International Journal of Research in Engineering, Science and Management
Volume 5, Issue 5, May 2022
https://www.ijresm.com | ISSN (Online): 2581-5792

Performance Enhancement of PV Systems Using Adaptive Reference PI Controller

Deepthi Shetty[1], Sherya Rao[2], K. U. Rohan[3*], Kishan[4], Vindhya[5]
[1,2,3,4,5]Department of Electronics and Communication Engineering, Mangalore Institute of Technology and Engineering, Moodabidri, India

***Abstract*: The Solar photovoltaic (PV) energy has many advantages which makes it one of the great sources for power generation. Photovoltaic systems are linked to the electrical grid with the help of a DC-AC converter and a DC-AC inverter. The project's major goal is to improve the grid's interoperability with PV installations. To get the desired performance, the converter as well as inverter characteristics are adjusted. The inverter is controlled by an ARPI (adaptive reference PI) controller, which improves the performance of the system by allowing for low voltage ride through (LVRT). It also smooths out the oscillations in PV-generated electricity that occur because of the due to environmental changes. The converter is utilized to provide MPPT while the PV system is under varied environmental conditions (MPPT). To assess the efficiency of the suggested method, a simulation of system performance employing the suggested ARPI is provided.**

***Keywords*: PV systems, PI controller, MPPT.**

1. Introduction

Solar photovoltaic systems have emerged as among the most significant forms of renewable energy production in recent years. This significance is universal owing to the stats of existing PV systems and the predicted future increase. By 2021, it was estimated and expected that roughly 1TW of electricity will be generated in PV systems. There are several issues in integrating Photovoltaic system to the electricity grid. These difficulties result in variations in the power produced by the PV system as a result of environmental changes such as solar irradiance and temperature, non-linearities in power electronics components, non-linearities in PV attributes such as converters and inverters, as well as reliability and stability. Grid faults are also other kind of technical challenges that show up during the unusual operating conditions. The most common grid failures are short circuits and sagging situations, which are caused by a rapid rise in load, however faults are not restricted with those at the common coupling point (PCC). The state of grid whether it is connected to PV system or not is determined by these faults. Therefore, some measures are needed to be taken in order to determine whether PV system is connected or disconnected from the grid. During failures, the grid will describe whether PV systems can be connected or detached from the grid, as well as offer low voltage ride through (LVRT) and fault ride through (FRT). There are two zones depending on the PCC operating voltage during disturbances: trip and connection. A DC-AC inverter and DC-DC converter are used to link the Photovoltaic system to the electrical grid. To increase PV system connectivity with the electrical grid, several solutions are proposed. Using a MPPT approach, a DC-DC chopper controlling mechanism is implemented to optimize the captured energy through PV systems during climatic fluctuations. By managing the reactive and active load flow between both the photovoltaic system and the grid, the DC - AC inverters control techniques, but on the other hand, aim to improve the effectiveness of grid-connected Photovoltaic system under abnormal operation scenarios.

2. Literature Review

[1] Several control strategies were tried to control the amount of active power present between Photovoltaic system and the grid, thereby optimizing the levels of voltage at PCC by modifying the grid side inverters. According to the findings, PI controllers were employed to satisfy the LVRT requirements of PV systems. Furthermore, by managing the voltage and current of grid side inverters, PI controllers are commonly used to improvise LVRT capabilities.

[2] The continuous expansion in solar power output has produced substantial integration operations and challenges for power utility system engineers of present grid network. This study focuses on the steady-state integration effects of solar PV electricity on established transmission and distribution system. The study looks at how steady state integration affects the voltage level, reference voltage, transmission losses, voltage drop, and network voltage stability in an existing network.

[3] Specifically, in proportional plus integral and derivative (PID) feedback is the most significant and powerful concept in control systems. It is accurate and effective in all sorts of control systems. The role of PID feedback, which is regarded the primary controller of all control loops, is examined. PID is used as controller feedback in over 90% of control systems, and its appropriate application necessitates skills, knowledge, and controlling approaches. As a result, there is a qualitative analysis of PID for applications in this work.

[4] This study discusses the challenges of connecting solar PV systems to the main grid. The performance of a grid-integrated rooftop solar PV system, as well as the proposed control approach, is shown under various operating situations.

*Corresponding author: rohanrohan99153@gmail.com

The current solar power generating scenario in India has also been examined in this research for stand-alone, grid-connected and rooftop PV systems.

[5] Large-scale PV grid-connected power generating systems have posed a threat to the grid's stability and management, and also the grid-tied solar system with an energy storage device. An 8 kW PV system and an energy storage were built to solve these challenges. The battery components of this system can be linked to the grid in DC or AC mode. The viability and adaptability of the MPPT charge controller are confirmed by a dynamic model incorporated into the household solar PV system.

