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RESEARCH ARTICLE

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AN IMPROVEMENT OF VOLTAGE QUALITY USING FUZZY LOGIC CONTROLLER FOR PV BASED DVR SYSTEM

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ABSTRACT

This paper presents a novel photovoltaic fed Dynamic Voltage Restorer (PV-DVR) is proposed to moderate deep voltage sags, voltage swells and power on a low voltage residential supply arrangement for the duration of both day time and night time. During extra voltage regulation, the proposed PV-DVR reduce the power conservation from the utility grid by disconnect the utility grid from the load in the semiconductor switch. As the PV arrangement generates average or same power to the critical load require through the day time. But the decrease of power conservation is permanently needed for the decrease of panel tariff and over all warm gas. Extra they manage of low step-up DC–DC converter. Considered interleaved high step up DC-DC converter with PI controller algorithm eliminates the drawback of conventional PV based DVR by tracking perturb&observe maximum power point(MPPT) of the photo voltaic array. Simulation and experimental results are presented to validate the improvement of the proposed system.

Keywords— Photovoltaic (PV), Voltage sag, Voltage swell, power conservation, interleaved high step up DC-DC converter

I. INTRODUCTION

Dynamic Voltage Restorer (DVR) can supply the most cost valuable resolution to moderate voltage sags, voltage swells and outages by establish the proper voltage quality level that is require by the sensitive loads. PV-DVR arrangement has become a good solution for a residence or manufacturing unit. For the largest part in Tamil Nadu, India, rural areas that have a large quality of isolation and have extra regular power disturbance on each day. This could occur in the going up countries, wherever the generated electrical power is fewer 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]. 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. According to the IEEE 519-1992 and IEEE 1159-1195 set, a characteristic time of voltage sag and voltage swell is 10 ms to 1 min [1]. The outage refers to an intermission of power for long duration. The voltage change measure record at a 230 V home low voltage distribution is observed that the voltage sag, voltage swell and outages have occur in the low voltage distribution system. 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 power quality development in electrical supply system. The conventional DVR having following demerits: (1) The high cost DVRs are only used for the improvement of voltage instability. (2) It consumes extra power from the utility grid for the advantages of long duration voltage variation. (3) It increases the possible panel tariff and electricity demand. To overcome the demerits of the above mentioned conventional DVRs, a new idea for best 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 new interleaved DC-DC converter is proposed to control the PV solar system as DVR, consume the rated inverter ability during night time and inverter capacity remaining after excess or equal real power consumption of expensive the 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 sunny days[3]. It reduces the potential panel tariff around $900 per year by reducing the power utilization from the utility grid. Photovoltaic system a simple interleaved dc-dc converter is connected with a function called MPPT [1].

II. Block Diagram Description

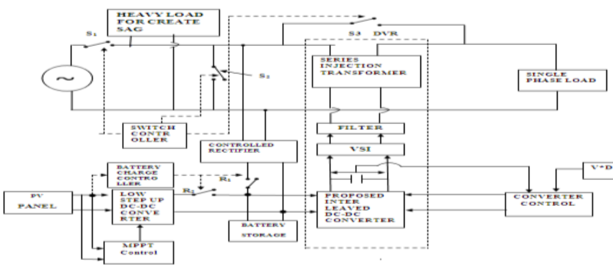

Fig. 1.Proposed block diagram

TABLE. I. OPERATION OF DVR

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. II. BATTERY CHARGE CONTROL

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

The block diagram of the proposed PV-DVR is shown in Fig.1.The proposed system consists of a PV array, low step-up DC–DC converter Closed loop control, Interleaved high step-up DC–DC converter, PWM inverter, series injection transformer, converter control and load, battery.

III. DVR Modes of Operation

A. *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]

B. *UPS mode:*

In this method, 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.

C. *Power protection mode:*

During additional power generation on the solar panel, the proposed PV-DVR disconnects the service net work 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.

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

(i) Interleaved high step up DC-DC converters are operated for high ratios, it leads to high voltage and current stress on the switch.

(ii) It produces high voltage gain when compared to the other boost converter.

(iii) To avoid the high level switching losses.

(iv) Ripple current rejection.

(v) To reduce loss minimum

IV. In-Phase Voltage Compensation Method

In general, there are three techniques such as pre sag, in-phase and minimum power injection technique are utilize to analyze the injection voltage of DVR. In-phase compensation technique is used to analyze injection voltage of DVR due to its easy performance e and quick response in calculate the compensate voltage. A DVR be able to compensate the voltage drop across a load by injecting a voltage through a series injection transformer in-phase with the source voltage[15]. The injected voltage across the secondary of the series injection transformer is in-phase with source voltage shown in fig.2 In regular form the supply voltage (Presag) 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.

