IJEASM

International Journal of Engineering Applied Science and Management
ISSN (Online): 2582-6948
Vol. 4 Issue 8, Aug 2023

A Review on a design and Performance Analysis of Three-Phase Solar PV Integrated UPQC

Shriyank Kumar Pandey[1], Indrajeet Kumar[2], Priyank Gour[3]
Research Scholar, Department of Electrical and Electronics Scope College of Engineering, Bhopal (M.P.)[1]
Assistant Professor, Department of Electrical and Electronics Scope College of Engineering, Bhopal (M.P.)[2,3]

Abstract: *This paper depicts a PV integrated UPQC system that is been utilized for enhancement of voltage magnitude of the system. The PVA is been connected to UPQC at the DC link in order to inject active and reactive power to the grid. Separate controllers that work in synchronization are been designed for series and shunt converters along with feedback circuit from load and source currents and voltages. Sinusoidal PWM and MPPT technique forms a major base. For improvement of voltage magnitude a SVPWM control system is been integrated. Various literature works has also been reviewed for a better understanding of the topic.*

Keywords: *UPQC, adaptive filter, SVPWM , MPPT, PV systems, sinusoidal PWM.*

1. Introduction

In the present scenario, as the conventional energy sources are moving towards depletion at a faster rate the research and development of non-conventional sources of energy like solar, wind, hydel, bioenergy etc are finding wide boost. To make further improvement in this field, they are interfaced and augmented with the power electronic devices. This has also led to the improvement in the performance of the industries. However, majority of these power electronic devices acts as non-linear loads that introduce harmonics in the system and reduces the power factor of the system [5]. The rise of inductive loads in the system, has led to higher consumption of reactive power that increases the utility size and power losses of the system, thereby making the whole power system network unstable [2]. The implementation of the conventional methods may lead to harmonic reduction and power factor improvement but faces conditions like resonance, fixed compensation characteristics and bulky size. Here comes the role of power electronic based

custom power devices such as unified power quality conditioner (UPQC) that are superior to the conventional methods and highlights optimal solutions for power quality problem mitigation. The conventional PV power systems had stand-alone mode of operation that supplied power to only some fixed loads and was not been used optimally. In the current scenario it is been integrated with utility lines and grid and the inverters connected to them help in providing real power to the loads. The problem of harmonics in the system has led to the development of inverters and filters that help in active and reactive power compensation. However, the development of the previously mentioned inverter requires several sensors and also the non-linear effect of filter is not taken into account, this has lead to non-optimal utilization of filter capacity [14].
Section II gives a general overview of UPQC followed by the overview of PV systems and MPPT algorithm in section III. Section IV gives a brief introduction of Sinusoidal PWM. Section V discusses the concept of Fuzzy Integrated System. Lastly, the paper is concluded in section VI along with references.

2. Unified Power Quality Conditioner (UPQC)

A Unified Power Quality Conditioner (UPQC) is a device that is very much in similar in construction to a Unified

International Journal of Engineering Applied Science and Management
ISSN (Online): 2582-6948
Vol. 4 Issue 8, Aug 2023

Power Flow Conditioner (UPFC). The UPQC utilizes two voltage source inverters that are connected to energy storage capacitor. One of these is connected in series and the other is connected in shunt with the ac system[1].

A UPQC present in a power transmission system performs shunt and series compensation at the same time. Taking the load voltage, V_L as a reference phasor and assuming the lagging load power factor as cos φ_L we obtain:

$$v_t = v_L(1+k)\angle 0°$$
$$k = \frac{v_t - v_L}{v_L}$$

k represents source fluctuations

The voltage injected by series APF:

$$V_{sr} = V_L - V_t = -kV_L\angle 0°$$

The UPQC is assumed to be lossless and the active power required by the load is equivalent to the active power input at PCC. The UPQC gives a unity power factor source current, therefore, for a given load condition the input active power at PCC is expressed by –

$$P_t = P_L$$
$$v_L(1+k).I_s = V_L.I_L.\cos\emptyset_l$$

From the above equation we can see that the source current depends on the factor k, since φ_L and i_L are load characteristics and they are constant for a particular type of load. The apparent power absorbed by the series APF is expressed as:

$$S_{sh} = V_L.i_{sh}$$

The current offered by the shunt APF, is the difference between input source current and load current, that includes reactive current and load harmonics current. Hence we derive:

$$i_{sh} = i_s - i_L$$
$$P_{sh} = V_L.i_{sh}.\cos\emptyset_{sh}$$
$$Q_{sh} = V_L.i_{sh}.\sin\emptyset_{sh}$$