[6] This study established a hybrid strategy based on power quality (PQ) augmentation in a grid-connected PV system. The hybrid technique combines the Radial Basis Function Neural Network (RBFNN) and Proportional Integral (PI) controllers.

[7] Solar-Grid integration is a technique that allows huge amounts of solar energy generated by PV or CSP systems to be integrated into an existing power grid. This technique needs considerable thought and study in areas such as solar component installation, production and operation.

[8] All grid-connected solar PV power plants must install the appropriate equipment to continually monitor solar radiation, ambient temperature, wind speed, and other meteorological data, as well as the generation of both DC and AC electricity.

[9] This article discusses the possibility of grid-integrated solar photovoltaic power creation system to fulfil energy demands throughout the day and lower the community's energy expenses. The study's initial goal is to assess solar energy's potential as a power source for this purpose.

[10] The influence of grid-integrated large-scale photovoltaic on the power system operation (availability, stability and reliability) and protection philosophy is the topic of this research. It evaluates the certification techniques and standards of utility-interactive equipment (grid inverters), which has a direct effect on that of the grid's supply security and power quality.

3. Proposed Method

The adoption of an adaptive controller with the capacity to update its settings at each of the operating situations is a viable solution for the PI controller's lack of retuning parameters. The suggested adaptive reference PI (ARPI) controller is simulated using Scilab and MATLAB to enhance the performance by the on-grid PV system. This is accomplished by smoothing the power fluctuation caused by changes in temperature and irradiance. Furthermore, LVRT augmentation capability is achieved when failures that occur at the point of common coupling between the Photovoltaic system and the grid. In order to increase the efficacy of the suggested adaptive controller, the system execution is contrasted to that of an ideal Proportional integral controller.

A. Working

A DC-DC converter and a DC-AC inverter link the PV system to the grid. The converter raises the PV system's output DC voltage (boost converter). Furthermore, it uses the perturb and observe MPPT approach to track maximum power, while the inverter converts DC voltage to AC voltage and connects to the grid. The inverter is also adjusted to increase the PV system's grid integration.

A DC-DC chopper control approach is used to optimise the collected energy from PV systems utilising a MPPT method during environmental changes like as temperature and irradiation. By controlling the active and reactive load that flows in between the Photovoltaic system and the system's grid, the DC to AC inverter management methods, on the other hand, aim to enhance the performance of grid-connected Photovoltaic systems under unusual operation scenarios. The inverter is a controller that increases the grid integration of a PV system. PV systems use PI controllers to meet their LVRT requirements. Furthermore, PI controllers are widely utilised to increase LVRT capabilities by controlling the current and voltage of grid side inverters. The PI controllers improve the grid-connected PV systems' transient stability. All of the studies that have been published have suggested using a PI controller for only the LVRT to improve the power transfer from PV systems to the grid. There are many trial and error methods for determining PI control settings.

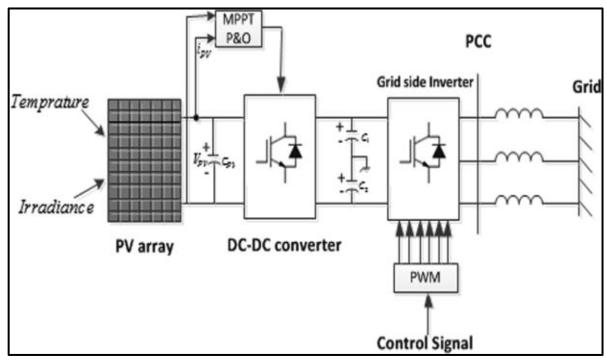

Fig. 1. Block diagram of photovoltaic system with the grid connection

B. PI Controller

The DC link voltage is altered other than the reference voltage when the operational conditions change. The power, current, and voltage of the inverter will all be affected by this adjustment. The system performance will be improved if the DC link voltage is correctly managed. The PI controller is utilized as a benchmark in this study to show how successful is the ARPI (adaptive reference) controller.

By managing the error signal present in between the DC link voltage and anticipated reference value of 800 V, the recommended PI controller updates and stimulates the reference power (Pref), which is then matched to the output power PV. The power needed from the grid to sustain the DC connection voltage changes is the distinction between the two powers. To generate inverter gate pulses, the PCC voltage and reference current are computed, then contrasted to the inverter output current.

C. Maximum Power Point Tracking

MPPT (Maximum power point tracking) is a method that is used for transferring the utmost amount of energy from a transducer. Nonlinear characteristic power curves exist in energy transducers such as the solar modules; the ideal load for maximum power production is determined by the operating point for the particular parameters. This method necessitates energy monitoring, establishing the best operating point, and adjusting the load. A variety of strategies may be used to calculate the ideal load.

Through a power converter, the MPPT ensures utmost power transmission from the photovoltaic panels to the grid. An MPPT algorithm is included in the control scheme. This iterative process determines the current or/and voltage of the solar photovoltaic array and serves as a reference for the control system. This reference is then imposed at the solar panel terminals by the power converter.