$|V_{inj}| = |V_{presag}| - |V_{sag}|$ (1)

$V_{DVR} = V_{inj}$ (2)

$V_{DVR} = |V\_{presag}| - |V_{sag}|$ (3)

$V_{inj} = \theta_{inj} = \theta s$ (4)

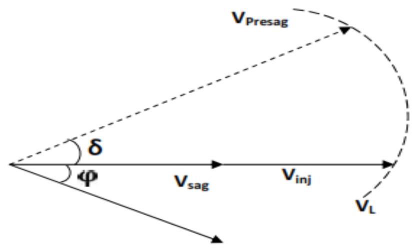

Fig.2. In phase compensation to presage voltage

V. PHOTOVOLTAIC ARRAY MODELING

Photo voltaic array is a arrangement which consists of extra photo voltaic cells to change sunlight 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 introduce between the photo voltaic and battery bank of the DC link[10]. The electrical energy powered 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 intensity as well as cell working temperature shown in fig.3

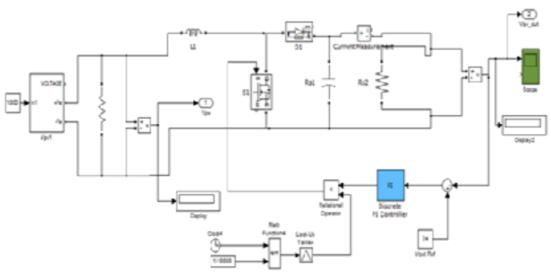

Fig.3.Photovoltaic with low step up dc-dc converter

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}+Io -Ic)-Rs Ic (5)

$V_{pv}=V_c \times N_s$ (6)

I_c=Ipv/Np (7)

CTv=1+$_{\beta T}$ T_a-T_y (8)

$C_{TI}=1+\gamma_T/S_r\ T_y-T_a$ (9)

Where bT = 0.004 and cT = 0.006. These two parameters are used to scale the effects of high temperature and solar irradiation levels on photo voltaic cell voltage and current. bT is the slope of the coefficient CTV, affect the change in voltage due to temperature change. cT is a constant in a place of change in working temperature due to solar irradiation. Ta and Ty represent the ambient temperature of the cell respectively.

The change in the photocurrent and working temperature due to change in the solar irradiation level can be expressed as follows:

$C_{SV}=1+\beta_T\ \alpha_s\ (S_X-S_R)$ (10)

$C_{SI}=1+1/S_c\ (S_X-S_R)$ (11)

Where Sc is the benchmark reference solar irradiation level during cell testing. Sr is the reference solar irradiation level (1000 W/m3), Sx is the new level of solar irradiation and as is the slope of the change in the solar irradiation level (0.2).

The recent value of cell output voltage and photo current can be expressed as follows:

$V_{cy}=C_{TV}\ C_{SV}\ V_C$ (12)

$I_{phy}=C_{TI}\ C_{SV}\ I_{ph}$ (13)

The temperature (ΔTc) can be expressed

ΔTc =αs (Sx-Sr) (14)

VO=Vin+Vc1+Vc2+VL2+Vc3 (15)

I. 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 photo voltaic unit. The parameters VPV and IPV calculated from the output of photo voltaic array is utilized to generate control signal (Vref) for the PWM generator. The flow chart of P&O MPPT algorithm shown in fig.4.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 volt- age (Vref) is obtained. The Vref compared to a saw tooth wave with 10 kHz frequency generates the PWM pulse.

