|---|---|---|
| $0\text{-}60^0$ | $-1-\sqrt{3}*M*\cos(\theta+\frac{5\pi}{6})$ | $-1+\sqrt{3}*M*\sin(\theta)$ | -1 |
| $60^0\text{-}120^0$ | $+1+\sqrt{3}*M*\cos(\theta+\frac{\pi}{6})$ | +1 | $+1-\sqrt{3}*M*\sin(\theta)$ |
| $120^0\text{-}180^0$ | -1 | $-1-\sqrt{3}*M*\cos(\theta+\frac{\pi}{6})$ | $-1+\sqrt{3}*M*\cos(\theta+\frac{5\pi}{6})$ |
| $180^0\text{-}240^0$ | $+1-\sqrt{3}*M*\cos(\theta+\frac{5\pi}{6})$ | $+1+\sqrt{3}*M*\sin(\theta)$ | +1 |
| $240^0\text{-}300^0$ | $-1+\sqrt{3}*M*\cos(\theta+\frac{\pi}{6})$ | -1 | $-1-\sqrt{3}*M*\sin(\theta)$ |
| $300^0\text{-}360^0$ | +1 | $+1-\sqrt{3}*M*\cos(\theta+\frac{\pi}{6})$ | $+1+\sqrt{3}*M*\cos(\theta+\frac{5\pi}{6})$ |

*Table 5 :* Composite modulating function- DPWMMIN

| Alpha (degree) | Phase A | Phase B | Phase C |
|---|---|---|---|
| $0\text{-}120^0$ | $-1-\sqrt{3}*M*\cos(\theta+\frac{5\pi}{6})$ | $-1+\sqrt{3}*M*\sin(\theta)$ | -1 |
| $120^0\text{-}240^0$ | -1 | $-1-\sqrt{3}*M*\cos(\theta+\frac{\pi}{6})$ | $-1+\sqrt{3}*M*\cos(\theta+\frac{5\pi}{6})$ |
| $240^0\text{-}360^0$ | $-1+\sqrt{3}*M*\cos(\theta+\frac{\pi}{6})$ | -1 | $-1-\sqrt{3}*M*\sin(\theta)$ |

*Table 6 :* Composite modulating function- DPWM3

| Alpha (degree) | Phase A | Phase B | Phase C |
|---|---|---|---|
| $0\text{-}30^0$ | $-1-\sqrt{3}*M*\cos(\theta+\frac{5\pi}{6})$ | $-1+\sqrt{3}*M*\sin(\theta)$ | -1 |
| $30^0\text{-}60^0$ | +1 | $+1-\sqrt{3}*M*\cos(\theta+\frac{\pi}{6})$ | $+1+\sqrt{3}*M*\cos(\theta+\frac{5\pi}{6})$ |
| $60^0\text{-}90^0$ | $-1+\sqrt{3}*M*\cos(\theta+\frac{\pi}{6})$ | +1 | $+1-\sqrt{3}*M*\sin(\theta)$ |
| $90^0\text{-}120^0$ | $-1-\sqrt{3}*M*\cos(\theta+\frac{5\pi}{6})$ | $-1+\sqrt{3}*M*\sin(\theta)$ | -1 |
| $120^0\text{-}150^0$ | -1 | $-1-\sqrt{3}*M*\cos(\theta+\frac{\pi}{6})$ | $-1+\sqrt{3}*M*\cos(\theta+\frac{5\pi}{6})$ |
| $150^0\text{-}180^0$ | $+1+\sqrt{3}*M*\cos(\theta+\frac{\pi}{6})$ | +1 | $+1-\sqrt{3}*M*\sin(\theta)$ |
| $180^0\text{-}210^0$ | $+1-\sqrt{3}*M*\cos(\theta+\frac{5\pi}{6})$ | $+1+\sqrt{3}*M*\sin(\theta)$ | +1 |
| $210^0\text{-}240^0$ | -1 | $-1-\sqrt{3}*M*\cos(\theta+\frac{\pi}{6})$ | $-1+\sqrt{3}*M*\cos(\theta+\frac{5\pi}{6})$ |
| $240^0\text{-}270^0$ | $-1+\sqrt{3}*M*\cos(\theta+\frac{\pi}{6})$ | -1 | $-1-\sqrt{3}*M*\sin(\theta)$ |
| $270^0\text{-}300^0$ | $+1-\sqrt{3}*M*\cos(\theta+\frac{5\pi}{6})$ | $+1+\sqrt{3}*M*\sin(\theta)$ | +1 |
| $300^0\text{-}330^0$ | +1 | $+1-\sqrt{3}*M*\cos(\theta+\frac{\pi}{6})$ | $+1+\sqrt{3}*M*\cos(\theta+\frac{5\pi}{6})$ |
| $330^0\text{-}360^0$ | $-1+\sqrt{3}*M*\cos(\theta+\frac{\pi}{6})$ | -1 | $-1-\sqrt{3}*M*\sin(\theta)$ |

## III. Performance Evaluation

Parameters that is taken in consideration for performance evaluation of the proposed DPWM methods namely Total Harmonic Distortion (THD) is defined in by equations (1),

$$THD = \sqrt{\sum_{n=3,5,7..}^{\infty}\left(\frac{V_n}{V_1}\right)^2} \quad (1)$$

Where $V_n$ represents $n^{th}$ order harmonic component and $V_1$ represent fundamental output phase voltages. The lowest order harmonic contents (upto $25^{th}$ order) are considered for calculation of THD. The resulting THD are shown in Figure 4. Their measured %THDs is compared (Table-7).

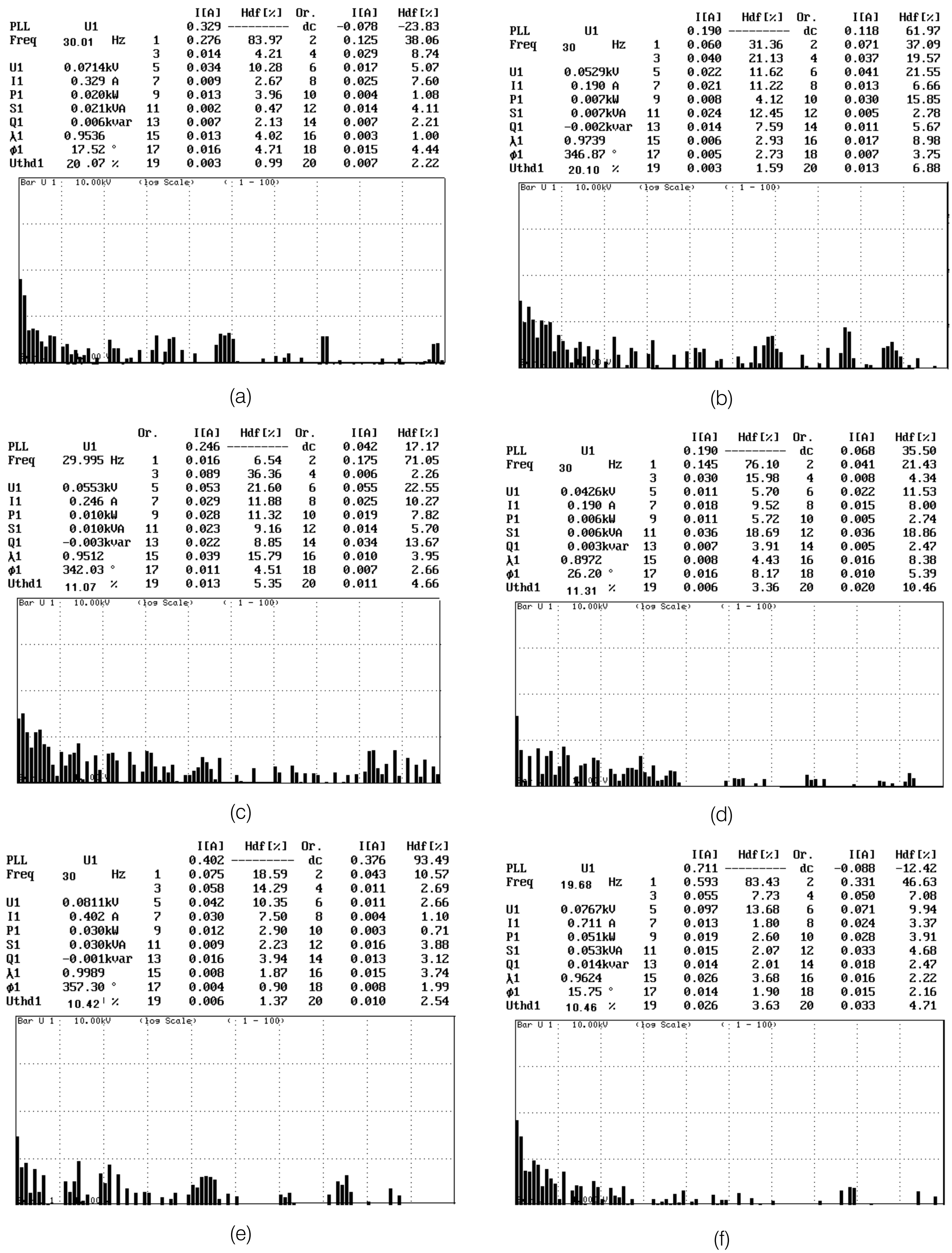


*Figure 4 :* Harmonic spectra (% of fundamental) , (a) for DPWMMAX ; (b) for DPMIN ; (c) for DPWM 1; (d) for DPWM 2 ; (e) for DPWM 3 and (f) for DPWM 0

*Table 7 :* Comparison of % THDs of various PWM methods at different modulation indices (M)

| | M=0.8 | | M=0.6 | | M=0.3 | |
|---|---|---|---|---|---|---|
| | at 30Hz | at 50Hz | at 30Hz | at 50Hz | at 30Hz | at 50Hz |
| DPWMMAX | 4.21 | 5.21 | 6.70 | 8.10 | 20.01 | 21.46 |
| DPWMMIN | 4.21 | 5.20 | 6.71 | 8.10 | 20.10 | 22.60 |
| DPWM1 | 3.65 | 5.41 | 3.99 | 11.20 | 11.07 | 21.93 |
| DPWM2 | 3.61 | 5.40 | 4.20 | 9.52 | 11.31 | 19.62 |
| DPWM3 | 3.70 | 5.02 | 4.48 | 9.40 | 10.42 | 19.70 |
| DPWM0 | 3.71 | 5.01 | 4.54 | 9.42 | 10.46 | 19.68 |

It is seen from that at low modulation index the THD of DPWMMAX is lowest compared to all other schemes and DPWM1 has highest THD. Since the DPWMMAX may not be employed for implementation purposes, thus the next best scheme is DPWM2. At high modulation index the value of THD is smaller compared to the value at lower modulation index, which implies that the output voltage is very near to the sinusoidal. DPWM1 has the lowest THD and DPWM0 and DPWM3 has highest THD at high modulation index.

## IV. Experimental Results

The proposed DPWM techniques has been implemented in real time using Texas Instrument TMS320F2812 DSP Processor, intelligent power modules and was programmed through the software Vissim. The DSP board is integrated interfacing communication board. The PC is connected to the DSP board through printer parallel port.

The DSP board is connected through cable to the Inverter intelligent power modules. Current sensors are used for feedback purposes. The code is run using Code Composer studio CCS 3.2V, and the .out file thus created is then converted to the ASCII file which is loaded to the DSP for further processing. The complete experimental set up is illustrated in Figure 5 (a) and (b).

(a) (b)

*Figure 5 :* Experimental set-up (a) TMS320F2812 DSP board and Intelligent Power Module (b) Induction Motor with Load setup

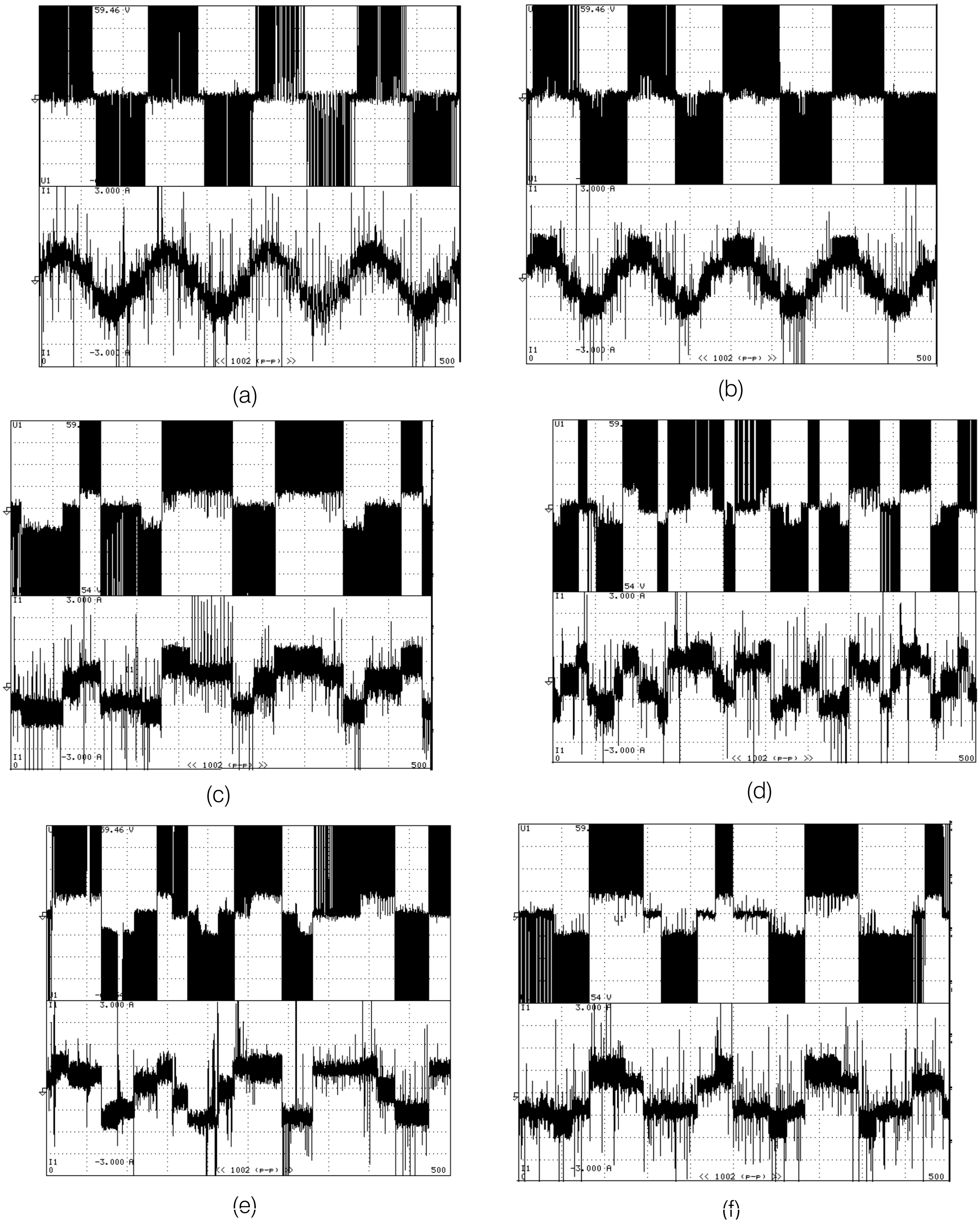


*Figure 6 :* Line voltage and Line Current of, (a) for DPWMMAX; (b) for DPMIN; (c) for DPWM 1; (d) for DPWM 2; (e) for DPWM 3 and (f) for DPWM 0

Illustrative experimental results are given in Figures 6 (a), (b), (c), (d), (e), (f) and (g) showing voltage and current waveforms when a loaded induction machine is fed with a voltage source inverter under various types of generalized discontinuous modulation.

## V. Conclusions

The paper present PWM technique termed as Discontinuous PWM for voltage source inverter. This proposed method of PWM offers a reduction in overall number of switching and consequently switching losses.. The analysis is done on the basis of THD in output phase voltages. It can be concluded that the DPWMMAX provide lowest THD for low modulation index. However, this method is not recommended for practical implementation as this may shorten the life of inverter. DPWM2 offers the next best result and thus it may be used for implementation. At high modulation index DPWM1 is recommended for use. The viability of the proposed schemes is validated using simulation and experimental result

## References Références Referencias


1. S. R. Bowes (1975), "New sinusoidal pulsewidth modulated inverter," *Proc. Inst. Elect. Eng.*, vol. 122, pp. 1279–1285, 1975.
2. Hava, R. J. Kerkman and T. A. Lipo (1999), " Simple Analytical and Graphical Methods for Carrier based PWM VSI Drives, IEEE Trans. on Power Electronics, vol. 14, no. 1, pp. 49-61.
3. Hava, R. J. Kerkman and T. A. Lipo (1998), "A High Performance Generalized Discontinuous PWM Algorthim," IEEE Trans. On Industry Applications, vol. 34, no. 5, pp. 1059-1071.
4. B. K. Bose (1977), Power Electronics and Variable Frequency Drives, Technology and Applications, IEEE Press, New York.
5. J. Holtz (1994), "Pulse-width modulation for Electronic Power Conversion," Proceedings of the IEEE, vol. 8, pp. 1194-1214.
6. B. K. Bose (2002), Modern Power Electronics and AC Drives, Prentice-Hall,Upper Saddle River, New Jersey.
7. H. Van Der Broeck, H. Skudelny and G. Stanke (1988), "Analysis and Realization of a Pulse Width Modulator Based on Voltage Space Vectors," IEEE Trans. on Industry Applications, Vol. IA-24, No. 1, pp. 142-150 1988.
8. S. L. Capitaneanu, B. De Fornel, M. Fadel, J. Faucher, A.Almeida(2001), "Graphical and algebraic synthesis for PWM methods", *EPE Journal,* vol.11, pp.1-12.
9. D. G. Holmes and T. A. Lipo (2003), "Pulse Width Modulation for Power Converters: Principles and Practice", M.E. El-Hawary, Ed. New Jersey: IEEE Press, Wiley- Interscience, pp. 215–313.
10. D. Dujic, M. Jones, E. Levi (2009), "Generalised space vector WPM for sinusoidal output voltage generation with multiphase voltage source inverter", *Int. Journal of Ind. Elect. And Drives,* vol. 1, NO. 1.
11. G.D.Holmes, T.A.Lipo (2003), "*Pulse Width Modulation for Power Converters –Principles and Practice*," IEEE Press Series on Power Engineering, John Wiley and Sons, Piscataway, NJ, USA.
12. M.A. Khan and A. Iqbal, "Discontinuous space vector PWM for a five-phase VSI with higher dc bus utilisation", *Proc. IEEE INDICO.*
13. T. Brahmananda Reddy, J. Amarnath and D. Subba Rayudu. (2006). New Hybrid SVPWM Methods for Direct Torque Controlled Induction Motor Drive for Reduced Current Ripple. IEEE Proc. Power Electronics, Drives and Energy systems for Industrial Growth, PEDES'06, New Delhi, India. Paper No.3B.

