International Journal for Modern Trends in Science and Technology
Volume 10, Issue 03, pages 480-485.
ISSN: 2455-3778 online
Available online at: http://www.ijmtst.com/vol10issue03.html
DOI: https://doi.org/10.46501/IJMTST1003076

Reactive Power Compensation in Grid-Connected PV System Using STATCOM and Fixed Capacitor

D. Devi Vara Prasad[1], Sd Adam Safiullah[2], G. Mahesh Venkata Ramana[2] , J. Balu[2], N. Navya Sri Durga[2]

[1]Assistant Professor, Department of Electrical and Electronics Engineering, PSCMR College of Engineering and Technology (Autonomous), Vijayawada, AP, India.
[2]Department of Electrical and Electronics Engineering, PSCMR College of Engineering and Technology (Autonomous), Vijayawada, AP, India.

To Cite this Article
D. Devi Vara Prasad , Sd Adam Safiullah, G. Mahesh Venkata Ramana , J. Balu, N. Navya Sri Durga, Reactive Power Compensation in Grid-Connected PV System Using STATCOM and Fixed Capacitor, International Journal for Modern Trends in Science and Technology, 2024, 10(03), pages. 480-485.https://doi.org/10.46501/IJMTST1003076

Article Info
Received: 02 February 2024; Accepted: 26 March 2024; Published: 30 March 2024.

ABSTRACT

This study presents a comprehensive analysis of reactive power compensation in grid-connected photovoltaic (PV) systems through the synergistic use of Static Synchronous Compensator (STATCOM) and Fixed Capacitor (FC), validated by MATLAB software simulations. Aimed at addressing voltage stability and improving power factor, the integration of STATCOM and FC provides a dual strategy for dynamic and steady-state reactive power support, respectively. The MATLAB-based simulation framework meticulously evaluates the performance under varying solar irradiance, load fluctuations, and grid disturbances, focusing on voltage regulation, power factor enhancement, and the efficacy of reactive power management. Results demonstrate that the combined application of STATCOM and FC significantly improves voltage stability and maintains a high power factor, underscoring the effectiveness of this approach in enhancing the efficiency and reliability of grid-connected PV systems. This study contributes valuable insights into optimizing reactive power compensation mechanisms, facilitating the seamless integration of renewable energy sources into the power grid.

KEYWORDS: Reactive Power Compensation, Grid-Connected Photovoltaic System, Static Synchronous Compensator (STATCOM), Fixed Capacitor (FC), Voltage Stability, Power Quality

1. INTRODUCTION

Most of the world's energy needs are now met by burning rapidly depleting fossil fuels including petroleum, coal, and natural gas. Carbon dioxide, a byproduct of burning fossil fuels, is a key contributor to global warming and poses a serious threat to all forms of life on Earth [1].

The PV array systems are expected to play a key part in future energy generation among all the existing Renewable energy sources. Photovoltaic (PV) systems convert light into electricity. Fuel cells, wind generation, and solar systems all provide low voltage output and need large step-up dc/dc converters to meet their various application requirements. The rising need for power, coupled with the scarcity and high cost of nonrenewable sources, has led to the development of the photovoltaic (PV) energy conversion system, which offers a viable alternative due to its cheap initial investment, absence of environmental impact, and ease of upkeep. Therefore, both independent and grid-connected PV systems should make more use of this energy source. Even though photovoltaic (PV) is a renewable energy resource, its installation cost is very costly and its reliability varies depending on factors like location, time of year, and the weather. Operating the system close to the MPP so as to acquire about the maximum power of PV array is a key aspect for improving the efficiency of PV systems. To get the most power from a solar array.

