© November 2018 | IJIRT | Volume 5 Issue 6 | ISSN: 2349-6002

Analysis of Various Power Quality Issues and Power Conditioning of Grid by DVR with Solar PV for Better Power Quality

Ashik Joy

B.Tech Student, Electrical and Electronics Engineering Dept., A P J Abdul Kalam Technological University, Kerala, India

***Abstract*- The energy crisis is due to the limited resources and increased consumption. However with the advent of renewable energy this energy crisis solved to a great extends. Poor distribution system is one of the reasons for such energy crisis. The poor distribution is due to the wide use of non linear loads because non linear load is responsible for the generation of harmonics and thereby it affects the power quality of the system. The unexpected occurring of power quality issues such as voltage sag, voltage swell, transients, flickering, etc... Affects the quality of power delivered to the distribution section of power system. So it is important to eliminate or mitigate this power quality issues for improving the power quality. In this paper, power conditioning of power system by Dynamic Voltage Restorer (DVR) with solar PV- battery storage system is explained to mitigate mainly voltage sag and voltage swell issues. Power conditioner consists of the novel integration of solar PV, DC-DC boost converter and DVR.**

Index Terms- Solar Photovoltaic (PV) Array, Voltage sag, DC- DC Boost converter, Dynamic Voltage Restorer (DVR), Maximum power point Tracking(MPPT).

I. INTRODUCTION

Electrical energy is one of the most efficient and popular form of energy in the modern society and it is highly depending on the electric supply. There is no life without electricity. For the efficient functioning of the end user equipment, it is important to maintain the quality and continuity of electric power supplied because consumer need better power supply with better power quality and least voltage issues like harmonics, sag, swell, etc...Also high quality uninterrupted power is needed for most of the commercial and industrial load. So it is utmost important to maintaining the qualitative power.

If there is any deviation in the voltage and frequency values of the supplied power then it surely affects the quality of power being supplied. The performance and life time of the end user equipment is dependent on the quality of the power. So the change in quality of power affects the performance and life time of end user equipment to a great extent. Power quality has become major concern to both electric utilities and customers. In many countries, the effects of lack of power quality have been resulting in wastage of several billions of dollars every year. One of the reasons for the lack of power quality is due to the huge dependency over the non linear loads. The fault occur in the power system determines the continuity of the power that distributed to the end users. So it is important to maintain the continuity of supply to minimize the fault and to obtain better power quality. The power systemswitchgear should be designed in a manner that it should operate without any time lag in order to clear the fault at a faster rate to maintain the continuity of the supply.

The quality of power is affected many problems which occur in both transmission system and distribution system. Some of the power quality issues are harmonics, transients, interruptions, voltage fluctuations, frequency variations etc. These power quality issues contributes major role for the deterioration of the consumer appliances. All these problems should be eliminated, in order to enhance the behavior of power system. With the help of one of the distributed FACTS (Flexible AC Transmission system) device, called Dynamic Voltage Restorer (DVR), this voltage problem can be mitigated. DVR is useful to mitigate the voltage sag as well as voltage swell and hence to increase the power quality of the system.

In [2], different types of power quality issues have explained along with power quality causes and power quality effects. In [3], G.K Singh explained the solar power generation by PV technology. Also he illustrated the Maximum Power Point Tracking (MPPT) to obtain the maximum power from the array. M.Ramaswamy and S.Thangavel studied experimental verification of PV based Dynamic Voltage Restorer (PV-DVR) with significant energy conservation [4].The author in [5] has presented the control algorithm of Incremental conductance method of Maximum Power Point Tracking (MPPT) technique. The followed papers support the proposed methods with relevant explanations.

In this paper, solar PV with battery storage system is integrated with Dynamic Voltage Restorer (DVR) is coupled to utility grid at Point of Common Coupling (PCC) and act as a power conditioner to mitigate the voltage issues such as voltage sag and voltage swell and also thereby the mitigating the power quality issues, better power quality of power system has established. This method possesses high efficiency and better cost effectiveness compared to other power conditioners.

II.POWER QUALITY ISSUES, CAUSES AND EFFECTS

The most common types of Power Quality problems are explained below along with their waveform, causes and effects:

A. Voltage sag (or dip):

It is the decrease in the normal voltage level between 10% and 90% of the nominal rms voltage at the power frequency, for durations of 0.5 cycles to 1 minute. The waveform for the voltage sag is shown in figure.1.

