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Performance Evaluation of a Square Lattice Micro- Structure Optical Fibre in Communication & Multiplexing Technique

By Avizit Basak & Mohibur Rahman

Rajshahi University of Engineering & Technology, Bangladesh

Abstract - Although optical fiber communication is the best for transmitting data at a high rate, we are trying to push the data rate even higher. While the fiber channel may be capable of transmitting terabit-per-second data rates, no existing single communication system can make complete use of this speed. Adding more and more fibers to the system as a method of increasing speed is uneconomical. Optical fibers in discussion that guide signals in the form of light are typically made of from two glasses. It is a cylindrical in shape waveguide consisting of a higher refractive index solid glass core which runs down middle of the fiber. The other solid glass with a lower refractive index surrounds the core and makes the homogeneous cladding. The two glasses are made of from the common material silica. Photonic crystal fibers can be divided into two modes of operation, according to their mechanism for confinement. Those with a solid core, or a core with a higher average index than the micro structured cladding, can operate on the same index-guiding principle as conventional optical fiber.

Keywords : *micro-structure optical fibre, CWDM, DWDM, WDM, crosstalk, power penalty, etc.*

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PERFORMANCE EVALUATION OF A SQUARE LATTICE MICROSTRUCTURED OPTICAL FIBRE IN COMMUNICATION MULTIPLEXING TECHNIQUE

Strictly as per the compliance and regulations of :



Performance Evaluation of a Square Lattice Micro-Structure Optical Fibre in Communication & Multiplexing Technique

Avizit Basak^α & Mohibur Rahman^σ

Abstract - Although optical fiber communication is the best for transmitting data at a high rate, we are trying to push the data rate even higher. While the fiber channel may be capable of transmitting terabit-per-second data rates, no existing single communication system can make complete use of this speed. Adding more and more fibers to the system as a method of increasing speed is uneconomical. Optical fibers in discussion that guide signals in the form of light are typically made of from two glasses. It is a cylindrical in shape waveguide consisting of a higher refractive index solid glass core which runs down middle of the fiber. The other solid glass with a lower refractive index surrounds the core and makes the homogeneous cladding. The two glasses are made of from the common material silica. Photonic crystal fibers can be divided into two modes of operation, according to their mechanism for confinement. Those with a solid core, or a core with a higher average index than the micro structured cladding, can operate on the same index-guiding principle as conventional optical fiber. They can have a much higher effective- refractive index contrast between core and cladding, and therefore can have much stronger confinement for applications in nonlinear optical devices, polarization-maintaining fibers. Alternatively, one can create a photonic band gap fiber, in which the light is confined by a photonic band gap created by the micro structured cladding – such a band gap, properly designed, can confine light in a *lower-index* core and even a hollow core. Band gap fibers with hollow cores can potentially circumvent limits imposed by available materials, for example to create fibers that guide light in wavelengths for which transparent materials are not available. Another potential advantage of a hollow core is that one can dynamically introduce materials into the core, such as a gas that is to be analyzed for the presence of some substance. MOF can also be modified by coating the holes with sol-gels of similar or different index material to enhance its transmittance of light. Microstructure optical fibre technique has the advantage of higher bit rates and is well equipped for long haul applications. This types of fibres are mostly used for its advantages over other multiplexing schemes. In this paper, performance analysis of MOF in multiplexing technique was explored and different aspects of communication and multiplexing. Dense WDM and Coarse WDM technique has the advantage of higher bit rates and is well equipped for long

haul application and MOF performs here in better way in communication and Multiplexing technique.

Keywords : Micro-structure optical fibre, CWDM, DWDM, WDM, crosstalk, power penalty, etc.

I. INTRODUCTION

In optical communications system the transmitter is a light source whose output acts as the carrier wave. Although frequency division multiplexing techniques are used in longer broadcast systems, most optical communication links use time division multiplexing techniques. The components that are used to transmit or receive the optical signal are usually semiconductor devices. For transmission the most common light source used are laser diode and light emitting diode. At the receiving end of the optical link a PIN photodiode or Avalanche photodiode, acts as a photo detector and converts the modulated light back into an electrical signal. The photodiode current is directly proportional to optical power. The receiver block which is the last part of the system which converts the optical signal back into the replica of the electrical signal using PIN-type photodiode then to the amplification stage before reaching the end. The early all-glass fibers experienced large amount of optical losses thus limiting the transmission distance. This was because the transparent transmitting rod was surrounded by air and as a consequence, excessive losses occurred at any discontinuities of the glass-air interface. This realization motivated scientists to develop glass fibers that included a separate glass coating. The fiber was made of two layers. The innermost region of the fiber referred to as the core, was used to transmit the light while the glass coating or the cladding prevented the light from leaking out of the core by reflecting it within its boundaries.

II. BASIC OF MICROSTRUCTURE OPTICAL FIBRE

Development of wavelength division multiplexing (WDM) networks in recent years and the requirement of transmitting data over optical fibers in high bitrates in the second and third wavelength window have caused serious concerns using conventional single mode fibers in optical communications. High dispersion

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in conventional single mode fibers leads to partial loss of data in long distances of data transmission. The MOF is a single material optical fiber consisting of a silica-air microstructure. It contains microscopic air-holes in a silica background running down length of the fiber that form the silica-air microstructure as well as the lower refractive index cladding. The former core type MOF guides light based on the modified TIR in terms of coupling between air and dielectric modes in a single tube waveguide, a simple and useful model is proposed and numerically validated. It is able to predict mechanism likewise conventional fibers. The later guides light based on a new mechanism which is known as the photonic band gap. Most MOF have been fabricated in silica glass, but other glasses have also been used to obtain particular optical properties. MOFs with small core and large sized identical air-holes tend to shift zero dispersion wavelengths toward shorter wavelengths. The mode field distribution has its maximum amplitude at the center core region. The structural parameters of the fiber to enhance or to degrade the high nonlinearity of the fiber, effective mode index, and group velocity dispersion. Through optimizing design parameters, we can alter and improve the propagation characteristics in this fibre according to its application, which makes it a proper choice for communication applications, is that nearly zero flattened dispersion and low confinement loss in this fiber is attainable at the same time.

III. FUNDAMENTAL OF WDM SYSTEM

A WDM system uses a multiplexer at the transmitter to join the signals together and a demultiplexer at the receiver to split them apart. With the right type of fiber it is possible to have a device that does both simultaneously, and can function as an optical add-drop multiplexer. WDM combines multiple optical time division multiplexed (TDM) data streams onto one fiber through the use of multiple wavelengths of light. Each individual TDM data stream is sent over an individual laser transmitting a unique wavelength of light. Wavelength division multiplexing was used with only two wavelengths 1310 nm and 1550 nm. However, this was suitable only for limited applications for example; applications in which analog optical cable television signals co-existed with digital optical telecommunication signals. WDM takes advantage of the fact that different wavelengths of light can be transmitted over a single fiber simultaneously. The light sources of different wavelengths can be combined using suitable components like couplers, splitters etc.

IV. OPTICAL LOSSES

Once power is coupled into the fiber, the optical signal will interact with the fiber. One of these interactions is the attenuation of the light signal as it

moves through the medium. Attenuation is caused by two physical effects, which are absorption and scattering. Absorption has an effect of removing photons, when they interact with atoms and molecules of the medium while scattering redirects the light out of the core of the fiber. Absorption occurs when the energy of the photon is equal to a difference between two electronic energies. A major cause of absorption is the presence of OH⁻ radicals, which results from the presence of water (H₂O). The OH⁻ enters the fiber through either a chemical reaction (during fiber manufacturing) by-product, or as humidity in the operating environment. The main OH⁻ absorption peak occurs at 1400nm and the second peak at 950 nm, while the lowest absorption occurs in the wavelength window around 1300 nm and 1550 nm.

V. BIDIRECTIONAL TRANSMISSION SYSTEM

Bidirectional transmission is an appealing means of increasing the bandwidth utilization in a single optical fiber and, at the same time, reducing the operation and maintenance cost, and therefore a long haul optical links will likely require a considerable increase in total spectral efficiency. Recently the most interesting area is engaging (WDM) in Bidirectional transmissions over a single fiber in terms of increase the capacity of transmitted data. Recent progress on access network systems has increased the communication bit rate to several Gb/s. Now a low cost optical transceiver is required for optical access network systems. Specifically, a bidirectional single fiber optical transceiver is expected to be an effective way of reducing system cost. There are certain approaches to designing the optical transceiver configuration that will enable achieving such a low cost

VI. SYSTEM CROSSTALK & POWER PENALTY

Crosstalk occurs in multi channel optical transmission systems. Crosstalk can be caused by the following: the spectral skirts of one channel entering the de-multiplexing and filtering pass-band of another cause crosstalk, practical limits on selectivity and isolation cause crosstalk. Non-linear effects within the fiber at the high power densities possible in single mode systems can cause crosstalk or cross modulation, the mechanism is Raman scattering, which is a non-linear stimulated scattering effect that allows the optical power at one wavelength to affect scattering and thus the optical power in another wavelength. In optical communication the receiver sensitivity is defined with respect to the receiver noise for several basic detection scenarios. The power penalty is equal to the increase in signal power that is needed to keep the Q-factor and BER at the same level that would exist if no impairments were present. The impact of different impairments can

due to Extinction Ratio, Power Penalty due to Intensity Noise, etc.

VII. SYSTEM DISPERSION

Dispersion factor must be taken into account during designing any fiber optic transmission system. The effect of this factor causes crosstalk problem at the far end of the system, especially in transmitting more than one wavelength in both directions with close wavelengths between channels. There are two kinds of dispersion. Material dispersion and chromatic dispersion, the most common is called Dispersion chromatic dispersion. The effects of polarization mode dispersion are much more insidious and difficult to make compensation for in the real networks.

VIII. GEOMETRIC DESCRIPTION OF BEAM PROPAGATION IN MOF FIBER

The ray description of light propagation in fiber is based on the phenomenon of total internal reflection. The theory of TIR states that when a beam is incident at the boundary between two media where the incident medium is of a higher refractive index than the second medium and the angle of incidence exceeds a critical value θ_c , the light will be totally reflected. Beyond this angle light is no longer transmitted into the second medium, instead it is reflected into the original medium.

IX. MULTIPLEXING

Multiplexing is an essential technique for fibre optic communication. It is a method by which multiple analogue message signals or digital data streams are combined into one signal over a shared medium. The aim is to share an expensive resource. The multiplexed signal is transmitted over a communication channel, which may be a physical transmission medium. The multiplexing divides the capacity of the high-level communication channel into several low-level logical channels, one for each message signal or data stream to be transferred. Multiplexing technologies may be divided into several types. Such as space-division multiplexing (SDM), frequency-division multiplexing (FDM), time-division multiplexing (TDM), and code division multiplexing (CDM), Dense WDM, Coarse WDM, etc. CWDM, DWDM, OADM are mostly used in telecommunication & computer networks. Wavelength Division Multiplexing is the technology enabling cost efficient upgrade of capacity in optical networks. This explains the fundamental principles for optical networks.

X. SYSTEM DESIGN ANALYSIS

Two analyses are usually carried out to ensure that the system performs satisfactorily: the link power budget and the system rise-time budget analyses. The

power budget analysis is used to determine the power margin between the output power of the transmitter and the minimum receiver sensitivity needed to ensure a specified bit error rate (BER). The power loss between transmitter and receiver can be allocated to the connector, splices and fiber losses. Should the system not meet the desired performance, components used in the link must be varied. This process is iterated until the desired performance is met. Once the power budget has been established, a system rise-time analysis is performed to ensure that the desired overall performance is achieved.

XI. LINK POWER BUDGET & RISE TIME BUDGET

The link power budget is determined by establishing the minimum power required to fall on the photodiode in order to ensure a certain BER. In light wave system a $BER = 10^{-9}$ is considered acceptable. The light coupling efficiency of the transmitter, the loss of the fiber and the sequential loss contributions of each element in the link determine the power received at the detector. The dispersion limitation of an optical fiber link must be determined because it sets the upper limit for the transmission bit-rate. The rise-time budget analysis is a convenient method for establishing the allowable bit rate in the optical system. The rise time budget analysis is essentially a measure of how fast the system responds to a step stimulus. There are four basic elements that limit the speed of response of an optical system: these are the transmitter rise-time t_{tx} , the fiber rise time that comprises of the GVD rise-time t_{GVD} and the inter modal dispersion rise-time t_{mod} , and finally the receiver rise-time.

XII. PERFORMANCE EVALUATION OF SQUARE LATTICE MICROSTRUCTURE OPTICAL FIBER

The analyses performed according to the waveguide contribution to the dispersion, noise level, losses, frequency distribution etc.

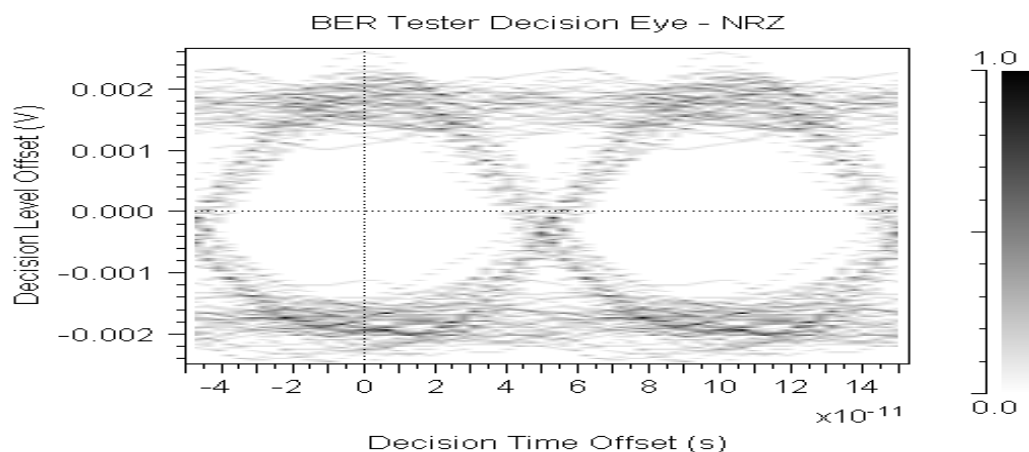


Figure 1 : NRZ operation for multiplexing technique in MOF

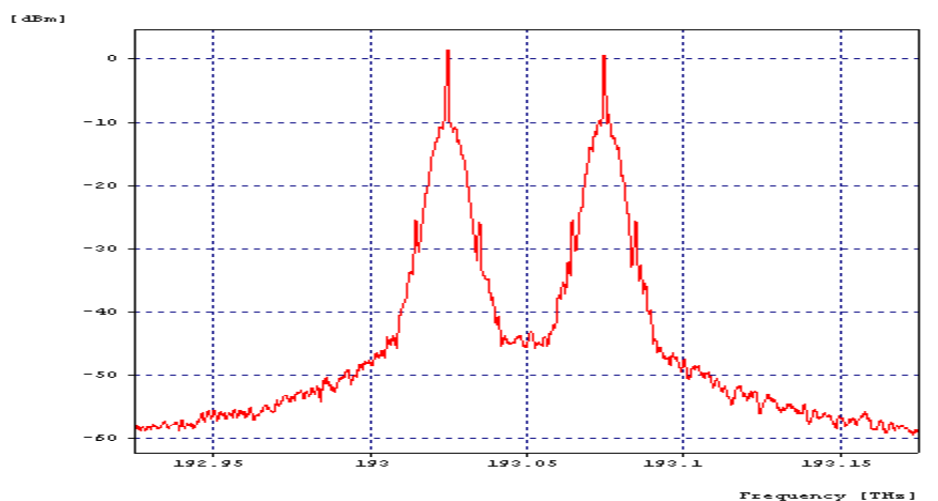


Figure 2 : Optical spectrum while multiplexing operation

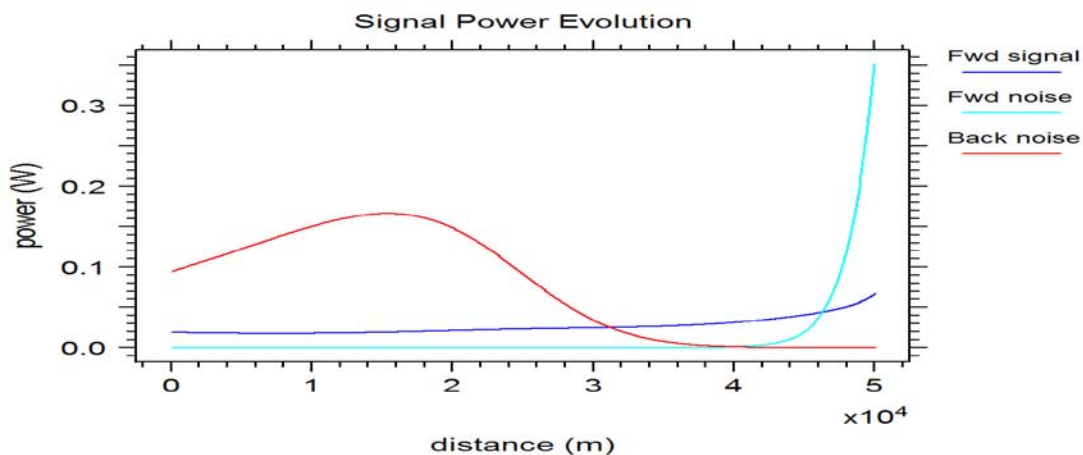


Figure 3 : Noise Level in MOF while multiplexing

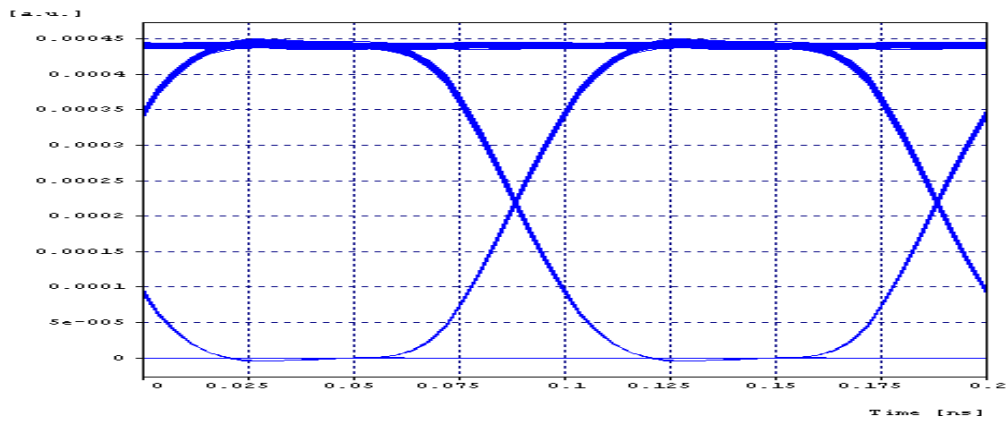


Figure 4 : Eye diagram while transmission

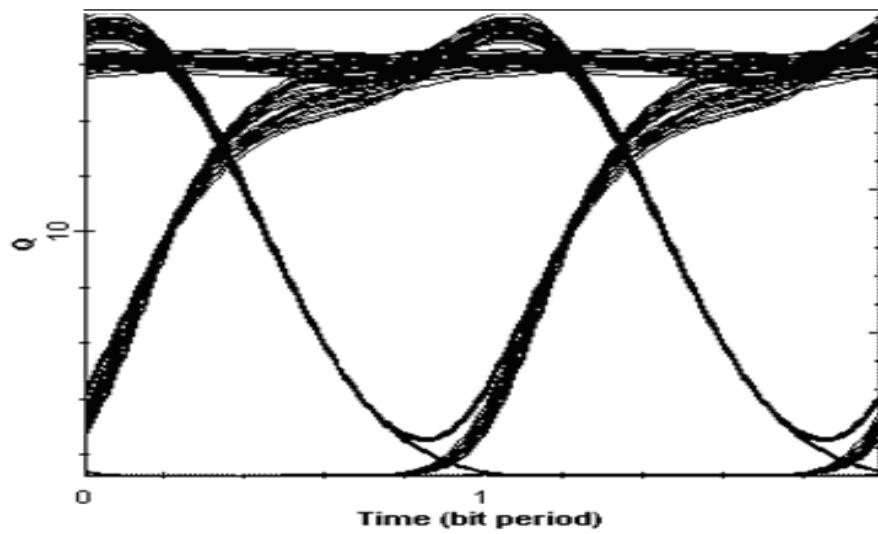


Figure 5 : Dispersion in MOF while multiplexing

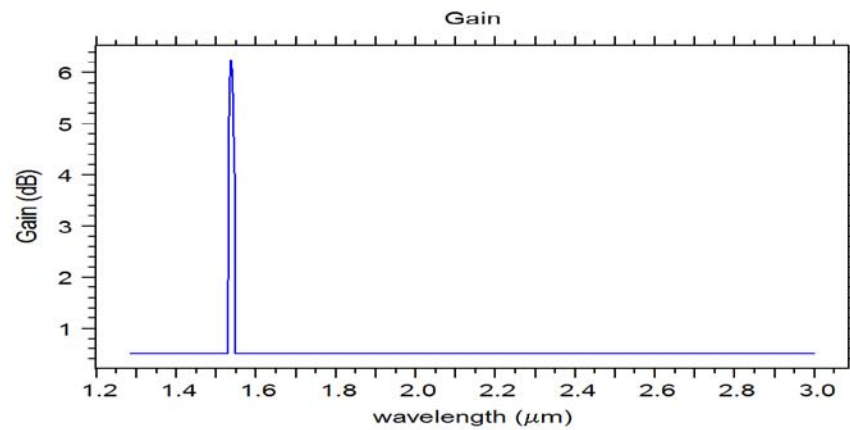


Figure 6 : Frequency response in MOF while multiplexing

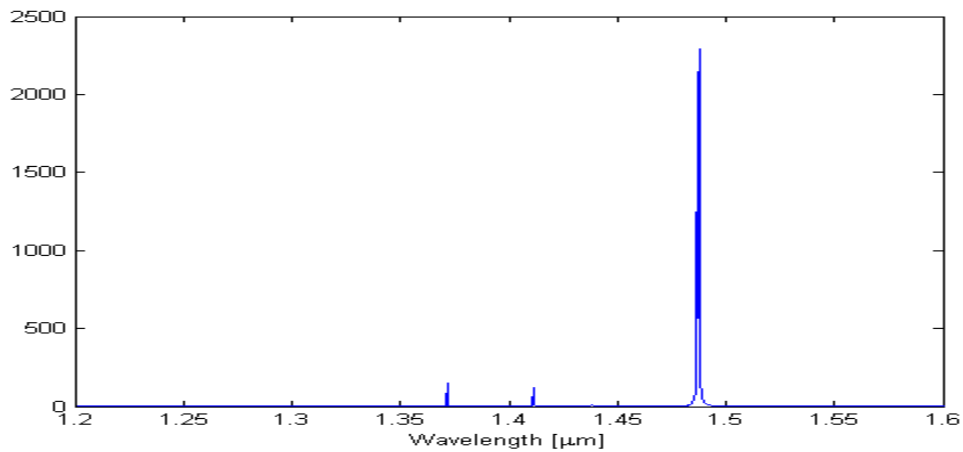


Figure 7 : Spectrum of a MOF while multiplexing

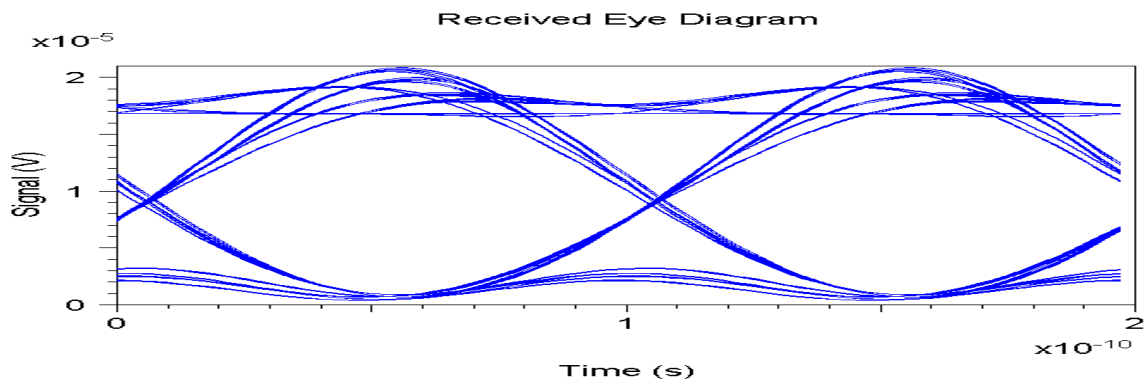


Figure 8 : Received eye diagram of Received signal

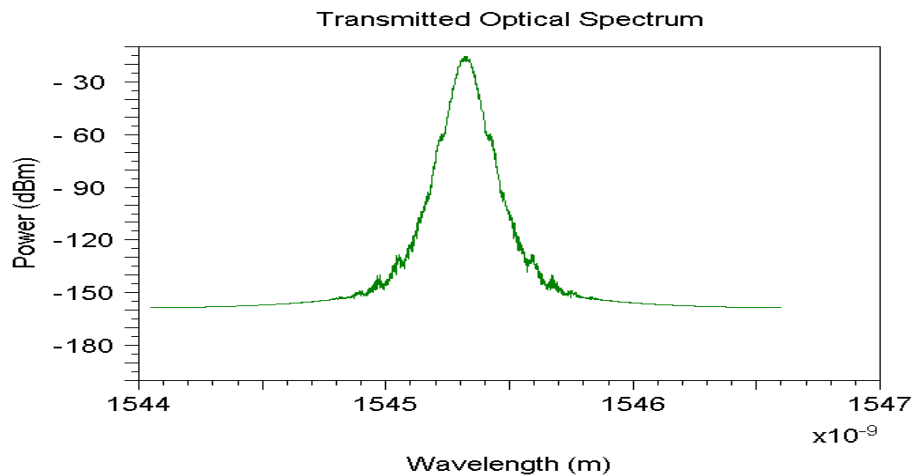


Figure 9 : Transmitted optical spectrum

XIII. ADVANTAGES OF MOF

Excellent performance, high Mechanical sensitivity, operational flexibility, transparent to digital signal format and data rate, reduces transmission losses, economical etc.