In order to maximize the output of PV systems, maximum power point tracking (MPPT) methods are used, and a high efficiency power converter tailored to draw maximum power from a PV panel is often taken into account. In most cases, there will be a single maximum power point (MPP) on the V-I curve where the PV system is both most efficient and provides the most power [l5-17]. In any case, search techniques or computation models may be used to pinpoint the MPP's location, which is currently unknown. The operational point of the PV array is kept at the sweet spot where maximum power is generated by using Maximum Power Point Tracking Techniques (MPPT) [26–28]. Perturb and Observe (P&O) [2–5], Incremental Conductance (lC) [2–6], Artificial Neural Network (ANN) [7], Fuzzy Logic (FL) [8], etc. are only a few of the MPPT algorithms that have been examined in the literature. Two of the most common methods are P&O and IC. In this study, four MPPT algorithms—P&O, the Incremental Conductance (lC) technique [2-6], the Fuzzy Logic (FL) method [8], and the Particle Swarm Optimization (PSO) method [l0]—are examined. These techniques are simple to execute and have found widespread use in low-budget uses because of this. Sliding Mode [9], along with other similar approaches, are not discussed in this study due to their added complexity and low frequency of use.

In order to build and scale the hybrid system appropriately for different loads and weather situations, this work focuses on constructing a simulation model. Mat lab and SimPower Systems are used to run a simulation model, and the resulting data is used to prove that the proposed system works as intended. In Figure 1, we can see the hybrid energy generating system that will be linked to the grid.

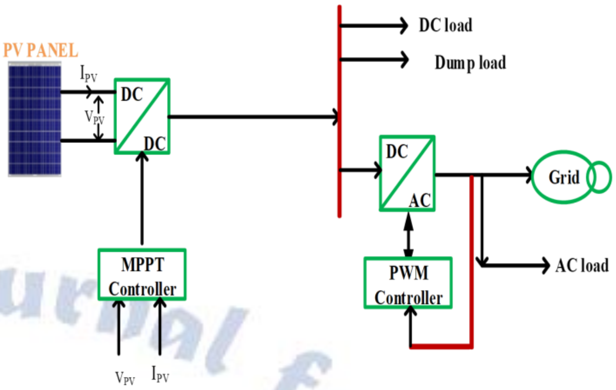

Figure 1: Configuration of proposed grid connected hybrid system

2. LITERATURE SURVEY:

Single-stage photovoltaic (PV) inverter control solutions were examined by Ciobotaru et al. It has been developed and compared experimentally, using two distinct current controllers. A full control system for the single-phase PV system is also provided. To preserve active and reactive power equilibrium during isolated operation of micro grids, Mahmud et al. suggested a resilient nonlinear distributed controller architecture. Micro grids are defined in this research as inverter-dominated networks that include renewable energy sources (RESs) and battery energy storage systems (BESSs), such as solar photovoltaic generators and plug-in hybrid electric cars. The implementation and enhancement of the performance of the electrical power system rely heavily on power electronics converters. More and more DERs are being implemented as a direct result of the increasing need for both new power sources and improved power supply quality. A model predictive controller's goal is to reduce common mode voltages and voltage deviations from nominal values across capacitors. Finally, a diagram, parameters, and results from a simulation run in the programme PLECS are supplied to prove the efficacy of the suggested control approach and the value of multilevel inverters..

3. SOLAR SYSTEM:

A solar cell is the fundamental building block of any photovoltaic (PV) system. To generate the necessary current, voltage, and high power, solar cells in a PV array are linked in series or parallel. Each solar cell may be thought of as a diode with a p-n junction made of semiconductor material [5]. By virtue of the photovoltaic effect, it generates currents whenever light is incident onto the junction. Power characteristics at insulation level for PV array are shown in Figure 3. Each characteristic curve for output power displays a maximum power point. The (I-V) and (P-V) properties of the PV array are shown at varying solar intensities in Figure 3. A solar cell's equivalent circuit consists of a forward-biased diode connected in series with the current source. The terminals at the output are hooked up to the load. The solar cell's current equation is as follows:

