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A NEW CONTROL STRATEGY FOR HIGHLY EFFICIENT PHOTOVOLTAIC SINGLE PHASE GRID CONNECTED INVERTER SYSTEM USING PARTIAL POWER CONVERTERS

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ABSTRACT--*An advanced power control strategy by limiting the maximum feed-in power of PV systems has been proposed, which can ensure a fast and smooth transition between maximum power point tracking with Partial Power Converter (PPC) and Phase Locked Loop and Current Controller (PLL-CC) method. Regardless of the solar irradiance levels, high-performance and stable operation are always achieved by the proposed control strategy. It can regulate the PV output power according to any set-point and force the PV systems to operate at the left side of the maximum power point without stability problems. The effectiveness of the proposed PPC control in terms of high accuracy, fast dynamics, and stable transitions improvement. Overall power management unit is controlled by the converter & control loop. Performance analysis (power & stability) of the overall system is carried out.The study has been carried out using MATLAB/SIMULINK model.*

Keywords--PV*, SRF, PPC, MATLAB/SIMULINK.*

I. INTRODUCTION

The performance of a solar photovoltaic array PV depends on the temperature and irradiance level and it is required to analyze the photovoltaic (PV) array characteristics. Presently, Maximum Power Point Tracking (MPPT) [5] operation is essential for [8]-connected PV systems for increasing the energy yield. Provisioning for more installations of PV needs improving the power control approaches in addition to the guidelines so as to prevent the negative effects. Perturb & Observe MPPT algorithm is used through dc-dc boost converter for tracking MPP and increase the dc voltage for the desired application.

One among the most efficient and sufficient application and usage of power generated usage PV is the operation in the grid connected mode. The grid integration with regard to PV system needs a power electronics interface with the capability of dc-ac conversion. Voltage source inverter (VSI) utilized in the form of a power electronics interface and dc voltage in the form of an input to converter needs to be controlled to the necessary level for the power flow from converter end to load/grid side. With the aim of increasing the conversion efficacy in photovoltaic (PV) systems[4], various configurations and topologies were designed. Based on the application, the converters utilized for grid connection are developed utilizing one or two stages of conversion. The benefits

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of the converters using a DC-stage chiefly include the distributed maximum power point tracking algorithm per PV string or PV module and, whenever necessary for grid connection, the feasibility of voltage increase. But, the conversion efficiency is lesser compared to configurations having a single-stage in the form of the central inverter [7]. Hence, the newly introduced work introduces a Partial Power DC-DC converter (PPC) that processes a part of the whole system power and the rest of the power is directly provided to the output end. The PLL is utilized for the grid frequency synchronization and SRF is utilized for improving the stability. VSI interfaced grid connected PV system realized based on the external voltage control loop hold the responsibility for the dc voltage control and inner current control driven by the generated reference current. Different control algorithms exists for generating the reference quantity realized for grid interfaced PV system [1-2]. The current control based approach is implemented in abundance compared to the voltage control based mechanism due to the high power factor achieving potential with better transient current reduction under distortion. Synchronization [9] and power control scheme is necessary for the operation of PV system integration to grid. Different control mechanisms are studied in the literature and the researches that depend on the power control algorithms and synchronization are also mentioned [8-12]. The synchronous reference frame (SRF) theory is implemented for control. The SRF based control is implemented employing phased locked loop (PLL) for frequency synchronization. Generally, the internal current loop is implemented with proportional-integral (PI) control and it helps in generating the ac voltage reference for the inverter. The PI controller realized for dq reference quantity is achieved employing synchronously rotating frame (SRF) due to its incapability of tracking the reference signal with accuracy under static frame. abc-dq transformation transforms the ac signal into dc one by varying from static frame to rotating frame. PI controller used on stable signal in the dq reference frame can help in tracking the reference accuracy with simple design and realization. The VSI comprises of six switching devices for the generation of the three-phase ac voltage output and couples to the grid by correctly generating the gate signals. The voltage reference/current error generated is utilized for generating the gating signals supplied to the switching device. Few typical approaches used for the generation of the switching signal includes sinusoidal pulse width modulation (SPWM) [13-17].