XIV. CONCLUSION

Here, investigation are made according to the specific air hole size and hole to hole spacing over a wide wavelength range. From the numerical simulation results, better dispersion slope, and low losses in the telecommunication operation. Moreover, Optical

communications by Dense Wavelength Division Multiplexing (DWDM) uses 100 wavelength channels enabling high-speed, high-capacity optical communication system for the Internet age. A new trend is to use Coarse Wavelength Division Multiplexing (CWDM) system in these networks to lower the cost dramatically at sufficient bandwidth capacity. In addition, to the stability required for DWDM sources passive modules such as mux/demux and add/drop modules used in DWDM systems also need to have very narrow filtering or wavelength separating characteristics that stay stable over a considerable temperature range. These filters are required to have very stringent tolerance. For a CWDM system, on the other hand the spacing between channels wavelengths is large so that the requirements and tolerances for components and modules are more relaxed. To maintain proper operation with less losses and to confirm operational flexibility, square lattice multi structure optical fiber is used in these type of multiplexing. Propagation in this fibre is acceptable than conventional fibre, noise level and losses is also low of this fiber. Moreover we can choose the parameters to achieve the desirable dispersion compensation over different communication band and multiplexing technique.

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Small Pumped Storage Hydro Power Plant - A Feasibility Study for MIDC Dhule, Maharashtra

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Abstract - Electrical energy utilization is one of the indicators of development of a country. India targets 9 – 10% economic growth rate in a sustainable manner over next 10-15 years, for which the adequate availability of energy would be crucial. Hence, the country is fully committed to develop and expand its energy generation capacities. The development in small scale development sector has enough potential in country, which are equally beneficial as the large projects are.

The consumption or demand for electricity varies with time in a day. A trough and peak may be observed in demand pattern of electricity. It is not economical to build base load power plant to satisfy the peak demand. The easier way is to increase peak hydropower production by pumping up the already flown water through turbines back to the high reservoir using cheap electricity of trough periods.

Keywords : annual capital cost, hydro power, pumped storage power plant, sensitivity analysis.

GJRE-F Classification : FOR Code: 850503, 660201



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Abstract - Electrical energy utilization is one of the indicators of development of a country. India targets 9 – 10% economic growth rate in a sustainable manner over next 10-15 years, for which the adequate availability of energy would be crucial. Hence, the country is fully committed to develop and expand its energy generation capacities. The development in small scale development sector has enough potential in country, which are equally beneficial as the large projects are.

The consumption or demand for electricity varies with time in a day. A trough and peak may be observed in demand pattern of electricity. It is not economical to build base load power plant to satisfy the peak demand. The easier way is to increase peak hydropower production by pumping up the already flown water through turbines back to the high reservoir using cheap electricity of trough periods. By development of electrical generator which can work as motor and turbines and also as pump when rotation direction is reversed, investment cost of pump storage hydropower has decreased to half and it became economically more attractive. The net effect is to store the electricity produced during the low demand period in the form of potential energy of water, which can be used during peak demand. Pumped water storage is at present the most widely used method of peak satisfaction of electric power systems.

In this paper the economic feasibility of installation of a pumped storage hydroelectric power plant is demonstrated, at MIDC area of Dhule town by taking the advantage of available water at MIDC reservoir and the Laling hills in nearby area. The preliminary survey, planning and design of pumped storage hydro electric power plant for MIDC Dhule is done along with the cost analysis.

Keywords : annual capital cost, hydro power, pumped storage power plant, sensitivity analysis.

I. INTRODUCTION

Hydroelectricity is the term referring to electricity generated by hydropower; the production of electrical power through the use of the gravitational force of falling or flowing water. The hydroelectric power is an excellent source in terms of stable supply and generation cost over the long term. It

is the most widely used form of renewable energy, accounting for 16 percent of global electricity generation – 3,427 terawatt-hours of electricity production in 2010, and is expected to increase about 3.1% each year for the next 25 years.[4]

Hydropower is produced in 150 countries, with the Asia-Pacific region generating 32 percent of global hydropower in 2010. China is the largest hydroelectricity producer, with 721 terawatt-hours of production in 2010, representing around 17 percent of domestic electricity use.[9]

The cost of hydroelectricity is relatively low, making it a competitive source of renewable electricity. Hydro is also a flexible source of electricity since plants can be ramped up and down very quickly to adapt the changing energy demands. Once a hydroelectric complex is constructed, the project produces no direct waste, and has a considerably lower output level of the carbon dioxide (CO₂) than fossil fuel powered energy plants. Almost all the developing and developed nations are facing the crisis of electrical power and environmental problems due to burning of coal in thermal power plants; hence most of them have used nearly all potential sites for constructing large-scale hydroelectric facilities, and currently focusing on development of smaller scale.

The list of the first ten largest producers of hydro electric power is given in Table - 1.[6]

a) Pumped Storage Hydro Electric Power

The pumped storage hydropower plant produces the electricity to supply high peak demands by moving water between reservoirs at different elevations. At times of low demand of electricity, the excess electricity is used to pump the water into the higher reservoir, which is released back into the lower reservoir through turbine at the time of higher demand. The pumped storage schemes improve the daily load factor of the generation system. The small hydro power generation units in the range 1 MW to about 30 MW are available from multiple manufacturers using standardized packages; in which all the major mechanical and electrical equipment (turbine, generator, controls, switchgear), selecting from several standard designs to fit the site conditions are available.[4]

As the gap in demand between daytime and nighttime continues to widen, the electric power companies are developing pumped-storage power

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generation plants to meet peak demand. The share of pumped-storage generation facilities of the total hydroelectric power capacity is growing year by year in many of the developed and developing nations [12]. As electricity is nearly impossible to store in large quantities, electric power companies generate electricity by combining various power sources, considering optimal operational and economic performance, to ensure the fluctuating demand. The thermal, major hydroelectric, liquefied natural gas and nuclear power provides base load supply whereas, the oil and pumped-storage hydroelectric power respond to peak demand fluctuation and contribute to consistent stable supply of electricity.[8]

II. BACKGROUND

Dhule is the district place of Maharashtra India, and is located at the junction of NH-3, NH-6 and NH-211. The industrial zone in Dhule is located in south of the town on left side of NH-3, near village Awadhan. The various industries are located in the area and all the necessary infrastructures for their smooth functioning are provided by Maharashtra Industrial Development Corporation (MIDC). The MIDC own a dam on the Moti Nalla (a local stream), which flows on west side of the area and is the tributary of river Panzara. The capacity of the MIDC reservoir is much more than the water demand of Industries. The electricity to the various industries is supplied by the Maharashtra State Electricity Distribution Company Limited (MSEDCL).

The various industries in MIDC area are the small or medium scale categories, which are working maximum in two shifts i.e. from 8.00 hrs to 16.00 hrs and from 16.00 hrs to 24.00 hrs, thus there is no any demand of electricity for 8.00 hours i.e. from 00.00 hrs i.e from mid night to 8.00 hrs in the morning. However, the MSEDCL supplies the energy to MIDC for their industrial activities for 24 hours as per agreement between both. The electrical energy which is available during the slack period cannot be diverted to other users as the demand does not exist during this period. The rate of electricity during this slack period is too less, sometime less than $1/4^{\text{th}}$ of the rate during the peak hours of demand. The available electricity during the slack hours at cheap rate from 0.00 hrs to 8.00 hrs can be used for pumping operations to store the energy in terms of potential energy of water at higher elevation.

a) Suitability of Geography of Area for Pumped Storage Power Plant

The Laling Hill exists on the south of the MIDC area. It divides the two river basins i.e. Panzara and Bori, which are the tributaries of river Tapi, which is one of the main west flowing rivers of India. The local Nalla which originates from Laling hills flows towards North forms the boundary of MIDC area on west side and meet river Panzara. The MIDC dam is constructed on this Nalla,

and the reservoir is the main source of water supply for MIDC area. This reservoir can be used as the main source of water for pumped storage power plant. During the pumping phase, the water from the reservoir may be lifted to the upper reservoir which may be constructed at Laling hills, in which the water can be stored with potential energy. The stored potential energy in turn can be utilized for generating the electrical energy at lower reservoir level and the water can be discharged back to main reservoir.

The pumping phase may be scheduled during the no business hours in MIDC area, when the electricity is available at cheap rates whereas the generating phase may be scheduled during the peak demand period in MIDC area thus reducing the load on the electrical energy generation system attached to supplying grid. The geography of the area showing the existing and proposed locations of reservoirs is shown in Figure -1.

Table 1 : Largest Producers of Hydro Electric Power

Country	Annual Hydroelectric production (TWh)	Installed capacity (GW)	Capacity factor	% of total Capacity
Brazil	363.8	69.08	0.56	85.56
Canada	369.5	88.974	0.59	61.12
China	652.05	196.79	0.37	22.25
India	115.6	33.6	0.43	15.8
Japan	69.2	27.229	0.37	7.21
Norway	140.5	27.528	0.49	98.25
Russia	167	45	0.42	17.64
Sweden	65.5	16.209	0.46	44.34
United States	250.6	79.511	0.42	5.74
Venezuela	85.96	14.622	0.67	69.2

III. DATA COLLECTION

a) Survey

The survey is conducted by using a total station meter. The contouring is done at the proposed site of power house and upper reservoir and contour maps are prepared. The level survey of the proposed pipe route is done, in which the RLs are taken at an interval of 30 meters, in addition to all prominent points such as peaks of levels and bottom RLs of Nallas on the route of pipe and the drawing of L-section is prepared. During the survey, the information regarding the strata classification is also collected.

b) Reservoir

The catchment area of the Moti Nala at dam site is 19.16 sq kms. The dam is planned and prepared considering 75% dependable rainfall i.e. 498.90 mm, for 65 years life. The gross storage capacity of the dam is 1698.72 Thousand Cubic meter and the live storage capacity is 1455.236 Thousand Cubic meter.

IV. PROPOSAL

As per outcome of the final survey and the information regarding the levels in dam, the planning for the pumped storage power plant is done. The schematic diagram with the different components of proposed pumped storage hydro electric power plant is shown in Figure - 2.

The salient features of the proposed pumped storage power plant are as under;

- [a] In the proposal, the MIDC reservoir is considered as lower reservoir and is the primary source of water. The upper reservoir is proposed at the top of Laling hills.
- [b] A three unit pumped storage installation is proposed. It consist of the three units i.e. Pumping Unit, Generation Unit and Common Rising Main and Penstock
- [c] The existing jack well and the pump house constructed above it can be used for installation of pumps. Hence, the same is proposed to accommodate the pumping unit.
- [d] The site for the proposed power house, which will accommodate the turbine is selected 210 m away from the submergence of reservoir with sufficient free board above the high flood level on plain ground. An area of 100 m x 100 m is available, which is quite enough to house the power station.
- [e] The Pelton turbine is proposed along with the other necessary installation for which 30 x 30 m constructed area is enough.
- [f] The length of proposed route of pipe from jack well to the upper reservoir is 4933 m, which is along the left bank of Moti Nala from MIDC reservoir to Laling Hills. The ground RLs are steadily rising with moderate gradient towards the foot of Laling hill and thereafter with steep gradient up to the top of Laling hill.

[g] The site for upper reservoir ground is plain and an area of 200 m x 200 m is available which is quite enough than required.

[h] The obligatory levels for the planning and designing of the power plants are taken as under;

- Minimum water level in the lower reservoir = 94.325 m.
- Ground level at power house = 100.167 m\
- Ground level at upper reservoir level = 401.110 m

The following assumptions are made for in the planning and designing of hydro electric power system.

[a] The Pre-stressed Concrete Cylinder Pipes is selected as penstock/rising main.

[b] The Darcy Weisbach Equation is used for calculation of head loss through rising main/penstock. The value of f in which is considered as 0.012.

$$H_f = \frac{f \cdot L \cdot Q^2}{12.10 d^5}$$

Where; f = Darcy Weishbach Friction Factor = $\square$ (in ner surface condition of pipe, pipe material), Q = Discharge m^3/s , H_f = Friction Loss in m, L = Length of Rising Main / Penstock in m, d = Internal Diameter of Rising Main/Penstock in m

[a] The capacity of the upper reservoir is taken as the 5% of the live storage capacity of reservoir. Another constraint for fixing the capacity of reservoir is the availability of land for construction of reservoir at Laling hills. The plain land of size 200 m x 200 m is hardly available over here.

[b] The unit rate of electricity during off peak hours is taken as Rs.2.50 per kWh.

[c] The unit rate of electricity during peak hours is taken as Rs.9.00 per kWh.



Figure 1 : Geography of Area showing Existing and Proposed Locations of Reservoirs

V. DESIGN

a) Design and Economical Diameter of Rising Main

The pumping system is designed for 9.30 hours of pumping as the excess electricity is available for this

period. The schematics diagram showing the levels of lower reservoir from which the water is to be lifted to upper reservoir, where the water is to be stored for generation is shown in Figure - 2.

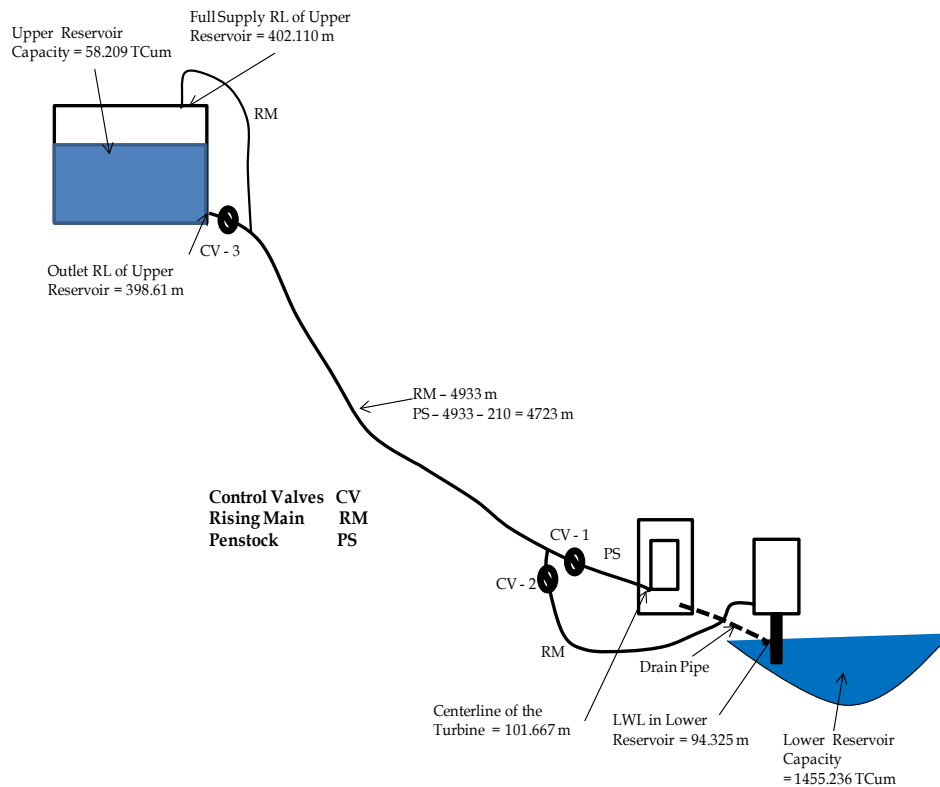


Figure 2 : Schematic Diagram showing the Pumping & Generating System

The annual water requirement for MIDC area for industrial and other activities is 280.000 TCum whereas for pumped hydroelectric power generation the water in circulation is 58.209 TCum, which is very less as compared to live storage capacity of MIDC reservoir.

As the gross head is around 299.40 m, it is decided to use the pre stressed concrete cylinder pipe (PCCP) of class 30.00 kg/cm² is considered. The economical diameter of the rising main is calculated by considering the different diameters of pipe ranging from 600 mm to 1300 mm. The pipes made of other materials are not considered while calculating the economical diameter. The cost calculations are done by considering the following data –

- Rate of Interest – 10%
- Useful life of Pumps – 20 years
- Useful life of Pipe – 40 years
- Period of Analysis – 40 Years
- Rate of Pipe – As per DSR of MJP 2011-12.

A plot of annual cost of pump, pumping and rising main versus diameter is shown in Figure - 3. It is clear from the plot that the annual cost is minimum corresponding to 900 ~ 1000 mm, hence economical diameter of the pipe is considered as 900 mm. The

design and cost analysis of the rising main and pumping system is shown in the Appendix – A.

b) Selection of Turbine

The schematic diagram of generation and pumping system is shown in Figure - 2. A three unit pumped storage power system is proposed, which consist of Rising Main / Penstock, Pumping System and Turbine & Generation System.

The generation phase is designed to fulfill the demand during the peak hours. In the present case the demand at the peak hours of MIDC is not taken into consideration. The availability in the market of turbine-generator system is considered as criteria for the same. The gross head on the turbine is 299.940 m. The Pelton wheel of make "Litostr & Jpower" with two nozzles is selected which is suiting to the available head. The pitch diameter of the selected turbine is 1170 mm and its output under the net head of 233 m is 4140 kW. The design and cost analysis of the generating system is shown in the Appendix -B.

VI. COST ANALYSIS

The annual operation cost for running the plant on salaries of technical and non-technical staff

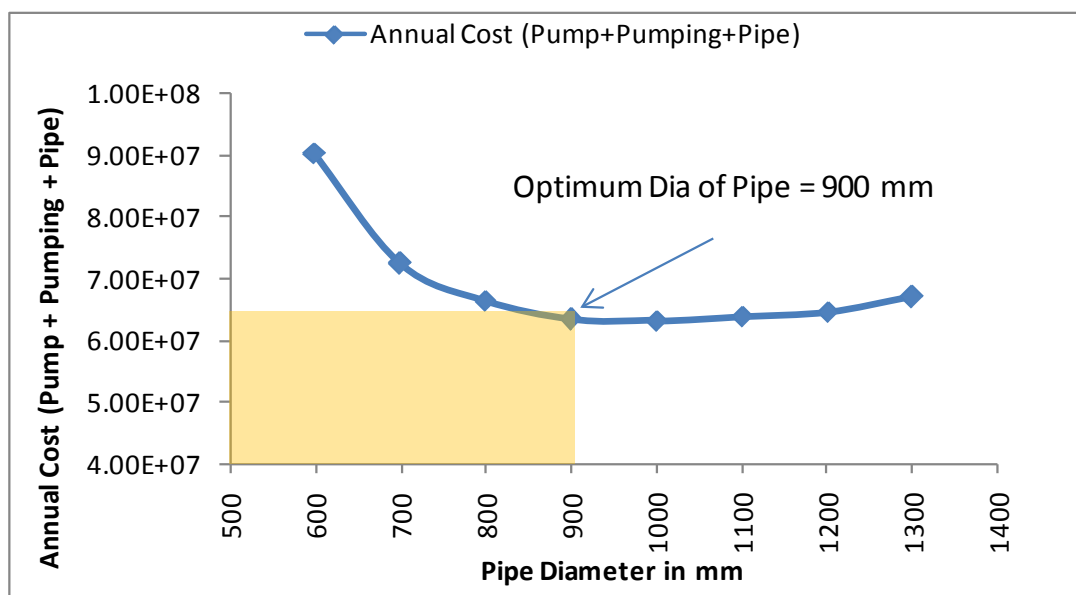


Figure 3 : Economical Diameter of Pipe

excluding the maintenance and energy cost which is already taken into account) is Rs.1332000.00. The cost estimate of the upper reservoir is done for which the annual cost including maintenance is estimated as Rs.3750152.18. The capital cost of power house building is estimated on the basis of unit cost per unit area @Rs.8000.00 per sqm. The annual cost of which is calculated as Rs.722372.47.

