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Power Normalizing Modified Hysteresis Controlled Inverter for Varying Irradiation and Temperature in Solar PV Modules

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***Abstract*-Worldwide renewable energy resources, especially solar energy, are growing dramatically in view of energy shortage and environmental concerns. This work are provide variable radiation and variable temperature input to each solar module and study its effect on the power output from the system. The work should extract maximum power in these varying input conditions from the solar system. And to stabilize and improve the active power output from the solar system by designing an efficient controller for the inverter for DC to AC conversion. Enhance the system reliability and efficiency by integrating it with the grid via a transformer with the desired grid voltage and frequency. The computational methodology of the proposed modulation technique is very easy and the technique can be applied to multilevel inverter with any number of levels. This implementation would be preferable in the solar system having different input parameters and still give output power stable and efficient.**

Keyword: solar system, grid, DC converter, controller.

I. INTRODUCTION

Worldwide renewable energy resources, especially solar energy, are growing dramatically in view of energy shortage and environmental concerns. Large-scale solar photovoltaic (PV) systems are typically connected to medium voltage distribution grids, where power converters are required to convert solar energy into electricity in such a grid-interactive PV system. To achieve direct medium-voltage grid access without using bulky medium-voltage transformer, cascaded multilevel converters are attracting more and more attraction due to their unique advantages such as enhanced energy harvesting capability implemented by distributed maximum power point tracking, improved energy efficiency, lower cost, higher power density, scalability and modularity, plug-N-power operation, etc.[5-7] Motivations are toward addressing the aforementioned issues and approaching to mitigate the negative effect of active power mismatch. In, MPPT is achieved for each module in these approaches to enhance energy harvesting.[8]

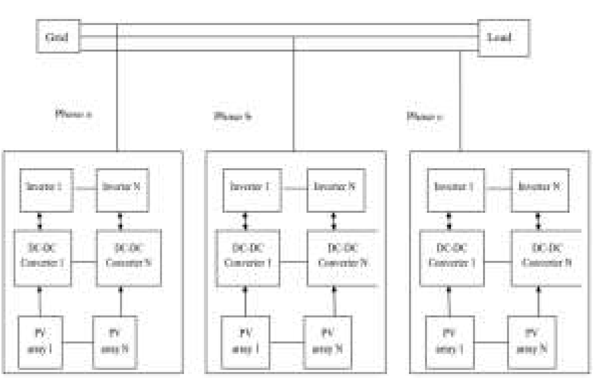

Figure 1: Block diagram of Grid-connected PV system with Cascaded PV inverters.

II. LITERATURE REVIEW

Milad Samady Shadlu et al. [1] This article compares two MPPT (Maximum Power Point Tracking) strategies for a medium-sized multi-chain photovoltaic energy conversion system based on a multi-level modular converter (MMC). Perturb and Observe (P&O) and Incremental Conductance (INC) techniques are considered MPPT controllers and their credit monitoring performance is compared. The results show that the INC method performs better with regards to the PV output power and the oscillations of the three-phase load power and also extracts the maximum power point from the PV module.

Cheng Wang et al. [2] The document presented is the Modular Multilevel Cascade Converter (MMCC), a promising technology for high / medium voltage high voltage photovoltaic systems (photovoltaic systems), characterized by modularity, scalability and the ability to distribute power points Maximum (MPPT), etc. In this way, the MMCC system can maintain high performance in a wide range of operating conditions. The effectiveness of the proposed modulation strategy has been demonstrated by experiments.

Ersan Kabalcı et al. [3] This article presents the most commonly used reactive power compensators, taking into account recent advances in industrial applications. In order to provide authors with better and more in-depth knowledge, the basic principles of reactive power compensation and symmetric systems are presented. The circuit diagrams and control properties of the different compensation devices are presented with their analytical expressions. Energy flow control, voltage and current variations and stability problems are presented with pointer diagrams to provide more information on the operating principles of each device. The comparisons concern similar devices and emerging technologies.