Causes: The main causes for voltage sag are faults on the transmission or distribution network, connection of heavy loads and start-up of large motor.

Effects: Process stoppage due to the malfunction of information technology equipment, namely microprocessor-based control systems (PCs, PLCs, ASDs, etc). Tripping of contactors and electromechanical relays are other side effects of voltage sag. Disconnection and loss of efficiency in electric rotating machines is also considered as the effects of voltage sag.

B. Voltage swell:

It is the momentary increase of the voltage, at the power frequency, with duration of more than one cycle and typically less than a few seconds, outside the normal tolerances. The voltage swell's waveform is shown in figure.2.

Causes: The main reasons for the voltage swell are the start/stop operation of heavy loads, badly dimensioned power sources and badly regulated transformers.

Effects: If the voltage values are too high, it results the data loss, flickering of lighting and screens, stoppage or damage of sensitive equipment.

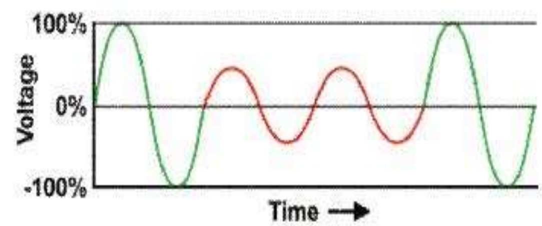

Figure 1: waveform for voltage sag

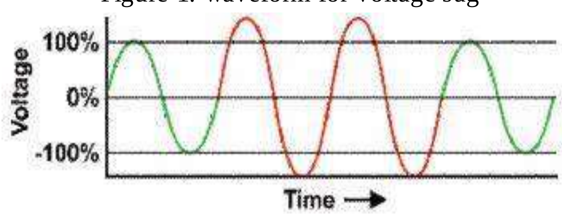

Figure 2: waveform for voltage swell

B. Very short interruptions:

The total interruption of electrical supply is take place for duration of few milliseconds to one or two seconds. Waveform is illustrated in figure.3.

Causes**:** The causes of very short interruptions are mainly due to the opening and automatic reclosure of protection devices to decommission a faulty section of the network.

Effects**:** The main effect of this voltage problem is tripping of protection devices, loss of information and malfunction of data processing equipment. If they're not prepared to deal with this situation, stoppage of sensitive equipment, such as ASDs, PCs, PLCs, etc . also occurs.

C. Long interruptions:

The total interruption of electrical supply is take place for duration greater than 1 to 2 seconds. The waveform for long interruptions is shown in figure.4.

Causes: Equipment failure in the power system network lead to long interruptions. The other causes are storms and objects like trees, vehicles, etc… striking lines or poles, fire, human error.

Effects: The long interruptions results the stoppage of all equipment.

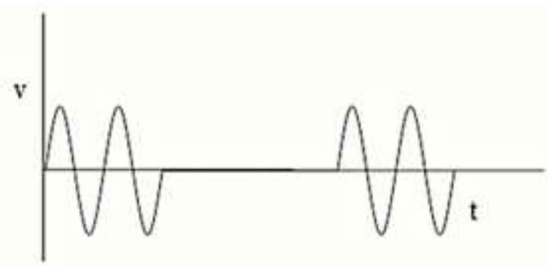

Figure 3: waveform for short interruptions

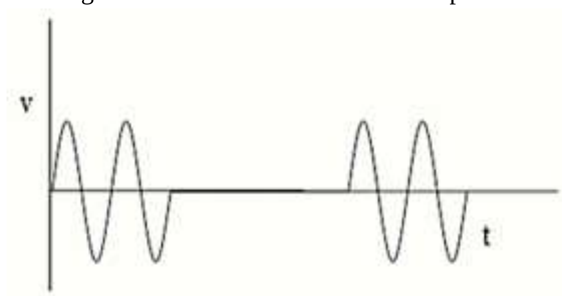

Figure 4: waveform for long interruptions

D. Voltage Spike: The value of voltage gets varied immediately for duration from microseconds to milliseconds. This may vary even in low voltage and it may reach up to thousands of volts. The following figure.5 shows the waveform of voltage spike.

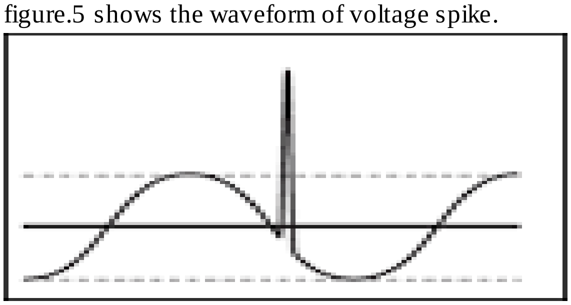

Figure 5: waveform of voltage spike

Causes: Switching of lines or power factor correction capacitors, disconnection of heavy loads and lightning are the major causes for voltage spikes.