Figure 1 a gives phasor representation of the normal working condition, considering load voltage V_L taken as reference and power factor angle φL lagging to load. In this condition i_s will be exactly equal to the i_L as no compensation is provided.

When shunt APF is operated, it supplies the load by injecting a 90° leading current in such a way that the source current is in phase with the terminal voltage as depicted in fig.1 b. The phasor representations of voltage sag and voltage swell of the system are shown in the fig 1c and 1d respectively. The below phasor representation shows that a little amount of active power flows through the shunt APF[3].

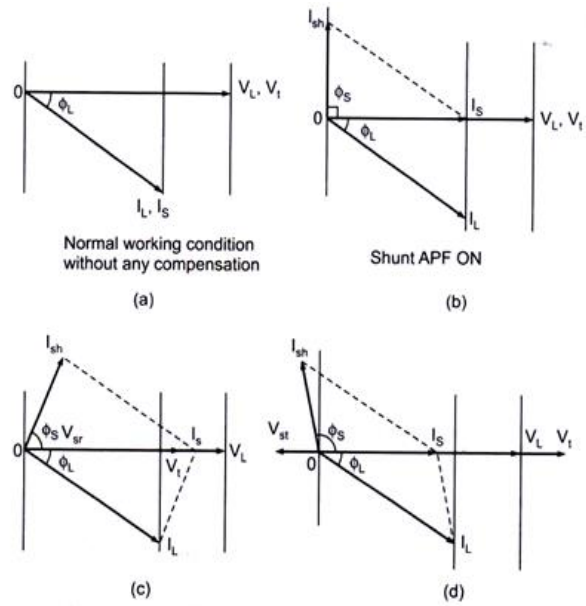

Fig. 1 Phasor representation for inductive load

Fig. 2 a shows the phasor representation of the normal working condition, considering leading power factor angle of the load. In this condition i_s will be exactly equal to the i_L. When shunt APF operates, it cancels ut and the VARS generated by the load on injecting a 90° lagging current in such a way that the source current is in phase with the terminal voltage as shown in phasor diagram Fig. 2b. The phasor representations of voltage sag and voltage swell condition are shown in fig. 2c and fig. 2d respectively.

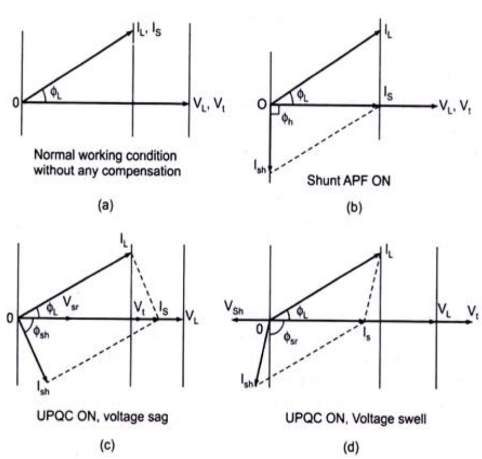

Fig. 2 Phasor representation for conductive load.

International Journal of Engineering Applied Science and Management
ISSN (Online): 2582-6948
Vol. 4 Issue 8, Aug 2023