All the annual costs estimated are summarized as under;

Annual Cost of Pumps (In both Phases)	Rs	986068.52
Annual Cost of Pumping	Rs	54312000.00
Annual Cost of Penstock/Rising Main	Rs.	8193101.62
Annual Cost of Turbine & Generator	Rs.	1217142.68
Annual Cost of Power House	Rs.	722372.47
Annual Cost of Upper Reservoir	Rs.	3750152.18
Annual Administration Cost (Operation)	Rs.	1332000.00
Total Annual Cost	Rs.	70512837.46

The annual earnings from the sale of electrical units during the peak hours is **Rs. 74268101.25**. Thus net annual benefit from the project is Rs.3756263.78, which exhibit the financial feasibility of project.

VII. SENSITIVITY ANALYSIS

The net annual benefit depends upon many external factors. Some of the financial parameters such as rate of interest and the rates of purchase of electricity during pumping and rate of sale of electricity generated are important, which directly affects the net annual benefits.

a) Rate of Interest

The rate of interest with which the money will be borrowed from the financial institutions do have direct impact on the net annual benefits of the project and thus its affect should be critically studied. The net annual benefits corresponding to different rates of interest varying from 6% ~ 14% is shown in Figure – 4, which explains that the economical feasibility of the project lies at the rate of interest below 12.75%, which if increases beyond this, the annual benefits becomes negative i.e. loss.

b) Unit Rate of Electricity during Pumping and Generation

The rates of purchase of electricity during the slack hours for pumping and rate of sale of electrical units during the peak hours for generation affects the net annual benefits. The sensitivity of the annual benefits for variation in the purchase and sale rates of electrical units is tested and is shown in Figure – 5 and 6. The effect on net annual benefit is estimated by varying the rates of purchase of electricity during pumping from Rs.2.30/kWh to Rs.2.80/kWh. It is clear that the economical feasibility of the project is possible only if the electrical units are available at the rate of Rs.2.67/kWh or less than that and at the same time the unit price of the sale of generated electricity during peak period is Rs.9.00/kWh.

The effect on net annual benefit is estimated by varying the rates of sale of generated electricity from Rs.8.45/kWh to Rs.9.00/kWh. It is clear from the plot that the economical feasibility of the project is possible only if the sale of electrical units is at the rate of Rs.8.55/kWh or more than that and at the same time the unit cost of the electricity to be purchased during slack hours for pumping is Rs.2.50/kWh.

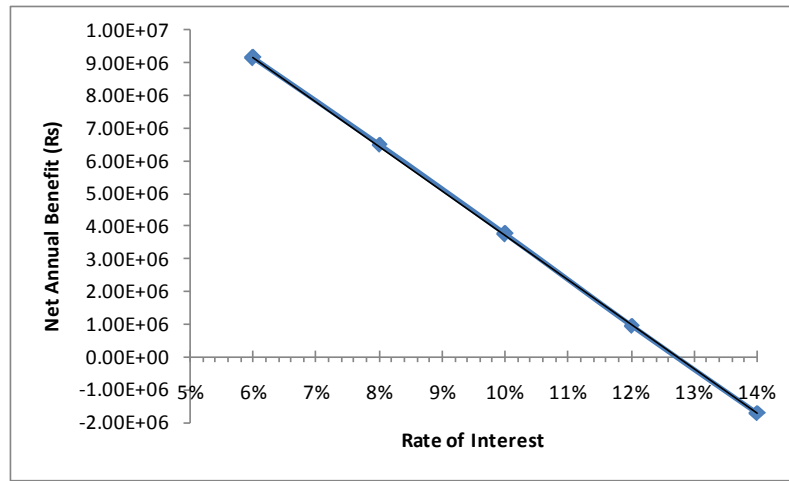


Figure 4 : Sensitivity Analysis – Rate of Interest

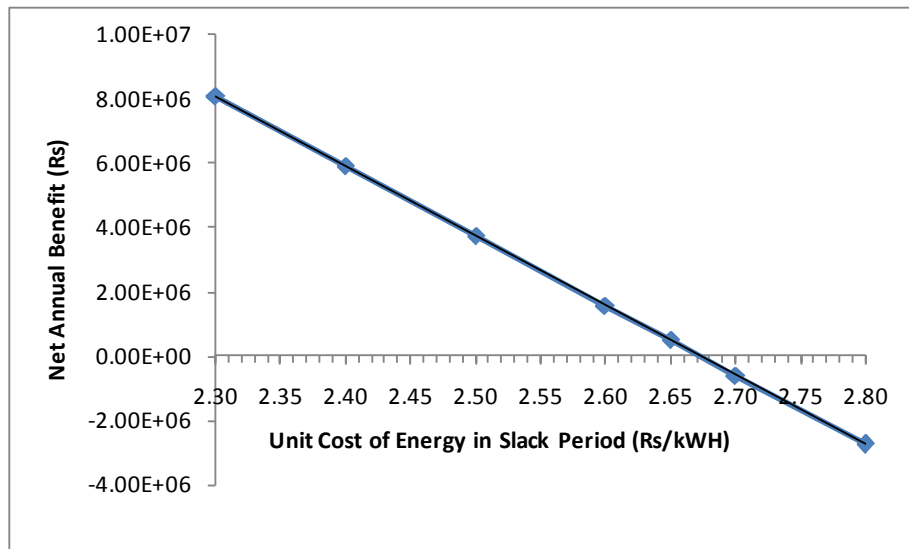


Figure 5 : Sensitivity Analysis – Rate of Electricity in Pumping Phase

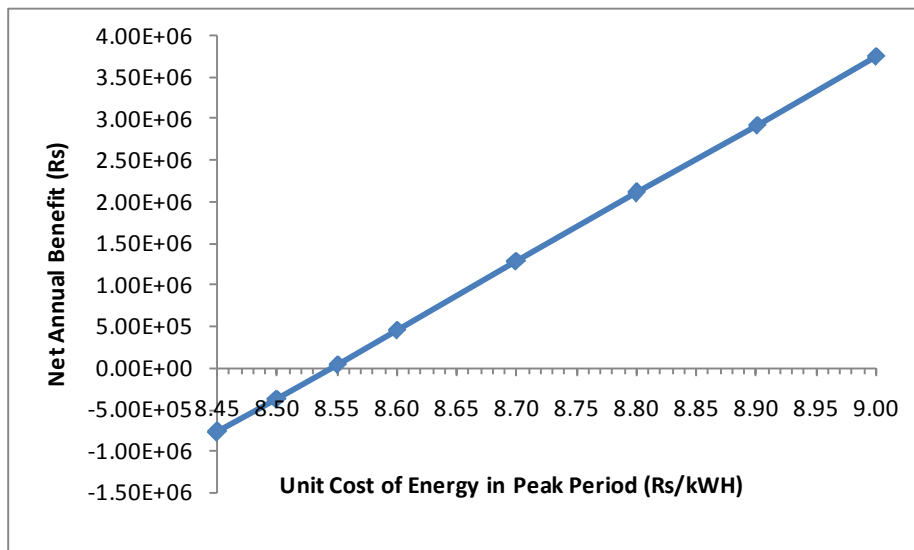


Figure 6 : Sensitivity Analysis – Rate of Electricity in Generating Phase

VIII. CONCLUSIONS

The main aim of work is to prepare a detailed engineering plan, preliminary estimate for installation of pumped hydro electric power plant and to check its economic feasibility, which includes a detailed planning, designing along with the cost analysis. The following conclusions are drawn from the study -

- (i) The optimum diameter of the pipe as rising main is obtained from economical analysis as 900 mm and the same is proposed as penstock. The pipe proposed is pre stressed concrete cylinder pipe (PCCP).
- (ii) The vertical turbine pumps totaling 6400 kW are proposed for pumping water from lower to upper reservoir.
- (iii) The Pelton wheel of make "Litostr & Jpower" with two nozzles is selected as turbine. The pitch diameter of the selected turbine is 1170 mm and its output under the net head of 233 m is 4140 kW.
- (iv) The total annual cost of the project is Rs.7,05,12,837.46, which is calculated on the basis of 10% rate of interest and 20 years life of pumping machineries, 40 years life of turbines and 60 years life of upper reservoir and pump house. The unit cost of electricity is considered as Rs.2.50/kWh for pumping and the sale price of generation during peak hours is Rs.9.00/kWh.
- (v) The annual earnings from the sale of electrical units during the peak hours is **Rs. 74268101.25**. Thus net annual benefit from the project is Rs.3756263.78, which exhibit the financial feasibility of project.
- (vi) The economical feasibility of the project lies at the rate of interest below 12.75% as concluded from the sensitivity analysis. In the case, the rate of interest increases beyond 12.75%, the annual benefits becomes negative i.e. loss.
- (vii) The sensitivity analysis exhibit that the project is economically feasible only if the electrical units are available at the rate of Rs.2.67/kWh or less than that and at the same time the unit cost of the generated electricity is Rs.9.00/kWh.
- (viii) The annual cost on different as % of the total annual cost is shown in the Figure 7, which indicates the annual cost of pumping have the maximum share i.e. 85.92%.

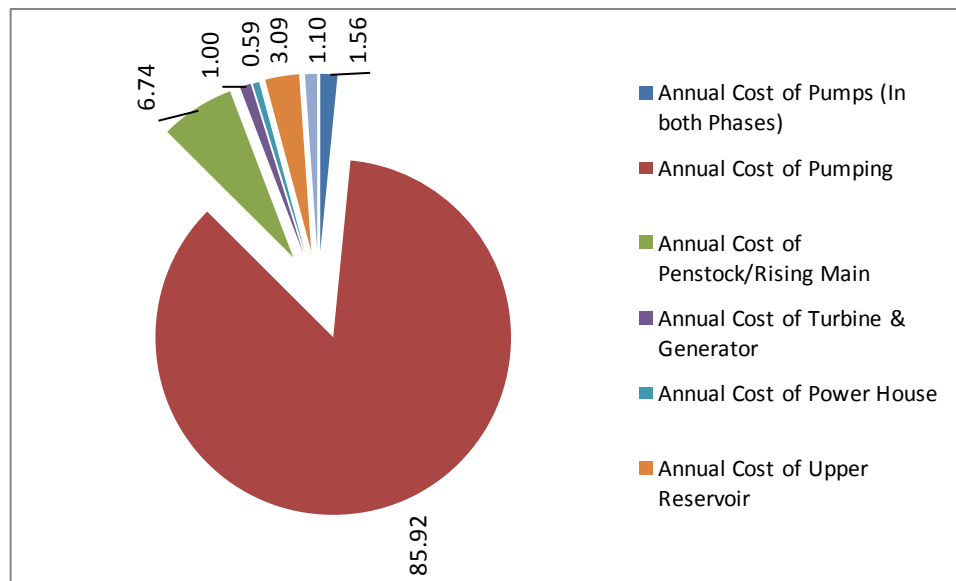


Figure 7 : Distribution of Annual Cost

a) Limitation of Study

In this analysis the actual demand pattern of the electricity in and around the MIDC area is not considered. The sensitivity of the net annual benefit is verified for rate of interest, unit rate of electricity for pumping and unit rate of electricity generated. There are many other factors for which the sensitivity analysis would have revealed more realistic results such as size of the upper reservoir, rate of construction, hours of pumping (i.e. availability of electricity in slack period), change in operation and administration cost and many more. In the present case the rate of inflation is also not taken into account.

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APPENDIX

Appendix - A : Design and Cost Analysis of Economical Diameter of Rising Main

RISING MAIN -		
Live Storage Capacity of the MIDC Reservoir	1455.236	TCum
Live Storage Capacity of the MIDC Reservoir	1455.236	TCum
Gross Volume of Water Available for generation of Electricity in one cycle @ 5%	72.762	TCum
Gross Volume of Water Available for generation of Electricity in one cycle with 20% Loss	58.209	TCum
Pumping Hours	9.30	Hours
Discharge through Rising Main	1.739	m ³ /s
Length of Rising Main (from Survey Record)	4933	m
Static Head	306.785	m
Type of Pipe Selected & Friction Factor	PCCP/0.0120	
Inner Diameter and Wall Thickness	900.00/27.50	mm
Total Head including frictional losses	367.50	m
Water Hammer Pressure	391.79	m
Suitable Water Hammer control devices are recommended at U/S of turbine		
Safe Time for Closure of Valve	148.73	seconds
PUMPING MACHINERY -		
Total Discharge of Pump	1.739	m ³ /s
Total Head on Pump (Rounded up)	337.00	m
Efficiency of pump & motor (%)	90.00	
Power required (Roundup)	6400.00	kW
COST ANALYSIS -		
Annual Maintenance Cost for Pumps(as fraction of Annual Capital Cost)	0.08	
Annual Maintenance Cost for Pipes(as fraction of Annual Capital Cost)	0.025	
Total Number of Electrical Units to be consumed by pumps per cycle	59520.00	kWh
Unit Cost of Electrical Unit during off Peak Hours	2.50	INR/kWh
Cost of Electricity Consumed/Day	148800.00	INR
Cost of Electricity Consumed/Year	54312000.00	INR
Unit Cost of Pumps including the Cost of Electrical Items & Connection Cost	1000.00	INR /kW
Capital Cost of Pumps (0-20 Years)	6400000.00	INR
Present Value of Capital Cost of Pumps (21 - 40 Years)	1373108.53	INR
Annuity Factor	8.51	
Annual Cost of Pumps	913026.41	INR
Annual Maintenance Cost	73042.11	INR
Annual Pumps Cost including Maintenance	986068.52	INR
Annual Cost of Pumps and Pumping	55298068.52	INR
Unit Cost of Pipes	10223.00	INR/m
Cost of Excavation, Lowering, Laying and Jointing (as fraction of unit cost of pipe)	0.30	
Cost of Fittings such as WH Control, Valves etc (as fraction of unit cost of pipe)	0.25	
Gross Unit Cost of Pipe	15845.65	INR/m
Gross Cost of Pipe	78166591.45	INR
Annuity Factor	9.78	
Annual Cost of Pipes including fittings, excavation, lowering, laying and jointing	7993269.87	INR
Annual Maintenance Cost	199831.75	INR
Annual Pipe Cost including Maintenance	8193101.62	INR
Annual Cost of Pumps, Pumping and Pipe (Rising Main)	63491170.14	INR

Appendix - B : Detailed Calculations & Cost Analysis of Generating System

TURBINE & GENERATOR SYSTEM -		
Gross Head on Turbine = H	296.942	m
Maximum Head Loss for Optimum Power = $H_f = H/3$	98.981	m
Calculation of Discharge : $Q = P / \{9.81 \times (H - H_f)\}$	2.132	Cum/s
Live Capacity of Upper Reservoir	58.209	Tcum
Actual Time of Running of Turbine	27305.017	s
Actual Time of Running of Turbine	7.585	Hours
Rated Power of Selected Pelton Turbine	4140.00	kW
Efficiency of Turbine System "Eff(T)"	80.00%	%
Power "Pa" - Actual = Eff(T) x Theoretical Power	3312.00	kW
Efficiency of Electricity Generation System "Eff(G)"	90.00%	%
Electrical Power "Pae" - Actual = Eff(G) x Pa	2980.80	kW
Period of Generation	7.585	Hours
Electrical Units Generated in One Cycle of Operation	22608.55	kWH
COST ANALYSIS -		
Unit Cost of Electrical Unit during Peak Hours	9.00	INR/kWH
Value of Electricity Generation/Day	203476.99	INR
Value of Electricity Generation/Year	74269101.25	INR
Unit Cost of Turbine & Generators including the Cost of Electrical Items & Connection Cost	2500.00	INR
Cost of Turbine & Generators including the Cost of Electrical Items & Connection Cost	10350000.00	INR
Annual Maintenance Cost for Turbines (as fraction of ACC)	0.15	
Annuity Factor	9.78	
Annual Cost of Turbine Generator Set	1058384.94	INR
Annual Maintenance Cost	158757.74	INR
Annual Cost of Turbine Generator Set including Maintenance	1217142.68	INR



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Green Electricity Generation: Prospective Analysis on Proposed Padma Bridge, Bangladesh

By T. Ghosh, N. Paul, P.K. Halder, S. Rahman & P. Mondal

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Abstract - Energy is one of the indispensable inputs for the existence of human being in the earth. The socio-economic development, industrialization and civilization of any country depend on reliable energy supply. Great deal of effort is going on for energy generation mainly for finding eco-friendly energy sources. Natural gas, coal and petroleum products are facing pressure of rapid diminishing to meet this increasing energy demand. Meanwhile wind and hydro power have less possibility in Bangladesh. Nuclear power can be a huge source of clean energy. But huge investment with high end technology along sophisticated maintenance and danger of possible accident makes it very difficult and vulnerable for a country like Bangladesh. Solar shows good prospect. But piezoelectric materials, a potential source of power harnessing, can be utilized effectively in a developing country like ours. This paper outlines the electricity generation from highway using piezoelectric materials. Proposed Padma Bridge, linking the south-west of the country to northern and eastern regions, is the place for implementing the proposed project. All calculations are focused on this Bridge but this project can be implemented in any roadside too.

Keywords : piezoelectric, PZT, chopper circuit, inverter, MOSFET.

GJRE-F Classification : FOR Code: 090699



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Keywords : piezoelectric, PZT, chopper circuit, inverter, MOSFET.

I. INTRODUCTION

There is a close relationship between the level of energy consumption in a country and its economic development. The energy consumption in the world has been growing at an alarming rate. The energy crisis is becoming the main problem to mankind facing today due to rapid depletion of non-renewable energy resources like fossil fuels, oils and natural gases [1]. In a third world country like ours, there is always a tug-of-war between limited resources and unlimited public demand.

Despite the audacious effort of our govt. to make Bangladesh a Load-shedding free country, it seems to be a day-dream unless there is some contribution from other innovative sources. Power generators often use fossil fuels like gas, oil which are not unlimited on earth. A recent survey shows that the proven probable natural gas reserves in the country is

as much as 28.8567 Trillion Cubic Feet (TCF), although the actual reserve of this most important fossil fuel of Bangladesh has not yet been ascertained [2, 3]. Fuel costs for generators are significant and extreme heat emission and sound pollution from the radiator make the generators environment unfriendly. Again total storage capacity of petroleum products (Diesel, kerosene, petrol and octane) in the country is 687,500 tons which is only 8% of the total demand [4]. But renewable sources like sunlight and piezoelectric material are free as well as unlimited and of course, make environment friendly generation of power. Moreover, less maintenance cost and robustness makes renewable energy the favorite fuel for generation of power.

Piezoelectric materials are a potential source of energy that has never been used in Bangladesh before for power generation. But once implemented properly, it can serve as a perpetual source of energy. This material is gaining an upsurge trend in other country.

II. PIEZOELECTRIC ENERGY

The piezoelectric effect is understood as the linear electromechanical interaction between the mechanical and the electrical state in crystalline materials with no inversion symmetry. Energy harvesting from piezoelectric elements are becoming popular. Input vibration or pressure causes mechanical strain in the device that is converted to electrical charge. For power generation Lead-zirconate-titanate, commonly known as PZT, is used though there are over 200 piezoelectric materials that could be used for energy harvesting [5, 6]. Figure 1 shows piezoelectric materials.

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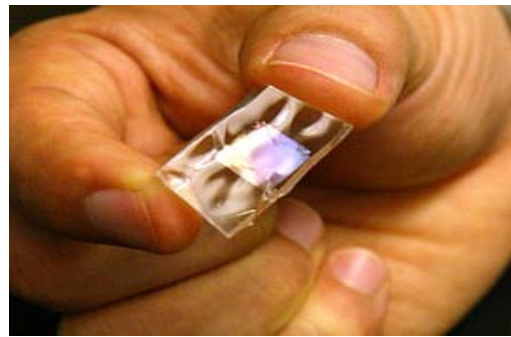
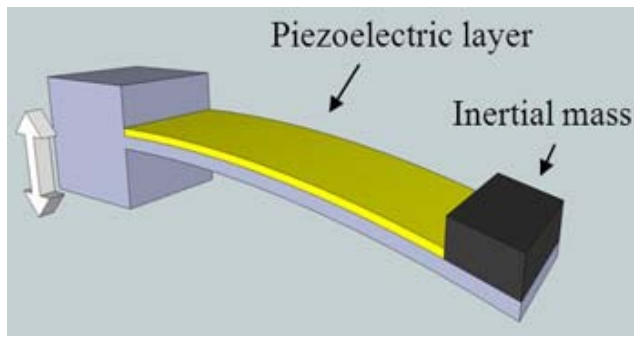


Figure 1 : Piezoelectric Materials[7, 8]

III. MECHANISM

The nature of the piezoelectric effect is closely related to the occurrence of electric dipole moments in solids. Of decisive importance for the piezoelectric effect is the change of polarization P when applying a mechanical stress. This might either be caused by a re-configuration of the dipole-inducing surrounding or by re-orientation of molecular dipole moments under the influence of the external stress. Piezoelectricity may then manifest in a variation of the polarization strength, its direction or both, with the details depending on (a) the orientation of P within the crystal, (b) crystal symmetry and (c) the applied mechanical stress. The

change in P appears as a variation of surface charge density upon the crystal faces, i.e. as a variation of the electrical field extending between the faces, since the units of surface charge density and polarization are the same, $[C/m^2] = [Cm/m^3]$. However, piezoelectricity is not caused by a change in charge density on the surface, but by dipole density in the bulk. For example, a 1 cm^3 cube of quartz with 2 kN of correctly applied force can produce a voltage of 12500 V . The simplest and most compact method of obtaining high voltage from the piezoelectric was to compress it axially. The compression was quasi-static, so that the dynamic mechanical processes need not be considered. [9]

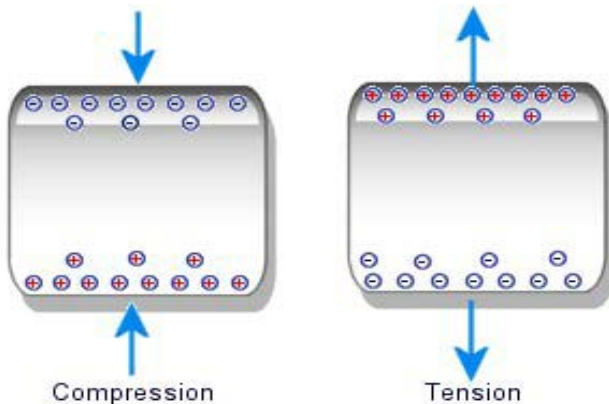


Figure 2 : Charge accumulation in piezoelectric material as pressure is applied externally [10,11]

The constitutive equations are:

$$S_j = s_{kj}^E T_k + d_{im} E_m \quad (1)$$

$$D_i = d_{im} T_m + \epsilon^T E_m \quad (2)$$

Or equivalently:

$$S_j = s_{ki}^D T_k + g_{nj} D_n \quad (3)$$

$$E_n = \beta_{mn}^T D_m - g_{nj} T_j \beta_{mm} = \epsilon_{mm}^{-1} \quad (4)$$

where s^D is the open-circuit compliance defined by:

$$S^D = S^E - d_{jk} d_{mi} (\epsilon_{mj}^{-1}) \quad (5)$$

g is the piezoelectric voltage coupling, d contains the piezoelectric coupling terms which relate the electrical and mechanical properties of the material,

S is the strain dimensionless), D is the electric displacement or charge density (C/m^2), E is the electric field (V/m), and T is the applied stress (N/m^2).