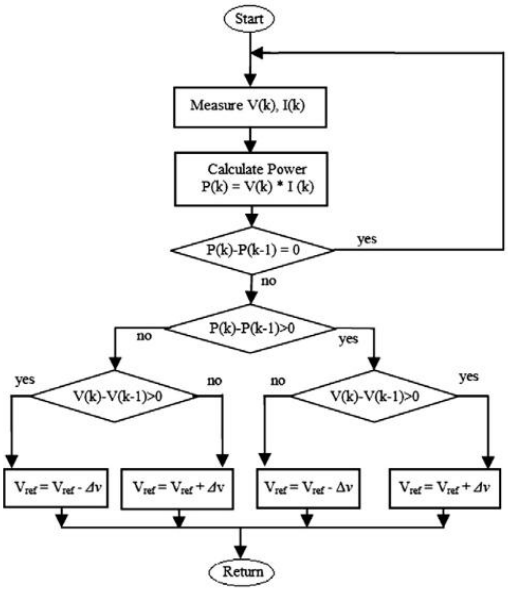

Fig.4. Flowchart P&O MMPT algorithm

II. PROPOSED METHOD INTERLEAVED HIGH STEP-UP DC–DC CONVERTER

During excessive current or excessive power function, interleaving of boost converters are well established. To receive benefit of the compensation of interleaving, interleaved coupled-inductor boost converter can be used. During this method, a single coupled inductor boost converter cell is treat as a cell and n such cells are coupled in parallel and operate at the constant switching frequency. More all the cells are operated at the equal duty ratio. It can be mention that due to inter leaving, the actual switching frequency as seen by the input and the output of the interleaved converter circuit is n times high than the switching frequency of a phase. Below standard or full-load condition, each of the interleaved cells uniformly shares the total output load. However less than lower output power demand condition, the number of working cells can be used for maximum efficiency operation of the individual cells. The number of parallel cells n in an interleaved converter mainly depends on the maximum power demand of the load and the maximum power rating of the interleaved cell. In the practical coupled inductors, due to the non ideal coupling between the primary and the secondary windings, there will be leakage inductances. This leakage inductance will cause high-voltage spikes when the switch is turned off

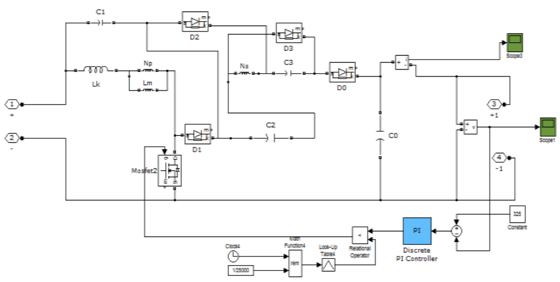

Fig. 5. Interleaved high step up dc-dc converter

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.

TABLE.3. COMPARISON OF PROPOSED INTERLEAVED BOOST CONVERTER WITH OTHER CONVERTER

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 vm	227	0.1	0.06
Proposed interleaved boost converter	400	0.07	0.25

VII.FUZZY LOGIC CONTROLLER DESIGN

In the conventional controllers like P, PI and PID, the control parameters are fixed at the time of design. So the conventional controllers offer good performance only for the linear system. When the operating point of the system is changed, the parameters of the conventional controllers should be designed again, and some trials and prior information of the systems are needed to design the parameters. The FLC is used to overcome the drawbacks of the conventional controllers

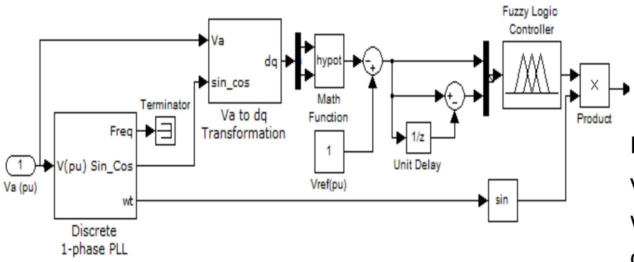

Fig. 6. Control structure of the proposed DVR

In the proposed method, discrete single phase PLL is used to track the phase angle of the source voltage and generates a reference signal with a magnitude of unity, locked to supply frequency. The supply voltage is converted into p.u. The p.u value of supply voltage is converted into |Vs| through d-q transformation, and error is obtained from the difference of |Vs| and reference value (Vref (pu)). Error and change in error are the inputs of FLC. The output of FLC is used to generate the Vref. The Vref in p.u. is fed to the Sinusoidal Pulse Width Modulation (SPWM) generator to produce switching pulses for VSI. The basic idea of SPWM is to compare a sinusoidal control signal (Vref) of normal frequency 50 Hz with a triangular carrier waveform (Vcarrier) with 1080 Hz signal to produce the PWM pulses. When the control signal is greater than the carrier signal, the switches turned on, and their counter switches are turned off. The output voltage of the inverter mitigates the sag, swell and outage.

The membership functions of the error and change in error inputs and output variables are shown in Figs.10, 11 and 12. The membership functions are triangular shaped with 50% overlap for a precise control.