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Global Journal of Researches in Engineering: F
Electrical and Electronics Engineering
Volume 14 Issue 8 Version 1.0 Year 2014
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)
Online ISSN: 2249-4596 & Print ISSN: 0975-5861

# Transmission Line Fault Detection Using Android Application Via Bluetooth

By MD Asaduzzaman Nur, Jahidul Islam, Md. Golam Mostofa & Moshiul Alam Chowdhury
*American International University, Bangladesh*

*Abstract-* Technological advancement and its incorporation is playing significant in human life. In present days, the demand on the electric power for the household, commercial and industrial loads is increasing. Also, the management of electric power distribution system is becoming more complex. Bluetooth based fault detection is a newly developing concept in the power system fault detection. This is a part of smart grid. The system is designed to detect the transmission line fault for the user to easily recognize the current condition of the distribution line. The ultimate objective is to monitor the distribution line status continuously and hence to guard the fault of distribution line due to the constraints such as overvoltage, under voltage, SLG, DLG faults. If any of these does occurs then a user can easily detect the fault.

*Keywords: microcontroller, transformer, ICE, bluetooth module, bridge rectifier, android application.*

*GJRE-F Classification : FOR Code: 090609*

TRANSMISSIONLINEFAULTDETECTIONUSINGANDROIDAPPLICATIONVIABLUETOOTH

*Strictly as per the compliance and regulations of :*

# Transmission Line Fault Detection Using Android Application Via Bluetooth

MD Asaduzzaman Nur [α], Jahidul Islam [σ], Md.Golam Mostofa [ρ] & Moshiul Alam Chowdhury [ω]

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## I. Introduction

Protection system's main function is to clear faults from the power system at high speed to ensure safety, minimize equipment damage and maintain power system stability[2]. Protection of power systems requires an understanding of system faults, their detection, and safe isolation of the faulted device. By taking an inventory of all the essential electrical loads and doing a basic electrical load evaluation [2], an idea regarding how much power our system needs to produce has been obtained. We are also aware about the power fluctuation situations also that means what voltage minimum / maximum we are getting from the A.C supply mains. In doing this project we would be using concepts of microcontrollers, Bluetooth Module and Android Application.

## II. Fault Types and Protection

*a) Single-Line-to-Ground Fault*

A short circuit between one line and ground, very often caused by physical contact, for example due to lightning or other commomeans. The single line to ground fault can occur in any of the three phases[1]. However, it is sufficient to analyze only one of the cases.

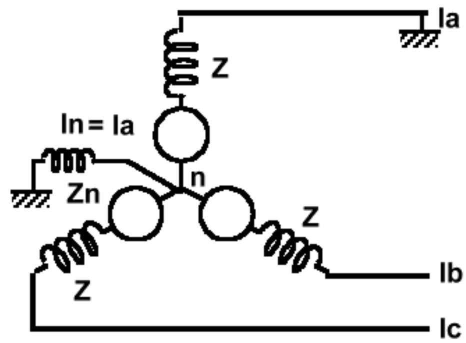


*Figure 1 :* Single Line to Ground fault

*b) Line-to-Line Fault*

A short circuit between lines, caused by ionization of air, or when lines come into physical contact[1], for example due to a broken insulator. For a Line-to-line fault, the currents will be high, because the fault current is only limited by the inherent (natural) series impedance of the power system up to the point of faulty (refer Ohms law).

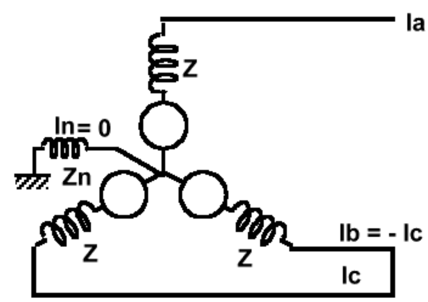


*Figure 2 :* Line to line fault

*c) Double- Line -to Ground Fault*

Two lines come into contact with the ground (and each other), also commonly due to stormy weather or some other means [1].

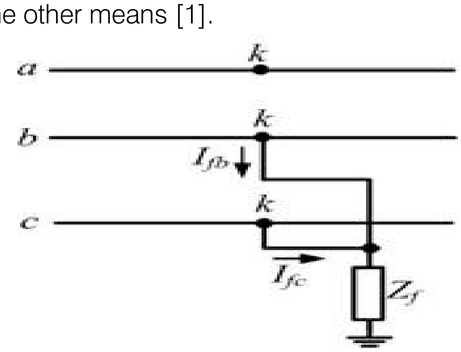


*Figure 3 :* Double line to Ground Fault

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*d) Lower Voltage*

Low voltage is a relative term, the definition varying by context. Different definitions are used in transmission and distribution line, and in the electronics industry. Electrical safety codes define "low voltage" circuits that are exempt from the protection required at higher voltages. These definitions vary by country and specific code. Lower voltage is defined as incoming line voltage at the point of use which is smaller than the Public Service Commission's mandated legal limits; and/or smaller than the voltage ratings of the connected equipment. Lower voltage is considered a safety hazard by all industry standards and can cause premature failure of connected equipment. Devices could be damaged by lower line voltage.

*e) Over Voltage*

Overvoltage is defined as incoming line voltage at the point of use which is greater than the Public Service Commission's mandated legal limits; and/or greater than the voltage ratings of the connected equipment. Overvoltage is considered a safety hazard by all industry standards, and can cause premature failure of connected equipment. Overvoltage has been a widely known industry problem for many years, but it is not generally understood by many who have to deal with it. Power companies have been unable to control it adequately. Overvoltage occurs most often during severe cold winter weather for the following reasons: (1) Inadequate size of power distribution systems; (2) slow reaction time for power company's distribution systems to regulate voltage during extreme load variations; and (3) abrupt reductions of loads.

## III. Block Diagram Arrangement

In figure 4, the basic arrangement of the implemented project can be found.

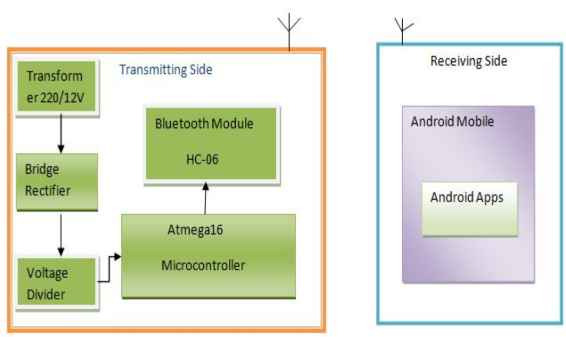


*Figure 4 :* Block diagram arrangement of the project

Among the major components required to establish the project, few of them are the power transformers (step down), microcontroller ATMEGA 16 and Bluetooth module ,Bridge rectifier.

*a) Transformer*

Transformer is an electrical device used to step up and down the AC voltages. There are two types of transformers: Step up and step down transformer. Step up transformer increases the magnitude of voltage while step down transformer decreasethe magnitude of voltage. Depending on the ratio of the number ofturns in the primary & secondary winding a transformer is characterized as step up or step down. For this project purpose, considering 1Φ voltage to be around 220 V, 3 step down power transformer of rating 220/12 has been used to represent a realistic representation of the 3Φ system.

*Figure 5 :* 220v/12v transformer

*b) Microcontroller ATMEGA 16*

Brain of this project is Atmega16 micro-controller. It is a 8 bit Micro controller with RISC architecture. Its speed is up to 16MIPS throughput at 16MHz. It has 16K bytes of flash and 512bytes EEPROM. Operating voltage 2.7v -5.5v, in active mode it consumes only 1.1mA & in sleep mode it consumes less than 1uA current which made it a perfect choice for his project [3].

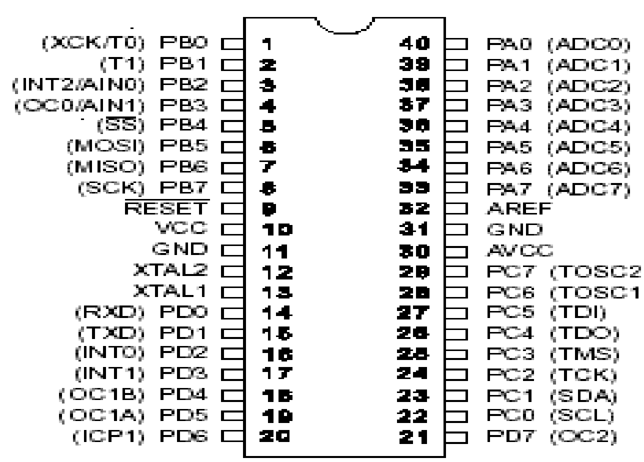


*Figure 6 :* Atmega16 microcontroller

*c) Bluetooth module*

HC-06 has been used as Bluetooth module. The Baud rate is 9600. Master and slave mode can't be switched in this Module. HC-06 module have paired memory to remember last slave device. The working voltage is 3.3V, but it can work at 3.00-4.2v.The Current pairing 20~30mA, connected 8mA[5].

*Figure 7 :* Bluetooth module HC-06

*d) Bridge rectifier*

An AC power source is required for powering major appliances but almost all electronic circuits require a steady DC supply. A simple rectifier circuit described in this project converts the input from AC source to DC voltage. Firstly, the AC input from mains is stepped down to a lower value of voltage. This AC supply is then passed through a rectifier circuit to remove the negative cycle of AC waveform. The resulting signal is then filtered to get the DC output. The major part of the circuit is connected to the secondary coil of the transformer which is comprised by diodes and capacitor. While the diodes act as a rectifiers, capacitor filters out the DC component from the circuit.

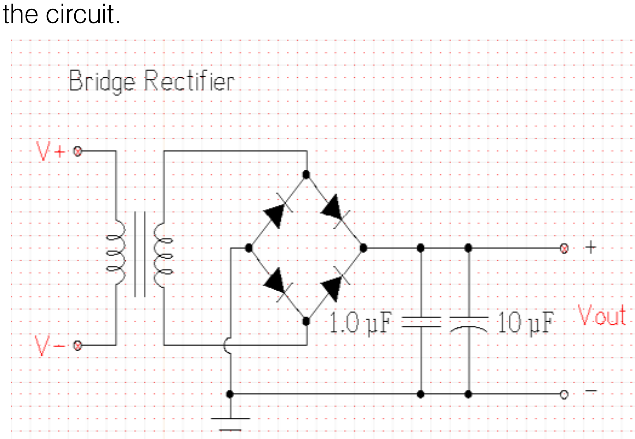


*Figure 8 :* Bridge rectifier

## IV. Simulation

The initial stage, the circuits have been designed and simulated in PROTEUS. The circuit have been utilized to analyze the line to line, single line to ground, double line to ground, open conductor, over voltage and under voltage in the sides of the transformer. The circuit diagram can be found in figure 9.

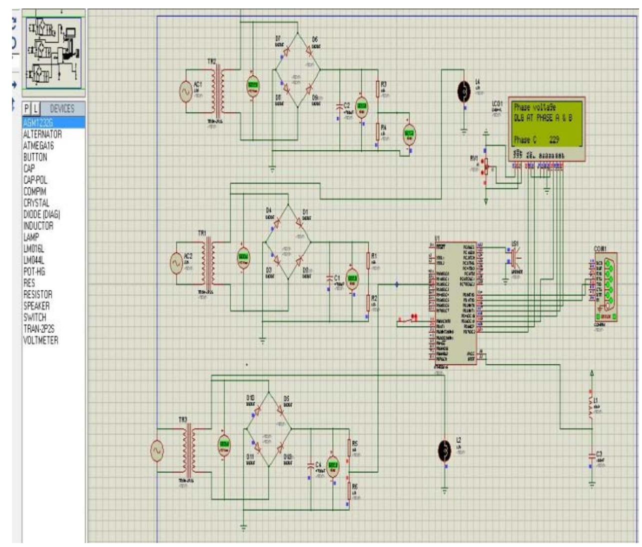

*Figure 9 :* Circuit Simulation

## V. Hardware Implementation

In reference to figure 4, the transmitting and receiving side can be described as follows:

*a) Transmitting side*

Heart of the project is the microcontroller ATMEGA 16. In general the normal distribution phase voltage is 220 V, in this project we used a step down transformer 220/12 V for converting the phase voltage from 220 V to 12 V. Then, a bridge rectifier has been used for converting the 12 V ac to 12 V dc; after that, applied voltage divider converts the 12 V to 5 V because the microcontroller works at maximum 5 V. By this process the three distribution phase is connected into three microcontroller pins. At cases, when the distribution side is in load shedding protection of transformer must be ensured, which is why the microcontroller power is given from an external power source (5 V battery) backup and also the Bluetooth module power is given from external power source(4V battery). Bluetooth module communicates with atmeg16 through UART. RXD of Bluetooth module is connected with TXD of atmega16 and TXD of Bluetooth module is connected to RXD of atmega16.

*b) Receiving side*

In receiver Side an Android Phone is connected with Transmitting side via Bluetooth Module CI Android Apps[6]. At first we connect the android phone with HC-

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06 and the password of the HC-06 is 1234 then android apps shows the data which is send by transmitting side. The communication protocol is UART and baud rate is 9600[4].

In view of the descriptions above, the implemented hardware can be found in figure 10.

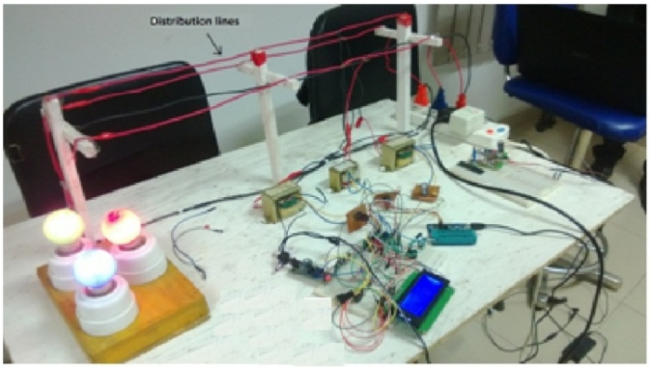


*Figure 10 :* Implemented Hardware model

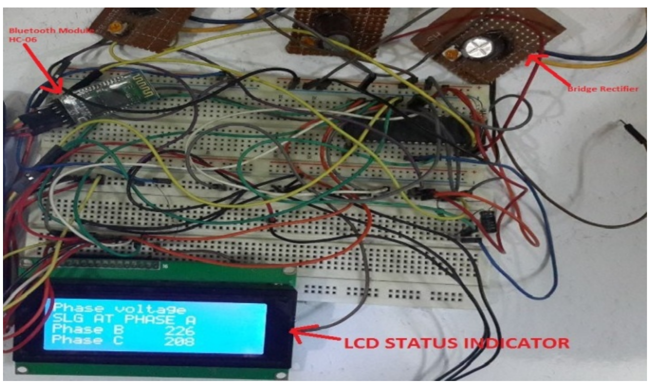


*Figure 11 :* LCD status indicator

As viewed from figure 10, the system was found to be balanced three phase system. In figure 11, the corresponding representation appears in the LCD display with the phase voltages in all the phases to be around 219 V. The view from Android Phone is also shown in figure 12.

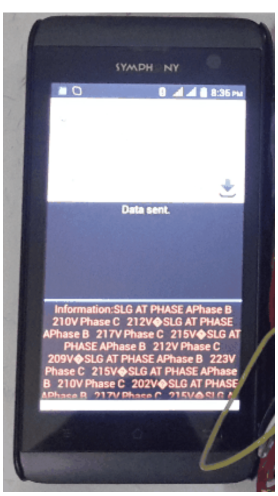


*Figure 12 :* Android Phone output

## VI. Future Prospects

In view of a wide and Short range of possibilities on the basis of Bluetooth based fault Detection system, a few has been depicted below:

1. Fault detection of a Generator and motor.
2. Improvements to human-machine interface.
3. Improvements in computer-based protection of Industry automation.

## VII. Conclusion

Microcontroller and Bluetooth based fault detection system is a reliable technique for monitoring and controlling the electric distribution system, the microcontroller works up to 100 ºC temperature. For Short distance data transmission Bluetooth technology is a reliable and robust one. Any kind of fault occurring in the distribution system results the Bluetooth modules to send instant messages automatically to the nearest user. Bluetooth based microcontroller Fault detection system will serve as a reliable, easy and cost effective solution for monitoring and controlling the electric distribution system.

## References Références Referencias

1. Md Asaduzzaman Nur, Mehdi Hasan Sourov, M. S. Muhit & Md Khaled Hossain,'' Fault Analysis and Electrical Protection of Distribution Transformers" E-Journal_GJRE_(F)_Vol_14_Issue_3.
2. V. Thiyagarajan & T.G. Palanivel ''AN EFFICIENT MONITORING OF SUBSTATION-SUSING MICROCONTROLLER BASED MONITORING SYSTEM'' IJRRAS 4 (1). July 2010.
3. Datasheet of Atmega16" http://www.atmel.com/-images/7766s.pdf"
4. Datasheet of Bluetooth module HC-06" http://www.-micro4you.com/files/ElecFreaks/Bluetooth%20HC-06.pdf "
5. Wadhwa, C. L. (2005). ''Electrical Power Systems''. New Age International (P) Ltd., Publishers: New Delhi. Pp. 656-657.
6. Google play store "Bluetooth module CI".
7. Grainger, John J. (2003). Power System Analysis. Tata McGraw-Hill. p. 380. ISBN 978-0-07-058515-7.

