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# Implementation of Photovoltaic Energy based Dynamic Voltage Restorer in Grid

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**ABSTRACT:** In this report, we will study the implementation of photovoltaic fed Dynamic Voltage Restorer (PV-DVR) that can be used to maintain the voltage level during poor voltage quality conditions and also can be used to maintain power on a low voltage residential supply arrangement for the duration of both day time and night time. During excess voltage regulation, the PV-DVR reduce the power saving from the utility grid by disconnecting the utility grid from the load. As the Photovoltaic arrangement generates average power to the required critical load through the day time. Many research has insisted on using a low step-up DC-DC converter, but the use of an interleaved high step up DC-DC converter with PI controller algorithm can get rid of the drawback of conventional PV based DVR by tracking disorder & detect maximum power point (MPPT) of the photo voltaic array. The positive results are validated using Simulation results.

**KEYWORDS:** Photovoltaic (PV), Voltage Regulator, Voltage Sag, Voltage swell, power conservation, interleaved high step up DC-DC converter.

## I. INTRODUCTION

Dynamic Voltage Restorer has the capacity to overcome low voltage levels during low to moderate voltage sags, voltage swells and outages. It achieves this task by establishing the proper voltage magnitude level and appropriate quality level that is required by the sensitive loads. A photovoltaic power fed -DVR arrangement is seen as a good solution for a residence or manufacturing unit, as mentioned by many researchers. Voltage sag is defined as a rapid decrease of utility supply voltage which may vary from 10% to 90% of its actual value. Voltage swell is defined as a rapid increase of supply voltage from 110% to 180% of its actual value. The outage refers to an intermission of power for long duration. According to the IEEE 519-1992 and IEEE 1159-1195 set, a characteristic time of voltage sag and voltage swell is 10ms to 1 min [1]. For the largest part in India, rural areas that have a large quality of isolation and have extra regular power disturbance on every day. This could occur in the growing up countries, wherever the generated power is lesser than their demand. Difficulty facing industry and residence concerning the power qualities are mainly due to voltage sag, short duration voltage swell and long duration [2]. The idea of utilize the DVR for voltage sag and outage improvement without PV system is obtainable [1]. The rating and plan of series injection transformer of the DVR is offered. Online type DVR has been presented to give back the voltage sag in the system [2]. The DVR without PV structure supported by the super capacitor as power storage device for improving the power quality supply system. The conventional DVR having following demerits:

- It consumes extra power from the utility grid for the advantages of long duration voltage variation.
- The high cost DVRs are only used for the improvement of voltage instability.
- It increases the possible panel tariff and electricity demand.

To overcome the demerits of the above mentioned conventional DVRs, operation of PV solar system inverter as a DVR for voltage sag, voltage swell and outage mitigation with significant power management has been proposed [2]. In this paper, a DC-DC converter is proposed to control the PV solar system acting as DVR, it use the rated inverter ability during night time and inverter capacity remaining after excess or equal to the real power consumption of expensive the

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PV system over 8 h period. The proposed DVR, if connected at the terminals of a residence or small manufacturing unit can conserve 12.6 kW h in summer or at high temperature days [3]. PV system a simple interleaved dc-dc converter is connected with a function called MPPT [1].

## II RELATED WORK

Quite a few studies have been done to check the feasibility of different energy storage methods to be used as voltage source in order to use them with voltage restoring devices. Dynamic Voltage Restorer is one of custom power device specially used to inject a (fundamental frequency) voltage in each phase of required magnitude and phase to maintain the load voltage constant in the distribution system. The power circuit of a general DVR is given in figure below.

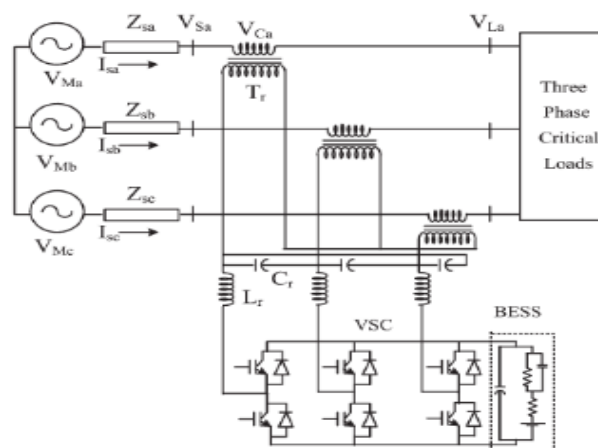


Fig 1 - Power circuit of a general DVR(1)

