THREE PHASE SOLAR INTEGRATED UPQC USING MPPT WITH P&O ALGORITHM

Sonali L. Jawade[1],Dr. K. D. Thakur [2]
Electrical Engineering Department
Government College of Engineering, Amravati,
Maharashtra, India

Abstract : This paper deals with the performance analysis of a three-phase single stage solar photovoltaic integrated unified power quality conditioner (PV-UPQC). The PV-UPQC consists of a sries and shunt connected voltage compensators connected with common DC-link. The shunt compensator extracts power from the PV-array by using a maximum power point tracking (MPPT) algorithm. The series compensator protects the load from the grid side power quality problems such as voltage sags/swells by injecting appropriate voltage in phase with the grid voltage. The main intent of this paper is to integrate a solar photovoltaic (SPV) generating system to three-phase grid and to provide a clean and uninterrupted flow of power at abnormal and peak load conditions. In this work, (P& O) algorithm is used for implementing MPPT. The presented system is modelled, designed and simulated on MATLAB/Simulink.

***IndexTerms* - Power Quality, shunt compensator, series compensator, UPQC, Solar PV, MPPT.**

I. INTRODUCTION

Due to the growing demand on electricity, the limited stock and rising prices of conventional sources (such as coal and petroleum, etc.), photovoltaic (PV) energy becomes a promising alternative as it is omnipresent, freely available, environment friendly, and has less operational and maintenance costs [1]. Therefore, the demand of PV generation systems seems to be increased for both standalone and grid-connected modes of PV systems. Therefore, an efficient maximu1m power point tracking (MPPT) technique is necessary that is expected to track the MPP at all environmental conditions and then force the PV system to operate at that MPP point. MPPT is an essential component of PV systems.

Review on MPPT Techniques

The following techniques are some of the widely used MPPT techniques applied on various PV applications such as space satellite, solar vehicles, and solar water pumping, etc.

1. Curve-Fitting Technique
2. Fractional Short-Circuit Current(FSCI) Technique
3. Perturbation and Observation (P&O) And/Hill-Climbing Technique

1.Curve-Fitting Technique:

MPP is the extreme value of the – characteristic of a PV panel, hence first the – characteristic of a PV panel is predicted in this technique. To predict, this – characteristic, PV panel can be modeled offline based on mathematical equations or numerical approximations. To achieve an accurate P-V curve fitting, a third-order polynomial function as

$$P = aV^3 + bV^2 + cV + d \quad (1.1)$$

Where the coefficients b, c and are determined by sampling of PV voltage and power in intervals. Differentiation of (1) gives

$$\frac{dP}{dV} = 3aV^2 + 2bV + c \quad (1.2)$$

$$\text{At MPP, } \frac{dP}{dV} = 0 \quad (1.3)$$

Thus, the voltage at MPP can be calculated as

$$V_{mpp} = \frac{-b \pm \sqrt{b^2 - 3ac}}{3a} \quad (1.4)$$

In this technique, a, b, c and d are are repeatedly sampled in a span of few milliseconds using mathematical equations and then V_{mpp} is calculated.

2. Fractional Short-Circuit Current (FSCI) Technique :

There exists a single operating point P(Vmpp, Impp) called MPP at which the power of the panel is maximum (Pmpp) at a given environmental condition (Fig. 1). If by some means, any one of Impp or Vmpp are tracked then the corresponding Pmpp can be tracked.

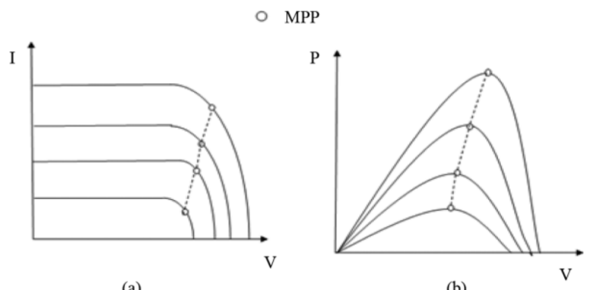


Fig.1. (a) I-V and (b) P-V characteristics of PV panel at different environmental conditions

In the FSCI technique, the nonlinear – characteristics of PV system is modeled using mathematical equations or numerical approximations taking account of a wide range of environmental conditions and degradation level of PV panel. Based on those – characteristics, a mathematical relation between and is constructed as is linearly dependent on by an empirical relation shown as follows:

$$I_{mpp} \approx K_{sc} I_{sc} \qquad (2.1)$$

Equation (2.1) constructs the FSCI method. The value of K_{sc} generally varies between 0.64 and 0.85. K_{sc} can be calculated by analyzing the PV system at wide range of solar radiations and temperatures.