Global Journal of Researches in Engineering: F
Electrical and Electronics Engineering
Volume 14 Issue 8 Version 1.0 Year 2014
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)
Online ISSN: 2249-4596 & Print ISSN: 0975-5861

# Optimal Power Flow in the Presence of Practical Constraints and with TCSC using Imperialistic Competitive Algorithm

By G. Nageswara Reddy, S. S. Dash, S. Sivangaraju & Ch. V. Suresh
*Yogi Vemana University, India*

*Abstract-* At present, power system operation, control, Management becomes very complex due to continuously increasing demand. Flexible AC Transmission System (FACTS) controllers are used to increase power transfer capability of the transmission lines closer to their limits. This paper proposed a methodology to solve Optimal Power Flow (OPF) problem in the presence of Thyristor Controlled Series Capacitor (TCSC) while satisfying system operating and practical constraints. A novel cost objective function is formulated by combining investment cost of the TCSC with the conventional fuel cost function. The proposed methodology is tested on standard IEEE-14 bus test system with supporting results.

*Keywords: economic dispatch, ramp-rate limit, prohibited operating zones, TCSC, investment cost.*

*GJRE-F Classification : FOR Code: 090607*

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*Abstract-* At present, power system operation, control, Management becomes very complex due to continuously increasing demand. Flexible AC Transmission System (FACTS) controllers are used to increase power transfer capability of the transmission lines closer to their limits. This paper proposed a methodology to solve Optimal Power Flow (OPF) problem in the presence of Thyristor Controlled Series Capacitor (TCSC) while satisfying system operating and practical constraints. A novel cost objective function is formulated by combining investment cost of the TCSC with the conventional fuel cost function. The proposed methodology is tested on standard IEEE-14 bus test system with supporting results.

*Keywords: economic dispatch, ramp-rate limit, prohibited operating zones, TCSC, investment cost.*

## I. Introduction

Most important problem in power systemoperation and control is Economic Load(ED). This problem should be optimized tomaximize the lowest cost of fuel to meet the load. The main objective of OPF problem is to optimize the chosen objectives such as classical quadratic fuel cost function and non-convex fuel cost functions in the presence of operating as well as practical constraints. In general, OPF problem is described as a highly constrained, large-scale, non-linear, non-convex optimization problem.

In the last three decades eminent population based optimization techniques have been developed. They are: Grenade Explosion Method (GEM) [1], Ant Colony Optimization (ACO) [2], Shuffled Frog Leaping (SFL) [3], Artificial Immune Algorithms (AIA) [4], Harmony Search (HS) [5], Genetic Algorithm (GA) [6], Artificial Bee Colony (ABC) [7], Particle Swarm Optimization (PSO) [8], Bacteria Foraging Optimization (BFO) [9], Gravitational Search Algorithm (GSA) [10], Biogeography-Based Optimization (BBO) [11] and Differential Evolution (DE) [12] these algorithms have been applied to solve OPF problems effectively for specific type of problems.

All of these algorithms are population based optimization methods, but they have some limitations in some aspects. To overcome this limitations research is continued, to improve the performance of the above methods. Improvement of the existing methods is reported in GA [13], PSO [14, 15], ACO [16, 17], ABC [18, 19]. Combining merits in the different optimization techniques known as hybridization of the optimization techniques. Some hybrid algorithms can found in [20, 21], etc.

The performance comparison of optimization techniques such as DE, PSO and GA for power loss minimization using FACTS devices is presented [22]. Optimal location and best setting of TCSC is proposed. Best location is performed using sensitivity analysis [23]. In [24], the improvement of the power system security against contingencies with TCSC approach is proposed. In this GA and PSO algorithms are used to find the optimal location and parameter settings of TCSC under contingency. Mathematical modeling of varies series FACTS devices are presented in economic dispatch problems [25]. Here selection of optimal location of FACTS devices is based on the improvement of the economic dispatch.

In [26], OPF problem formulation has been presented along with considering effects of FACTS devices and power flow constraints. To solve OPF problem a two stage problem formulation has been proposed. This reference [27], Presents the performance comparison of PSO and GA optimization techniques for FACTS based controller design. In [28], the main aim is the optimal allocation of TCSC device in the power system so the power loss become minimized and also increase power transfer capacity of the transmission line that ultimately yields minimum operating cost with different load conditions. In this, first the locations of the TCSC device is identified by calculating line flows. TCSC is placed in line where reactive power flows are very high. To solve OPF problem Hybrid GA incorporating TCSC is proposed. To select best control variables, to minimize the generation cost and maintain the power flow within the control

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range, hybrid GA is integrated with conventional OPF [29].

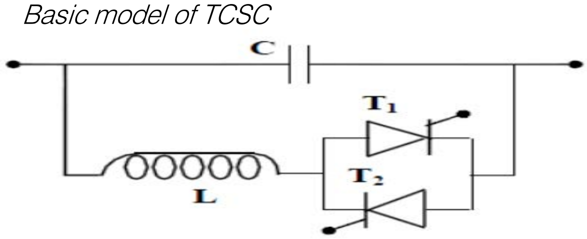
The generation cost is minimized subjected to equality and inequality constrains. The optimal active power flow control strategy with TCSC is proposed. In this method problem is solved in two steps. First step is power flow control and second step is normal OPF problem [30]. In [31], presents solution of OPF with different objective functions such as generation cost and total power loss minimization using GA. In base case OPF solution is obtained with generation cost minimization and optimal setting of the control parameters are determined. In this OPF with TCSC is carried out with generation cost and total power loss as objective functions.

This paper mainly concentrates on certain power system issues such as quadratic fuel cost function and non-convex fuel cost functions are optimized while satisfying operating and practical constraints is analyzed in the presence of TCSC. A methodology to install TCSC in an optimal location is presented. The proposed OPF problem is solved using Imperialistic Competitive Algorithm (ICA) while satisfying equality, in-equality, ramp-rate constraints and prohibited operating zones in the presence of TCSC.

## II. Modeling of TCSC

TCSC is a variable impedance type series compensator which is connected in series with the transmission line to increase the power transfer capability, improve transient stability, reduces transmission losses. The basic configuration of TCSC and its equivalent pi-representation for transmission line modeling is shown in Fig.1.

*a) Basic model of TCSC*




*b) Equivalent pi-representation of TCSC*

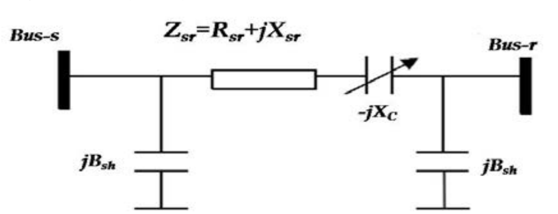



*Fig 1 :* TCSC model

This device is incorporated in a line between buses, 's' and 'r' then, the new line reactance can be expressed as

$$X_{sr\,new} = X_{sr} - X_C \quad (1)$$

Therefore new line admittance between buses's' and 'r' can be derived as follows

$$Y'_{sr} = \frac{1}{Z'_{sr}} = \frac{1}{R_{sr} + j(X_{sr} - X_C)} \quad (2)$$

$$Y'_{sr} = G'_{sr} + jB'_{sr} = \frac{R_{sr} - j(X_{sr} - X_C)}{R_{sr}^2 + (X_{sr} - X_C)^2} \quad (3)$$

$$G'_{sr} = \frac{R_{sr}}{R_{sr}^2 + (X_{sr} - X_C)^2} \;;\; B'_{sr} = -\frac{(X_{sr} - X_C)}{R_{sr}^2 + (X_{sr} - X_C)^2}$$

The modified active and reactive power flows from bus-s to bus-r, and from bus-r to bus-s of a line having series impedance and a series reactance are

$$P_{sr}^{TCSC} = V_s^2 G'_{sr} - V_s V_r \left(G'_{sr} Cos(\delta_{sr}) + B'_{sr} Sin(\delta_{sr})\right)$$

$$Q_{sr}^{TCSC} = -V_s^2 \left(B'_{sr} + B_{sh}\right) - V_s V_r \left(G'_{sr} Sin(\delta_{sr}) - B'_{sr} Cos(\delta_{sr})\right)$$

$$P_{rs}^{TCSC} = V_r^2 G'_{sr} - V_s V_r \left(G'_{sr} Cos(\delta_{sr}) - B'_{sr} Sin(\delta_{sr})\right)$$

$$Q_{sr}^{TCSC} = -V_r^2 \left(B'_{sr} + B_{sh}\right) + V_s V_r \left(G'_{sr} Sin(\delta_{sr}) + B'_{sr} Cos(\delta_{sr})\right)$$

The power loss in the line with TCSC can be written as

$$P_{Loss} = P_{sr}^{TCSC} + P_{rs}^{TCSC} = G'_{sr}\left(V_s^2 + V_r^2\right) - 2V_s V_r G'_{sr} Cos(\delta_{sr})$$

$$Q_{Loss} = Q_{sr}^{TCSC} + Q_{rs}^{TCSC} = -\left(V_s^2 + V_r^2\right)\left(B'_{sr} + B_{sh}\right) + 2V_s V_r B'_{sr} Cos(\delta_{sr})$$

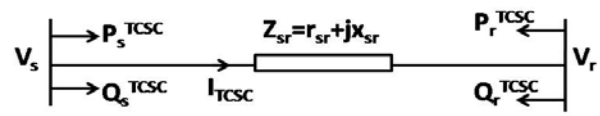



*Fig 2 :* Power injection model of TCSC

Due to TCSC, the change in line flow can be represented as a line without TCSC plus with power injected at the sending and receiving ends of the line with device as shown in Fig.2. The active and reactive power injections at bus-s and bus-r can be written as

$$P_s^{TCSC} = V_s^2 \Delta G_{sr} - V_s V_r \left[\Delta G_{sr} Cos(\delta_{sr}) + \Delta B_{sr} Sin(\delta_{sr})\right] \quad (4)$$

$$P_r^{TCSC} = V_s^2 \Delta G_{sr} - V_s V_r \left[\Delta G_{sr} Cos(\delta_{sr}) - \Delta B_{sr} Sin(\delta_{sr})\right] \quad (5)$$

$$Q_s^{TCSC} = -V_s^2 \Delta B_{sr} - V_s V_r \left[\Delta G_{sr} Sin(\delta_{sr}) - \Delta B_{sr} Cos(\delta_{sr})\right] \quad (6)$$

$$Q_r^{TCSC} = -V_r^2 \Delta B_{sr} + V_s V_r \left[\Delta G_{sr} Sin(\delta_{sr}) + \Delta B_{sr} Cos(\delta_{sr})\right] \quad (7)$$

Where

$$\Delta G_{sr} = \frac{X_C R_{sr}(X_C - 2X_{sr})}{\left(R_{sr}^2 + X_{sr}^2\right)\left(R_{sr}^2 + (X_{sr} - X_C)^2\right)}$$

$$\Delta B_{sr} = \frac{-X_C\left(R_{sr}^2 - X_{sr}^2 + X_C X_{sr}\right)}{\left(R_{sr}^2 + X_{sr}^2\right)\left(R_{sr}^2 + (X_{sr} - X_C)^2\right)}$$

TCSC device is modeled with power injection model so far by using the TCSC control variable. It is possible to calculate the complex power injected $S_s^{TCSC}$ and $S_r^{TCSC}$ at bus-s and bus-r respectively.

$$S_s^{TCSC} = P_s^{TCSC} + j\,Q_s^{TCSC}$$
$$S_r^{TCSC} = P_r^{TCSC} + j\,Q_r^{TCSC}$$

i. *Installation cost*

In this paper, device life time is considered for 15 years during the analysis. The Installation Cost (IC) of

$$IC_{TCSC} = \frac{C_{TCSC} \times S_{TCSC} \times 1000}{n \times 8760} \quad \$/h \qquad (8)$$

Where, $C_{TCSC}$=[0.0015S$^2$-0.713S+153.75] \$/KVAr, and $S_{TCSC}$=|Q2|-|Q1| MVAr. Here, $C_{TCSC}$ and $S_{TCSC}$ are the cost and operating range of TCSC, $Q_1$ and $Q_2$ are the reactive power flows in the line without and with TCSC; 'n' is the device life time in years (15 years).

ii. *Optimal location*

In order to select appropriate branch for placement of FACTS devices, contingency analysis and sensitivity index method is used. Sensitivity index is introduced for ranking the optimal location. Sensitiveness of each branch towards the change in power transfer capability, voltage profile with respect to change in line reactance, reactive power injection at various branches, buses are identified. The sensitivity indexes at different branches have been evaluated to select appropriate branch for device location by using load flow program suitable to transmission networks. These sensitivity indexes reflect how the load ability of branch change with respect to line reactance, how the voltage profile can be change with respect to reactive power injection at a particular bus. Sensitivity indices are evaluated for the base case and arrange in descending order. The branch which corresponds to highest sensitivity index is highest severe contingency.

The power flows of highest severe contingency are considered as base case. From these flows, the branch with least power flow can be considered as the best location for the TCSC device. Because the transmission line has inductive reactance where as the TCSC is a series controlled device which can provide a capacitive reactance so that the total reactance of the branch which leads to the increase of load ability of the line where the device was located. The objective is, to increase the power transfer capability of the transmission line. The power transfer capability of the transmission line depends on the line reactance as well as bus voltages. Hence the load ability of the line can be increased either by reducing line reactance or increasing voltage profile. In order to reduce the reactance of the transmission line TCSC can be used. The voltage profile can be improved by injecting the reactive power at a particular bus where the voltage is minimum. The optimal location of the device is that where it gives maximum benefit for optimal size of FACTS devices placed at selected location. The contingency analysis and severity index based ranking procedures are explained as follows:

a. *Contingency analysis*

Usually, outage of one of the transmission lines can be considered as the contingency condition. This happens due to many reasons; it may be because of maintenance of the transmission lines, environmental conditions, etc. Because of this situation, the transmission lines get overloaded. This contingency analysis analyzes the system security and gives future directions for the proper planning and designing. Because of this analysis, the preventive and corrective measures under contingency conditions can be predicted. Usually, the contingency condition may be due to a transmission line or a generator failure or a transformer failure. Out of which, transmission line failure plays an important role to assess the power system security.

b. *Performance Index and Ranking*

It is not required to consider each and every line outage to assess power system security. Because, for a particular line outage, there are few lines and buses do not have line flow and voltage variations beyond the limits. If there are any line overloads and bus voltage variations then the outage line is considered as critical line. The critical lines or credible contingencies are identified by contingency analysis and only these critical lines need to be taken to assess the power system security. A parameter which is known as performance index used for security analysis. It indicates how much a particular outage might affect the security of power system. In general the performance index (PI) or severity index (SI) is defined as

$$Severity\ Index = \sum_{l=1}^{N_{line}} \left( \frac{S_l}{S_l^{\max}} \right)^{2m} \qquad (9)$$

Where, $S_l$ and $S_l^{\max}$ are the MVA flow in line 'l' and MVA rating of the line 'l' respectively. 'm' is an integer exponent taken as 1.

The line flows are obtained by using power flow solution method. In Eqn. (9), the performance index is defined only based on over loaded lines.

## III. Opf Problem Formulation

A novel cost objective function is formulated by combining TCSC investment cost (ICTCSC) along with the conventional fuel cost function. Because of the combining ICTCSC with fuel cost function, the system and the FACTs controller control variables are readjusted to optimize the combined fuel cost function. This objective function is optimized while satisfying system operating, practical and the device limits. The modified fuel cost function with TCSC investment cost can be expressed as follows:

$$Minimize \quad FC = \sum_{i=1}^{NG} C_i(P_{Gi}) + IC_{TCSC} \qquad (10)$$

Where, 'FC' is the total generation cost, '$C_i(P_{Gi})$' is the fuel cost function of the i[th] unit, '$P_{Gi}$' is the power generated by the i[th] unit and '$N_G$' is the total number of generating units.

*a) Quadratic Fuel cost function*

The conventional quadratic fuel cost function can be expressed as follows:

$$C_i(P_{Gi}) = a_i P_i^2 + b_i P_i + c_i \qquad (11)$$

Where, $a_i$, $b_i$, and $c_i$ are the fuel-cost coefficients of the i[th] unit.

*b) Non-Convex Fuel cost function*

The conventional quadratic fuel cost function with valve-point effects can be considered as non-convex /non-smooth fuel cost function and this can be expressed as follows:

$$C_i(P_{Gi}) = a_i P_i^2 + b_i P_i + c_i + \left| e_i \times \sin\left(f_i \times \left(P_i^{\min} - P_i\right)\right)\right| \qquad (12)$$

Where $e_i$ and $f_i$ are the fuel cost-coefficients of the i[th] unit reflecting valve-point loading effects.

The above problem is solved while satisfying equality, in-equality constraints explained in earlier chapters and the following device limits.

*c) Constraints*

The objective functions are subjected to the following equality, inequality and practical constraints.

i. *Equality constraints*

These constraints are usually load flow equations described as

$$P_{Gk} - P_{Dm} - \sum_{m=1}^{NB} |V_k||V_m||Y_{km}| \cos(\theta_{km} - \delta_k + \delta_m) = 0$$

$$Q_{Gk} - Q_{Dm} + \sum_{m=1}^{NB} |V_k||V_m||Y_{km}| \sin(\theta_{km} - \delta_k + \delta_m) = 0$$

where, '$P_{Gk}$, $Q_{Gk}$' are the active and reactive power generations at k[th] bus, '$P_{Dm}$, $Q_{Dm}$' are the active and reactive power demands at m[th] bus, 'NB' is number of buses, $|V_k|$, $|V_m|$ are the voltage magnitudes at k[th] and m[th] buses, '$\delta_k$, $\delta_m$' are the phase angles of voltages at k[th] and m[th] buses, $|Y_{km}|$, $\theta_{km}$ are the bus admittance magnitude and its angle between k[th] and m[th] buses.

ii. *In-equality constraints*

Generator bus voltage limits

$$V_{G_i}^{\min} \le V_{G_i} \le V_{G_i}^{\max}; \qquad \forall i \in N_G$$

Active Power Generation limits

$$P_{G_i}^{\min} \le P_{G_i} \le P_{G_i}^{\max}; \qquad \forall i \in N_G$$

Transformers tap setting limits

$$T_i^{\min} \le T_i \le T_i^{\max}; \qquad i = 1,2,\ldots,n_t$$

Capacitor reactive power generation limits

$$Q_{Sh_i}^{\min} \le Q_{Sh_i} \le Q_{Sh_i}^{\max}; \qquad i = 1,2,\ldots,n_C$$

Transmission line flow limit

$$S_{l_i} \le S_{l_i}^{\max}; \qquad i = 1,2,\ldots,N_{line}$$

Reactive Power Generation limits

$$Q_{G_i}^{\min} \le Q_{G_i} \le Q_{G_i}^{\max}; \qquad \forall i \in N_G$$

Load bus voltage magnitude limits

$$V_i^{\min} \le V_i \le V_i^{\max} \qquad i = 1,2,\ldots,N_{load}$$

TCSC limits $\quad -0.8 X_{line} \le X_{TCSC} \le 0.2 X_{line}$

where '$n_t$' is the total number of taps, '$n_c$' is the total number of VAr sources, '$N_{load}$' is the total number load buses.