The concept of using photovoltaic system based inverter as DVR, for the mitigation of voltage changes with capacity to save power at the load side for single-phase supply is detailed in [1]. The reference [2] has proposed the concept of utilizing the DVR for voltage sag and outage mitigation without PV system. The rating and design of series injection transformer of the DVR is presented in [3]. The design and control of DVR have been carried out in [4]. Fault clearing single energy storage device based DVR working under condition when only Grid is the power source available alone, provides grid support for clearing long voltage variation and absence of Battery and PV system short voltage response is compensating super capacitor and fuel cell hybrid system.[4]

## III. DVR MODES OF OPERATION

- I. *DVR mode:* In this mode, the proposed PV-DVR is utilized to control the voltage at the load side. Through this function a series injection transformer is configured in series with the load balance the voltage sag/swell [5]
- II. *UPS mode:* In this mode, the series injection transformer of PV-DVR is reconfigured into parallel to supply the ups power supply to load on during daytime and night time.
- III. *Power protection mode:* During additional power generation on the solar panel, the proposed PV-DVR disconnects the service network from load and it configures the series injection transformer into parallel to make the inverter operation to feed the additional energy generated by the solar panel to load.

Advantages of interleaved high step up DC-DC converter over DC-DC converter.

1. Interleaved high step up DC-DC converters are operated for high ratios, it leads to high voltage and current stress on the switch.
2. It produces high voltage gain when compared to the other boost converter.

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3. Ripple current rejection.
4. To avoid the high level switching losses.
5. To reduce loss minimum

Supply Voltage	S1	S2	S3	Mode of Operation
230	1	0	1	Ideal
<230	0	0	1	DVR
>230	1	0	0	DVR
0	0	1	0	UPS

Table. I. Operation of DVR

PV Voltage	R1	R2	Charging Unit
>14	0	1	PV array
<14	1	1	Rectifier with PV array

Table. II. Battery Charge control

## III. In-Phase Voltage Compensation Method

In general, there are three techniques such as in-phase, pre-sag and minimum power injection technique are utilize to analyse the injection voltage of DVR. In-phase compensation technique is used to analyse injection voltage of DVR due to its quick response and easy performance in calculating the compensate voltage. The injected voltage across the secondary of the series injection transformer is in-phase with source voltage. In regular form the supply voltage is different to the load voltage with zero phase angles. For the period of the voltage sag/swell, the supply voltage high or low to a value less than or greater than its actual value. The DVR reacts to the voltage sag/swell calculate and injects the compensate voltage injection in-phase with the source voltage to return the voltage at actual value.

- $|V_{inj}| = |V_{presag}| - |V_{sag}|$
- $V_{DVR} = V_{inj}$
- $V_{DVR} = |V_{presag}| - |V_{sag}|$
- $V_{inj} = \theta_{inj} = \theta_s$

## IV. PHOTOVOLTAIC ARRAY MODELLING

Photo voltaic array is a arrangement which consists of extra photo voltaic cells to change solar energy into electrical energy. In the proposed DVR, photo voltaic array with a low step-up DC–DC converter is connected with a function of DC voltage source for the inverter of DVR. It is introduced between the photo voltaic and battery bank of the DC link [10].

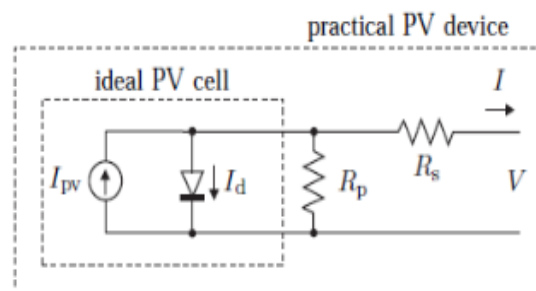


Fig 2- Modelling of Photovoltaic Cell

The electrical energy produced by the photo voltaic array need DC–DC converter due to the varying environment of the generated solar energy, resultant from rapid change in climate conditions. By which modify the solar irradiation

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intensity as well as the cell working temperature. The photo voltaic array is developed by the basic equations of photovoltaic cells including the property of temperature change and photo voltaic irradiation intensity [11]. The output voltage of the photo voltaic cell is a purpose of photo current that is mostly determined by load current depending on the solar irradiation level. The photo voltaic cell output voltage is expressed as:

$$V_c = AKTc/e \ln (I_{ph} + I_o - I_c) - R_s I_c$$

These two parameters are used to scale the effects of high temperature and solar irradiation levels on photo voltaic cell voltage and current.  $b_T$  is the slope of the coefficient  $C_{TV}$ , affect the change in voltage due to temperature change.  $c_T$  is a constant in a place of change in working temperature due to solar irradiation.  $T_a$  and  $T_y$  represent the ambient temperature of the cell respectively.

