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PV-STATCOM Based Smart Inverter for Reliable Distribution System: A Review

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Abstract*: The design technique based on the well-established concept of PV-STATCOM is implemented. The main task towards the achievement of more reliable increased integration of distributed energy resources on to the grid requires new pattern shift to improve the efficiency as well as overall performance of the system. The inverter which can act as smart inverter by controlling active and reactive power, frequency control and regulation of voltage and power factor apart from its typical function of DC to AC conversion could be a potential solution. PV inverter based reactive power control strategies. The control algorithm is based on balancing the power production from a solar PV depends directly on solar isolation. Hence the solar PV remains idle when there is no isolation. Solar PV along with its inverter resembles the functionality of STATCOM. The PVSTATCOM concept allows utilization of solar farm throughout the day. During daytime, real power generation takes place normally and switches to compensate dynamic reactive power needs on critical times. The dual functionality of the proposed system to regulate the reliable voltage at PCC and mitigate low voltage issues is demonstrated through MATLAB simulation to make reliable effective use of available resources Arduino controller is used to switch between the functions depending on the system requirement*

Keywords: STATCOM, MATLAB, DC to AC conversion, PCC etc.

I. INTRODUCTION

Increased integration of distributed energy resources on to the grid requires the inverter which can act as smart inverter by controlling active and reactive power, frequency control and regulation of voltage and power factor apart from its typical function of DC to AC conversion could be a potential solution [1]. Voltage source converter (VSC) technology has certain attributes which can be beneficial to overall system performance [17]. Voltage source converters (VSC) with series-connected IGBT (insulated gate bipolar transistor) valves controlled with pulse width modulation (PWM) [2-7]. VSC converters used for power transmission with voltage support combined with an energy storage source with permit continuous and independent control of real and reactive power source [11-13].

Reactive power control is also mostly independent of that at any other terminal point. Reactive power control can be optimum use for dynamic voltage regulation to support the interconnecting grid ac system. This capability can increase the overall transfer levels [8-10]. Forced commutation with VSC even permits the converter can be used to synthesize a balanced set of three phase voltages much like a synchronous machine PV inverter based reactive power control strategies in the distribution process [9-19]. The STATCOM system consists of a voltage source converter, DC link capacitor and a DC source. The DC voltage from the capacitor is converted to AC by the VSC in order to drive the grid requirements [18].

Arduino controller is used to produce PWM signals for IGBT switching of VSC [12]. In PVSTATCOM during daytime operation the required DC power is obtained from PV whereas at night a battery is used for real power support [16]. In conventional operation of solar farm, the photovoltaic (PV) modules remains idle most of the time after meeting the required load active power during day[5-6]. Hence in order to increase the efficiency and transmission capability of system PV system along with its voltage source inverter can be made act as Static synchronous compensator (STATCOM) [3-4]. Unit vector controller-built PV control as STATCOM for power quality enhancement is depicted in .But the current controller used leads to oscillations as the controller deviates around set point. [12]

Introduces virtual inertia based Photovoltaic controller to stabilize unbalanced grid and frequency situations. The virtual inertia controller when it tries to imitate the actual system it may result in large value of inertia constant than required. It leads to increased size of storage systems. On the other hand, low inertia constant lessens the stability of the system. Therefore, the behavior of the total system at any time depends on the choice of inertia constant.

The combined usage of PV as inverter along with Battery energy storage system [BESS] improves the system performance in terms of voltage regulation and reactive power compensation [14-15]. Neutral point clamped Voltage Source Converter with Fundamental frequency switching along with phase shifting transformer is introduced in [20]. However, there is a problem of current shoot through and spiking of voltage ma occur. Hence Arduino controller was introduced to act as controller for PV-STATCOM since I is quite efficient and simple to implement and control.

