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VOLTAGE SAG MITIGATION IN PHOTOVOLTAIC SYSTEM

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***Abstract*— This work presents the mitigation of the voltage sag in the photovoltaic system using Dynamic Voltage Restorer (DVR). Modeling of photovoltaic system (PV), dynamic voltage restorer (DVR) and local grid are implemented and the results of simulation are presented. In order to extract the maximum power from PV and to increase efficiency P&O algorithm based Maximum Power Point Tracker (MPPT) is used. For the exchange of real and reactive power cascaded H-bridge inverter is used. Modeling of the proposed system was developed by MATLAB Simulink. The objective of the proposed system is to alleviate the voltage hang down.**

NOMENCLATURE

PV	**Photovoltaic system**
MPPT	**Maximum Power Point Tracking**
DVR	**Dynamic Voltage Restorer**
SMC	**Sliding Mode Controller**
SDCS	**Separate dc Sources**
P & O	**Perturb and Observe**

Index Terms*— *Dynamic Voltage Restorer, H-bridge multi level inverter, Photovoltaic system, sliding mode controller

I. INTRODUCTION

Energy market is directed towards the renewable energies. Now a day, photovoltaic (PV) generation is assuming increased importance because of their advantages such as simplicity, no fuel cost, no maintenance, lack of noise and wear due to the absence of moving parts. For the grid connected type, the main problem is the power quality issues which includes voltage hang down, voltage flicker, transient [1].

DVR is one of the custom power devices that is similar to that of series type of FACTS device. The significance of this device is to protect the sensitive load from wilt and deviations in the supply side by quick succession voltage booster to compensate for the fall or grow in the supply voltage. This series device will inject the distorted voltage to counteract the harmonic voltage whenever there is a distortion in the source voltage. [2]-[3].

Among the existing control methods of DVR, SMC technique has high simplicity and robustness, the proposed controller improves the disturbance rejection, uses invariant control system to modify the system by switching the controlled variable according to the known system state and make the system locus move on the predefined sliding surface[4].

Photovoltaic system directly converts the sunlight into electricity when exposed to solar radiation. Modeling and simulation of the PV array is presented [5]. In order to extract the maximum output from PV source, MPPT is used [7]. In this paper PV power generation is used as energy source for DVR when disturbance occurs. It can be done through various converter topologies. The general function of this multilevel inverter is to synthesize the desired voltage from several separate dc sources which may be obtained from batteries or solar cells [15].

The objective of this paper includes

1. Voltage mitigation for sag or swell.
2. To effectively use the renewable energy resources.
3. Compensation for the voltage disturbance using Dynamic Voltage Restorer (DVR).

In section II proposed system model is presented and discussed. The simulation results are discussed for different condition in section III. Conclusion and future scope of work is given in section IV.

II. PROPOSED POWER SYSTEM MODELING

The proposed power system model comprises PV system, DVR, SMC, energy storage devices and Cascaded (H-bridge) multilevel converter as shown in fig.6.

A. Modeling of PV cell

The photovoltaic cells convert the incident photons to electron or hole pairs. The photovoltaic module is the result of associating a group of PV cells in series and parallel and it represents the conversion unit in this generation system. The relationship between the PV cell output current and terminal voltage according to the single-diode model is governed by equation (1), (2)and(3).

$$I = I_{pv} - I_D \qquad (1)$$

$$I_D = I_0 \left[exp\left(\frac{q*v}{\alpha*k*T}\right) - 1\right] \qquad (2)$$

Practical modules are compose of several connected PV cells which requires the inclusion of additional parameters, Rs and Rp, which is given by (3)

$$I = I_{ph} - I_0 \left[\exp\left(\frac{V+R_s*I}{V_t*\alpha}\right)\right] - \frac{V+R_s*I}{R_p} \qquad (3)$$

Where, I_{ph} is the current generated by the incident light, I_D is the diode current, I_0 is the reverse saturation current, q is the electron charge, k is the Boltzmann constant, α is the ideality factor. T is the temperature, R_s is the series resistance, R_p is the parallel resistance.

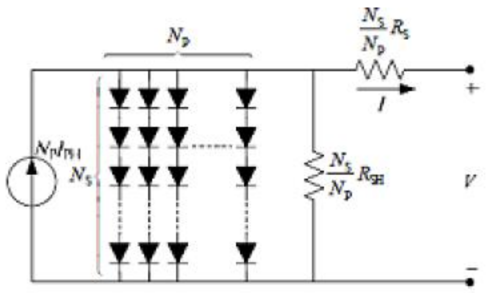

Fig.1. Equivalent circuit of PV array

The numbers of cells are connected to form a PV array. The equivalent circuit of PV array is shown in fig.1. where N_s be number of cells in series and N_p denote number of cells in parallel arrangements. The cells connected in series provide greater voltage output and similarly the cells connected in parallel provide greater current outputs.