Considering the simple case of a cylindrical piezoelectric element, which is compressed axially in the z -direction, there are two cases of specific interest. The first one is when the electrodes at each end of the element are short-circuited together. In this case, $E_3=0$ and the charge produced by the piezoelectric element can be calculated readily from Eq. (2)

$$Q = D_3 A = d_{33} T_3 A = d_{33} F \quad (6)$$

Where F is the applied force, A is the cross-sectional area of the element and the subscripts refer to the location in the respective matrices. Note that the

force cannot be increased indefinitely due to a nonlinear piezoelectric effect in the short circuit case, which can lead to irreversible depolarization of the piezoelectric element. This effect occurs when the mechanical stresses in the piezoelectric element are sufficient to cause changes in the ferroelectric domain boundaries. The other case of interest is when the electrodes are open-circuit, so that no charge displacement is possible and $D_3 = 0$. The voltage V developed across the piezoelectric material when the force is applied can be calculated using Eq. (4)

$$V = E_3 l = -g_{33} T_3 l = -g_{33} \frac{Fl}{A} = -\frac{d_{33} F}{C_0} \quad (7)$$

Where C_0 is the capacitance of the unstressed piezoelectric element. From Eq. (4) & (7) the voltage V across the piezoelectric and load capacitances is given by

$$V = E_3 l = -g_{33} T_3 l = -\frac{C_L l}{\epsilon_{33} A} V \quad (8)$$

So that

$$V = -\frac{g_{33} T_3 l}{\frac{C_L}{C_0} + 1} = \frac{V_{oc}}{\frac{C_L}{C_0} + 1} \quad (9)$$

Where V_{oc} is the open-circuit voltage that would have been obtained without the load. The efficiency, η with which the piezoelectric energy is transferred to the load is given by

$$\eta = \frac{\frac{1}{2} C_L V^2}{\frac{1}{2} C_0 V_{oc}^2} = \frac{\frac{C_L}{C_0}}{\left(\frac{C_L}{C_0} + 1\right)^2} \quad (10)$$

Equation (10) is shown graphically in Fig. 3. The maximum charging efficiency is 25 % and occurs when the load and piezoelectric capacitances are equal. The equivalent circuit for piezoelectric generator is

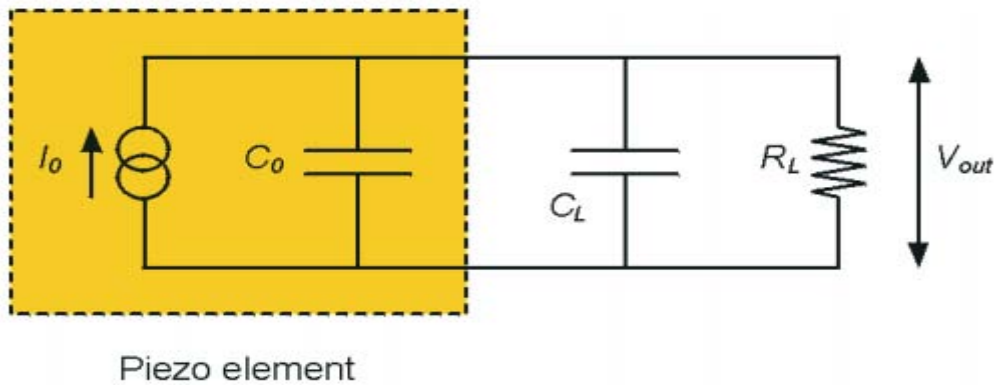


Figure 3 : Equivalent circuit of piezoelectric material when stressed

IV. PROPOSED PROJECT

The following diagram shows the proposed plan for power generation from Padma Bridge which can also be utilized in any bridge or road side for green electricity generation.

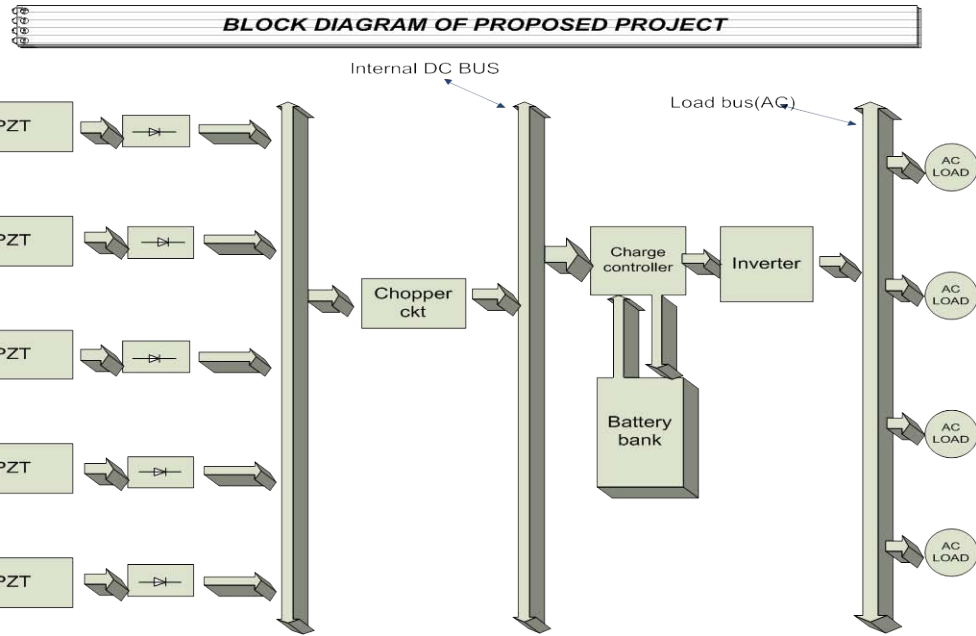


Figure 4 : Proposed Plan

a) Required Materials

In this scheme of power generation required materials are; PZT Pad, chopper circuit, battery bank, charge controller and inverter.

i. PZT pad

PZT pad will be installed within the road track under the pitch layer. When the vehicles run over the

PZT pad, it will extract the mechanical energy and convert it into usable electrical energy. The vehicles pressure deforms the piezoelectric materials and providing a small amount of electrical charge. This pad is actually capturing wasted energy, energy that was previously just heat lost.

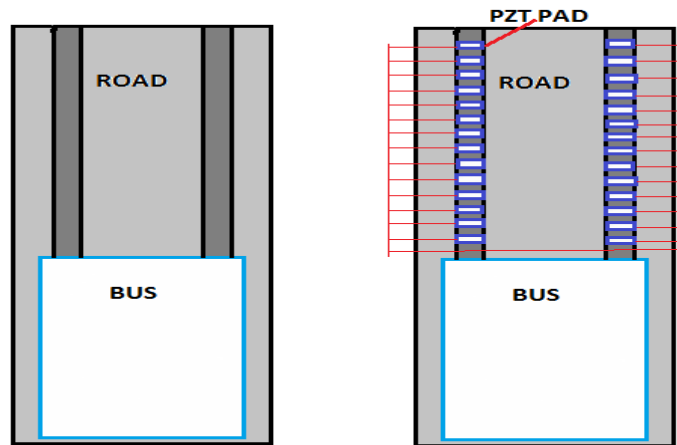


Figure 5 : PZT pad

ii. Chopper Circuit

Chopper circuit is commonly known as DC to DC converter circuit. At the terminals of the PZT pads, very high voltage up to 150kV is generated. It is difficult to work with and store energy at this high voltage. That

is why we need to lower the high DC voltage to a value at which the energy generated can be stored at the battery bank. For this reason, chopper circuit is needed.[12]. A simplified chopper circuit is:

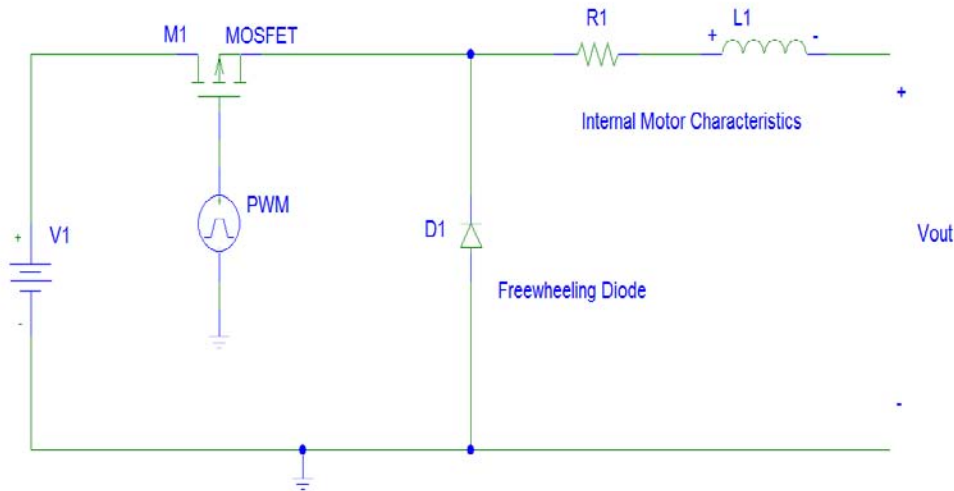


Figure 6 : Simplified chopper circuit

iii. Battery Bank

Battery bank is an important component of our power scheme. The power scheme does not always generate energy. Sometimes it generates excess energy and sometimes it does not energy at all. To deliver

energy to the load all the time and to utilize the excess energy, battery bank is a must. It doesn't matter how much power we generate - if it is not stored safely and efficiently then we will have no electricity when we need it.



Figure 7 : Practical battery bank [13]

iv. Charge Controller

Charge Controller is needed to prevent overcharging of the batteries. Proper charging will prevent damage and increase the life and performance of the batteries. In this power scheme, charge controller is used to control the flow of energy. When piezoelectric materials are generating energy, charge controller connects the battery bank with the piezoelectric

materials and battery is charged. The battery bank also delivers energy to the load through charge controller. We have used PWM type charge-controller to reduce the controller cost.

The rating of charge controller used in this proposed project is 48V as the battery is charging at that voltage.

v. Inverter

The inverter is one of the most important and most complex components of an independent system. The inverter converts DC to AC, and also changes the voltage. In other words, it is a power adapter. DC flows in a single direction. AC alternates its direction many times per second. [14]. The standard DC voltages for home-size systems are 12, 24 and 48 volts. The standard for AC utility service in USA is 120 and 240 volts at 60 Hertz (cycles per second). In Europe and some countries in Latin America, Asia and Africa, it's 220V at 50 Hertz.

Here the power scheme is to produce 220VAC at 50Hz from 48V. Inverter is selected with such rating.

V. POWER CALCULATION

Each of the PZT pad will eventually face the force of the whole Bus. So the approximated force on each PZT pad is equal to the weight of the vehicle.

Approximate weight of medium size vehicle is 5 Ton. And each boggy has four wheel. So, weight on each wheel, $F = 1.25\text{Ton} = 1.25 \times 9.8 = 12.25 \text{ kN}$.

For PZT, $d_{33} = 390 \times 10^{-12} \text{ C/N}$.

So, Charge accumulated in one PZT unit = $d_{33} \times F = 4.778 \mu\text{C}$.

Due to depolarization effect of the piezoelectric material, the charge accumulation exceeds the theoretical value and becomes $= 5 \mu\text{C}$.

This charge is accumulated in one PZT crystal with 15mm diameter and 20mm length.

So, no of PZT crystals in one PZT pad = 100 unit
Charge accumulated = $100 \times 5 = 0.5 \text{ mC}$

If we install PZT pad on every 1m, then total number of PZT pads are installed in 6150m (length of proposed Padma bridge) in one lane = $2 \times 6150 = 12300$

There are four lane so total number of PZT pads = $12300 \times 4 = 49200$

So total charge accumulated when one vehicle passes, $Q = 49200 \times 0.5 \text{ mC} = 24.6 \text{ C}$

Now, the intrinsic capacitance of one PZT unit = 135 pF

So, total intrinsic capacitance for one PZT pad = 13.5 nF

For stability of the system, capacitor equal magnitude of total intrinsic capacitance is connected parallel with the PZT pad.

So, the output voltage becomes, $V = 37.04 \text{ kV}$.
[From Eq. 9]

Energy generated for one vehicle = $V \times Q = 911.18 \text{ kJ} = 0.253 \text{ kWh}$

Let a Padma bridge receives 16272 vehicles a day in 2018 [15]. So per hour 678 vehicles

Then the energy generated in one day is = 171.534 kWh .

Let the efficiency of Chopper Circuit = 0.9

Efficiency of charge controller = 0.9

Efficiency of Inverter = 0.94

So output energy = $0.9 \times 0.9 \times 0.94 \times 171.534 = 130.606 \text{ kWh}$

VI. CONCLUSION

The main purpose of the proposed project is to generate piezoelectricity from highway road to supply its own electricity demand. As an example, proposed Padma bridge is taken. The sufficient calculation shows that this is an effective way to produce electricity through the road vehicles movement to support the bridge own electricity demand. All the calculations are considered for the Proposed Padma Bridge in Bangladesh. Although this project is costly but at the long run it is fruitful. This project can be implemented at any road side too. In Bangladesh, there is a total 21,481.25 Km road including national and regional highway and Zilla road. Huge number of bridges and culverts are also available amounting 18258 [16]. This project can effectively also be utilized in railway track as Bangladesh railway covers a length of 2855 km including 3650 bridges. [17]

Again further development can be made as hybrid power generation. This piezoelectricity along with solar cell or wind can be utilized as electricity source for large power generation.

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Allocation of Transmission Losses in a Deregulated Power System

By Ch.Chengaiyah & P.Jyoshna

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Abstract - This paper focuses on the problem of Transmission loss allocation in a power system. It is a centralized issue in today's deregulated market. Due to non linear nature of line flows, it is necessary to allocate the real power losses effectively without affecting the market participants. In this paper a simple novel methodologies are proposed to allocate the real power losses to the market participants by using simple circuits' laws and loss formulae. These methodologies are tested on IEEE 5-Bus and IEEE 30-Bus systems. The simulation results are compared by using MATLAB environment and analyzed.

Keywords : bus wise Loss allocation method, deregulation, postage stamp method, proportional sharing principle method, transmission loss allocation.

GJRE-F Classification : FOR Code: 090699, 290901



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Allocation of Transmission Losses in a Deregulated Power System

Ch.Chengaiiah^α & P.Jyoshna^σ

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I. INTRODUCTION

Deregulation has brought many market configurations and created competition among them in the electricity business. Transaction of electric energy may take many forms like bilateral contracts, power exchange or power pool. Since in deregulated power system generators and loads are connected to the same network, actions by one participant can have significant effect on others making it difficult to allocate the losses .So there is a need for allocating losses to the market participants in a more satisfactory and transparent mechanism. Market participants whether they are generators or consumers want to allocate the loss in more practical way and it is able to reflect each participant's contribution of generation or usage in the network.

In a deregulated power system transmission loss pertains to allocate the cost associated with losses to individual suppliers, generators and contracts of the network. Loss allocation does not affect generation levels or power flows and it is about the distribution of revenues and payments at the network buses among suppliers and consumers and every supplier has to supply the power they want to sell plus the transmission loss corresponding to that transaction. Transmission loss allocation became contentious issue as it corresponds to a huge amount of money. Transmission loss is a highly nonlinear function of line flows. If linearization techniques are used to allocate flow of a given line to generators and loads, the cross terms

associated with quadratic functions doesn't allow assigning losses to generators and consumers in a unique manner. The main problem associated with loss allocation is the fact that transmission loss is a non-separable entity. If any attempt is made to separate it, becomes further complicated by its nonlinear nature.

The challenge facing by a typical power pool and an Independent System Operator (ISO) in [1] is how to allocate the transmission loss and what should be the criterion for charging other utilities. Utilities in general look for locational signal, consistency, simplicity, accuracy and predictability in a loss allocation method. It is extremely hard task to accommodate all these considerations in complex phenomenon of transmission loss allocation. So, in a deregulated environment the economic and market related factors are important as technical factors. In this environment not only accurate calculations but fair and equitable allocation of losses to the stake holders are also important. Hence the issue power loss allocation within the deregulated market still remains an unsolved set back to progress to a fully competitive electricity market. Based on these problems, simple novel methodologies are proposed to allocate the losses transparently, which is illustrated in subsequent sections.

II. METHODOLOGIES

a) Postage stamp method

Postage stamp (P.S) method is the simplest and easy to implement the methodology of transmission loss allocation [2]. It is a fixed charge per unit of power transmitted with in a particular zone. It is transparent and is easily understood by all .There is no mathematical rigor involved in this method. In this method 50% of losses are allocated to generators and 50% of losses to the loads. In this method network topology is never taken in to account. Further it will not be beneficiary for two identical loads where one load is locating nearer to the load centre and another load is locating far away from load centre to allocate the loss with the same amount of cost.

i. Transmission loss allocation

Transmission loss allocation for generator is

$$L_{PGI} = \frac{L}{2} \frac{PGI}{PG}$$

Transmission loss allocation for generator is

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$$L_{PDj} = \frac{L_{PDj}}{2} \frac{P_{Dj}}{P_D}$$

Where, P_{Gi} , P_{Dj} — real power generation and load at buses i and j

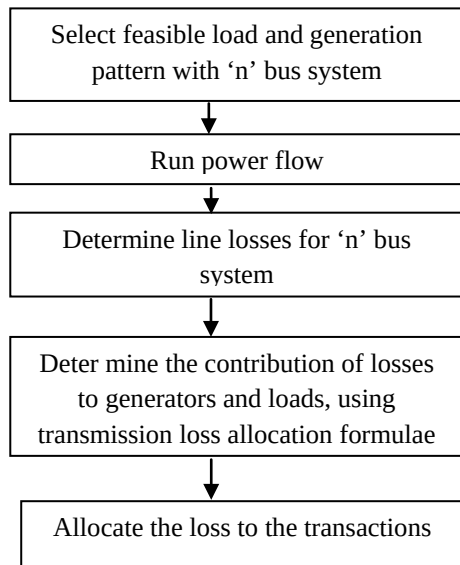
P_G , P_D —Total power generation and load of this system

L_{PGi} —Losses allocated to the generator i

L_{PDj} —Losses allocated to the demand j

L —Total losses of the system

ii. Algorithm for postage stamp method



b) Proportional sharing principle (Flow tracing method)

Proportional Sharing Principle (PSP) procedures on top of electrical laws requires the assumption of the proportional sharing principle [3]. Using this principle, losses are allocated by linear procedure and it is not dependent on slack bus and considers the network flow conditions.

To allocate the losses to individual generators and loads, the method depends on simple principle, that the losses associated with certain node in electrical network is proportionally shared by all the paths going out from that node thus satisfying Kirchhoff's current law. It should be noted that a systematic applications of this principle originates that all losses are allocated to generators and loads proportionally.

One of the main features of this method is that it is slack-bus independent. Though during the power flow, one bus is considered to be slack bus which supplies system loss, while forming transactions, this bus also participates. Once transactions are formed, loss is allocated to all transaction pairs, including one involving slack bus. So final result does not depend on the choice of slack bus.

The information required [4] to apply this method is the real power flow and the losses in every line and the power generated or consumed in every bus.

Since there is no unique or ideal procedures exist, the loss allocation should have some desirable properties stated below:

1. To be consistent with the results of power flow.
2. To depend on the amount of energy either produced consumed.
3. To be simple and transparent (important to market participants and public policy makers).
4. To be politically implementable (especially important to regulators and public policy makers).
5. To provide correct marginal signals to the network.

i. Transmission loss allocation

Proportional sharing principle method express branch flows as the sum of components supplied from individual generators or to loads.

$$P_{i-j}^{(gross)} = (P_{ij} / P_i) \sum [A_{u(i,k)}]^{-1} P_{GK} \text{ for } j \in \alpha_i^d \quad (1)$$

α_i^d = set of nodes supplied from node i

P_i = nodal power

K = Buses (generator bus)

P_{GK} = generating power at bus k

P_{ij} = branch power flow ($i \in$ upstream, $j \in$ downstream)

A_u = upstream distribution matrix

$$[A_u]_{ij} = \begin{cases} 1 & \text{for } i=j \\ -|P_{ji}|/P_j & \text{for } j \in \alpha_i^u \\ 0 & \text{otherwise} \end{cases}$$

$$P_{i-j}^{(net)} = (P_{ij} / P_i) \sum [A_{d(i,k)}]^{-1} P_{DK} \text{ for } j \in \alpha_i^d \quad (2)$$

K = buses (load bus)

P_{ij} = branch power flow ($j \in$ upstream, $i \in$ downstream).

α_i^u = set of nodes supplying node i .

A_d = downstream distribution matrix

$$[A_d]_{ij} = \begin{cases} 1 & \text{for } i=j \\ -|P_{ji}|/P_j & \text{for } j \in \alpha_i^d \\ 0 & \text{otherwise} \end{cases}$$

In order to assign 50% of losses to the generation and 50% to the demand, the final generation and demand per bus are computed as,

$$P'_{Gi} = (P_{i-j}^{net} + P_{Gi})/2 \quad (3)$$

$$P'_{Dj} = (P_{i-j}^{(gross)} + P_{Dj})/2 \quad (4)$$

Finally the real power losses allocated to every generator and demand are computed as

$$L'_{Gi} = P_{Gi} - P'_{Gi} \quad (5)$$

$$L'_{Dj} = P'_{Dj} - P_{Dj} \quad (6)$$

c) Bus Wise Loss Allocation

Bus Wise Loss Allocation Method (BWL) is based on simple circuit laws in [5] and does not involve any assumptions. Considering the real power injection and real power loss contribution factors of the buses transmission lines, transmission loss allocation can be done. It does not require any assumptions in the network

i. Transmission loss allocation

In this method entire data related to the network such as bus voltages, complex line flows, slack bus power generation etc are obtained from the load flow solution. From the load flow solution the complex line flow S_{ij} in terms of the node voltage V_i and line current I_{ij} through the line $i \rightarrow j$ as

$$S_{ij} = V_i I_{ij}^* \quad (7)$$

From the Z based system equations the voltage at node i is given by

$$V_i = \sum_{k=1}^n Z_{ik} I_k \quad (8)$$

The current through the line $i \rightarrow j$ is obtained as

$$I_{ij} = (V_i - V_j) y_{ij} + V_i y_{ij}^{sh} \quad (9)$$

Substituting (8) in (9)

$$I_{ij} = \sum_{k=1}^n [(Z_{ik} - Z_{jk}) y_{ij} + Z_{ik} y_{ij}^{sh}] \quad (10)$$

Substituting the values I_{ij} from (10) in (7)

$$S_{ij} = \sum_{k=1}^n \text{factor1}^k_{ij} \quad (11)$$

Thus the complex power flow S_{ij} through the line $i \rightarrow j$ is represented as a function of all bus currents; $k=1, 2, 3, \dots, n$. Factor 1^k_{ij} represents contribution of k^{th} bus to $i \rightarrow j$ line power flow.