II. LITERATURE REVIEW

K.Sujatha, M.Satyanarayana, ***"Control Application of PV Solar Farm as PV-STATCOM for Reactive Power Compensation during Day and Night in a Transmission Network"*** describes a new application of a grid connected PV solar farm inverter as a PV-STATCOM, during both night and day for increasing transient stability and consequently, the power transmission limit of long transmission line. It utilizes the entire solar farm inverter capacity during the night and the remainder inverter capacity after real power generation during the day; both of which remain unused in conventional solar farm operation.

Sateesh Bandharupalli, Kommu Jyothi, ***" New Control of Solar PV Farm As STATCOM (PVSTATCOM) for Increasing Grid Power Transmission Limits During Night And Day "***describes a completely unique concept of utilizing a photovoltaic (PV) solar farm inverter as STATCOM, called PV-STATCOM, for improving stable power transfer limits of the interconnected transmission system.

Nandini Pillaia, Mrs T PhaniSwechabandMr Elijah Toppo, ***"Modelling and Control of PV inverter as STATCOM in Grid connected PV systems"***describes a grid-connected PV simulation system with D-STATCOM. By using Matlab/Simulink for modeling PV system, this paper shows I-V and P-V characteristics of PV array, and uses D-STATCOM as the grid-connected converter to realize power coordination, voltage stabilizing and power quality improvement.

k. Turitsyn, P. Sulc, S. Backhaus, and M. Chertkov, ***"Options for Control of Reactive Power by Distributed Photovoltaic Generators "***describes discuss and compare via simulation various design options for control systems to manage the reactive power generated by these inverters. An important design decision that weighs on the speed and quality of communication required is whether the control should be centralized or distributed.

L. Liu, H. Li, Y. Xue, and W. Liu, ***" Reactive Power Compensation and Optimization Strategy For Grid-Interactive Cascaded Photovoltaic Systems "***describes optimized reactive power compensation algorithm (RPCA) is proposed to improve the system operation stability and reliability, and facilitate MPPT implementation for each converter module simultaneously.

III. METHODOLOGY

The operating modes of the system under consideration vary with time of the day and the system's present condition. To denote specific modes an index M is used. The working of the smart inverter operation modes is as depicted in the flowchart in figure 1 is explicated below. Voltage control at PCC is high priority task both at daytime and night time. Power factor control is done only when the voltage levels were under acceptable limits. In general at daytime the real power generation mode (M=0) and at night time reactive power support mode (M=2).

A novel smart inverter PVSTATCOM in which a PV inverter can be controlled as a dynamic reactive power compensator STATCOM.

The proposed PV-STATCOM can be utilized to provide voltage control during critical system needs on a 24/7 basis. In the nighttime, the entire inverter capacity is utilized for STATCOM operation.

During a critical system disturbance in the daytime, the smart inverter discontinues its real power generation function temporarily (for about a few seconds), and releases its entire inverter capacity for STATCOM operation.

Once the disturbance is cleared and the need for grid voltage control is fulfilled, the solar farm returns to its pre-disturbance real power production.

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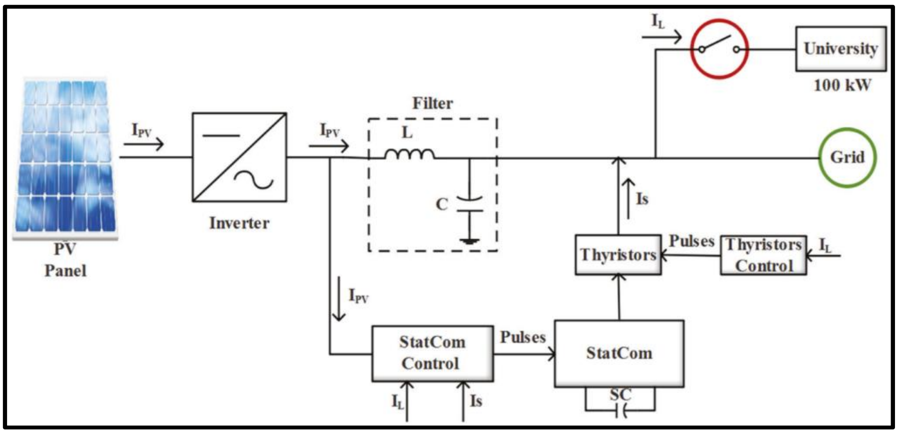