3. PV Systems

3.1 Overview

A basic Si PV cell comprises of a thin wafers of an ultra-thin layer of phosphorus-doped (N-type) Si on top of a thicker layer of boron-doped (P-type) Si. An electrical field is produced at the surface contact of these two. When sunlight strikes the surface of a PV cell, this electrical field gives energy and excites light-animated electrons, prompting a stream of current through the cell and thereby providing it to the electrical load [4]. Regardless of size, even a small semiconductor PV cell produces about 0.5 – 0.6 volt DC under open-circuit, no-heap conditions. The power yield of a PV cell depends on its proficiency and size and is relative to the force of sunlight falling on the surface of the cell. PV systems are simply placed like all alternative electric power generating systems. The instrumentation used is totally different than that used for typical mechanical device creating frameworks. The PV system is interfaced with the alternate electrical systems by proper steps and following electrical codes and standards.Though a PV array produces power once exposed to sunlight, range of alternative parts are needed to appropriately direct, control, convert, disseminate, and store the vitality made by the exhibit. Depending upon the use and operational needs of the system, the particular parts needed may embrace major parts like a DC-AC power electrical converter, battery bank, framework and battery controller, assistant vitality sources and commonly the required electrical load. In addition, assortment of balance of system (BOS) hardware, wiring, over current, flood insurance, detach gadgets and different power processing instruments need to be taken care of properly. Photovoltaic power systems are usually classified according to the use and operational necessities, their element configurations, and the connection way of the instrumentation to different control sources and electrical burdens. The two essential characterizations are square measure matrix associated or utility-intelligent frameworks and complete systems. Electrical phenomenon systems are designed to produce DC and/or AC.

Grid-connected or utility-intelligent PV frameworks are proposed to work in parallel with and interconnected with the electrical utility lattice. The initial segment in the associated PV framework is the electrical converter or power obtaining unit. The PCU changes over the DC control made by the PV and exhibits it into AC control in accordance with the voltage and power quality necessities of the utility lattice, and mechanically stops the movement capacity to the matrix once the utility framework is not stimulated. A bi-directional interface is made between the PV framework AC yield circuits and also the electrical utility system, for the most of the part at partner on-the-scene circulation board or passage. This allows the AC control made by the PV framework to either give on-the-spot electrical burdens or to feedback the network once the PV framework yield is greater than the one location stack request[4].

3.2 Maximum Power Point Tracking Algorithm

MPPT algorithms are essential in PV applications because the MPP of a solar panel varies with the irradiation and temperature, and in order to obtain the maximum power from a solar array one of the following MPPT algorithms are used:

3.3 Perturb and Observe Method

Various MPPT techniques are used for solar PVA. One among them is Perturb and Observe. The P&O algorithm is also called “hill-climbing”, both the names denote the same algorithm based on how it is implemented.

Hill climbing consists of a perturbation on the duty cycle of power converter and P&O involves a perturbation in the operating voltage of the DC link in between the PV array and the power converter [8]. In case of the Hill climbing technique, perturbing the duty cycle of the power converter means modifying the voltage of the DC link between the PV array and the power converter, therefore both the names refer to one and the same technique. In this method, the point of the last perturbation and the point of last increment in power are used to determine next perturbation. As it can be seen in Figure 3, on the left of the MPP that increasing the voltage raises the power whereas on the right decreasing the voltage increases the power[5].

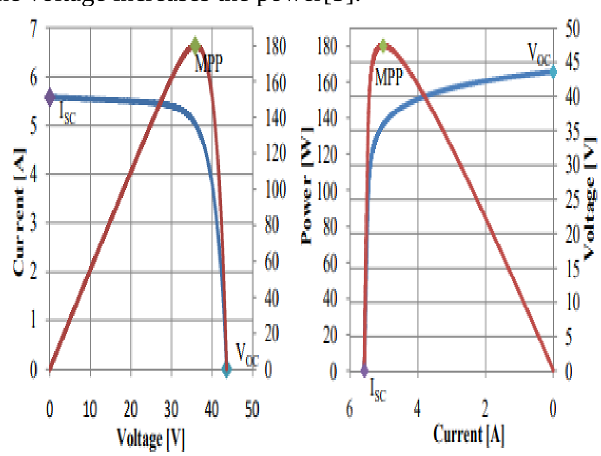

Fig.3 PV characteristics

If there is an increase in power, then perturbation should be kept in same direction and if there is decrease in power, then the next perturbation should be in opposite direction. Based on these facts, the algorithm is implemented [8]. This process is repeated till the MPP is reached. Here the operating point oscillates around MPP. The algorithm scheme is shown in Figure 4.