Similarly complex line flow

$$S_{ji} = \sum_{k=1}^n \text{factor2}^k_{ij} \quad (12)$$

Factor 2^k_{ij} represents contribution of k^{th} bus to $i \rightarrow j$ line complex power flow i.e. counter flow.

Complex line loss in any line is the algebraic sum of active and counter complex line flows. Therefore

$$S_{\text{line loss}} = S_{ij} + S_{ji} = \sum_{k=1}^n \text{factor}^k_{ij} \quad (13)$$

Factor k_{ij} represents the contribution of k^{th} bus to the $i \rightarrow j$ line loss and also the contribution of line $i \rightarrow j$ to the power injection at bus k .

The matrix [B] is the real part of $S_{\text{line loss}}$.

By using [B] matrix real power losses can be allocated in the following manner.

- Find the sum of the "absolute contribution of all buses to the real power loss of line $i \rightarrow j$ (say " l^{th} line") i.e. cumulative power loss " $C_{\text{ploss}}(l)$ " where

$$C_{\text{ploss}}(l) = \sum_{k=1}^n B(k, l) \quad (14)$$

- to find the contribution of i^{th} bus to the real power loss of line $i \rightarrow j$ (l^{th} line) a power loss factor is given by

$$C(k, l) = \frac{B(k, l)}{C_{\text{ploss}}(l)} * \text{r loss}(l) \quad (15)$$

- By summing up all individual real power loss factors $C(k, l)$ of all lines, the total loss allocated to i^{th} bus is defined as $LA(k)$ given by

$$LA(k) = \sum_{l=1}^{n_{\text{line}}} C(k, l) \quad (16)$$

III. CASE STUDY ON IEEE- 5 BUS SYSTEM

A case study on IEEE-5 bus system is illustrated to test the performance of the three methodologies which is discussed in section II. The layout of IEEE- 5 bus system taken from [6], consists of two generator buses and four load buses and is represented by bus power injections, line power flows and line power losses obtained from the base case solution i.e. Newton Raphson method. The total real power loss for 5 bus system is 4.802 MW. It can be obtained by using PS, PSP and BWLA methods, which is shown in Table.1.

Table 1

Bus	Loss allocation in MW (Total loss=4.802)		
	PS	PSP	BWLA
1	1.8355	2.0884	2.131
2	0.8566	0.4318	0.330
3	0.6549	0.6708	0.730
4	0.5821	0.5946	0.650
5	0.8731	1.0167	0.962
Total	4.802	4.802	4.802

From Table.1, shows that the results of loss allocation for the three methods, in PS Method, the network is not considered. It allocates the losses to the generators and loads marginally and it is independent of transmission distance. In this method, it allocates the losses of 1.8355MW to the bus -1 with its more contribution of 129.802MW (bus power injection from load flow studies) power flow to the other loads and it allocates losses of 0.8566 MW to the bus-2, but its contribution of power flow is only 40 MW(bus power injection from load flow studies) apart from its own load.

In PSP method taking the network in to consideration, loss allocation can be done. It allocates the losses of 2.0884MW to bus-1 as it contributes the 129.802MW to other loads and it allocates the 0.4318 MW to bus -2 with its contribution of 40 MW to the other loads.

In BWLA method allocation can be done directly by using circuit laws. It allocates the losses of 2.131MW to the bus-1 with its contribution of power flow to the other loads is 129.802MW and it allocates the losses of 0.330MW to the bus-2 with its contribution of power flow to other loads is 40MW.

Based the above analysis in PS method the participant with more contribution will get more benefited compared to less contribution of the participants. But with PSP method though network is taken in to consideration, customers are not reasonably benefited compared to the BWLA method. So Bus wise loss allocation method allocates losses more accurately compared to the other two methods.

IV. CASE STUDY ON IEEE - 30 BUS SYSTEM

A case study of IEEE-30 Bus system is illustrated to test the performance of the three methodologies which is discussed in section II. The lay out of IEEE- 30 bus system taken from [7], it has 30 nodes and 41 branches and consists of one slack bus, 5 PV buses and 24 load buses and is represented by is represented by bus power injections, line power flows and line power losses obtained from the base case solution i.e. Newton Raphson method. The total real power loss for 30 bus system is 20.15MW It can be obtained by using PS, PSP and BWLA methods which is shown in Table.2..

From the Table.2 shows that the results of loss allocation for the three methods all the methods allot zero loss to the transfer bus which has zero injection power and in PSP method counter flows (negative losses) occur when no of buses increases, but in BWLA method counter flows (negative losses) never occur though no of buses increases as shown in Table .2 respectively.

Bus	Loss allocation in MW(Total loss=20.15)		
	PS	PSP	BWLA
1	8.8314	9.3567	9.833
2	1.9665	1.0322	0.544
3	0.0797	0.049	0.075
4	0.2524	0.2035	0.243
5	3.1288	-8.6284	3.056
6	0	0	0
7	0.7573	12.7622	0.736
8	0.9964	0.5869	0.987
9	0	0	0
10	0.1926	0.1869	0.306
11	0.3321	0.3223	0.422
12	0.372	0.3	0.327
13	0.3321	0.2679	0.41
14	0.2059	0.1968	0.206
15	0.2724	0.2723	0.27
16	0.1162	0.108	0.106
17	0.2989	0.2993	0.276
18	0.1063	0.1179	0.109
19	0.3155	-3.8748	0.308
20	0.0731	4.319	0.075
21	0.5812	0.6423	0.547
22	0	0	0
23	0.1063	0.1166	0.103
24	0.289	-1.4931	0.304
25	0	0	0
26	0.1162	-1.4823	0.162
27	0	0	0
28	0	0	0
29	0.0797	0.8176	0.116
30	0.3521	3.6936	0.624
Total	20.15	20.15	20.15

Table 2

V. CONCLUSIONS

From the three methodologies the following conclusions are drawn P.S method though simple and transparent to implement it does not take the network in to consideration and allocates the fixed real power losses to the participants irrespective of distance between the generators and loads.

Proportional sharing method takes the network in to consideration and allocates the real power losses proportionally to all the transactions. But in this method assumptions are made that the line inflows are equal to the line out flows. This method does not depend up on the choice of the slack bus.

Bus wise loss allocation method overcomes the disadvantages of postage stamp method and proportional principle method and it allocates the real power losses directly by using simple circuit laws. This method gives accurate results compared to the other two methods.

VI. FUTURE SCOPE

In this paper only real power losses are considered for loss allocation. The three methods can be extended to allocate the reactive power losses for better voltage stability and pricing can also be done which is a major issue in today's competitive market.

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High Speed Voltage Switching Converter from Single Phase to Three Phase: A Design and Implementation Process

By Abdul Rehman & Muhammad Shakeel Faridi

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Abstract - A single phase to three phase converter topology for domestic use and for small industries is presented in this project. Phase converter, included in this project, is a device that supplies three phase power from a single phase source to power inductive, resistive and capacitive loads with distinct advantages over any existing converter device. Three phase converters are finding increased applications in industrial environment with greater demand for high voltage, high power processing techniques with improved efficiency. The essential advantage is the improvement in the improvement in the output voltage signal quality using devices of low voltage rating with lesser switching frequency, thereby increasing the overall efficiency of the system. This converter is applied to drive the motor.

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High Speed Voltage Switching Converter from Single Phase to Three Phase: A Design and Implementation Process

Abdul Rehman^α & Muhammad Shakeel Faridi^σ

Abstract - A single phase to three phase converter topology for domestic use and for small industries is presented in this project. Phase converter, included in this project, is a device that supplies three phase power from a single phase source to power inductive, resistive and capacitive loads with distinct advantages over any existing converter device. Three phase converters are finding increased applications in industrial environment with greater demand for high voltage, high power processing techniques with improved efficiency. The essential advantage is the improvement in the improvement in the output voltage signal quality using devices of low voltage rating with lesser switching frequency, thereby increasing the overall efficiency of the system. This converter is applied to drive the motor.

1. INTRODUCTION

This type of converter is required in those areas where the three phase electric power is not present. Most of these areas include domestic areas because most of the domestic use appliances are powered by single phase electric power. One of the reasons of not giving three phase electric power to the domestic customers is its high cost of connection installation. But still, if any customer wants to run a three phase appliance on a single phase electric power, the single phase to three phase converter can be used. The reason of using three phase power is that three phase appliances are available in high ratings as compared to appliances available in single phase. For example [1,2,3]

- 1) In case of loads, three phase motors are more compact and less costly than a single phase motor of same voltage and rating. Moreover single phase AC motors above 10 HP (7.5 kW) are rarely available. Three phase motors have self-starting torque because they can produce rotating magnetic field whereas single phase motors requires a special starting winding.
- 2) From generation point of view, the three phase AC generators are smaller in size as compared to single phase generators. The kVA rating of three phase generator is 1.5 times greater than that of single phase AC generators.

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In single phase AC electric power system, the power falls to zero three times during one complete cycle i.e. at the interval of $0, \pi$ (180°) and 2π (360°) as shown in fig. 1 below. Whereas in three phase electric system the power never falls to zero and a continuous same power is delivered to the load at all time as shown in fig. 2 below.

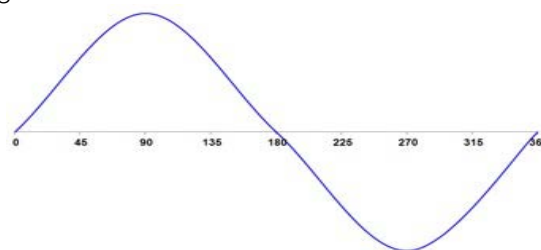


Fig. 1 : One complete cycle of single phase voltage

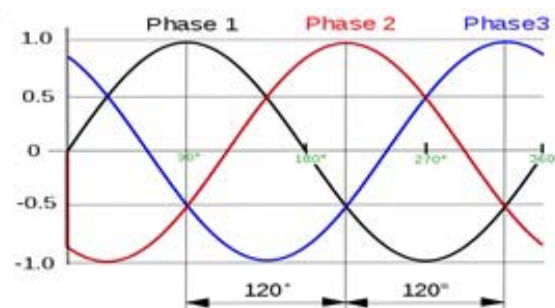


Fig. 2 : One complete cycle of three phase voltage

Most motors and equipment's need this continuous power to run properly.

The above discussion emphasis on a strong need of efficient and cost effective static single phase to three phase voltage converter. Previous work done in this regard has created a wide variety of possible circuits that could be used for single phase to three phase voltage conversion but these works have some disadvantages as well for example in [4] thyristors are used in combination with L-C components. The disadvantage of this conversion technique is that the L-C values must be matched with the load impedances. Furthermore in [5] the technique proposed has a disadvantage that only two semiconductor devices are used for the conversion purpose therefore the conversion would not be that much accurate i.e. phase difference between each phase cannot be exactly 120° .

In response to above two mentioned techniques the technique mentioned in this paper will nullify the above mentioned disadvantages.

II. PROPOSED THREE PHASE CONVERTER

The converter proposed in this project converts the single phase electric power to three phase electric power in two steps:

- 1) **POWER CIRCUIT:** Conversion of single phase A.C voltage to D.C voltage i.e. from 220V, 50Hz single phase A.C supply to 400V D.C supply.
- 2) **CONTROL CIRCUIT:** Conversion of D.C voltage to three phase A.C voltage i.e. from D.C 400V to 380V, 50Hz three phase A.C supply by using PIC microcontroller.

Both of these steps are described in detail below

a) Power Circuit

The power circuit is that part of the converter in which rectification is done i.e. single phase A.C voltage 220V, 50Hz is converted to D.C voltage 400V. The reason of converting 220V A.C to 400V D.C is to get the three phase voltage of amplitude of 400V which is then switched with the help of hex-bridge and microcontroller in such a way to get a three phase voltage with phase difference of 120°. This rectification can be done by using a full bridge rectifier which can be made either by using diodes or by using an I.C whose output voltages are equal to 400V. The full bridge rectifier circuit is shown in fig. 3.

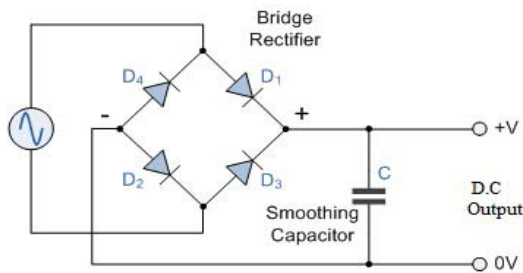


Fig. 3 : Rectifier

The smoothing capacitor is used to remove the ripples so that we can get a smooth D.C voltage. The value of this capacitor can be found out by Eq. 1

$$C = \frac{2 (P_o)(T_h)}{(V_1^2 - V_2^2) (\eta)} \quad (1)$$

Where

C = Capacity of filtering capacitor

P_o = Output power of the rectifier

T_h = Hold-up time

V_1 = Input D.C voltage i.e.

Input A.C voltage (rms) $\times \sqrt{2}$

V_2 = Input D.C voltage which can hold output voltage

η = Efficiency

These 400V D.C produced will be given to the hex-bridge. The hex-bridge is the heart of three phase inverter. It takes a D.C voltage and uses six switches arranged in three legs for switching purpose. The hex-bridge used is shown in fig. 4

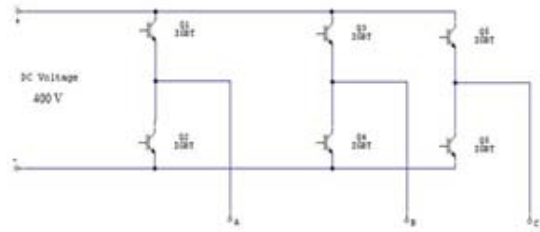


Fig. 4 : Hex-bridge

In fig. 4 Q1-Q6 are six switching devices and A, B, C are the three phase output terminals that will be connected to the motor terminals. There are two types of switching devices that could be used IGBT or MOSFET. In this project IGBTs are used instead of MOSFETs [6,7]. This selection is made on the conditions for which these two devices are to be used. Mostly the decision is made keeping two factors in mind

- 1) Switching frequency
- 2) Voltage bearing capability of device

The IGBT is chosen for voltages above 1000V, while the MOSFET is certainly chosen for voltages below 250V. Between 250 to 1000V, some technical papers prefer MOSFETs and some IGBTs this is shown graphically in fig. 5

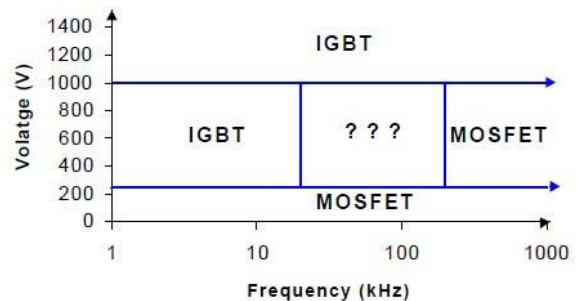


Fig. 5 : Regions where IGBTs and MOSFETs are preferred

As working voltage for the hex-bridge is 400V D.C and switching frequency is between 20-25 kHz, so IGBTs are used.

b) Control Circuit

The control circuit is that part of the converter in which electrical components are used to control the switching of the six IGBTs to generate three phase 380V, 50Hz voltage with exact phase shift of 120°. To see the control circuit at a glance, block diagram of control circuit is shown in fig. 6

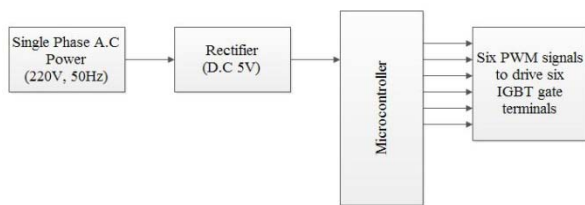


Fig. 6 : Block diagram of control circuit

As mentioned earlier that a microcontroller is used to control the switching of the six IGBTs connected in hex-bridge. Any one output port of the PIC microcontroller can be used for output signals. Total six microcontroller pins will be used for output purpose. These pins will then give signal to each gate terminals of six IGBTs connected in hex-bridge while travelling through bridge driving IC. The method used to generate control signals through microcontroller is pulse width modulation (PWM) as shown in fig. 7.

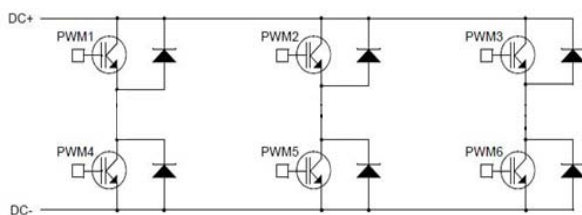


Fig. 7 : PWM connected with hex-bridge

The reason of using PWM technique is that a switching wave of constant magnitude and frequency is required. The PWM signals are generated in such a way that three IGBTs will conduct at a time i.e. either one upper or two lower or two upper and one lower. Upper and lower IGBTs of the same limb are not made conductive at the same time otherwise the D.C bus supply would become short circuited. There is a time delay given between switching the upper IGBT ON and lower IGBT OFF and vice versa. This time delay is called dead time. To control the switching of the upper three IGBTs three PWMs are required. For switching the lower three IGBTs the inverted PWM signals of the corresponding upper IGBTs are used. The three PWMs used for the three phase sine wave generation are shown in fig. 8

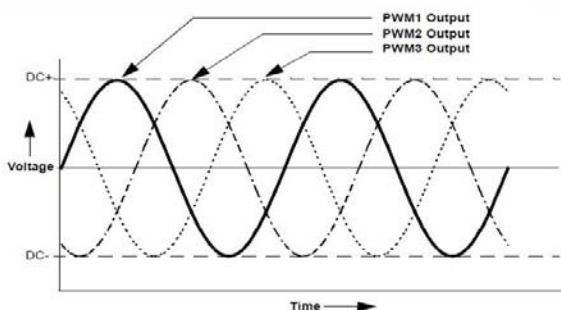


Fig. 8 : Generation of three phase sine wave using PWM

In the used PWM technique the duty cycle of the square wave will determine the phase voltages. To control this duty cycle a sine table is created in the program memory which is then transferred to the data memory upon initialization. A phase shift of 120° is maintained between phases by using three offset pointers to the sine table. So a voltage of each phase will be calculated as

For phase 1: Sine table value + offset1

For phase 2: Sine table value + offset2

For phase 3: Sine table value + offset3

Above explained generation of three phases with phase shift of 120° is shown graphically in fig. 9

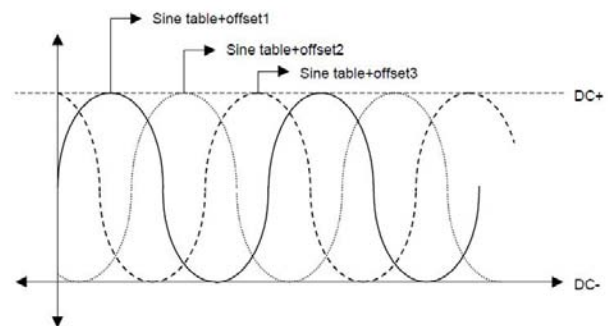


Fig. 9 : Generation of three phase waveform from the sine table

To control the values of the sine table + offset, three timers are used. These timers are Timer0, Timer1 and Timer2. The functions performed by each of these timers is given in table 1

Table 1 : Timers and their functions

Timers	Function
Timer0	Interrupt timer after which duty cycle changes
Timer1	Interrupt timer for the positive peak of A.C wave
Timer2	Interrupt timer for the negative peak of A.C wave

Another purpose of using these timer registers is that as the program for the microcontroller is written in software and then burned in hardware i.e. in microcontroller, so the hardware and software PWMs will be leading or lagging from one another. To control this problem and to get same PWM signals. The detailed working of the three timers from this point of view is discussed below.

1. Timer2

It is an 8-bit timer used to control the timing of hardware PWMs. The main processor is interrupted when the Timer2 value matches the PR2 value.

2. Timer1

Timer1 is used for setting the duty cycle of the software PWM. In Timer2 to PR2 match interrupt, the port pin designated for PWM3 is set to high. Also Timer1 is loaded with the value which corresponds to PWM3 duty cycle. In Timer1 overflow interrupt, the port pin for PWM3 is cleaned and as a result the hardware and software PWMs will have the same frequency.

3. Timer0

After every Timer0 overflow interrupt, the value pointed by the offset register on the sine table is read. The value is loaded to the PWM duty cycle registers and the offset registers are updated for next access.

After the three PWM signals are generated they are connected to the driver chip that will generate dead time of 200 ns between upper and lower switches of all phases.

III. SIMULATION & EXPERIMENTAL RESULTS

If we simulate the above discussed method for the generation of three phase voltage waveform from single phase voltage then the waveforms obtained from MATLAB software when the scope is connected across the PWM generating pins of microcontroller are as shown in fig. 10



Fig. 10 : Waveforms of all three PWM

The waveforms shown in fig. 10 are switching waveforms that's why they are in the form of pulse these pulses can be created to the A.C waveforms

IV. CONCLUSIONS

The single phase to three phase voltage converter presented in this research by which three phase motor is driven is made up of six IGBTs and PWM technique is used for its switching purpose. The advantages of using this converter are as follows:

1) The IGBT has the output switching and conduction characteristic of BJT but is voltage controlled like

MOSFET. In general it means that it has the advantage of high current handling capability with the ease of control of MOSFET.

2) The PWM technique used for the switching of IGBTs has the advantage that power loss in the switching device is very low because when the switch is OFF there is practically no current and when the switch is ON there is almost no voltage drop across the switch.

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New Robust Energy Storage Devices for Deregulated AGC Problems

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Abstract - This paper presents a suitable mathematical model of Hydro-Thermal (H-T), Wind-Diesel (W-D) and Combined Cycle Gas Turbine (CCGT) system under deregulated environment. The variable power consumption as well as intermittent load variation may cause large fluctuations on system frequency. To reduce the system oscillations Superconducting Magnetic Energy Storage (SMES) and Capacitive Energy Storage (CES), which will supply and absorb active, reactive powers quickly, can be applied. In addition, variation of system parameters, load and unpredictable power demands cause various uncertainties in the system. Energy storage devices so far designed without considering such uncertainties may lose control effect. To enhance the robustness of storage devices, this paper focuses on a new SMES and CES robust frequency controllers are designed for three area power system. The coprime factorization method is used to represent the unstructured uncertainties in a system modeling. The structure of SMES and CES controller are the practical first order lead/lag compensator. To tune the controller parameters, the optimization problem is formulated based on loop shaping technique.