Figure 1: Flow Chart for operation mode selection

During Daytime:

The reactive power compensation ability of the inverter (Qrem) after real power injection is computed in every interval. In case of disturbances like fault, if the voltage limits are violated the PV inverter now works fully as STATCOM (M=2). Reactive power support is provided at the full inverter capacity (Qreq=Qrem). At any instant if the reactive power available goes lower than required at that instant the PVSTATCOM is switched into partial mode (M=1). The real power available at point from PV module is injected to the grid and voltage regulation occurs. The power factor correction is also made during partial mode up to the capacity of the inverter. The solar system then enters real power mode when the power factor correction is not required.

During Night time:

In case of fault or any such disturbance, it tends to violate the voltage beyond the defined limits. Then the PV inverter switches to work fully as STATCOM (M=2). With the full capacity of inverter reactive power is exchanged to control the voltage. If the above is performed within its range, power factor improvement can also do if required.

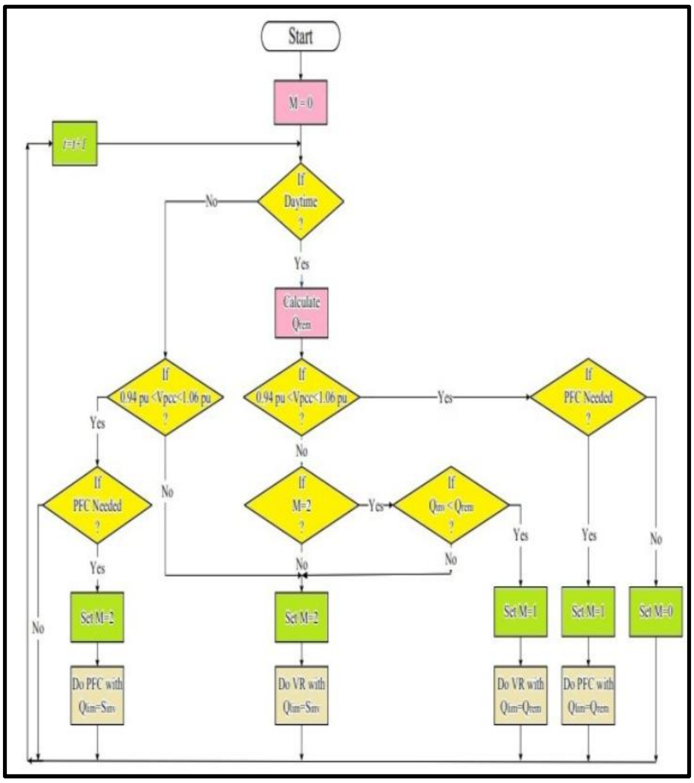

Figure 2: Flow Chart for operation mode selection

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IV. CONTROL OF DC LINK VOLTAGE AND LOAD CURRENT

The power loss occurred due to the inverter switches were compensated by DC link capacitor by suppling real power. Thus there is a steady decrease in DC link voltage. The inverter in turn absorbs active power from the solar panel output in order maintain the DC link voltage. When power from solar panel isavailable the inverter absorbs a part of it to maintain the charged state of DC link capacitor. During night hours when there is no real power generation active power required to maintain the DC link voltage is obtained from the grid.