$$I = I_{ph} - I_D - I_{sh}$$

$$I = I_{ph} - I_o\,[\exp(q\,V_D / nKT)] - (V_D / R_S)$$

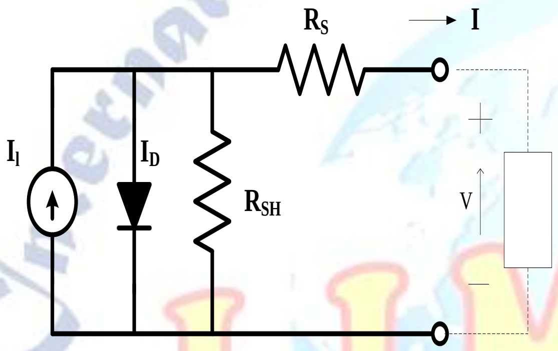

Figure 2: Equivalent circuit of PV Module

Power output of solar cell is $P = V * I$

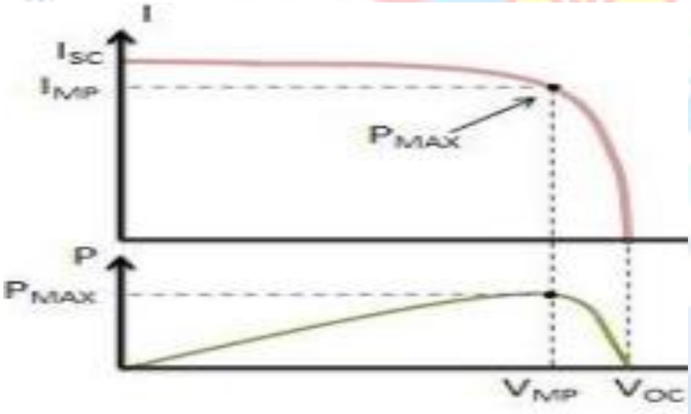

Figure 3: Output characteristics of PV Array

MAXIMUM POWER POINT TRACKING METHOD:

The output power characteristics of a PV system are mostly determined by its irradiance and temperature curves. In addition, solar radiation and temperature hold these two constant for a short time. In Figure 1 we can see how the levels of solar radiation will sharply fluctuate during the day, as was previously described. Only around 30% to 40% of the solar irradiance that hits a typical solar panel is converted into usable electricity. The Maximum Power Transfer theorem states that a circuit's power output is maximised when its thevenin impedance (source impedance) is in phase with its load impedance. Therefore, the Maximum power point tracking approach must be used to raise the solar panel's efficiency.

In response to rising input voltage or current, a PWM generator's repetition rate may be raised, hence increasing the output current. Simultaneously, the inductor's charge current is increased by applying a higher voltage to it. Where sensor-collected data on current and voltage are used to calculate initial voltage and power [9]. After determining the true power output, the Vref reference voltage is adjusted by comparing the current measurement to the previous one.

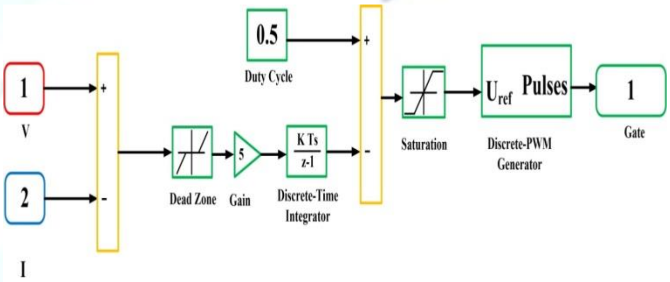

Figure 4: DC-DC converter MPPT Controller

3. PROPOSED SYSTEM:

The amount of solar insolation affects the amount of active electricity put into the grid by a solar inverter that is connected to the grid. If the solar irradiation is not high enough, the solar inverter will not be able to provide as much active electricity to the grid as it was intended to (which actually happens as the solar irradiance is not uniformly maximum throughout the day). It causes the inverter to be underutilised. The inverter can still function at its rated capacity even when the solar resource is not at its full potential if it is set to supply reactive power in addition to active power (depending on solar irradiance availability). Through the injection and absorption of reactive power, network voltages may be controlled, and reactive power compensation using solar inverter is an intriguing approach for doing so.