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New Robust Energy Storage Devices for Deregulated AGC Problems

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Abstract - This paper presents a suitable mathematical model of Hydro-Thermal (H-T), Wind-Diesel (W-D) and Combined Cycle Gas Turbine (CCGT) system under deregulated environment. The variable power consumption as well as intermittent load variation may cause large fluctuations on system frequency. To reduce the system oscillations Superconducting Magnetic Energy Storage (SMES) and Capacitive Energy Storage (CES), which will supply and absorb active, reactive powers quickly, can be applied. In addition, variation of system parameters, load and unpredictable power demands cause various uncertainties in the system. Energy storage devices so far designed without considering such uncertainties may lose control effect. To enhance the robustness of storage devices, this paper focuses on a new SMES and CES robust frequency controllers are designed for three area power system. The coprime factorization method is used to represent the unstructured uncertainties in a system modeling. The structure of SMES and CES controller are the practical first order lead/lag compensator. To tune the controller parameters, the optimization problem is formulated based on loop shaping technique. The particle swarm optimization (PSO) is applied to solve the problem to achieve the controller parameters and also to optimize the Integral Controllers of three area power system in deregulated environment.

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1. INTRODUCTION

Load Frequency Control (LFC) is a mechanism by which power generation and power demand are balanced. The frequency control is one of the most profitable ancillary services. This service is related to the short-term balance of energy and frequency of the power systems. The goal of LFC is to reestablish primary frequency regulation capacity, return the frequency to its nominal value and minimize unscheduled tie-line power flows between neighboring control areas. From the mechanisms used to manage the provision this service in ancillary markets, the bilateral contracts or competitive offers stand out [1]. In the past decade, the electrical industry has undergone deregulation and restructuring, when vertically integrated utilities were forced to split into separate independent Generation (GENCO), Transmission (TRANSCO) and distribution (DISCO) companies. There have been continuing efforts in design of LFC with better

performance according to the change of environment in power system operation under deregulation using various optimal and robust control strategies during the recent years [2-4].

A simple, mathematical model of Heat recovery steam generator (HRSG), Steam turbine (ST), and pertinent controls are described and the model of a single-shaft CCGT is completed in [5]. Dynamics of combined cycle gas turbines to frequency deviations on an island electricity system is considered [6]. In [7] proposes the design and development of a new fuzzy GA predictive supervisory control strategy for gas turbines based on nonlinear predictions using the fuzzy model. Different gas turbine models are identified presented and discussed in [8]. The identified models are of different level of accuracy, suitable for different types of studies and have been utilized for different purposes in the past. However, these models are too complex and unsuitable for the use in large power system studies. In [7] has more detailed analysis of power system and governor behavior, especially for equipment specific studies and large frequency excursions, models.

In [9-10] compares various models and concluded that models have different level of accuracy. This study illustrates the usefulness and accuracy of frequency dependent model as well as the detailed model of gas turbines in CCGT, since these three models consider the IGV. One of the aim of this paper is to study the dynamic behavior of the CCGT in the presence of a frequency drop coordinated by energy storing devices like SMES/CES under deregulated environment. Detailed model which giving the available thermal power to the gas turbine and the steam turbine is modeled by algebraic equations. These equations are relating the adiabatic compression and expansion, as well as to the heat exchange in the recovery boiler [11-13] and it is presented in Appendix-3.

Wind power systems are considered economically for supply of electrical energy to remote and isolated areas where utility lines are uneconomical to install due to high costs, right of way difficulties or environmental impacts [14,15]. Since wind power sources are naturally fluctuating or intermittent, they are generally integrated with the diesel generation [16]. Different technologies such as flywheel [17], Battery Energy Storage (BES), Superconducting Magnetic Energy Storage (SMES), etc., can be adopted to

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alleviate system frequency fluctuation in isolated systems. Finally, robust controller of SMES for frequency control in the hybrid wind-diesel power system has been presented in [18].

In [19] the power systems with three areas are considered, the simulation is implemented by using MATLAB/Simulink Program and MATLAB Fuzzy Logic Toolbox (FLT), to damp out the oscillations, due to instantaneous load perturbations as fast as possible. In [20] has detailed model for the simulation of the SMES system and this model is intended to provide guidelines for a detailed SMES device simulation in the power system as well as to provide a basis for comparison of various simulation tools, control strategies, algorithms and realization approaches.

References [21-22] made comprehensive mathematical model for the AGC of a two area interconnected hydrothermal power system fitted with SMES unit in either thermal or hydro area with generator rate constraints has been presented. It has been shown that these oscillations can be effectively damped out with the use of a small capacity SMES unit in either of the areas following a step load disturbance.

Similarly like SMES, CES is one of the alternate energy storage for control the frequency oscillations in power system, [23] proposes new incorporation of ultra-capacitor banks in an interconnected power system for improved load frequency control. In ref. [24] analyses the usage of energy storage devices shows that super-capacitors are best suited for short-term low power (<100kW) applications.

This paper proposes a new robust frequency controller of SMES, CES in a three area deregulated system. To take system uncertainties mentioned above into account in the control design, the normalized coprime factorization [26, 27] is applied to represent all unstructured uncertainties in the system modeling. The configuration of the frequency controller of SMES/CES is the first-order lead/lag compensator. The performance and stability conditions in the H^∞ loop shaping method [28] are applied to formulate the optimization problem. To achieve the controller parameters, the Particle Swarm Optimization (PSO) [29-30] is used to solve the objective function.

II. PROBLEM FORMULATION

Since the system under consideration is exposed to a small change in load during its normal operation, a linearized model is sufficient for its dynamic representation. Fig. 1 shows the small perturbation transfer function block diagram model of H-T system. SMES and CES conventional energy storage and proposed frequency controllers devices are fitted to either area 1 or 2 to examine its effect on the power system performance.

Fig. 2 shows the basic configuration of the hybrid W-D system. In addition to the random wind energy supply, it is assumed that loads with sudden change have been placed in this deregulated system. Variation of wind power and load change results in a serious problem of large frequency fluctuation in the system. Such frequency fluctuation severely affects the system stability. Furthermore, the life time of machine apparatus on the load side is reduced.

Fig 3(a) shows the model of CCGT, it consists of the power generation units and the control branches. The thermodynamic part giving the available thermal power to the gas turbine and the steam turbine is modeled by Algebraic Equations are given in Appendix-3, corresponding to the adiabatic compression and expansion, as well as to the heat exchange in the recovery boiler. These equations correspond to the block 'Algebraic equations of energy transform are in subsystem in Fig 3(b). The nominal parameters of these three power system data's are given in the Appendix 1.

First these three dynamics models are considered separately to design SMES and CES frequency controllers. The co-prime factorization method is used to represent the unstructured uncertainties in a system modeling. After designing the energy storage controllers for all these systems, these systems are combined and the effects of bilateral contracts are taken in to account. In the considered power system, each area contains two GENCOs, the GENCOs at the first areas include H-T, Second and Third area includes W-D and CCGT generating units respectively. After deregulation, to describe bilateral contract for three-area AGC, DISCO participation matrix used. The performance of the system is studied for different operating cases, in terms of the conventional controller gains optimized by PSO. Finally, obtained results are compared with conventional energy storage devices.

Fig. 5 (a) and (b) shows, the block diagram of SMES/CES consists of two transfer functions connected in series in [31]-[32], i.e. energy storage model and frequency controller. Both models are first order transfer function with time constant of $T_{SMES}=0.06s$, $T_{CES}=0.056s$ both frequency controllers are first order lead/lag compensator and with three control parameters. Change in frequency deviation is the input signal to the controllers.

III. PROPOSED CONTROL DESIGN

This paper proposes a robust control design of energy storage frequency controllers in H-T, W-D and CCGT systems. The configuration of SMES, CES frequency controller's are 1st-order lead/lag compensator [26]-[27]. The normalized co prime factor is used to model system uncertainties. The H^∞ loop shaping technique is applied to formulate the

optimization problem of controller parameters. The PSO referred in [29]-[30] is employed to solve the problem.

Proposed algorithm is summarized as

- Specify weighting function W_1 and W_2 , shape the nominal plant G_s .
- Evaluate the $\gamma_{\min}$ using (3). If $\gamma_{\min} \geq 4$, then go to step (i), adjust the weight function.
- Generate the objective for PSO.
- Initialize the PSO parameters.
- Randomly generate the population and evaluate the objective function of each individual.
- Select the best individual in the current generation and update the velocity factor then go to step iv. Repeat the process until the last iterations reached.

H^∞ Loop shaping is a feasible method for designing robust controller, however the controller design by this method is complicated and higher order. To overcome this problem this paper proposes an algorithm compared with PSO based fixed structure H^∞ loop shaping control technique for designing controller, by this method a simple structured and robust controllers are achieved. The objective of the control design is to optimize three control parameters using PSO, so that the resulted controller is robust to system uncertainties. Based on the H^∞ loop shaping control the optimization problem can be formulated subsequently the design procedure is divided into (vi) steps as follows:

$$W_1 = 296 \frac{(0.786S + 7.0)}{(S + 0.085)}, W_2 = 1 \text{ for H-T at this point } \gamma_{\min} \text{ is } 1.8875$$

$$W_1 = 947 \frac{(S + 167)}{(S + 544)}, W_2 = 1 \text{ for W-D at this point } \gamma_{\min} \text{ is } 2.5496.$$

$$W_1 = \begin{bmatrix} 1277 \frac{S + 324}{S + 329} & 0 \\ 0 & 1279 \frac{S + 335}{S + 360} \end{bmatrix}, W_2 = 1 \text{ for CCGT at this point } \gamma_{\min} \text{ is } 3.1256$$

$$\gamma_{\min} \leq 4.0 \text{ for all the three systems.}$$

ii. Formulate the Shaped Plant G_s

The figure 4 shows W_1 and W_2 that are employed to form the shaped plant G_s . $G_s = W_2 G W_1$, which is enclosed by the solid line. The proposed robust controller $K = W_1 K W_2$ is enclosed by the dotted line where K^∞ is the H^∞ controller.

iii. Robust Stability margin of the system

In this approach, the shaped plant is formulated as Normalized Co prime factorization method, which separates the plant G_s into normalized nominator N_s and denominator M_s factors. The variation of system parameters, unpredictable load demand and fluctuation in real power are considered as uncertainties. These uncertainties cannot be clearly represented by mathematical equations. So co prime factorization

i. Selection of the Weighing Functions

H^∞ Loop requires only a desired open loop shape in frequency domain. In this work pre compensator W_1 and Post compensator W_2 are used to shape the transfer function of the plant G_s in [18], [31] shown in figure 4, so that specification in frequency domain is achieved. The most crucial part of the design procedure is to find the appropriate weighing matrix. In this work W_1 and W_2 are designed by a systematic procedure by [26] and it has given excellent result. The shape of the weight is designed by the closed loop design specification. The faster settling time can be achieved with a high loop cross over frequency and a good ϵ .

$$W_1 = K_w \frac{S+a}{S+b}, W_2 = 1 \quad (1)$$

Where K_w , a and b are positive values. Because, the frequency control problem is in a vicinity of low frequency ($< 1\text{Hz}$), W_1 is set as a high pass filter ($a < b$). The W_2 is used to reject the high frequency noises and this is a common practice in real application and it can be chosen as unity matrix in [26]. Here the linearised H-T, W-D and CCGT models are used in this simulation. Now the shaped plant G_s is established by weighting functions W_1 and W_2 . The weighting functions are chosen as:

methods is used to represent these uncertainties. If the shaped plant G_s is expressed in the form of:

$$G_s = W_2 G W_1 = N_s M_s^{-1} \quad (2)$$

Then perturbed plant G_s is defined as

$$G_\Delta = \{(M_s + \Delta M_s)^{-1} (N_s + \Delta N_s) : \|\Delta N_s \Delta M_s\| \leq 1/\gamma\} \quad (3)$$

Where ΔM_s , and ΔN_s are stable unknown transfer functions which represent unstructured uncertainties in the nominal plant model G . Based on this definition, the robust control problem can be established by G_Δ and K . The objective of robust control design is to stabilize not only the nominal plant G , but also the family of perturbed plant G_Δ . In (3) $1/\gamma$ is defined as the robust stability margin ϵ . The ϵ can take

the value between 0 and 1. ϵ is an indicator of success of the design procedure. If the value ϵ is small, it means that the desired loop shape and robust stability requirements cannot be achieved simultaneously. In this case designer should reshape the open loop scaled plant. The theoretical basis for H^∞ loop shaping is that K does not modify the desired loop shape significantly at low and high frequencies, if the achieved ϵ is not too small, thus shaping of the open loop plant G corresponds to shaping the loop gain GK and KG . In contrast with the conventional loop shaping, the control engineer does not need to shape of the phase of G

explicitly. It has been shown that a value of $\epsilon > 0.25$ to 0.3 is satisfactory for a SISO system in the same way gain margin is ± 6 dB, and phase margin of 45° .

The value of $\gamma_{\min}$ can be easily calculated from

$$\gamma_{\min} = (I + \lambda_{\max}(XZ))^{1/2} \quad (4)$$

Where $\lambda_{\max}(XZ)$ denotes the maximum Eigen value of XZ . For minimal state space realization (A, B, C, D) of G_s , the values of X and Z are unique positive solutions to the generalized control algebraic Riccati equation.

$$(A - BS^{-1}D^TC)^TX + X(A - BS^{-1}D^TC)^T - XBS^{-1}B^TX + C^TR^{-1}C = 0 \quad (5)$$

and the generalized filtering algebraic Riccati equation

$$(A - BS^{-1}D^TC)Z + Z(A - BS^{-1}D^TC)^T - ZC^TR^{-1}CZ + BS^{-1}B^T = 0 \quad (6)$$

Where $R = I + DD^T$ and $S = I + D^TD$. Note that no iteration on γ is needed to solve for $\gamma_{\min}$. To ensure the robust stability of the nominal plant, the weighting function is selected so that $\gamma_{\min} \leq 4.0$. if $\gamma_{\min}$ is not satisfied then go to step (i) and adjust the weighting functions. Thus the shaped plant is established at this point the values for H-T system the value of $\gamma_{\min} = 3.1256$, similarly W-D $\gamma_{\min} = 2.5496$, and CCGT $\gamma_{\min} = 1.8875$.

iv. Formulate the Objective Function for PSO Optimization function

In this study, the performance and robust stability conditions in H^∞ loop shaping design approach are adopted to design a robust frequency controller K . The frequency controller is represented by:

$$K = K_{SMES} \frac{(1 + ST_{SMES1})}{(1 + ST_{SMES2})} \quad (7)$$

The necessary and sufficient condition of the designed robust controller K is

$$\left\| \begin{bmatrix} I \\ K_\infty \end{bmatrix} (I - G_s K_\infty)^{-1} \begin{bmatrix} I & G_s \end{bmatrix} \right\|_\infty \leq \gamma \quad (11)$$

Substituting (10) into (11) yields

$$\left\| \begin{bmatrix} I \\ W_1^{-1}K \end{bmatrix} (I - G_s W_1^{-1}K_\infty)^{-1} \begin{bmatrix} I & G_s \end{bmatrix} \right\|_\infty \leq \gamma \quad (12)$$

Equation (12) implies that if the ∞ -norm of transfer function matrix in the left side is lower than γ , the robust controller K can be obtained. As a result, the ∞ -norm of the left side term in (12) can be used to formulate the optimization problem as

$$\text{Minimize } \left\| \begin{bmatrix} I \\ W_1^{-1}K \end{bmatrix} (I - G_s W_1^{-1}K_\infty)^{-1} \begin{bmatrix} I & G_s \end{bmatrix} \right\|_\infty \leq \gamma \quad (13)$$

Subject to

System

SMES

CES

H-T

$$\begin{aligned} 0 &\leq K_{SMES} \leq 0.65, \\ 0.01 &\leq T_{SMES1} \leq 1.0 \\ 0.01 &\leq T_{SMES2} \leq 1.0 \end{aligned}$$

$$\begin{aligned} 0 &\leq K_{CES} \leq 0.95, \\ 0.001 &\leq T_{CES1} \leq 1.0 \\ 0.001 &\leq T_{CES2} \leq 1.0 \end{aligned}$$

CCGT	$1.0 \leq K_{sm} \leq 125.0,$ $0.04 \leq T_{sm1} \leq 1.0$ $0.01 \leq T_{sm2} \leq 1.0$	$1.0 \leq K_{CES} \leq 150.0,$ $0.05 \leq T_{CES1} \leq 1.0$ $0.001 \leq T_{CES2} \leq 1.0$
W-D	$1.0 \leq K_{SMES} \leq 50.0,$ $0.001 \leq T_{SMES1} \leq 1.0$ $0.001 \leq T_{SMES2} \leq 1.0$	$0 \leq K_{CES} \leq 35.0,$ $3.0 \leq T_{CES1} \leq 1.0$ $0.001 \leq T_{CES2} \leq 1.0$

v. PSO Algorithm

- Initialize a population of the particles with random position and velocities.
- Evaluate the objective function in (13) for each particle.
- Compare the fitness value of each particle with its the best position for each particle (P_{best}). The best fitness value among all the P_{best} is the best position of all particles in the group (G_{best}).
- Update the velocity V_i and position of particle x_i by

$$V_{i+1} = w V_i + c_1 \text{rand}_1 (p_{best} - x_i) + c_2 \text{rand}_2 (g_{best} - x_i) \quad (14)$$

$$X_{i+1} = x_i + V_{i+1}$$

$$w = w_{\max} - \frac{w_{\max} - w_{\min}}{\text{iter}_{\max}} \text{iter}$$

Where c_1 , c_2 are the cognitive and social acceleration factors. rand_1 , rand_2 are the random numbers of range 0 to 1. w is the inertia weight factor. $w_{\min}$, $w_{\max}$ are the minimum and maximum of inertia weight factors. iter and $\text{iter}_{\max}$ are the iteration count and maximum iterations.

- The maximum number of iteration is arrived, stop the process. Otherwise go to process (b). The proposed controller achieves good robust performance by applying two specified weighting functions. Although design of a fixed-structure controller is difficult because of its inherently non-convex nonlinear problem, the PSO algorithm simplifies this by searching for optimal solutions. Based on the concept of convention H_∞ loop shaping, only a single index, stability margin, γ is applied to indicate performance of the designed controller. Optimal stability margin γ_{opt} is found to be 3.1256 for H-T system, 2.5496 for W-D system and 1.8775 for CCGT.

- After running PSO algorithms for 100 to 150 iterations for all the three systems and the obtained values listed are Table-1, in the frequency response of the complicated controller in the conventional design, the proposed approach significantly improves

practical control by simplifying the controller structure and reducing the controller order while retaining robust performance. This makes the proposed controller more practical and attractive.

IV. RESTRUCTURED SYSTEM FOR AGC WITH THREE AREA

Power system contains three areas, each area includes two GENCOs and two DISCOs as shown in Fig.6. In the system, any GENCOs in any area may supply both DISCOs in its user pool and DISCOs in other areas through tie-lines allowing electric power to flow between areas. The transactions have to be implemented through an independent system operator (ISO). The impartial entity, ISO has to control many of ancillary services, one of which is AGC. In deregulated environment, any DISCOs has the liberty to buy power at competitive prices from different GENCOs, which may or may not have contract in the same area as the DISCOs. For practice, GENCOs-DISCOs contract is proposed in [33] with DISCO participation matrix (DPM). Essentially, DPM gives the participation of a DISCO in contract with a GENCO, total of entries of column belong to DISCO1 of DPM is $\sum C_{pij} = 1$.

$$DPM = \begin{bmatrix} C_{p11} & C_{p12} & C_{p13} & C_{p14} & C_{p15} & C_{p16} \\ C_{p21} & C_{p22} & C_{p23} & C_{p24} & C_{p25} & C_{p26} \\ C_{p31} & C_{p32} & C_{p33} & C_{p34} & C_{p35} & C_{p36} \\ C_{p41} & C_{p42} & C_{p43} & C_{p44} & C_{p45} & C_{p46} \\ C_{p51} & C_{p52} & C_{p53} & C_{p54} & C_{p55} & C_{p56} \\ C_{p61} & C_{p62} & C_{p63} & C_{p64} & C_{p65} & C_{p66} \end{bmatrix}$$

Where C_p represents “contract participation factor”. In the case of three-area power system, scheduled steady state power flow on any tie-line is given as follows:

$$\Delta P_{i-j \text{ scheduled}} = [\text{Demands of DISCOs in area } j \text{ from GENCOs in area } i] - [\text{Demand of DISCOs in area } i \text{ from GENCOs in area } j] \quad (15)$$

and

$$\Delta P_{1 \text{ scheduled}}(k) = \Delta P_{1-2 \text{ scheduled}}(k) + a_{31} \Delta P_{3-1 \text{ scheduled}}(k) \quad (16)$$

$$\Delta P_{2 \text{ scheduled}}(k) = \Delta P_{2-3 \text{ scheduled}}(k) + a_{12} \Delta P_{1-2 \text{ scheduled}}(k) \quad (17)$$

$$\Delta P_{3 \text{ scheduled}}(k) = \Delta P_{3-1 \text{ scheduled}}(k) + a_{23} \Delta P_{2-3 \text{ scheduled}}(k) \quad (18)$$

Where $a_{12} \neq a_{23} \neq a_{31}$ are different and not equal to -1, because in this study it is taken as $P_{r1} \neq P_{r2} \neq P_{r3}$ such that P_{r1} , P_{r2} and P_{r3} are rated power of areas and k is sampling index. The error for the power defined in (16)-(18) is given as follows:

$$\Delta P_{i \text{ error}} = \Delta P_{i \text{ actual}} - \Delta P_{i \text{ scheduled}} \quad (19)$$

The error signal is used to generate its ACE signals in the steady state as follows:

$$ACE_i = B_i \Delta f_{i \text{ error}} + \Delta P_{i \text{ scheduled}}; \text{ where } i = 1, 2, 3 \quad (20)$$

Equation of the considered power system including two areas is given in steady state form as follows:

$$\dot{X}(t) = AX(t) + BU(t) \quad (21)$$

Where X is state vector, U is the demands of DISCOs.

$$\left. \begin{aligned} PG_1 &= PG_{(H1)} + PG_{(T2)} \\ PG_2 &= PG_{(CCGT1)} + PG_{(CCGT2)} \\ PG_3 &= PG_{(W-D1)} + PG_{(W-D2)} \end{aligned} \right\} \quad (23)$$

The speed changer signal is given by

$$\left. \begin{aligned} \Delta P_{C(T)} &= K_{P(T)} ACE + K_{I(T)} \int (ACE_i) dt \\ \Delta P_{C(H)} &= K_{P(H)} ACE + K_{I(H)} \int (ACE_i) dt \\ \Delta P_{C(CGT)} &= K_{P(CGT)} ACE + K_{I(CGT)} \int (ACE_i) dt \\ \Delta P_{C(W-D)} &= K_{P(W-D)} ACE + K_{I(W-D)} \int (ACE_i) dt \end{aligned} \right\} \quad (24)$$

$$ACE_i = B \Delta f_i + \Delta P_{ie} \quad (25)$$

From (14), PSO algorithm updates the velocity for each particle then adds that velocity to the particle position or values. Velocity updates are influenced by both the best global solution associated with the lowest cost ever found by a particle and the best local solution associated with the lowest cost in the present population. If the best local solution has a cost less than the cost of the current global solution, then the best

V. PSO APPLICATION FOR PARAMETER OPTIMIZATION

Fig 1 to 3, represents the detailed transfer function block of an area with diverse source of electric power generation namely thermal, hydro, gas and Wind-Diesel. The uncontrolled three area power system is shown in fig 6. The Thermal, Hydro, Gas and Wind-Diesel based units are presented by respective single plant dynamics under normal operating conditions, there is no mismatch between generation and load. The total generation in units 1,2 and 3 are given by:

$$PG = PG_{1(HT)} + PG_{2(CCGT)} + PG_{3(W-D)} \quad (22)$$

local solution replaces the best global solution. The particle velocity is reminiscent of local minimization that uses derivative information, because velocity is the derivative of position. The advantages of PSO are that it is easy to implement and there are few parameters to adjust. The PSO is able to tackle tough cost function with many local minima. In this problem PSO is used to optimize the gains of conventional PI controller with (ISE+ITAE) performance index as fitness function. The performance index is given by:

$$ISE = \Delta f_1^2 + \Delta f_2^2 + \Delta f_3^2 + \Delta P_{tie12} + \Delta P_{tie23} + \Delta P_{tie31} \quad (26)$$

$$ITAE = t(|\Delta P_{tie12}| + |\Delta P_{tie23}| + |\Delta P_{tie31}| + |\Delta f_1^2| + |\Delta f_2^2| + |\Delta f_3^2|) \quad (27)$$

$$\eta_{ISE+ITAE} = \int (ISE + ITAE) dt \quad (28)$$

VI. RESULT DISCUSSIONS

Typical examples of three area power systems are considered for the simulation. The initial values of the performance indices were obtained by carrying out simulation of the system over a period of 150s with AGC gain parameters obtained from randomly selected initial population. The values were used to produce next generation of individuals and procedure is repeated until the population has converged to some minimum value of the performance index. The parameters for PSO process are given in Appendix-2. The three area system with diverse sources of power system under deregulated environment is simulated for different cases with 1% step load perturbation in either of the area.

