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Organised by

Department of Electrical Engineering, Dr. BabasahebAmbedkar College of Engineering & Research, Nagpur, Maharashtra, India (NAAC Accredited)

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Organised by

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Simulation of Power Electronics Interface Used In Wind Energy Conversion System

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ABSTRACT

With the development in Wind Energy Conversion System (WECS), various types of electrical generators according to the application along with appropriate power electronic interface has been used to provide electrical power to grid/load. The main component of rectifier-inverter interface is inverter, which uses Pulse Width Modulation (PWM) for control purpose. Various modulation schemes are used to generate pulses of voltage source inverter. In this paper, triangular carrier based pulse width modulation scheme is used and simulation results are presented and performance of the system is investigated. The system performance is investigated on the basis of voltage and current THD, power factor, and active and reactive power consumption.

Keywords : Wind Energy Conversion System (WECS), Pulse Width Modulation (PWM), Space Vector Modulation (SVM), Sinusoidal Pulse Width Modulation (SPWM)

I. INTRODUCTION

The wind turbine generates power at variable voltage and frequency due to variability of wind speed. Power electronic interface between WECS and grid/load resolves this problem to a great extent. Generated power is converted into DC by the rectifier of power electronic interface. This power of DC-link is converted into AC power at rated voltage and frequency through inverter of interface, to be fed to the grid/load.

It is essential to observe the impact of power output variation on the power quality of stand-alone WECS [1]. The impact on power quality is mainly observed in terms of voltage harmonics, current harmonics and reactive power consumption. In stand-alone WECS, load also shows impact on system voltage and power factor, such as at light load conditions the voltage may go up and power factor become leading.

A review paper by Frede Blaabjerg et al. [2] has presented the detailed study of various power electronics interface and control system used for WECS. This paper is mainly focused on triangular carrier based space vector modulation used in power electronics interface of stand-alone WECS. PMSG based WECS is developed by C. N. Bhende et al. in [3] in which a novel control strategy for maximum power extraction and output voltage and frequency controller is discussed.

Errami et al. in [4] has proposed a PMSG based wind energy conversion system in which generator is modelled in synchronous reference frame. MPPT based control is applied to control the torque. The speed control is implemented through field orientation in which to control the generator speed, q-axis current is used and the d-axis current is set to zero. Numerous literature is available which is mainly based on generator side control, dc-link voltage control and controlling of grid side inverter. Stand-alone WECS is presented by many authors in [5-7] but load side inverter controlling is not presented in detail.

A review paper by Orlando et al. [8] is presented the various control issues for small wind energy conversion systems. Specific issues for small WECS and their universal mode operation are also presented which leads such system to work either as stand-alone or grid connected system. But controlling in stand-alone mode is not covered in detail for load side inverter.

Main objective of this paper is to implement the triangular carrier based pulse width modulation method used for load side inverter simulated model of a wind energy conversion system. The performance of WECS is discussed through analysis on factors influencing power quality like %THD in voltage and current, power factor and reactive power consumption. The detailed mathematical modeling of WECS is covered in reference [9] and out of the scope for this paper.

Rectifier-inverter power electronic interface is discussed in subsequent section to observe the performance of control method used for generating gate pulse for inverter by simulation results.

II. WECS WITH RECTIFIER-INVERTER INTERFACE

The rectifier-inverter interface is most commonly used power electronic interface in WECS for getting constant power and sinusoidal voltage at rated frequency as shown in Fig.1. The generator output voltage is fed to the three phase rectifier, which converts it into the DC voltage. The DC link capacitor on the DC side of rectifier regulates this voltage and feeds it to the three phase IGBT inverter. The 3-phase voltage available lastly at the output of the inverter at rated frequency is supplied to the grid/load as shown in Fig.1

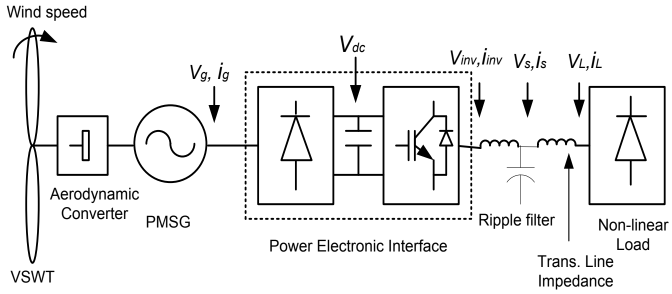


Figure 1. Power Transfer Stages in Wind Energy Conversion System

III. LOAD SIDE CONVERTER CONTROL SCHEME

In WECS, a control method is used to generate gate pulses for inverters to regulate frequency and voltage. The dc-link in the middle of interface used in WECS provides decoupling between rectifier and inverter. The main component of interface is inverter, which uses Pulse Width Modulation (PWM) for controlling purposes. The switching elements are power semiconductors that operate at high frequencies. There are various methods for controlling converter.

The voltage source converter must keep voltage and frequency constant for different load conditions. Hence, in any converter control scheme, the main objective is to determine the reference signal in the PWM control block to allow the load voltage to track the reference. The most commonly used PWM methods for 3-∅ VSIs are carrier-based sinusoidal PWM, and space vector PWM. In PWM schemes switching instants are selected such as the desired output waveform with acceptable harmonic limit is obtained. Simulations results are obtained using triangular carrier based SVM methods are discussed.

For simulation studies for a 10 KVA system are as follows-

V_S= 3-Φ, 400V, f = 50 Hz,

DC link capacitance - V_{dc} = 2200 μF,

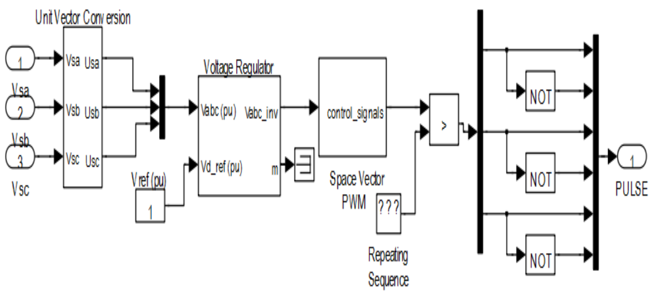
Snubber circuit values - C_S = 0.1 μF,

$R_s = 100\Omega$,

PI controller - $K_p = 0.02$, $K_i = 20$

IV. TRIANGULAR CARRIER BASED PULSE WIDTH MODULATION

An appropriate control scheme is needed to cope up with uncertainties in the network different operating conditions due to the load/ parameters variations. Space Vector Modulation (SVM) was formerly evolved as vector approach to PWM for three phase inverters. Triangular carrier pulse width modulation is an advanced and more revolutionary approach for generating sinusoidal waveform that offers a higher voltage to the load with lower THD [10]. The main objective of any modulation method is to get variable output having maximum value of fundamental component along with desired harmonics. The triangular carrier based SVM method is implemented by user defined subsystems. These are shown in Fig.2.



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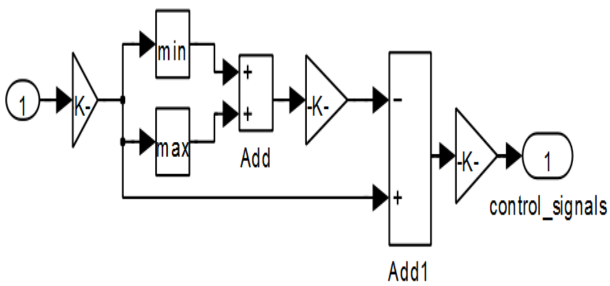


(b)

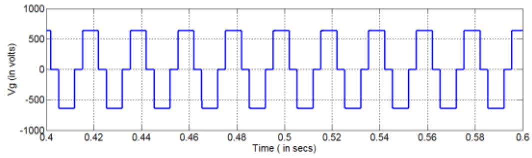
Figure 2. (a) Simulation block diagram for SVM to generate gate pulse (b) SVM control signal generator for triangular carrier based SVM

V. RESULTS AND DISCUSSIONS

In triangular carrier based pulse width modulation, rather than using a separate modulator for each of the phases, the complex reference voltage vector is processed as a whole. Space vector PWM can be easily implemented in digital signal processor [11] which has increased its uses in the last decade. In conventional SVM, synthesis of the output voltage is achieved by chosen the appropriate states of VSI switches and their time slot in such a way that the output voltage is best approximated. Quick implementation of SVM is possible by using triangular carrier based pulse width modulation. It is easy in implementation as sector determination is not required in carrier based PWM. The pulses can be generated by comparing duty ratio profile with high frequency triangular carrier similar to sinusoidal pulse width modulation.

Simulation results for WECS in steady state condition are shown in Fig.3 (a)-(e). Generator voltage (V_g), generator current (I_g), DC-link voltage (V_{dc}), source current (I_s) and load current (I_L) waveforms for 'A' phase are shown in Fig.3 at steady state condition. Various voltage and current waveforms and their frequency spectrums are shown in Fig.4 Total harmonic distortions in voltage waveform are reduced from 29.46 % on generator side to 0.86 % on power electronic (rectifier-inverter) interface output after filter, while the current output from the generator having THD of 22.51% improves to the current at power electronic interface output after filter with THD 3.35 %. The notches in current waveform are the result of creeping in DC-link voltage which may be further reduced by advanced tuning of controller parameters.

Fig.5 (a)-(c) represents instantaneous active power (P), reactive power (Q), and at WECS output at steady state. It is found that rectifier-inverter interface with active filter makes the power flow smooth by reducing the generator voltage harmonics. Hence, fulfills the requirement of IEEE Standards.



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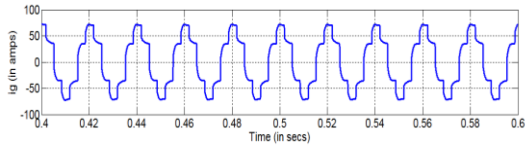

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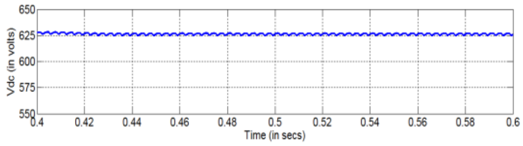

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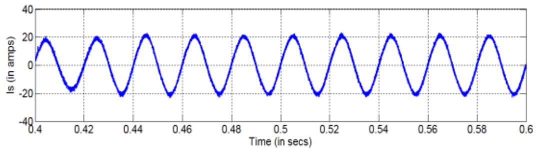

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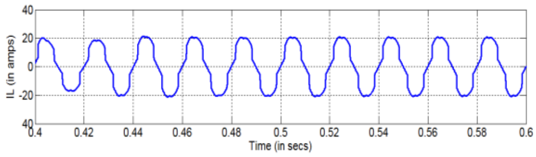
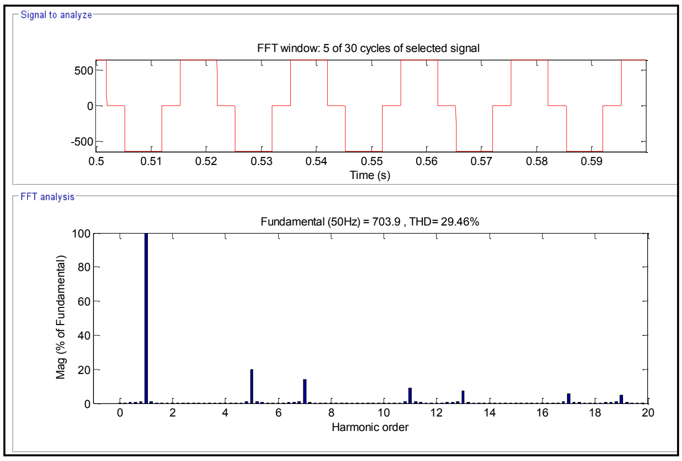


(e)

Figure 3. (a) Generator voltage V_g (b) generator current I_g (c) DC-link voltage V_{dc} (d) inverter current I_i (e) load current I_L



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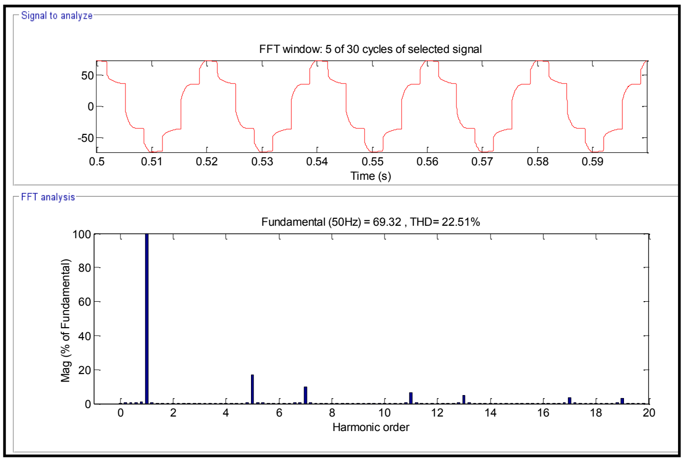
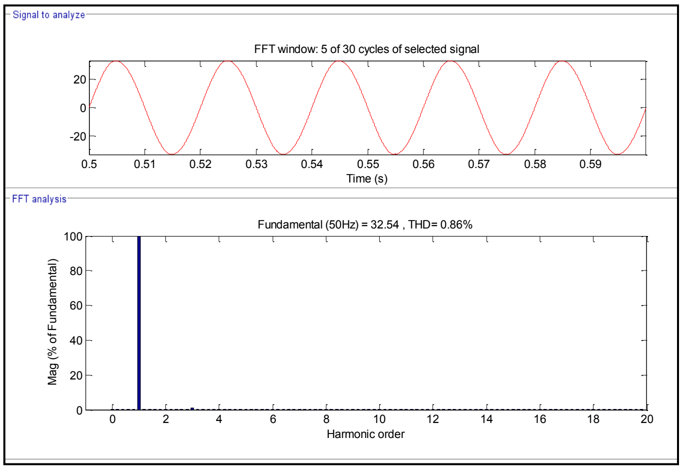


(b)

Figure 4. Frequency spectrum of (a) generator voltage V_g (b) generator current I_g



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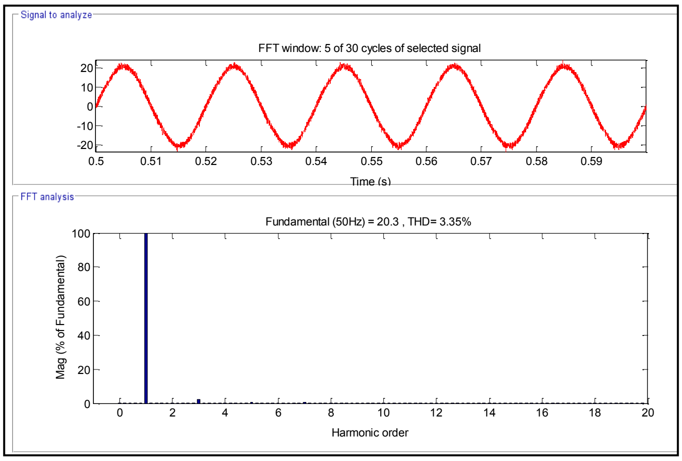
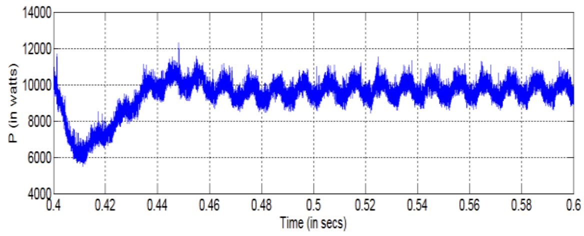


(d)

Fig. 4(c) source voltage V_s and (d) source current I_s at WECS



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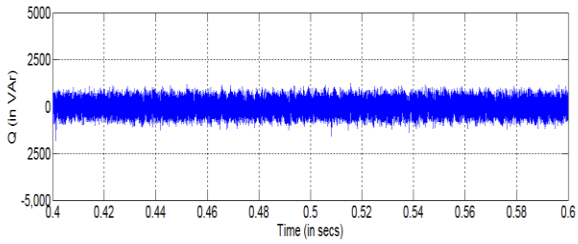

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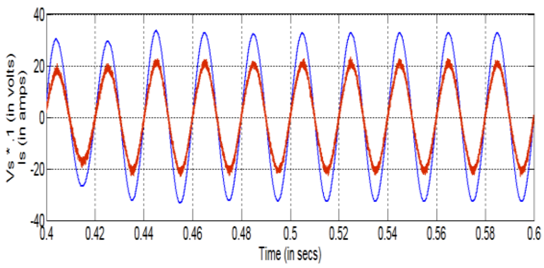

(c)

Figure 5. (a) Instantaneous active power P, (b) reactive power Q and (c) source voltage V_s and source current I_s at WECS

Table 1 enlists the performance of switching scheme used for generating pulses for voltage source inverters to provide controlled output. The performance of WECS is better in triangular carrier based SVM in terms of %THD in source current and source voltage, both are under the limits in both methods.

Table 1 Summary of various components for WECS in RII with triangular carrier based SVM switching scheme

Component	**Triangular Carrier based SVM**
%THD of Source voltage	0.86
%THD of Source current	3.34
Active Power (W)	9775
Reactive Power (VAr)	129
DC-link voltage variation (V)	625 - 630
Power factor	0.9999

VI.CONCLUSION

Use of power electronics interface is essential between the generator and grid/load to convert the variable generated output to constant voltage and frequency to feed to grid/load. This paper presents the performance of a WECS with RII connected to a stand-alone load. The effectiveness of applied modulation method is discussed on the basis of total harmonic distortion in voltage and current waveforms, variation in dc–link voltage, reactive power compensation and power factor of the system. It is observed that triangular carrier PWM have better utilization of the dc-link voltage, low current ripple and relatively easy to implement in hardware. It is concluded that triangular carrier pulse width modulation control method works well in stand-alone WECS. Triangular carrier pulse width modulation is more sophisticated, and it gives more voltage output. Thus, DC voltage utilization is increased by using above method.

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Simulation of Transformerless Single Phase Inverter Using Solar System

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ABSTRACT

Solar energy is the major source of power. Its potential is 178 billion MW, which is about 20,000 times the world's demand. Solar energy, received in the form of radiation (electromagnetic waves), can be converted directly or indirectly into other forms of energy, such as heat and electricity which can be utilized by man .Inverters are the devices usually solid state which change the array DC output to AC suitable voltage, frequency and phase to feed photo voltaic ally generated power into the power grid or local load. Solar energy is time dependent and intermittent energy resources. Inverter may also contain a suitable output step up transformer perhaps some filtering and power factor correction circuits and some power conditioning circuitry to initiate the battery charging and to prevent overcharging .Inverters of PV system based distributed generation (DG) are subjected to wide changes in the inverter input voltage, thus demanding a buck-boost operation of inverters . Further the inverter size, weight and cost is increased. It is designed transformer less inverter that can be operated over a wide dc input voltage range making it suitable for distributed generation applications. Depending on the reference signal, the inverter output voltage can be either boosted or bucked with respect input voltage.

Keywords: Solar Panel, Buck-Boost Converter, Reference Signal, Transformer-Less Inverters, PWM

I. INTRODUCTION

Renewable energy substitutes conventional fuels or distinct areas air and water heating and cooling, motor fuels, electricity generation. Photovoltaic systems (PV) that supply power directly to the grid are becoming more popular due to the cost reduction achieved from the lack of a battery subsystem. This design can be used in high power ranges providing high system flexibility.

Energy conversion devices which are used to convert sun light to electricity by the use of the photo voltaic effect are called "Solar cells". Inverters are the devices usually solid state which change the array DC output to AC suitable voltage, frequency and phase to feed photo voltaic ally generated power into the power grid or local load. Inverter may also contain a suitable output step up transformer for some filtering and power factor correction circuit.

Distributed generation (DG) systems are usually small modular devices which are nearly to electricity consumers. These include wind turbines, solar energy systems, fuel cells, micro gas turbines, and small hydro systems, as well as relevant control and energy storage systems. These systems normally need inverters as interfaces between their single phase loads and source.

The functions of inverters for small DG systems can be summarized as follows:

1. It converts power conversion from variable dc voltage into fixed ac voltage for stand-alone applications and ac output in synchronism with the grid voltage and frequency for grid-connected applications.
2. Variable dc voltage can be higher or lower than the ac voltage in a system, which is observed normally in a solar energy and wind turbine systems. Thus, there is a need to buck boost the inverter voltage.

Based on the electrical isolation between the output and input, inverters can be classified as isolated or non-isolated. Electrical isolation is normally achieved using either line frequency or high-frequency transformers. Inverters are used for many applications, as in situations where low voltage DC sources such as batteries, solar panels or fuel cells should be converted so that devices can run off of AC power.

II. LITERATURE SURVEY

When no transformer is used in a grid connected pv system, a galvanic connection between grid and a pv array exists. In this condition, dangerous leakage current can appear through thr stray capacitance between the pv array and the ground. In order to avoid these leakage currents, different inverter topologies that generate no varying common mode voltages, such as half bridge and the bipolar pulse width modulation(PWM) full bridge topologies have been proposed".

The elimination of the output transformer from grid connected photovoltaic (pv)systems not only reduces the cost, size ,and weight of the conversion stage but also increases the system overall efficiency . However, if the transformer is removed, the galvanic isolation between the pv generator and the grid is lost .This may cause safety hazards in the event of ground faults. In addition, the circulation of leackage currents (common –mode currents) through the stray capacitance between the PV array and the ground would be enabled.

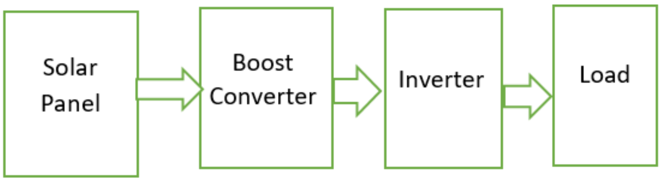

Figure 1: Block Diagram DC to AC

The boost converter is best if a significant and much step up is required, such as with a short string of 12-PV panels. A cascaded multilevel inverter consists of a series of Hbridge inverter devices. The work of multilevel inverter is to synthesize a desired voltage from Several Separate DC Source. The main disadvantage of this system is that each single H-bridge cascaded inverter modules needs a separate DC supply source.

Traditional full-bridge inverters do not have flexibility of handling a wide range of dc input voltages. Especially when the DC voltage is lower than the AC voltage, heavy line frequency step-up transformers are required. Although these inverters show robust performance and high reliability, they demand higher volume, weight and cost for DG system applications.

III. PROPOSED DC TO AC CONVERTER

The block diagram of boost inverter used for the proposed system is shown in Fig 3. DC voltage obtained from the photo voltaic cells is given as input to dc- dc converter.

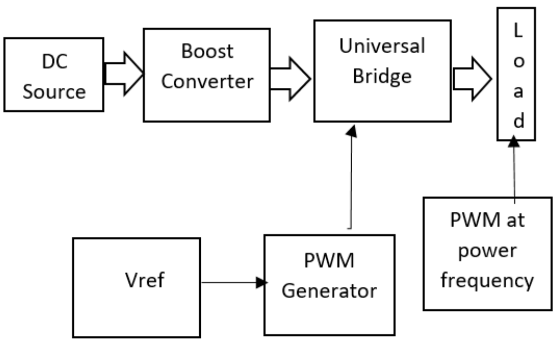

Figure 2. Block Diagram of AC to DC Convert

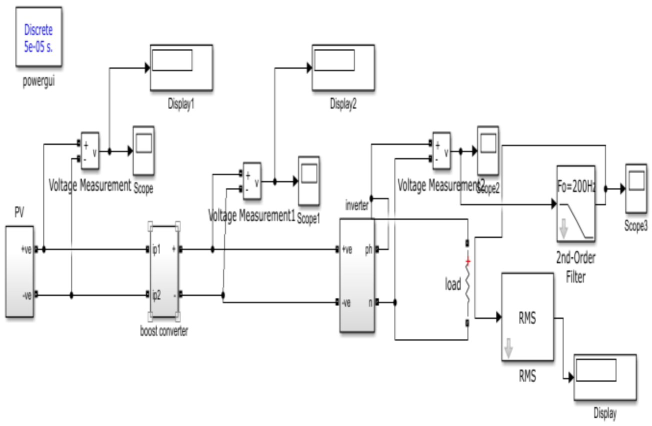

Figure 3. Proposed Dc to Ac converter

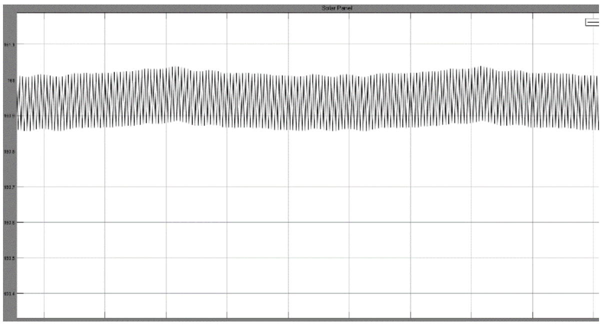

Figure 4. Output from Solar Panel

IV. WORKING PRINCIPLE

Normally the Pulse Width Technique (PWM) uses the sine wave reference but it is proposed that triangular wave is taken as reference .When the Switch 1 is closed .then inductor coil stores the energy from the source, When the switch is opened, inductor coil is releases the energy in the form of voltage, so that it is added to the source voltage thus boosts the output voltage.

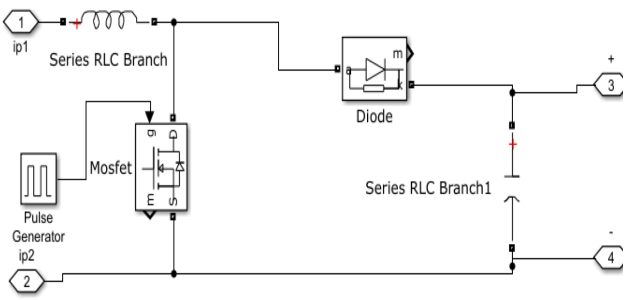

Figure 5. Inductor storing energy

The output from the dc-to-dc converter is as shown in Fig (7) is approximate pulsated dc wave.