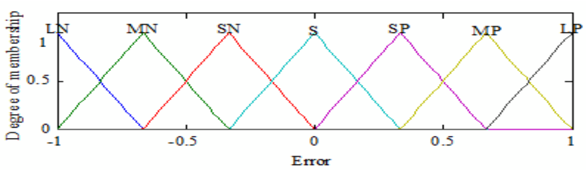

Fig. 7. Membership function used for input variable "error"

Fig. 8. Membership function used for input variable "change in error"

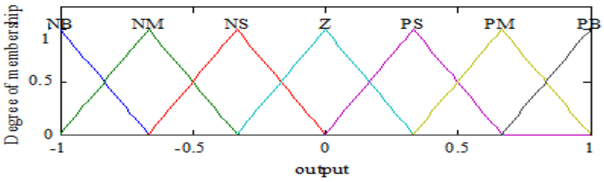

Fig. 9. Membership function used for output variable "output"

where, the inputs and output linguistic variables called fuzzy sets are labeled as follows: LN- Large Negative, MN- Medium Negative, SN- Small Negative, S- Small, SP – Small Positive, MP- Medium Positive, LP- Large Positive, NB- Negative Big, NM- Negative Medium, NS- Negative Small, Z- Zero, PS – Positive Small, PM- Positive Medium and PB- Positive Big.

Table.4 FUZZY RULES

e/	NB	NM	NS	Z	PS	PM	PB
NB	PB	PB	PB	PM	PM	PS	Z
NM	PB	PB	PM	PM	PS	Z	NS
NS	PB	PM	PM	PS	Z	NS	NM
Z	PM	PM	PS	Z	NS	NM	NM
PS	PM	PS	Z	NS	NM	NM	NB
PM	PS	Z	NS	NM	NM	NB	NB
PB	Z	NS	NM	NM	NB	NB	NB

Table.4 FUZZY RULES

The input signals are fuzzified and represented in fuzzy set notations by membership functions. The defined 'if and then' rules produce the linguistic variables and these variables are defuzzified into control signals to generate PWM gating pulses for VSI. There are 49 rules are utilized to produce the optimum control signal. The fuzzy rules used for simulation are shown in Table 4.

I. 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. 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 1 s. 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.

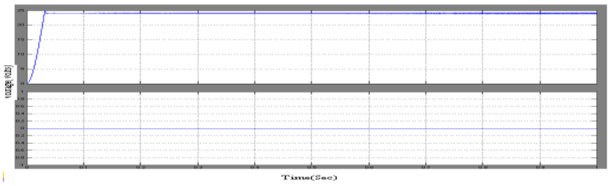

Fig.10 PV array output with boost converter

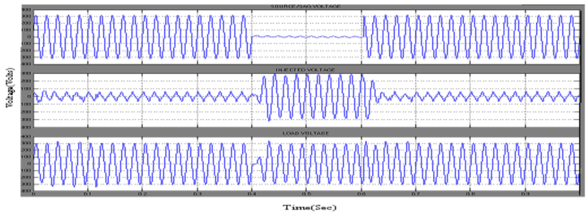

Fig:11.Supply voltage,Injectedvoltage,Load voltage

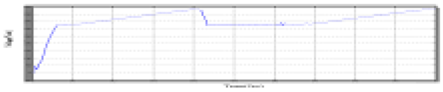

Fig.12 Constant Dcvoltage

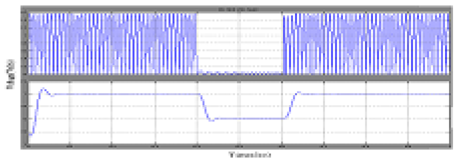

Fig:13 Filter output voltage

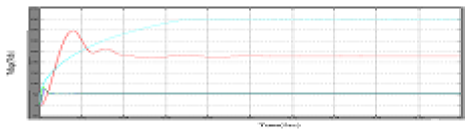

Fig.14 Interleaved Output with other Boost converter

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. 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 × 9), 9 cells are linked in 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, Fig. 7 Shows 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. Voltage sag formed the duration of 0.3 to 0.6s .Fig. 8 shows injected voltage by using PV-DVR. The output voltage is compensated Fig.9 shows the output voltage and fig.10 of the interleaved high step-up DC–DC converter with constant DC voltage.. A control circuit is incorporated with the proposed converter to regulate the output voltage at 230 V. Fig.10 Shows constant filter voltage and compensate using dynamic voltage restorer.Fig.10.Shows proposed interleaved high step up dc-dc converter with other converter and having setting time of 0.6 and constant 400dc voltage.

VI.Conclusion

For voltage sag/swell and outage mitigation at a houses or factories, an innovative application using a PV solar system as DVR is suggested. To track 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 too much 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 panel cost and prevents the utilize 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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