## V. MAXIMUM POWER POINT TRACKING

The MPPT is an important measurement of a photovoltaic solar system. The P&O MPPT algorithm apply a small increase or decrease of perturb voltage dynamic voltage to the operating voltage of PV unit. The parameters  $V_{PV}$  and  $I_{PV}$  calculated from the output of photo voltaic array is utilized to generate control signal ( $V_{ref}$ ) for the PWM generator. The flow chart of P&O MPPT algorithm shown in fig.4.

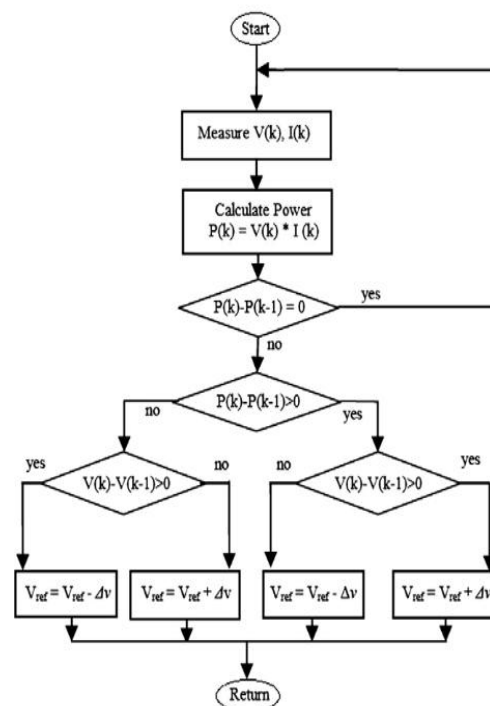


Fig 3- MPPT search P&O method

The rule of function of the P&O MPPT has been explained in [16]. The estimation of actual state (k) and previous state (k-1) of the parameters V and I are measured. The actual and previous state of the power is calculated from the product of actual and previous state V and I. According to the condition as represented the increase or decrease of reference voltage ( $V_{ref}$ ) is obtained. The  $V_{ref}$  compared to a saw tooth wave with 10 kHz frequency generates the PWM pulse. The flowchart of the method is shown in figure above..

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## VII. VOLTAGE INJECTION USING PARKS TRANSFORMATION

The control method used to keep a constant voltage magnitude at the load point, under system trouble. In the proposed controller, a discrete single phase locked loop is used to track the phase angle of the source voltage to perform the parks transformation on the measured single phase voltage [9]. The measured per unit value of supply voltage is improved into  $|V_s|$ , and the error is obtain from the variation of  $|V_s|$  and reference voltage ( $V_{ref}$ ). The PI controller designed by the Ziegler–Nichols tuning method processes the error and generates required angle  $d$  to drive the error to zero [9]. The PI controller with the proportional and integral gain of 5 and 0.1 process the error signal and generates the control signal required shown in fig.6. The generated  $V_{ref}$  is utilized to produce switching pulses for VSI[5]. The basic idea of SPWM is to compare a sinusoidal control signal ( $V_{ref}$ ) of normal frequency 50 Hz with a triangular carrier waveform (Carrier) with 20 kHz signal to produce the PWM pulses. When the control signal is higher than the carrier signal, the output voltage of the inverter mitigate the low, voltage, high voltage, and outage.