II. LITERATURE SURVEY

In 2018, Enkhtsetseg Munkhchuluun, Power system voltage stability is of paramount importance to maintain a secure and reliable power network with high penetration of renewable. This paper investigates the impact of the solar photovoltaic (PV) generation on long-term voltage stability of a power network. Long-term voltage stability is investigated using the Nordic-32 bus test network comprised of dynamic models of automatic voltage regulators (AVRs), over excitation limiters (OELs) and on-load tap changing (OLTC) transformers combined with static and dynamic loads. The investigation is conducted using an aggregated solar-PV system operating at voltage control mode under various loading conditions. A systematic approach has been followed for solar-PV integration. The results show that solar-PV systems enhance the long-term voltage stability of a stressed transmission grid when they operate under low loading conditions due to the improved reactive power support provided by solar-PV systems.

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In 2017, Shivananda Pukhrem, Proliferation of rooftop solar PV distributed generator (PVDG) installation in low voltage distribution network (LVDN) imposes voltage fluctuation challenges that are a threat to distribution system operators. Reactive power control (RPC) methods are insufficient in isolation to combat the overvoltage fluctuations manifested in LVDN with significant grid-tied PVDG installations. Whereas active power curtailment (APC) control can alleviate the voltage fluctuation in such situations and it is achieved at the cost of reduced active power injection. This paper explores how deficiencies in both RPC and APC as separate approaches can be mitigated by suitably combining RPC and APC algorithms. Strategies combining two RPCs and one RPC in conjunction with APC are proposed as two coordinating algorithms by means of instantaneous measurement of node voltage and active power. These coordinating algorithms are embedded in all the rooftop PVDG grid-tied-inverters (GTI), where the GTI coordinates among them for voltage support without exceeding individual inverter VA rating. The result of the combined approach show significant improvement in managing and stabilising the voltage and allows the penetration of PVDG to be increased from 35.65% to 66.7% of distribution transformer (DT) kVA rating.

In 2017, Md Saleh Ebn Sharif, Nowadays the hybrid power system is getting popular because of its advantage of renewable integration to the traditional power grid. In this paper, a review of the hybrid power system is presented and detailed analysis of steady state & transient stability is performed. For detailed analysis, IEEE 9 bus system has been adopted and modified for this study. The proposed isolated hybrid system consists of the wind turbine, solar PV array, energy storage system, a backup diesel generator and battery bank to study the system analysis. The hybrid wind-solar electric power system was modeled in ETAP software. The variation in power angle of the system after a three-phase fault is studied. The whole system also is studied and simulated for different case studies and combination of some outages to study the impact of disturbance in system stability.

In 2016, Konstantinos F. Krommydas, The challenging issue of designing stable active power controllers for photovoltaic (PV) systems interfaced to the load with dc/dc boost converters is addressed in this paper. In particular, exploiting the inherent voltage and current ripple of power converters, a new proportional-integral (PI) controller with error variable the power-voltage gradient is proposed which is capable to ensure maximum power point (MPP) operation. Taking into account the nonlinear model of the PV source and the accurate nonlinear dynamics of the dc/dc boost converter an extensive stability analysis is addressed. Based on the singular perturbation theory and Lyapunov's direct method, it is proven that for appropriate values of the PI controller gains, stability and convergence to the MPP can be guaranteed. The excellent performance of the proposed PI controller is evaluated through simulations results and it is compared with the commonly used perturb and observe algorithm and the conventional MPP method based on ripple correlation control.

In 2012, Thomas Stetz, This work discusses the technical and economical benefits of different active and reactive power control strategies for grid-connected photovoltaic systems in Germany. The aim of these control strategies is to limit the voltage rise, caused by a high local photovoltaic power feed-in and hence allow additional photovoltaic capacity to be connected to the mains. Autonomous inverter control strategies, which do not require any kind of data communication between the inverter and its environment, as well as an on-load tap changer for distribution transformers, is investigated. The technical and economical assessment of these strategies is derived from 12-month root mean square (rms) simulations, which are based on a real low voltage grid and measured dc power generation values. The results show that the provision of reactive power is an especially effective way to increase the hosting capacity of a low voltage grid for photovoltaic systems.