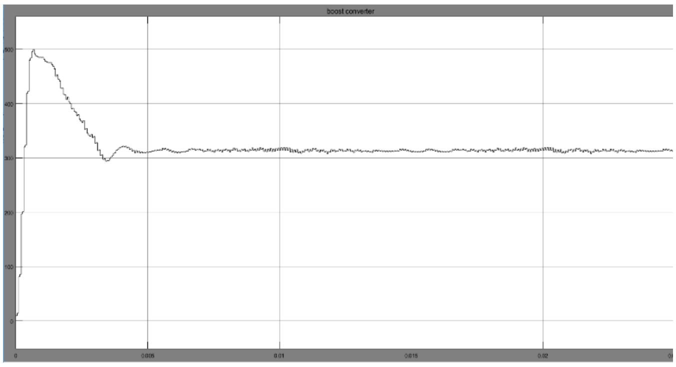

Figure 6. Output from DC to DC Converter

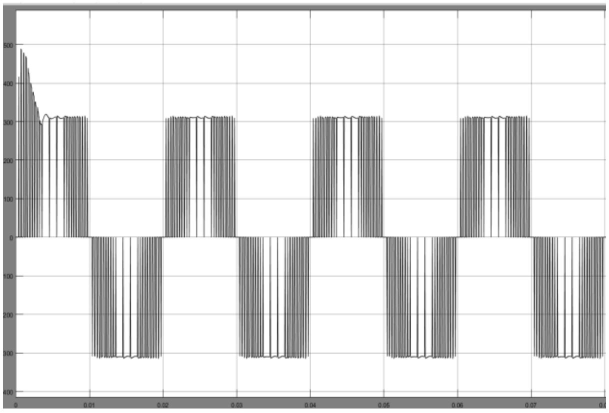

Figure 7. Output wave from H-Bridge

This pulsated dc wave is given to the H Bridge inverter as shown in the Fig (8). The output from the DC-to-DC converter is fed to the H Bridge, which is cosists of four Mosfets.

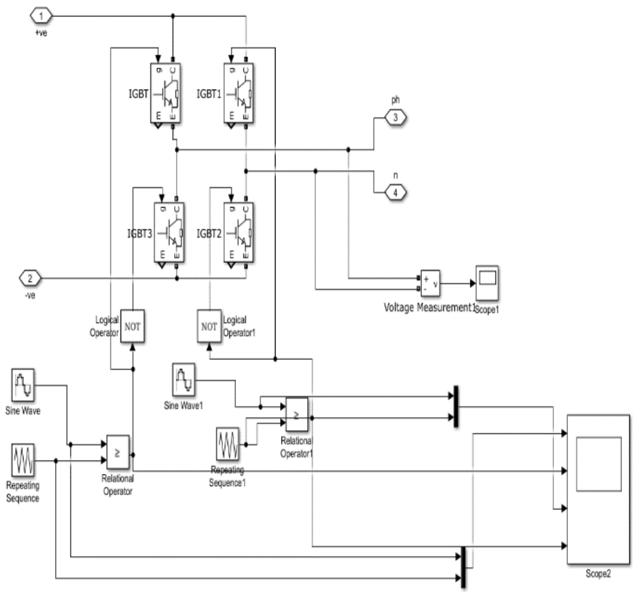

Figure 8. H-Bridge Schematic Diagram

The implementation of this circuit is done. The system Parameters of the circuit to generate triangular wave from integrated circuit logic inverter 74hc14 are in table (1).

Table 1: System Parameters

Power frequency	Resistance
50HZ	50 ohm

The proposed design of the inverter is implemented using boost converter and PWM generator .The input voltage is varied from 1Vto 30V. The output voltage is varied from 85 to 105V (lower rated devices used for implementation, XL6009 voltage regulator) with corresponding input voltage. The circuit working is examined are in table (2).

V. RESULTS

It is implemented and validated the proposed design of circuit .The summary of results are given in table (2).

Table 2: Summary of Results

S.NO	V in(V)	V out(V)
1.	1	0
2.	2	45
3.	3	67
4.	4	96
5.	5	105
6.	6	105
7.	12	105

In this case the proposed design of the inverter circuits acts as a boost inverter since the reference triangular wave is set to maximum, so that voltage is constant. The implemented inverter acts as boost inverter converting 10 volts to 105 volts. It is observed that the output voltage is remains same when further increase in input voltage from 5V.

VI. CONCLUSION

From the results it is seen that designed boost single phase voltage inverter works well producing an ac wave outputs depending upon the reference signal. From the summary table it can be summarized that proposed design of the inverter circuit operates for wide voltage range of the dc input voltage producing a sinusoidal ac voltage 50Hz.

The proposed design uses only five switches, the low switching frequency of the output H-bridge reduces the inverter switching losses and cost compared to multilevel inverters.

The drawbacks of the inverter, compared to traditional H Bridge inverters are relatively high cost (switches) and relatively high switching losses in one of the five switches.

VII. SCOPE OF FUTURE WORK

The present trend of research, the cost of photovoltaic cells is expected to go down in future. This design of inverter under consideration is capable of minimizing the no of components and design portable, thus occupying less space reducing the size of the equipment. This design can be extended by using suitable inductor coils and switching circuitry.

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Z Source Inverter for Three-Phase Induction Motor

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ABSTRACT

This paper present the impedance source inverter for adjustable speed drive (ASD). Utilization of ZSI in industrial applications greatly increases the reliability by allowing only lower inrush current; lower harmonic injection and high immunity to EMI noises. Z Source Inverter can overcome this limitation, with the use of impedance source network. The impedance network connected between rectifier and inverter circuit, act as storage during input voltage, higher than required voltage and provide string voltage during input voltage is less than required voltage. By controlling shoot through duty cycle impedance source can be produce required ac voltage even greater than line voltage. As a result this impedance source system, provides, capability during voltage sag and swell, reduce harmonic, improve power factor and reliability, and extent the output voltage, analysis simulation and experimental result can be analyzed.

Keywords: Line Harmonics, Motor Drives, Voltage Sags, Z-Source Inverter

I. INTRODUCTION

There are two traditional converter existing: voltage source converter (voltage kept constant / voltage fed) & current source converter (current kept constant / current fed).The voltage source converter has larger application than current source converter. Figure 1 shows the conventional 3ø voltage source converter.

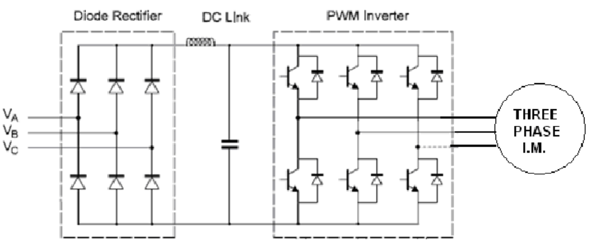

Figure 1. Conventional 3ø Voltage Source Converter

For designing the inverter first we have to convert an AC voltage to DC voltage because the input require to an inverter is DC voltage. The AC voltage is converted into a DC by using Diode rectifier circuit. The DC voltage is passed from inductor and capacitor, which is act as a filter device. When an AC is converted to an DC then DC voltage is roughly equal to 1.35 times of AC voltage. The inverter circuit is step down converter that can only produces an limited AC voltage is quite below the input voltage.

For example, if we convert an 3ø 440 volt AC to DC voltage, then the DC voltage from an rectifier circuit is equal to 1.35 times i.e. 590 volts. This DC voltage is converted into an AC voltage by using an conventional inverter circuit, which gives an output approximately 420 volts. If this lower voltage is given to the 3 phase motor drive , during an light load condition the motor work efficiently but for heavy load condition the motor requires larger voltage at the starting but it required is not given by the traditional inverter circuit hence, the motor draws more inrush current and harmonics because of that the efficiency of motor get reduces and power factor affected.

Performing and Reliability are compromised by the conventional voltage source because,

I) Misgating from EMI (Electro Magnetic Interference) can cause a shoot through that increase the chances of failure of inverter .

II) The dead time is needed to avoid the shoot through that also increase losses in an inverter.

The output of conventional converter is shown in following Figure below,

Waveform of voltage:

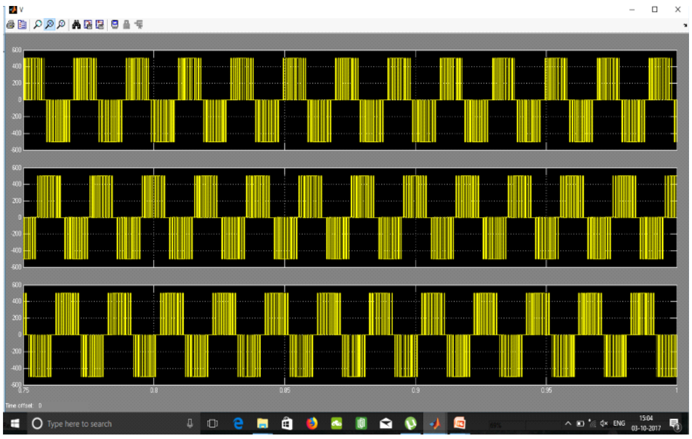

Figure 2. Output Voltage

Waveform of Current:

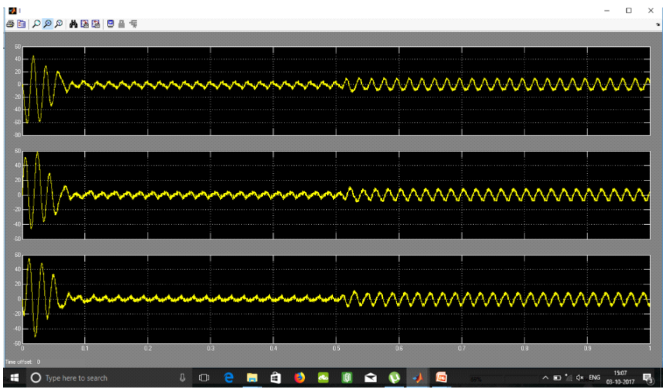

Figure 3. Output Current

Waveform Of Power:

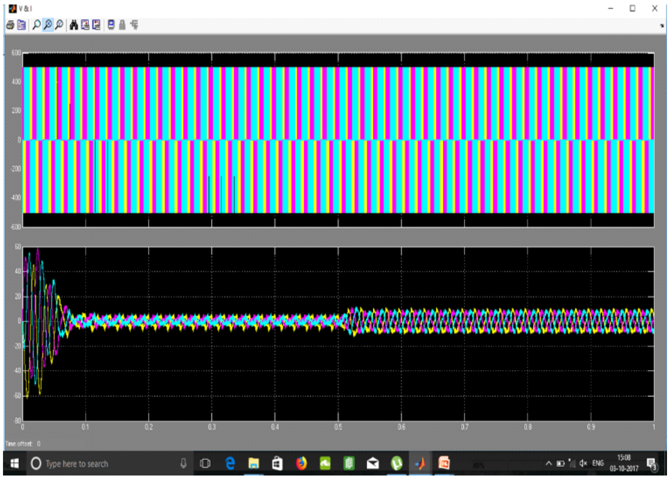

Figure 4. Output Power

II. Z-SOURCE NETWORK

The Z-source network is logically design which has a unique impedance network to connect both the circuits i.e. main supply to power supply, it can produce any desire output ac voltage which can be greater than the input dc voltage by controlling the shoot-through duty cycle.

The Z-Source network consists of two inductors (L1&L2) and capacitors (C1&C2) connected in a triangular to provide an impedance source (Z-Source) coupling between the inverter and DC source. Thus, the DC source connected to the Z-Source network can be a voltage or current source. Therefore, the DC source can be a battery, diode rectifier, thyristor converter, an inductor, a capacitor or any combination of these can be used. Another advantage of this inverter over a traditional inverter is that one can use a variable DC source such as fuel cell, Photovoltaic cell or a wind turbine. The in-rush current and harmonics in current can be reduced due to inductor used in Z-Source network.

The unique feature of the ZSI is that the output AC voltage can be any value between zero and infinity regardless of the input DC voltage. That is, the ZSI is a buck–boost inverter that has a wide range of obtainable voltage .The traditional VSI cannot provide such feature.

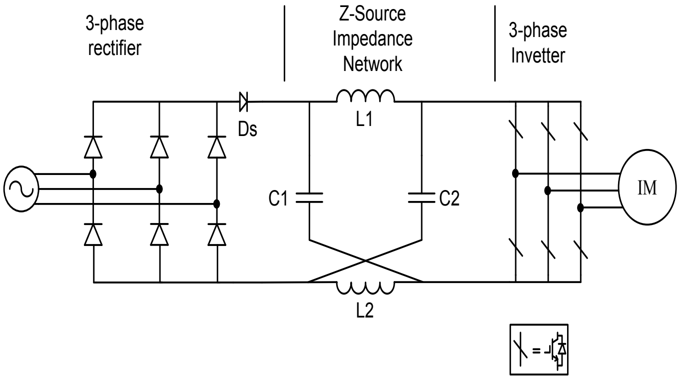

Figure 5. Z-source inverter

To describe the operating principle and control of the ZSI shown in Figureure1.4, let us briefly examine the ZSI structure. In Figureure 1.4, the three-phase Z-Source inverter bridge has nine switching states unlike the traditional three-phase VSI that has eight. The traditional three-phase VSI has six active states when the DC voltage is impressed across the load and two zero states when the load terminals are shorted through either the lower or upper three devices. However, the three-phase Z-Source inverter bridge has one extra zero state when the load terminals are shorted through both the upper and lower devices of any one phase leg, or any two phase legs, or all three phase legs. This state is forbidden in the traditional VSI, because it would cause a shoot-through. We call this third zero state the shoot-through zero state, which can be generated by seven different ways: shoot-through via any one-phase leg, combinations of any two-phase legs, and all three-phase legs. The Z-Source network makes the shoot-through zero state possible. This shoot-through zero state provides the unique buck-boost feature to the inverter. During this state, energy is transferred from the capacitors to inductors, there by giving rise to the voltage boost capability of the ZSI.

Figure shows the equivalent circuit of the ZSI shown in Figure 5, when viewed from the DC-link. The inverter bridge is equivalent to a short circuit when the inverter bridge is in the shoot-through zero state, as shown in Figure 6 (a).Whereas inverter bridge is equivalent to open circuit when it is in one of the traditional zero state, as shown in Figure 2.1-(b). And the inverter bridge becomes an equivalent current source as shown in Figureure 2-1(c) when in one of the six active states. Note that the inverter bridge can be also represented by a current source with zero value (i.e., an open circuit) when it is in one of the two traditional zero states. The three modes are used as listed below,

Mode 1: Active state

The inverter bridge is operating in one of the six traditional viewed from active vectors, thus acting as a current source and conduct the Z-source circuit. The diodes carry currents. Figure. 1.1(a) shows the circuit of this mode. In the traditional ASD system, the diode bridge may not con- duct depending on the dc capacitor voltage level. However, and to the Z-source circuit always forces diodes conduct and carry the current difference between the inductor and inverter dc current as shown current in Figure. 1.1(a). Note that both inductors have an identical current value because of the circuit symmetry. This unique feature the line current conducting intervals, thus reducing harmonic current.

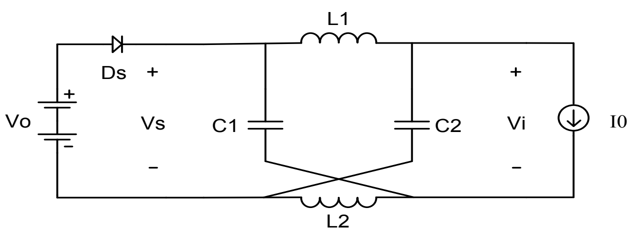

Figure 6. (a): when the inverter bridge is producing one of the six traditional active vectors

Mode 2: Zero State

The inverter bridge is operating in one of the two traditional zero vectors and shorting through either the upper or lower three devices, thus acting as a open circuit viewed from the Z-source and conduct and carry currents the circuit. (Figure. 2.1(b) shows the circuit for this mode). Again, under this conduct and carry mode, the two diodes the inductor current, which contributes to the line current's harmonic reduction.

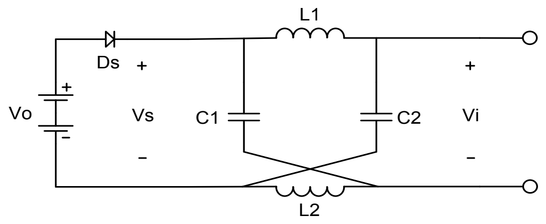

Figure 6 (b): When Inverter Bridge Is Producing One Of The Two Traditional Zero Vectors

Mode 3: Shoot-through Mode

In this the shoot through states both diodes are off, separating dc link from ac link. Figure 6. a and 7. b shows the equivalent circuit of ZSI when the diode is conducting state (Non- Shoot through mode) and the non-conducting state (Shoot through mode) respectively [8-11].In shoot through mode as in Figure1. 2. b., a diode placed at the input side is reverse biased and the capacitors charge the inductors and voltage across the inductor is:

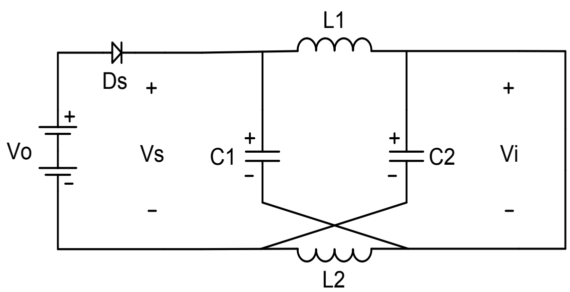

Figure 6(c). Shoot Through Mode

III. SIMULATION AND EXPERIMENTAL VERIFICATION

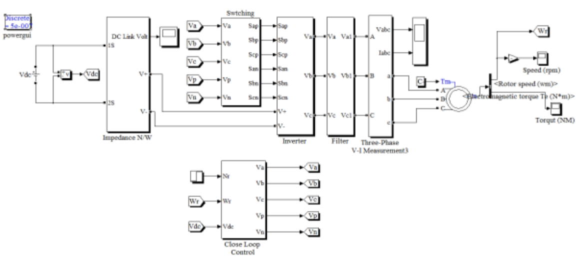

Figure 7. Simulation and Experimental Diagram

Simulation Parameter

S.No	Quantity	Value
1	Z-Source Impedance Value	L1=L2=1mH and C1=C2=1.3μF
2	Input DC Voltage	400V
3	Carrier Wave Frequency	10KHZ
4	Cutoff Frequency of LC Filter	1KHZ
5	Induction Motor	4kW,400V(LL),50Hz, 1430RPM, 4 Pole
6	Load Torque	20Nm

Waveform of Output Voltage:

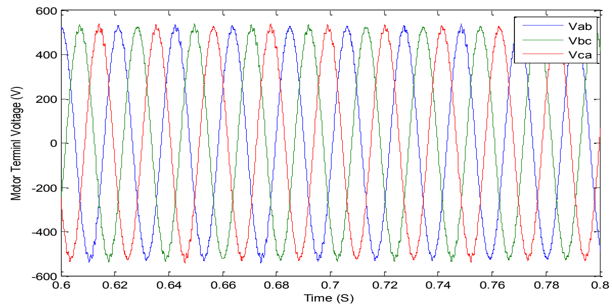

Figure 8(a). Output voltage waveform

Waveform of Output Torque:

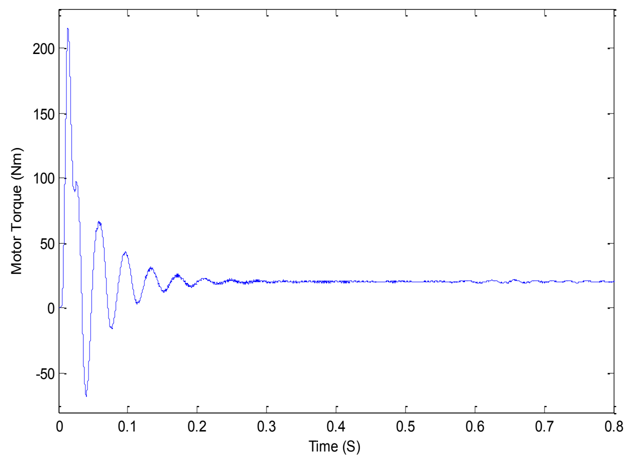

Figure 8(b). Output Torque Waveform

IV. CONCLUSION

This paper has presented a new ASD system based on the

Z-source inverter. The operating principle and analysis have been given. Simulation and experimental results verified the operation and demonstrated the promising features. In summary, the Z-source inverter ASD system has several unique advantages that are very desirable for many ASD applications, it

- Can produce any desired output ac voltage, even greater than the line voltage;
- Provides ride-through during voltage sags without any additional circuits and energy storage;
- Minimizes the motor ratings to deliver a required power;
- Reduces in-rush and harmonic current.

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Plant Efficiency Improvement by Effective Maintenance Procedures: a Case Study of Wind Farms Limited, Dewas, Madhya Pradesh (M.P.), India

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ABSTRACT

The Madhya Pradesh (M.P.) Wind Farms Limited Dewas, India is a leading power generating industry in wind power and it is having 58 conventional wind electric generators along with 58-unit sub stations and three main sub stations. At present this machine, which is an integral part of case company, is not running smoothly, it is observed that there are too many breakdowns and due to this it is causing too many difficulties to the maintenance department. Initially as such no scheduled maintenance program was given by the supplier, which leads to number of problems like production loss, lack of quality power and too much time consuming, so it is intended to reform this expensive conventional system and bring about a lot of improvement in the way of handling this machine. Preventive maintenance can provide the effective solution to this. This companion part of the paper presents the overall analysis of operating status of the machines of Wind Farms Limited, Dewas, Madhya Pradesh (M.P.), India, which is a leading power generating company in wind power sector as per the analytical data collected for continuous five years. According to the data the need of preventive maintenance can be executed.

Keywords : Preventive Maintenance, M.P. Wind Farms Limited, Wind Electric Generator (WEG)

I. INTRODUCTION

M.P. Wind Farms Ltd., Dewas, M.P. is India's first joint sector company, in this company three different body's are involved.

i. M.P. UrjaVikas Nigam Nodal agency of state government having 24% share
ii. Indian Renewable energy development agency nodal agency of central government having 25% share
iii. Consolidated Energy Consultants Ltd. Bhopal CECL is a consultant company provides technical support and having 51% share in this company.

The technical details of machine are as given below,

Capacity of project - 15 MW
No. of machine running - 58 Nos.
Capacity of one machine - 225/40KW
Area covered - 5 acre
Expected annual generation m/c. - 3, 00,000 units
Minimum wind speed required- 2 m/s.
First WEG inaugurated on - 26th July 1995

Estimated wind power potential India state wise given below [1, 2].

Table 1State Wise Wind Power Potential In India

SN	State and installed capacity	Gross potential (MW)
1.	Tamil Nadu (4301.63 MW)	4500
2.	Maharashtra (1942.25 MW)	3650

3.	Gujarat (1565.61 MW)	9675
4.	Karnataka (1340.23 MW)	6620
5.	Rajasthan (738.5 MW)	5400
6.	Madhya Pradesh (212.8 MW)	5500
7.	Andhra Pradesh (122.45 MW)	8275
8.	Kerala (26.5 MW)	875
9.	West Bengal (1.1 MW)	450
10.	other states (3.20 MW)	1700
Total		46645

Table 2 presents the wind electric generators operational hours and stopped hours of consecutive three years of case company.

Table 2 Wind electric generator's operational hours and stopped hours, of previous year of case company

Month	Operational and stopped hours									
	Total hours	2012			2013			2014		
		Op. hr.	Stop hr.	Grid fail	Op. hr	Stop hr.	Grid fail	Op. hr	Stop hr.	Grid fail
Jan	744	610	120	14	587	142	15	624	102	18
Feb	672	568	94	10	595	60	17	618	42	12
Mar	744	630	94	20	664	68	12	669	62	13
Apr	720	626	82	12	616	92	12	645	64	11
May	744	656	58	30	647	82	15	688	40	16
Jun	720	637	64	19	607	106	7	646	66	08
July	744	660	65	19	694	50	11	630	105	09
August	744	640	93	11	698	32	14	665	64	15
Sep	720	610	92	18	580	134	06	645	59	16
Oct	744	626	93	25	590	135	19	689	49	06
Nov	720	610	94	16	586	122	12	648	63	09
Dec	744	620	101	23	620	108	16	649	85	10

In the Table 2 the average operational hours are given for 58 units of wind electric generators. If we calculate the Total stopped hours in a year that is only in year 2012 stopped hours of WEG are 1050 hour, in year 2013, 1131 hours and in year 2014, 801 hours, at this time machines is not in operation. The only two reasons are behind it, first is wind speed is not sufficient i.e. less than 2 m/s. and the second is machines are not working properly.

This will show that if we are taking an average of 48 hours, for one maintenance schedule there will be only 144 hours which may be required for the maintenance purpose in a year that means we are stopping wind electric generators for only 144 hours per year which will be very less because after applying this maintenance schedule the stopped hours due to improper working of wind electric generator will surly decreases.

From data given in Table 2 the percentage machine availability can be evaluated as given in Table 3

Table 3 Percentage Machine Availability

Month	2012	2013	2014
January	82	78.9	83.9
February	84.5	88.7	92
March	84.6	89.2	89.9
April	86.9	85.5	89.5
May	88.1	86.9	92.4
June	88.4	84.3	89.5
July	88.7	93.2	84.6
August	86.0	93.8	89.3
September	84.7	80.5	89.5
October	84.1	79.3	92.6
November	84.7	81.3	90
December	83.3	83.3	87.2

Figure 1 presents the comparative analysis of percentage of machine availability of year 2012, 2013 and 2014. It indicates that there is sufficient possibility for improvement in maintenance availability.

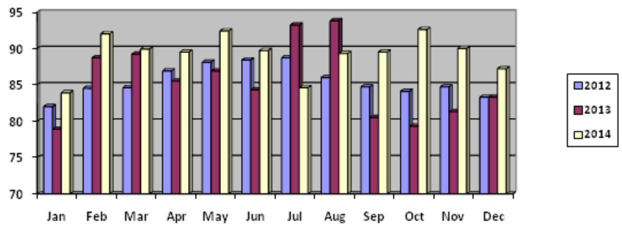

Figure 1 Percentage machine availability for year 2012, 2013 and 2014

II. PARTICULARS OF ELEMENTS CONSIDERED FOR APPLYING PREVENTIVE MAINTENANCE SCHEDULE

This section covers the detailed list of components of wind electric generator (WEG). Here each components of WEG are listed and maintenance requirement of components is given [3, 4, 5, 6].

Each component and its parts are used for scheduling maintenance procedure. In this paper the assortment of WEG's components failure history of previous five year is given. This analytical data is used to set the priority i.e. low, medium and high by which each component may be placed in different maintenance schedules. The components which require more emphasis in maintenance were set at the high priority. It was found that those components were failed too many times in previous years. The components set at medium and low priority are the components which require less maintenance were found to be comparatively failed less time in previous years. It is recommended that the maintenance schedule should be applied before season of peak performance i.e. in the approximate ending of March and it ends with August for the case plant as in this period the speed of wind is good for the high generation of electric power. Thus the WEGs should be in perfect status at this time period with minimum breakdowns and maximum machine availability. So the Quarterly maintenance schedule is suggested to be applied before the peak season comes and after the end of the season (i.e. in September month) half yearly maintenance schedule can be scheduled and in December month yearly maintenance schedule can be scheduled.