*d) Practical constraints*

The following practical constraints are considered to analyze the effect on the considered objectives.

i. *Ramp-rate limits*

The constraints of the ramp-rate limits, the operating limits of the generators are restricted to operate always between two adjacent periods forcibly. The ramp-rate constraints are

$$\max\left(P_{G_i}^{\min}, P_i^0 - DR_i\right) \le P_{G_i} \le \min\left(P_{G_i}^{\max}, P_i^0 + UR_i\right)$$ where, $P_i^0$ is i[th] unit power generation at previous hour. $DR_i$ and $UR_i$ are the respective down and up ramp-rate limits of i[th] unit.

ii. *Prohibited Operating Zone (POZ) limits*

To improve the efficiency of the thermal power plant generators are avoid to operate in the prohibited operating zones. This can be represented as

$$P_i = \begin{cases} P_i^{\min} \le P_i \le P_{i,1}^L \\ P_{i,k-1}^U \le P_i \le P_{i,k}^L \quad ; k = 2,3,\ldots,n_i \\ P_{i,n_i}^U \le P_i \le P_i^{\max} \end{cases}$$

where $n_i$ is the number of POZ's and k-index of POZ of unit-i. $P_{i,k}^L$ and $P_{i,k}^U$ are the respective lower and upper limit of k[th] POZ of i[th] generator.

Finally the above proposed problem is more generalized to solve in-equality constraints can be given as

$$FC_{aug} = FC + R_1\left(P_{g,slack} - P_{g,slack}^{\lim}\right)^2 + R_2 \sum_{i=1}^{N_{Load}} \left(V_i - V_i^{\lim}\right)^2 + R_3 \sum_{i=1}^{NG} \left(Q_{G_i} - Q_{G_i}^{\lim}\right)^2 + R_4 \sum_{i=1}^{N_{line}} \left(S_{l_i} - S_{l_i}^{\max}\right)^2$$

Where, R1, R2, R3 and R4 are the penalty quotients having large positive value. The limit values are defined as

$$x^{\lim} = \begin{cases} x^{\max}, & x > x^{\max} \\ x^{\min}, & x < x^{\min} \end{cases}$$

Here '$x$' is the value of $P_{g,slack}$, $V_i$, $Q_{Gi}$.

## IV. Imperialistic Competitive Algorithm

Imperialistic competitive algorithm [33] is inspired by the imperialistic competition in geo-political interactions between countries. Initially, countries for the considered control variables are generated. Out of which, some of them are best countries (lowest cost) treated as "imperialist" and the remaining are treated as "colonies". All colonies are moved towards their imperialists based on their powers. Here the power of each country is inversely proportional to its cost value. Finally, the "empires" are formulated by combining imperialists with the corresponding colonies.

After this, the assimilation policy is applied to move the empires towards their imperialist. Then power of each empire is calculated as the sum of the power of the imperialist and percentage of mean of power of its colonies. Then, all these empires participate in imperialistic competition and finally, the empire which has least power is eliminated from the system. The colonies will move towards their relevant imperialist and cause all the countries to converge to a state with single empire in the process.

The important steps in this algorithm are briefly discussed below:

### a) *Generating initial empires*

Initially population is generated for all control variables as countries (Ncountry). For N-dimensional problem, the position of ith country is defined as follows:

$$Country_i = \left[P_{G_1},...P_{G_{NG}}, V_{G_1},...V_{G_{NG}}, T_1,...T_{nt}, Q_{sh_1},.....Q_{sh_{nc}}\right]$$

The control variables corresponds to each population are updated in bus and line data then perform load flow and finally calculate the cost $(C_i)$ of each country. Initialize the total number of imperialists $(N_{imp})$ and there by calculate the number of colonies ($N_{Col}=N_{Country}-N_{imp}$). To divide the colonies among imperialists proportionally, the normalized cost of all imperialists is calculated and based on this normalized powers are calculated. From this the number of colonies for nth empire is evaluated. As the imperialists force to move the colonies towards them by applying attraction policy.

### b) *Moving colonies towards their imperialists*

If a colony has best cost value than that of the imperialist, then exchange these colony and imperialist to continue this process in new location.

### c) *Calculation total power of an empire*

The total power of an empire is the sum of the power of the imperialist and powers of the colonies.

### d) *Imperialistic competition*

All these empires try to take the possession of colonies of other empires and try to control them. In this process, the power of the powerful empire increases where as the weak empire decreases. This competition is modeled by choosing some of the weakest colonies of the weakest empires and competition among all empires to possess these colonies. Then, total power of each empire is calculated.

### e) *Eliminating powerless empires*

The powerless empires will collapse in the imperialistic competition. Different criteria can be defined for collapse mechanism. In this paper, an empire is assumed collapsed when it loses all of its colonies. Weak empires gradually decline in imperialistic competition and strong empires take the possession of their colonies. There are different conditions for declining an empire.

### f) *Stopping criteria*

After some imperialistic competitions, all the empires except the most powerful one will collapse all of the countries under their possession become colonies of this empire. All the colonies have the same positions and the same costs and there is no difference between the colonies and their imperialist. In such a case, the algorithm stops.

## V. Results and Analysis

An IEEE 14 bus system has been considered as first example to find the efficacy of the proposed method without and with TCSC. In 14 bus test system, bus 1 is slack bus, while buses 2, 3, 6 and 8 are generator buses and other buses are load buses. The input parameters of the proposed ICA method are given in Table.1.

As a preliminary computation the contingency analysis and ranking is performed on the test system for one branch outage at a time. The over loaded line flows and ranking during contingency analysis are tabulated in Tables 2 and 3 respectively. In this paper, Rank 1 contingency is considered to investigate the effectiveness of the proposed method without and with TCSC device to eliminate the over loaded lines.

As the TCSC is a series controlled FACTS device a line in which least power will flow is required for the best location of TCSC. The required best location for the TCSC is determined from the rank 1 contingency by using severity index. The SI values for the test system are given in Table3. From this table it can be seen that the line outage 4-5 is the most severe which is represented as rank 1 contingency. From rank 1 contingency result in order of priority of the line for the location of TCSC is 3-4 based on the power flows intransmission lines under rank 1 contingency.

*Table 1 :* Input parameters for test example

| Parameters | Quantity |
|---|---|
| Number of initial countries | 1000 |
| Number of initial imperialists | 8 |
| Number of decades | 200 |
| Revolution rate | 0.05 |
| Assimilation coefficient | 0.2 |
| Zeta (ζ) | 0.02 |
| Damp ratio | 0.99 |
| Uniting threshold limit | 0.02 |

*Table 2 :* Overloaded lines of IEEE-14 bus system during contingency analysis

| S. No | Outage line | Over loaded lines | Line Flow (MVA) | Line limit (MVA) | PI |
|---|---|---|---|---|---|
| 1 | 4-5 | 1-2 | 179.4369 | 150 | 1.1962 |
| | | 2-3 | 89.1447 | 85 | 1.0488 |
| | | 2-4 | 89.2352 | 85 | 1.0498 |
| | | 5-6 | 62.1180 | 45 | 1.3804 |
| | | 6-11 | 17.4159 | 14 | 1.244 |
| | | 6-13 | 23.7676 | 22 | 1.0803 |
| | | 10-11 | 13.4437 | 12 | 1.1203 |
| 2 | 7-9 | 1-2 | 157.5373 | 150 | 1.0502 |
| | | 5-6 | 60.7119 | 45 | 1.3492 |
| | | 6-11 | 17.6322 | 14 | 1.2594 |
| | | 6-13 | 24.1568 | 22 | 1.098 |
| | | 10-11 | 13.0879 | 12 | 1.0907 |

*Table 3 :* Contingency ranking of IEEE-14 bus system

| S. No | Outage line | Severity Index | Rank |
|---|---|---|---|
| 1 | 4-5 | 8.1198 | 1 |
| 2 | 7-9 | 5.8475 | 2 |

The results of optimized values for all control variables for minimization of quadratic and nonconvex fuel cost objective using proposed ICA method with considering effect of practical constraints for without and with TCSC are tabulated in Table.4. The convergence characteristics of the proposed algorithm for all the cases are shown in Figs 3 and 4.

From Table.4, it is observed that, with TCSC, the quadratic fuel cost is decreased by 0.6855 $/h and the non-convex cost is decreased by 0.3291 $/h when compared to without device. It is also observed that, the total real power generation is increased with TCSC and consequently the system power losses also increased.

The ramp-rate and POZ limits followed by the generators are tabulated in Table.5. From this table, it is observed that, while minimizing quadratic fuel cost objective the 2$^{nd}$ generator is following up ramprate and operative above the POZ upper limit whereas while minimizing non-convex fuel cist objective 2$^{nd}$ generator is following down ramp-rate and operating below the POZ lower limit.

From figures 3 and 4, it is observed that proposed method with TCSC starts the iterative process with good initial value and reaches final best value in less number of iterations when compared to without device.

*Table 4 :* OPF results of IEEE-14 bus system for convex and non-convex costs

| S.No | Parameter | | Quadratic cost ($/h) | | Non-convex cost ($/h) | |
|---|---|---|---|---|---|---|
| | | | Without | With TCSC | Without | With TCSC |
| 1 | Real power generation (MW) | PG1 | 168.7799 | 173.1421 | 213.2493 | 213.563 |
| | | PG2 | 50.3254 | 47.0367 | 23.2421 | 25.5652 |
| | | PG3 | 21.1789 | 20 | 20 | 20 |
| | | PG6 | 18.1432 | 16.3694 | 7.7983 | 5.3562 |
| | | PG8 | 8.6787 | 10.6415 | 5 | 5 |
| 2 | Generator voltages (p.u.) | VG1 | 1.0886 | 1.1 | 1.0883 | 1.1 |
| | | VG2 | 1.0565 | 0.9164 | 1.0599 | 0.9 |
| | | VG3 | 0.9419 | 1.0264 | 1.007 | 0.9912 |
| | | VG6 | 1.0505 | 0.9628 | 0.9836 | 0.9739 |
| | | VG8 | 1.015 | 1.0307 | 1.0507 | 0.9224 |
| 3 | Transformer tap setting (p.u.) | TAP4-7 | 1.0508 | 1.0321 | 1.1 | 0.9631 |
| | | TAP4-9 | 0.9362 | 0.9962 | 0.9579 | 0.9692 |
| | | TAP5-6 | 1.0188 | 0.9226 | 1.0773 | 0.9598 |
| 4 | Shunt compensator (MVAr) | QC9 | 19.4419 | 25.5866 | 9.3157 | 17.9661 |

| | | | | | |
|---|---|---|---|---|---|
| 5 | $X_{TCSC}$, p.u. | - | -0.0227 | - | 0.0201 |
| 6 | Total generation (MW) | 267.1061 | 267.1897 | 269.2897 | 269.4844 |
| 7 | Total power loss (MW) | 8.1061 | 8.1897 | 10.2897 | 10.4844 |
| 8 | Total generation cost ($/h) | 715.6184 | 714.9329 | 824.7462 | 824.4171 |

*Table 5 :* Ramp rates and POZ limits followed by the generators of quadratic cost with TCSC for IEEE-14 bus system

| Gen. No | Quadratic cost ($/h) | | Non-convex cost ($/h) | |
|---|---|---|---|---|
| | Without | With TCSC | Without | With TCSC |
| 1 | Up, 2 | Up, 2 | Up, 2 | Up, 2 |
| 2 | Up, 2 | Up, 2 | Down, 1 | Down, 1 |
| 3 | Down, 1 | Down, 1 | Down, 1 | Down, 1 |
| 6 | - | - | - | - |
| 8 | - | - | - | - |

1-Below POZ lower limit 2-Above POZ upper limit
3-Equal to POZ lower limit 4-Equal to POZ upper limit
UP-following up-ramp rate Down-following down-ramp rate

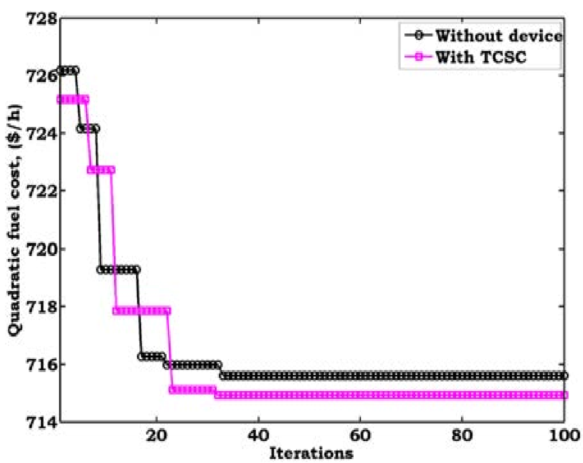



*Fig 3 :* Convergence characteristics of quadratic cost with TCSC for IEEE-14 bus system

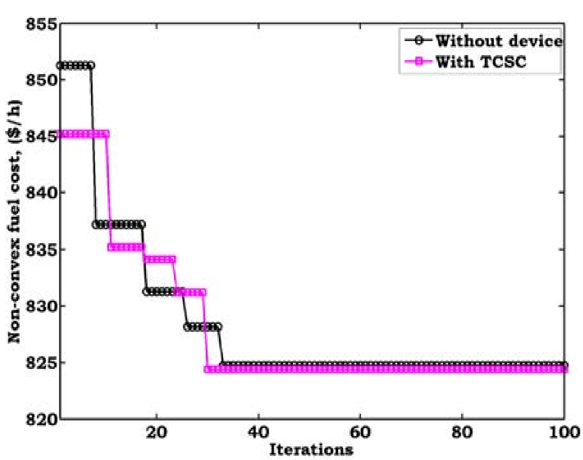



*Fig 4 :* Convergence characteristics of non convex cost with TCSC for IEEE-14 bus system

## VI. Conclusion

The ICA method has been successfully employed to solve the optimal power problem with generator constraints and valve point loading effect. Using this proposed method, the power system objectives such as quadratic and non-convex fuel cost objectives are optimized while satisfying system operating and practical constraints. The power injection modeling of TCSC has been presented with its incorporation procedure in conventional NR load flow. An optimal location identification methodology of TCSC has been identified to enhance the system security in terms of transmission line loadings. Obtained numerical results for IEEE-14 bus test system confirms that, the proposed methodology can handle any type of the objectives and can be applied to solve any size of the system.

## References Références Referencias


1. Ahrari A, Atai A, "Grenade Explosion Method-A novel tool for optimization of multimodal functions", Appl Soft Comput, 2010, Vol.10, No.4, pp: 1132–1140.
2. Dorigo M "Optimization, learning and natural algorithms", PhD Dissertation, 1992, Politecnico di Milano, Italy.
3. Eusuff M, Lansey E "Optimization of water distribution network design using the shuffled frog leaping algorithm", J Water Resour Plan Manag, ASCE 129, 2003, pp: 210–225.
4. Farmer JD, Packard N, Perelson A, "The immune system, adaptation and machine learning", Physica 22, 1986, pp: 187–204.
5. Geem ZW, Kim JH, Loganathan GV, "A new heuristic optimization algorithm: Harmony Search",