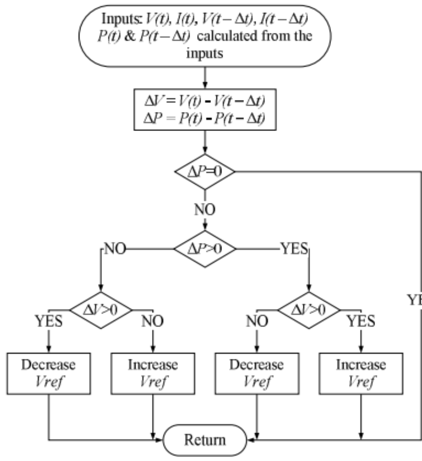

Fig.4 P& O algorithm.

3.4 Incremental Conductance

The incremental conductance algorithm depends on the fact that slope of the curve power vs. voltage (current) of PV module at the MPP is zero, positive (negative) on the left of it and negative (positive) on the right of it. By comparing the increment of the power vs. that of the voltage (current) between two consecutive samples, the MPP voltage changes can be determined. The algorithm scheme is shown in Figure 5.

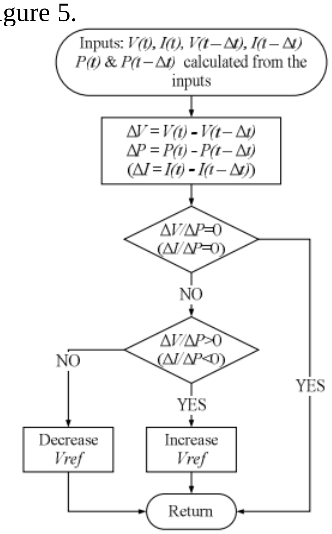

Fig.5 Incremental Conductance algorithm.

In both Cond and P&O schemes, based on the size of the increment of the reference voltage how fast the MPP is reached is found out. Mainly there are two drawbacks of these techniques. The first and foremost is that they can easily lose track of the MPP if the irradiation changes rapidly [15]-[18]. Second drawback of both methods is the voltage and current oscillations around the MPP during steady state [7], [17], [19], [20]. The control technique that is used to govern the VSI (Voltage source Inverter) utilizes IRP (immediate reactive power) hypothesis. This control method points out the specified responsive energy that must be infused to repay the need of the load. It takes a criticism of the load cutting-edge and moreover supply voltage to persuade the DG to synchronize to the matrix. By growing the reference of the modem the system produces six heartbeats for six switches utilizing PWM (Pulse width modulation) strategy.

There may be a chance that PV sun powered boards are constructed from individual photovoltaic cells attached together, at that point the sun Photovoltaic Array, i.e. stated just as a solar Array being a machine made up of a meeting of sun-based boards related together. A photovoltaic show off is on this way numerous solar-orientated boards electrically stressed together to frame a considerably bigger PV establishment (PV system) called a cluster, and all in all the bigger the mixture surface territory of the exhibit, the greater the solar-oriented strength it's going to create.

4. Sinusoidal Pulse Width Modulation

Pulse width modulation is a method that is used to lessen the overall harmonic distortion (THD) in a load current or in other words is a technique where a controlled ac output voltage is attained by adjusting the on-off periods of the inverter elements on application of a fixed dc input voltage. It is a conventional method of controlling the output voltage. It makes use of a pulse wave in square or rectangular form that results in a variable average waveform value f(t), after the modulation of its pulse width. The modulation time period is depicted by T. Hence the waveform average value is given by

$$\bar{y} = \frac{1}{T}\int_{0}^{T} f(t)\, dt$$

International Journal of Engineering Applied Science and Management
ISSN (Online): 2582-6948
Vol. 4 Issue 8, Aug 2023

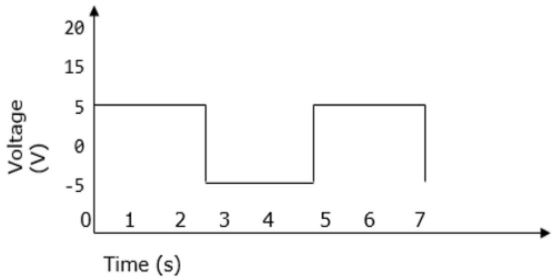

Fig.6 PWM

When the switches of a voltage inverter are switched ON and OFF a number of times then a harmonic profile with an improved waveform is obtained in place of a square wave. When the desired modulated waveform is compared to that of a high frequency triangular waveform a sinusoidal PWM waveform is obtained. The resultant output voltage of the DC bus would either be positive or negative despite the signal voltage being smaller or larger than the carrier waveform.