III. PROPOSED MODULE

3.1 PROPOSED TOPOLOGY & ITS PRINCIPLE

- In this system NRF control loop is brought into use.
- Overall switching losses is minimized in this system, just one switches is required for the complete operation though no focus is given to power management control.
- In this methodology, two or more PV units are integrated together for enhancing power-supply reliability.
- A new control approach dependent on the PPC converter is utilized for improving the smoothing performance of a grid-connected system.

3.1.1. EXISTING SYSTEM DRAWBACKS

The available system exhibits drawbacks such as

- Stability problem.
- In partial shading condition existing converter not able to track the global peak.
- Power management problem raised.
- System Performance Reduced.
- Less Efficiency.

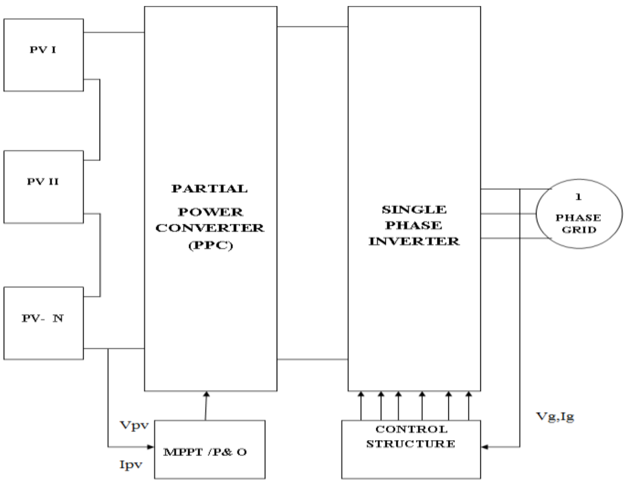

Figure3.1: Block diagram of Proposed System

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3.2PROPOSED SYSTEM BLOCK DIAGRAM DESCRIPTION

- A high-performance active power control scheme by limiting the maximum feed-in power of PV systems has been proposed in this method. The proposed solution can ensure a stable constant power generation operation.
- Compared to the traditional methods, the proposed control strategy forces the PV systems to operate at the left side of the maximum power point, and thus it can achieve a stable operation as well as smooth transitions.
- Simulation results have verified the effectiveness of the proposed control solution in terms of reduced overshoots, minimized power losses, and fast dynamics.
- However, in that case, the PV voltage operating range is limited and minor changes in the algorithms are necessary to ensure a stable operation.
- To improve the stability of injected power in PV-NRF is changed to SRF control technique.
- In partial shading condition FPC will not able to track the global peak, that is high powers but the proposed system (PPC) rectifies the above drawback.

3.2.1 PROPOSED SYSTEM ADVANTAGES

- In partial shading condition, the converter is capable of tracking the global peak.
- Power flow management is regulated.
- Cost of design is less.
- System Performance enhanced.
- Overall Stability enhanced
- Overall Efficiency of the system increased.

IV. SIMULATION RESULTS

4.1About MATLAB

The simulation of the project is done in MATLAB R2011a tool, a user friendly software. MATLAB is a high-level language and interactive environment used for numerical computation, visualization, and programming. Making use of MATLAB, data can be analyzed, algorithms can be developed, and models and applications can be created. The language, tools, and built-in math functions facilitate in exploring several mechanisms and attain a solution quicker compared to spreadsheets or conventional programming languages, like C/C++ or Java™. MATLAB can be used for an array of applications, inclusive of signal processing and communications, image and video processing, control systems, test and measurement, computational finance, and computational biology. Greater than a million engineers and scientists in industry and academia make use of MATLAB, which is the language of technical computing,Simulink is a data flow graphical programming language tool used for modeling, simulation and analysis of multi domain dynamic systems. Its primary interface is basically a graphical block diagramming tool and a set of block libraries that can be customized. It provides strong integration with the remaining MATLAB environment and can either run MATLAB or be scripted from it. Simulink is extensively utilized in control theory and digital signal processing for multi domain simulation and Model-Based Design [18].

