

# Design and Implementation of Photovoltaic Distribution Static Compensator

Dr Deepthi Janyavula

Lecturer, EEE Government Polytechnic, Sangareddy, Telangana

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**ABSTRACT:** Power quality is an important aspect of power systems. This paper deals with the design and implementation of Photovoltaic Distribution Static Compensator(PV-DSTATCOM). The work is done in MATLAB/SIMULINK. Perturb and Observe algorithm is used to simulate the proposed work. Maximum Power Point Tracking (MPPT) using Perturb and Observe algorithm is used to obtain duty ratio for controlling the switching devices of DSTATCOM.

**KEYWORDS:** Photovoltaic cell, PV-DSTATCOM, Perturb and Observe, MPPT.

## I. INTRODUCTION

Solar based devices have gained wide popularity due to their innumerable advantages. Solar energy is freely available, omnipresent and is renewable energy source. Solar PV-DSTATCOM can be used to supply active power to the grid. It can also be used for voltage regulation, power factor correction, and load balancing. A comprehensive review of solar PV-DSTATCOM is given by Nimita et.al [1].

Perturb and observe control algorithm based PV-DSTATCOM with multidirectional power flow has been demonstrated by Bhimsingh et.al[2]. Power supply to the grid and connected loads was demonstrated in this paper. Load balancing and power quality improvement conforming to IEEE-519 and IEEE-1547 was also shown.

An adaptive control algorithm for a multiobjective grid tied solar PV-DSTATCOM is demonstrated in [3]. The author explained the methodology to improve the grid currents power quality by estimating fundamental component of load current. This algorithm has proven to improve tracking accuracy, reduce steady state error and oscillation from the desired output.

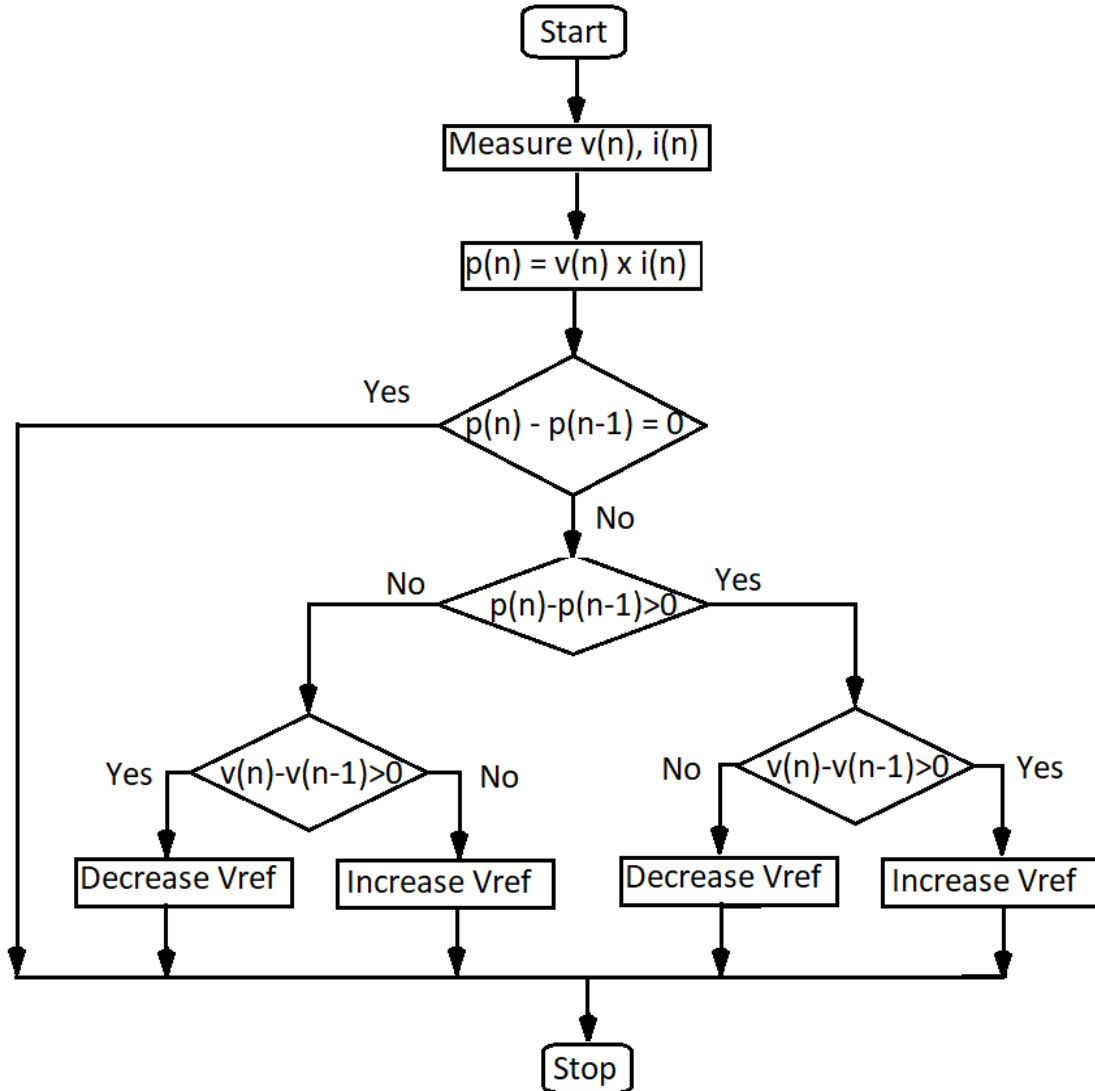
Meenakshi et.al demonstrated performance investigation of two-level reduced-switch DSTATCOM in grid-tied solar PV array with stepped perturb and observe maximum power point tracking algorithm and modified synchronous reference frame strategy [4]. This paper demonstrates maintenance of unity power factor along with feeding active power to the grid and feeding active and reactive power requirements of an unbalanced load. Modified synchronous reference frame theory was proposed in this paper which along with sustaining the DC link voltage also balances the voltages across split capacitors.