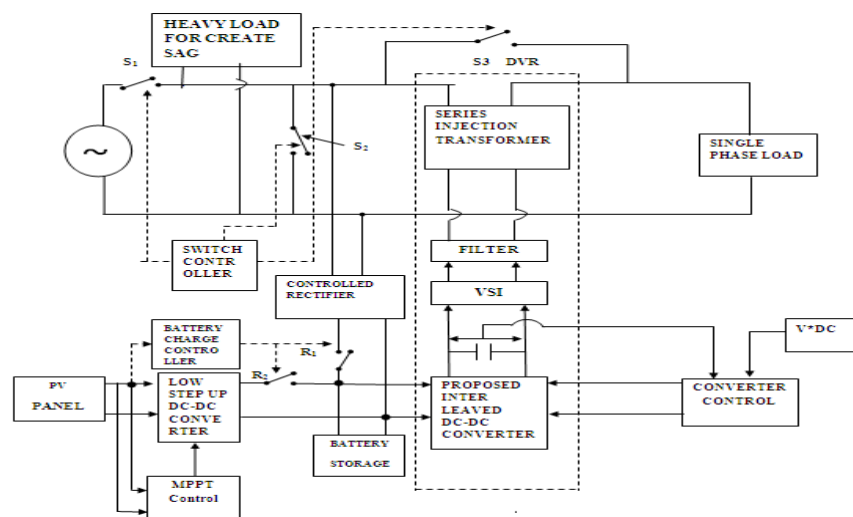


Fig 4- Block Diagram of DVR (1)

The main working of this converter is to keep a constant Voltage (230 V) across the DC link of inverter. For that, a simple Control structure with PI controller is implemented in the high Step-up DC–DC converter. The control part comprised of Low Pass Filter (LPF), pulse width modulation, PI controller, comparator and relational operator. The low pass filter eliminates the high frequency component from the output of converter. The comparator forms an error signal by comparing the reference and actual output of the converter. The PI controller with the proportional and integral gain of 5 and 0.1 process the error signal and generates the control signal required shown in fig.5. The relational operator generates the required duty cycle by comparing the process error signal with input supply.

Type	Voltage	Setting time	Ripple Factor
Boost converter	55	0.016	0.15
Interleaved boost converter	57	0.014	0.029
Interleaved boost converter with $V_m$	227	0.1	0.06
Proposed interleaved boost converter	400	0.07	0.25

Table 3. Comparison of proposed Interleaved Boost Converter with other converter

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## VIII. SIMULATION RESULTS AND DISCUSSION

To illustrate the capacity of the PV-DVR used for voltage sag, voltage swell and outage improvement, a single phase system is considered. In MATLAB Simulink, the DVR is simulated to be in operation only when the supply voltage differs from its nominal value or when the PV array generates excessive power or equal power to the load demand. It reduces the energy consumption from the utility grid. The simulation parameters of the system proposed. The proposed DVR model is simulated by MATLAB Simulink to compensate voltage sag, voltage swell and outages at the load side. The total simulation period is 1s.

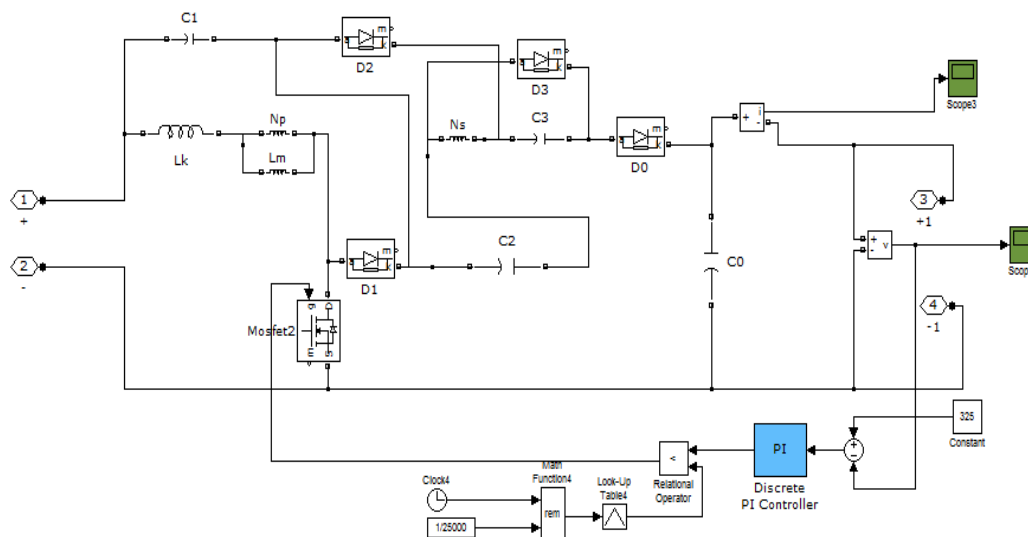


Fig 5-Controller modelling for DVR

The voltage waveforms regarding the effect of DVR during sag or short duration interruption condition. A single phase controlled voltage source is used to provide a single phase variable voltage at the source end. Fig. 6 a reduced voltage (114 V) is applied, during the period 0.1–0.2 s, a raised voltage (253 V) is applied, during the period 0.7–0.8 s and zero voltage (0 V) is applied, during the period 0.3– 0.6 s. The voltage sag and voltage swell at the source point is 50% and 110% with respect to the reference voltage.