Effects: Mainly it destroys the electronic components and insulation material. It also results in data loss and electromagnetic interference.

E. Harmonic distortion:

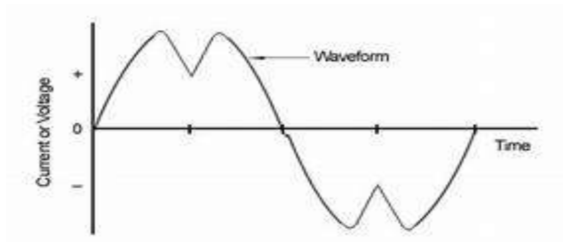

Figure 6: waveform of harmonic distortion

The above figure.6 shows the harmonic waveform distortion. Harmonic wave are sinusoidal voltages or currents and they have frequencies which are integer multiples of the fundamental frequency (usually 50 or 60 Hz).

Causes: The classic sources for the harmonic distortion are arc furnaces, rectifiers, DC brush motor and welding machines...

Effects: Due to harmonic distortion there is increased probability in occurrence of resonance, neutral overload in 3-phase systems, overheating of all cables and equipment, loss of efficiency in electric machines, decrease in electrical machines, electromagnetic interference with communication systems, errors in measures when using average reading meters and nuisance tripping of thermal protections.

F. Voltage fluctuations:

In voltage fluctuations, there is oscillation of voltage value and amplitude is modulated by a signal with frequency of 0 to 30 Hz. The waveform for voltage fluctuation is given in figure.7.

Causes: The major causes are arc furnaces, frequent start/stop of electric motors and oscillating loads.

Effects: The most common effect is the flickering of lighting and screens, as it gives the impression of unsteadiness of visual perception.

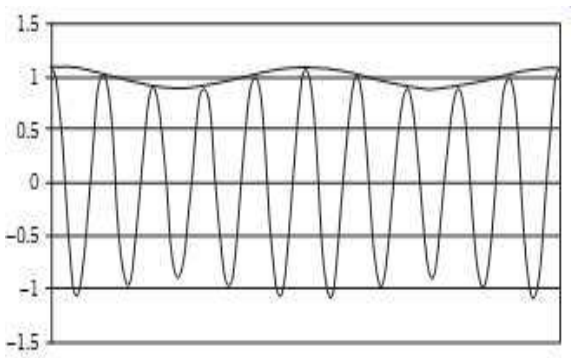

Figure 7: waveform of voltage fluctuations

G. Noise:

Noise is unwanted signal. Noise is produced by superimposing of high frequency signals on the waveform of the power-system frequency. Figure.8 shows the waveform of noise.

Causes: Improper grounding, television diffusion, radiation due to welding machines, arc furnaces, and electronic equipment are the major causes for noise.

Effects: It disturbs the sensitive electronic equipment, usually not destructive but it may cause data loss and data processing errors.

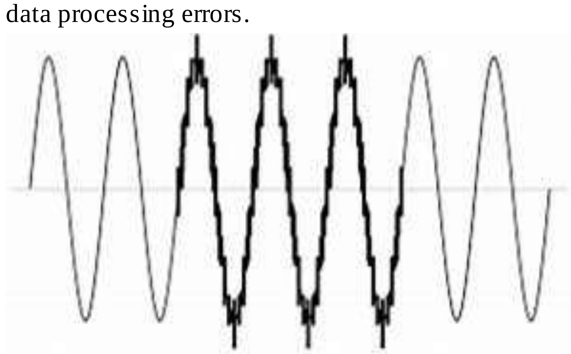

Figure 8: waveform of noise

H. Voltage unbalance:

It is the condition in which three phase voltages differ in amplitudes or are displaced for their normal 120 degree phase relationship or both. The figure.9 shows the waveform of voltage unbalance.

Causes: There are many causes for the production of voltage unbalance and some of the causes are: Large single-phase loads (induction furnaces, traction loads), incorrect distribution of all single-phase loads by the three phases of the system (this may be also due to a fault).

Effects: This unbalanced system implies the existence of a negative sequence and also it is harmful to all three- phase loads. The most affected three phase loads are three-phase induction machines.