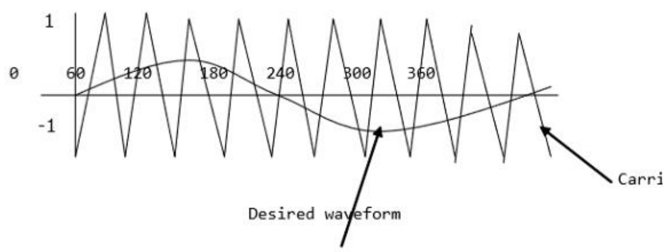

Fig.7. Sinusoidal PWM

$$\text{Modulating Index (m)} = {}^{Am}/_{Ac}$$

Where, A_m is sinusoidal amplitude and A_c is carrier amplitude. A sinusoidal PWM signal finds many functions in the field of electronics. The gate signal is produced by comparing a triangular carrier wave and a reference sinusoidal wave and each pulse width varies relatively to the amplitude of a sine wave which is evaluated at the center. The output frequency (f_o) of the inverter is set by means of reference signal frequency (f_r). The modulation index M, restricted by peak amplitude (A_m) restricts the output voltage (v_o). The voltage is calculated as V_o=v_s(S_1-S_4). The carrier frequency governs the number of pulses per half cycle. Here unidirectional triangular carrier wave is used to produce the gating signal [6]. In case of sinusoidal PWM waveform, the pulse width seldom changes with the variation of modulation index as it is the characteristics of the sine wave. Thus the sinusoidal PWM technique is modified so that the carrier signal is applied for the first and last 600 intervals per half cycle. This increases the basic element and its harmonic characteristics are improved. The main advantages include increased basic component, improvement in harmonic characteristics, reduction in number of switching power devices and decrease in switching losses are the main advantages of this technique. human judgments and its easier for the user to understand the target control and results.

5. Conclusion

It can be concluded that the use of PVA integrated UPQC with SVPWM has attracted various research and developmental works in the field. The main point to be noted is that it helps in maintaining a constant load voltage during various source voltage fluctuations such as sag and swell. The series converter present in the system helps in injecting the deficit load voltage thereby maintaining constant voltage magnitude. The presence of series and shunt compensators also helps to maintain THD, reduce harmonic components, provide active and reactive power compensation. On using FIS controller the voltage profile is improved.

References

[1] 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.

[2] A. R. Malekpour, A. Pahwa, A. Malekpour, and B. Natarajan, “Hierarchical architecture for integration of rooftop pv in smart distribution systems,” IEEE Transactions on Smart Grid, vol. PP, no. 99, pp. 1–1, 2017.

[3] 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.

[4] 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.

[5] 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.

[6] 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, May2016.

[7] P. Jayaprakash, B. Singh, D. Kothari, A. Chandra, and K. Al-Haddad, "Control of reduced-rating dynamic voltage restorer with a battery energy storage system," IEEE Trans. Ind. Appl., vol. 50, no. 2, pp. 1295– 1303, March 2014.

[8] B. Singh, C. Jain, and S. Goel, "ILST control algorithm of single stage dual purpose grid connected solar PV system," IEEE Trans. Power Electron., vol. 29, no. 10, pp. 5347–5357, Oct 2014.

[9] R. K. Agarwal, I. Hussain, and B. Singh, "Three-phase single-stage grid tied solar pv ecs using PLL-less fast CTF control technique," IET Power Electronics, vol. 10, no. 2, pp. 178–188, 2017.

[10] Y. Singh, I. Hussain, B. Singh, and S. Mishra, "Single-phase solar grid interfaced system with active filtering using adaptive linear combiner filter-based control scheme," IET Generation, Transmission Distribution, vol. 11, no. 8, pp. 1976–1984, 2017