Application of PV-DSTATCOM for power quality improvement employing active current control was explained by Nirav et.al [5]. Along with active current control this paper also demonstrates using feed-forward control loop. Zero current harmonic suppression, load reactive current compensation, zero sequence content mitigation and power factor correction were obtained using PV-DSTATCOM. This configuration is computationally efficient and unconditionally stable.

Synchronous reference frame based PV-DSTATCOM with battery energy storage is demonstrated in for a 11kV/440V system for real power injection and improvement and power quality[6]. In this paper incremental conductance method is used to track the highest power of PV module. DC bus voltage is preserved using Bidirectional DC-DC converter.

The proposed work deals with design and implementation of PV-DSTATCOM connected to the grid using Perturb and Observe algorithm. Perturb and Observe algorithm is explained along with its implementation. The design of the system is explained along with its implementation. MATLAB/SIMULINK is used to implement the proposed work.

## II. MPPT ALGORITHM

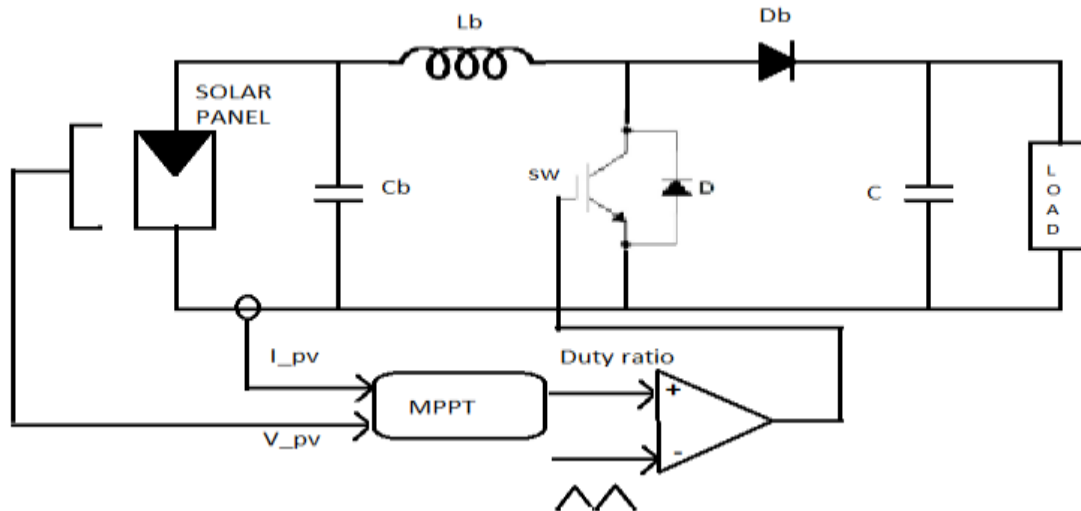


### MPPT algorithm flow chart

MPPT with Perturb and Observe algorithm gives outstanding performance because of its inherent adaptive capabilities [6]. Perturb and Observe algorithm is also easy to implement [7]. MPPT algorithm flowchart is as shown above. Initially  $v(n)$  and  $i(n)$  are measured. Then, the power  $p(n)$  is computed. If  $p(n)-p(n-1)$  is equal to zero, then the algorithm does not do anything. Whereas if  $p(n)-p(n-1)$  is not equal to zero, two

conditions arises. The first condition is  $p(n)-p(n-1)$  greater than zero. If yes, we further check if  $v(n)-v(n-1)$  is greater than zero. If yes, the reference voltage  $V_{ref}$  is increased. Otherwise  $V_{ref}$  will be decreased. The second condition is when  $p(n)-p(n-1)$  is lesser than zero. If yes, we further check if  $v(n)-v(n-1)$  is greater than zero. If yes, the reference voltage  $V_{ref}$  is decreased. Otherwise  $V_{ref}$  will be increased.