The I-V characteristics of PV device not only depends on the internal characteristic but also with external influences such as temperature and irradiation which is influenced by equation (4)

$$I_{pv} = (I_{pv,n} + k_1 \Delta_T)\frac{G}{G_n} \quad (4)$$

Where G is irradiation on surface, G_n is nominal irradiation.

B. MPPT algorithm

MPPT or Maximum Power Point Tracking is a technique used for extracting maximum available power from PV module under certain conditions. The voltage at which PV module can produce maximum power is called 'maximum power point' (or peak power voltage). Perturbation and Observation (P&O) method is the most frequently used algorithm to track the maximum power due to its simple structure and fewer required parameters. This method finds the maximum power point of PV modules by means of iteratively perturbing, observing and comparing the power generated by the PV modules [11].

The power versus voltage curve for the P&O algorithm in fig.2 shows the terminal voltage and output power generated by a PV module can be observed that regardless of the magnitude of the sun irradiance and the terminal voltage of PV modules, the maximum power point is obtained while the condition dP/dV=0 is accomplished. The advantages of the P&O method are simple structure, easy implementation and less required parameters.

C. DC-DC converter

DC-DC converters can be used as switching mode regulators to convert an unregulated dc voltage to a regulated dc output voltage. The regulation is normally achieved by pulse width modulation at fixed frequency and the switching device is BJT, MOSFET or IGBT. Here boost converter is used and hence the voltage boost occurs across the load which causes the output voltage to be higher than the input voltage

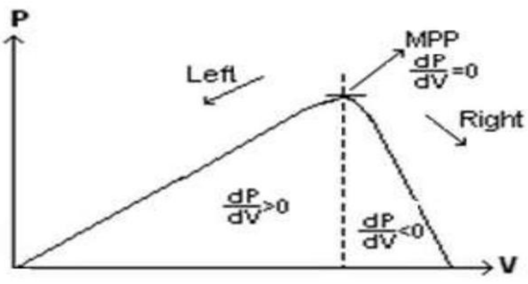

Fig.2. Power versus Voltage curve for P&O algorithm

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D. Sliding mode controller

Sliding mode control is a form of variable structure control. It is a non linear control that alters the dynamics of a non linear system by the application of a high frequency switching signal. The main strength of the sliding mode control is its robustness [4].

Sliding mode control is a non linear control methodology, which uses a combined control of continuous equivalent control (u_{eq}) and discontinuous switching control (u_{sw}) which are used to force the state trajectory to reach a predefined sliding surface/ switching surface(s) in the phase plane and then forces it remain on the surface in the sliding mode until the desired state is reached. The equivalent control ensures that the operating point slides along the sliding surface until the error approaches to zero. The dynamics of the system is given by equation(5) which tends to zero if the poles is on the left hand plane and condition of overshoot does not occur and act as the state feedback control system. The principle of sliding mode control is shown in fig. 3.

$$X_1(t) = (A+BK)X(t) \quad (5)$$

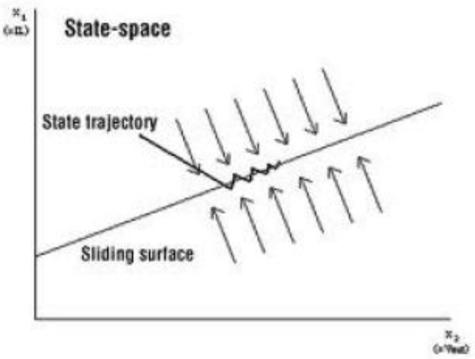

Fig.3. Principle of sliding mode controller

E. Multilevel inverter

A cascaded multi level inverter consists of a series of H-bridge (single phase, full bridge) inverter units. The general function of this multi level inverter is to synthesize a desired voltage from several separate dc sources (SDCSs), which may be obtained from batteries, fuel cells, or solar cells [11]. Fig. 4 shows the basic structure of single phase cascaded inverter with SDCSs. Each SDCS is connected to an H-bridge inverter. The switches are controlled to generate three discrete output voltage with levels V_{dc}, 0, $-V_{dc}$. Each H-bridge unit generates a quasi square waveform by phase shifting the positive and negative phase leg switching timing. It is to be noted that each switching device always conducts for 180° (or half cycle) regardless of the pulse width of the quasi- square wave. The switching method makes all of the switching device current stress equal.