Milad Samady Shadlu et al. [4] this article proposes a new MMC control method that integrates photovoltaic panels directly into the electricity grid. Traditionally, regulation has been used, although regulation of the circulating current and equalization of the voltage of the capacitors in each branch have remained unsolved. Various topologies of photovoltaic converters have therefore appeared, among which the modular multi-level converter (MMC) is very attractive for its modularity and its transformer less properties. MMC modeling and control have become an interesting topic due to the huge expansion of photovoltaic systems in the residential area and the energy quality requirements of this application.

III. OBJECTIVE

There are following objective are to be expected from the present work

- To design a solar photovoltaic system in MATLAB/SIMULINK environment so as to enhance its output capacity before its integration with the grid.
- To provide variable radiation and variable temperature input to each solar module and study its effect on the power output from the system. The work should extract maximum power in these varying input conditions from the solar system.
- To stabilize and improve the active power output from the solar system by designing an efficient controller for the inverter for DC to AC conversion.
- Enhance the system reliability and efficiency by integrating it with the grid via a transformer with the desired grid voltage and frequency.

IV. METHODOLOGY

Various modeling techniques are developed by researchers to model components of HRES. Performance of individual component is either modeled by deterministic or probabilistic approaches. [8] This paper discusses the basic modeling structures of solar energy system, and proposed controller for inverter along with modeling of power system stability controls.

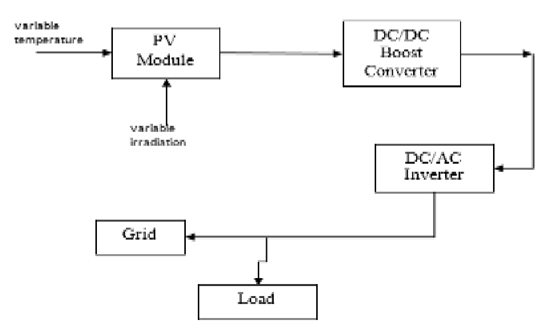

Figure 2: Proposed Hybrid energy system topology

1) PV Module Modelling

PV cells have single operating point where the values of the current (I) and voltage (V) of the cell result in a maximum power output. These values correspond to a particular resistance, which is equal to V/I. A simple equivalent circuit of PV cell is shown in Fig. 3.

The MPPT algorithm has been employed in order to obtain the operation of solar module at maximum power continuously. P & O technique has been brought into use. A cell series resistance (Rs) is connected in series with parallel combination of cell photocurrent (I_{ph}),exponential diode (D), and shunt resistance R_{sh}, I_{pv} and V_{pv} are the cells current and voltage respectively. It can be expressed as

$$I_{pv} = I_{ph} - I_s\left(e^{q(V_{pv}+I_{pv}*R_S)/nKT} - 1\right) - (V_{pv} + I_{pv} * R_s)/R_{sh}$$

Where:

I_{ph} - Solar-induced current

I_S - Diode saturation current

q - Electron charge (1.6e^{-19}C)

K - Boltzmann constant (1.38e^{-23}J/K)

n - Ideality factor (1~2)

T - Temperature ^{0}K

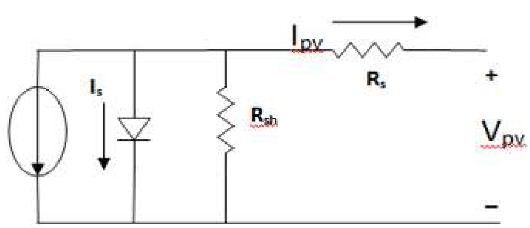

Figure 3: Equivalent circuit of solar pv cell

The solar induced current of the solar PV cell depends on the solar irradiation level and the working temperature can be expressed as:

$$I_{ph} = I_{sc} - k_i(T_c - T_r) * \frac{I_r}{1000}$$

Where:

I_{SC} Short-circuit current of cell at STC

k_i Cell short-circuit current/temperature coefficient (A/K)

I_r Irradiance in w/m

T_C ,T_r Cell working and reference temperature at STC

A PV cell has an exponential relationship between current and voltage and the maximum power point (MPP) occur at the knee of the curve as shown in the Fig 4.