### III. SOLAR PV-DSTATCOM



#### Solar Inverter acting as solar PV-DSTATCOM

In a PV-DSTATCOM, solar panel is connected in parallel to the DC capacitor of a DSTATCOM as shown in figure above.  $V_{pv}$  and  $I_{pv}$  are the voltage across the solar panel and current generated by solar panel respectively.  $V_{pv}$  and  $I_{pv}$  are measured and fed to MPPT block. The MPPT block calculates the reference voltage  $V_{ref}$ , which is given to a comparator. A high frequency triangular carrier signal is also given to the comparator block. The comparator block compares the reference voltage  $V_{ref}$  and the high frequency triangular carrier signal in order to determine the duty ratio of switching device SW. Pulses generated by the comparator block are hence fed to the gate terminal of the IGBT which is acting as the switching device SW. Several other methods such as sliding mode controller [8] have been reported in literature for generation of pulses.

#### IV. DESIGN OF SYSTEM

Input voltage of the system i.e voltage generated by solar photovoltaic cell is in the range of 250-350V depending on the solar irradiance. PV module can be used to regulate the desired voltage at the DC link[9]. Output voltage is around 600V. Rated power of the system is 100kW. Switching frequency of the high carrier triangular wave is 5kHz. Acceptable values of current and voltage ripples are chosen to be 5% and 1% respectively.

The PV array is chosen to be consisting of ten modules connected in series to form a string. Forty seven such strings are connected in parallel. Each module has 60 cells. This array is connected in parallel to DC capacitor of DSTATCOM. Temperature and solar irradiance are given as

inputs to the PV array.

Design aspects pertaining to some of the parameters used in PV-DSTATCOM are given below [10]:

(i) **Input current :**

$$\text{Input current } I_{ip} = \frac{P}{V} = \frac{100 \times 10^3}{250} = 400A$$

(ii) **Current ripple :**

$$\text{Current ripple, } \Delta I = 5\% \text{ of } 400 = 20A$$

(iii) **Voltage ripple :**

$$\text{Voltage ripple, } \Delta V = 1\% \text{ of } 600 = 6V$$

(iv) **Output current :**

$$\text{Output current, } I_{op} = \frac{100 \times 10^3}{600} = 166A$$

(v) **Boost converter inductance :**

$$\text{Boost converter inductance, } L = \frac{V_{ip}(V_{op} - V_{ip})}{f_{sw} \times \Delta I \times V_{op}}$$

Upon substitution, we get  $L = 1.45 \text{ mH}$ .