Schematic diagram of components of WEG s is shown below:

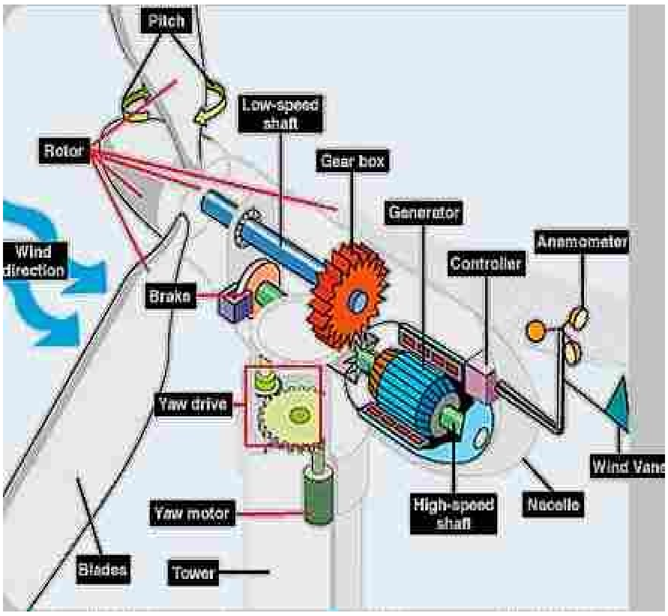

Figure 2 Components of wind electric generator

Schematic diagram of Wind Electric Generator's main components mounted over the tower is shown in Figure 2 and cross view of the same is shown is Figure 3

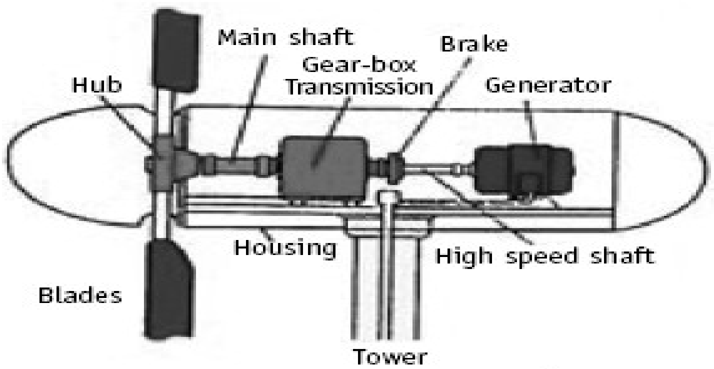

Figure 3 Wind Electric Generator's main components mounted over the tower

Specification of elements are discussed below which can be undertaken for preparing of preventive maintenance schedule.

2.1 TOWER

Tower is the base of WEG which consist of control panel, switch board and capacitor bank which are discussed in the category "Electrical installation".

The specification of tower is:

Material - Galvanized steel

Type - Shell type bolted tower

Height - 30 miters.

Weight - 8 tons

Thickness of sheet - 10 m

Internal diameter - 2.5 meter at bottom & 1.5 meter at top.

Make - NEPC

Sub parts of tower (maintenance requirement of components of tower)

- Tower bolts
- Door
- Blade inspection door
- Top flange
- Top Platform
- Ladder
- Safety devices and rope

All these components require less maintenance because they are rigid in nature and stable (not movable).

2.2 ROTOR

It consist of Blades, blade hydraulic unit and nose-cone

The specification of Rotor are

Make - L.M. Glass fiber

Material - Glass fiber

Length - 13.4 meter.

Weight - 850 kg / blade

Type - movable tip spoiler

Length of tip - 2.2 meter

Sub parts of Rotor (maintenance requirement of components of rotor).

- Blades
- Blade tip and hydraulic System or blade hydraulic unit
- Blade hub

The rotor is a moving part so it requires a frequent maintenance.

2.3 Transmission

Transmission of WEG is consisting of main shaft which connect the rotor to the gear box, by main shaft.

The specification of Transmission is:

Weight of main shaft - 1 tons

Diameter of main shaft - 600mm

Material of main shaft - M.S.

ID of main bearing - 600 mm

Make of main bearing - SKF

Sub parts of Transmission (maintenance requirement of components of Transmission)

- Bolt connection blade hub/ main shaft
- Main bearing housing
- Sealing
- Bolt connection bearing housing
- Shrink disk
- Main shaft

2.4 Gear Box

Gear box is used for converting the low speed rotation of rotor to high speed rotation for generator. The gear box used in WEG is normally having ratio 1:40 i.e. for one rotation of low speed rotor the high speed rotor rotates 40 times. Low speed rotor of gear box is connected to the main shaft and high speed rotor is coupled to the generator. This means for one rotation of WEG blades the generator rotates 40 times. Gear box is filled with oil for lubrication.

The specifications of Gear box are:

Make - flender / hansan

Ratio - 1/40

Weight - 2 tons

Oil use - castrol 460

Quantity of oil - 7 liters

Sub parts of Gear box (maintenance requirement of components of Gear box).

- Shrink disk on low speed shoes
- Sealing
- Oil level indicator
- Breather
- Gear teeth
- Oil cooler

Gear box of WEG is the most important component. Hence it requires more emphasis in maintenance point of view.

2.5 Brake Disc

Brake disc is coupled with the high speed shaft for providing Brake operation in WEG.

The specification of Brake disc is:

Make	-	NEPC
Thickness	-	30 mm
Diameter	-	900 mm
Weight	-	110 kg
Material	-	MS

Subparts of Break disc (maintenance requirement of components of Brake disc). Bolt connection hub / Brake disk

2.6 Hydraulic Brake

On Brake disc hydraulic Braking system operates. In WEG the Braking phenomenon is applied for stopping the rotor of WEG in case if the wind speed is below or above the rated speed, at the time of maintenance, failure of WEG etc.

The main components of the hydraulic Brake system are accumulator in which high pressure oil is filled by the motor pump set. An electrically operated Solenoid valve is used when braking operation is required, the solenoid valve releases the high pressure oil which forces the Brake pads for applying brakes.

The specifications of Hydraulic brake are:

Make	-	SIME
Type	-	Horizontal
Oil Quantity	-	2.2 Liter
Oil type	-	SERVO – 32

Subparts of Hydraulic brake (maintenance requirement of components of Hydraulic brake)

- Bolt connection brake / console
- Bolt connection console /gear box
- Hydraulic oil
- Accumulator
- Motor pump set
- Hose pipe
- Low / High level limit switches
- Solenoid valve

Hydraulic breaking plays important role in WEG operation hence it requires maintenance with more emphasis.

2.7 Flexible Coupling

It is the coupling between gear box high speed shaft and generator shaft.

The specifications of Flexible coupling are:

Make - Magi flex / central flex

Material - (molding) Rubber element with hollow MS shaft.

Weight	-	40 Kg
Diameter	-	500 mm
No. bolt	-	4 Nos.
Type of bolt LN key	-	LN key

Subparts of Flexible coupling (maintenance requirement of components of Flexible coupling)

- Rubber elements
- Bolt connection Rubber element / center shaft
- Bolt connection rubber elements Brake disc
- Alignment

The distance between brake disc and generator hub must correspond with the length of the coupling +/- 1mm.

Flexible coupling needs emphasis on maintenance in its moving part.

2.8 Generator

To generate electrical power from the mechanical power of rotor induction generator is used which works on two modes of operation. First is of 225 kW rating which has 4 pole winding and rated speed is 1500 RPM and the second one is 40 kW rating which has 6 pole winding and rated speed is 1000 RPM.

The specifications of Generator are:

Make : Jyoti/ Comptor/ Siemens.
Capacity : 225/40 KW
Voltage : 415 V
Power frequency : 50 Hz A.C.
Weight : 1.2 tones
No. of poles : 4/6 poles
RPM : 1500/1000 RPM

Subparts of Generator (maintenance requirement of components of Generator)

- Bolt connection Generator / Frame
- Lubrication Arrangement
- Seals
- Generator Terminal box
- Cover for Generator

2.9 Electrical Installation

Electrical installation mainly covers the electrical panels, conductors, lightning arrestors, control equipments etc. which requires negligible maintenance hence in electrical installation we cover only specifications. From maintenance point of view checking of loose connection in the terminal blocks, retightening the connector screw, check connection to the earth, sign of overheating etc. are required. Inspection against proper working of the electrical component is very important because failure of electric component directly affect the working of the WEG.

2.10 Electrical Panels

2.10.1 Main MCCB with trip unit

Make - ABB / GEC Alsthom
Voltage - 600 V
Amperes - 630 Amperes
Frequency - 50 Hz AC.
No. of poles - three
Trip coil voltage - 24 V DC/220 V A.C.

2.10.2 Power Contactor for G 1 Gen. & by Pass

Make - ABB/BCH Allen Bradley
Voltage - 415 V A.C. 50 HZ
Amperes - 550 Amperes
No. of poles - three
Coil voltage - 24 V A.C.

2.10.3 Power contactor for G2 Generator

Make - ABB / BCH / Allen Bradley
Voltage - 415 V
Amperes - 110 Amperes
Coil voltage - 415 V A.C. 50 HZ
No. of poles - three

2.10.4 Auxiliary Contactor

Make - ABB /BCH / Allen Bradley with 3No. & 3NC
Rating - 9.1 Amps
Coil Voltage - 24 V A.C.

2.10.5 Over Load for yaw / Hyd. Motor

Make - ABB / BCH with 1 No and 1 NC
Range - 9.1 to 2.4

2.10.6 Current transformer

Make - ABB
Ratio - 500/1 Amps
Loading - 15 VA

2.10.7 Lighting Arrestor

Make - Uberspannungs
Type - OBO
Amperes - 15 kA
Voltage - 1.8 kV

2.10.8 Thyristor with heat sink

Make	-	Herict
Rating	-	550 Amps
Voltage	-	600 V 50 Hz A.C.
Control voltage	-	1 to 10 V D.C.

2.10.9 WP- 2060 wind controller

Make	-	Mita Teknikas

2.10.10 Control MCBs

Make	-	Siemens
Amps .	-	10 Amps.
Voltage	-	415 V 50 Hz A.C.
No. of Poles	-	4/3

2.10.11 Wind Power – 2000 :-

Make	-	Mita Taknikas
Type	-	Microprocessor based
Supply	-	24 V A. C. & D.C.

2.10.12 Control transformer:-

Make	-	Made in Den mark
Input	-	415 V + 13 % Hz
Rating	-	24 V - 6.5 Amps
Outputs	-	19 V - 2.63 Amps

2.10.13 Diode

Make	-	Bridge rectifier type
Voltage	-	19 V A.C. input
Filter capacitor	-	4700 micro farad, 6.3 V

2.10.14 MCCB for capacitors

Make	-	ABB
Rating	-	250 Amps.
Setting	-	110 to 250 Amps.
No. of poles	-	three
Voltage	-	415 V 50 Hz A.C.

2.10.15 Capacitors :-

Make	-	Rodrastrain/ Vishwa made in Germany
Roting	-	12.5 KVAR.
Voltage	-	415 V A.C. 50 Hz
Discharge resistance	-	30

III. CONCLUSION

The focus of these companion papers is to provide an efficient tool to evaluate the status of any plant and to understand the need of proper maintenance schedule to improve the operating efficiency of the plant by attaining the maximum machine availability and minimum down time. Part I discusses the detailed analysis of the most commonly used maintenance procedures which leads to the conclusion that the most promising technique is preventive maintenance which may provide the fruitful solution. Thus to execute the efficacy of the outcome method the case study of Wind Farms Limited, Dewas, Madhya Pradesh (M.P.), India has been presented in Part II. The detailed analytical analysis presented in this part of companion papers may help the plant operators to evaluate the exact space of need to apply the necessary actions.

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Preventive Maintenance Procedures for Improving Plant Efficiency : A Review

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ABSTRACT

The systematic approach of preventive maintenance is a plan which provides a positive course of action to remove the unwanted breakdown and unnecessary cost of repair or replacement by analyzing the previous five year components failure data of any plant. M.P. Wind farms limited's wind electric generators (WEGs). This paper proposed three types of scheduled maintenance programs namely quarterly, half yearly and yearly for In this report I have proposed three types of scheduled maintenance programme namely quarterly, half yearly and yearly. Activities involved in these schedules are based on previous break down history of M.P. Wind farms limited's wind electric generators. Activities involved in these schedules are based on previous break down history of M.P. Wind farms limited's wind electric generators.

Keywords : Preventive maintenance, M.P. Wind farms limited's wind electric generators

I. INTRODUCTION

The main concern of any generating plant is to generate power with maximum machine availability and minimum down time. There are many electrical and mechanical components in the wind electric turbine, it is intended to concentrate on the different component and equipment of the turbine through new technologies, suitable maintenance procedures and refine processes. Preventive maintenance has been recognized throughout the world as an essential tool of reducing down time and improving availability of machine. It is a conventional method whose focus is to reduce the breakdown and cost of replacement. The Madhya Pradesh (M.P.) Wind Farms Limited is a leading power generating industry in wind power and it is having 58 conventional wind electric generators along with 58- unit sub stations and three main sub stations. At present this machine which is an integral part of case company is not running smoothly, it is observed that there are too many breakdowns and due to this it is causing too many difficulties to the maintenance department. Initially as such no scheduled maintenance programme was given by the supplier, which leads to a number of problems like production loss, lack of quality power and too much time consuming, so it is intended to reform this expensive conventional system and bring about a lot of improvement in the way of handling this machine

Need of the Maintenance

The significance of these procedures is to enumerate the impact of effective maintenance procedures as an efficient tool which enables the power plant operators to,

- Improve system reliability
- Decrease cost of replacement
- Decreases system downtime electrical as well as mechanical breakdown

- Providing the data to develop preventive maintenance procedure for different components of wind electric turbine
- Reduce injury
- Protect assets and prolong the useful life of production equipment
- To rise the profit of the company
- Increase generation level.

In the literature it has been observed that researchers are still working hard to find out the major factors which affect the performance of the wind electric generator (WEG). One of the most important is regular maintenance of the most critical components of the wind electric generator. Various maintenance procedures are in practice which ensure the efficient generation of power by a wind electric generator. Most commonly executed maintenance procedure on wind electric generator includes: periodic gearbox oil changes, rotor blade cleaning, bolt tensioning etc. Through all these minor maintenance procedures a wind electric generator can operate at its peak performance level as well as help to prevent major breakdowns like gearbox bearing failure, which could potentially lead to replace the entire gearbox, one of the most expensive components of the entire wind tower. Imad Alsyouf and Idriss El-Thalji [1], discusses and analyses the recent practices in the area of maintenance of wing electric generators and gives brief review of operation and maintenance of wind electric generator. Inacio Fonseca et al [2], present a predictive model to manage wind electric generator maintenance. Julia Nilsson [3], explained the benefits of condition based system with two case studies of wind electric generator by breaking down the entire maintenance cost into several components. Francois et al [4], proposed an approach to optimize the maintenance of components in which degradation is classified on the basis of severity of the damage. Frascois Besmard et al [5], discussed the benefits of the preventive maintenance and showed that there is a large potential in cost savings by maintenance optimization to make the project more cost effective. This part of the paper focuses on the overall review of most commonly used and efficient maintenance procedures prevailing in the field. The assortment of relevant information may help the plant operators to analysis and execute the necessary actions which lead the plant in improving its performance.

II. DEFINITION OF MAINTENANCE

"Maintenance is the routine and recurring process of keeping a particular machine or quality in its normal operating condition so that it can deliver its expected performance or service without causing any loss of time on account of accidental damage or breakdown"[6].

Or

"The care and servicing by personnel for the purpose of maintaining equipment and facilities in satisfactory operating condition by providing for systematic inspection, detection, and correction of incipient failures either before they occur or before they develop into major defects" [7].

III. NEED OF MAINTENANCE

The purpose of maintenance is to attempt the improvement in the performance of equipment by ensuring that the all its parts will perform reliably and efficiently, by preventing the rate of breakdowns or failures, and by minimizing the adverse effects resulting from breakdowns or failures. In fact it is the objective of the maintenance procedures to maintain or increase the reliability of the operating system as a whole.

IV. SIGNIFICANCE OF MAINTENANCE

Maintenance is necessary for the smooth and efficient working of an industry and helps in improving the productivity. It also helps to keep the machine in their optimum operation conditions [7]. The significance of plant maintenance varies with the type of plant and its production. Plant maintenance plays a prominent role in production management because plant breakdown creates major problem such as:

- Loss of productive time.
- Re-scheduling of production.
- Need for overtimes.
- Need for subcontracting work.
- Temporary work shortage, worker may require alternative work to have maximum work to have maximum utilization of labor.

V. FUNCTION OF MAINTENANCE

The significant functions of maintenance can be listed as follows:

- To develop maintenance policies, procedures and standards for the organization
- To scheduled planned maintenance work in consultation with the concerned production departments
- To carry repairs and rectify or repair planned equipment and other facilities to ensure good availability and optimum operational efficiency
- To ensure scheduled inspection of plant, machinery and equipment
- To keep record of all maintenance work (repairs, replacements, modification, lubrication, overhauls etc.
- To carry out periodic inspections of equipment and facilities to know conditions, this may lead to their stoppage and breakdown
- To prevent inventory of spare parts and other materials needs for maintenance work.
- To carry out alteration, modifications or improvement in existing equipments and buildings to minimize breakdown
- To prepare maintenance budget and to ensure that maintenance expenditure does not exceed the planned budget.
- To enforce and train personal to carry out maintenance work effectively and efficiently.

VI. TYPES OF MAINTENANCE

Basically maintenance can be divided into two groups:

a) Breakdown maintenance.
b) Planned maintenance.

The planned maintenance can further be subdivided into:

- Scheduled maintenance.
- Preventive maintenance.
- Corrective maintenance

6.1 Breakdown maintenance

Breakdown maintenance implies that repairing can be done after the failure of equipment to perform its normal function. For example an electric motor fails to start, a belt is broken etc. this practice allows a maintenance of any other facilities to run without much routine attention, till it actually breakdown or fails to carry out its function. In this type of maintenance no attempt is made to prevent the occurrence of breakdown.

Disadvantages of breakdown maintenance:

a) The type, gravity, place and time of breakdown are of random nature. This practice leads to disruption of production plants.
b) It also makes it impossible to plant workload and distribution of maintenance work force for balanced attention of all equipments.

6.2 Planned maintenance

The planned maintenance is an organized type of maintenance which takes care of other aspects such as control and records required for this type of work. Under this type of maintenance, the work is planned before hand to avoid random failures. To meet the requirements of the planned maintenance, first of all thorough study has to be carried out to decide the periodicity of maintenance work. Time study can also suggest ways and means of devising optimal maintenance schedule for the given system.

6.2.1 Scheduled maintenance

In this type of maintenance work, the actual maintenance program is scheduled in consultation with the production department, so that the relevant equipment is made available for maintenance work. The frequency of such maintenance work is pre-determined from experience so as to utilize the ideal time of the equipment effectively. Though schedules maintenance is costly compare to breakdown maintenance, the availability of equipment is enhanced.

6.2.2 Preventive maintenance

Preventive maintenance consists of routine action taken in a planned manner to prevent breakdown and to ensure operational efficiency to the extent it is economically and practicably possible. In preventive maintenance periodic inspection is carried out to anticipate breakdowns and to prevent them before they occur, instead of allowing the breakdown to happen and then take action. The under laying principle is prevention is better than cure. Therefore, for adopting preventive maintenance policy, one must have the data showing the frequency with which machine have maintenance free performance for a given number of operating hours.

Functions of Preventive Maintenance

- To minimize the possibility of unanticipated production interruptions by locating or uncovering any condition this may lead to it.
- To make plant equipment and machines always available and ready for use.
- To maintain the value of the equipment, machinery and other services facilities by periodic inspection, repairs, over halting etc.
- To reduce the work content of maintenance jobs.
- To ensure safety of life of employees.

Elements of Preventive Maintenance

a) Routine attention: This involves maintenance activities that take regular care of the machine. Routine servicing includes cleaning, oiling and adjusting.

b) Routine examination: it is carried out to identify dormant faults or items prone to failure. This type of preventive maintenance work helps to detect faults before they can actually occur.

c) Preventive replacement: The preventive maintenance work comprises preventive replacement of parts and components that have a definite life. Such type of replacement help to avoid emergency situations and prolonged downtime and risk of hazards associated with sudden breakdowns.

d) Inspection measurements: Inspection measurements comprise jobs of preventive maintenance that aim at identifying the degradation rate and such items which are at unacceptable service conditions. This type of maintenance work requires many costly instruments.

Planning and implementation of a preventive maintenance system is a costly affair because during inspection all deteriorated parts are replaced. This type of maintenance is effectively applied in situation where risk in operations caused by failures of equipment must be avoided. However the higher cost of maintenance usually gets compensated by prolonged operational life of the equipment. To avoid serious breakdowns the preventive mode of maintenance is usually implemented.

6.2.3 Corrective maintenance

The use of planned preventive maintenance brings out the nature of repetitive failure of certain parts of the equipment. When such repetitive failures are observed, corrective maintenance can be applied so that re-occurrence of such failure can be avoided. These types of failure can be reported to the manufacturer to suggest modification to the equipment. Corrective maintenance can be defined as the maintenance carried out to restore equipment that has stopped working to acceptable standards.

6.3 Conclusion

This part of the paper presents the overall analysis of all the promising methods of maintenance which may help any plant to improve its operating status and so do the efficiency. The overall analytical analysis exhibited in this paper leads to the conclusion that the preventive maintenance can be recommended as the most fruit full and effective method which can be applied successfully for improving the working status of any plant. In the Part II of this companion set the case study of Madhya Pradesh (M.P.) Wind Farms Limited Dewas, India has been presented which will demonstrate the utility the proper maintenance procedures.

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Emergency Vehicle System

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ABSTRACT

Now days the road accidents in modern urban areas are increased to uncertain level. The loss of human life due to accident is to be avoided. Traffic congestion and tidal flow are major facts that cause delay to ambulance. To bar loss of human life due to accidents we introduce a scheme called EES (Emergency Evacuation System). The main theme behind this scheme is to provide a smooth flow for the emergency vehicles like ambulance to reach the hospitals in time and thus minimizing the delay caused by traffic congestion. The idea behind this scheme is to implement EES which would control mechanically the traffic lights in the path of the ambulance. The ambulance is controlled by the control unit which furnishes adequate route to the ambulance and also controls the traffic light and thus reaching the hospital safely. This scheme is not fully automated, thus the emergency vehicle driver has to control the traffic lights, helping to reach the hospital in time.

Keywords: Accident, Congestion, Predetermined, Intelligent, Traffic Control

I. INTRODUCTION

Traffic management on the road has become a severe Problem of today's society because of Growth of the Urbanization, industrialization and population; there has been a tremendous growth in the traffic. With growth in traffic, there is occurrence of bundle of problems too; these problems include traffic jams, accidents and traffic rule violation at the heavy traffic signals. This in turn has an adverse effect on the economy of the country as well as the loss of lives. So problem given above will become worst in the future.

In order to confiscate the need of controlling traffic Congestion and implementing EES, we can use 8051 Microcontroller (Family - AT89S51) along with RFID Technology . The problem of traffic light control can be solved by RFID based system. With this system, we can consider the priority of different type of vehicles on the road intersections. Radio frequency identification is a technique that uses the radio waves to identify the object uniquely. RFID is a technique that is widely used in the various application areas like medical science, commerce, security, Electronic toll collection system, access control etc.

II. LITERATURE REVIEW OF RELATED WORK

In proposed system if emergency vehicle gets stuck in traffic then the driver of emergency vehicle is enabled to clear his lane by providing the trigger which turns on the green signal through which the emergency vehicle is get its path cleared to pass further. The transmitter mounted in emergency vehicle communicates with traffic signal through RF communication.

The system would be installed in emergency vehicles during critical hours. Every time a vehicle with Emergency enters a road blocked with many other Vehicles on the road, traffic signal receive the signal from emergency vehicle.

The signal light is turned green in that lane. They maintain green signal till it completes the time provided in the module. Systems provided an efficient time management scheme, in which a dynamic time schedule is worked out in real time for the passage of each traffic column.

As the target of the proposed system to be achieved, the system is to be analysed in the range of RF frequency and to be designed in an emergency mode for traffic light when emergency vehicle approaching and to prevent from emergency vehicle crash.

III. MATERAIAL AND METHOD

3.1. System Flow Chart

3.1.1. Case study

Transportation Research and Injury Prevention Programme

Indian Institute of Technology Delhi

http://tripp.iitd.ernet.in/

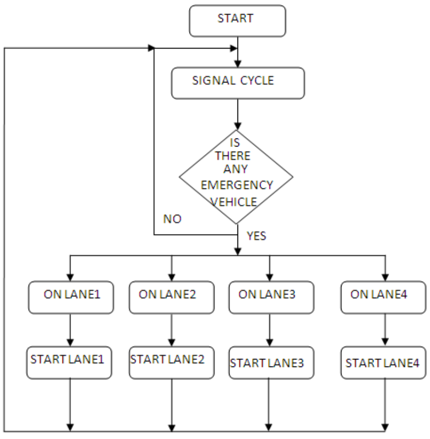
3.1.2. Design circuit

The circuit of this system is designed and constructed roughly using the entire chosen component during this phase. The components are assembled on breadboard to ensure that the circuit work properly.

3.1.3. Simulate design

After done all drawing, assemble and analysis process, the complete design can be seen using a Proteus software. The completed design must be rechecked so that the defect in the design can be reconsidered. If there is a defect, it must return back to configuration design process

3.2. System Block Diagram



3.2.1. Encoder:

Encoder is a device that encode the information in Particular way such as compressing, converting or Secure it in a different format.

3.2.2. Decoder

Decoder is a divide that decode the information from Encoder, decoder will remove the information from Previously encode state and return to its original format.

3.2.3. RF Transmitter and Receiver Module:

A radio frequency transmitter and receiver module will be used in the circuit to implement wireless Communication for this system

3.2.4. Microcontroller

The AT89S51 is a low-power, high-performance CMOS 8-bit microcontroller with 4K bytes of in-system programmable Flash memory. The device is manufactured using Atmel's High -density non-volatile memory technology and is compatible with the industry standard 80C51 instruction set and pin out. The on-chip Flash allows the program memory to be reprogrammed in-system or by a conventional non-volatile memory pro-grammar. By combining a versatile 8-bit CPU with in-system programmable Flash on a monolithic chip, the Atmel AT89S51 is a powerful microcontroller which provides a highly flexible and cost-effective solution to many embedded control application.