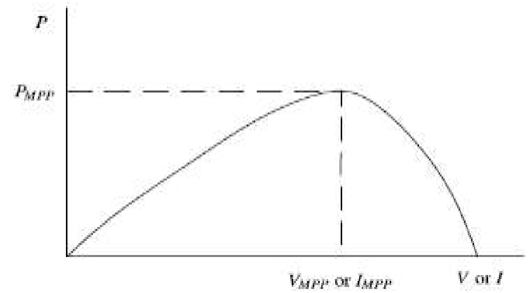

Figure 4: Characteristic PV array power curve

The P&O algorithm will track the maximum power to supply the DCMGs system. The assumptions for model derivation are that the ideal current source can be presented as the PVs behavior. In addition, all power converters are operated under the continuous conduction mode (CCM) and the harmonics are also ignored

2) Inverter modeling

The inverter system described in this paper is a three phase grid connected Voltage Source Inverter (VSI) configuration commonly used in distributed generation interfaces. A synchronous frame PI current regulator was chosen to control the inverter.

When the generated power is transmitted to the grid, or used by AC loads, it is necessary to use DC-AC converters (inverters). Inverters can be single phase or three phase output. There are four inverters integrated into the grid for photovoltaic systems: the central system inverter system, the string inverter system, the multistring inverter system and the micro-grid inverter system (AC modules).

Central inverters are the technology of the past and are based on centralized inverters that have a large number of photovoltaic modules connected to the grid. The photovoltaic modules are connected in series (called chain). These chains are connected in parallel to the chain diodes for high performance. String inverters are the current technology and are the reduced type of central inverter that each string connects to the inverter. Multistring inverters have multiple strings and are connected to a common DC-AC inverter with its own DC-DC converter. String inverters$_2$ are better than central inverters for their individual controllability. The block diagram of the inverter with connection to the three-phase grid is shown in Figure 5.

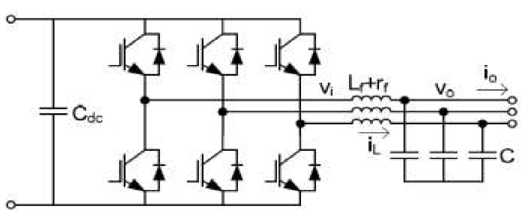

Figure 5: Block diagram of three phase inverter.

Table 1 : Inverter Parameters

Power electronic device	IGBT/Diodes
Snubber resistance	5000 ohms
Forward voltages	0
Ron	$1x10^{-3}$ ohms

3) Power Normalizing Hysteresis control

The VSC is a complex dynamic system that interfaces with the grid. The model of the coordination of VSC in DG systems must incorporate every one of the dynamics of the converter in the frequency scope of intrigue. This model ought to then incorporate both the LC filter in the interface between the converter and the grid, and the control system related with the converter circuit.

The Power Normalizing hysteresis controller is a non-linear controller loop with hysteresis comparators. Switches are turned on and off, and forms the voltage vectors on where the error of the current is compared to a reference band. Among advantages using a hysteresis control is predominantly the simplicity, robustness, independence of load parameters and good dynamics. The current errors are compensated in order to produce power (V I cosφ) stable.

In a basic implementation of the hysteresis current controller, the switching signals are derived from the comparison of the current error with a fixed hysteresis band.

The fundamental prerequisites for the present controllers are low harmonics to reduce losses, low power pulsation, and fast response in order to provide high dynamic performance the logic operation of the voltage source inverter under current control is accounted.

An exact design of the controller depends on the triangular waveform amplitude and frequency parameters noted respectively. The purpose of the proposed controller is to impose a fixed switching frequency to the inverter. As a result, the following expression is always true.

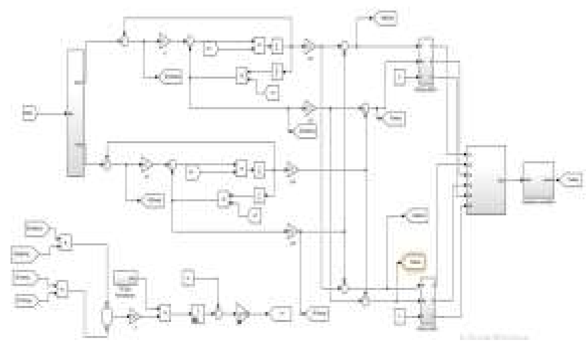

Figure 6: Extension of the proposed work.