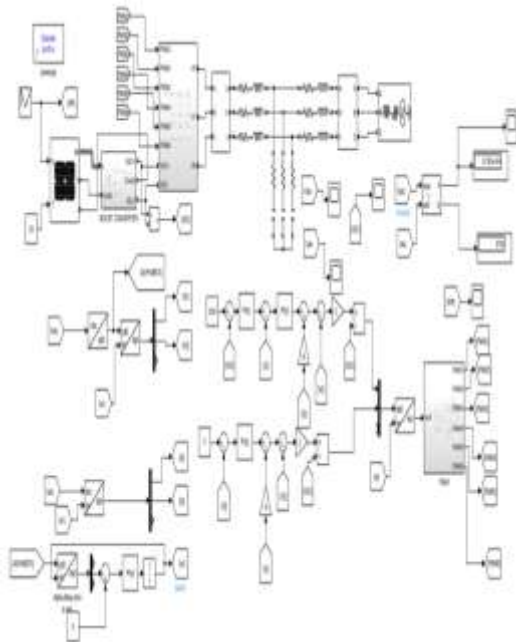
(vi) **Boost converter capacitance :**

$$\text{Boost converter capacitance, } C = \frac{I_{op}(V_{op} - V_{ip})}{f_{sw} \times \Delta V \times V_{op}}$$

Upon substitution, we get  $C = 3227 \mu\text{F}$ .

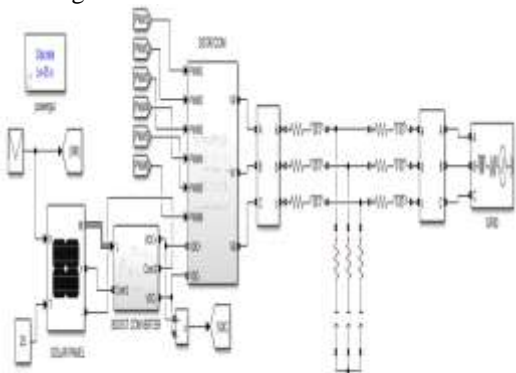
#### V. MODELING OF THE SYSTEM

The MATLAB/SIMULINK model of the PV-DSTATCOM connected to the grid is given below:



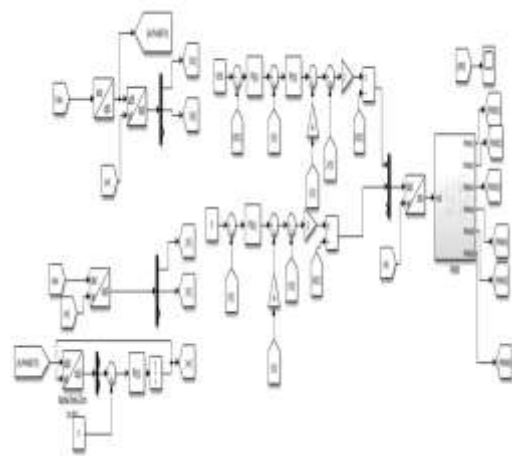
**SIMULINK model of complete system**

For clarity sake the SIMULINK models of individual blocks are given below. The solar PV-DSTATCOM connected to the grid is as shown in the figure below. This figure does not include the control block which generates the pulses for switching device of PV-DSTATCOM.



**PV-DSTATCOM connected to the grid**

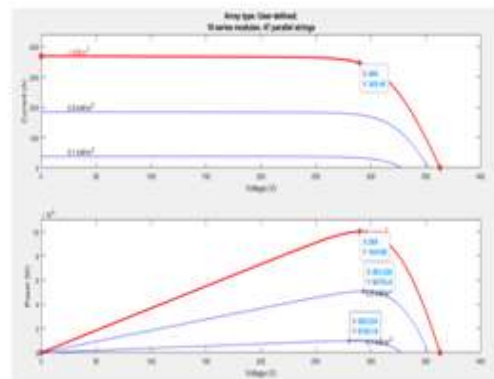
The control block that generates pulses for IGBT of the PV-DSTATCOM is shown in the figure below.