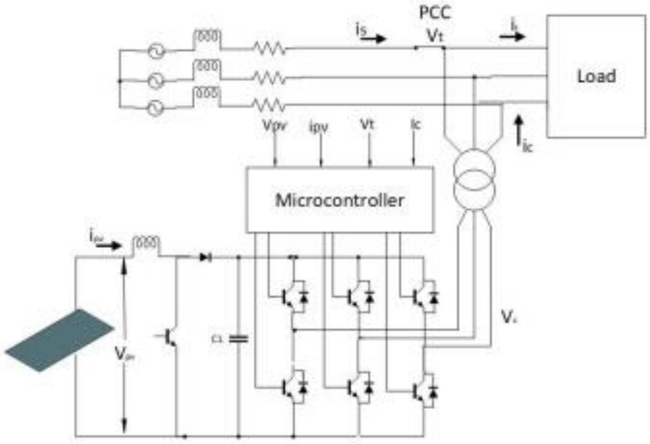

Figure 5: Structure of Grid Connected PV system for Reactive Power Control

Space Vector Modulation Technique:

As an alternative to the standard pulse width modulation method, gate triggering signals may be obtained by using the system's two phase vector components, d and q, in space. Figure 6 depicts the 8 space vector switching pattern locations of the inverter, each of which is represented by a space vector representation of the neighbouring vector V1 and V2.

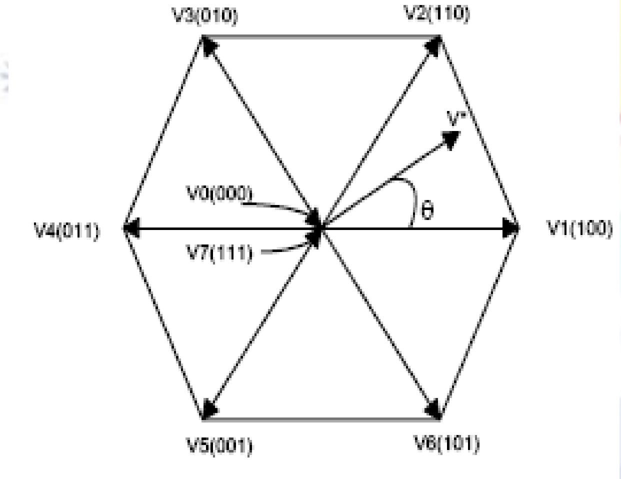

Fig 6: Space Vector Modulation Technique

By using the Space Vector Modulation Technique, which is one of the most common pulse width modulation techniques for three-phase voltage source inverters, it is possible to reduce harmonic distortion in the applied ac motors' voltage and current. In this research, the reference vectors are formed by varying the switching time sequence of space vectors in each of six sectors, as illustrated in figure 6. As shown in Figure 6, six of the sectors are employed for inversion, while two act as null vectors. The following methods may be used to carry out space vector modulation:

Converting three-phase values to their two-phase counterparts.

Calculate T1, T2, and T0 to see how long each event takes.

This formula produces the voltage reference signals, the switching time sequences, and the V0–V7 voltage references.

$V^* T_z = V_1 * T_1 + V_2 * T_2 + V_0 * (T_0/2) + V_7 * (T_0/2)$

4. RESULTS AND DISCUSSION:

Figure 1 depicts the whole hybrid grid-connected system. The photovoltaic system includes a series-connected array of PV modules and a boost converter.

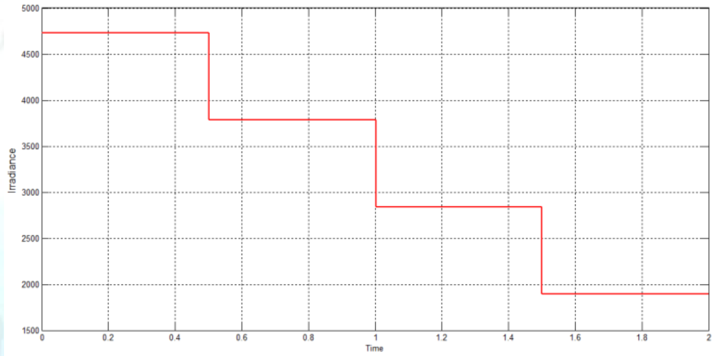

Figure 6: Simulation Waveform for Solar Irradiance (W/m2)