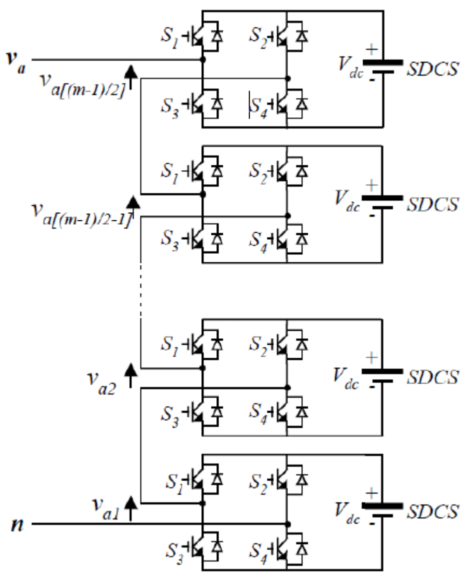

Fig. 4 Basic structure of H- bridge inverter

F. Dynamic voltage restorer

Dynamic Voltage Restorer (DVR) is a solid state device that injects the voltage into the system in order to regulate the load side voltage [13]. The basic components of the DVR as shown in fig.5 which comprises of Injection transformer,

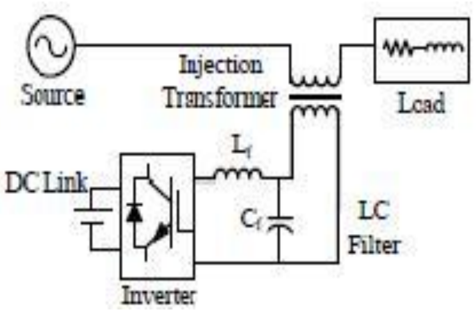

Fig. 5 Basic Components of DVR

Harmonic filter, voltage source converter, Dc charging unit. The primary function is to boost up the load side voltage in the event of disturbance in order to avoid the power disruptions to the load. The difference between the pre sag voltage and the sag voltage is injected by the DVR by supplying the real power from the energy storage element and the reactive power. During the normal operation as there is no sag, DVR will not supply any voltage to the load.

The momentary amplitude of the three injected phase voltages is controlled. This means that any differential voltage caused by the transient disturbances in the ac feeder will be compensated by an equivalent voltage generated by the converter and injected on the medium voltage level through booster transformer.

III. SIMULATION RESULTS AND DISCUSSIONS

Simulation results are given from fig.7 to fig.11. Voltage disturbance are sensed and is compared with the desired voltage and based on the error signal the modulating signal varies the PWM signal and necessary voltage is injected by the DVR.