Simul, the Soc for Model and Simul Int, Vol.76, No. 2, 2001, pp: 60–68.
6. Holland J, "Adaptation in natural and artificial systems", University of Michigan Press, Ann Arbor, 1975.
7. Karaboga D, "An idea based on honey bee swarm for numerical optimization", Technical Report- TR06, Erciyes University, Engineering Faculty, Computer Engineering Department, Turkey, 2005.
8. Kennedy J, Eberhart RC, "Particle swarm optimization", Proceedings IEEE International Conference on Neural Networks, Piscataway, 1995, pp: 1942–1948.
9. Passino KM, "Biomimicry of bacterial foraging for distributed optimization and control", IEEE Control Syst Mag 22, 2002, pp: 52–67.
10. Rashedi E, Nezamabadi-pour H, Saryazdi S, "GSA: a gravitational search algorithm", Inf Sci 179, 2009, pp: 2232–2248.
11. Simon D, "Biogeography-based optimization", IEEE Trans Evol Comput 12, 2008, pp: 702–713.
12. Storn R, Price K, "Differential evolution–a simple and efficient heuristic for global optimization over continuous spaces", J Glob Optim 11, 1997, pp:341–359.
13. Preechakul C, Kheawhom S, "Modified genetic algorithm with sampling techniques for chemicalengineering optimization", J Ind and Eng Chem 2009, pp: 101–107.
14. Cui H, Turan O, "Application of a new multiagent hybrid co-evolution based particle swarm optimisation methodology in ship design", Comput-Aided Des 2, 2010, pp: 1013–1027.
15. Montalvo I, Izquierdo J, Perez-Garcia R, Herrera M, "Improved performance of PSO with selfadaptive parameters for computing the optimal design of water supply systems", Eng Appl Artif Intell 23, 2010, pp: 727–735.
16. Ying PC, "An ant direction hybrid differential evolution algorithm in determining the tilt angle for photovoltaic modules", Expert Sys Appl 37, 2010, pp: 5415–5422.
17. Yue H, Gu G, Liu H, Shen J, Zhao J, "A modified ant colony optimization algorithm for tumor marker gene selection", Genomics Proteomics Bioinforma 7, 2009, pp:200–208.
18. Karaboga D, Akay B, "A modified artificial bee colony (ABC) algorithm for constrained optimization problems", Appl Soft Comput, 2010.
19. Mouti FSA, Hawary MEE, "Modified artificial bee colony algorithm for optimal distributed generation sizing and allocation in distribution systems", IEEE Electr Power and Energy Conf (EPEC), Montreal, 2009, pp:1–9.
20. Hui L, Zixing C, Yong W, "Hybridizing particle swarm optimization with differential evolution for constrained numerical and engineering optimization", ApplSoftComput10, 2010, pp:629– 640.
21. Wen YL, "A GA–DE hybrid evolutionary algorithm for path synbook of four-bar linkage", Mech Mach Theory 45, 2010, pp: 1096–1107.
22. K. Chandrasekar, N. V. Ramana, "Performance comparison of DE, PSO and GA approaches in Transmission Power Loss minimization using FACTS Devices", International Journal of Computer Applications, Volume 33– No.5, 2011.
23. Abouzar Samimi, Peyman Naderi, "A New Method for Optimal Placement of TCSC based on Sensitivity Analysis for Congestion Management", Smart Grid and Renewable Energy, vol. 3, 2012, pp.10-16.
24. G.I. Rashed, H.I. Shaheen, X.Z. Duan, S.J. Cheng, "Evolutionary optimization techniques for optimal location and parameter setting of TCSC under single line contingency", Applied Mathematics and Computation, 205, 2008, pp:133–147.
25. Tjing T Lie and Wanhong Deng, "Optimal Flexible AC Transmission Systems (FACTS)devices allocation", Electrical Power & Energy Systems, Vol. 19, No. 2, 1997, pp: 125-134.
26. G Shaoyun and T S Chung, "Optimal active power flow incorporating FACTS devices with power flow control constraints", Electrical Power & Energy Systems, Vol. 20, No. 5, 1998, pp: 321-326.
27. Sidhartha Panda, Narayana Prasad Padhy, "Comparison of particle swarm optimization and genetic algorithm for FACTS-based controller design", Applied Soft Computing, Vol.8, Issue.4, 2008, pp: 1418–1427.
28. B. Bhattacharyya, Vikash Kumar Gupta, "Application of DE & PSO Algorithm for the Placement of FACTS Devices for Economic Operation of a Power System", wseas transactions on power systems, Issue 4, Volume 7, 2012, pp. 209-216.
29. T.S. Chung, Y.Z. Li, "A Hybrid GA Approach for OPF with Consideration of FACTS Devices", IEEE Power Engineering Review, February 2001.
30. S. Y. Ge, T S Chung, "Optimal active power flow incorporating power flow control needs in flexible ac transmission systems", IEEE Transactions on Power Systems, Vol. 14, No. 2, 1999, pp:738-744.
31. G. Venkata Lakshmi, K. Amaresh, "Optimal Power Flow with TCSC using Genetic Algorithm", 2012 IEEE International Conference on Power Electronics, Drives and Energy Systems, December16-19, 2012, Bangalore, India.
32. AA Alabduljabbar, J V Milanovic, "Assessment of techno-economic contribution of FACTS devices to power system operation", EPSR, 2010, Vol.80, pp: 1247-1255.
33. Atashpaz-Gargari E, Lucas C. Imperialist competitive algorithm: an algorithm for optimization inspired by imperialistic competition. IEEE congress on evolutionary computation; 2007. p. 4661-7.

Global Journal of Researches in Engineering: F
Electrical and Electronics Engineering
Volume 14 Issue 8 Version 1.0 Year 2014
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)
Online ISSN: 2249-4596 & Print ISSN: 0975-5861

# An Improvement Strategy on Direction Cosine Matrix based Attitude Estimation for Multi-Rotor Autopilot

By Nazia Ahsan Dilshad & Mohammed Kawser Jahan
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*Index Terms: attitude estimation, unmanned aerial vehicle, VTOL, RC aircraft, multi rotor copter, hover, MEMS, IMU, DCM, roll, pitch, yaw, euler angles, autopilot, gyro bias, gyro drift, accelerometer, magnetometer, calibration iron distortion, tilt compensation, normalization.*

*GJRE-F Classification : FOR Code: 090699*

ANIMPROVEMENTSTRATEGYONDIRECTIONCOSINEMATRIXBASEDATTITUDEESTIMATIONFORMULTIROTORAUTOPILOT

*Strictly as per the compliance and regulations of :*

# An Improvement Strategy on Direction Cosine Matrix based Attitude Estimation for Multi-Rotor Autopilot

Nazia Ahsan Dilshad [α] & Mohammed Kawser Jahan [σ]

*Abstract-* In present days, autonomous multi-rotor copters are increasingly becoming popular due to its advantages in terms of multi-purpose functionalities, robustness, high dynamic response and more significantly inexpensive costs of development and usage. However, real-time attitude estimation is a key component which needs to have further development for better control and precise navigation to drive these unmanned aerial vehicles reliably. This paper presented an approach to improve the method of attitude estimation by Direction Cosine Matrix for multi-rotor copters that is based on low cost MEMS inertial sensors, a magnetometer and a commercial GPS receiver. In connection with the Direction Cosine Matrix attitude estimation scheme, a novel algorithm design for dealing with limitations on attitude sensing accuracy and reducing latency in real-time is proposed. The design is insensitive to noise or loss of GPS signals. The viability of the proposed design is demonstrated by an experimental scenario with real-time attitude information under different observations. From the experiment, some issues have been noticed and their reasons have been discussed.

*Index Terms: attitude estimation, unmanned aerial vehicle, VTOL, RC aircraft, multi rotor copter, hover, MEMS, IMU, DCM, roll, pitch, yaw, euler angles, autopilot, gyro bias, gyro drift, accelerometer, magnetometer, calibration iron distortion, tilt compensation, normalization.*

## I. Introduction

These days unmanned flying robots or unmanned aerial vehicles (UAVs) are gaining popularity because of their wide range of applications. One type of UAV with a strong potential for both indoor and outdoor applications, is the multi-rotor copter. This special type of rotorcraft has the capability of vertical takeoff and landing (VTOL), as well as the ability to achieve rapid and stable motion in every direction. For these characteristics, multi-rotorcraft is suitable for hands-off autonomous operation within cluttered environments such as small buildings or caves and has many applications including surveillance, search and rescue, exploration in hazardous by human command, and therefore autopilot system with suitable control algorithm is required to make them stable. However, building a real-time attitude estimator in autopilot module for controlling multi-rotorcraft is the most critical challenge that engineers face while developing such aircraft. The attitude estimator is widely known as inertial measurement unit (IMU). Low-cost IMU systems are mainly based on micro-electro-mechanical systems (MEMS) technology. A typical IMU is equipped with 3-axis accelerometers, 3-axis rate gyroscopes and 3-axis magnetometers. Due to the limitations in sensing technologies and embedded processing, an IMU system cannot perform with zero error. Developing the control law with a better attitude estimating method can effectively improve the system performance and flight stability. Several attitude estimation methods have been developed in this research field, and direction cosine matrix (DCM) based attitude estimation is one of them. An improvement strategy on this estimation method is depicted in this paper.

The DCM is the matrix of rotation between a Cartesian coordinate frame, which is rigidly fixed in the aircraft body, and a reference Cartesian coordinate frame. This matrix is also known as rotation matrix (denoted by R) [1]. The DCM is a 3×3 matrix, whose nine elements are not independent. Like any rotation matrix, DCM is a proper orthogonal matrix, which implies six constraints connecting the nine elements. In spite of the redundancy created by the constraints, the DCM is a convenient rotation representation because the equations that describe the vector measurement model and the aircraft kinematical model are linear in DCM [1]. The DCM IMU estimation is a popular attitude estimation method that has been developed for model airplanes by William Premerlani and Paul Bizard [2]. According to this method a rate gyro is required to derive attitudes by integrating the rigid body kinematic equations, accelerometer is required to provide gravity direction and GPS is essential to get the YAW reference.

This paper is organized as follows. Section III addresses the problem definition. Section IV describes the improvement strategy on DCM based attitude estimation for multi-rotor autopilot which includes coordinate system modification, step by step formation of rotation matrix for the modified coordinate systems, experimental analysis on using magnetometer-heading instead of GPS-heading, discussion on magnetometer error compensation and fusing reference vectors from

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Global Journal of Researches in Engineering ( F ) Volume XIV Issue VIII Version I Year 2014

GPS, and development of a new attitude estimation algorithm. The experimental results and analysis on the developed system are presented and discussed in Section V to validate and evaluate the system's usability.

## II. Nomenclature

Some of the notations which have been used in this paper to understand the mechanical and mathematical relationships are presented in this section:

DCM: Direction Cosine Matrix

KF: Kalman Filter

EKF: Extended Kalman Filter

QUEST: Quaternion Estimator

GPS: Global Positioning System

CG: Center of gravity

FPU: Flight Processing Unit

IMU: Inertial Measurement Unit

PID: Proportional Integral Derivative

YAW: Twist or oscillation about a vertical axis

VTOL: Vertical takeoff and landing

Attitude: Roll, pitch and yaw

Heading: Aircraft's nose direction

R: Rotation Matrix

$\varphi$: Roll angle

$\theta$: Pitch angle

$\psi$: Yaw angle

$\omega$: Angular Rate Vector

W: Gyro sensor readings

$R_e$: Earth frame, which is attached to the ground

$x_e, y_e, z_e$: Axes of earth frame

$R_b$: Body fixed frame, which is attached to the aircraft

$x_b, y_b, z_b$: Axes of body fixed frame

$(X, Y, Z)_{MAG}$: Measured values of X, Y, Z axes

$(X, Y, Z)_{COMP}$: Compensated values of X, Y, Z axes

$\omega_x$: Angular rate on x-axis in $R_b$-frame

$a_x$: Acceleration on x-axis in $R_b$-frame

$I_3$: $3 \times 3$ Identity matrix

## III. Problem Definition

In real world, the original technique of DCM based attitude estimation suffers some unavoidable problems. As any of these problems can cause occasional malfunctions, it cannot be used as a standalone process without support from a strong reference. The initial task of this process is to gather raw attitude data from gyroscope which includes angles of roll, pitch and yaw. As gyroscope drifts over long time periods, it is necessary to take reference attitude data repeatedly to minimize its errors before calculating the final flight angles. So the accelerometer is used to get the reference vector of roll and pitch and the GPS is used to get the reference vector of yaw. GPS signal availability is essential for running the whole process because the IMU will lose its track over time without GPS. Since the transient response of GPS is not fast enough, the original technique of DCM based attitude estimation is not suitable for VTOL aircrafts. VTOL aircrafts are dynamically very sensitive along their yaw axis and this makes controlling the movement along yaw axis very hard. It is not possible to overcome this issue with any slow process like GPS. Magnetometer is a device for locating the direction of earth's magnetic poles with faster transient response than GPS system. So it can be used as the reference sensing element for yaw movement in VTOL aircraft. But in most cases, output data from magnetometer has offset values so using this device cannot help the estimation process with accurate data like GPS. Magnetometer outputs true values of earth's magnetic field only when it stays parallel to the ground and that means magnetometer will give wrong orientation data when the aircraft stays tilted to the ground. Also, magnetometer data gets distorted because of the nearby power lines as erroneous data will be produced if magnetometer cannot distinguish earth's true magnetic field due to interference of external magnetic and electric fields.

In today's market, the coordinate system followed by the orientation sensing devices does not match with the conventional coordinate system used in the original DCM IMU estimation method and this will cause inconvenience for any autopilot system developer. Another drawback of this method is that it takes a lot of time to process the output.

DCM based attitude estimation method is more stable and provides accurate result than any other method. But still it is not suitable for multi-rotor crafts due to the issues mentioned above. So improving its methodology is necessary to use it for multi-rotor crafts.

## IV. Improvement Strategy

The objective of improving the DCM based attitude estimation process by developing its algorithm to the next level of advancement is to make it suitable to use in real-time control processor of any autopilot module of multi-rotorcraft. The step-by-step development approaches are described below.

### *a) Coordinate System Modification*

The conventional coordinate system that was used to develop the rotation matrix of DCM IMU algorithm consists of two Cartesian coordinate frames, as shown in figure 1, one frame $(x_b, y_b, z_b)$ is rigidly fixed to the aircraft body, and the other one $(x_e, y_e, z_e)$ is the earth's frame of reference.

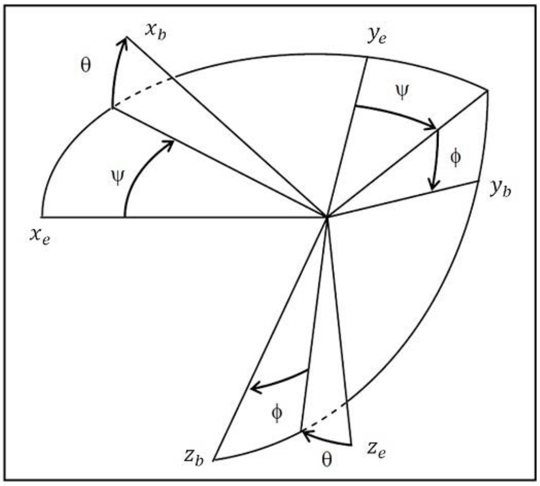


*Fig.1 :* The conventional coordinate system [2]

In conventional coordinate system the $x_b$ and $x_e$ axes, $y_b$ and $y_e$ axes, and $z_b$ and $z_e$ axes are directed towards forward, right, and downward direction respectively. If both the frames are rotated 180 degree along forward axis then the coordinate system will match with the coordinate system followed by the commercially available IMU hardware. So the inertial axes about the centre of gravity (CG) of aircraft body are:

- $x_b$ axis - positive forward
- $y_b$ axis - positive to left, perpendicular to $x_b$ axis
- $z_b$ axis - positive upwards, perpendicular to $x_b$-$y_b$ plane

According to the Euler theorem, the orientation of the aircraft body fixed frame $(R_b)$ with respect to the earth fixed frame $(R_e)$ can be described by three consecutive rotations of $R_b$ along each of its axis, whose order is arbitrary, but the same axis may not be used twice in succession. The rotation sequences are usually denoted by three numbers, 1 for x-axis of $R_b$, 2 for y-axis of $R_b$, and 3 for z-axis of $R_b$. Among the twelve valid rotation sequences, we have proposed to choose the rotation sequence 132 or x−z−y for obtaining the attitude of aircraft in modified coordinate system. So the three consecutive rotations have been accomplished in the following order, assuming that the aircraft is initially positioned in such a way that the body frame is parallel to the earth frame:

- Rotating the body about $x_b$ axis through roll angle (φ)
- Rotating the body about $z_b$ axis through yaw angle (-ψ)
- Rotating the body about $y_b$ axis through pitch angle (-θ)

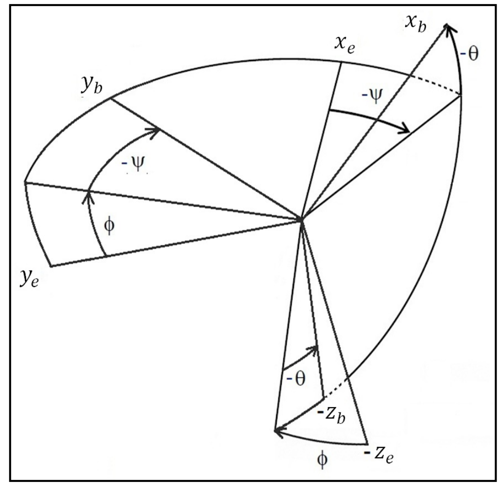


*Fig. 2 :* The modified coordinate system

*b) Rotation Matrix Formation*

In the previous section, the rotation sequence that has been proposed is the 132 or x−z−y. So considering a rotation from F reference frame to F''' reference frame, the first rotation that is illustrated in Fig. 3, is about x-axis through an angle $\theta_x$ which is positive according to the right hand rule about the x-axis. With two rotations to go, the resulting alignment in general is oriented with neither of F or F''', but some intermediate reference frame (the first of two) denoted F'. Since the rotation was about x, x' is parallel to it but neither of the other two primed axes are.

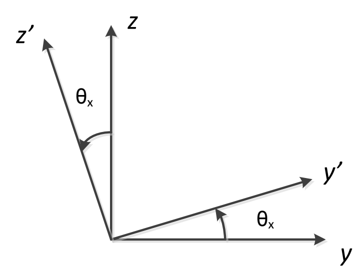


*Fig 3 :* Anti-clockwise rotation from the reference frame F to F'

Now to describe this rotation, we can write:

$$\begin{bmatrix} F_{x'} \\ F_{y'} \\ F_{z'} \end{bmatrix} = \begin{bmatrix} \cos_{xx'} & \cos_{xy'} & \cos_{xz'} \\ \cos_{yx'} & \cos_{yy'} & \cos_{yz'} \\ \cos_{zx'} & \cos_{zy'} & \cos_{zz'} \end{bmatrix} \begin{bmatrix} F_x \\ F_y \\ F_z \end{bmatrix}$$

$$= \begin{bmatrix} \cos 0^o & \cos 90^o & \cos 90^o \\ \cos 90^o & \cos \theta_x & \cos(90^o + \theta_x) \\ \cos 90^o & \cos(90^o - \theta_x) & \cos \theta_x \end{bmatrix} \begin{bmatrix} F_x \\ F_y \\ F_z \end{bmatrix}$$

$$\therefore \begin{bmatrix} F_{x'} \\ F_{y'} \\ F_{z'} \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos \theta_x & -\sin \theta_x \\ 0 & \sin \theta_x & \cos \theta_x \end{bmatrix} \begin{bmatrix} F_x \\ F_y \\ F_z \end{bmatrix} = R_x(\theta_x) \quad (1)$$

The next rotation that is shown in Fig. 4, is through an angle $-\theta_z$ about the z'-axis of the first intermediate reference frame to the second intermediate reference frame, F". Angle $\theta_z$ is negative according to the right hand rule about the z-axis. Note that z" = z', and neither x" or z" are necessarily axes of either F or F'".