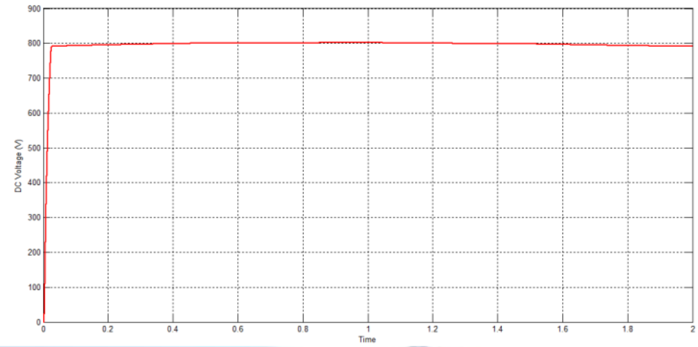

Figure 7: Simulation Waveform for Solar DC Voltage

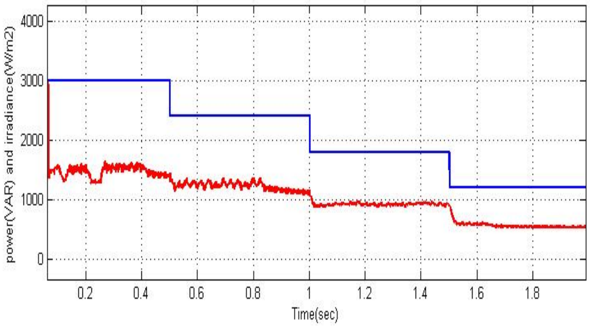

Figure 8: Simulation Waveform for Active and Reactive Powers of PV System

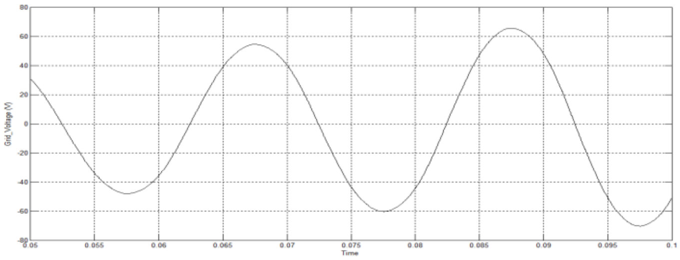

Figure 8: Simulation Waveform for Grid Voltage

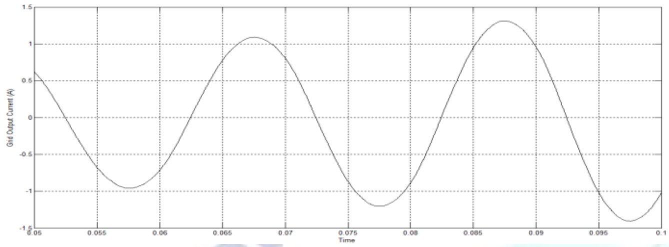

Figure 9: Simulation Waveform for Grid Current

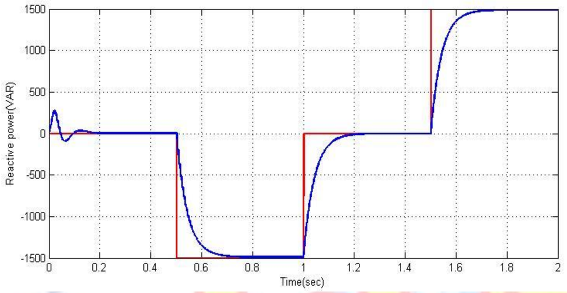

Figure 10: Simulation Waveform for Reference and Actual Reactive Power under fixed Q-Mode

Table-1: Comparative Analysis Between Conventional and SVM Controller

PARAMETER	PWM CONTROLLER	SVM CONTROLLER
POWER FACTOR	0.79	0.84
DC VOLTAGE (V)	495	847
ACTIVE POWER (W)	750	750
REACTIVE POWER (VAR)	385	236.3
LOAD VOLTAGE (V)	232	221
LOAD CURRENT (A)	17.5	40
THD (%)	7.27	0.32

5. CONCLUSION

In this piece, we present a SVM-controlled PV system that can be connected to the grid and used to offset reactive power demands. The article also describes the best converters to use with each MPPT method, whether the system is grid-tied or operates independently. In this article, we will go over the latest hybrid MPPT techniques and their advantages. It is hoped that the designers and commercial manufacturers of PV systems will also find this review to be a useful resource. This research shows that the foundations of both P&O and IC are in the extreme value theory. They should be able to accurately monitor the maximum power point if the condition for maximum value is met. However, due to noise and quantization error etc., it is difficult to guarantee the stability and accuracy of the numerical approximation of differentiation upon which both methods rely. There is a fundamental flaw in the algorithms that causes them to perpetually bob up and down near the sweet spot.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

REFERENCES

[1] R. Datta and V. T. Ranganathan, “Variable-speed wind power generation using doubly fed wound rotor induction machine—A comparison with alternative schemes,” IEEE Trans. Energy Convers., vol. 17, no. 3, pp. 414–421, Sep. 2002.