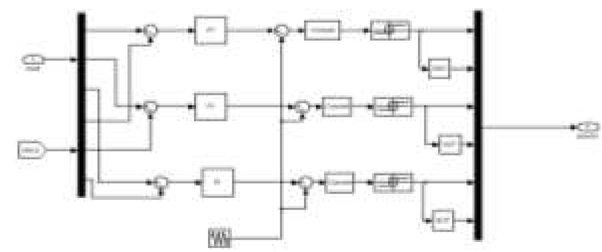

Figure 7: Extension Hysteresis PWM Techniques

PI controller is chosen as to combine with hysteresis current control because to overcome undesirable drawback of classical hysteresis current controller. The input of PI controller is an error in the current between the reference current and output current from the solar system for each phase. The advantages of this controller is its simple implementation, fast transient response, direct limiting of device peak current and practical insensitivity of voltage ripple.

The output is then integrated with the hysteresis current control for removal of the distortion and in power outputs. In hysteresis current control, there are two upper bands and lower bands in order to change the slope of converter output current based on their level voltages, +Vo, 0 and -Vo. The idea is to keep the current within the main area but the second upper and lower bands are to change the voltage level in order to increase or decrease the di,/dt of output current.

V. RESULTS

MATLAB stands for MATrix LABoratory, which is a programming package exclusively designed for speedy and effortless logical calculations and Input/output. It has factually hundreds of inbuilt functions for a large form of computations and plenty of toolboxes designed for specific analysis disciplines, as well as statistics, optimization, solution of partial differential equations, information analysis.

In this research work MATLAB platform is used to show the implementation or simulation of implemented algorithm performance

Solar energy is the cleanest and best source of renewable energy available. Modern technology can use this energy for a variety of uses, including generating electricity, providing light and heating water for domestic, commercial or industrial use. Photovoltaic systems currently play a leading role as a solar-based renewable energy source (RES) because of their unique advantages. This trend is particularly strong in grid-connected applications due to the many advantages of using renewable energy sources in decentralized production systems. Large-scale photovoltaic solar systems are generally connected to medium voltage distribution networks, where power converters are required to convert solar energy into electricity in such an interactive grid photovoltaic system.

It is therefore important not only to identify the characteristics of the photovoltaic modules or panels, but also the dynamic behavior of the electronic conversion system (PCS) for connection to the public electricity grid. The pulse control of these converters / inverters can vary the waveform of the output current and therefore the active output power of the system.

The work here is containing a solar panel array model in which each module is fed with variable irradiation and varying temperature. Each array is subjected to varying irradiation and hence the output obtained from them also varies, this variation has resulted in variation in the output power from the system. The work here is done in order to not only enhance the power output generated from the renewable energy resource but also to accommodate the variation in temperature and irradiation of the solar panels.

The objective is meant to be achieved by designing a controller for the inverter that will produce an enhanced and stable output power to the grid.

This chapter shall discuss the output obtained from the solar based renewable energy system that is also meant to be integrated to the grid. The comparative analysis has been carried out in terms of the power output from the system. The chapter here discusses the outputs in following three cases:

I. CASE 1: Solar system with having variable radiation and basic inverter control
II. CASE 2: Proposed Solar PV system with Power normalizing hysteresis controller

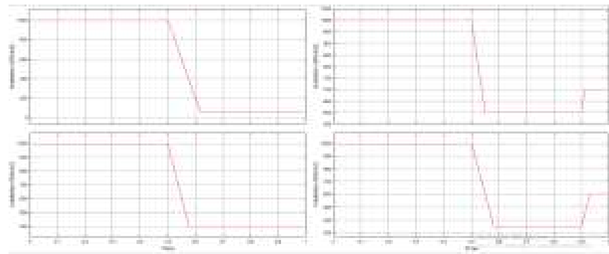

Figure 8: Varying irradiation input to the solar panels

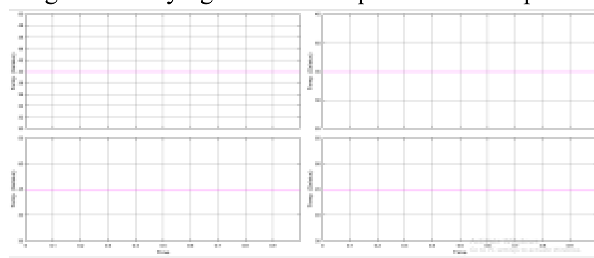

Figure 9: Varying temperature input to the solar panels

CASE 1: Solar system with having variable radiation and basic regulation inverter control