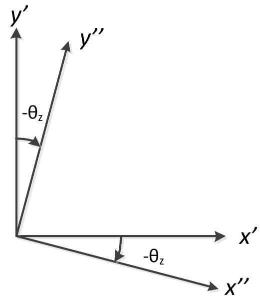


*Fig. 4 :* Clockwise rotation from the reference frame F' to F"

For this rotation, we can write:

$$\begin{bmatrix} F_{x''} \\ F_{y''} \\ F_{z''} \end{bmatrix} = \begin{bmatrix} \cos_{x'x''} & \cos_{x'y''} & \cos_{x'z''} \\ \cos_{y'x''} & \cos_{y'y''} & \cos_{y'z''} \\ \cos_{z'x''} & \cos_{z'y''} & \cos_{z'z''} \end{bmatrix} \begin{bmatrix} F_{x'} \\ F_{y'} \\ F_{z'} \end{bmatrix}$$

$$= \begin{bmatrix} \cos(-\theta_z) & \cos(90^o - \theta_z) & \cos 90^o \\ \cos(90^o + \theta_z) & \cos(-\theta_z) & \cos 90^o \\ \cos 90^o & \cos 90^o & \cos 0^o \end{bmatrix} \begin{bmatrix} F_{x'} \\ F_{y'} \\ F_{z'} \end{bmatrix}$$

$$\therefore \begin{bmatrix} F_{x''} \\ F_{y''} \\ F_{z''} \end{bmatrix} = \begin{bmatrix} \cos\theta_z & \sin\theta_z & 0 \\ -\sin\theta_z & \cos\theta_z & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} F_{x'} \\ F_{y'} \\ F_{z'} \end{bmatrix} = R_y(\theta_y) \quad (2)$$

The final rotation that is illustrated in Fig. 5 is about y" through angle -$\theta_y$ and the final alignment is parallel to the axes of F'". Angle $\theta_y$ is negative according to the right hand rule about the y-axis.

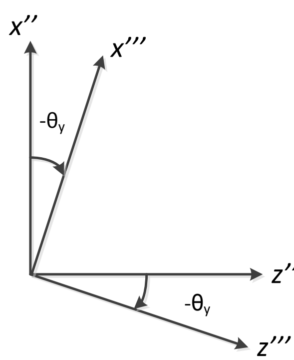


*Fig 5 :* Clockwise rotation from the reference frame F" to F'"

For describing the final rotation, we can write:

$$\begin{bmatrix} F_{x'''} \\ F_{y'''} \\ F_{z'''} \end{bmatrix} = \begin{bmatrix} \cos_{x''x'''} & \cos_{x''y'''} & \cos_{x''z'''} \\ \cos_{y''x'''} & \cos_{y''y'''} & \cos_{y''z'''} \\ \cos_{z''x'''} & \cos_{z''y'''} & \cos_{z''z'''} \end{bmatrix} \begin{bmatrix} F_{x''} \\ F_{y''} \\ F_{z''} \end{bmatrix}$$

$$\begin{bmatrix} \cos(-\theta_y) & \cos 90^o & \cos\{-(90^o - \theta_y)\} \\ \cos 90^o & \cos 0^o & \cos 90^o \\ \cos(90^o - \theta_y) & \cos 90^o & \cos(-\theta_y) \end{bmatrix} \begin{bmatrix} F_{x''} \\ F_{y''} \\ F_{z''} \end{bmatrix}$$

$$\therefore \begin{bmatrix} F_{x'''} \\ F_{y'''} \\ F_{z'''} \end{bmatrix} = \begin{bmatrix} \cos\theta_y & 0 & -\sin\theta_y \\ 0 & 1 & 0 \\ \sin\theta_y & 0 & \cos\theta_y \end{bmatrix} \begin{bmatrix} F_{x''} \\ F_{y''} \\ F_{z''} \end{bmatrix} = R_z(\theta_z) \quad (3)$$

It is known that the DCM is the product of three sequential rotations, so we can derive our desired DCM using the above results of all three sequential rotations. Later, the relation between the direction cosine matrix and rotation angles was found by replacing angle $\theta_x$, $\theta_y$, and $\theta_z$ by φ (roll angle), θ (pitch angle) and ψ (yaw angle) respectively. Finally the resultant matrix of direction cosines was used to rotate vectors, such as directions, velocities, accelerations, and translations by multiplying with each other. However, the R matrix is also called the DCM, because each entry is the cosine of the angle between an axis of the plane and an axis on the ground:

*c) Magnetometer-Heading Experiment*

A three-axis magnetometer has been used instead of using the GPS as the primary source to get the reference vector of yaw. In the process, the gyro sensor has been used to get the total orientation change along all three axes which include change in the yaw axis and the magnetometer checks the course over ground in every 125ms and detects the drifts of yaw information of gyro sensor for canceling out the drift to achieve a yaw-lock performance. After analyzing the timing for measuring input, we have found that magnetometer took 1.289ms for each measurement [3].

$$R = R_X(\theta_X) \times R_Y(\theta_Y) \times R_Z(\theta_Z)$$

$$= \begin{bmatrix} \cos\theta_y \cos\theta_z & \sin\theta_z & -\sin\theta_y \cos\theta_z \\ -\cos\theta_y \cos\theta_x \sin\theta_z + \sin\theta_y \sin\theta_x & \cos\theta_x \cos\theta_z & \sin\theta_y \cos\theta_x \sin\theta_z - \cos\theta_y \sin\theta_x \\ \cos\theta_y \sin\theta_x \sin\theta_z + \sin\theta_y \cos\theta_x & \cos\theta_z \sin\theta_x & \sin\theta_y \sin\theta_x \sin\theta_z - \sin\theta_y \cos\theta_z \end{bmatrix}$$

$$= \begin{bmatrix} \cos\theta \cos\psi & \sin\psi & -\sin\theta \cos\psi \\ -\cos\theta \cos\varphi \sin\psi + \sin\theta \sin\varphi & \cos\varphi \cos\psi & \sin\theta \cos\varphi \sin\psi - \cos\theta \sin\varphi \\ \cos\theta \sin\varphi \sin\psi + \sin\theta \cos\varphi & \cos\psi \sin\varphi & \sin\theta \sin\varphi \sin\psi - \sin\theta \cos\psi \end{bmatrix} = \begin{bmatrix} R_{xx} & R_{xy} & R_{xz} \\ R_{yx} & R_{yy} & R_{yz} \\ R_{zx} & R_{zy} & R_{zz} \end{bmatrix} \quad (4)$$

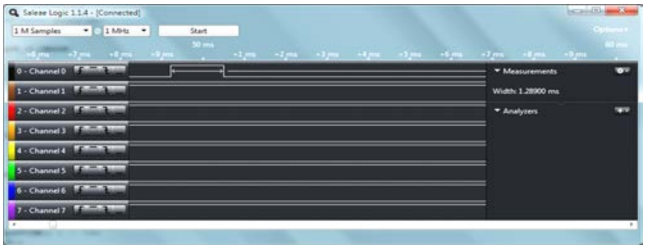

*Fig. 6 :* Timing Analysis of HMC5843 Magnetometer [3]

To analyze the magnetometer data, we have collected real time sensor readings for each of the three axes over time under specific orientations such as positive x-axis, positive y-axis, and positive z-axis, all of them were separately towards North direction. Figure 7 shows the superimposition of measured magnetic fields for all three of the above mentioned arrangements:

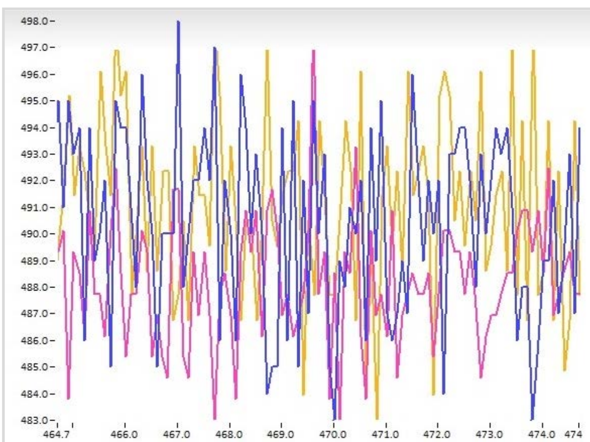


*Fig. 7 :* Magnetometer outputs (raw magnetic field vs. time).

*b) Magnetometer Error Compensation*

A low cost magnetometer works very well in clean magnetic environments, but this device is strongly influenced by its orientation or any magnetic perturbations produced by nearly available ferrous material or radio waves from mobile phone, loud speakers.

In the magnetometer-heading experiment it has been observed that the magnetometer needs to be held flat to function properly. Tilting would result in less accurate readings because magnetometer only uses two of the axes of earth's magnetic field. When this device is not parallel to these axes, the amount of magnetism felt by it will change based on the misalignment of the magnetometer to these axes. Magnetic disturbances were also observed during the experiment which developed a constant magnetic field component along each axis of the sensor outputs. To compensate these errors, the following processes were executed:

i. *Tilt compensation*

It is necessary to include the third axis, z, in magnetometer-heading calculation which can provide the magnetic field lost by the other two axes when they are out of alignment. So at first, a triple axis accelerometer has been used in parallel with the magnetometer to know how much the magnetometer is tilted. This was done for integrating the z-axis measurement properly to correct the tilt. The roll and pitch angles which can be calculated from accelerometer data, are never $0^o$ when the device is tilted. If $X_{MAG}$, $Y_{MAG}$ and $Z_{MAG}$ are the measurement values for their respective axes (x, y, z) of the magnetometer and $X_{COMP}$ and $Y_{COMP}$ are the compensated values, then:

$$X_{COMP} = X_{MAG} . \cos(pitch) + Z_{MAG} . \sin(pitch) \quad (5)$$

$$Y_{COMP} = X_{MAG} . \sin(roll) . \sin(pitch) + Y_{MAG} . \cos(roll) - Z_{MAG} . \sin(roll) . \cos(pitch) \quad (6)$$

$$\text{So, Heading} = \arctan\,(Y_{COMP} \,/\, X_{COMP}) \quad (7)$$

i. *Iron distortion compensation*

Iron distortions can be categorized as two types: hard iron and soft iron effects. Hard iron distortions arise from permanent magnets, magnetized iron or steel nearby the magnetometer and remain constant and in a fixed location relative to the magnetometer for all heading orientations. To compensate for hard iron distortion, the offset in the origin of each of the reading scale is necessary to be determined. So for all three axes, these offsets were calculated by taking into account the minimum and maximum values as Eqn. 8 and using it on the readings of magnetometer on all three axes after rotating the magnetometer platform in a circle for each of the three axes [4]

$$OFFSET_{Reading} = \frac{MAX_{\,Reading} + MIN_{\,Reading}}{2} \quad (8)$$

The soft iron distortion is the effect of electromagnetic fields, which causes the ideal sphere of the 3D environment created by all the readings of the magnetometer to become an oval shape. It is necessary to perform the soft iron calibration in the firmware after the magnetometer values have been read and hard iron calibration has been done.

*e) Fusing References from GPS*

GPS provides a drift-free reference vector for the yaw orientation of the aircraft over the long term. The reasons why GPS has not been used as the primary source of reference vector for yaw information are:

- The transient response of the magnetometer is much faster than the GPS.
- The GPS device must move in order to provide direction information.

- The yaw reference cannot be updated under GPS denial environment.

In the attitude estimation process, magnetometer has been used for yaw reference vector and over a period of time the readings are jammed with offset values for various reasons. So when the GPS is available to calculate the heading information, the course over ground is collected from GPS and used to compensate the readings of magnetometer. While using the GPS signal, reporting latency and filtering have been taken into account. The procedure that has been followed to obtain the course over ground information using a low-cost GPS receiver is:

- *First:* Three consecutive GPS positions had been measured.
- *Second:* Those position measurements had been compared to obtain two velocity measurements
- *Third:* The velocity measurements had been used to calculate the average velocity over a short period.
- *Finally:* The course over ground had been calculated from average:

$$\text{Heading} = \arctan\left(Y_{velocity} \;/\; X_{velocity}\right) \qquad (9)$$

*f) Attitude Estimation Algorithm Design*

After taking all these approaches into account, a new development over the attitude estimation algorithm of [5] have been proposed for better flight performance of multi-rotor aircrafts. The proposed attitude estimation algorithm calculates the orientation of an aircraft, in respect to the rotation of the earth by using rotation matrices. Figure 8 is a visual representation of the proposed attitude estimation algorithm. The input devices that were used in the algorithm are:

- Triple-axis gyro sensor: It measures angular velocity.
- Triple-axis accelerometer: It measures earth's gravitational field minus acceleration.
- Triple-axis magnetometer: It measures earth's magnetic field.
- GPS receiver: It measures drift free orientation and position information.

In this algorithm, the gyro sensor is the primary sensor used to calculate the orientation of a rigid body. Since gyro sensor's readings have different offsets depending on which direction the gyro sensor is facing; when these readings are integrated over time, it causes the integral result to drift. The accelerometer is not affected by drift; therefore, it has been used as an orientation reference of that rigid body to compensate the roll-pitch error (i.e. gyro's offset error). After error compensation, the magnetometer's readings has been used to calculate the heading (i.e. yaw movement) of that rigid body. To refresh the measured yaw information with true values over long time period, the GPS signal has also been used when the signal is available and ready to generate valid yaw information.

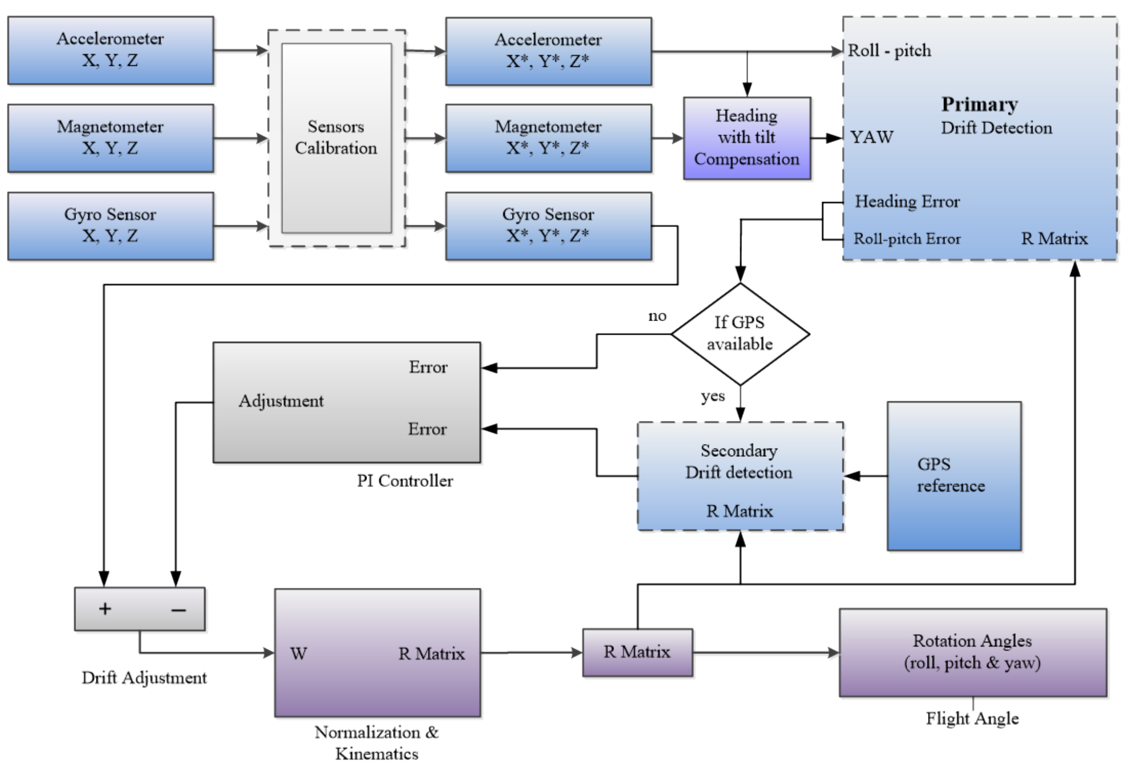


*Fig. 8 :* Proposed attitude estimation algorithm for multi rotor aircrafts

Therefore, accelerometer, magnetometer and GPS receiver all these devices allow the system to calculate the rotation correction matrix.

Afterwards, a proportional plus integral feedback controller has been used on the correction matrix to remove the drift from the gyro sensor's readings. The compensated gyro sensor's readings, W, are then passed onto another process known as normalization and kinematics. The rotation matrix's columns are unit vectors which is why the gyro readings have been normalized before calculating the kinematics portion. Once normalized, the gyro readings along with the previous rotation matrix are used to calculate the current rotation matrix by using Equation 17 for updating the direction cosine matrix from gyro signals in the 'Computing Direction Cosines From Gyro Signals' section in [1]. Finally, the rotation angles (roll, pitch and yaw) are calculated from the updated rotation matrix by the following equations which were generated from Equation 4:

$$\varphi = a\tan 2\left(R_{zy}, R_{yy}\right) \tag{10}$$

$$\theta = -a\tan 2\left(R_{xz}, R_{xx}\right) \tag{11}$$

$$\psi = \arcsin\left(R_{xy}\right) \tag{12}$$

## V. Experimental Results and Analysis

The proposed design of attitude estimation algorithm is required to validate and evaluate before considering its usability in real world. This is why real-time attitude reading test has been performed under different conditions. A 9DoF MEMS based IMU hardware setup has been made by following the modified coordinate system. This setup includes a 3-axes digital gyro sensor - ITG3200, a 3-axes digital accelerometer - BMA180 and a 3-axes magnetometer - HMC5843. Along with a 5Hz 66-channel GPS receiver -LS20031, the 9DoF IMU setup has been integrated into a quad-rotor copter that can hover in the air for more than 10 minutes. In this test, the real-time attitude data from the implemented prototype have been passed through the wireless serial data communication with 115200 baud rate to computer for performance observation in Matlab.

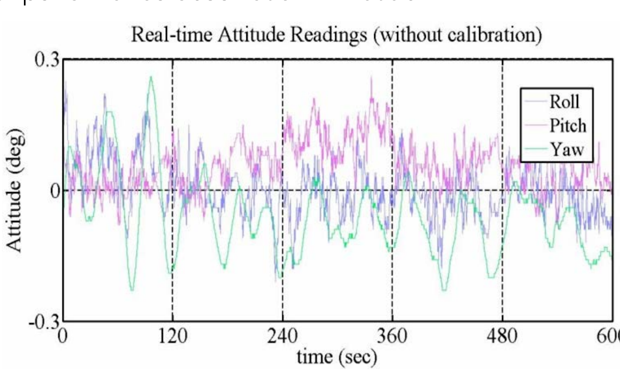


*Fig. 9 :* Real-time Attitude Readings

The procedure of the test is, first the system remained static for calculating the real-time attitude initials on ground. During this part of the test, no calibration was done so that the impact of the algorithm on unprocessed input data from sensor with random offset values can be observed. By writing a script, 5700 samples of the measured data has been collected in Matlab for 10 minutes and plotted on a graph (Fig. 9) with a time vector.