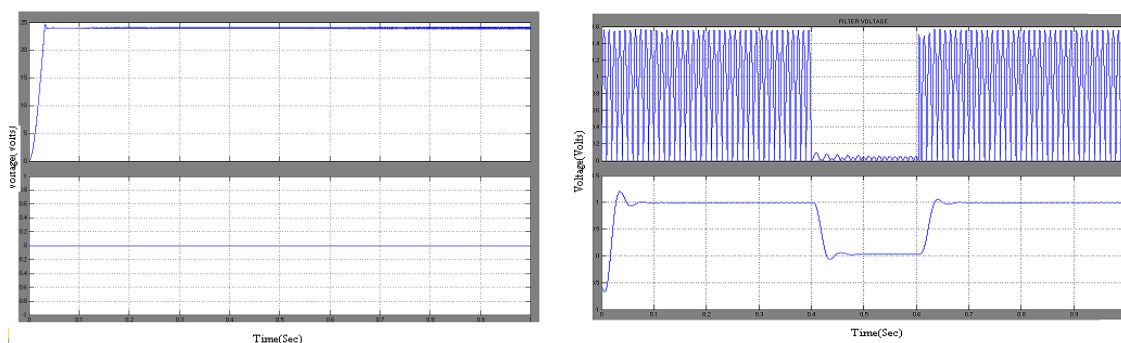


Fig 6 Simulation output showing sag in voltage

The inject voltage, load voltage and load current of the DVR. From the simulation results, it is observed that the load voltage is affected by the voltage change events. The PV array consists of 54 PV cells ( $6 \times 9$ ), 9 cells are linked in



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series to have a desired voltage output of 12 V and there are 6 parallel branches giving a total power of 200W the number of parallel PV arrays is increased to 15 to get 3000W power output. Photo voltaic array with interleaved high step up DC-DC boost converter can give greater output voltage. It is observed that the proposed power generated by the PV array with 82% of efficiency and shows the discharge characteristic of the battery for various constant outputs voltage (24V). The voltage sag is formed when heavy load is connected to source.

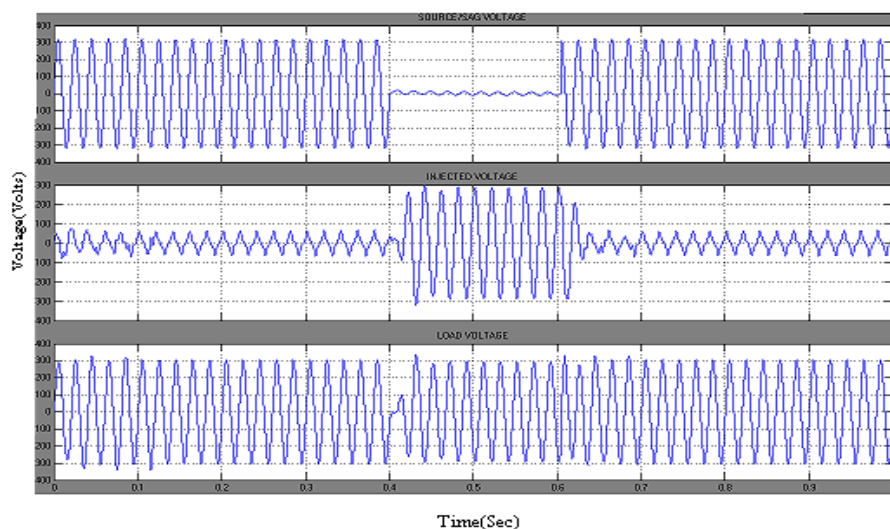


Fig 7- DVR Simulation Results of Voltages showing voltage compensation

## IX. CONCLUSION

For voltage sag/swell and outage lessening at a factories or houses, an innovative application using a PV solar system as DVR is recommended. To tracking the maximum power point of the PV array, proposed interleaved high step up DC-DC converter including PI controller build P&O MPPT algorithm is realized. While the PV array produce same or more real power to encounter the load required, proposed PV-DVR is constructed to reduce the power consumption from utility grid by means of separating the utility grid from the load via semiconductor switches. Additionally it decreases the cost of panel and prevents consumption of UPS & stabilizer for the distinct tools at a house, factory and organization. The simulation results illustrate the ability of PV DVR in justifying voltage modifications.

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