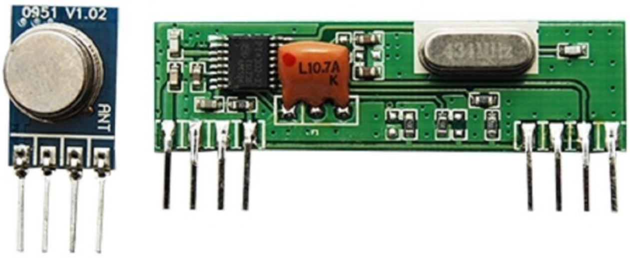
IV. RESULTS/FINDINGS AND DISCUSSION

This system consists of two part, the first part is Radio Frequency (RF) Transmitter circuit. The Function of Radio Frequency (RF) Transmitter circuit is to override the system of traffic light. The second part is Radio Frequency (RF) Receiver circuit.

The function of Radio Frequency (RF) receiver is receive the data from transmitter and change the sequence of traffic light system according to transmitter.

4.1. Radio Frequency (RF) Transmitter circuit

The transmitter consist of a Radio Frequency module, HT12E.Six push button and one LED indicator.



4.2. Radio Frequency (RF) Receiver

The receiver consist of Radio Frequency Module, HT12D.The sequence of the traffic lights is generated by the microcontroller. A LED is connected to microcontroller AT89S51; The controller will decode the data from transmitter. When the data was received from transmitter, controller will decode the data that which button is transmitted from transmitter.

4.3. Push Button Switch

A set of four push Button switches is used in the RF transmitter circuit. Each switch labelled with number 1, 2, 3 and 4 to indicate which traffic light at the intersection. These switch need to be push (switch on) in order to trigger the emergency sequence mode of the traffic light intersection.

The other switch is reset button and on/off button.

4.4. The Normal Sequence

The sequence of traffic lights started as green light of traffic light 1 and red light for others traffic light. The duration for each traffic light is 5 seconds only unless the Radio Frequency (RF) receiver received any signal from transmitter, it will trigger the emergency mode for traffic light.

4.5. The Emergency Mode sequence

The emergency mode is triggered when the RF receiver received the transmitted signal from the RF transmitter to override the normal sequence of the traffic light. For example, an ambulance arrives at the traffic light 4 and the green light of the traffic light 1 is on. When the push-on button no.4 is turned on, the RF receiver received the transmitted signal and changed the sequence to the emergency sequence mode.

V. CONCLUSION

In conclusion, traffic light control system for emergency vehicle using radio frequency (RF) facilitate emergency vehicle to cross at the intersection of traffic light. This system implementing radio frequency (RF) as the medium for emergency vehicle communicate with traffic light system. This system can solve the problem for emergency vehicle when approaching traffic light with ease. In the future this prototype can be improved by upgrading the range of radio frequency can transmitted and applied this system to real traffic light system.

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Advanced Multistation Generation Using Non-Conventional Energy Resources

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ABSTRACT

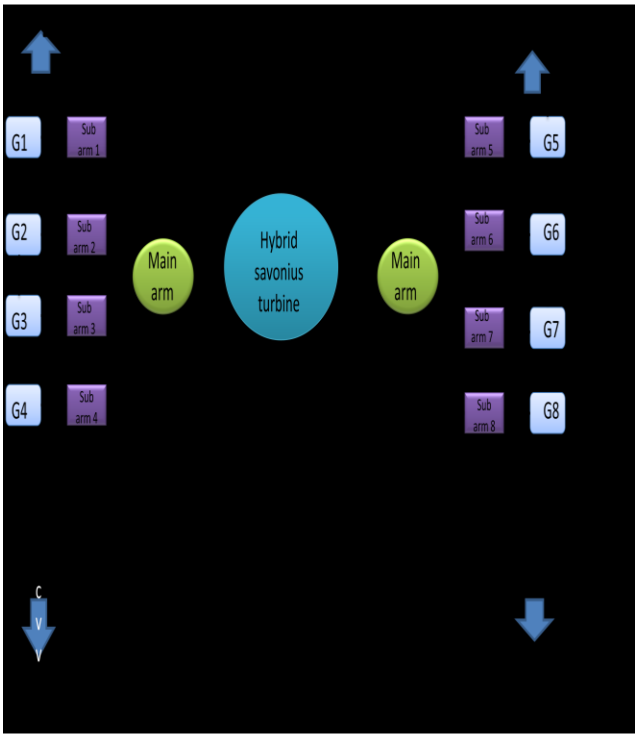
According to generate energy at different stations we used hybrid Savonious Turbine, which can rotate on both wind and water and also the structure of this project have tremendous ability to rotate different generator shaft by coupling them with a single shaft of savonius turbine. This makes the turbine more efficient, theoretically i.e. eight times because we are using eight generators with a single turbine. As other conventional turbines use with a generator with itself each. Moreover this turbine is capable to create more output as well as torque. Sothat we can use it to charge batteries etc. This construction contains 1 Savonius Turbine, 2 main arms, 8 sub arms, 8 moto-generators which are connected to eight different load(we have shown power LEDs as load). As we said that its efficiency is lot more than other turbines like aero turbine, just because of its shape which is simple but cover more air if we say using it for wind source. So the amount of energy generated is large. We can take power from here for industries, domestic use, commercial complexes etc. where the wind or water is in good amount. Hill station would be the Homerun for this project.

I. INTRODUCTION

As everyone known about the world facing problem due to use of non-renewable resources in huge amount. To overcome these problems we have constructed a power station using non-conventional resources.

The main advantages of this project is that it is multi-station generation using eight different generating station. It also becomes the invention which will very useful in country like India where the consumers are in very large number. Second major advantage of this project is that the turbine which we are using here is a hybrid type of turbine which can rotate on multiple resources i.e. wind and water.

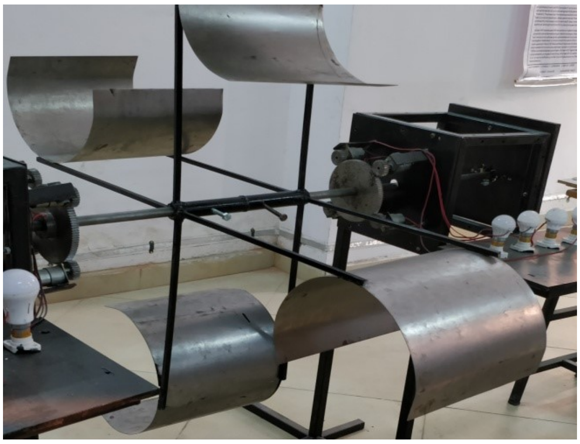
II. BLOCK DIAGRAM



This hybrid turbine consist of major parts as :
1. Hybrid Savonius turbine
2. Large main arms
3. Small sub arms
4. Generators

III. TURBINE

Blades are made up of Mild steel which is more malleable than normal steel thus it can get into various shape without getting breaking and cracking. In according to shape up the turbine blades of a Savonius turbine which looks like “S” in cross section, malleability of the mild steel plays lead role.
Scoops carries more wind and it produces more torque on the turbine shaft. Thus this construction takes lesser wind to produce the same torque. Size of blade id 12.5 width, 6.25 depth.

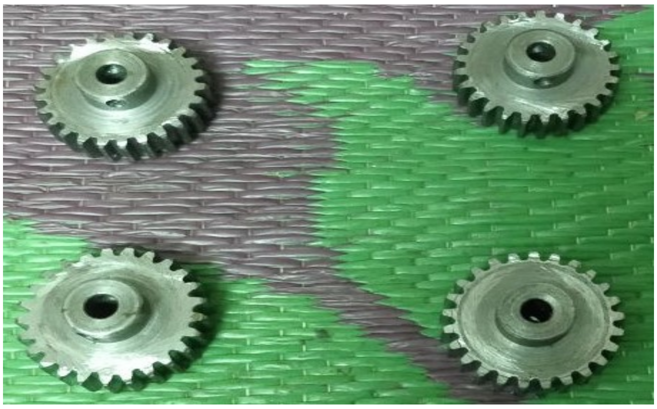


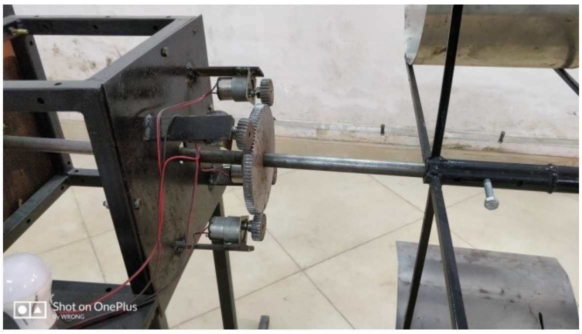
IV. MAIN ARM

Main arms are major moving part after the turbine shaft. Two main arms are used with the main shaft where it is connected with further units. it has 100 teethes which are link with the sub arm teethes, the rotation of main arm is depend upon rotation of main shaft RPM of main arm is more than that of main shaft and less than sub arm.

V. SUB-ARM

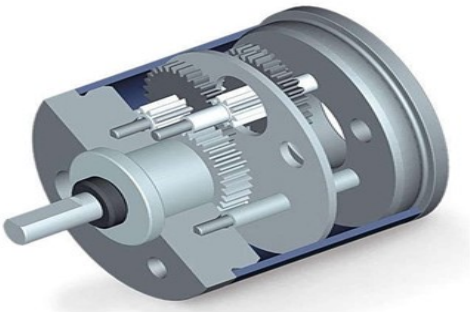
Sub arm are linked with main arm it has 24 teethes which means the rotation of main arm is about four rotation of sub arm. Foursub-arm are linked with each main arm. Size and shape of sub arm is less than main arm. All 8 sub arm are connected to the generator.





VI. GENERATOR

Eight generators are connected to each sub arm respectively. Rotation of main arm rotates sub arm and sub arms rotates generators which are either connected to load or transmission line.
The generators we are using here are geared generator which also have advantages of it converts the less rpm input into large rpm output due to its geared mechanism.



VII. ADVANTAGES

1. Its rotates on multiple natural resources i.e. water and wind.
2. Efficiency is high as compared to other turbines.
3. Long time investments.
4. Pollution free process.
5. Easy construction and operation.

VIII. APPLICATION

1. Industrial purpose.
2. Commercial complex.
3. Domestic use.
4. Hill area where adequate wind and water flow is available.

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Home Automation Using PLC and SCADA

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ABSTRACT

With the rising power of technology, it is able to accomplish things at a much quicker rate. By simply at the touch of a button access to large amounts of information due to the capability of computers and the Internet. Not only has technology given us more information, but it also has given us the ability to communicate, organize, and manage our time. This paper gives the solution for controlling the home appliances with the less man power in a different way by using programming logical devices(PLC).The numerous benefits of today's home automation solution includes safety and security, energy savings, money savings, convenience and control .It improves the daily life of seniors and disabled by offering voice control and safety items.

Keywords: Automating Devices, Programming Logic Device, Siemens Logo PLC

I. INTRODUCTION

The home automation has always been to make home more comfortable and secure, as well as to reduce the time spent managing an home by letting it do the work than a human would normally do, in essence making an home work for us. In addition to comfort and security, automating the home is the best way to regulate energy usage and reduce costs for heating, cooling and lighting. Home automation is taking centre stage in home technology circles for its ability to let home owners greatly reduce their energy consumption without changing their lifestyle, therefore helping them do their part to slow global warming, as well saving them money. Home automation can be an exciting, new innovations that make home appliances fun and easy to use for every member of the family. For example, a scenario such as I'm Home could be triggered by pressing one button from your vehicle as you approach the driveway. There were many papers presented before such as home automation using android application by remote control. It is used to design a home automation system with Android application that can be controlled remotely. This proposed system uses an Android OS based smart phone or tablet [9], upon a graphical user interface based touch screen operation. In order to achieve this, Android application acts as a transmitter, which sends the ON/OFF commands to the receiver. The project is touch screen based home automation is to design a system with touch screen based control panel. In order to achieve this, a touch panel is interfaced to the microcontroller on the transmitter side which sends ON/OFF commands to the receiver where the loads are connected.

II. HOME AUTOMATION SYSTEM OVERVIEW

Though there were many products in the market for home automation. In order to overcome the weakness of those project and increase the efficiency and reducing cost .Control the devices with PLC software decreases the programming complexity and increasing the number of inputs. Using of logo PLC one of the advanced PLC technology can produce delays for more than month or year this might overcome the drawbacks of earlier models. The PLC technology will be Economical control of complex systems. It can be reapplied to control other systems easily and quickly. Sophisticated control can be done with computational abilities. Programming is easier and reduces downtime through troubleshooting ability. Reliability and durability of the components make PLCs likely to operate for years.

The control of the home based appliances such as water heater, air-conditioner, exhaust fan, lights etc. without human interventions shown in Figure 1. For example, if the room is darker or insufficient light, the sensor senses it and commands the PLC to switch on the light. Similarly, if the smoke is detected, exhaust fan will be switched on. The Logo PLC can get four inputs and four outputs, the extensions could be made by connecting to main PLC. It has lithium ion battery, which provides power supply for 26 days. The water level in the tank will be maintain a level using a float switch ,when the float switch goes to a particular lower level ,the command goes to PLC and SCADA.

III. PROGRAMMING IN PC

The most common method used for programming PLCs is based on the ladder diagrams. Writing a program is then equivalent or resembles to drawing a switching circuit. The ladder diagram consists of two vertical lines on either side representing the power rails which are positive and neutral. Circuits are connected in the rungs of the ladder which are horizontal, between these two rails. Ladder logic was originally a written method to document the design and construction of relay racks as used in manufacturing and process control. Each device in the relay rack would be represented by a symbol on the ladder diagram with connections between those devices shown. In addition, other items external to the relay rack such as pumps, heaters, and so forth would also be shown on the ladder diagram. Although the diagrams themselves have been used since the days when logic could only be implemented using switches and electromechanical relays, the term 'ladder logic' was only latterly adopted with the advent of solid state programmable logic. Ladder logic acts as a programming language that represents a program in the form of graphical diagram based on the circuit diagrams of relay logic hardware and used in industrial control applications. The name Ladder Logic is appropriate as it resembles a ladder with two vertical rails on either side with a series of horizontally connected rungs between them. The system in the ladder diagram form will be programmed into the PLC. Once the programs have been downloaded into PLC, it can be monitored in the Diagram Workspace during execution. The Logo PLC provide the easy user interface to download the program, to upload the program, and to go back at online mode to see program desirable state. In this paper, the each home appliance is controlled by using PLC as shown in the flow charts.

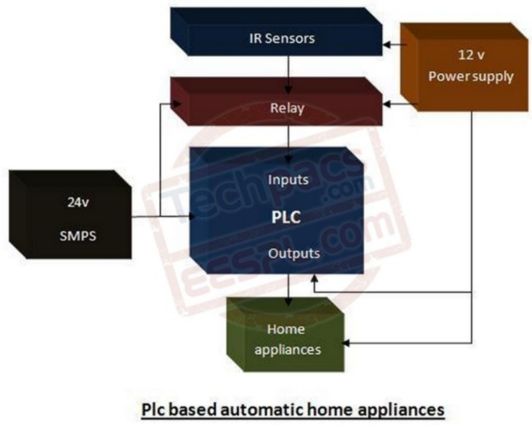

Figure 1. PIC based automatic home appliances

IV. RESULT AND DISCUSSION

In this paper, the real time data acquisition monitoring and control system has been developed using Programmable Logic Controller and is highly effective, efficient and robust. A number of input-output modules are attached to a PLC providing its expandability and competence. The new expansion modules can be either digital or analogue and in the present work digital modules are used. The ease of programming and networking of sensors with PLC demonstrates the high user friendliness of the device. A single PLC can control whole industry as it easily replaces the old, obsolete and cumbersome relay logics.

Hence the present work is of much importance to the electrical engineers and designers. During the operation, all activities that occur can be observed by the. computer using Logo PLC. The system needs to debugged along the way and fine-tuned if necessary. The system is test run thoroughly until it is safe to be operated. The prototype was mainly built by combining the mechanical design and the electrical design. The system requires external power supply of 24 V DC and 220 V AC. The requirement of 24 V DC voltages is fulfilled with the help of SMPS. The external power supply of 240 V AC is converted into 24 V DC through SMPS. The reason of choosing external Power Supply is that the PLC is operated on 24 V DC which is not available without any SMPS or external Power Supply.

V. CONCLUSION

In this paper, the real time data acquisition monitoring and control system has been developed using Programmable Logic Controller and is highly effective, efficient and robust. A number of input-output modules are attached to a PLC providing its expandability and competence. The new expansion modules can be either digital or analogue and in the present work digital modules are used. The ease of programming and networking of sensors with PLC demonstrates the high user friendliness of the device. A single PLC can control whole industry as it easily replaces the old, obsolete and cumbersome relay logics. Hence the present work is of much importance to the electrical engineers and designers. During the operation, all activities that occur can be observed by the. computer using Logo PLC. The system needs to debugged along the way and fine-tuned if necessary. The system is test run thoroughly until it is safe to be operated. The prototype was mainly built by combining the mechanical design and the electrical design. The system requires external power supply of 24 V DC and 220 V AC. The requirement of 24 V DC voltages is fulfilled with the help of SMPS. The external power supply of 240 V AC is converted into 24 V DC through SMPS. The reason of choosing external Power Supply is that the PLC is operated on 24 V DC which is not available without any SMPS or external Power Supply.

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Modulation Techniques for Transformer-less Inverters

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ABSTRACT

In grid connected applications which is having low power, a single-phase inverter can have a good performance. As can be inferred from the title, the PV inverter is a key element of grid connected PV power system whose main function is the conversion the DC power generated by PV panel into the grid synchronized AC power. These inverters use either a low frequency transformer or a high frequency transformer. In PV applications it has been studied that the transformer can be removed in order to reduce the losses, cost, size and weight of the system simultaneously increasing the system performance. In this paper different inverter modulation techniques are discussed which are used to analyse the system changes which occur due to the removal of transformer. This paper also presents some of the most important topologies like diode-clamped inverter (neutral-point clamped), capacitor clamped inverter (flying capacitor) and cascaded-multilevel inverter.

Keywords: Modulation techniques, Inverter Topologies, Transformerless System

I. INTRODUCTION

As it can be noticed from the current market trends that power electronics technology is gaining sudden boom of demand because of its fast response and autonomous control. In near future this technology will be able to provide sufficient advantages in processing power from renewable energy sources. Various technologies have also been developed for PV inverters with the main purpose of reducing the maintenance cost and increasing the efficiency the system. Recently, many other countries have taken their steps for increasing the share of renewable energy in power plants (e.g. wind, solar, tidal etc.). Once the renewable energy is used as a major player of energy in future power systems, the conventional technology of regulating voltage will encounter various problems and the voltage quality of power grids will be lowered significantly.

II. PHOTOVOLTIC CELL

The photovoltaic effect was experimentally demonstrated by French physicist Edmond Becquerel. The world's first photovoltaic cell was developed by him in 1983. Willoughby Smith first described it as the "Effect of Light on Selenium during the passage of an Electric Current" in a 20th February 1873 issue of Nature. Charles Fritts built the first solid state photovoltaic cell by coating the semiconductor selenium with a thin layer of gold to form the junctions, the device was only around 1% efficient. A grid-connected PV system consists of solar panels, inverters, a power conditioning unit and grid connection equipment. The grid-connected PV system supplies the excess power, beyond consumption by the connected load, to the utility grid.

When PV is installed in grid, certain problems appear, as the PV panel is typically built in a sandwich structure, a capacitance to earth appears creating a path for leakage current. This can compromise personal safety and potential difference imposed by switching action of the inverter which injects a capacitive ground current. The transformerless structure requires more complex solution, typically resulting in novel topologies in order to keep the leakage current and DC current injection under control in order to comply with the safety issue and to exhibit the high efficiency.

III. TRANSFORMERLESS CONCEPT

When power is transmitted to the grid using transformer, the size of the system is increased and system becomes more complex. Also, various types of losses such as iron losses, copper losses, hysteresis losses, eddy current losses, stray loss, and dielectric losses increases. When transformer is connected to the system the overall cost (installation as well as maintenance cost) increases.

Transformerless inverters are light, compact, and relatively in-expensive. Transformerless concept is advantageous because of their high efficiencies which reach up to 97-98% which is highly attractive for distributed power generator systems.

To make the system transformerless, certain multilevel inverter topologies are used which include an array of power semiconductors and capacitor voltage sources whose output generates voltages with stepped waveform. By adding the number of levels of the inverter, the output voltage will be a step voltage generating a staircase waveform which has reduced harmonic distortion. However, a high number of levels increases the complexity and introduce voltage Imbalance problem in the system. Three different topologies have been proposed for multilevel inverters:

1) Diode-Clamped Inverter (neutral-point clamped)
2) Capacitor-Clamped Inverter (flying capacitor)
3) Cascaded Multilevel Inverter

The most important features of multilevel inverters are:

1) They can generate output voltages with extremely low distortions.
2) They can draw input current with very low distortion.
3) They operate with a lower switching frequency.

IV. INVERTER TOPOLOGIES

A. Diode-Clamped Inverter

A three-level diode-clamped inverter is presented in below Fig. 1(a). In this circuit dc-voltage is split into three levels by two series-connected bulk capacitors C_1 and C_2. The middle point of the two capacitors (*n)* can be defined as the neutral point. The output voltage has 3 states $+V_{dc}/2$, 0 and $-V_{dc}/2$. For voltage level $+V_{dc}/2$ switches S_1 and S_2 need to be turned on, for $-V_{dc}/2$ switches S_1' and S_2' need to be turned on and for 0 level S_2 and S_1' need to be turned on. The key components that distinguish this circuit from a two-level inverter are diodes D_1 and D_1'. These two diodes clamp the switch voltage to half the level of the dc voltage. When both S_1 and S_2 are turned on, the voltage across a and 0 is V_{dc} i.e. $V_{an} = V_{dc}$. In this case D_1' balances out the voltage sharing between S_1' and S_2'. Note that the output voltage V_{an} is ac and V_{a0} is dc.

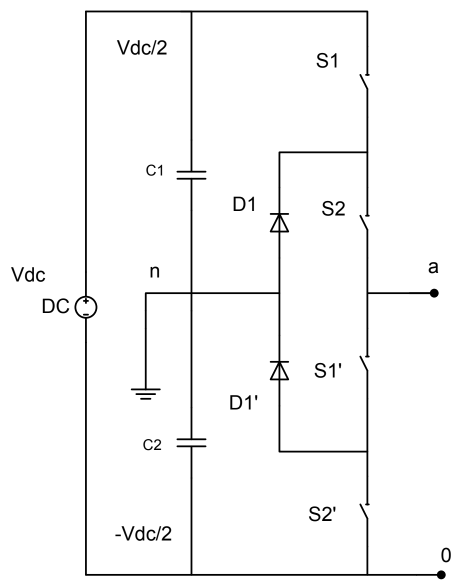

Figure 1(a). Three level Diode-Clamped Multilevel Inverter Circuit

Fig.1(b) shows a five-level diode-clamped inverter where the dc bus consists of four capacitors C_1, C_2, C_3

and C_4. For dc-voltage V_{dc}, the voltage across each capacitor is $V_{dc}/4$.

To explain the synthesis of staircase voltage, the neutral point (n) is considered as the reference point. There are five switch combinations to synthesize five-level voltages across a and n.

1) For voltage level $V_{an} = V_{dc}/2$, turn ON all upper switches from S_1 to S_4.

2) For voltage level $V_{an} = V_{dc}/4$, turn ON three upper switches $S_2 – S_4$ and one lower switch S_1'.

3) For voltage level $V_{an} = 0$, turn ON two upper switches S_3 and S_4 and two lower switches S_1' and S_2'.

4) For voltage level $V_{an} = -V_{dc}/4$, turn ON one upper switch S_4 and three lower switches S_1' – S_3'.

5) For voltage level $V_{an} = -V_{dc}/2$, turn ON all lower switches S_1' to S_4'.

Four complementary switch pairs exist in each phase. The complementary switch pair is defined such that turning on one of the switches will exclude the other from being turned on. In this example, the four complementary pairs are (S_1, S_1'), (S_2, S_2'), (S_3, S_3'), and (S_4, S_4').

The number of diodes required for each phase will be (m-1) * (m-2).

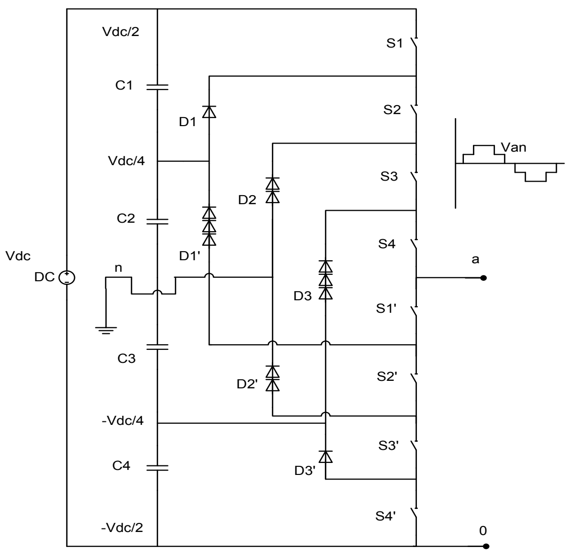

Figure 1(b). Five level Diode-Clamped Multilevel Inverter Circuit

B. Capacitor-Clamped Inverter

Fig.2 shows one phase-leg of capacitor-clamped inverter. The inverter is also called the flying capacitor inverter. The independent capacitors clamping the device voltage to one capacitor voltage level. The inverter in Fig. 2 shows a three-level output across a and n, i.e. $V_{an} = V_{dc}/2$, 0 or $-V_{dc}/2$. For voltage level $V_{dc}/2$, switches S_1 and S_2 needs to be turned on, for $-V_{dc}/2$ switches S_1 and S_2 need to be turned on and for 0 level voltage either pair (S_1, S_1') or (S_2, S_2') needs to be turned on. Clamping capacitor C_1 is charged when S_1 and S_1'are turned on and is discharged when S_2 and S_2' are turned on.

The voltage output of a five-level capacitor-clamped converter has more flexibility as compared to a diode-clamped converter of same level. The neutral point (n) and V_{an} can be synthesized by the following switch combinations-

1) For voltage level $V_{an} = V_{dc}/2$, turn on all upper switches $S_1 – S_4$.

2) For voltage level $V_{an} = V_{dc}/4$, there are three combinations:

a) S_1, S_2, S_3, S_1'.
b) S_2, S_3, S_4, S_4'.
c) S_1, S_3, S_4, S_3'.

3) For voltage level $V_{an} = 0$, there are six combinations:

a) S_1, S_2, S_1', S_2'.
b) S_3, S_4, S_3', S_4'.
c) S_1, S_3, S_1', S_3'.
d)S_1, S_4, S_2', S_3'.
e) S_2, S_4, S_2', S_4'.
f) S_2, S_3, S_1', S_4'.

4) For voltage level $V_{an} = -V_{dc}/4$, there are three combinations:

a) S_1, S_1', S_2', S_3'.
b) S_4, S_2', S_3', S_4'.
c) S_3, S_1', S_3', S_4'.