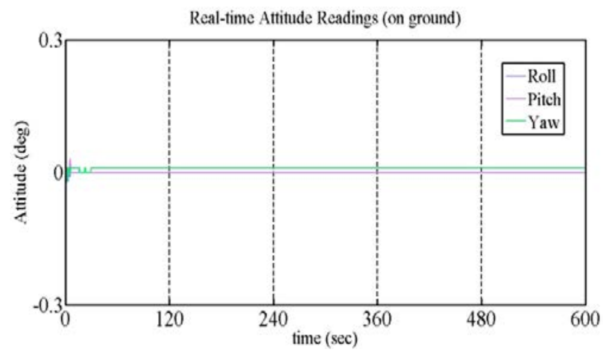


*Fig. 10 :* Real-time Attitude Readings on ground

After the attitude calculation converges with the aid of proper calibration process, the results found were more precise, static and valid for the same event. Figure 10 show that the estimated roll and pitch angle stays zero after some random fluctuations for a few seconds. Meanwhile, the yaw angle also stays static with a very little value.

In the final part of the test, the device was flown and allowed to hover throughout the test. Meanwhile, the readings were captured in Matlab simultaneously. The duration of this test was also 10 minutes (600 seconds). The real-time attitude estimation depicted in Fig. 11, portrays that estimated attitude information holds a very little noise which occurred mostly due to the disturbance from external sources. It was observed that the roll and pitch angle remained much more stable than the yaw parameter and the yaw reading behaved like a wave.

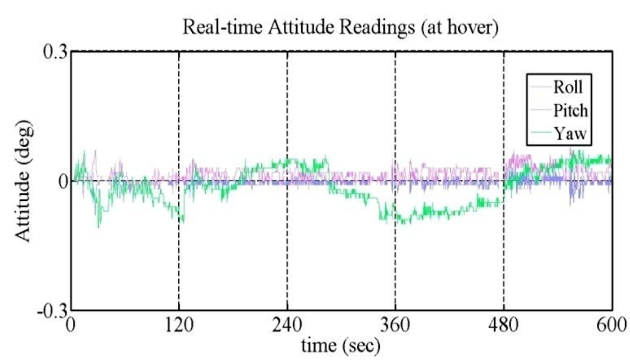


*Fig. 11 :* Real-time Attitude Readings at hover

One of the reasons which caused this wave is the slight time delay between readings of MEMS sensors and the reference from GPS. I rotation rate errors consist of the constant bias and the random noise. During the test, GPS observation is available every 200ms. Therefore the attitude data derived from MEMS sensors updated by GPS are at a rate of 5Hz.

From these test results, it can be concluded that the proposed algorithm can impressively deal with the MEMS gyro drifts with better consistency. So, this test validates the proposed design algorithm and strategy.

## VI. Conclusions

This paper presented an improved attitude estimation method based on the Direction Cosine Matrix. This estimator is built for attitude control and stabilization of multi-rotor autopilot systems. The unresolved issues that still exist can be corrected and considered for future improvements. Future applications will be presented with the integration of position, attitude and altitude estimation based on GPS/IMU/computer vision/ ultrasonic sound, resulting in an estimator of twelve degrees of freedom that will be used for tracking and navigation.

## VII. Acknowledgment

The authors would like to convey very special thanks to Prof. Dr. Tafazzal Hossain, Vice President (Academics) and Prof. Dr. A. B. M. Siddique Hossain, Dean (Faculty of Engineering), American International University-Bangladesh, for their valuable advice and encouragement. The authors would also like to acknowledge their undergraduate project and thesis supervisor, Rezwan Ahmed, Assistant Professor, Department of Computer Science, American International University-Bangladesh, for his support and helpful suggestions regarding the subject matter.

## References Références Referencias

1. D. Choukroun, H. Weiss, I. Y. Bar-Itzhack, and Y. Oshman, "Direction cosine matrix estimation from vector observations using a matrix Kalman filter", IEEE Trans. Aerosp. Electron. Syst., vol. 46, no. 1, 2010, pp. 1.
2. W. Premerlani and P. Bizard, "Direction Cosine Matrix IMU: Theory", Tech. Rep., May 2009. pp. 8-20.
3. AQ. flight software timing, Carancho Engineering, November 2010, unpublished.
4. Konvalin, "Compensating for Tilt, Hard-Iron, and Soft-Iron Effects", 2009.
5. (http://www.sensorsmag.com/sensors/motion-velo-city-displacement/compensating-tilt-hard-iron-and-soft-iron-effects-6475)
6. E.Macias, D. Torres, and S. Ravindran, "Nine-axis sensor fusion using the Direction Cosine Matrix Algorithm on the MSP430F5xx Family", Application report, Texas Instruments Inc., Texas, February 2012, pp. 3–7.

Global Journal of Researches in Engineering: F
Electrical and Electronics Engineering
Volume 14 Issue 8 Version 1.0 Year 2014
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)
Online ISSN: 2249-4596 & Print ISSN: 0975-5861

# The Peak to Average Power Reduction (PAPR) Technique of OFDM Signal by using Clipping and Filtering Method

By S.M. Yahea Mahbub, Purno Mohan Ghosh, Iffat Ara & Md. Kislu Noman

*Pabna University of Science and Technology, Bangladesh*

*Abstract-* Orthogonal Frequency Division Multiplexing (OFDM) has several attributes which make it a preferred modulation scheme for high speed wireless communication. Orthogonal Frequency Division Multiplexing (OFDM) has been currently under intense research for broadband wireless transmission due to its robustness against multipath fading. However OFDM signals have a problem with high Peak-to- Average power ratio (PAPR) and thus, a power amplifier must be carefully manufactured to have a linear input-output characteristic or to have a large input power back-off. In recent years, many peak-to-average power ratio (PAPR) reduction techniques have been proposed for orthogonal frequency division multiplexing (OFDM) signals. Among various techniques, the clipping and filtering technique has been considered as a practical scheme, and widely used owing to its non-expansion of bandwidth, low computational complexity, and simplicity in implementation without receiver-side cooperation.

*Keywords: CCDF, CDF, CDMA, DAB, DVB, FFT, IFFT, ISI, LAN, MCM, OFDM, PAPR.*

*GJRE-F Classification : FOR Code: 090609, 090699*

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## I. Introduction

Orthogonal frequency division multiplexing (OFDM) is becoming the chosen modulation technique for wireless communications. Orthogonal Frequency Division Multiplexing (OFDM) can be termed as an alternative wireless modulation technology to CDMA. OFDM (Orthogonal Frequency Division Multiplexing) is a multicarrier modulation that is implemented in many recent wireless applications due to its ability to combat impulsive noise and multipath effects and make better use of the system available bandwidth. It has been adopted for the European Digital Audio Broadcasting (DAB) [1] and Digital Video Terrestrial Broadcasting (DVB) standards, it has been proposed for UMTS (Universal Mobile Telecommunication Systems) [2] and it has just been standardized for new wireless LAN generations (HIPERLAN: High Performance Radio LAN. OFDM offer high spectral efficiency, immune to the multipath delay, low inter- symbol interference (ISI), immunity to frequency selective fading and high power efficiency. Due to these merits OFDM is chosen as high data rate communication systems such as Digital Video Broadcasting (DVB) and based mobile worldwide interoperability for microwave access (mobile Wi-MAX)[3]. The basic principle of OFDM is to split a high-rate data stream into a number of lower rate streams that are transmitted simultaneously over a number of subcarriers. These subcarriers are overlapped with each other. Because the symbol duration increases for lower rate parallel subcarriers, the relative amount of dispersion in time caused by multipath delay spread is decreased. Inter-symbol interference (ISI) is eliminated almost completely by introducing a guard time in every OFDM symbol [4]. The entire data stream of OFDM is divided into different blocks of N symbols each. Each block is multiplied with U different phase factors to generate U modified blocks before giving to IFFT block. Each modified block is given to different IFFT block to generate OFDM symbols. PAPR is calculated for each modified block and select the block which is having minimum PAPR ratio.

In this paper we have investigate OFDM signals, Clipping and Filtering method, OFDM signals with and without Clipping and Filtering method and compare between them.

## II. Ofdm System Model

OFDM is a special form of multicarrier modulation (MCM) with densely spaced subcarriers with overlapping spectra, thus allowing multiple-access [5]. MCM works on the principle of transmitting data by dividing the stream into several bit streams, each of which has a much lower bit rate and by using these sub-streams to modulate several carriers. In multicarrier transmission, bandwidth divided in many non-overlapping subcarriers but not necessary that all subcarriers are orthogonal to each other [5]. In OFDM the sub-channels overlap each other which leads to an efficient use of the total bandwidth. The information and sent over the N sub-channels, one symbol per channel. To permit dense packing and still ensure that a

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minimum of interference between the sub-channels is encountered, the carrier frequencies must be chosen carefully. By using orthogonal carriers, frequency domain can be viewed so as the frequency space between two sub-carriers is given by the distance to the first spectral null [6].

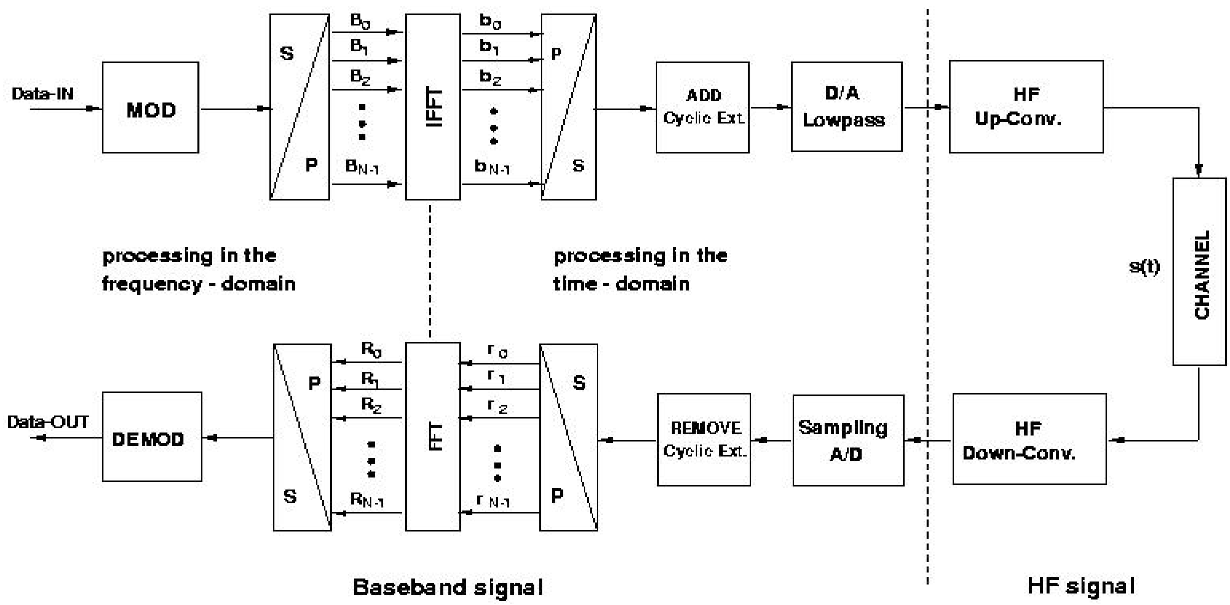


*Fig 1 :* OFDM system model

By converting a single high frequency carrier to several sub-carriers, OFDM enhances the ability to cope with frequency selective fading effects and narrow bandwidth interference. The orthogonal property also greatly simplifies the design of both transmitter and receiver. A receiver can detect every sub-carrier data, which commonly is done via Fast Fourier Transform (FFT). Therefore a separate filter for each sub channel is not required. However, in practice, the sub-carriers are modulated in different amplitude and phase [7].

*a) Peak to Average Power Ratio(PAPR) for OFDM signal*

The peak to average power ratio for a signal x(t) is defined as

$$PAPR = \frac{\max[x(t)x*(t)]}{E[x(t)x*(t)]} \quad (1)$$

Where $()^*$ corresponds to the conjugate operator [8]. Expressing in deciBels,

$$PAPR_{dB} = 10\log_{10}(PAPR) \quad (2)$$

*b) PAPR of a complex sinusoidal signal*

Consider a sinusoidal signal $x(t) = e^{2\pi ft}$ having the period T. The peak value of the signal is

$$\max[x(t)x*(t)] = +1 \quad (4)$$

The mean square value of the signal is

$$E[x(t)x*(t)] = \frac{1}{T}\int_0^T \exp^{4\pi ft} = 1 \quad (5)$$

Given so, the PAPR of a single complex sinusoidal tone is, PAPR=1[8].

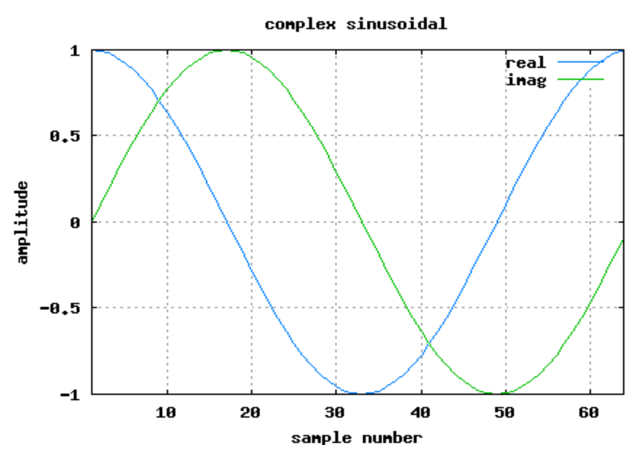


*Fig 2 :* PAPR of a complex sinusoidal

*c) Clipping and Filtering Technique*

In OFDM, signal contains high peaks (exceeding a certain threshold) will be applied to clipping and Filtering processes (CAF) as illustrated in fig.-3. In the Clipping part, when amplitude exceeds a certain threshold, the amplitude is hard-clipped while the phase is saved [9-10].

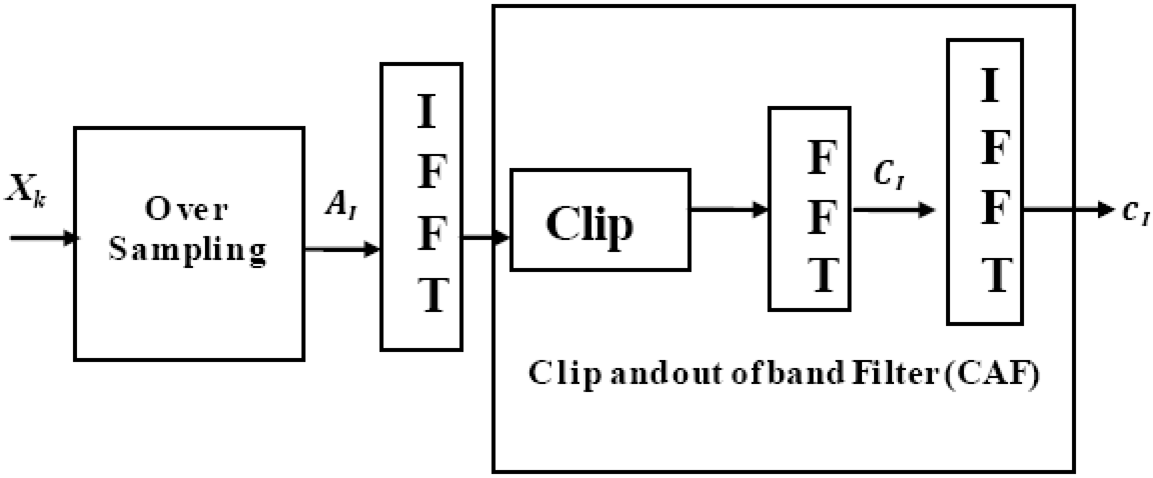


*Fig 3 :* Repeating clipping and filtering technique

In fig-3, vector $A_1 = [A_0........A_{N-i}]$, obtained after oversampling stage is first transformed using an oversize inverse fast Fourier transformation (IFFT). For an oversampling factor denoted by IF, $A_1$ is extended by adding N(IF-I ) zeros in the middle of the vector. This results in a trigonometric interpolation of the signal time domain signal [I]. The interpolated signal is then clipped. In this paper, hard-limiting is applied to the amplitude of the complex values at the IFFT output. However, any other form of nonlinearity could be used. The clipping ratio, CR, is defined as the ratio of the clipping level value to the root mean square value of the unclipped signal. The clipping is followed by filtering to reduce out-of band power. The filter consists of two FFT operations. The forward FFT transforms the clipped signal back into the discrete frequency domain resulting in vector. The in- band discrete frequency components of, $[C_{0,i}.....,C_{N/2-1,i},C_{NI1-N/2,i},...C_{NI1-1,i}]$, are passed unchanged to the inputs of the second IFFT while the out-of-band components ,$[C_{N/2+1,i},.... C_{NI1-N/2,i}]$ are nulled. In systems where some band-edge subcarriers are unused the components corresponding to these are also nulled. The resulting filter is a time-dependent filter, which passes in-band and rejects out-of-band discrete-frequency components. This means that it causes no distortion to the in-band OFDM signal. Since the filter operates on a symbol-by-symbol basis, it causes no Inter-symbol interference. The filtering does cause some peak to re-growth. Clipping method sets a clipping threshold, when the amplitude of the signals over the threshold, then cut the high peak power. According to the system acquirement, the following function has been used to calculate the clipping ratio. PAPR0=10logCR, where, PAPR0 is the threshold value, and CR is the clipping ratio. Due to the relation between PAPR0 and the system BER, PAPR0 is selected to be inverse ratio to BER. In this case, proper threshold value should be selected carefully.