**PWM generation block**

**VI. RESULTS AND DISCUSSION**

Initially the solar PV array is considered as a stand-alone unit. Its current versus voltage and power versus voltage are as shown in the figure below for irradiance values of 1000W/m<sup>2</sup>, 500W/m<sup>2</sup> and 100W/m<sup>2</sup> at a constant temperature of 25°C.

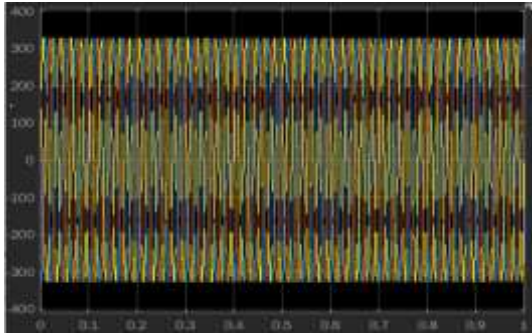


**Current and power versus voltage for varying irradiance**

The MPPT points for corresponding values of irradiance are also depicted in the above figure. Further results are displayed based on the value of irradiance in two cases. First one corresponds to constant irradiance and second one is for varying irradiance.

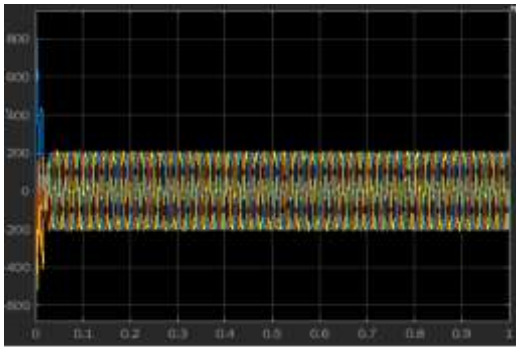
**Case (i): Constant irradiance**

In this case the irradiance is maintained constant at 1000W/m<sup>2</sup> at constant temperature of 25°C. The waveforms pertaining to output voltage are shown in the figure given below.



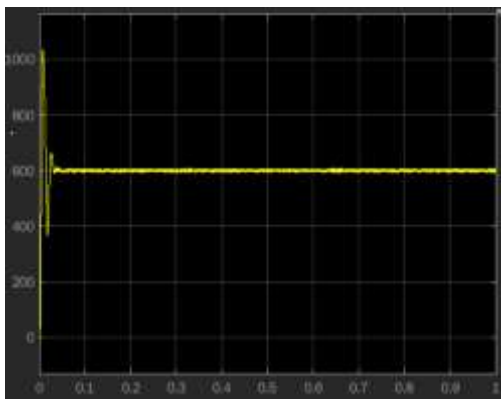
**Three-phase voltages**

Three-phase current waveforms are shown in the waveform below.



**Three-phase currents**

DC capacitor voltage is shown in the figure below. It can be seen that the DC capacitor voltage is being maintained at 600V.



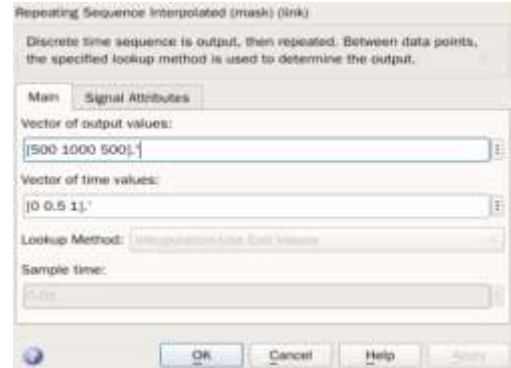
**DC capacitor voltage**

Three-phase instantaneous power waveform is shown in the figure below. From this figure, it can be inferred that the power is being maintained at MPPT value i.e. 100kW.