3.Perturbation and Observation (P&O) And/Hill-Climbing Technique:

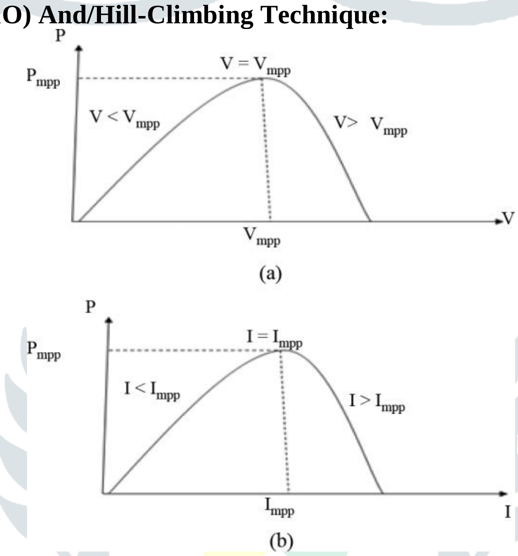


Fig 2. (a) I-V curve explaining feedback variation of power with voltage
(b) P-V curve explaining feedback variation of power with current

In this technique, first the PV voltage and current are measured and hence the corresponding power P1 is calculated. Considering a small perturbation of voltage(**Δ**V) or perturbation of duty cycle (**Δ**d) of the dc/dc converter in one direction corresponding power P2 is calculated.P2 is then compared with P1. If P2 is more than P1, then the perturbation is in the correct direction; otherwise it should be reversed. In this way, the peak powerpoint (P_{mpp}) is recognized and hence the corresponding voltage (V_{mpp}) can be calculated. The major drawbacks of P&O/hill-climbing are occasional deviation from the maximum operating point in case of rapidly changing atmospheric conditions, such as broken clouds. To solve this problem, a modified adaptive hill climbing technique(Fig.3) with a variable perturbation step size can be used, where an automatic tuning controller varies the perturbation step size to a large value when the power changes in a large range primarily due to environmental variation, to satisfy the fast response requirement during the transient stage.