The figure shows the solar MATLAB/SIMULINK model of the system having solar panels. These panels are subjected to variable irradiation and varying temperature. The output from the tem is then analyzed for the changes due their input variation. The output DC voltage is converted in to AC by inverter. This inverter is provided pulses with basic controlling technique by utilizing voltage and current regulators and producing pulses after their regulation. The output is then sent to the transformer after which it is integrated with the grid of 10KV voltage output.

The graphical output waveforms of voltage, current, active power and reactive power is shown in the figure below. Various loads are also driven to study the system efficiency and reliability.

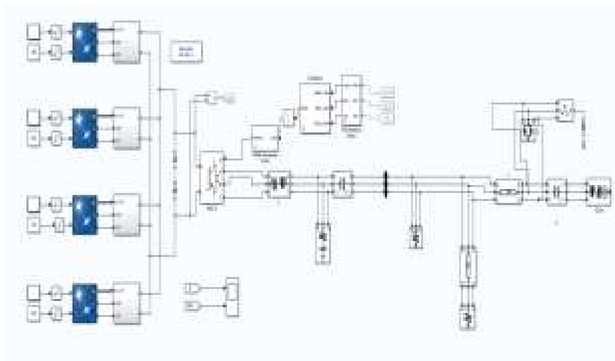

Figure 10: Solar system with having variable radiation and basic inverter control