Case 1

During the study, error signals Δf_1 , Δf_2 , Δf_3 and ΔP_{tie} (i.e 1-2,2-3,3-1) are required for the controller is transferred to PSO algorithm. All positions of particles on each dimension area clamped in limits which are specified by the user, and the velocities are clamped to the range $[V_{min}, V_{max}]$ given in [30] and a step increase in demand of 0.01p.u kW is applied to area1,2 and 3. The frequency deviation and tie line power signals are shown in fig.7. The PI value which was obtained by the PSO algorithm is compared with that of the one derived from Zeigler-Nichols method in various perspectives, namely robustness and stability, performance and the optimum values are tabulated in 2.

Fig 7 reveals that there is a substantial improvement in the time domain specification. The proposed PSO controller is proved better than conventional controller tuned by Ziegler method. In addition, the proposed controller is very simple and easy to implement since it does not requires many information about system parameters. The typical three area has been simulated for different scheduled generations under different load conditions with the variation of 25% from the nominal value in either area and the scheduled power generation from H-T, W-D and CCGT are adjusted to match the system normal operating load. But when the variation of system parameters, unpredictable power demands and fluctuation under these case, CCGT the acceptable speed variation is about 96% to 104% from their nominal values are greatly affects the system stability and system temperature increases which reduces the life of the CCGT equipment. For the case of W-D, wind is

factor it will not always constant particularly, when the W-D connected the deregulated environment, the diesel system improves the stability only some acceptable range and diesel time constant is somehow high so again there is a problem of stability issues coming in to the picture.

First, a 0.01 pukW step increase in any one of the area in deregulated system at $t = 0.0$ s. Fig.8 (a),(b) and (c) shows the bar chart comparative analysis between % load variations with respect to Ts, Mp. Without SMES & CES, the system frequency highly oscillates, the deregulated three areas has very high Ts, Mp and high frequency oscillations and these oscillations about 140 sec in H-T, 100 sec in CCGT and 80 sec in W-D systems to reach zero. This indicates that the PSO controllers are not able to work well. On the other hand, the peak frequency deviation is reduced significantly and returns to zero within shorter period in case without or with the presence of energy storage devices.

Case 2

The optimisation algorithms used to reduces the damping of oscillations but has been proved that the AGC alone may not be sufficient to suppress these oscillations. With recent advances in high temperature superconductor materials, and power electronics and control techniques, the SMES/CES system, which combines the superconducting conductors and the power electronics converters, has become an important issue in electrical engineering. The installed SMES/CES system successfully damped the emerging 0.35Hz low frequency oscillation that had ever occurred on this transmission line and improved the stability of the transmission line.

Case 3

The validity of SMES, cES for power system dynamics performance improvement has been widely reported in [10]-[18]. Their applications in real power system have invited problems from the view point of operation, maintenance and cost involvement but capacitive energy storage (CES) is a better choice to damp out power system oscillations, following any perturbation in power system. Thus a corrective measure against power system perturbation, CES plays an important role to damp out local modes of oscillations.

Case 4

Comparative analysis: From the fig.9 shows bar chart shows the settling time, peakover shoot

performance of proposed SMES and CES are close to each other in the context of transient analysis particularly under deregulated environment. But CES is practically maintenance free, it does not impose any environmental problem, and it is quite simple and less expensive. CES damping effects are slightly better than SMES when variation in load.

Case 5

The system parameter variations can be defined in uncertainties. To compare the performance of proposed SMES and CES under variations of system parameters in the presence of random load variations. The values of settling time for all the by changing H-T, CCGT and W-D parameters are presented in table II and it shows that three area parameters are varied 25% from their normal values. The Ts values for three areas with conventional SMES/CES largely increase/decreases the above mentioned parameter variations. In contrast, the Ts values of three areas with proposed SMES/CES are lower and slightly changed. The values in case of conventional SME/CES highly increase when all the system parameter decreases. This implies that conventional SMES/CES is very sensitive to the variation of system parameters. The proposed SMES/CES is very robust to the variations of system parameters under this random load changes.

VII. CONCLUSION

- i. Modified AGC after deregulation, is an important issue in power system. AGC of a three area power system having power generation from Hydro Thermal sources in area-1, two Wind-Diesel turbines in area-2 and two combined cycle gas turbines in area-3 has been studied and ACE parameters are optimized for an appropriate performance index by using PSO.

- ii. Further to improve the system performance, particularly with the presence of uncertainties. In this paper new SMES and CES robust frequency controllers are successfully implemented in three area power system. Finally comparative studies have been made between two energy storage frequency controllers and compared with the work published in ref [18] and [33].
- iii. H_∞ loop shaping is a feasible method for designing robust controllers, however the controller design by this method is complicated and higher order. To overcome this problem, we propose an algorithm called PSO based fixed structure H_∞ loop shaping control to design a robust controller.
- iv. By this method a simple structured robust controllers are designed, from this study it is found that this work may seems to be quite simple and easy to analyze in real power system. It has given very good results in terms of performance and stability.
- v. The Simulation result clearly shows that proposed method is robust to change in system parameters and it has given better performance than conventional PI, SMES and conventional CES at all the Operating conditions. Performance of proposed robust frequency controllers, SMES and CES are close to each other in the context of transient analysis. But CES is practically maintenance free, it does not impose any environmental problem, and it is quite simple and less expensive. CES damping effects slightly better than SMES when variation in load for LFC problem in deregulated environment.

APPENDIX 1

Wind Diesel System:

$P_R = 350$ kW, $H_W = 3.5$ s, $H_D = 8.5$ s, $K_{fc} = 16.2$ Hz/pu kW, $K_D = 16.5$ Hz/pu Kw, $K_{P2} = 1.25$, $K_{P3} = 1.4$, $T_{P1} = 0.6$ s, $TP2 = 0.041$ s, $K_{PC} = 0.08$, $K_{P1} = 4.0$, $K_{PP} = 1.5$.

CCGT Data:

$T_{io}=303$ K, $T_{do}=390$ C, $T_{fo}=1085$ C, $T_{eo}=532$ C, $P_{ro}=11.5$, $\Gamma=1.4$, $\eta_c=0.85$, $\eta_t=0.85$, $K_0=0.00303$ (1/K), $K_1=0.000428$ (1/K), $R=0.04$, $T_g=0.05$ s, $K_4=0.8$, $K_5=0.2$, $T_3=15$ s, $T_4=2.5$ s, $T_5=3.3$ s, $T_t=0.4699$ s, $T_{c\max}=1.1$ s, $T_{c\min}=0$ s, $F_{d\max}=1.5$, $F_{d\min}=0$, $K_3=0.77$, $K_6=0.23$, $T_v=0.05$ s, $T_f=0.4$ s, $T_6=60$ s, $g_{\max}=1.001$, $g_{\min}=0.73$, $T_w=0.4699$ s, $T_b=20$ s, $T_{cd}=0.2$ s, $T_m=5$ s, $T_i=18.5$ s, $T_{off}=0.01$ s.

H-T Data:

$P_{r1}=P_{r2}=2000$ MW, $H_1=H_2=5$ s, $D=8.33 \times 10^{-3}$ pu.MW/Hz, $K_r=0.5$, $R_1=R_2=2.4$ Hz/pu.MW, $T_r=10$ s, $K_{p1}=K_{p2}=120$ Hz/pu.MW, $T_{p1}=20$ s, $T_{12}=0.86$ pu.MW/Radian, $f=60$ Hz, $T_w=1.0$ s, $a_{12}=-1$, $T_g=0.08$ s, $T_t=0.3$ s.

APPENDIX-2

List of PSO parameters;

Number of particle – 20

Fitness function: $\frac{1}{1 + (ISE + ITAE)}$

Particle size: 14

Number of iteration: 100

C₁: 02C₂: 02

Inertia Weight (w): decreasing from 0.9 to 0.2.

APPENDIX-3

$$X = (P_r)^{\frac{\gamma-1}{\gamma}} \quad \dots(A.1)$$

$$P_r = P_{ro} * W \quad \dots(A.2)$$

$$X = (P_{ro} * W)^{\frac{\gamma-1}{\gamma}} \quad \dots(A.3)$$

$$\eta_c = \frac{t_{d, is} - t}{t_d - t} \quad \dots(A.4)$$

$$t_d = \frac{t_l (1 + X - 1)}{\eta_c} \quad \dots(A.5)$$

$$W_f = \frac{W(t_f - t_d)}{(t_{fo} - t_{do})} \quad \dots(A.6)$$

$$t_f = t_d + (t_{fo} - t_{do}) \frac{W_f}{W} \quad \dots(A.7)$$

$$\eta_t = \frac{t_{t, is} - t}{t_t - t} \quad \dots(A.8)$$

$$t_e = \frac{t_f [l - (l-1)\eta_t]}{X} \quad \dots(A.9)$$

$$E_g = K_o [(t_f - t_e) - (t_d - t_i)] W \quad \dots(A.10)$$

$$E_s = K_l * t_e * W \quad \dots(A.11)$$

$$T_f = \frac{t_f - 273}{t_{fo}} \quad \dots(A.12)$$

$$T_e = \frac{t_e - 273}{t_{eo}} \quad \dots(A.13)$$

$$P = E_g + E_s \quad \dots(A.14)$$

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Table 1 : PSO algorithms for 100 to 150 iterations for all the three systems and the obtained values listed below

System	SMES Frequency controller value			CES Frequency controller value		
	K_{SMES}	T_{sm1}	T_{sm2}	K_{CES}	T_{CES1}	T_{CES2}
CCGT	112	0.5875	0.6547	146.7	0.79250	0.8813
H-T	0.56	0.2782	0.3652	0.865	0.3659	0.5651
W-D	48.9	0.9547	0.5682	29.8	0.7657	0.4864

Table 2 : Different System Controller Values obtained from PSO Algorithm

System	SMES Frequency controller value			CES Frequency controller value		
	K_{SMES}	T_{sm1}	T_{sm2}	K_{CES}	T_{CES1}	T_{CES2}
CCGT	112	0.5875	0.6547	146.7	0.79250	0.8813
H-T	0.56	0.2782	0.3652	0.865	0.3659	0.5651
W-D	48.9	0.9547	0.5682	29.8	0.7657	0.4864

Table 3 : Various Gain Values Obtained from Conventional and PSO Controller for Three Different Areas

		AREA 1		AREA 2		AREA 3	
		Hydro	Thermal	CCGT	CCGT	W-D	W-D
Conventional Controller	K_P	3.7640	3.6514	0.0121	0.021	3.500	3.500
	K_I	0.6561	0.5583	0.6631	0.6631	0.785	0.785
PSO controller	K_P	3.3260	3.5439	0.0562	0.0671	3.6762	3.6732
	K_I	0.6879	0.5983	0.8454	6.8456	0.8364	0.8366

Table 4 : $\pm 25\%$ changing parameter from their typical values the system uncertainties are obtained

System Parameter variation from the nominal value		Three Area T_s Value with Proposed SMES			Three Area T_s Value with Proposed CES		
		Δf_1	Δf_2	Δf_3	Δf_1	Δf_2	Δf_3
1.CCGT Power System							
R (Nominal Value 0.04)		59	45	45	50	40	43
$\pm 25\%$	0.05/0.03	65	54	56	52	43	44
$\pm 15\%$	0.046/0.034	60	50	44	51	43	43
T_g (Nominal Value 0.05)		59	45	45	50	40	43
$\pm 25\%$	0.0625/0.0375	65	49	56	60	49	50
$\pm 15\%$	0.0575/0.0425	62	47	49	56	42	47
T_i (Nominal Value 18.5)		59	45	45	50	40	43
$\pm 25\%$	23.13/13.88	70	65	65	55	48	50
$\pm 15\%$	21.3/15.72	65	55	57	54	45	47
T_{cd} (Nominal Value 0.2)		59	45	45	50	40	43
$\pm 25\%$	0.25/0.15	59	45	45	50	40	43
$\pm 15\%$	0.23/0.17	59	45	45	50	40	43

T_m(Nominal Value 5)		59	45	45	50	40	43
±25%	6.25/3.75	66	60	60	51	42	44
±15%	5.75/4.25	65	59	58	49	40	42
2.W-D Power System							
H_w (Nominal Value 3.5)		59	45	45	50	40	43
±25%	4.375/2.626	66	60	60	51	42	44
±15%	4.025/2.975	65	59	58	49	40	42
H_D (Nominal Value 8.5)		59	45	45	50	40	43
±25%	10.625/7.225	70	55	56	52	43	45
±15%	9.775/7.225	65	50	56	51	42	45
K_{PI} (Nominal Value 4.0)		59	45	45	50	40	43
±25%	5.0/3.0	59	45	45	50	40	43
±15%	4.6/3.4	59	45	45	50	40	43
3. H-T Power System							
T_g (Nominal Value 0.08)		59	45	45	50	40	43
±25%	0.1/0.06	59	45	45	50	40	43
±15%	0.0925/0.0675	59	45	45	50	40	43
T_t (Nominal Value 0.3)		59	45	45	50	40	43
±25%	0.375/0.225	59	45	45	50	40	43
±15%	0.345/0.255	59	45	45	50	40	43
T_w (Nominal Value 1.0)		59	45	45	50	40	43
±25%	1.25/0.75	66	60	60	51	42	44
±15%	1.15/0.85	65	59	58	49	40	42
H (Nominal Value 5)		59	45	45	50	40	43
±25%	6.25/3.75	75	65	72	55	48	43
±15%	5.75/4.25	70	55	65	50	45	43