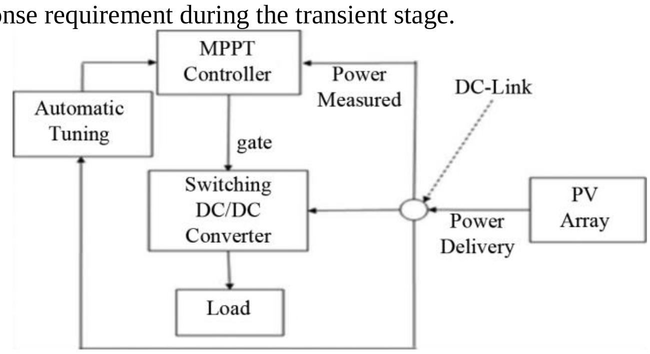


Fig. 3. Block diagram of adaptive Hill-climbing technique

II. SYSTEM CONFIGURATION

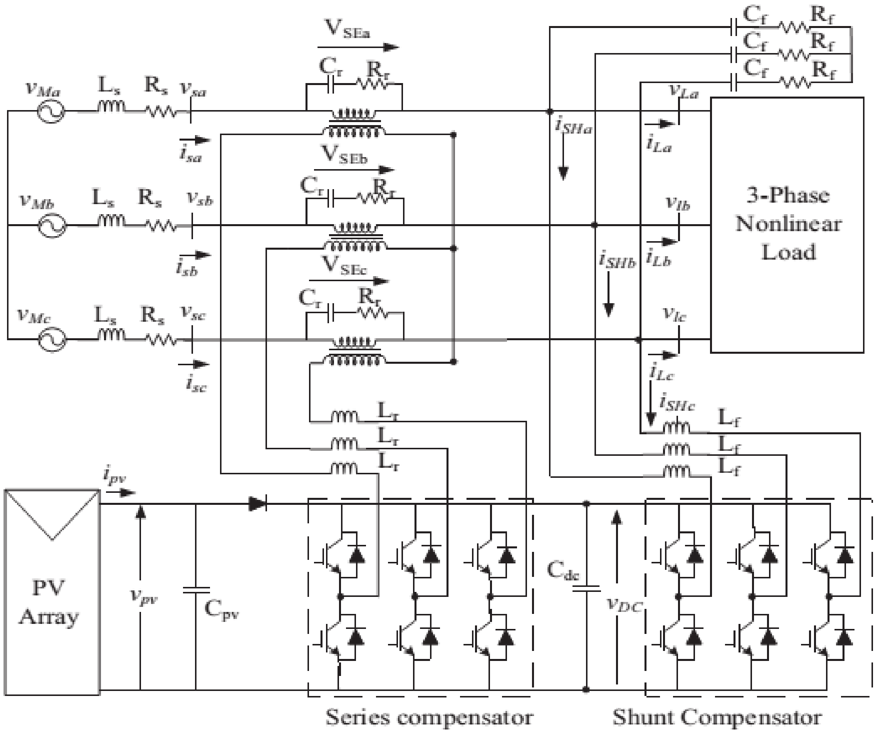


Fig. 4. System Configuration PV-UPQC

The structure of the PV-UPQC is shown in Fig.4. The PV-UPQC is designed for a three-phase system. The PVUPQC consists of shunt and series compensator connected with a common DC-bus. The shunt compensator is connected at the load side. The solar PV array is directly integrated to the DC-link of UPQC through a reverse blocking diode.

III. CONTROL STRATEGY OF PV-UPQC:

3.1.Control of Shunt Compensator:

The shunt compensator extracts the maximum power from the solar PV-array by operating it at its maximum power point. The maximum power point tracking (MPPT) algorithm generates the reference voltage for the DC-link of PV-UPQC. In this work, (P& O) algorithm is used for implementing MPPT. The DC-link voltage is maintained at the generated reference by using a PI-controller. To perform the load current compensation, the shunt compensator extracts the active fundamental component of the load current. For this work, the shunt compensator is controlled by extracting fundamental active component of load current using SRF technique. The control structure of shunt compensator is shown in Fig. 5. The load currents are converted to d-q-0 domain using the phase and frequency information obtained from PLL. The PLL input is the PCC voltage. The d-component of the load current (ILd) is filtered to extract DC component (ILdf) which represents the fundamental component in abc frame of reference. To extract DC component without deteriorating the dynamic performance, a moving average filter (MAF) is used to extract the DC component. The transfer function of moving average filter is given as,

$$\text{MAF}=\frac{1-e^{-T_w s}}{T_w s} \qquad (3.1.1)$$

Where $T_w s$ the window length of the moving average filter

$$I_{pvg} = \frac{2}{3}\frac{P_{pv}}{V_s} \qquad (3.1.2)$$

Where P_{pv} is the PV array power and Vs is the magnitude of the PCC voltage.