[2] Y. Rajendra Babu, Dr.C.Srinivasa Rao, “Power Quality Improvement Using Intelligent Control Based Distributed Generation inverter”, International Journal of Management, Technology And Engineering, 2019.

[3] A. Luna, K. Lima, D. Santos, R. Paul, and S. Arnaltes, “Simplified modeling of a DFIG for transient studies in wind power applications,” IEEE Trans. Ind. Electron., vol. 58, no. 1, pp. 9–19, Jan 2011.

[4] M. J. Hossain, H. P. Pota, V. A. Ugrinovskii, and R. A. Ramos, “Simultaneous STATCOM and pitch angle control for improved LVRT capability of fixed-speed wind turbines,” IEEE Trans. Sustainable Energy, vol. 1, no. 3, pp. 142–151, Oct. 2010.

[5] Krishna Mohan Tatikonda, Udaya K. Renduchintala, Chengzong Pang, and Lin Yang, " ANFIS-fuzzy logic based UPQC in interconnected microgrid distribution systems: Modeling, simulation and implementation," 2021 The Authors. The Journal of Engineering published by John Wiley & Sons Ltd on behalf of The Institution of Engineering and Technology, https://doi.org/10.1049/tje2.12005.

[6] M. E. Haque, M. Negnevitsky, and K. M. Muttaqi, “A novel control strategy for a variable-speed wind turbine with a permanent-magnet synchronous generator,” IEEE Trans. Ind. Appl., vol. 46, no. 1, pp. 331–339,Jan./Feb 2010.

[7] Tulasichandra Sekhar Gorripotu, Krishna Mohan Tatikonda, B. Omkar Lakshmi Jagan, “Performance Analysis of Grid Synchronization Method for Three-Phase Three-Wire Networks under Grid Fault Conditions”, International Journal of Advanced Science and Technology, Vol. 29, No. 6, (2020), pp. 3451-3458.

[8] Rajendrababu yadiki, C. Srinivasa rao, “Performance analysis of instantaneous harmonic power theory based active power filter under different loading conditions”, International Journal Of Electrical And Electronics Engineering Research (Ijeeer), 2017.

[9] S. Bhowmik, R. Spee, and J. H. R. Enslin, “Performance optimization ́ for doubly fed wind power generation systems,” IEEE Trans. Ind. Appl., vol. 35, no. 4, pp. 949–958, Jul/Aug. 1999.

[10] C.-H. Liu and Y.-Y. Hsu, “Effect of rotor excitation voltage on steady-state stability and maximum output power of a doubly fed induction generator,” IEEE Trans. Ind. Electron., vol. 58, no. 4, pp. 1096–1109, Apr. 2011.

[11] A. Petersson and S. Lundberg, “Energy efficiency comparison of electrical systems for wind turbines,” in Proc. IEEE Nordic Workshop Power Ind. Electron. (NORPIE), Stockholm, Sweden, Aug. 2002, pp. 12–14.

[12] A. C. Smith, R. Todd, M. Barnes, and P. J. Tavner, “Improved energy conversion for doubly fed wind generators,” IEEE Trans. Ind. Appl., vol. 42, no. 6, pp. 1421–1428, Nov./Dec. 2006.

[13] S. Muller, M. Deicke, and R. W. De Doncker, “Doubly fed induction ̈ generator systems for wind turbines,” IEEE Ind. Appl. Mag., vol. 8, no. 3, pp. 26–33, May/Jun. 2002.

[14] G. D. Marques and D. M. Sousa, “Air-gap-power-vector-based sensor less method for DFIG control without flux estimator,” IEEE Trans. Ind. Electron., vol. 58, no. 10, pp. 4717–4726, Oct. 2011.