**Case (ii): Varying irradiance**

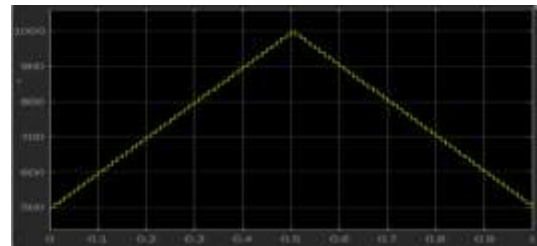
If the irradiance is not constant and changes as shown in the figure below, then the

results are shown in this sub-section.



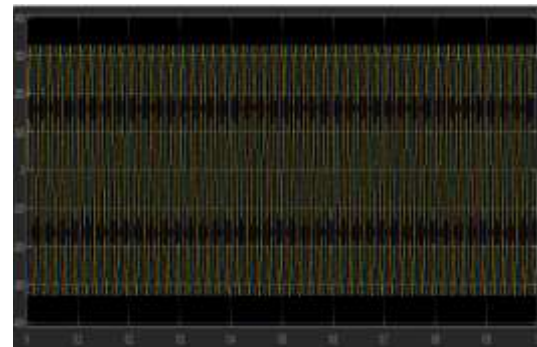
**Variation of irradiance**

The same variation of irradiance with respect to time is shown graphically in the figure given below.



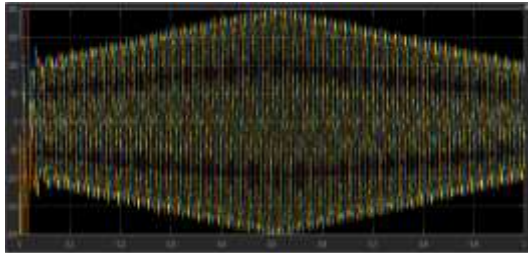
**Variation of irradiance**

In this case the three-phase voltage waveforms are shown in the figure below.



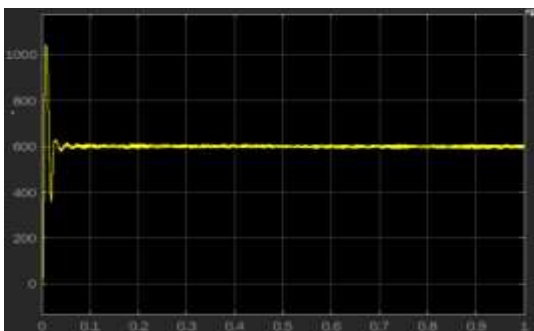
**Three-phase voltages**

Three-phase current waveforms are shown in the figure below. It is clearly evident that the current generated is directly proportional to the irradiance values.



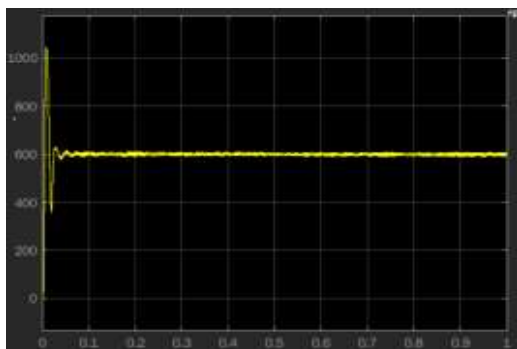
**Three-phase currents**

DC capacitor voltage is shown in the figure below. It can be seen from the figure below that inspite of variation in irradiance, the DC capacitor voltage is being maintained at 600V.



**DC capacitor voltage**

Three-phase instantaneous power graph is shown in the figure below. It can be seen from this graph that the power is directly proportional to irradiance.



**Three-phase instantaneous power**

## VII. CONCLUSION

This paper gives a bird's-eye view into the design aspects pertaining to a solar PV-DSTATCOM based on MPPT implemented by Perturb and Observe algorithm. All the aspects pertaining to design of PV-DSTATCOM were discussed in detail. The PV-DSTATCOM hence designed is connected to the grid and results are observed in MATLAB/SIMULINK. The results pertaining to the waveforms of three-phase voltages, three-phase current, DC capacitor voltage

and three-phase instantaneous power are shown. It was also inferred that DC capacitor voltage can be controlled independent of the level of irradiance, whereas three-phase currents and instantaneous three-phase power are directly proportional to irradiance values at constant temperature.

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