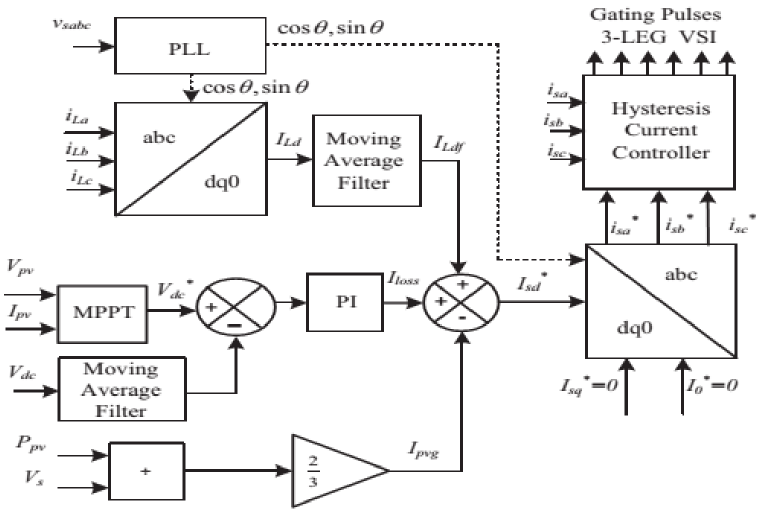


Fig. 5 Control Structure of Shunt Compensator

3.2. Control of Series Compensator:

The control strategy for the series compensator are presag compensation, in-phase compensation and energy optimal compensation. In this work, the series compensator injects voltage in same phase as that of grid voltage, which results in minimum injection voltage by the series compensator. The control structure of the series compensator is shown in Fig.6. The fundamental component of PCC voltage is extracted using a PLL which is used for generating the reference axis in dq-0 domain. The reference load voltage is generated using the phase and frequency information of PCC voltage obtained using PLL. The PCC voltages and load voltages are converted into d-q-0 domain. As the reference load voltage is to be in phase with the PCC voltage, the peak load reference voltage is the d-axis component value of load reference voltage. The q-axis component is kept at zero. The difference between the load reference voltage and PCC voltage gives the reference voltage for the series compensator. The difference between load voltage and PCC voltage gives the actual series compensator voltages. The difference between reference and actual series compensator voltages is passed to PI controllers to generate appropriate reference signals. These signals are converted to abc domain and passed through pulse width modulation (PWM) voltage controller to generate appropriate gating signals for the series compensator.

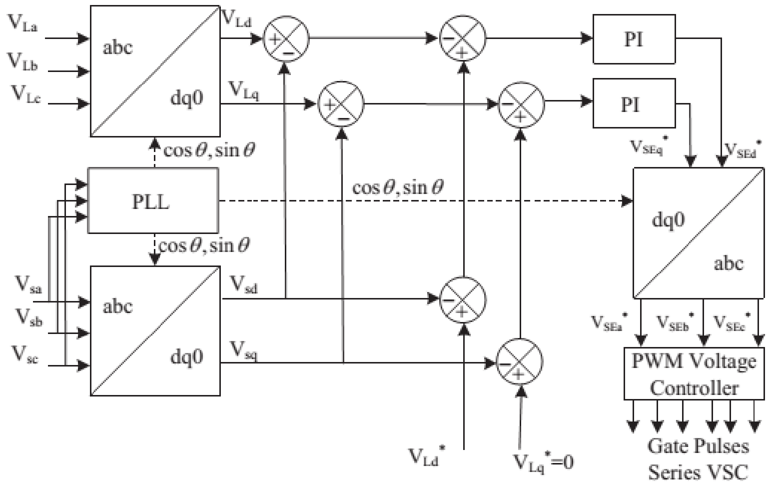


Fig. 6.Control Structure of Series Compensator

Table 1: Simulation parameters

System Quantities	Values
PCC line voltage	415V ,50Hz
DC-link voltage	700V
DC-link Capacitor	9.3 Mf
Shunt comp inductor	1 mH
PWM freq	10kHz
Ripple filter	10µF ,10**Ω**
Series comp inductor	3.6mH
DC-link PI controller gains	Kp=1.5 Ki=0.1
Series VSC PI gains for d	Kp=8

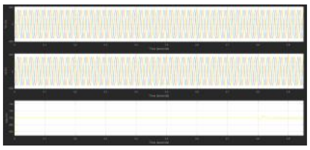
and q axis	Ki=1200
PV array parameters	
	Voc=864V Isc=62.65 A Vmpp=701 V Impp=58.94 A Ppv=41.35 kW

IV. RESULTS AND DISCUSSION

V. The steady state and dynamic performances of PV-UPQC are analyzed by simulating the system in Matlab-Simulink software. The load used is a nonlinear load consisting of three phase diode bridge rectifier with R-L load. The solver step size used for the simulation is 1e-6s. The system is subjected to various dynamic conditions such as sag and swell in PCC voltage and PV irradiation variation.