5) For voltage level $V_{an} = -V_{dc}/2$, turn on all lower switches S_1' – S_4'.

The capacitors with positive polarity are in discharging mode, whereas those with negative polarity are in charging mode. By selecting the proper combination of capacitors, it is possible to balance the capacitor charge. Similar to diode clamping, this also requires a large number of bulk capacitors to clamp the voltage.

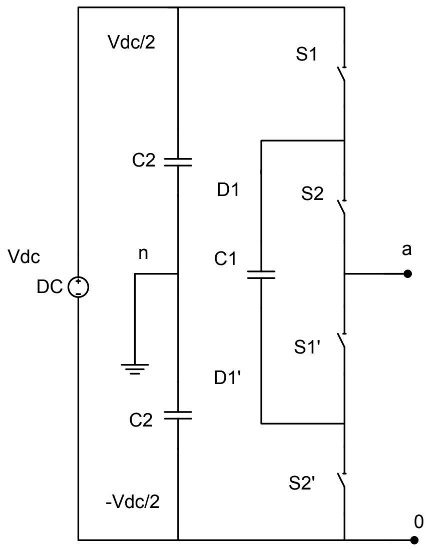

Figure 2. Three level Capacitor-Clamped Multilevel Inverter Circuit

C. Cascaded Multilevel Inverter

Another converter topology can be used in transformerless system, which is based on the series connection of several single-phase inverters. Fig.3 shows the circuit diagram of one phase leg of a nine-level inverter. The resulting phase voltage is obtained by the addition of the voltages generated by the different cells. Each single-phase full-bridge inverter generates three voltages of the output: $+V_{dc}$, 0 and $-V_{dc}$. The resulting output ac voltage varies from $-4V_{dc}$ to $+4V_{dc}$ and the staircase waveform is nearly sinusoidal even without filtering.

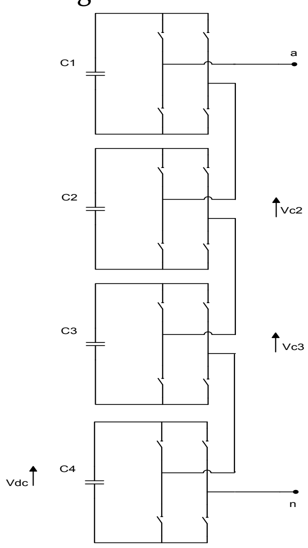

Figure 3. Cascaded Multilevel Inverter Circuit

V. MODULATION TECHNIQUES

Different PWM switching patterns can be used in transformerless single phase inverter bridges. The main modulation strategies used are:

(a) Bipolar Modulation
(b) Unipolar Modulation

Fig.4 shows a simplified circuit diagram of a single-phase H-bridge inverter. It is composed of 2 inverter legs with 2 IGBT devices in each leg. The inverter dc bus voltage V_d is usually fixed, while its ac output voltage V_{AB} can be adjusted by either bipolar or unipolar modulation schemes.

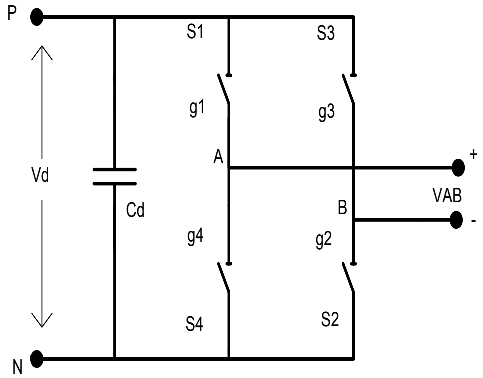

Figure 4. Single-phase H-bridge Inverter

A. Bipolar Pulse-Width Modulation

Fig.5 shows a set of typical waveforms of the H-bridge inverter with bipolar modulation, where v_m is the sinusoidal modulating wave, v_{cr} is the triangular carrier wave, and v_{g1} and v_{g3} are the gate signals for the upper switches S_1 and S_3, respectively. The upper and the lower switches in the same inverter leg operate in a complementary manner with one switch turned on and the other turned off. Thus, we only need to consider two independent gate signals, v_{g1} and v_{g3}, which are generated by comparing v_m with v_{cr}. Since the waveform of v_{AB} switches between the positive and negative dc voltages $\pm V_d$ and $-V_d$ this scheme is known as bipolar modulation. The switching frequency of the IGBT device, referred to as device switching frequency f_{sw} is equal to the carrier frequency f_{cr}.

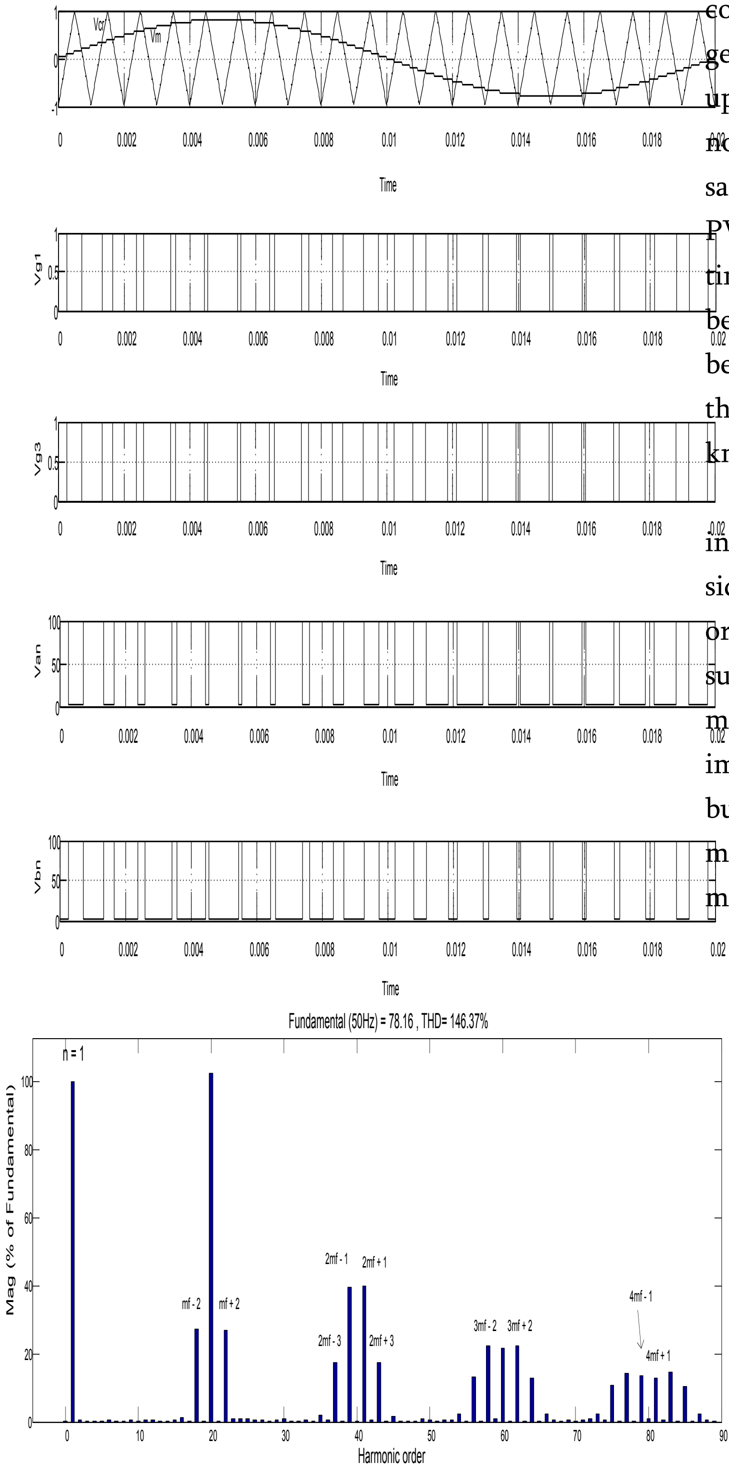

Figure 5. Bipolar PWM for the H-bridge inverter operating at mf = 20, ma = 0.8, fm = 50 Hz, and fcr = 1000 Hz.

B. Unipolar Pulse-Width Modulation

The unipolar modulation requires two sinusoidal modulating waves, vm and -vm of the same magnitude and frequency but 180° out of phase as shown in Fig.6(a). The two modulating waves are compared with a common triangular carrier wave vcr, generating two gating signals, vg1 and vg3, for the upper switches, S1 and S3, respectively. It can be noted that the 2 upper devices do not switch at the same time, which is distinguished from the bipolar PWM where all four devices are switched at the same time. The inverter output voltage vAB switches either between 0 and +Vd during the positive half-cycle or between 0 and –Vd during the negative half-cycle of the fundamental frequency. Thus, this scheme is known as unipolar modulation

Fig.6(b) shows the harmonic spectrum of the inverter output voltage vAB. The harmonics appear as sidebands centred around 2mf and 4mf. The low-order harmonics generated by the bipolar modulation, such as mf and mf ± 2, are eliminated by the unipolar modulation. The unipolar modulation can also be implemented by using only one modulating wave vm but two phase-shifted carrier waves, vcr and -vcr. This modulation technique is often used in the CHB multilevel inverters.

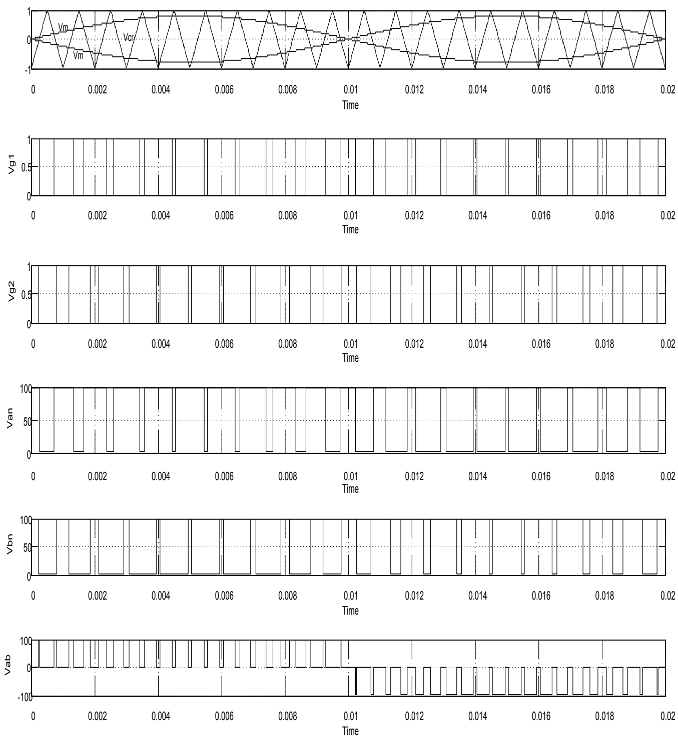

Figure 6(a). Unipolar PWM with two phase-shifted modulating waves (mf = 20, ma = 0.8, fm = 50 Hz and fcr = 1000 Hz).

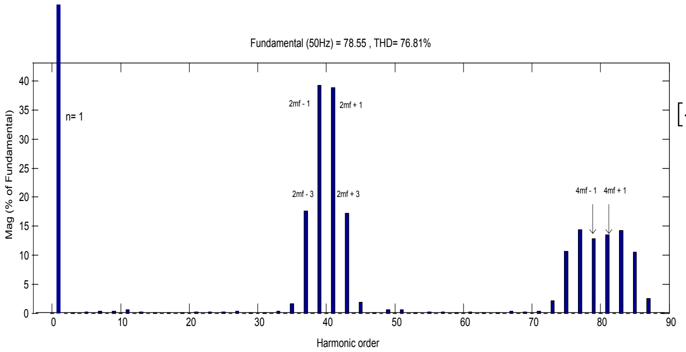

Figure 6(b). Harmonic Spectrum

VI. CONCLUSION

In this paper several topologies without transformer suitable for low power grid connected systems have been studied. Both topologies and modulation techniques have a great effect on PV based grid connected inverters. Amongst these topologies cascaded multilevel inverter topology has been identified as the most promising topology. With the use of this topology measures are necessary to decrease the capacitive current which is caused by the potential difference imposed on PV array. Two modulation techniques have been discussed briefly and the waveforms as well as THD results have been shown. Unipolar modulation is better than bipolar as it eliminates the lower order harmonics which is good for the system.

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Power Factor Improvement By Reactive power compensation using STATCOM

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ABSTRACT

This paper presents a study on MATLAB/SIMULINK model of STATCOM (Static synchronous compensator) for reactive power compensation. The STATCOM is shunt connected FACTS device used for improving the voltage profile of transmission system which connects the line with voltage source inverter (VSI) with DC link capacitor. Reactive power compensation using STATCOM is used for mitigating power loss & improves power factor and voltage profile in transmission system. In this paper, PWM technique is used as a control strategy using dq0 transformation and also different results with different percentage of compensation is also studied. It is the best way to overcome the problem of reactive power compensation without constructing new transmission lines.

Keywords: MATLAB/SIMULINK, STATCOM, Inverter, Reactive Power, PWM

I. INTRODUCTION

The main purpose of power system is to generate & transmit power via transmission line to various consumers efficiently. It is a complex process. There are many components in the power system. One of the main components to form a major part is the reactive power in the system. Various loads like motor loads and other loads require reactive power for their operation. The majority of power consumption has been drawn in inductive loads. These loads are operated as lagging power factor. The feeder power losses are increased due to reactive power and also the flow of active power is disturbed in distribution system.

Reactive power compensation is defined as, to manage reactive power in an efficient way to improve the performance of ac power systems. Different "FACTS (Flexible AC Transmission System)" technologies are used to compensate reactive power. The parameters of the power system such as, series impedance(current, voltage and phase angle) and shunt impedance can be easily controlled by using FACTS technology. The main purpose of the FACTS technology is to make system economically controllable by using devices on high voltage side. However, the FACTS technology consists of collection of various types of controllers and these can be applied to the power system individually or in the combination to control the parameters[4]. Basically there are four types of FACTS controllers:1]Shunt Controller, 2] Series controller, 3] Shunt-Series controller, 4]Series-Series controller.

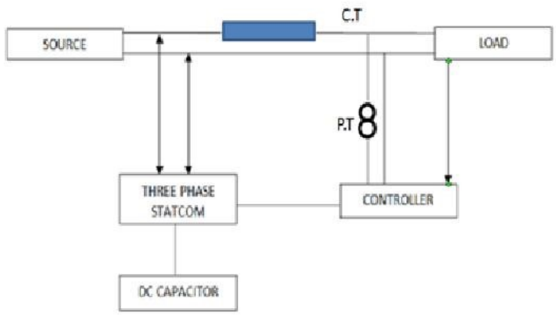

Figure1. Block diagram of STATCOM connected system

The series controller injects the voltage in series with the transmission line with any phase angle according to driving voltage to control the line current. The shunt controller draws or injects the current into the power system. The combination of shunt and series controller could inject the current via shunt controller of the system and injects the voltage via series controller of the system. These are co-ordinately control. The combined Series-Series controller provides independent reactive power compensation with the transmission of real power via DC link. In multiline transmission sytem these types of controller are used which is controlled co-ordinately.

By using statcom reactive power can be compensated by either absorbing or injecting. It is connected as shunt device which is used for compensation. There are more advantages of statcom over other devices. For ex. For same ratings of statcom by either absorbing or injecting. It is connected as shunt device which is used for compensation. There are more advantages of STATCOM over other devices. For example for same ratings of STATCOM and SVC, STACOMM is much more compact. STATCOM is also technically superior. For low values of the bus voltage, it can be able to supply required reactive current.

II. OPERATION OF STATCOM

The STATCOM is connected as shunt device which is used for compensation. By using STATCOM, reactive power can be compensated by either absorbing or injecting. Voltage profile and power factor of the transmission system is also improved by using STATCOM. Generally, STATCOM is connected near the loads at distribution system.

Fig.1 shows block diagram of STATCOM placed in transmission system. STATCOM consists of DC link capacitor, AC filter, 3- phase Inverter (IGBT/MOSFET/SCR).

For Fig.1 we can say that, By using controller, the inverter is operated so that the phase delay between inverter voltage (Vi) and supply voltage (Vs) is dynamically controlled. By doing this STATCOM can generates and absorbs power at the point of common coupling (PCC) for suitable VAR. The operation of STATCOM for in phase, lagging, leading current with respect to supply voltage is given in given fig.2 which varies depending upon Vi. If the value of Vi is equal to Vs, there is no reactive power and the STATCOM does not generate or absorb reactive power. If the Vi is higher than Vs, the current, I, flows through the coupling inductor from the STATCOM to the ac system, and the device generates capacitive reactive power. If Vs is higher than Vi, then the current flows from the ac system to the STATCOM, resulting in the device absorbing inductive reactive power.

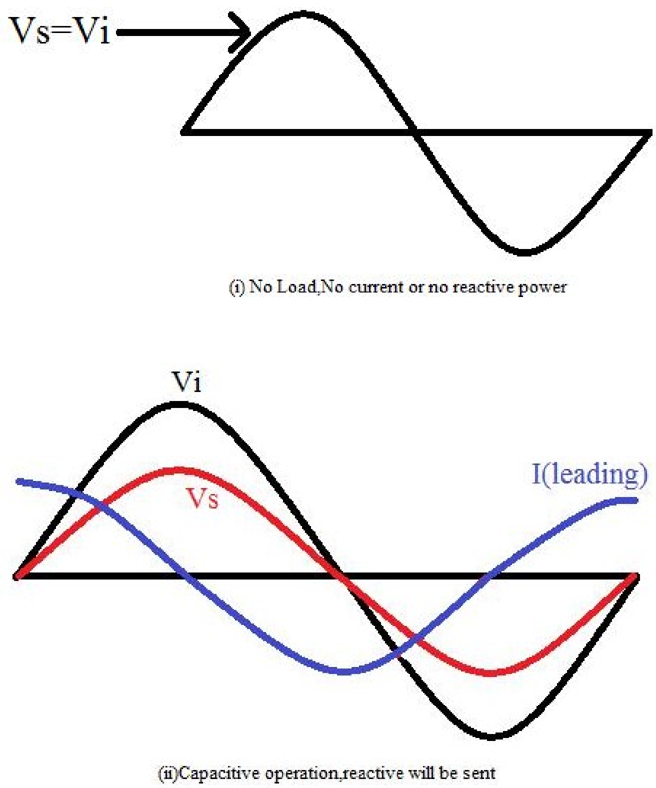

Figure 2. Operation of STATCOM

III. MODELING OF STATCOM USING MATLAB/SIMULINK

SIMULINK model of STATCOM is given below in Fig 3. The modeling of STATCOM consists of three phase voltage source (415 V), three phase R-L series load (Active power=50 kW, Inductive reactive power=30 kW), two buses B1, B2, Three phase inverter connected with parallel DC link capacitor (10000 micro F, 700 V). Here we connected series inductor (3mH) with inverter and transmission line for filtering purpose to reduce harmonics. Three phase inverter operated with IGBT switches.

The control circuit is shown in Fig.4 . It consists of a phase-locked loop (PLL), ABC to DQ0 transformation block, DQ0 to ABC transformation block, PID controller. Here we used PID controller for accurate result and fast response.

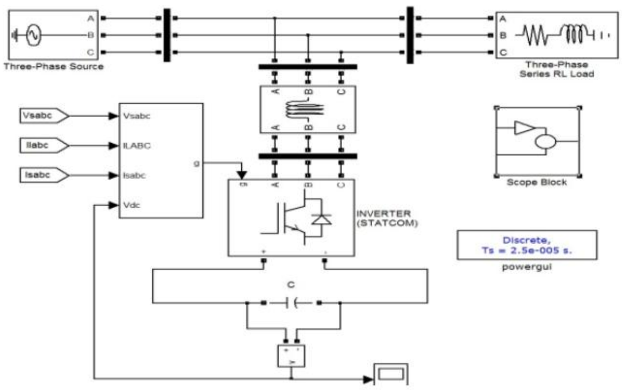

Figure 3. MATLAB simulation model of STATCOM 3-phase connected system

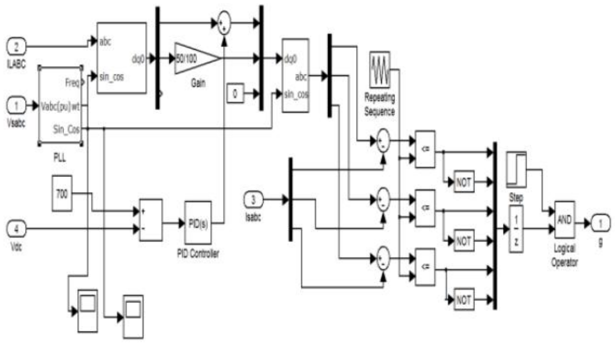

Figure 4. Control Circuit

This Phase Locked Loop (PLL) system can be used to synchronize on a set of variable frequencies, three-phase sinusoidal signal and it provides pu values of voltage and current. DQ and ABC transformation blocks are used to simplify the controller operation.

IV. SIMULATION RESULT

Here different results for waveforms of load current and load voltage before connecting STATCOM & after connecting STATCOM is shown in Fig.5.1, Fig.5.2.

In simulation, we set time delay 0.5 sec by using step input. Therefore after 0.1 sec STATCOM comes in operation in system. From the Fig.5.1, Fig.5.2, we can say that after connecting STATCOM, the current comes in phase with source at both load & source side and power factor becomes almost unity. By connecting STATCOM, we achieve best results of power factor and voltage profile.

Here all results are shown for series inductive load with resistance (LOAD: Active power=50 kW, Inductive reactive power=30 kW)

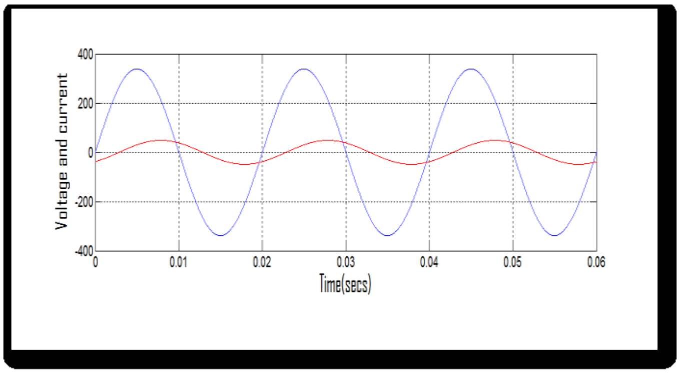

Figure 5.1.1. Source Voltage and Source Current waveform before compensation (1-phase)

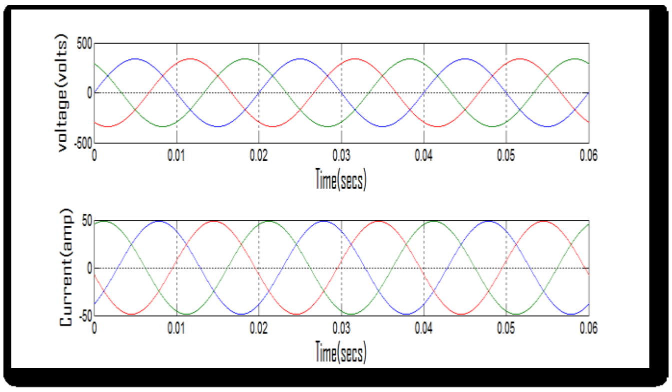

Figure 5.1.2. Source Voltage and Source Current waveform before compensation (3-phase)

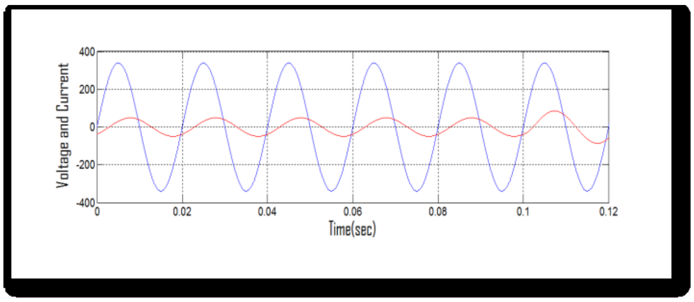

Figure 5.2.1.Source Voltage and Source Current waveform after compensation (1-phase)

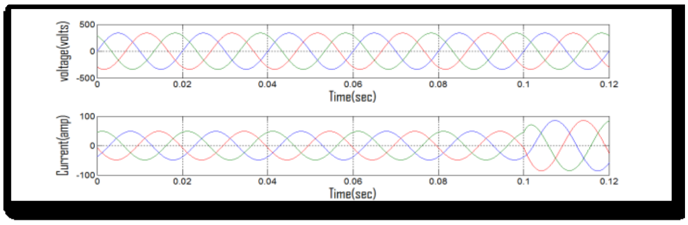

Figure 5.2.2. Source Voltage and Source Current waveform after compensation (3-phase)

V. CONCLUSION

From the above waveforms, the current profile of transmission system is improved after connecting the STATCOM. And we also derived different waveforms for different percentage of reactive power compensated by STATCOM. Therefore, we conclude that, by connecting STATCOM the overall voltage and current disturbances are reduced and power factor of the system is also improved and overall response of the STATCOM is more efficient than other Devices.

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Analysis of Leakage Current in a Transformerless PV Inverter Connected to the Grid

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ABSTRACT

Analysis of a leakage current in transformerless photovoltaic inverter (PV inverter) connected to the grid. In order to analyze the leakage current many inverter topologies have been proposed. In this paper examine the leakage current in a transformerless PV connected to the single phase grid system. For low power grid connected application a single phase converter can be used and it is possible to remove the transformer in the inverter in order to reduce losses, cost and size. Galvanic connection of the grid and the DC sources in transformerless system can introduce additional leakage current due to parasitic capacitance. This can also be prevented by using various topologies and pulse width modulation (PWM) techniques. Full bridge configuration with bipolar pulse width modulation has constant common mode voltage but with a reduced efficiency and large output current ripple. Full bridge with unipolar pulse width modulation has many advantages of increased efficiency and three level output to minimise the leakage current and improve the efficiency, the various topology for the transformerlessphotovoltaic applications and developed. In addition, the full-bridge inverter with bipolar, unipolar and hybrid modulation scheme is investigated.

Keywords: Transformerless, photovoltaic cell (PV), Leakage current, parasitic capacitance, H-Bridge

I. INTRODUCTION

Photovoltaic (PV) power systems are very attractive and widely used in recent years. the proposed inverter circuit Photovoltaic (PV) energy is generally believed to be one of the most valuable renewable energies for reasons several. In order to integrate the PV systems into grid, a power electronic component should be required to convert DC energy source generated by PV arrays to AC component, which is fed into grid.