4.1.1 SIMULINK

Simulink is a data flow graphical programming language tool used for modeling, simulation and analysis of multi domain dynamic systems. Its primary interface is basically a graphical block diagramming tool and a set of block libraries that can be customized. It provides strong integration with the remaining MATLAB environment and can either run MATLAB or be scripted from it. Simulink is extensively utilized in control theory and digital signal processing for multi domain simulation and Model-Based Design.

Simulink yields a graphical editor, customizable block libraries, and solvers used for modeling and simulation of dynamic systems. It is combined with MATLAB®, facilitating in incorporating MATLAB algorithms into models and export the simulation results to MATLAB for more analysis. Figure 4.1 shows the Simulation Diagram of PMSG based Current Control Structure with MATRIX Converter & SVPWM.

4.2. Simulation Diagram of Proposed Method

Figure 4.1 illustrates the PV- PPC-simulated model of a converter with SRF and current control loop for a grid connected system.

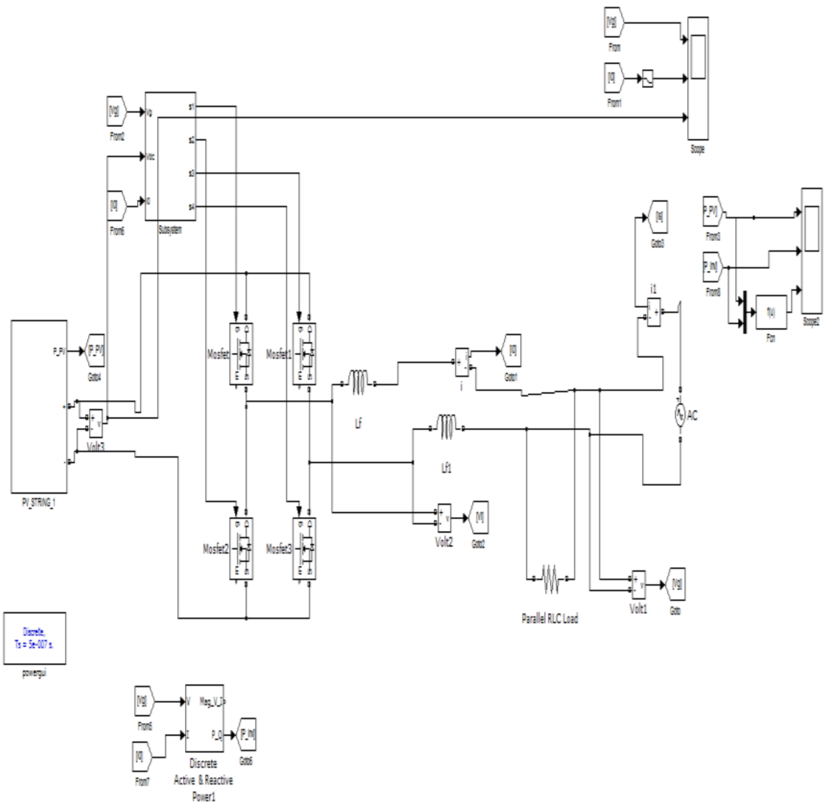

Figure 4.1: Simulation Diagram of PV based Partial Power Converter with Control Structure for Grid Connected System