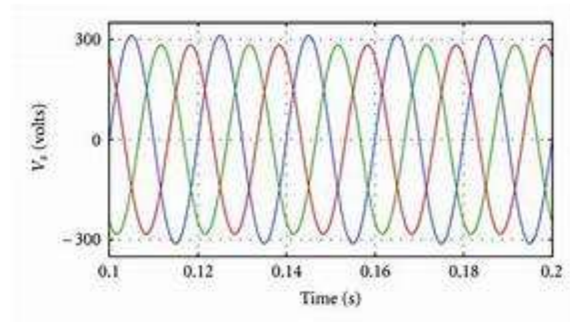

Figure 9: waveform of voltage unbalance

III. ECONOMIC IMPLICATIONS OF POOR POWER QUALITY

The most cost effective approach is: if corrective action is taken at the design stages of the equipment, the cost of correction is much lower. But this approach requires knowledge of the nature and probability of defects. In this section, consequences of poor quality and benefits of power quality improvement are discussed.

A. Implications of Poor Power Quality:

Due to poor power quality, line & equipment current increase which leading to additional ohmic losses. Also the increase in line and equipment current, result to blocked capacity and/or increased capital investment. The increase in ohmic loss increases the operating temperature and it gradually decreases the life of equipment. Another problem with poor power quality is it may results the failure of equipment due to increased electrical and thermal stresses. Malfunction of equipment, unplanned outage, poor quality of production are some of the other implications of poor power quality. So it is important for improving the power quality of the system.

B. General benefits of Power Quality improvement:

Better power quality implies reduction in line & equipments current and decrease in losses which decrease the energy bills, released blocked capacity hence reduced cost of capital investment. By improving the power quality, the improvement of power factor is also established. Reduction in maximum demand, reduction in harmonic distortion which results consequent reduction in copper losses and stray losses is possible when the system have better power quality. One of the main advantages is that it prevents malfunction of equipment and avoid loss of production. So it is necessary to improve the power quality of the power system for better operation.

IV. MODULES OF PROPOSED SYSTEM

A. Solar Photovoltaic System:

It is one of the renewable energy sources and it generates electricity by photo electric effect. Solar cell converts sunlight directly to dc power. It converts solar energy into electrical energy, when solar cell exposes to the sunlight. PV has become an important source of power with the focus on greener sources of power for a wide range of applications. Figure.10 shows the basic diagram of solar PV system.

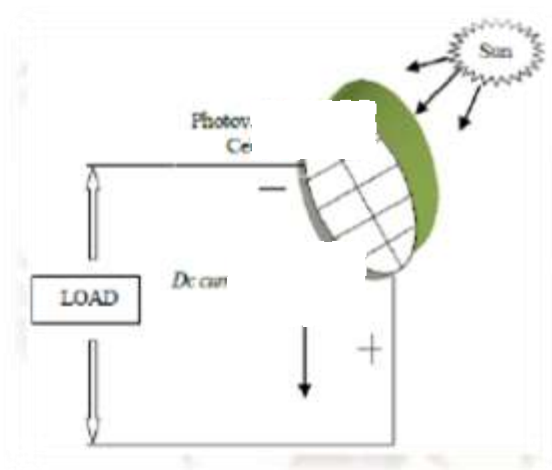

Figure 10: Basic diagram of solar PV system

One of the problems related to solar PV system is the efficiency of the system. Due to less power obtained from PV system, efficiency decreases. It is important to get maximum power from the solar PV system. For that various Maximum power point tracking (MPPT) techniques are used. Incremental Conductance method is one of the MPPT techniques used for obtaining maximum power from solar PV system.

The power from the solar PV is calculated as P=V*I (1)

Where P=calculated solar PV power (W),
V=solar PV voltage (V),
I=solar PV current (A)

Maximum power is obtained only if $\frac{dP}{dV} = 0$ (2)

$$\frac{d(V*I)}{dV} = V\frac{dI}{dV} + I = 0$$

This implies $\frac{dI}{dV} = -\frac{I}{V}$ (3)

Based on equation (3), the algorithm for incremental conductance method is obtained. And it is shown in figure.11.