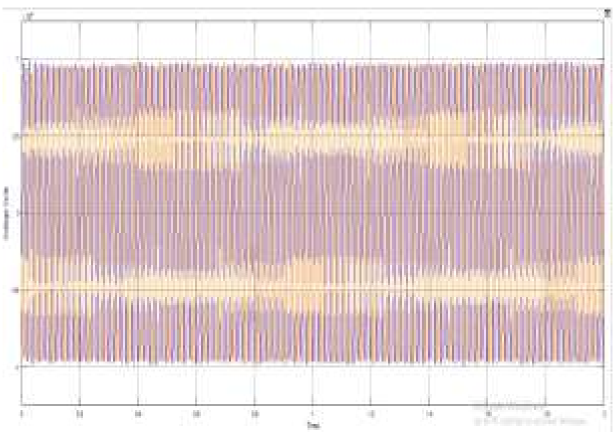

Figure 11: Voltage output from the system with basic inverter control

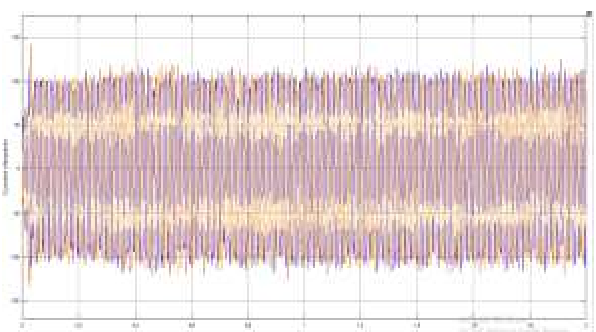

Figure 12: Current output from the system with basic inverter control

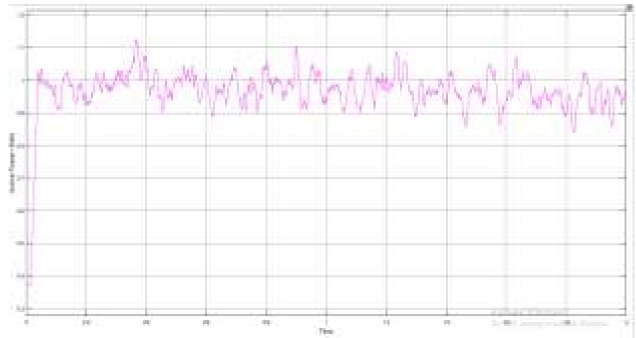

Figure 13: Active Power output from the system with basic inverter control

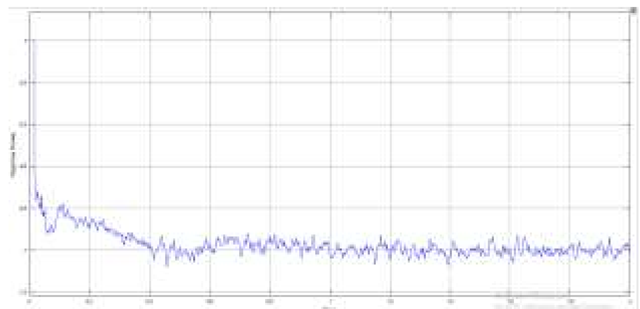

Figure 14: Reactive Power output from the system with basic inverter control

CASE 2: Proposed Solar PV system with Power normalizing hysteresis controller

The figure shows the proposed system in which the control of inverter has been changed in order to accommodate for the variation in the input parameters of the solar modules. The inverter proposed is designed to improve the active power output from the system as well as to make it a stable output. The inverter converts the input DC to AC and then it is connected to the transformer for its integration with the grid system. The various loads are also connected to this system. As the active power output is enhanced by using Power normalizing hysteresis controller for the inverter the loads of higher rating can also be connected to this system as compared to previous model.

The graphical output waveforms of voltage, current, active power and reactive power is shown in the figure below

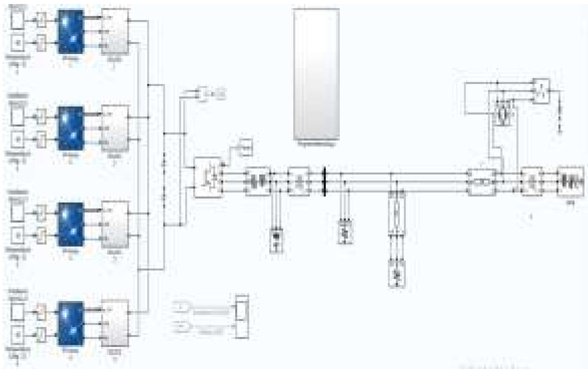

Figure 15: Solar PV system with Power normalizing hysteresis controller

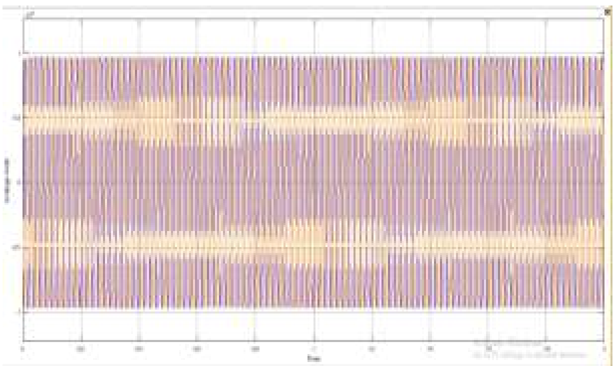

Figure 16: Voltage Output from the system having Power Normalizing hysteresis controller

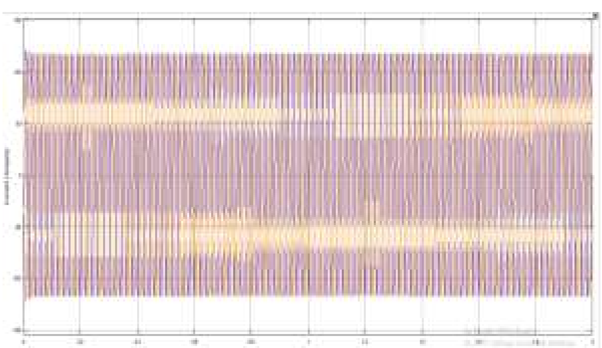

Figure 17: Current Output from the system having Power Normalizing hysteresis controller

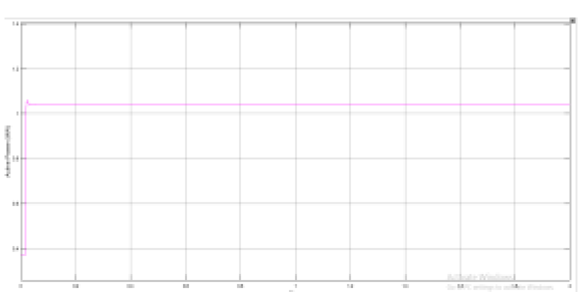

Figure 18: Active Power Output from the system having Power normalizing hysteresis controller