## III. Simulation and Results

The Cumulative Distribution Function (CDF) is one of the most regularly used parameters, which is used to measure the efficiency of any PAPR technique. Normally, the Complementary CDF (CCDF) is used instead of CDF, which helps us to measure the probability that the PAPR of a certain data block exceeds the given threshold. The CCDF of the PAPR of the data block is desired in our case to compare outputs of various reduction techniques [7-8].

The simulation result of amplitude clipping method is shown in Fig-4. It can be observe that OFDM signal is has higher PAPR and after applying this method PAPR is reduced significantly. This PAPR is decreases as the number of clip and filtering is increased from one to two levels. Because the clipping is followed by filtering to reduce out of band power.

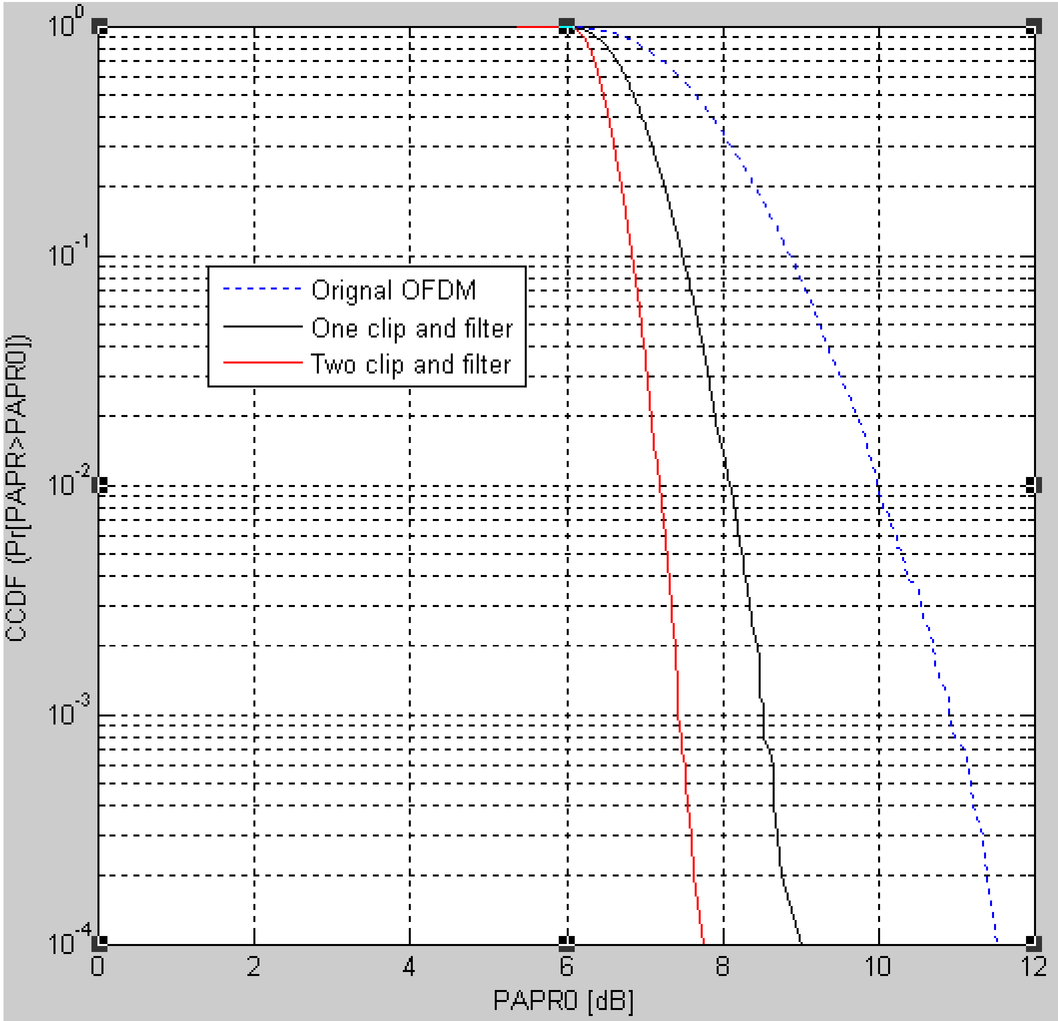


*Fig 4 :* Comparison of CCDF using one/two clipping and filtering method

## IV. Conclution

In conclusion, OFDM technology summed up a number of sub carriers modulated by group of data symbol. Therefore, transmitted signal may have a relatively large peak power which leads to high PAPR. The principal drawback of OFDM is that the peak transmitted power can be substantially larger than the average power. We observe that the PAR-reduction problem for OFDM has received a great deal of attention recently. In this paper, It can be observe that OFDM signal is has higher PAPR and after applying this method PAPR is reduced significantly. This PAPR is decreases as the number of clip and filtering is increased from one to two levels. Because the clipping is followed by filtering to reduce out of band power. The DFT transform the clipped signal into frequency domain signal.

## References Références Referencias


1. B. Le Floch, R. H. Lassalle, and D. Castelain, "Digital sound broadcasting to mobile receivers," IEEE Trans. Consumer Electronics, vol. 35, no. 3, pp. 493–503, Aug. 1989.
2. J. Van de Beek et al., "On synchronization in an OFDM based UMTS proposal," in Proc. COST 254 (Emergent Techniques for Communication Terminals, Toulouse, France, July 1997.
3. Suverna Sengar, Partha Pratim Bhattacharya," PERFORMANCE IMPROVEMENT IN OFDMSYSTEM BY PAPR REDUCTION," Signal & Image Processing : An International Journal (SIPIJ) Vol.3, No.2, April 2012 Department of Electronics and Communication Engineering, Faculty of Engineering and Technology, Mody Institute of Technology & Science (Deemed University), Lakshmangarh, Dist – Sikar, Rajasthan, Pin – 332311,INDIA.
4. Jenn-Kaie Lain, Shi-Yi Wu and Po-Hui Yang," PAPR reduction of OFDM signals using PTS: a real-valued genetic approach".
5. Muhammad Atif Gulzar, Rashid Nawaz and Devendra Thapa, "Implementation of MIMO-OFDM System for WiMAX*", M.Sc Dissertation*, Department

of Electrical Engineering, Linnaeus University, Sweden, 2011.
6. R. Prasad, *OFDM for Wireless Communications Systems*. London, Boston: Artech House, Inc, 2004.
7. P. J. Mathecken, "Performance Analysis of OFDM with Wiener Phase Noise and Frequency Selective Fading Channel", Department of Signal Processing and Acoustics, Aalto university, Espoo, December 29, 2010.
8. http://www.dsplog.com/2008/02/24/peak-to-average-power-ratio-for-of dm
9. S. Leung, S. Ju, and G. Bi, "Algorithm for repeat ed clipping and filtering in peak-to-average power reduct ion for OFDM," *Electron. Lett.*, vol. 38, no. 25, pp. 1726–1727, Dec. 2002.
10. D. Qing and Z. Hongsheng, " An Improved Algorit hm to Reduce PAPR Based Clipping and Filtering" Wireless Communicat ions, Networking and Mobile Computing,2008. WiCOM '08 International Conference, pp 1-4.

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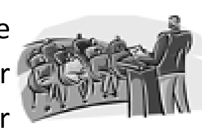

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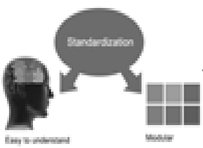

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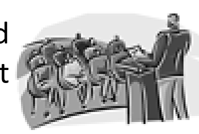

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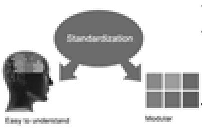


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The paper should be in proper format. The format can be downloaded from first page of 'Author Guideline' Menu. The Author is expected to follow the general rules as mentioned in this menu. The paper should be written in MS-Word Format (*.DOC,*.DOCX).

The Author can submit the paper either online or offline. The authors should prefer online submission.Online Submission: There are three ways to submit your paper:

**(A) (I) First, register yourself using top right corner of Home page then Login. If you are already registered, then login using your username and password.**

**(II) Choose corresponding Journal.**

**(III) Click 'Submit Manuscript'. Fill required information and Upload the paper.**

**(B) If you are using Internet Explorer, then Direct Submission through Homepage is also available.**

**(C) If these two are not conveninet , and then email the paper directly to dean@globaljournals.org.**

Offline Submission: Author can send the typed form of paper by Post. However, online submission should be preferred.

# Preferred Author Guidelines

**MANUSCRIPT STYLE INSTRUCTION** **(Must be strictly followed)**

Page Size: 8.27" X 11'"

- Left Margin: 0.65
- Right Margin: 0.65
- Top Margin: 0.75
- Bottom Margin: 0.75
- Font type of all text should be Swis 721 Lt BT.
- Paper Title should be of Font Size 24 with one Column section.
- Author Name in Font Size of 11 with one column as of Title.
- Abstract Font size of 9 Bold, “Abstract” word in Italic Bold.
- Main Text: Font size 10 with justified two columns section
- Two Column with Equal Column with of 3.38 and Gaping of .2
- First Character must be three lines Drop capped.
- Paragraph before Spacing of 1 pt and After of 0 pt.
- Line Spacing of 1 pt
- Large Images must be in One Column
- Numbering of First Main Headings (Heading 1) must be in Roman Letters, Capital Letter, and Font Size of 10.
- Numbering of Second Main Headings (Heading 2) must be in Alphabets, Italic, and Font Size of 10.

**You can use your own standard format also.**
**Author Guidelines:**

1. General,

2. Ethical Guidelines,

3. Submission of Manuscripts,

4. Manuscript’s Category,

5. Structure and Format of Manuscript,

6. After Acceptance.

**1. GENERAL**

Before submitting your research paper, one is advised to go through the details as mentioned in following heads. It will be beneficial, while peer reviewer justify your paper for publication.

**Scope**

The Global Journals Inc. (US) welcome the submission of original paper, review paper, survey article relevant to the all the streams of Philosophy and knowledge. The Global Journals Inc. (US) is parental platform for Global Journal of Computer Science and Technology, Researches in Engineering, Medical Research, Science Frontier Research, Human Social Science, Management, and Business organization. The choice of specific field can be done otherwise as following in Abstracting and Indexing Page on this Website. As the all Global

Journals Inc. (US) are being abstracted and indexed (in process) by most of the reputed organizations. Topics of only narrow interest will not be accepted unless they have wider potential or consequences.

**2. ETHICAL GUIDELINES**

Authors should follow the ethical guidelines as mentioned below for publication of research paper and research activities.

Papers are accepted on strict understanding that the material in whole or in part has not been, nor is being, considered for publication elsewhere. If the paper once accepted by Global Journals Inc. (US) and Editorial Board, will become the copyright of the Global Journals Inc. (US).

**Authorship: The authors and coauthors should have active contribution to conception design, analysis and interpretation of findings. They should critically review the contents and drafting of the paper. All should approve the final version of the paper before submission**

The Global Journals Inc. (US) follows the definition of authorship set up by the Global Academy of Research and Development. According to the Global Academy of R&D authorship, criteria must be based on:

1) Substantial contributions to conception and acquisition of data, analysis and interpretation of the findings.

2) Drafting the paper and revising it critically regarding important academic content.

3) Final approval of the version of the paper to be published.

All authors should have been credited according to their appropriate contribution in research activity and preparing paper. Contributors who do not match the criteria as authors may be mentioned under Acknowledgement.

Acknowledgements: Contributors to the research other than authors credited should be mentioned under acknowledgement. The specifications of the source of funding for the research if appropriate can be included. Suppliers of resources may be mentioned along with address.

**Appeal of Decision: The Editorial Board's decision on publication of the paper is final and cannot be appealed elsewhere.**

**Permissions: It is the author's responsibility to have prior permission if all or parts of earlier published illustrations are used in this paper.**

Please mention proper reference and appropriate acknowledgements wherever expected.

If all or parts of previously published illustrations are used, permission must be taken from the copyright holder concerned. It is the author's responsibility to take these in writing.

Approval for reproduction/modification of any information (including figures and tables) published elsewhere must be obtained by the authors/copyright holders before submission of the manuscript. Contributors (Authors) are responsible for any copyright fee involved.

**3. SUBMISSION OF MANUSCRIPTS**

Manuscripts should be uploaded via this online submission page. The online submission is most efficient method for submission of papers, as it enables rapid distribution of manuscripts and consequently speeds up the review procedure. It also enables authors to know the status of their own manuscripts by emailing us. Complete instructions for submitting a paper is available below.

Manuscript submission is a systematic procedure and little preparation is required beyond having all parts of your manuscript in a given format and a computer with an Internet connection and a Web browser. Full help and instructions are provided on-screen. As an author, you will be prompted for login and manuscript details as Field of Paper and then to upload your manuscript file(s) according to the instructions.

To avoid postal delays, all transaction is preferred by e-mail. A finished manuscript submission is confirmed by e-mail immediately and your paper enters the editorial process with no postal delays. When a conclusion is made about the publication of your paper by our Editorial Board, revisions can be submitted online with the same procedure, with an occasion to view and respond to all comments.

Complete support for both authors and co-author is provided.

**4. MANUSCRIPT'S CATEGORY**

Based on potential and nature, the manuscript can be categorized under the following heads:

Original research paper: Such papers are reports of high-level significant original research work.

Review papers: These are concise, significant but helpful and decisive topics for young researchers.

Research articles: These are handled with small investigation and applications

Research letters: The letters are small and concise comments on previously published matters.

**5.STRUCTURE AND FORMAT OF MANUSCRIPT**

The recommended size of original research paper is less than seven thousand words, review papers fewer than seven thousands words also.Preparation of research paper or how to write research paper, are major hurdle, while writing manuscript. The research articles and research letters should be fewer than three thousand words, the structure original research paper; sometime review paper should be as follows:

**Papers**: These are reports of significant research (typically less than 7000 words equivalent, including tables, figures, references), and comprise:

(a)Title should be relevant and commensurate with the theme of the paper.

(b) A brief Summary, "Abstract" (less than 150 words) containing the major results and conclusions.

(c) Up to ten keywords, that precisely identifies the paper's subject, purpose, and focus.

(d) An Introduction, giving necessary background excluding subheadings; objectives must be clearly declared.

(e) Resources and techniques with sufficient complete experimental details (wherever possible by reference) to permit repetition; sources of information must be given and numerical methods must be specified by reference, unless non-standard.

(f) Results should be presented concisely, by well-designed tables and/or figures; the same data may not be used in both; suitable statistical data should be given. All data must be obtained with attention to numerical detail in the planning stage. As reproduced design has been recognized to be important to experiments for a considerable time, the Editor has decided that any paper that appears not to have adequate numerical treatments of the data will be returned un-refereed;

(g) Discussion should cover the implications and consequences, not just recapitulating the results; conclusions should be summarizing.

(h) Brief Acknowledgements.

(i) References in the proper form.

Authors should very cautiously consider the preparation of papers to ensure that they communicate efficiently. Papers are much more likely to be accepted, if they are cautiously designed and laid out, contain few or no errors, are summarizing, and be conventional to the approach and instructions. They will in addition, be published with much less delays than those that require much technical and editorial correction.

The Editorial Board reserves the right to make literary corrections and to make suggestions to improve briefness.

It is vital, that authors take care in submitting a manuscript that is written in simple language and adheres to published guidelines.

**Format**

*Language: The language of publication is UK English. Authors, for whom English is a second language, must have their manuscript efficiently edited by an English-speaking person before submission to make sure that, the English is of high excellence. It is preferable, that manuscripts should be professionally edited.*

Standard Usage, Abbreviations, and Units: Spelling and hyphenation should be conventional to The Concise Oxford English Dictionary. Statistics and measurements should at all times be given in figures, e.g. 16 min, except for when the number begins a sentence. When the number does not refer to a unit of measurement it should be spelt in full unless, it is 160 or greater.

Abbreviations supposed to be used carefully. The abbreviated name or expression is supposed to be cited in full at first usage, followed by the conventional abbreviation in parentheses.

Metric SI units are supposed to generally be used excluding where they conflict with current practice or are confusing. For illustration, 1.4 l rather than 1.4 × 10-3 m3, or 4 mm somewhat than 4 × 10-3 m. Chemical formula and solutions must identify the form used, e.g. anhydrous or hydrated, and the concentration must be in clearly defined units. Common species names should be followed by underlines at the first mention. For following use the generic name should be constricted to a single letter, if it is clear.

**Structure**

All manuscripts submitted to Global Journals Inc. (US), ought to include:

Title: The title page must carry an instructive title that reflects the content, a running title (less than 45 characters together with spaces), names of the authors and co-authors, and the place(s) wherever the work was carried out. The full postal address in addition with the e-mail address of related author must be given. Up to eleven keywords or very brief phrases have to be given to help data retrieval, mining and indexing.

*Abstract, used in Original Papers and Reviews:*

Optimizing Abstract for Search Engines

Many researchers searching for information online will use search engines such as Google, Yahoo or similar. By optimizing your paper for search engines, you will amplify the chance of someone finding it. This in turn will make it more likely to be viewed and/or cited in a further work. Global Journals Inc. (US) have compiled these guidelines to facilitate you to maximize the web-friendliness of the most public part of your paper.

Key Words

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).

**6.1 Proof Corrections**

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.

As changes to proofs are costly, we inquire that you only correct typesetting errors. All illustrations are retained by the publisher. Please note that the authors are responsible for all statements made in their work, including changes made by the copy editor.

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The Global Journals Inc. (US) are enclosed by our publishing's Early View service. Early View articles are complete full-text articles sent in advance of their publication. Early View articles are absolute and final. They have been completely reviewed, revised and edited for publication, and the authors' final corrections have been incorporated. Because they are in final form, no changes can be made after sending them. The nature of Early View articles means that they do not yet have volume, issue or page numbers, so Early View articles cannot be cited in the conventional way.

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**6.4 Author Material Archive Policy**

Please note that if not specifically requested, publisher will dispose off hardcopy & electronic information submitted, after the two months of publication. If you require the return of any information submitted, please inform the Editorial Board or dean as soon as possible.

**6.5 Offprint and Extra Copies**

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You must strictly follow above Author Guidelines before submitting your paper or else we will not at all be responsible for any corrections in future in any of the way.

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.

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| ***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 |
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| ***References*** | Complete and correct format, well organized | Beside the point, Incomplete | Wrong format and structuring |

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ISSN 9755861