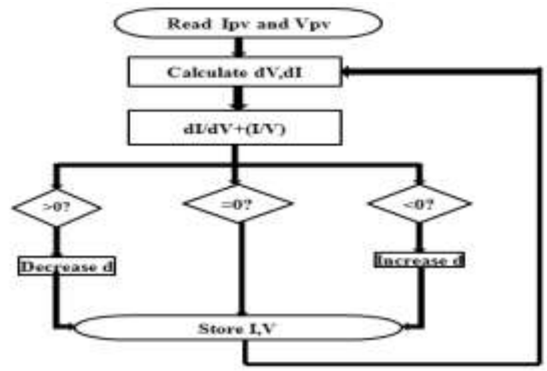

Figure 11: Algorithm for incremental conductance method

If this equation $\frac{dI}{dV} + \frac{I}{V} = 0$ satisfies, maximum power can obtained from solar PV system.

In the proposed system, solar PV system is integrated with the utility grid to meet the peak power as it generates the electricity. It is also integrated with Dynamic Voltage Restorer (DVR). To provide necessary DC link voltage at DC bus, it is also integrated with battery through DC-DC boost converter.

B. DC-DC Boost Converter:

The DC-DC Boost converter steps up voltage (or step down current) from input to output. It is connected between the solar PV and inverter to step-up the voltage. Natural voltage of solar PV is step up by using this converter. The basic diagram of boost converter is shown in figure.12. To track the maximum power from solar PV, switching operation of boost converter is optimized with incremental conductance based MPPT controller.

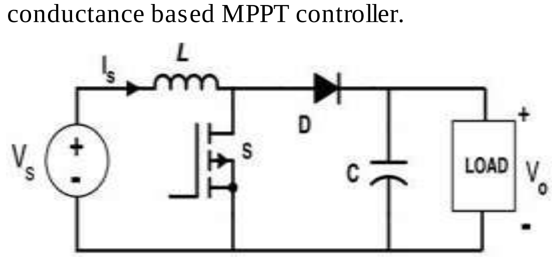

Figure 12: Basic diagram of DC-DC boost converter

C. Dynamic Voltage Restorer(DVR):

Dynamic voltage restorer (DVR) protects the load from voltage sag and voltage swells. During any source voltage abnormal conditions such as voltage sags/swells or distortion; DVR maintains the load voltage at a predetermined level. During dynamic variations in the load as well as during voltage sag, DVR restores the voltage in the distribution system. The two modes of operation of DVR can explain by using following equation (4).

$$V_L=V_S+V_{DVR} \quad (4)$$

Where V_L=Load voltage,

V_s=Source voltage,

V_{DVR}=Injected DVR voltage.

During primary mode, the DVR compensate the voltage in distribution line at the time of voltage disturbances by injecting a voltage that is equals to the difference between the load voltage and source voltage. In second mode of operation, there is no voltage disturbance, so that injected voltage to distribution line by DVR is zero. The basic model DVR is shown in Figure.13.

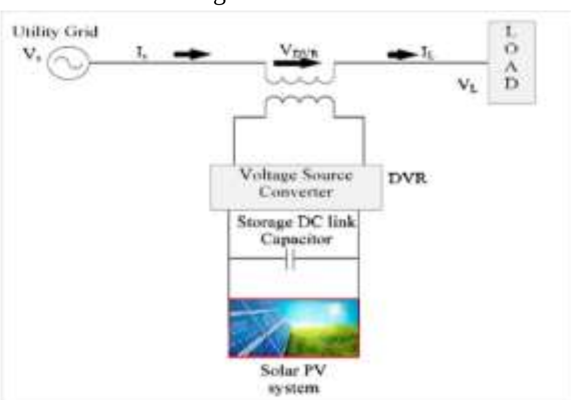

Figure 13: Basic block diagram of DVR

Injection transformer connects the DVR to the distribution network via the HV-windings. It will inject voltage when there is a voltage disturbance takes place. The solar PV system is integrated with the DVR to give necessary power for the operation. Voltage Source Converter (VSC) acts as an inverter and converts dc voltage from solar PV to AC voltage and it passes to the injection transformer. The DC link capacitor is connected to support the grid as well as filter the harmonics to maintain the necessary smoothening power to the load.

V. POWER CONDITIONING OF GRID BY DVR WITH SOLAR PV

The proposed hybrid system model is shown in figure.14. In this proposed method solar PV generates electricity and it is integrated with the utility grid through DC-DC boost converter and Voltage Source Inverter (VSC1) in order to meet the peak power. The output voltage from solar PV is step up by DC-DC boost converter or output current from solar PV is step down in order to convert the output DC parameters to AC parameters. Switching operation of DC-DC boost converter is done by Maximum Power Point Tracking (MPPT) technique in order to obtain maximum power from the solar PV system. AC power is needed in order to integrate the solar PV with grid. The obtained output from DC-DC boost converter is in DC form, so it should convert in to AC by Voltage Source Converter 1 (VSC1). Here VSC1 act as an inverter and it convert the DC from DC-DC boost converter to AC. This AC is then fed into the utility grid and it is integrated with the utility grid at the Point of Common Coupling (PCC).