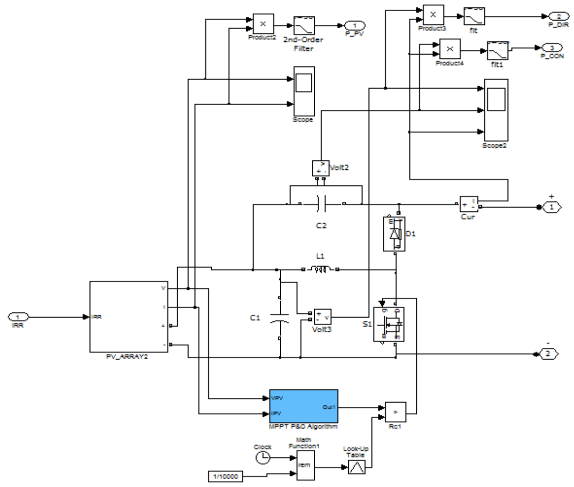

Figure 4.2: Simulation Diagram of Partial Power Converter

Owing to the stage that is added, the global conduction, switching and magnetic losses see an increase. Hence, the efficacy found in two-stage configurations is lesser in comparison with single-stage configurations. Also, the overall power that is generated by the system is dealt with by the converter that also minimizes the conversion efficacy. With the aim of overcoming the lesser efficiency, few authors have introduced various solutions depending on interleaved connections. Also, the concept of partial power converter, as illustrated in Fig. 4.2 has been introduced that makes use of the isolated converters with the aim of making the connection and preventing a short circuit. The method of partial power processing, where just a fraction of the overall power is necessary for elevating the input voltage, can considerably decrease the converter size and power loss [20-25] .

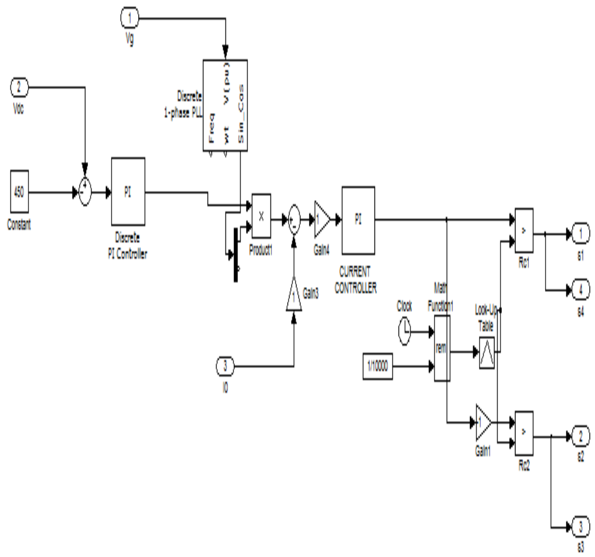

Figure 4.3: Simulation Diagram of Control Loop Structure

With the aim of comparing the performance of the newly introduced configuration, a simulation of a full power converter is done for the same operating point. Both the converters operate at the same parameters, except the voltage and current sizing for the semiconductors and the power ratings, such that they get optimized for

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attaining their maximum efficacies. It is observed that the partial power converter not just offers a better efficacy, but the needs for the semiconductors are also less. This aspect may result in an increased reliability of the grid system [19].

Various aspects of the design and operation are enhanced compared to a full power converter, like a greater efficiency of the DC-DC conversion and a small power rating for the converter is accomplished. In spite of the changes in solar irradiation, the power managed by a partial power converter stays less in comparison with a power converter, it results in lower conversion losses and a higher efficiency.