In general, a transformer is installed between PV arrays and grid for galvanic isolation. The transformer is heavy with large volume, along with the copper and iron losses during transformer operation. Furthermore, there are no limits on the installation area Therefore, the transformerless PV system is popular and received more and more attention, due to its low cost, small size, and high efficiency. Furthermore, there are no limits on the installation area. However, a technical challenge arises for transformerless PV systems.

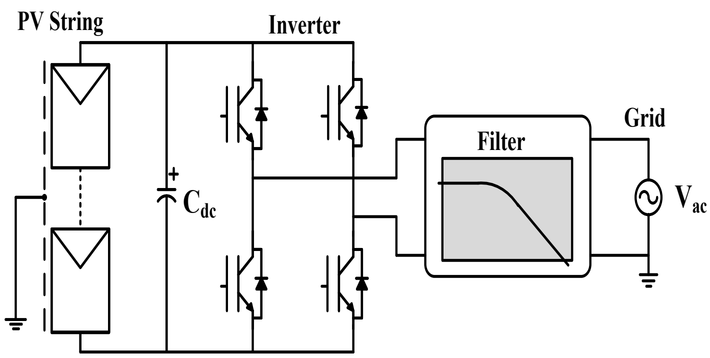

Figure 1. Voltage source transformerless inverter connected to the grid

More specifically, the capacitive leakage current is generated between photovoltaic modules and the ground. In practice, this capacitive leakage current is very difficult to handle, because the capacitance between photovoltaic modules and ground is usually highly unpredictable, and it varies significantly with temperature or humidity. The presence of leakage currents is very harmful, since they could put the life of a photovoltaic module installer at risk if he touches the photovoltaic module. Additionally, they will bring high-frequency harmonics, which may lead to problems with electromagnetic compatibility.In contrast, stand-alone systems are connected to the load and electric applications Grid-connected systems account for a large proportion ofinstalled PV energy systems according to the latestinternational energy agency (IEA) PV power systems report.

A grid connected PV system consist of a solar panel inverter a power conditioning unit and grid connection equipment. In this paper, the full-bridge inverter with bipolar, Unipolar and hybrid modulation scheme is investigated.

In addition, leakage current in thetransformer less PV inverter topology is analysed.

II. SOLAR PHOTOVOLTAIC

The word “photovoltaic” combines two terms, “photo” means light and “voltaic” means voltage.

PV power system. The photovoltaic effect was experimentally demonstrated by French physicist Edmond Becquerel. The world’s first photovoltaic cell was developed by him in 1983. A photovoltaic system in this discussion uses photovoltaic cells to directly convert sunlight into electricity. Photovoltaic power generation employs solar panels composed of a number of solar cells containing a photovoltaic material. Materials presently used for photovoltaics include mono crystalline silicon, polycrystalline silicon, amorphous silicon, cadmium telluride, and copper indium gallium selenide/sulfide. Due to the increased demand for renewable energy sources, the manufacturing of solar cells and photovoltaic arrays has advanced considerably in recent years. Solar photovoltaics is a sustainable energy source where 100 countries are utilizing it. solar photovoltaics is now, after hydro and wind power, the third most important renewable energy source in terms of globally installed capacity. Installations may be ground-mounted or built into the roof or walls of a building.

There are two main types of PV energysystems; grid-connected systems and stand-alone systems. The grid-connected systems are in parallel with the utility grid and provide PV to an increased acceptance of the grid-connected PV inverter technology. In the grid-connected PV system, the DC power of PV array should be converted into the AC power with proper voltage magnitude, frequency and phase to be connected to the utility grid. Under this condition, a DC to AC converter which is better known as inverter. The inverter is therefore an important component in grid- connected PV systems. There are various kinds of grid-connected PV inverters as shown in Fig.

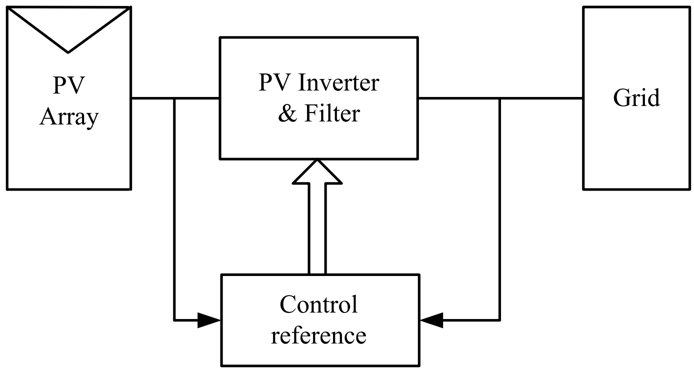

Figure 2. Power Electronic System with the grid, source (PV array), power converter and control

III. TRANSFORMERLESS PV INVERTER

The PV Inverter is the prime element of grid connected C Willough by Smith first discussed it as the effect of light on selenium during the passage of electric current in a 20th February 1873 issue of nature. Recently, the transformerless-type inverter has become more popular owing to its small system volume, low weight and low cost. As photovoltaic (PV) module prices become cheaper, the reduction of manufacturing costs of PV inverters becomes a must. The largest recent shift in inverter technology is the availability of transformer less inverters in the United State. Without heavy transformer, they weight about 50% to 70% less than a transformer-based inverter of similar output, and the size of the inverter housing can be reduced. Inverter efficiency is also increased there are no longer losses associated with having a transformer to step up the voltage. And because the transformer losses (which is comprised of copper windings on an iron or steel core) is eliminated, they are less expensive to produce. The majority of inverter manufacturers are now including a transformer less inverter line.

Transformerless concept is advantageous regarding to their high efficiency, reduced cost and weight of transformer. Topologies that use high frequency transformer in the DC-DC converter have a reduction in the overall efficiency, due to the leakage in the transformer.

These transformerless solutions offer all the before mentioned advantages, but there are some safety issues due to the solar panel parasitic capacitance. This resulting leakage capacitance value depends on many factors; some of these are enumerated below: PV panel and frame structure, surface of cells, distance between cells, module frame, weather conditions, humidity and dust covering the PV panel. It is mentioned that a typical value of 100-200pF was measured between the PV cells and the grounded palm of a person. But in case the surface of the panels was covered with water, this capacitance increased to 9nF, 60 times its previous value. In case of a solar array having a considerable surface, the resulting capacitance has values between 50-150 nF/kW, depending on the weather conditions and panel structure. This leads to leakage currents between the panel terminals and ground, depending on inverter topology and switching strategy. The level of the leakage current depends mostly on the amplitude and frequency content of the voltage fluctuations that are present at the PV panel terminals, but it also depends on the value of the parasitic capacitance.

A PV Inverter has to fulfil three main functions in order to feed energy from a PV array into the utility grid:

1. To shape the current into a sinusoidal waveform;
2. To invert the current into an AC current, and
3. If the PV array voltage is lower than the grid voltage, the PV array voltage has to be boosted with a further element.

IV. LEAKAGE CURRENT AND RESONANCE FREQUENCY

Removal of the transformer and hence its isolation capability and grounding of the PV panel frame is a requirement then PV earth parasitic capacitance needs to be considered in transformerless topologies. Due to the capacitance between the PV panel and earth, potential differences imposed by the switching actions of the inverter injects a capacitive ground current. This ground capacitance is part of a resonant circuit consisting of the PV panels, the AC filter elements and the grid impedance. Due to necessary efficiency optimization of systems, the damping of this resonant circuit can be very small so that the ground current can reach amplitudes well above permissible levels. Without transformer, there is a galvanic connection of the grid and the DC source and thus a leakage current appears. Disadvantages of the appearing leakage current are increased system losses, impairing of electromagnetic compatibility and safety problems.This resulting leakage capacitance value depends on many factors; some of these are enumerated below: PV panel and frame structure, surface of cells, distance between cells, module frame, weather conditions, humidity and dust covering the PV panel.This leads to leakage currents between the panel terminals and ground, depending on inverter topology and switching strategy. The level of the leakage current depends mostly on the amplitude and frequency content of the voltage fluctuations that are present at the PV panel terminals, but it also depends on the value of the parasitic capacitance. Ground current is limited by standards. In general, the leakage current is superimposed to the line current therefore the harmonic content is increased compared with inverters without transformer. In transformerless grid connected systems a resonant circuit is created if the DC source is not grounded. This resonant circuit includes the ground capacitance, the filters, the inverter and the impedance of the connected utility grid. Magnitude of the mentioned capacitance depends on the DC source and on the environmental conditions. capacitances isvery small so leakage currents with this kind of sources is not a topic. For fuel cells this ground Nevertheless, in photovoltaic applications the panels ground capacitance goes from nano-farads up to microfarads and here leakage current is an important topic., the first measure to reduce the ground currents is to decrease the excitation of the resonant circuit. A problem arises due to the great dependence of the ground capacitance with environmental conditions, and hence the resonant frequency of the system.

Also, the resonant frequency is not fixed due to the varying, on environmental conditions dependent PV array earth capacitance. Depending on the topology, switch states and environmental conditions the capacitive earth current can cause more or less severe (conducted and radiated) electromagnetic interference, distortion of the grid current and additional losses in the system. Measures to minimize this current are mention.

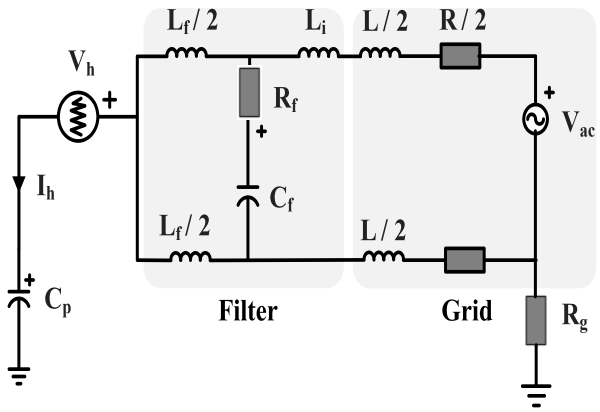

Figure 3. Model of resonant circuit

V. TRANSFORMERLESS MODULATION TECHNIQUE

This section gives an analysis of leakage current flowing through the parasitic capacitance.

1. Full-bridge topology

The full-bridge PV inverter is widely used in the PV power generation system. In the full-bridge inverter, three modulations schemes can be used:

1.1. Bipolar modulation
1.2. Unipolar modulation

2. Hybrid modulation.

1. Full Bridge Topology

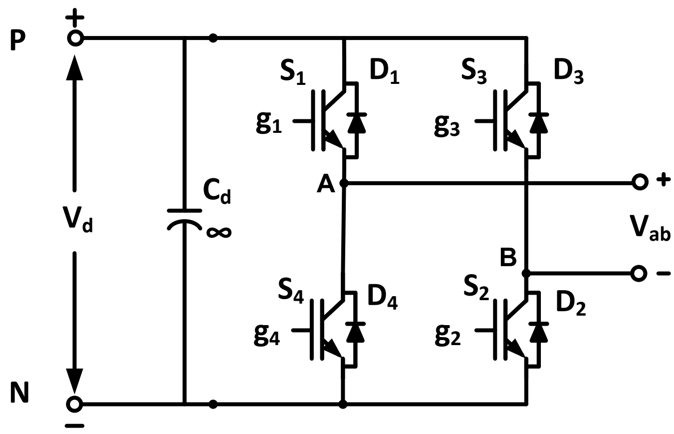

Figure 4. Full Bridge Topology

Figure 4. shows a simplified circuit diagram of a single-phase H-bridge inverter.

It is composed of two inverter legswith two IGBT devices in each leg. The inverter dc bus voltage *Vd*is usually fixed, while its ac output voltage *VAB* can be adjusted by either bipolar or unipolar modulation schemes.

1.1 Bipolar Pulse-Width Modulation

It shows a set of typical waveforms of the H-bridge inverter with bipolar modulation, where V_m is the sinusoidal modulating wave, V_{cr} is the triangular carrier wave, and v_{g1} and v_{g3} are the gate signals for the upper switches S_1 and S_3, respectively. The upper and the lower switches in the same inverter leg operate in a complementary manner with one switch turned ON and the other turned OFF. Thus, we only need to consider two independent gate signals, v_{g1} and v_{g3}, which are generated by comparing v_m with v_{cr}. Since the waveform of v_{AB} switches between the positive and negative dc voltages $+V_d$ and $-V_d$ this scheme is known as Bipolar modulation. Thus we need to consider only two independent gating signals vg1 and vg3 which are generated by comparing sinusoidal modulating wave vm and triangular carrier wave Vcr. The inverter terminal voltages are obtained denoted by VAN and VBN and the inverter output voltage VAB = VAN-VBN. Since the waveform of VAB switches between positive and negative dc voltages this scheme is called bipolar PWM.

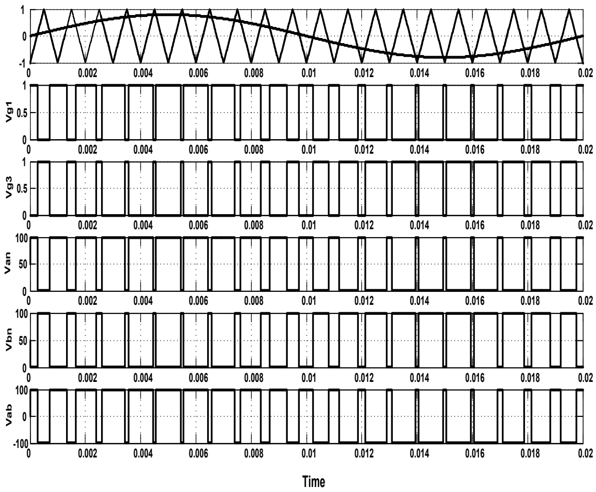

Figure 4. Waveform of Bipolar Modulation technique

1.2. Unipolar Pulse-Width Modulation

The unipolar modulation normally requires two sinusoidal modulating waves Vm and –Vmwhich are of same magnitude and frequency but 180 out of phase. The two modulating wave are compared with a common triangular carrier wave Vcr generating two gating signals Vg1 and Vg3 for the upper two switches S1 and S3. It can be observed that the upper two devices do not switch simultaneously, which is distinguished from the bipolar PWM where all the four devices are switched at the same time. The inverter output voltage switches between either between zero and +Vd during positive half cycle or between zero and –Vd during negative half cycle of the fundamental frequency thus this scheme is called unipolar modulation. The unipolar switched inverter offers reduced switching losses and generates less EMI.

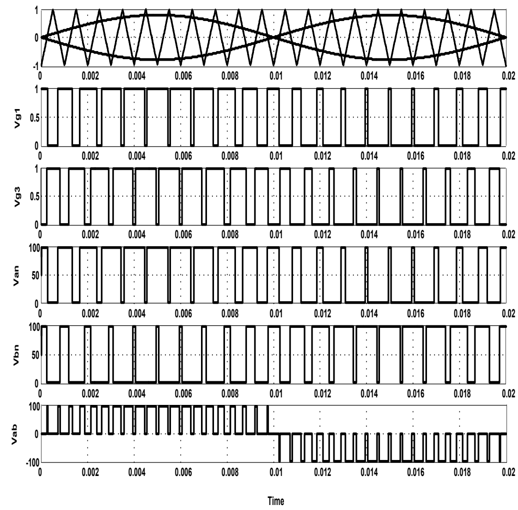

Fig.5. Waveform of Unipolar Modulation technique

2. HERIC TOPOLOGY

The HERIC (Highly Efficient and Reliable Inverter Concept) topology is another structure that avoids a fluctuating potential on the DC terminals of the PV generators by means of disconnecting the converter from the load (utility grid). In this case the zero voltage level is obtained using a bidirectional switch during freewheeling periods This topology is shown in figure.

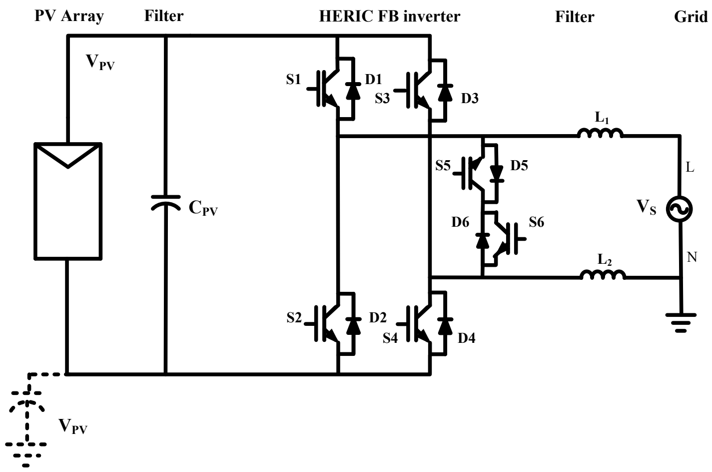

Figure 6. Heric inverter topology

This modulation technique is often used in the CHB multilevel inverters. HERIC topology in Fig. consists of a full-bridge with two extra switches in filter inductors L1 and L2. All switches independently operate with the high or grid frequency according to the polarity of vg. In the positive half-cycle,the switch

S5 is turned on and the switches S2, S3, S6 are turned off. The switches S1 and S4 are switched with the high-frequency.In the negative half-cycle, the switch S6 is turned on and the switches S1, S4 and S5 are turned off. The S2 and S3 are switched with the high-frequency. VAB has the three-voltage levels including the zero-output-voltage state. It leads to lower core losses and prevents the reactive power exchange during the freewheeling operation. Moreover, this scheme has low leakage current and EMI.

VI. MATLAB SIMULATION

In order to verify the level of leakage currents of different topologies simulations and experimental measurements have been done. Simulations were done using MATLAB used for simulation of electrical circuits within the Simulink environment. All simulation results are based on the general simulation model presented for the single-phase topologies.

A triangular generator and a sine wave generator are used for generating the carrier wave and the modulating wave respectively.

The carrier frequency is 1KHZ and the reference wave frequency is 1Hz. The modulation index can be varied by changing the amplitude of sinusoidal modulating wave. The waveforms are for modulation index of 1.0

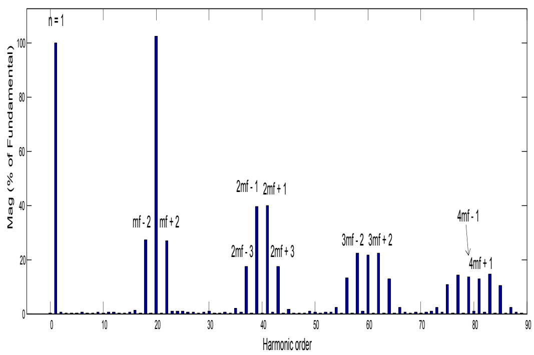

Figure 7. FFT Analysis of Bipolar PWM for full H-bridge

Figure 7 shows the FFT analysis of bipolar modulation technique for H-bridge inverter. It shows the harmonic spectrum of the inverter output voltage VAB. The harmonics appear as sidebands centered around 2*mf* and 4*mf*. The lower order harmonics generated by the bipolar modulation, such as mf and mf ± 2, are eliminated by the unipolar modulation. The unipolar modulation can also be implemented by using only one modulating wave vm but two phase-shifted carrier waves, Vcr and -Vcr. This modulation technique is often used in the CHB multilevel inverters.

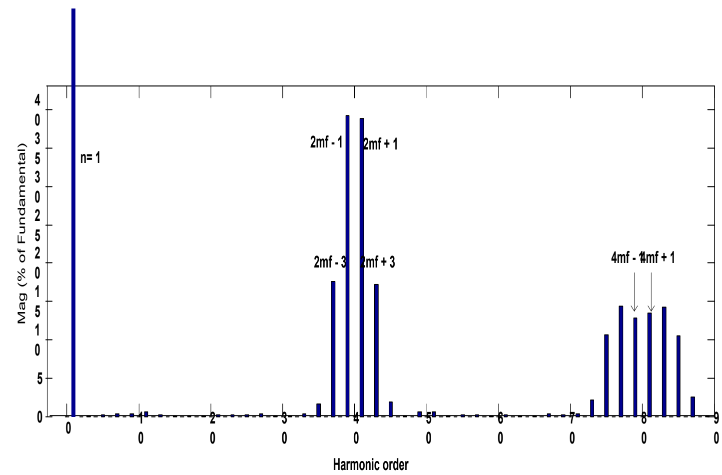

Figure 8. FFT Analysis of Unipolar PWM for full H-bridge

Figure 8 shows the harmonic spectrum of the inverter output voltage *VAB*. The harmonics appear as sidebands centred around 2*mf* and 4*mf*. The low-order harmonics generated by the bipolar modulation, such as *mf* and *mf* ± 2, are eliminated by the unipolar modulation.

VII. TRANSFORMERLESS MODULATION ANALYSIS

In order to verify the level of leakage currents of different topologies simulations and experimental measurements have been done. Simulations were done using MATLAB and PLECS toolbox, used for simulation of electrical circuits within the Simulink environment. All simulation results are based on the general simulation model presented on Fig. 1 for the single-phase topologies. Same filter and grid parameters have been used throughout the simulations, these are listed below. For the experimental measurements a single phase setup was used, made up of a DC power supply, with a direct connection to the utility grid. In case of the single-phase setup only 2 legs of the inverter have been used. For these single-phase measurements the 100W PV installation has been used, having the frame of the panels connected to ground, thereby creating a path for the flow of the leakage current. As seen on Fig. 3, representing the experimental scope data in the case of the full-bridge topology with bipolar switching, the PV terminals are fluctuating with the grid frequency and the fluctuations have half the amplitude of the grid voltage. Due to this sinusoidal fluctuation and the low frequency content of the fluctuation, the leakage current towards ground is small.

VIII. CONCLUSION

Based on the previously detailed comparison and the simulation and experimental results, it can be concluded that the single phase full-bridge topology with bipolar switching is suitable for transformer PV inverter because the leakage current is much lower than in case of the unipolar switching.
Besides this, harmonic issues are analyzed using fast Fourier transform.

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Compensation of Voltage Swell by Using STATCOM

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ABSTRACT

In power system, power quality is one of the important aspects as power quality problems are occurred due to occurrence of voltage swell, voltage sag, transient, harmonics distortion, etc. in the transmission line. Out of these, voltage swell has less predominantly occurred and creates severe impact on transmission line and sensitive devices connected to it. By IEEE 1159 Voltage swell is an increase in RMS voltage level from 110% to 180% of nominal voltage at power frequency for the duration of 1/2 cycle to 1 minute[1]. The voltage swell is occurred due to de-energising of large heavy loads, switching off load, lightening strokes, etc. The occurrence of voltage swell is very low but when it is occurred it creates severe impact on transmission line and connected devices. Hence it is necessary to mitigate or compensate the voltage swell to improve power quality of transmission line. The compensation of voltage swell is done by using FACTS devices (STATCOM). In this paper, the analysis of 132kv transmission line with including STATCOM and without including STATCOM is simulated in MATLAB/SIMULINK software, which shows the voltage swell is compensated and voltage profile has been improved.

Keywords: Static synchronous compensator (STATCOM), voltage swell, T.H.D., voltage stability.

I. INTRODUCTION

The electrical power system is very complex network consisting number of generating station, transmission line and distribution system. In this power system, power quality is one of the most important aspect as leads to power quality problems that arises due to the wide range of disturbances in power system such as voltage swell, voltage sag, harmonics, etc. From these power quality problems voltage swell (29%) has been less predominantly occurred than voltage sag (60%), transients (8%) and interruption (3%) but when he voltage is occurs it creates severe impact on the transmission line and connected devices with amplitude range from 110% to 180% for duration of 1/2 cycle to 1 minute [2]. The voltage swell can cause damage to the system or equipment's connected to the transmission line as well as it creates heavy current imbalance that tends to operation of circuit breaker or fuses. These effects are very expensive for the costumer and ranging from the minor quality variations to production downtime and also damage to the system and connected equipment's. There are many different methods are available to compensate or mitigate this voltage swell problem from those method one of the common and most efficient method to compensate this voltage swell is the STATCOM (static synchronous compensator). The STATCOM is an FACTS device consisting of voltage source converter made up of IGBT/DIODE, filter, insertion transformer and capacitor. STATCOM is a most efficient and fast device to compensate the voltage swell in transmission line as soon as it occurs by controlling the active and reactive power and injecting current into the transmission line system [3]. In this paper, the 3-phase, 132 kV, 50 Hz transmission line is simulated in MATLAB/SIMULINK software and the voltage swell is created by using programmable voltage source. The FACTS device i.e. STATCOM is connected in parallel with the 132 kV transmission line systems to compensate the voltage swell created by the programmable voltage source. The voltage swell can also be created by disconnecting large heavy load from the distribution system but in this paper we used programmable voltage source to create voltage swell. At the end, the results are observe on the scope 4 connected at output at the load end, which shows that the voltage swell has been compensated and voltage profile of the transmission line has been improved.

II. OVERVIEW OF POWER QUALITY

The term power quality (P.Q.) captures major attention while studying electricalpower system. The term power quality refers to maintaining sinusoidal waveforms of the bus voltage and frequency at constant required level. Power quality is simply an interaction of electrical power system with the electrical equipments. Power quality is a most important term in power system hence it will be always taken into consideration because disturbing the power quality will directly affects on the system equipment in power system.

TABLE I

Parameter	Voltage Variation (%)	Duration	Permissible Variation
Voltage Swell	110%-180%	½ Cycle To 1Minutes	+/- 10%

Power quality problem- The Power quality brings a wide range of disturbance such as voltage swell voltage sag, harmonics, interruptions, etc. From these the voltage swell occured nearly 29% and it will damge all the equipment connected in the line. The main causes of voltage swell are as following:

1. Suddenly disconnecting of an heavy load.
2. Lightening on transmission line.
3. Voltage transients [4].

There are some approaches to compensate the power quality problem. The solution comes to eliminates the power quality is the STATCOM which improve the stability of power system by compensating the voltage variation and their by increases the voltage stability of power system[5].

III. PRINCIPLE OF STATCOM

The static synchronous compensator (STATCOM) is a shunt connected device also known as static synchronous condenser (STATCON). The STATCOM is a member of Flexible Ac Transmission System or simply FACTS devices. The STATCOM uses power semiconductor devices such as IGBT, GTO, and MOSFET etc. and other components to control the power for improving the voltage stability of the power system. The STATCOM is used either to absorb or to generate reactive power in synchronised manner with the demand to stabilise the voltage fluctuation in transmission line.

IV. WORKING PRINCIPLE OF STATCOM

To observe the working principle of STATCOM let us look at equation of reactive power transfer. Let us consider two sources V1 and V2 connected through each other through an impedance given by, Z = R + jX Ω.

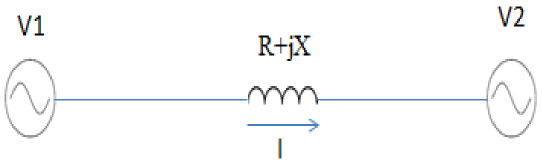

Figure 1. Block diagram of active or reactive power transfer.