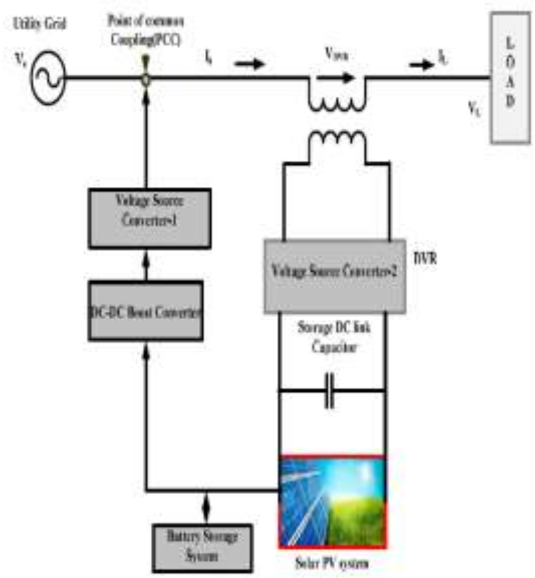

Figure 14: Basic block diagram of DVR with solar PV

During a voltage disturbance such as sag occurs, the DVR become active then it compares the load voltage and source voltage. The amount of voltage that is equal to difference between load voltage and source voltage is injected to the distribution line through injection transformer. Solar PV is also integrated to the DVR for efficient operation of proposed method through Voltage Source Converter (VSC2). VSC2 is also act as an inverter in order to convert DC to corresponding AC. This AC is then fed to the injection transformer. Injection transformer is also known as boost transformer.

There is DC link capacitor in the proposed method. It acts as a filter and by removing the unwanted signal such as harmonics it maintain the necessary smoothening power to the continuously. The function of battery storage system is to provide the required energy for compensation of load voltage during abnormal conditions of voltage sag.

VI. CONCLUSIONS

This paper has discussed the different power quality issues along with the causes and effects of power quality issues. The poor power quality results many problems and it is necessary to improve the power quality for the good performance of power system to distribute qualitative power to the consumers. One of the main voltage disturbances voltage sag is mitigated by the proposed method of novel integration of solar PV with DVR and utility grid. The sensitive load voltages and grid voltage are balanced by injecting the voltage in series with distribution line by the injection transformer.

ACKNOWLEDGMENT

Author is thankful to the supporting faculties for giving facility and opportunity while doing the work.

REFERENCES

[1] Thirumoorthi, P., S. Deepika, and N. Yadaiah. "Solar energy based dynamic sag compensator." In Green Computing Communication and Electrical Engineering (ICGCCEE), 2014 International Conference on, pp. 1-6. IEEE, 2014.

[2] P. A. Raut and A. P. Q. Problems, "an Overview and Design of Dynamic Voltage Restorer To Improve Power Quality in Microgrid," no. Icesa, pp. 632–635, 2015.

[3] G. K. Singh, "Solar power generation by PV (photovoltaic) technology: A review," Energy, vol. 53, pp. 1–13, 2013.

[4] M. Ramasamy and S. Thangavel, "Experimental verification of pv based dynamic voltage restorer (PV-DVR) with significant energy conservation," Int. J. Electr. Power Energy Syst., vol. 49, no. 1, pp. 296– 307, 2013.

[5] Huynh, Duy C., and Matthew W. Dunnigan. "Development and Comparison of an Improved Incremental Conductance Algorithm for Tracking the MPP of a Solar PV Panel." IEEE Transactions on Sustainable Energy 7.4 (2016): 1421-1429.

[6] T. Separate, E. Storage, S. Voltage, and S. Voltage, "Compensation Of Voltage Variations In Distribution System By Using DVR Based Separate Energy Storage Devices," vol. 4, no. 1, pp. 1017–1026, 2013.

[7] Ravi. Dharavath, Jacob Raglend and Atul Manmohan, "Implementation of Solar PV - Battery Storage with DVR for Power Quality Improvement" International Conference on Innovations in Power and Advanced Computing Technologies [i-PACT2017]. IEEE, 2017.