4. Simulation Results

The simulation for three PV modules was done in Scilab XCOS as shown in Figure 2. The results show that the small voltages are amplified to comparatively larger values. The controller and inverter outputs are as shown in Figure 3. The boost converter allows to get such a large amplification in the output voltage. Such units can be combined to get a large voltage at the grid that will help to meet the large-scale power requirements of the society.

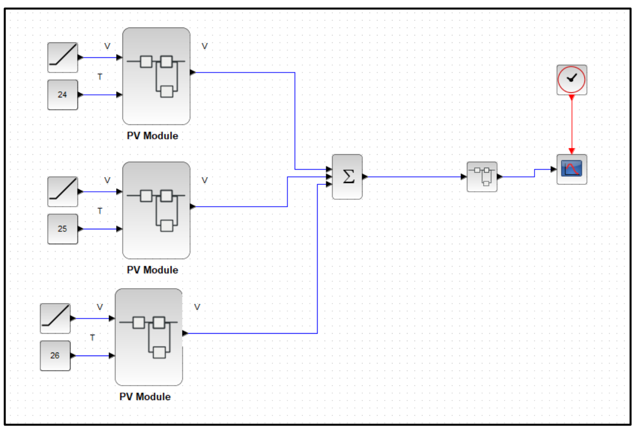

Fig. 2. Scilab-XCOS model of 3 connected PV modules

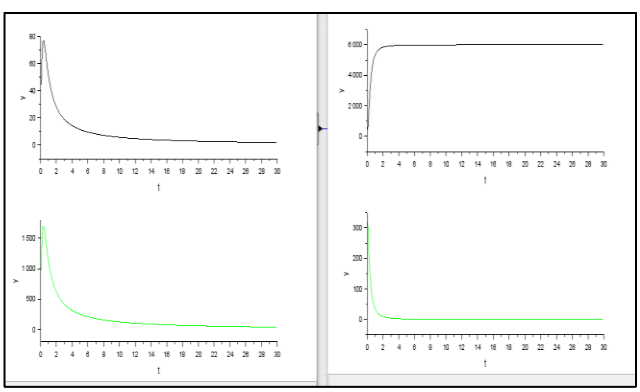

Fig. 3. Inverter and converter output in XCOS

The PV panel with an input of 17 parallel and 14 series modules is obtained. The reference voltage given is 700V. Figure 5 shows the parameters obtained in Simulink implementation.

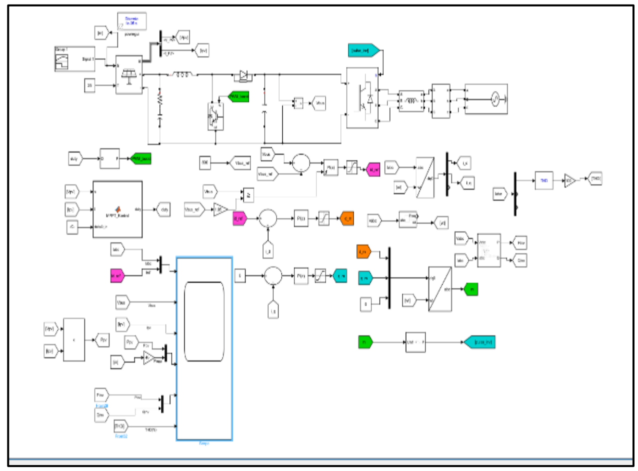

Fig. 4. MATLAB-Simulink implementation

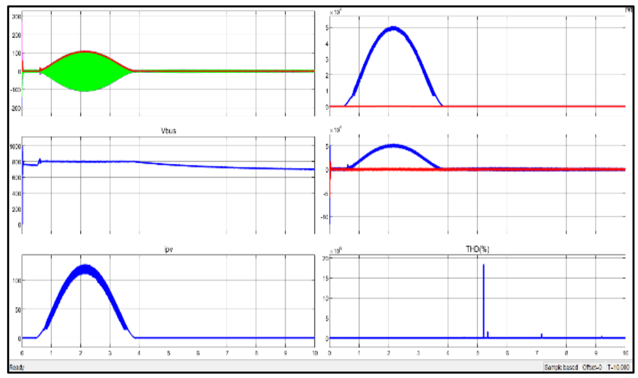

Fig. 5. Output obtained in Simulink implementation

5. Conclusion

The analysis and simulation of the PV system and grid connections are done in the open-source software Scilab and MATLAB Simulink. The Scilab features of SciNotes and XCOS are used for the simulations. The suggested control strategy aids in improving PV system grid integration by attaining MPPT and softening power fluctuations caused by environmental variations such as solar irradiance and temperature. Furthermore, it facilitates the grid-connected Photovoltaic system's LVRT functionality during three-phase outages at PCC. This system aids in the enhancement of LVRT capacity by acting as a protective mechanism whenever the DC link fails.

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