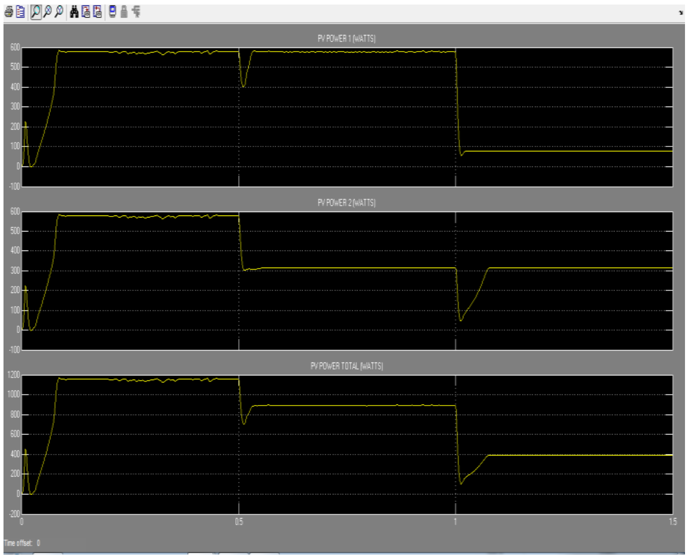

Figure 4.4: Output Waveform of PV1 & PV2

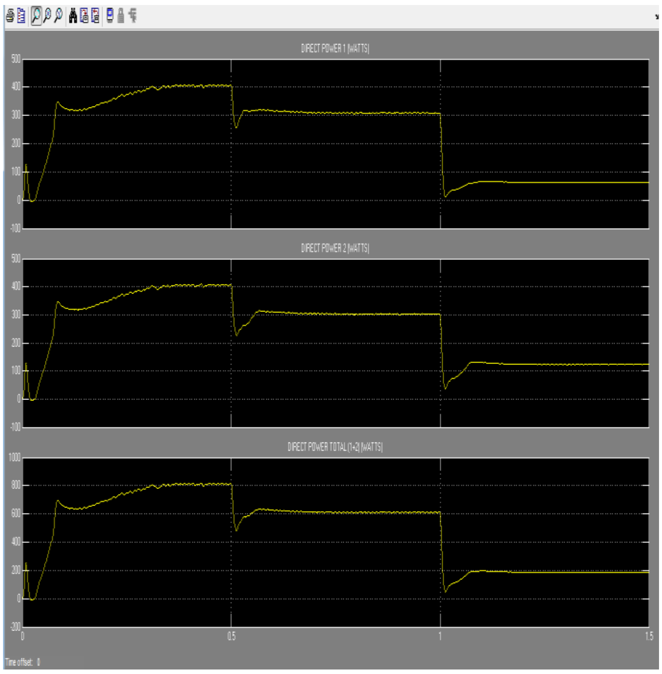

Figure 4.5 : Output Waveform of Direct Power from PV 1 & 2 to Inverter

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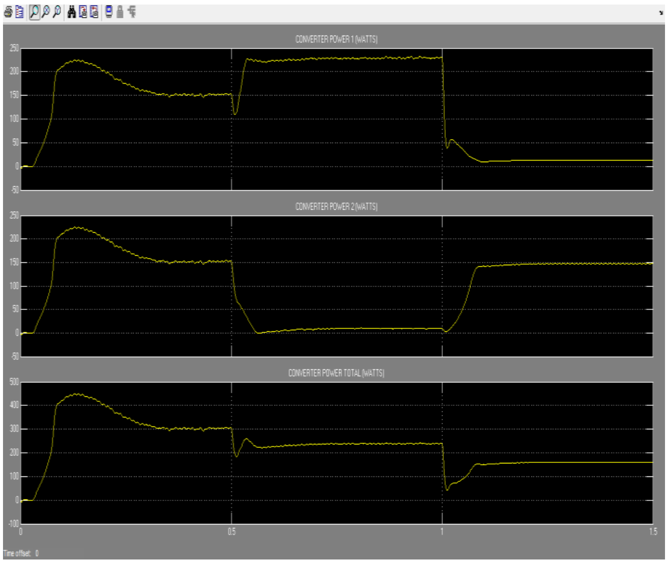

Figure 4.6: Output Waveform of Converter Power from PPC 1 & 2 to Inverter

V. CONCLUSION

A simple, high efficient dc/dc boost converter with MPPT control using Peturb and Observe algorithm desirable for medium to large scale PV systems is introduced. Higher efficiency of the converter is accomplished through partial power converter (PPC) processing also through the collaborative operation of the converter along with PLL-current control loop structure. In addition, the overall efficiency of the plant was observed to be increased by using MPPT. The reliability was found to increase by the design of the newly introduced converter. The simulation of converter proposed was done for testing the performance parameters inclusive of the efficiency, reliability, switching operation, MPPT performance and simultaneous operation. The results of simulation indicate that performance and satisfaction of the work goals are achieved. At last, the overall system performance increases in comparison with the available full power converter (FPC) and also the new system attains greater conversion efficiencies in comparison with the FPC configuration

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