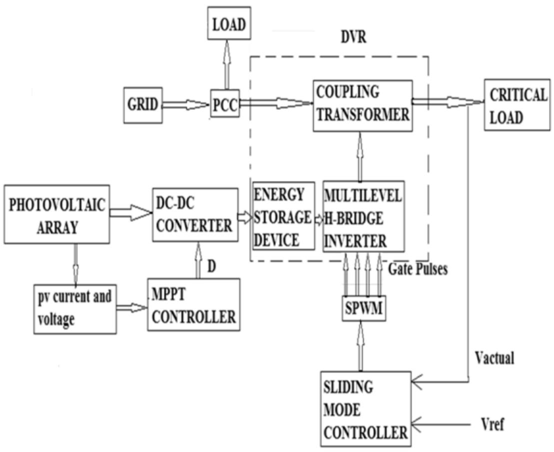

Fig. 6 Overall block diagram of the proposed system

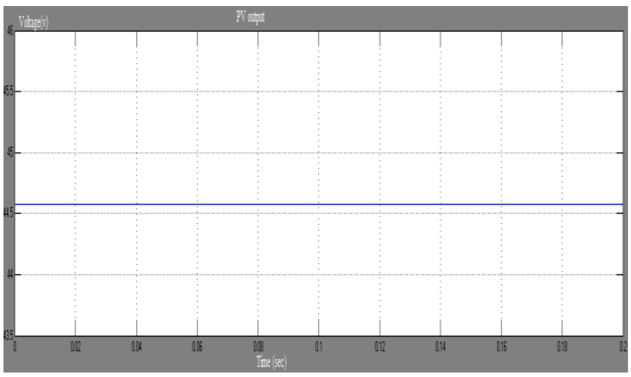

Fig. 7 PV output voltage waveform

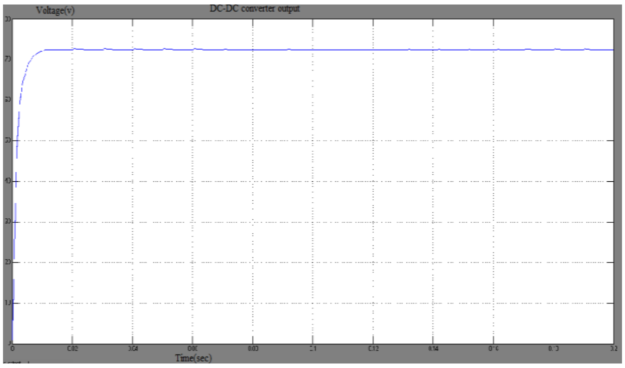

Fig. 8 DC-DC Converter output waveform

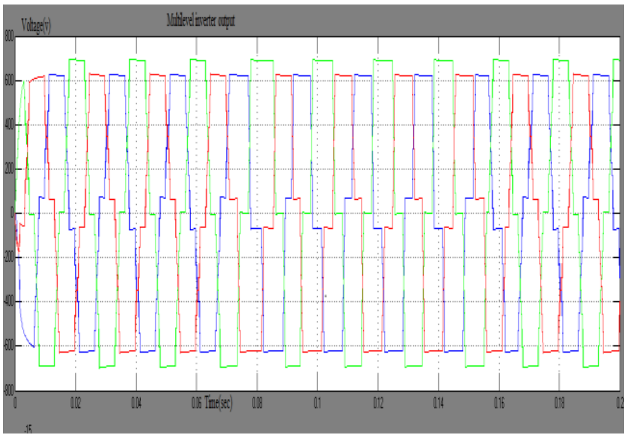

Fig. 9 Multilevel inverter output waveform

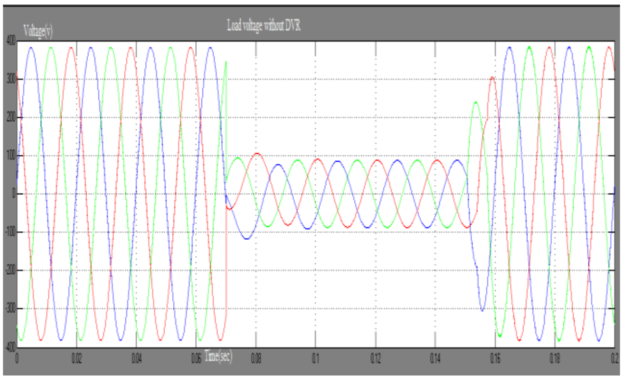

Fig. 10 Load voltage without DVR waveform

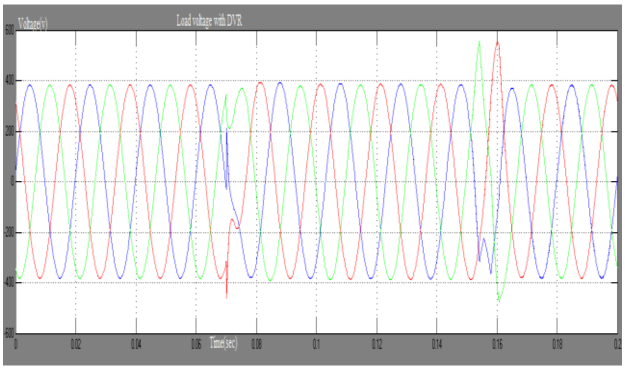

Fig. 11 Load voltage with DVR waveform

Fig. 5 shows the overall block diagram of the system. Fig. 7 and 8 shows the PV output and the DC-DC converter output. Multilevel inverter output is shown in the fig.9. Fig. 10 and 11 shows the load output voltage before interfacing with DVR and after interfacing with DVR respectively.

IV. CONCLUSION

In this work, the voltage in the distribution side was improved when the disturbance occurs in the load feeder by means of DVR which has excellent compensation for voltage disturbances. Simulation was carried out with PV interfaced multilevel inverter and DVR using MATLAB/SIMULINK software.

The future scope of the present work is to increase multi level inverter stages to ensure the harmonic free oscillation. We can get the desired results for the non linear load by means of the fuzzy based controller to drive the power switches in the inverter.

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