A. Performance of PV-UPQC at Load Unbalancing Condition

The dynamic performance of PV-UPQC under load unbalance condition is shown in Fig.7. At t=0.8s, phase ’b’ of the load is disconnected. It can be observed that the grid current is sinusoidal and at unity power factor. The current fed into the grid rises leading due to the reduction in the total effective load. The DC-link voltage is also stable and it is maintained near its desired regulated value of 700 V



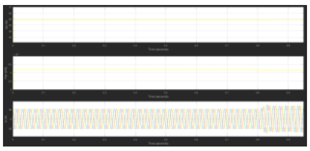
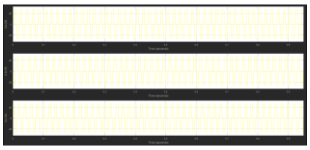
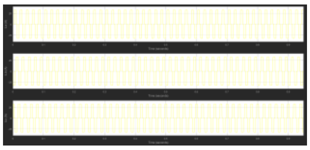


Fig. 7. Performance PV-UPQC during Load Unbalance Condition

A. Performance of PV-UPQC under Varying Irradiation

The dynamic performance of PV-UPQC under varying solar irradiation is shown in Fig.8. The solar irradiation is varied from 500W/m2 at 0.8s to 1000W/m2 at 0.85s. It is observed that as irradiation increases, the PV array output increases and hence grid current rises as the PV array is feeding power into the grid.





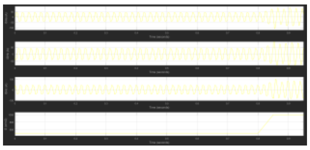


Fig. 8 Performance PV-UPQC at Varying Irradiation Condition

IV. CONCLUSION

The design and dynamic performance of three-phase PV UPQC have been analyzed under conditions of variable irradiation and under load unbalance condition. The system is found to be stable under variation of irradiation and load unbalance. The performance of d-q control particularly in load unbalanced condition has been improved through the use of moving average filter. It can be seen that PV-UPQC is a good solution for modern distribution system by integrating distributed generation with power quality improvement.

REFERENCES

[1] Sachin Devassy and Bhim Singh, "Design and Performance Analysis of Three – Phase Solar PV Integrated UPQC," IEEE Transaction on Industry Applications,2017.

[2] B. Mountain and P. Szuster, "Solar, solar everywhere: Opportunities and challenges for australia's rooftop pv systems,"IEEE Power and Energy Magazine, vol. 13, no. 4, pp. 53–60, July 2015.

[3] B. Subudhi and R. Pradhan, "A comparative study on maximum power point tracking techniques for photovoltaic power systems,"IEEE Trans actions on Sustainable Energy, vol. 4, no. 1, pp. 89–98, Jan 2013.

[4] Y. Yang, P. Enjeti, F. Blaabjerg, and H. Wang, "Wide-scale adoption of photovoltaic energy: Grid code modifications are explored in the distribution grid," IEEE Ind. Appl. Mag., vol. 21, no. 5, pp. 21–31, Sept 2015.

[5] M. J. E. Alam, K. M. Muttaqi, and D. Sutanto, "An approach for online assessment of rooftop solar pv impacts on low-voltage distribution networks,"IEEE Transactions on Sustainable Energy, vol. 5, no. 2, pp. 663–672, April 2014.

[6] J. Jayachandran and R. M. Sachithanandam, "Neural network-based control algorithm for DSTATCOM under nonideal source voltage and varying load conditions,"Canadian Journal of Electrical and Computer Engineering, vol. 38, no. 4, pp. 307–317, Fall 2015.

[7] A. Parchure, S. J. Tyler, M. A. Peskin, K. Rahimi, R. P. Broadwater, and M. Dilek, "Investigating pv generation induced voltage volatility for customers sharing a distribution service transformer,"IEEE Trans. Ind. Appl., vol. 53, no. 1, pp. 71–79, Jan 2017.

[8] E. Yao, P. Samadi, V. W. S. Wong, and R. Schober, "Residential demand side management under high penetration of rooftop photovoltaic units," IEEE Transactions on Smart Grid, vol. 7, no. 3, pp. 1597–1608, May