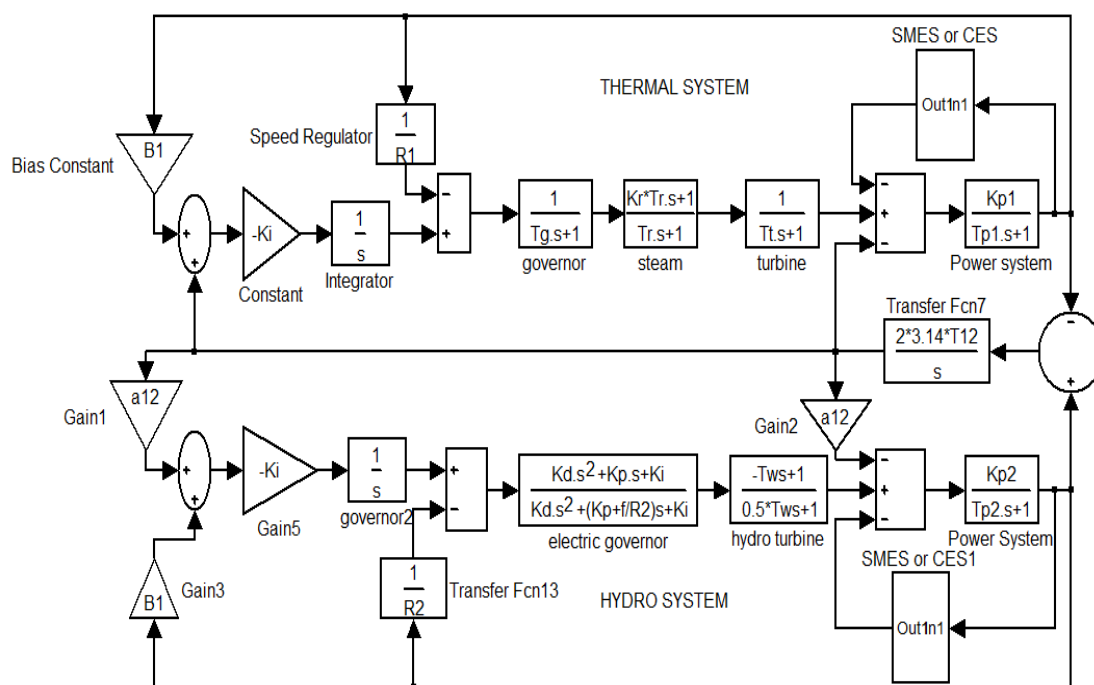


Fig. 1 : Transfer function model of H-T system co-ordinated with SMES or CES

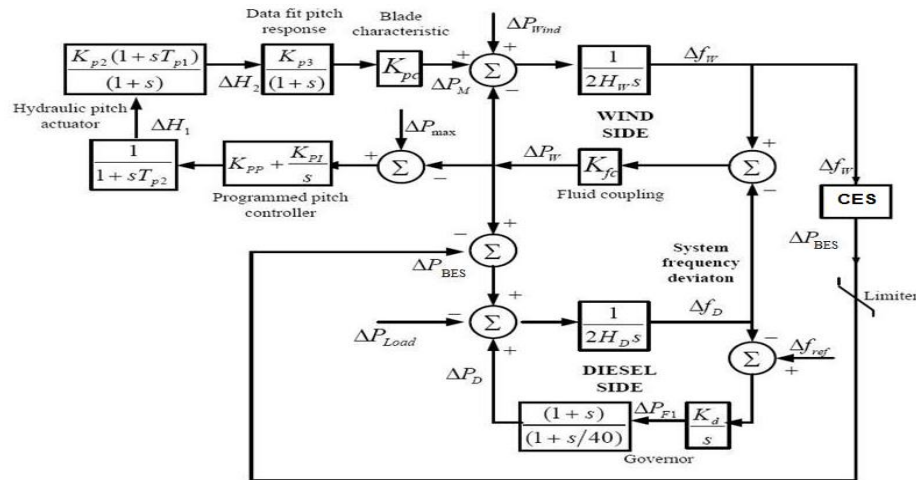


Fig. 2 : Transfer function model of W-D system co-ordinated with SMES or CES

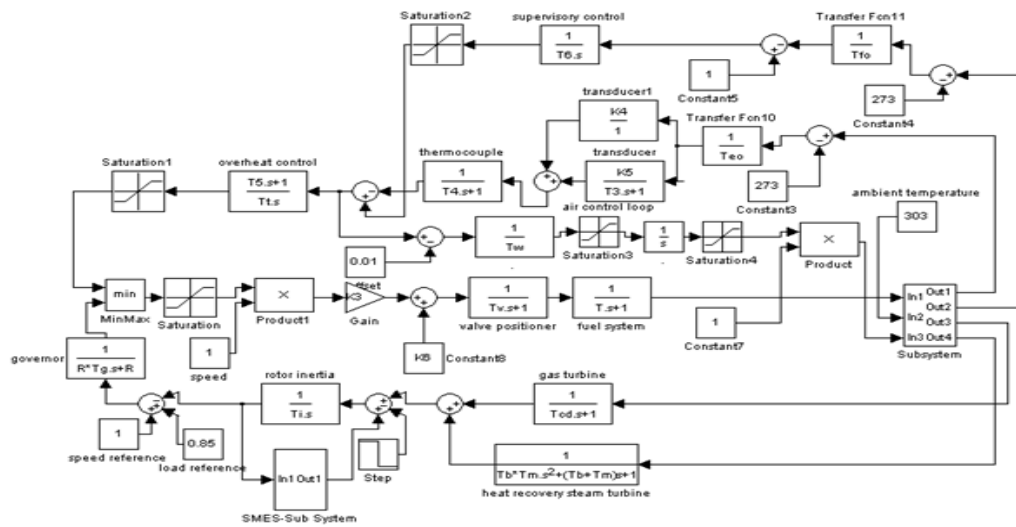


Fig. 3(a) : Transfer function model of CCGT system co-ordinated with SMES or CES

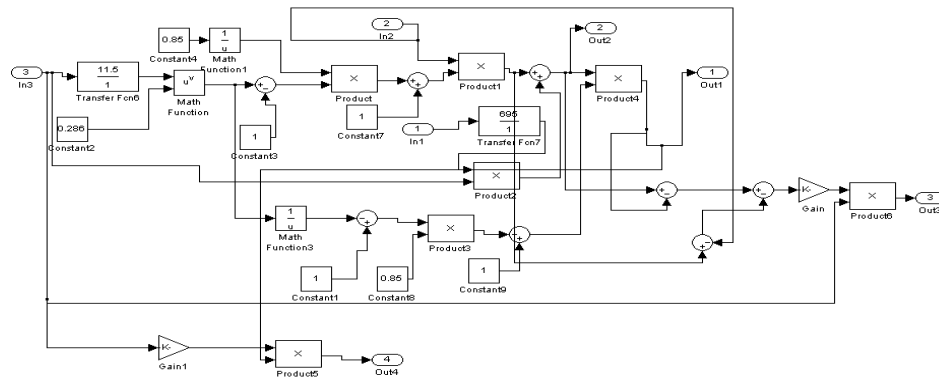


Fig. 3(b) : Sub System for adiabatic compression and expansion

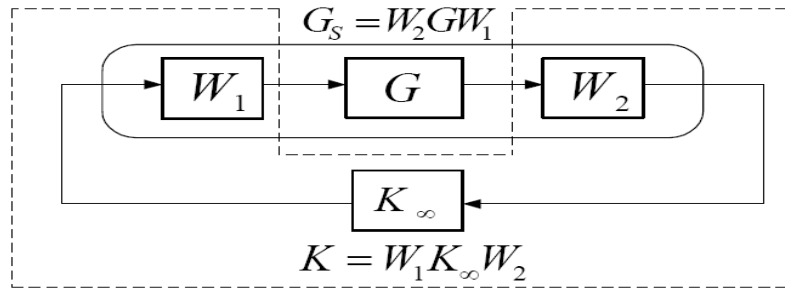


Fig.4 : Shaped Plant G_s and Robust Controller K

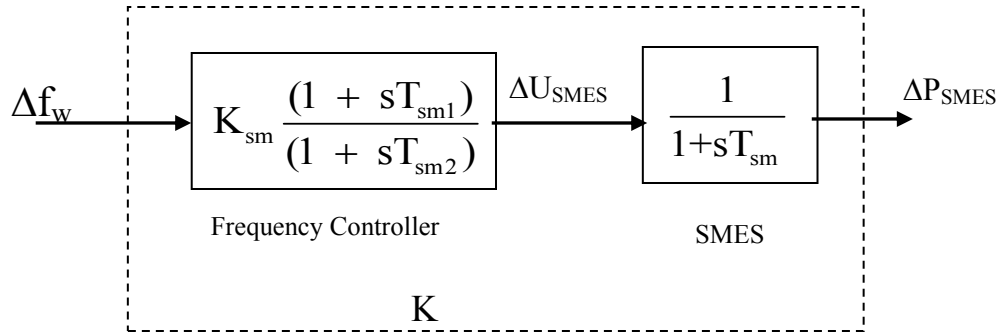


Fig. 5(a) : Block diagram of SMES with Frequency Controller

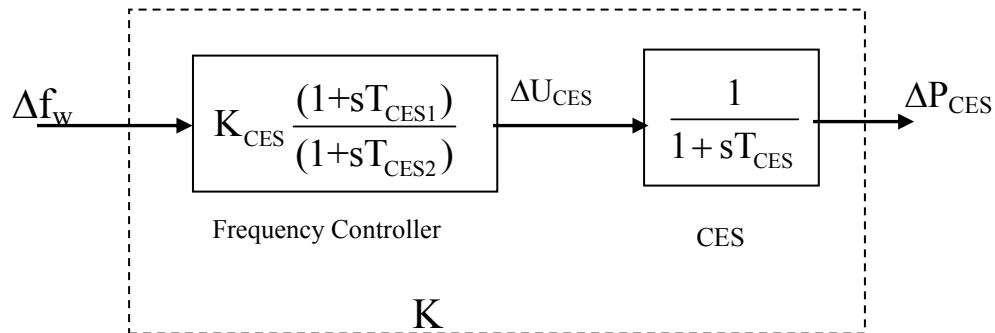


Fig. 5(b) : Block diagram of CES with Frequency Controller

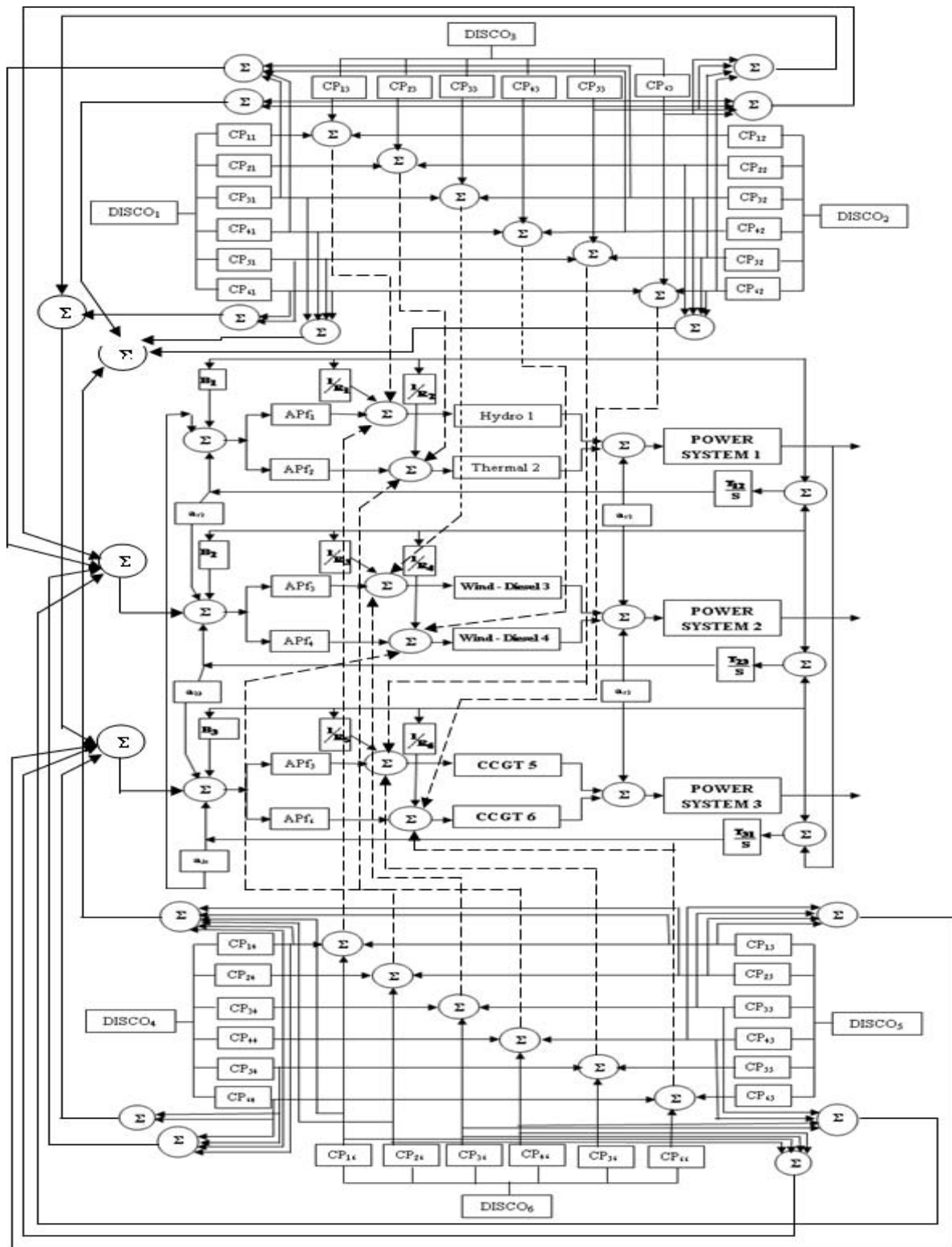


Fig. 6 : Transfer Function Model of Three Area H-T, CCGT & W-D System under Deregulated Environment using SMES/CES

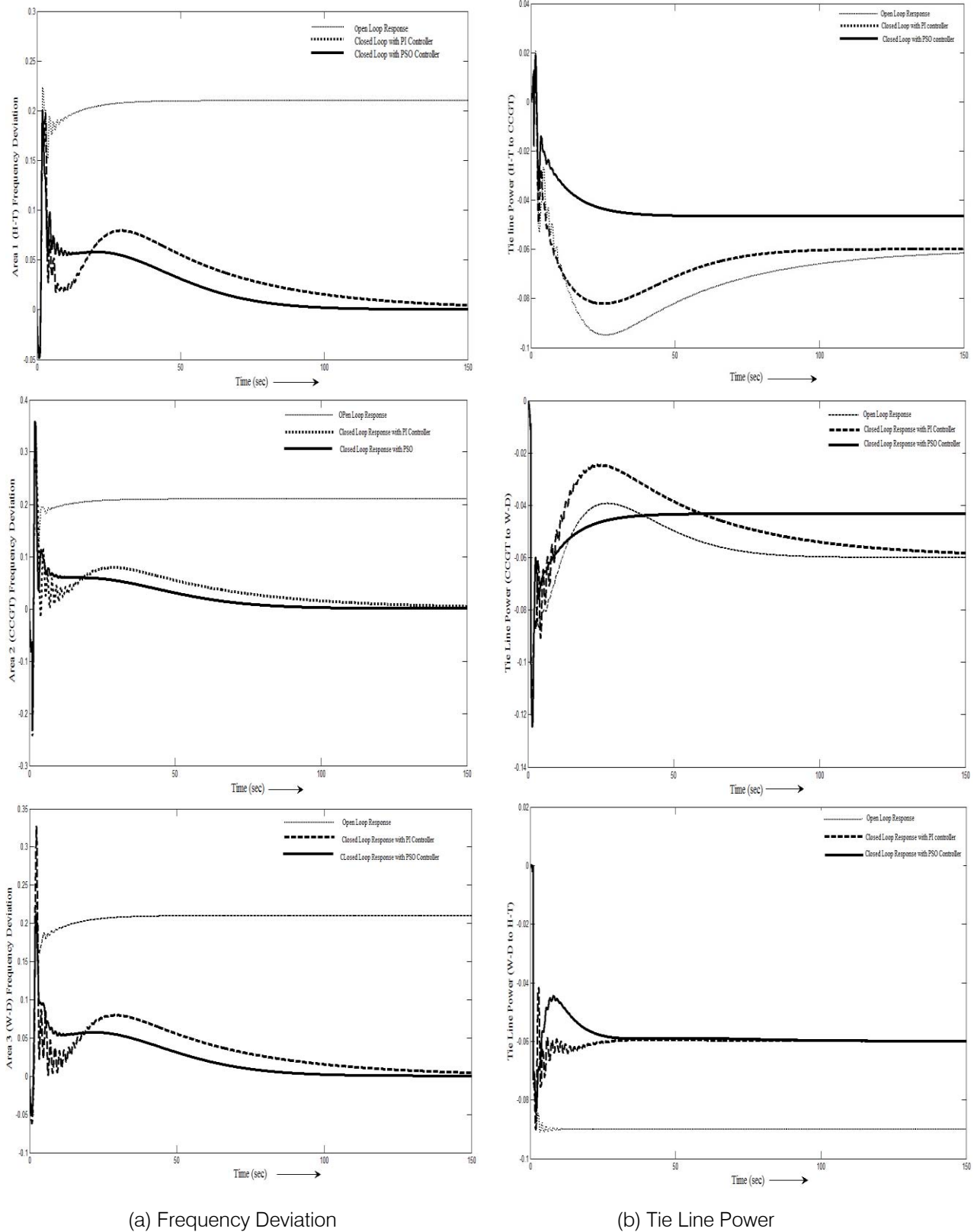
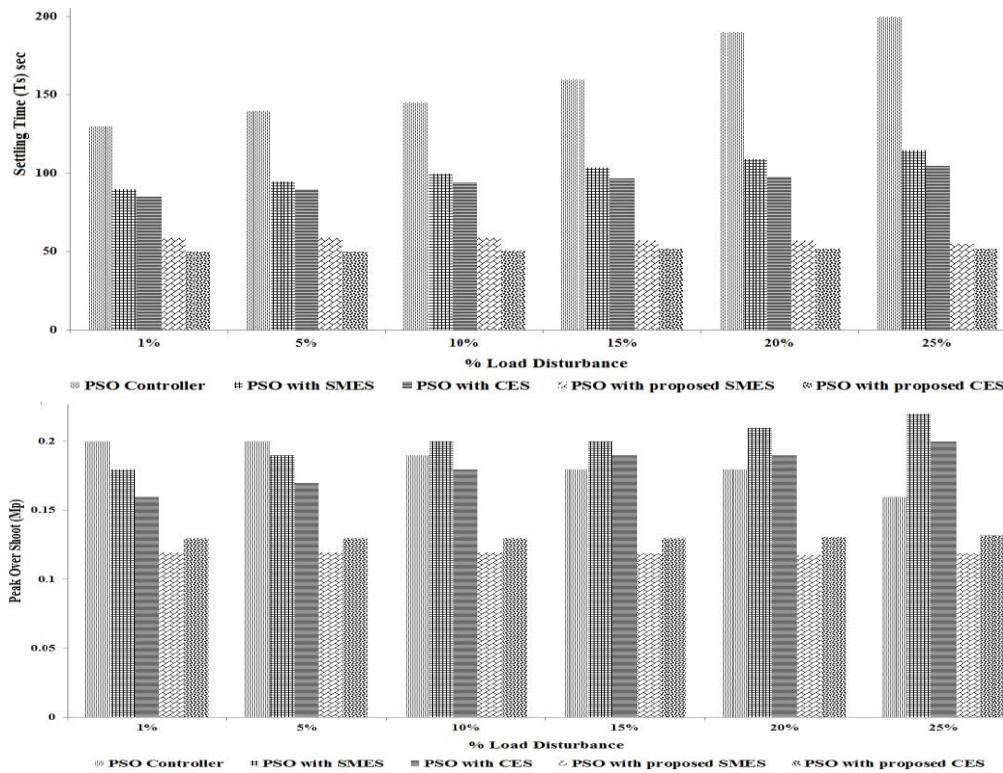
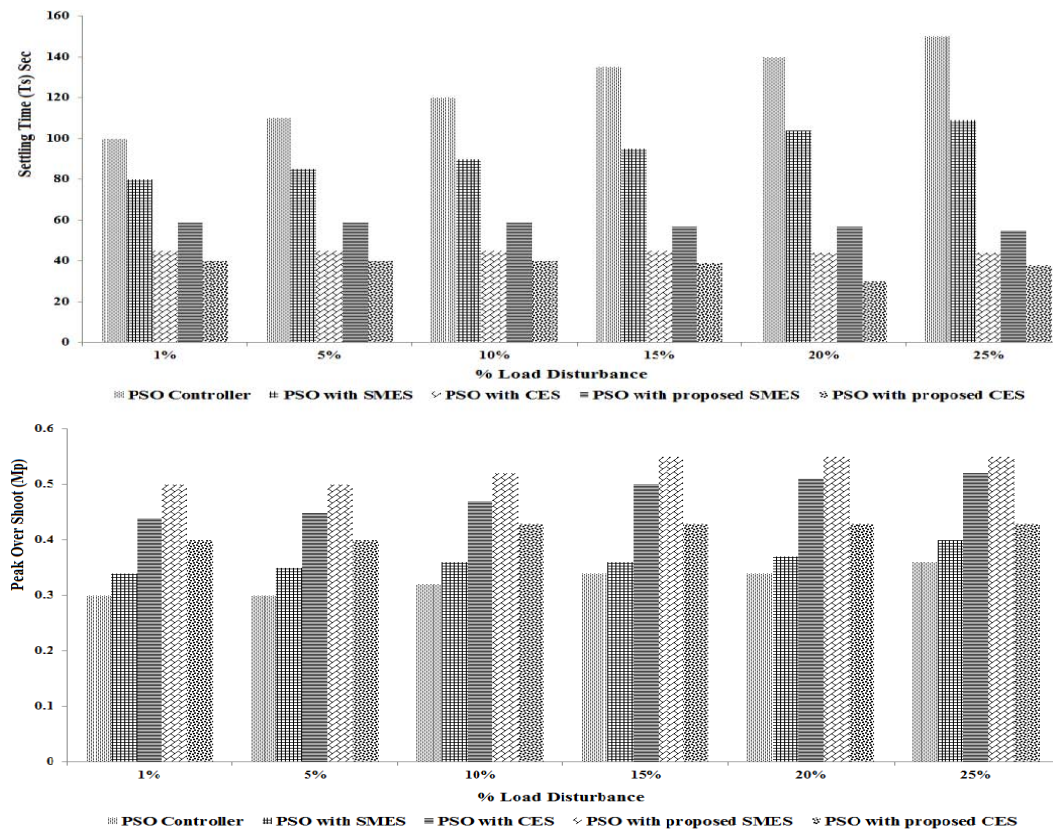


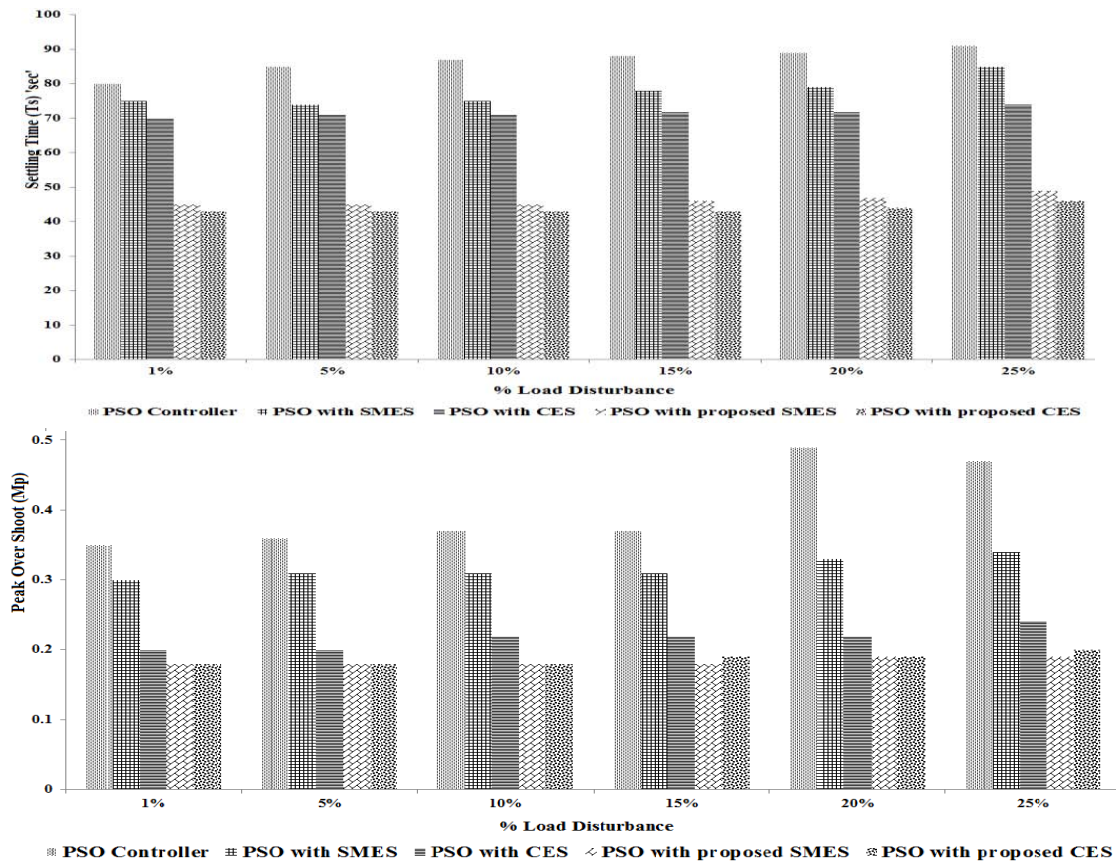
Fig. 7 : Comparative analysis of Three area H-T, CCGT & W-D under deregulated Environment without controller, with PI controller & PSO optimized controller



(a) Hydro -Thermal

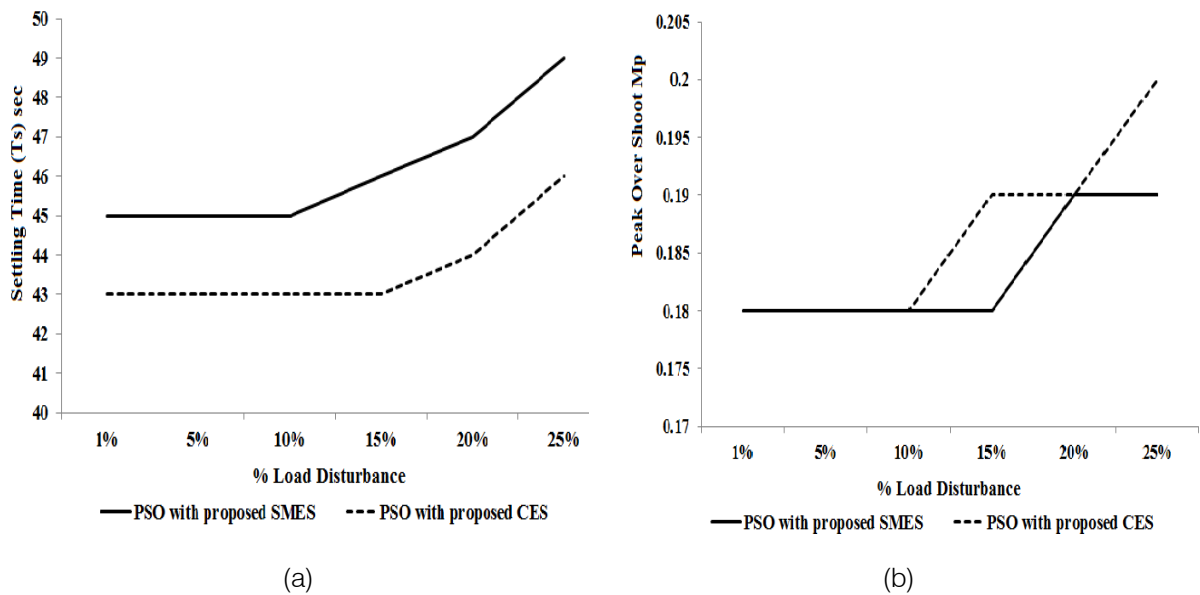


(b) Combined Cycle Gas Turbine



(c) Wind-Diesel

Fig. 8 : Ts and Mp Comparison of Three Area Deregulated H-T, CCGT & W-D System for Different Controller with 25% Load Variations



(a)

(b)

Fig. 9 : Settling Time & Peak Over Shoot Comparison Between Proposed CES & SMES under Various Load Conditions

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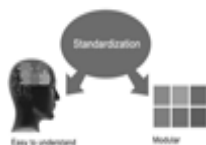
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29. Think technically: Always think technically. If anything happens, then search its reasons, its benefits, and demerits.

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 through 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.
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- As always, give awareness to spelling, simplicity and correctness of sentences and phrases.

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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
Result	Well organized, Clear and specific, Correct units with precision, correct data, well structuring of paragraph, no grammar and spelling mistake	Complete and embarrassed text, difficult to comprehend	Irregular format with wrong facts and figures
Discussion	Well organized, meaningful specification, sound conclusion, logical and concise explanation, highly structured paragraph reference cited	Wordy, unclear conclusion, spurious	Conclusion is not cited, unorganized, difficult to comprehend
References	Complete and correct format, well organized	Beside the point, Incomplete	Wrong format and structuring



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