Assume, the transmission line resistance R = 0 Ω, the reactive power flow,

$$Q= (V2/X)*[V1*\cos\delta-V2] \quad \dots (1)$$

Where, δ = Aangle between V1 and V2.

For maintaining the angle δ = 0, the reactive power equation becomes,

$$Q = (V2/X)/[V1-V2] \qquad ...(2)$$

The active power flow equation becomes,

$$P = (V1*V2*\sin \delta)/X=0 \qquad ... (3)$$

Thus we can summarized that if the angle δ between V1 and V2 is zero, then the flow of active power becomes zero and reactive power is depend upon V1-V2 [5].

Thus, it can be observe that,

1. If the voltage magnitude V1 is greater than voltage magnitude V2 then reactive power will flow from source V1 to V2.
2. If the magnitude of voltage V2 is greater than V1 then power will be flow from source V2 to V1 [6].

V. DESIGN OF STATCOM

The design of STATCOM is shown below in fig.2 consists of following equipments:

1) DC capacitor: The DC capacitor is used to store the constant dc voltage through VSC after the occurrence of voltage swell & also to supply constant dc supply to voltage source convertor (VSC) at the time of voltage sag.

2) Voltage source convertor (VSC): The voltage source convertor used to work as a rectifier; it consists of IGBT power electronics devices. When the voltage swell is occurred it converts 3-ph Ac into dc voltage and the amount of voltage swell has been stored in the capacitor.

3) Harmonic filter: The harmonic filter made up of inductor to attenuate the harmonics and other high frequency components due to VSC.

4) Insertion Transformer: As the STATCOM is shunt connected device, it inject the current into the system to control the voltage regulation. The insertion transformer is connected after the VSC and harmonic filter. The insertion transformer basically acts as a coupling medium between transmission line and STATCOM. The addition work of insertion transformer is to neutralized harmonics contained in square wave produced by VSC[6].

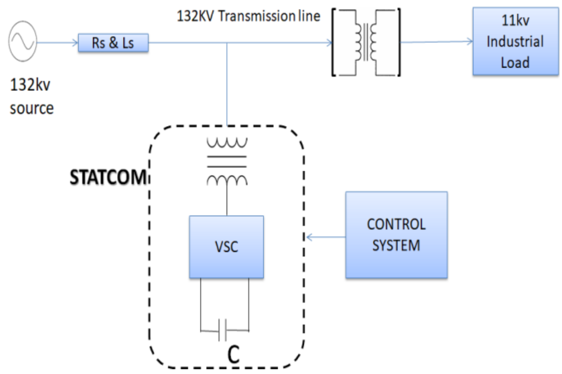

Figure 2. Block diagram of transmission line with STATCOM

VI. STATCOM AS A VOLTAGE COMPENSATOR

From the Fig.1, Voltage V1 represents voltage of STATCOM. In case of reactive power demand increases in power STATCOM increases its output voltage V1, while maintain the phase difference between V1 and V2 to zero. As, V1 > V2 reactive power will flow from STATCOM to transmission line. Thus STATCOM supplies reactive power and acts as a reactive power generator. Again, if voltage of the transmission line increases due to disconnecting of the large load, STATCOM will reduce its output voltage V1 and thus it will absorb reactive power to stabilize the voltage to normal value [7].

VII. VOLTAGE SOURCE CONVERTER (UNIVERSAL BRIDGE)

The three phase voltage source converter in Simulink form is made up of 6 IGBT thyristor. At the primary side of three phase transformer (delta-delta) the three phase AC supply is given. It consists of 6 controllable thyrister Cathode of D2, D4 & D6 are connected in +ve terminal of the capacitor while anode of D1, D3, and D5 are connected in -ve terminal of the capacitor. It can be seen that each of the secondary terminal are connected to anode of one thyristor and cathode of other thyristor. Thyristor D2, D4, D6 are conducted in +ve half cycle while the firing angle α is given to the thyristors D1, D3, D5 are conducted in -ve half cycle when the firing angle is given, at that time it produce +ve output. Thus the thyristor D1 and D4 are connected in phase 'A' while D3 and D6 are connected in phase 'B' as D5 and D2 are connected in phase 'C'. So D1 and D4 are of 60° phase shift and D3 and D6 are also 60° phase shift while D5 and D6 are also 60° phase shift. As the thyristor D1 and D4 are in same phase but do not conduct at the same time because phase have +ve and -ve peaks at the same time. Initially D6 are conducted when the firing angle α is given at an angle of ωt = 60° so output voltage is of Vab, at the time of D1 & D6 is ON. Then at ωt = 120° D1 is trigger so thyristor D1 & D2 are conducted and get output is Vac. now at ωt = 180' thyristor D2 are triggered and D3 & D2 are conduct and produce Vbc output.at the angle of ωt=240° D3 are trigger and D3 & D4 conduct at the same. At the angle ωt=300° firing angle is given the thyrister D4 and conduct the thyristor D5 & D4 and gives the output Vca. At an angle of 360° thyristor D5 are firing and conduct D5& D6 at the same time. In this way this can be repeat.

VIII. SINUSOIDAL PULSE WIDTH MODULATION

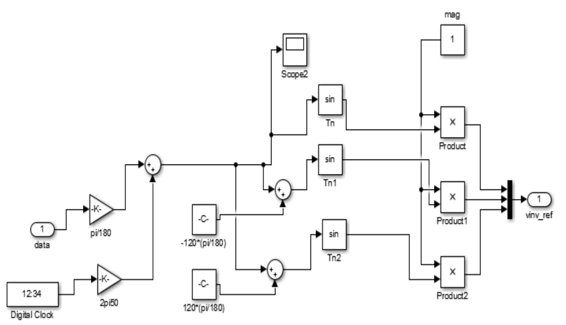

Figure 3. Sinusoidal PWM based control system.

The main objective of the control scheme is to maintain the constant voltage magnitude. This control system measures only the actual voltage at the load point with help of VI measurement block. The VSC switching technique is based on the sinusoidal pulse width modulation (SPWM). The PI controller is to identify the error signal and generates the required angle δ to obtain error to zero, the actual voltage of transmission line brought back to the reference voltage i.e. at comparator block. In SPWM technique to generate PWM signals three sinewaves and high frequency triangular carrier waves are used. The sinusoidal waves are used for voltage source convertor. The sinusoidal waves are used in SPWM are known as reference signal and they have a 120° phase shift with each other. Base on required convertor output frequency (50Hz). The frequency of these sinusoidal waves has been chosen. The carrier triangular wave having a several kHz frequency. By comparing the sinusoidal waves with the triangular wave the switching signals are generated. The comparator generates the pulses when the sinusoidal voltage is greater than the triangular voltage and this pulse is used to trigger the respective bridge convertor's IGBT switches. The switches of any leg cannot switch off simultaneously and the outputs of phases are mutually phase shifted by 120°[3].

IX. PI CONTROLLER

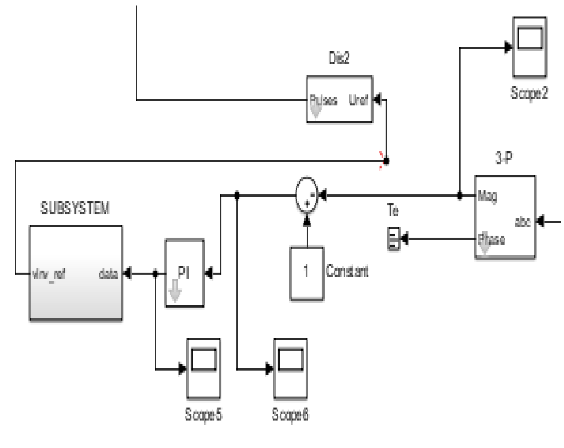

Figure 4. PI controller based on phase control method

The proportional integral (PI) controller is needed for non-integrating process, means any process that eventually return to the same output given the same set of input and disturbance. The purpose of the PI controller is to identify the error signal and generates the required and δ to run the error to zero, the load rms voltage (actual voltage) brought back to the reference voltage. This method is called as phase control method [7] shown above in fig.4. Then this error angle signal is given to the SPWM controller and accordingly error angle is generated by the pulse generator and given to the universal bridge of STATCOM. Then STATCOMis come into operation and inject the current into transmission line to compensate the voltage.

X. SIMULATION WITHOUT STATCOM

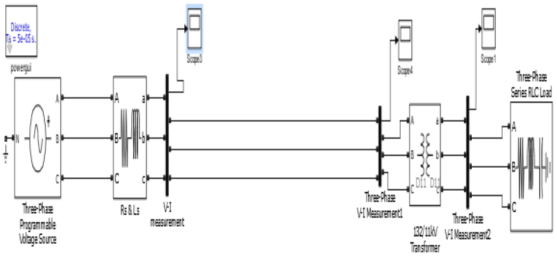

Figure 5. Simulation of 132kV transmission line without STACOM

The fig. 5 shows the simulation model of 132 kV transmission line without including STATCOM. It contain the following components,

i) Programmable voltage source: the programmable voltage source is act as a voltage source of 132 kV, the main aim of the programmable voltage source is to supply the 132kV voltage to the system and also create the swellof 1.2 p.u. for duration of 0.1 to 0.4 second which is done by the simple programming.

ii) Rs & Ls: These are the transmission line resistance and inductance it kept at negligible value.

iii) Step-down transformer: It is a distribution transformer used to step down 132 kV transmission line voltage 11 kV.

iv) Industrial Load: The 11kV industry is a load for 11kV supply.

v) VI measurement and scopes: The VI measurement blocks are used to measure the voltage in p. u. form.

The voltage swell of 1.2 p.u. for 0.1 to 0.4 second is created by using programmable voltage source and this voltage swell is travel along the line until it will be compensated.

XI. SIMULATION WITH STATCOM

The fig. 6 shows the simulation model of “Compensation of Voltage Swell by using STATCOM", the STATCOM is connected to 132kV transmission line. In the simulation model voltage is represented in per unit (p.u.) form i.e. 132kV=1p.u. The actual voltage of transmission line is sense by V-I measurement and the waveform is shown in fig.7 which show the voltage swell of 1.2 p.u. The actual magnitude of voltage (p.u.) is given to the 3-phase sequence analyser circuit block which used to represent the 3-phase voltage Va, Vb & Vc in the reference voltage respectively. The phaseterminal of the block is terminated by terminator block and only actual voltage (p.u.) signal is fed to the comparator. In the comparator actual voltage signal is compared with the reference voltage signal and it generates the error signal. In the next stage the PI controller will process this error signal and the output is the angle, which is provided to the SPWM generator, this method from 3-phase sequence analyser block to the pulse generator is known as phase control method. In SPWM generator, according to the error angle δ the pulse generator generates the firing pulses and applied to the universal bridge and acts a rectifier. Thus the amount of voltage swell occur in transmission line is store in the capacitor which is connected to the STATCOM. Thus in this way STATCOM compensate the voltage swell.

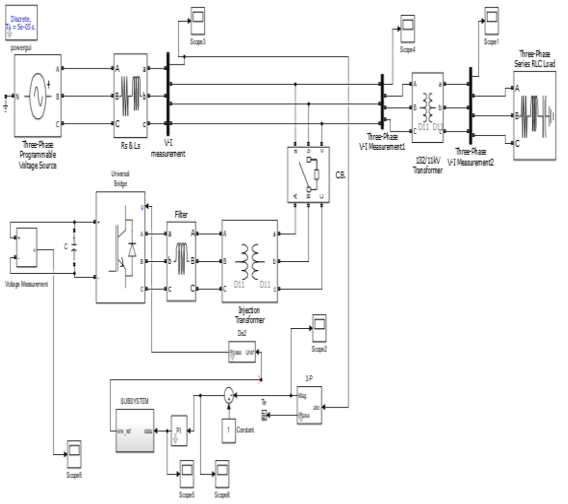

Figure 6. Simulation of 132kV transmission line with STACOM

XII. RESULT AND WAVEFORM

The basic transmission line model having rating of 3-phase, 132kV, 50 Hz. The 132 kV transmission line voltages is stepped down to 11kV by using distribution transformer and given to 11kV industrial load. The STATCOM is connected in parallel to transmission line to compensate the voltage swell is shown in fig.5, the voltage swell of 1.2 p.u. is created by using programmable voltage source for the duration of 0.1 to 0.4 second.

The fig.7 show the waveform of voltage swell of 1.2 p.u. on 132kv transmission line.

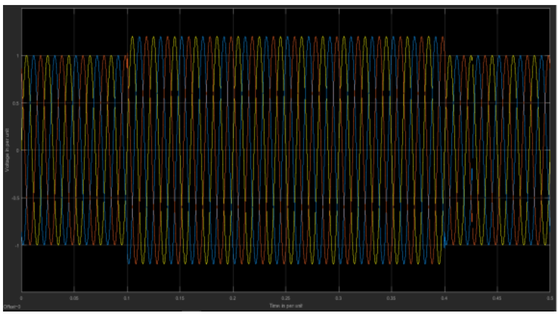

Figure 7. Waveform of voltage swell on 132 transmission line

To compensate the voltage swell the STATCOM is connected in shunt with the transmission line and it mitigates the voltage swell effectively. The waveform for compensation of voltage swell by using STATCOM is show below in fig.8.

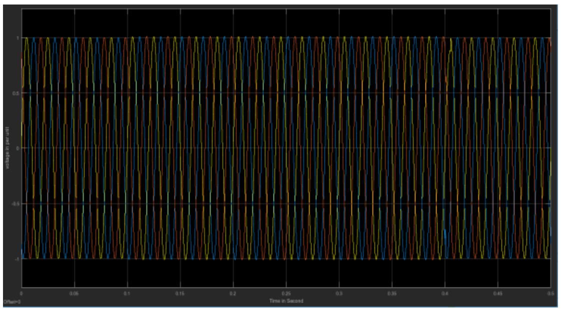

Figure 8. Waveform of compensation of voltage swell by using STATCOM

The STATCOM is very efficient device to improve the voltage stability by compensating the voltage swell.

The waveform of PI controller is shown below in fig.9

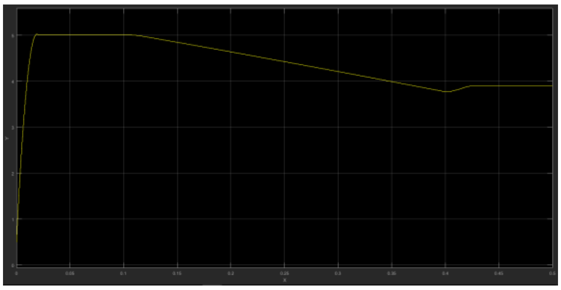

Figure 9. Waveform of PI controller

The waveform of capacitor voltage during period of compensation of voltage swell is shown below in fig.10.

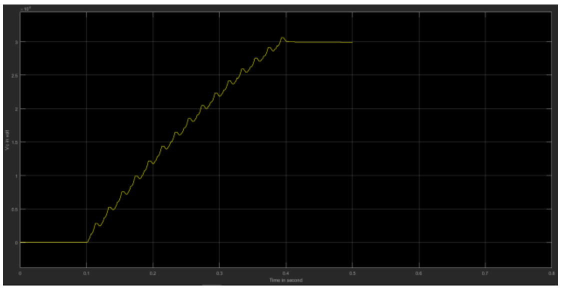

Figure 10. Waveform of voltage across capacitor during compensation of voltage swell by using STATCOM

XIII. CONCLUSION

This paper present, compensation of voltage swell by using STATCOM which has been develop with 3-phase, 132kV, 50 Hz transmission line with all necessary components and control system. The scheme has been demonstrated on MATLAB / SIMULINK software. The voltage swell of 120% i.e.

1.2 p.u. is created by using programmable voltage source and this voltage swell is compensated by using STATCOM. Hence, it can be conclude that the STATCOM is an effective device to improve the power quality by compensating the voltage swell.

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Design of Charge Controller for Photovoltaic System

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ABSTRACT

The aim of this paper is to design and construct a charge controller using OP-AMP as comparator for solar system. The charge controller varies its output to a step of 12V; for a battery of 10Ah rating. This paper deals with the scenario that a battery is needed in order to harness the solar energy when the sunlight is available and supply it in vice versa condition . The designed system is very functional, durable, economical and locally sourced and most cost effective. Due to this reason, a charge controller is built which charges a battery with the help of solar panel and protection is given to the battery in case of overcharge, deep discharge and under voltage condition.

Keywords: Metal oxide semiconductor field effect transistor (MOSFET),Operational Amplifier(OP-AMP), Optocoupler.

I. INTRODUCTION

Solar Power Charge Controller can be used in various sectors. For instance, it can be used in solar home system, Hybrid systems, solar water pump system etc. In this, a solar panel converts sunlight energy into electrical energy through an electrochemical process also know as photovoltaic process. Energy is stored in the battery with the help of solar panel through a diode and a fuse. Energy stored in the battery can be used when there is no sunlight as during discharge, chemical energy is converted into electrical energy which in turn illuminates electrical appliances . Hence, it is needed to protect battery form overcharge, deep discharging mode while dc loads are used or in under voltage as it is the main component in a solar power charge controller. In this paper, indications are provided by a green LED for fully charged battery while a red LED indicates that battery is charging, deep discharge or under voltage condition. Charge controller also uses MOSFET as power semiconductor switch to ensure cut off the load in low battery or overload condition. When the battery gets fully charged, a transistor is used in order to bypass the solar energy to a dummy load which protects the battery from getting over charged. A solar charge controller is a small box placed between a solar panel and a battery consisting of solid state circuits PCB. They are used to regulate the amount of charge coming from the solar panel in order to protect the battery from getting overcharged. Adding to this, it can also be used to allow different dc loads and supply appropriate voltage. In this circuit ,the main component use is an OP-AMP which is LM324 IC and used as a comparator.

II. CIRCUIT DIAGRAM

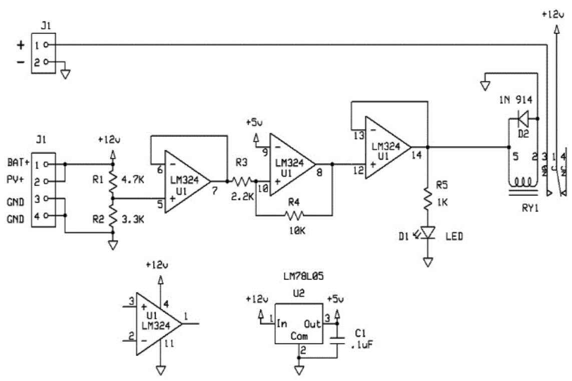

Figure 1. Circuit Diagram

III. COMPONENTS USED IN CIRCUIT

1. Operational Amplifier(LM324) – It is a 14 pin IC consisting of four independent operational amplifier compensated in a single package. They can be used as amplifiers, comparators, oscillators and rectifiers.
2. Relay (JQC-3FC(T73)) - Relay an electrically operated switch. It can be operated by a small electric current that turns a larger current ON or OFF by either releasing or retracting the armature contact,their by completing or cutting the circuit.
3. Transistor(BC547,431L) - It is the device that regulate current or voltage flow and acts as a switch or gate for electronic signal.
4. Capacitor(10uf,100uf,2A103K) - It is a passive two terminal electrical component that stores potential energy in an electric field.
5. Resistance(2.7k , 1k, 4.7k,3.3k,10k) - It is the opposition that a substance offers to the flow of electric current.
6. Optocoupler(4N35 IC) - It is an integrated circuit in which an infrared emitter diode rives a phototransistor.It is also called as optoisolator since they separate two circuits optically
7. Diode- A diode is a two terminal electronic component that conducts current primarily in one direction.
8. Inductor- It is a passive two terminal electrical component that stores electrical energy in a magnetic field when electric currnt flow through it.
9. Fuse- It is a device used in electrical systems to protect agains excessive current.
10. Mosfet(IRFZ44N)-It is a switch to control relays , motors and other high current electrical loads.
11. Heatsink- It is a passive heat exchanger that transfers the heat to a fluid medium , often air or a liquid coolant.

IV. WORKING

Charge Controller save battery if PV panels are used. The input of charge controller is 12V which is coming from solar panel. In this circuit OP-AMP (LM324 IC) is used as a comparator to compare the voltage and current . It read the voltage and current of the solar panel through the optocoupler and calculates the output power. It is a 14 pin IC and consists of four different amplifiers. Only three amplifiers are in use.Pin no. 1, 2, 3, 11 i.e first operational amplifier which is not connected(11 pin is grounded). The input which is coming from solar panel is connected to pin no. 5 and output. The analog charge controller resistor must be carefully chosen to keep the battery voltage between 10.5 volts and 14.5 volts. We used the simple voltage divider of 4.7K and 3.3K to sample the battery voltage and bring it close to the 5 volt reference. This voltage is then buffered with a voltage follower and placed on the left side of the 2.2K resistor. The voltage that appears on OP-Amp pin 10 is the voltage that is compared to the 5 volt reference. If this voltage is higher than 5V the charge controller relay is activated. Is this voltage is lower than 5 volts the charge controller relay is deactivated. As long as the voltage on pin 10 remains higher than 5 volts the relay remains activated, but if the battery voltage continues to drop the battery load will be disconnected.Charge controller also uses MOSFET as power semiconductor switch to ensure cut off the load in low battery or overload condition. When the battery gets fully charged, a transistor is used in order to bypass the solar energy to a dummy load which protects the battery from getting over charged. LED is connected between relay and fourth Op-amp(14 pin and 5)through diode. When the battery is fully charged, LED will glow. Green LED indicated for fully charged battery while a Red LED indicates that battery is charging, deep discharge or under voltage condition. The charger charges battery upto 12.9volt and then it charges very slowly. If the battery is fully charged the optocoupler senses , it and cut off the supply. Input voltage and battery voltage are compared by comparators.

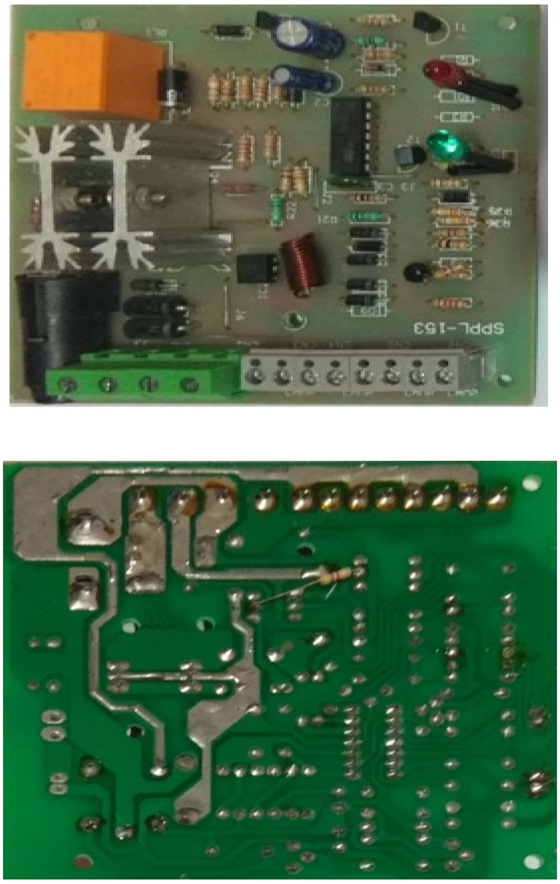

Figure 2. Circuits

V. CONCLUSION

In this paper, a photovoltaic charge controller using LM324 IC is use to protect better battery protection from overvoltage using optocoupler and mosfets.It also includes protection methods for the battery in order to curb problems like overcharging, deep discharge or under voltage which harm the life of the battery.

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Fouling effect in vacuum pump cooler replacing in plate type heat exchanger improves sealing water temperature and effectiveness

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ABSTRACT

Water Cooler is used widely in many systems in power plant for heat recovery or cooling purposes. A cooler is a device that allows heat energy in one process water to pass to process water in a controlled manner whose purpose is either to remove heat from water (cooling) or to add heat to raw water. Cooler are used in various systems and processes that involve the transfer of heat energy. Improper design, operation and maintenance of a cooler may result in degradation of the components due to scaling and fouling, performance of the system or unit. This paper evaluates the effects of fouling on shell and tube type in a thermal power plant. Cooler Data were obtained through steady state monitoring and direct measurements from the plant reading. The Cooler data were analyzed to determine the overall heat transfer, temperature and pressure range of hot and cold raw waters and effectiveness. The result shows that for the pump around cooler, the overall heat transfer was less than the design value. This was traceable to increased fouling that has affected the reduce effectiveness of cooler and increase temperature of sealing water. This was due to variation in temperature difference between cooler data and design value in the hot water side of the exchanger which has also affected the pressure drop. The results also show an increase the fouling factor over the design which also affected the effectiveness and capacity ratio of the cooler.

Keywords: Heat, Fouling, Energy, Efficiency, PHE, sealing water, temperature, Cost Optimization

I. INTRODUCTION

Fouling in cooler is not a new problem. In fact, fouling has been recognized for a long time and research on cooler fouling. Water cooler fouling remains today one of the major unresolved problems in Thermal Science, and prevention or mitigation of the fouling problem is still an ongoing process. The major cause of reduction in cooler performance is the effect of fouling .Fouling in cooler is a general term that includes any kind of deposit of extraneous materials that appears upon the heat transfer surface during the lifetime of cooler. It occurs during normal operation, when the tubes surface gets covered or blocked by deposits of dirt, oil and scales. Whatever the cause or exact nature of the deposit, additional resistances to heat transfer is introduced and the operational capability of the cooler is correspondingly reduced. In many cases, the deposit is heavy enough to significantly interfere with the water flow and increase the pressure drop required to maintain the flow rate through the cooler. Major detrimental effects of fouling include loss of heat transfer as indicated by charge outlet temperature decrease and pressure drop increase. Other detrimental effects of fouling may also include blocked tube bundle, under-deposit corrosion and pollution. Where the heat flux is high, as in heat exchanger, fouling can lead to local hot spots resulting ultimately in mechanical failure of the heat transfer surface. Such effects lead in most cases to production losses and increased maintenance costs.

The unexpected failure of equipment such as cooler in thermal power plant is always undesirable and when these equipments are critical, they may lead to drop in overall profit. It is therefore with a view to averting down time, reduction in overall heat transfer, lost production and costly repair, that it is necessary to carry out periodic evaluation of the cooler performance in the plant in order to maintain them at high efficiency level. This paper presents a performance analysis on plate type heat exchanger in power plant and compare with shell and tube type cooler to predict the effect of degradation due to fouling. This enables maintenance period to be predicted in order to eliminate the menace of fouling which increases the thermal resistance of cooler and consequently lowers the overall heat transfer.

II. PROBLEM FORMULATION

The thermal performance of a water cooler depends upon so many factors. Some of them are thermal conductivities of involved cooling water and materials, velocity of flow, turbulence etc. To make any exact prediction about the performance of water cooler under a set of loading conditions is always a tough job.