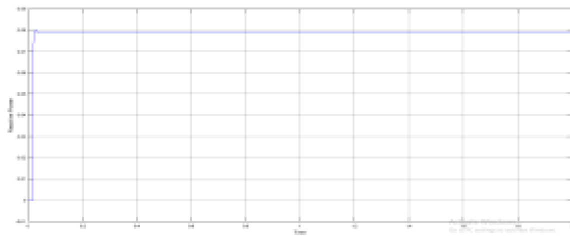

Figure 19: Reactive Power Output from the system having Power normalizing hysteresis controller

a) VALIDATION

The comparative analysis of the active power output from the two systems have been discussed here. The figure shows the comparative analysis of the active power output from the two systems. The green graph shows the active power output from the proposed power normalising hysteresis loop controller of the inverter and the red graph shows the active power output from the system with basic inverter control.

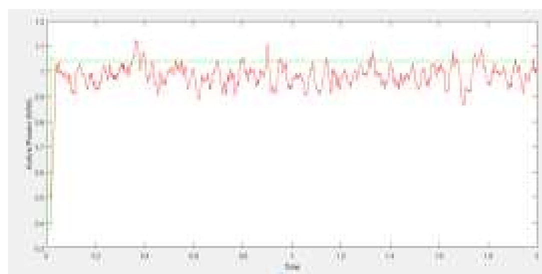

Figure 20: Comparative analysis of active power outputs

It was found that active power output was considered to be enhanced from varying power of approximately 1 MW to 1.03 MW and the voltage was kept constant to 10KV. The objective was to keep the active power output stable and balanced which was obtained from the proposed controller having inverter with power normalizing hysteresis loop control.

VI. CONCLUSION

This work provides a comprehensive design and implementation of three phase converter in a solar PV composed of various cell array model which are being fed with varying irradiation and temperature. The Inverter has been provided with proposed power normalizing hysteresis control while integrating it with the grid.

The work have discussed that the variation in irradiation and temperature input to each array of solar module may result in disturbance in the active power output from the system. With this objective a controller was designed that will stabilize the active power output as well as increase it. The comparative analysis of the proposed technique in a solar PV with dynamic input parameters based model shows its effectiveness and an efficient choice for operation of grid integrated inverters.

Table 2 : Comparative outcomes form the solar system

Parameters/ Model	Active Power	Voltage	Current
Model 1	1MW	10 KV	100 Ampere
Model 2	1.03MW	10 KV	120 Ampere

% increase in efficiency = $\left(\frac{New\ output\ power - Old\ output\ power}{old\ output\ power}\right)\ x\ 100$

= [(1.03-1)/1] x 100

= 3%

The following main conclusive points were drawn during the analysis of the system in the MATLAB/SIMULINK environment.

- The magnitude of active power output is better from the system having inverter with power normalizing hysteresis control l as compared to the system having inverter with basic voltage current regulation control. While calculating the value of the active power it was found to be approximately 1.03 Watts and less pulsating than that of power output from the inverter having basic voltage current regulation Control.
- The increase in efficiency of the system to about 3%
- Also the value of the reactive power in system having proposed controller is better as compared to value of reactive power in system having basic voltage current regulation in magnitude as well as in stability.
- The voltage output of the system from the modeled solar system with varying irradiation and temperature control is being fed to the inverter for DC to AC conversion. This voltage is then fed to the grid. The grid voltage being maintained constant to 10KV in both the systems.
- The computational methodology of the proposed modulation technique is very easy and the technique can be applied to multilevel inverter with any number of levels. This implementation would be preferable in the solar system having different input parameters and still give output power stable and efficient.

VII. FUTURE SCOPE

The work can further be extended to the hybrid system such that the controller is redesigned to accommodate for changes in both solar input and wind energy system input. The controller has to adjust changes in variation in wind speed as well. The hysteresis loop should also accommodate changes in the current output due to variation in wind speed along with changes in irradiation and temperature input. The hysteresis controller technique can thus become more efficient and reliable.

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