Fouling is generally defined as the deposition and accumulation of unwanted materials such as scale, algae, suspended solids and insoluble salts on the internal or external surfaces of processing equipment including cooler. Cooler are process equipment in which heat is continuously or semi-continuously transferred from a hot to cold raw water directly or indirectly through a heat transfer surface that separates the two waters. Cooler consist primarily of bundles of pipes, tubes or plate coils.

Fouling on process equipment surfaces can have a significant, negative impact on the operational efficiency of the unit. On most power plants today, a major economic drain may be caused by fouling. The total fouling related costs for major industrialized nations. One estimate puts the losses due to fouling of cooler in industrialized nations around 30%. According to 25% of the maintenance costs of a process plant can be attributed to cooler and of this, half is probably caused by fouling. Costs associated with cooler fouling include production losses due to efficiency deterioration and to loss of production during planned or unplanned shutdowns due to fouling, and maintenance costs resulting from the removal of fouling deposits with chemicals and/or mechanical antifouling devices or the replacement of corroded or plugged equipment. Typically, cleaning costs are in the range of Rs 50,000 per cooler per cooling.

Figure 1. Vacuum pump cooler found outside corrosion on outer surface and inside tubes

Loss of heat transfer and subsequent charge outlet temperature decrease is a result of the low thermal conductivity of the fouling layer or layers which is generally lower than the thermal conductivity of the waters or conduction wall. As a result of this lower thermal conductivity, the overall thermal resistance to heat transfer is increased and the effectiveness and thermal efficiency of cooler are reduced. All these and other factors that may affect fouling need to be considered and taken into account in order to be able to prevent fouling if possible or to predict the rate of fouling or fouling factor prior to taking the necessary steps for fouling mitigation, control and removal.

III. MAJOR FOULING DEPOSITION AND STAGES

Fouling can be divided into a number of distinctively different depositions. Generally speaking, several of this fouling deposition occurs at the same time and each requires a different prevention technique. Of this different deposition some represent different stages in the process of fouling. The major fouling deposition or stages include:

1. Particulate fouling and particle formation, aggregation and flocculation.
2. Mass transport and migration of foulants to the fouling sites.
3. Phase separation and deposition involving nucleation or initiation of fouling sites and attachment leading to deposit formation.
4. Growth, aging and hardening and the increase of deposits strength or auto-retardation, erosion and removal.

Detailed analysis of deposits from the cooler may provide an excellent clue to fouling deposition. It can be used to identify and provide valuable information about such deposition. The deposits consist primarily of organic material that is predominantly asphaltenic in nature, with some inorganic deposits, mainly iron salts such as iron sulphide. The inorganic content of the deposits is relatively consistent in most cases at 22-26%. In general, high turbulence, absence of stagnant areas, uniform water flow and smooth surfaces reduce fouling and the need for frequent cleaning. In addition, designers of cooler must consider the effects of fouling upon cooler performance during the desired operational lifetime of the cooler. The factors that need to be considered in the designs include the extra surface required to ensure that the cooler will meet process specifications up to shut down for cleaning, the additional pressure drop expected due to fouling.

Figure 2. vacuum pump cooler tubes fouling with corrosion on cooler dome

Deposits on tube of calcium and magnesium salts as the total dissolved solid of water 1400-1800 PPM. It is soluble with anti scaling because of protection and coatings of mild steel dome. The iron oxide layer get corroded. When it reacts with high amount of salt, through corrosion inhibitor is there in water but due to restriction of flow reduced that point or area inhibitor get exhausted. Same condition we found when in return line tubes and domes shown in picture above.

Corrosion-type fouling can also be minimized by the choice of a construction material which does not readily corrode or produce voluminous deposits of corrosion. A wide range of corrosion resistant materials based on stainless steel is now available in market. Noncorrosive but expensive materials such as titanium and nickel based alloys may be used sometimes to prevent corrosion. If one of the waters is more corrosive, it may be convenient to send it through the tube side because the shell can then be built with a lower-quality and cheaper material. The construction material selected must also be resistant to attack by the cleaning solutions in situations where chemical removal of the fouling deposit is planned. For water allocation, it is usually preferred to allocate the most fouling water to the tube side as it is easier to clean the tube interiors than the exteriors.

IV. FOULING DEPOSITION REMOVAL TECHNIQUES

Several techniques may be used for the control of fouling as part of power plant maintenance. Some of these techniques are designed to prevent or mitigate fouling. Various strategies and devices for the continuous mitigation and reduction of fouling have been proposed such as periodical reversal of flow direction for the removal of weakly adherent deposits, raising flow velocity or by increasing turbulence level. In order to enhance the removal of the fouling deposits, velocities in tubes should in general be above 2 m/s and about 1 m/s on the shell side.

Mechanical cleaning is generally preferred over chemical cleaning because it can be a more environmentally-friendly alternative, whereas chemical cleaning causes environmental problems through the handling, application, storage and disposal of chemicals. However, mechanical cleaning may damage the equipment, particularly tubes, and it does not produce a chemically clean surface. Furthermore, chemical cleaning may be the only alternative if uniform or complete cleaning is required and for cleaning inaccessible areas. The shell side in particular can only be chemically cleaned. The tubes on the other hand can be mechanically cleaning is required for one of the waters, the usual practice is to put that water in the tube side.

Figure 3. vacuum pump cooler cleaning by high pressure jet and mechanical brush cleaning

Mechanical techniques for the removal of fouling include for tightly plugged tubes, generally known as bullet cleaning, may be employed and for lightly plugged tubes roding is employed. In cases where biofouling occurs it may be removed by mechanical brushing processes. Particularly weakly adherent deposits may be mechanically removed by applying high velocity water jets. Jet cleaning can be used mostly on external surfaces where there is an easy accessibility for passing the high pressure jet shown in above pictures. For the chemical removal of fouling material, weak acids and special solvents or detergents are normally used. Chlorination may be used for the removal of carbonate deposits. The effect of fouling, as has been noted above all condition affected the vacuum pump performance.

V. EFFECT OF SEALING WATER TEMPERATURE IN VACUUM PUMP

Water Ring (WR) type vacuum pumps are subject to several possible operating conditions that can cause insufficient vacuum the most common of which are:

1. Sealing water vapor pressure is too high
2. Incorrect sealing water flow rate being supplied
3. Process contamination of the sealing water

Water Ring (WR) pumps utilize a sealing water which is most commonly DM water however; Generally, the lower the temperature of the sealing water, the lower its vapor pressure and results in increased pumping capacity and deep vacuum performance. In addition, as the process vacuum level approaches the sealing water's vapor pressure the sealing water will begin to flash from the water to the vapor phase (cavitation), subsequently displacing the pump's capacity. As a rule of thumb, to avoid pump cavitation when selecting sealing water, the vapor pressure (Pv) of the sealing water at operating temperature should be less than half of the required vacuum level (P1) as measured at the pump inlet. For instance, the vapor pressure of water at operating the vacuum pump's suction pressure below this level will result in cavitation of the water within the pump and can ultimately damage the pump's impeller rotor. High water temperature supplied to the pump directly as sealing water or indirectly as coolant to the cooler of a full sealing water recovery system will increase the vapor pressure of the sealing water. As the vapor pressure increases this value may approach the vacuum level of the pump and cause the sealing water to flash and reduce the pumping capacity. In many cases the use of cooling tower water used in cooler. When operating the pump at higher temperature due to scaling and fouling in shell and tube type cooler.

Figure 4 .vacuum pump impeller rotor damages due to cavitation

Above all problems facing in vacuum pump due to higher sealing water temperature maintain and cooler tube heavily fouling observed. This reason Turbine maintenance team decided the existing shell and tube cooler replaced by new plate type heat exchanger for vacuum pump.

VI. NEW DESIGN OF PHE FOR VACUUM PUMP

A plate type heat exchanger is uses a pack of corrugated metal plates with port holes for the passage to transfer heat between two waters. This has a major advantage over a conventional cooler in that the waters are exposed to a much larger surface area because the waters spread out over the plates. This facilitates the transfer of heat, and greatly increases the speed of the temperature change. The plate type heat exchanger (PHE) is a specialized design well suited to transferring heat between medium- and low-pressure waters. The hot water flows in one direction in alternating chambers while the cold raw water flows in true counter-current flow in the other alternating chambers. The heat transfer surface consists of a number of thin corrugated plates pressed out of a high grade metal. The pressed pattern on each plate surface induces turbulence and minimizes stagnant areas and fouling. Unlike shell and tube cooler, which can be custom-built to meet almost any capacity and operating conditions, the plates for plate and frame cooler are mass-produced using expensive dies and presses. In this paper we designed the PHE for the required operating conditions. In the design we calculated the overall heat transfer coefficient of PHE. The heat transfer rate and the number of plates required for the PHE were also calculated. Cost optimization of the designed PHE was carried out and it has been found that there is a considerable drop in the cost of the heat exchanger.

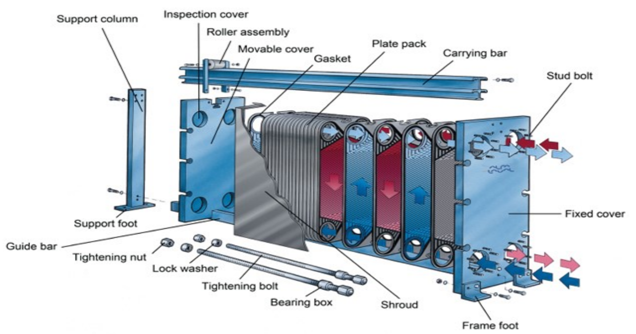

Figure 5. vacuum pump cooler replaced by cross section of Plate heat exchanger

VII. RESULTS AND DISCUSSIONS

The data collection was carried out through direct measurements from the equipment in the plant. Also data from the operational log book from September 2016 to October, 2017 were considered. Field investigation and observation of the various cooler units were also done. More data were obtained from the design data sheet and field operator's log book. In the analysis and treatment of the data, mean values of daily parameters were computed using statistical methods. This was followed by daily, monthly and the overall average for the period the research was carried out. From this, such parameter as vacuum pump sealing water temperature was determined.

Table 1 shows the vacuum pump sealing water temperature compared with shell and tube type cooler with plate type heat exchanger.

Vacuum pump sealing water temperature					
vacuum pump	**ACW inlet temperature**	**shell and tube type cooler**			**Plate type heat exchanger**
		Before cooler	After cooler	Before cooler	After cooler
2A	33.64	53	47.6	53	47.1
	30.91	49	44	53	47.1
2B	30.97	48	43.2	41.3	31.3
	29.3	46	41.6	43	31

The advantages of using PHE were investigated experimentally. The main results are listed as follows:

1. The Sealing water temperature was reduced from 43°C to 32°C.
2. A considerable increase of raw water cooling temperature from 30°C to 31.5°C was observed.
3. The observations on temperature of the newly plate type heat exchanger gives more cooling effect than existing shell and tube type cooler.

Table 2 shows the vacuum pump compared parameter such as condenser vacuum, sealing water temperature, hotwell temperature, suction temperature of pump, motor current etc.

Date and Time	LOAD	COND VACUUM	U#2 Abs Vacuum Pressure trans	Sealing water temperature		HOTWELL TEMP	suction temperature		Motor current	
				VACUUM PUMP A	VACUUM PUMP B		VACUUM PUMP A	VACUUM PUMP B	VACUUM PUMP A	VACUUM PUMP B
	With vacuum pump 2B ON									
10-Feb-18 09:00:00	310.63	-0.8766	78.04	29.90	43.60	46.54	33.59	44.19	0.00	141.10
10-Feb-18 10:00:00	310.75	-0.8773	78.02	29.85	43.58	46.56	31.73	44.18	0.00	140.99
10-Feb-18 11:00:00	310.60	-0.8791	77.19	29.77	43.41	46.32	30.68	43.87	0.00	140.65
10-Feb-18 12:00:00	310.54	-0.8774	77.92	30.02	43.65	46.51	30.41	44.18	0.00	140.86
Avg 2B	**310.63**	**-0.8776**	**77.79**	**29.89**	**43.56**	**46.49**	**31.60**	**44.11**	0.00	**140.90**
	With vacuum pump 2A ON									
11-Feb-18 09:00:00	309.99	-0.8894	72.34	30.23	29.86	44.17	42.56	34.44	151.63	0.00
11-Feb-18 10:00:00	309.92	-0.8896	72.43	30.40	29.93	44.25	42.65	32.49	150.40	0.00
11-Feb-18 11:00:00	310.00	-0.8883	73.09	30.79	30.26	44.51	42.93	31.72	149.50	0.00
11-Feb-18 12:00:00	310.03	-0.8834	74.81	31.62	30.93	45.26	43.72	31.51	148.84	0.00
Avg 2A	**309.99**	**-0.8877**	**73.17**	**30.76**	**30.24**	**44.54**	**42.96**	**32.54**	**150.09**	0.00
Diff between 2A&2B(Avg 2B - Avg 2A)	0.64	0.0101	4.63	-0.87	13.32	1.94	-11.36	11.56	-9.19	

Table 3. shows condenser vacuum pump energy saving impact

Condenser vacuum					
Parameters	**Unit**	**Design values**	**Deviation**	**Heat rate (Kcal/Kwh)**	**Monetary Impact (Rs/day)**
Condenser vacuum	Kg/Cm²	-0.8713	0.01 kg/cm²	13	82000

VIII. CONCLUSION

On the basis of above study it is clear that a lot of factors affect the performance of the cooler and the optimization obtained by the formulas depicts the cumulative effect of all the factors over the performance of the heat exchanger. Higher the thermal conductivity of the plate metallurgy higher the heat transfer rate will be achieved. Less is the spacing, higher the heat transfer at the less of the pressure drop. So, while optimization it must be taken care that the advantage in one of the output parameter can affect the other parameters, which can lead to increase in initial or operating cost.

This work has highlighted the deviations of plant operations from actual design values due to fouling of the cooler units. The fouling affected the cooler effectiveness and temperature range of the hot and cold water. This consequently affected the pressure drop and the overall system performance. The parameters used in assessing the efficiency of the cooler and also to check deterioration of the equipment design and operation with time was by steady state monitoring, direct collection of data from the equipment in the plant and analysis of the data compared with the equipment design data. It provided a good method of obtaining the performance of the cooler.

- The plate type heat exchanger is successfully optimized using LMTD with the objective functions of maximizing heat transfer rate and minimizing total cost.
- There is reducing in pressure drop with increase in water flow rate in plate type heat exchanger which reduces pumping power.

This leads to great reduction in space and cost without affecting the heat will transfer efficiency. Initial cost is generally a function of approach temperature. When considering the maintenance costs, the determining factor should be the properties of water involve. When the water has a greater tendency to foul, the plate and frame design offer easier access to heat transfer surface for cleaning. In addition, because of high turbulence, plate type heat exchanger has less of a tendency to scale or foul when compared to a shell and tube design. While the gasket is a weakness in the plate and frame design, the ability to expand or reduce the thermal capacity by adding or reducing plates is a major advantage for the plate and frame heat exchanger. If you want the application may be expanded in the future, a plate cooler is far the easiest and the most economical design. In summary, properly selected, installed and maintained cooler is probably the most trouble free piece of equipment in the system.

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IOT Based Home Energy Management System

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ABSTRACT

One of the fundamental need for the financial advancement of the nation is energy. It ought to be dispersed to its clients as most extreme client's right, as vitality creation is costlier. Energy Management System should assume an essential part in acknowledging private request reaction in keen network environment. Therefore, IOT based framework utilizing Arduino microcontroller is proposed, in which distinctive burdens are utilized and relating need is balanced in view of need of user. The controller board is utilized which settles on a choice to switch ON/OFF activity of the chose end utilize machines in light of mortgage holders stack need and preference setting. The proposed framework is likewise in charge of gathering electrical utilization information from all heaps and gives an interface to property holder to retrieve apparatuses status.

Keywords: Energy management,demand response, microcontroller(Arduino),HEM, demand response.

I. INTRODUCTION

Today the world in which we live is the universe of computerized gadgets. the innovative progression has taken to arrange where we can do nothing without the assistance of complex instruments like PCs, phones, mobiles, wirelesses. The way toward watching, controlling, and rationing power use in an association/building is known as Home Energy Management [1]. It has been accounted for that 40% of the worldwide power utilization happens inside private buildings [2]. An IOT based Home Energy Management System empowers request side administration program. Demand side administration obtains the use example of the purchaser and hence the choice to switch ON/OFF activity of the chose end utilize gadget in view of mortgage holders stack need and inclination setting. To manufacture a predominant IOT based canny home, there are some basic focuses that ought to be taken into consideration. In request to make the framework high qualified and successful, an experienced architect who is exceptionally appropriate for natural conditions, open to improvements and who is extremely well acquainted with the framework is needed. The term "Intelligent Design" incorporates implications, for example, economical design, high tech utilization and easy to understand design [3].

II. LITERATURE SURVEY

The consider shutdown of electric power in a section or parts of a power-circulation framework, by and large to keep the disappointment of the whole framework when the request strains the limit of the system, the demonstration or routine with regards to incidentally decreasing the supply of power to a territory to abstain from over-burdening the generators is stack shedding.

The electrical load arranging is the way towards evaluating the prompt weights working in an establishment. The stack design gives the store to the particular foundation with respect to clear, respective and dynamic control (KVA, KVAR and KW) and as a general rule did at the sub officer area or at the switchboard.

There are diverse strategies for control stack administration like:

Arduino based Home Energy Management System, in which diverse home apparatuses are utilized by the predefined need set by the house proprietor and furthermore by energy restrict as of now been characterized for a specific purchaser.

III. PROPOSED SYSTEM

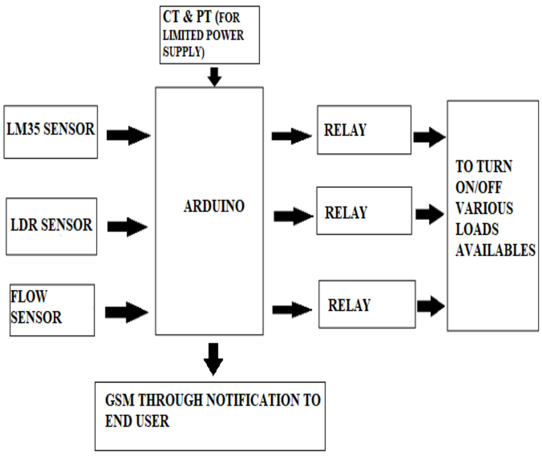

Figure 1. Proposed System

It consist of sensors like LDR ,LM35 and flow sensors which senses the light intensity ,temperature and water level respectively which helps in saving energy in case when light is sufficient or temperature is in between 17-25 degree Celsius so that appliances like fans ,cooler ,AC will not operate and in case if water level is enough the water pump won't operate .If the power consumed by the end user becomes greater than the prescribed limit the appliances would start tripping according to the priority been set by the home owner .The upper limit of the prescribed value is given by the CT and PT to the microcontroller which compares the given value with the predefined limits and then sends the trip signal to the relays if the value is greater .Thus the end user appliances status is changed from ON state to OFF state according to the relay conditions and also according to the priority been set by the end user .In case if the hose appliances like refrigerator ,water pump, TV, fans ,lights ,cooler are operating simultaneously than such heavy usage of energy has to be limited .The consumption becomes greater than the predefined value and the consumer is notified about this condition through SMS. Thus, the consumer can switch OFF the load, which is required the least by the consumer in order to maintain the energy consumption with in a limit. Demand Response is defined as "change in power use by request side assets from their ordinary utilization designs in light of changes in the cost of power or to motivating force instalments intended to instigate bring down power utilize are at high discount showcase costs or when framework dependability is endangered". The Demand Response can either be incentive based or time-based program.

A.Introduction to Microcontroller:

The Arduino Uno is a microcontroller board based on the AT mega 328. It has 14 digital input/output pins(of which 6 can be used as PWM outputs),6 analog inputs, a 16MHz ceramic resonator, a USB connection, reset button. It contains everything with AC to DC adaptor or battery to get started. The Arduino has a number of facilities for communicating with a computer, another Arduino. The ATmega 328 provides UART TTL(5v) serial communication, which is available on digital pins 0(RX) and 1(TX). The Arduino software includes a serial monitor which allows simple textual data to be send to and from the Arduino board. The RX and TX LED's on board will flash when data is being transmitted via the USB-to-serial chip and USB connection to the computer.

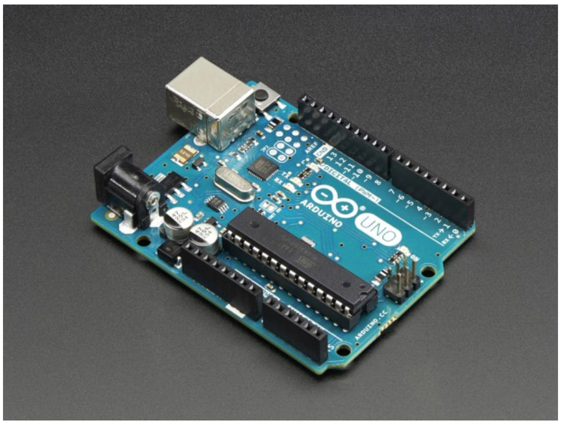

Figure 2. Arduino

1.Relay and relay drivers:

A relay is an electromagnetic switch which is used to switch high current using low power circuits. Relay isolates low power circuits from high power circuits. It is activated by energizing a coil wounded on a soft iron core and relay should not be directly connected to Arduino it needs a driving circuit because Arduino may stop working by negative voltages produced in the relay due to its back emf.

2. CT & PT:

A present transformer (CT) is a kind of transformer that is utilized to quantify rotating current (AC). It creates a current in its auxiliary which is relative to the current in its essential. Voltage transformers (VT), also called potential transformers (PT), are a parallel connected type of instrument transformer. They are designed to present negligible load to the supply being measured and have an accurate voltage ratio and phase relationship to enable accurate secondary connected metering.

Current transformers, alongside voltage or potential transformers, are instrument transformers. Instrument transformers scale the substantial estimations of voltage or current too little, institutionalized esteems that are anything but difficult to deal with for instruments and defensive transfers. The instrument transformers seclude estimation or assurance circuits from the high voltage of the essential framework. A present transformer gives an auxiliary current that is precisely relative to the present streaming in its essential. The present transformer shows a negligible load to the primary circuit.

3. LDR:

Two cadmium sulphide photoconductive cells with otherworldly reactions like that of the human eye. The cell protection falls with expanding light force. Applications incorporate smoke recognition, programmed lighting control, clump tallying and robber caution frameworks.

Like the human eye, the relative affectability of a photoconductive cell is subject to the wavelength (shading) of the episode light. Each photoconductor material compose has its own particular one of a kind unearthly reaction bend or plot of the relative reaction of the photocell versus wavelength of light.

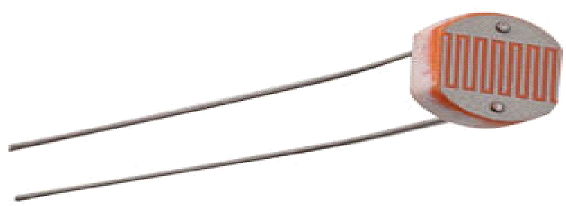

Figure 3. LDR sensor

The LM35 arrangement are exactness coordinated circuit temperature sensors, whose yield voltage is directly relative to the Celsius (Centigrade) temperature. The LM35 accordingly has favourable position over straight temperature sensors aligned in ° Kelvin, as the client isn't required to subtract a vast consistent voltage from its yield to acquire advantageous Centigrade scaling. The LM35 does not require any outer alignment or trimming to give average correctness's of ±1⁄4°C at room temperature and ±3⁄4°C over a full −55 to +150°C temperature extend. The LM35's low yield impedance, direct yield, and exact inalienable alignment make interfacing to readout or control hardware particularly simple. It can be utilized with single power supplies, or with in addition to and less supplies. As it draws just 60 μA from its supply, it has low self-warming, under 0.1°C in still air. The LM35 is evaluated to work over a −55°

to +150˚C temperature go, while the LM35C is appraised for a –40˚ to +110˚C territory (–10˚ with enhanced exactness). The LM35 arrangement is accessible pack

Matured in hermetic TO-46 transistor bundles, while the LM35C, LM35CA, and LM35D are additionally accessible in the plastic TO-92 transistor bundle. The LM35D is likewise accessible in a 8-lead surface mount little framework bundle and a plastic TO-220 bundle.

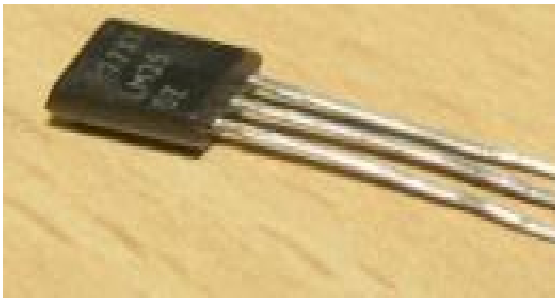

Figure 4. LM35 sensor

5. LCD:

A liquid-crystal display (LCD) is a flat-panel display or other electronically modulated optical device that uses the light-modulating properties of liquid crystals. Liquid crystals do not emit light directly, instead using a backlight or reflector to produce images in colour or monochrome.[1]LCDs are available to display arbitrary images (as in a general-purpose computer display) or fixed images with low information content, which can be displayed or hidden, such as present words, digits, and 7-segment displays, as in a digital clock. They use the same basic technology, except that arbitrary images are made up of a large number of small pixels, while other displays LCD have larger elements.

LCDs are used in a wide range of applications including LCD televisions, computer monitors, instrument panels, aircraft cockpit displays, and indoor and outdoor signage. Small LCD screens are common in portable consumer devices such as digital cameras, watches, calculators, and mobile telephones, including smartphones. LCD screens are also used on consumer electronics products such as DVD players, video game devices and clocks. LCD screens have replaced heavy, bulky cathode ray tube (CRT) displays in nearly all applications. LCD screens are available in a wider range of screen sizes than CRT and plasma displays, with LCD screens available in sizes ranging from tiny digital watches to huge, big-screen television sets.

IV. CONCLUSION

The Home Energy Management framework with request reaction assumes a most vital part in adequately dealing with the wastage of energy on consumer side. This venture introduces another plan to control utilization of apparatuses at home. The proposed home vitality administration framework for request reaction applications which can proactively and successfully control and deal with the machines activity to keep the aggregate family utilization underneath a predefined request constrain by overseeing chose control concentrated burdens as per their priority. The proposed vitality administration framework considers both load need and client preferences. The changes in status of machines will be advised to client through SMS. Consequently, the undertaking gives a minimal effort, flexible, user friendly, and exceptionally secure design for actualizing a Home Energy Management System. In HEM framework with Demand Response activity the power utilization is diminished by 20%to 30%.

V. REFERENCES

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