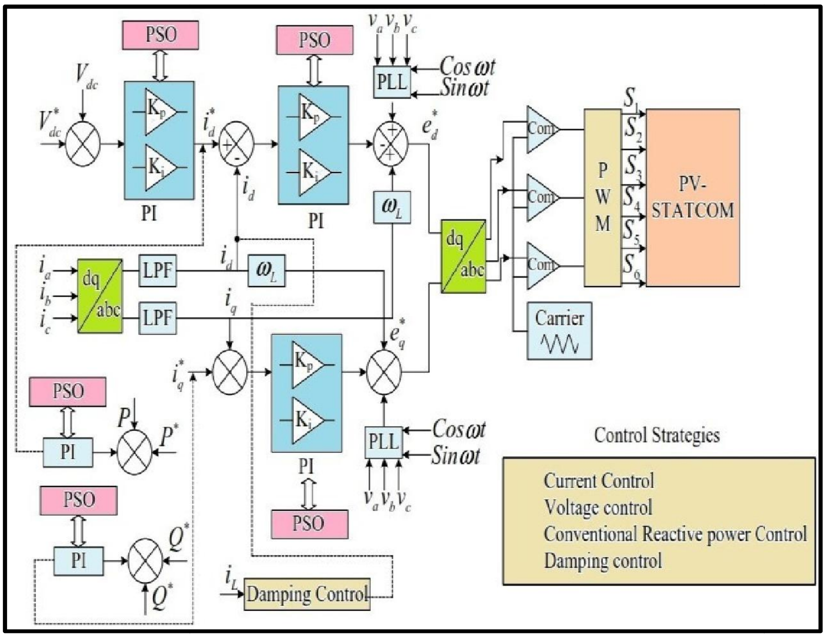

Figure 3: load current control

The load current is converted to dq frame (id and iq) from abc frame after passing through a low pass filter. Phase locked loop (PLL) is utilized for synchronization of PCC voltage and three phase signals. PWM technique is used to generate gate pulses of the inverter. In order attain optimum results PI controllers need to be fine-tuned. PI controller tuning general objectives are low overshoot and fast damping of oscillations. Optimization algorithms are used to reduce error values of PV-STATCOM voltage, active power, current and reactive power as well as in the updating process as depicted in figure 3. Particle swarm optimization (PSO) algorithm is used for Optimal tuning of PI controllers.

V. PROPOSED SIMULATION RESULTS

In this portion, the simulation results of a wind farm along with induction generator is exposed using MATLAB. The wind farm is connected with STATCOM and capacitor bank to compensate the reactive power. Simulation results have been compared along with necessary graphs.

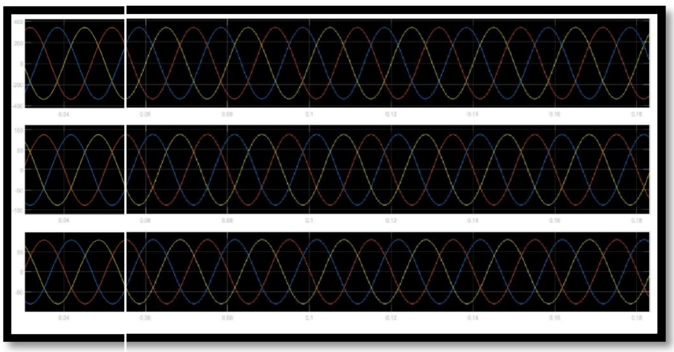

Fig. 4 Source Voltage, Source Current , Load Voltage.

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For the adjustments in power system (for example,increment in loading, generator achieving reactive powerlimits [10] etc.), voltage stability has been a great concernfor power system utilities. Induction generator (IG) basedwind turbine has been used because it canrecover *energy* with relatively simple control and it is alsocost-effective. Though the active power produced byconsistent speed, wind turbines is fluctuated because of theimpacts of disturbance, the wind slope, the tower shadow andthe reactive power request of these squirrel-cage inductiongenerators have additionally changed. Voltage fluctuationcan be caused at the point of normal coupling (PCC) due tothe active and reactive power variations. Despite the fact thatCapacitor bank is utilized to keep up reactive power at consistent state, it can't legitimately be controlled to keep thevoltage steady. In wind farms, STATCOM provides thevoltage which is more stable and it is also cost-effective. With the ever increasing use of renewable energy [11, 12]resources, the use of STATCOM has become absolutely essential grid-connectedwind farm stability has been upgraded by mitigating voltagefluctuation and attaining reactive power compensation using Static Synchronous Compensator (STATCOM).

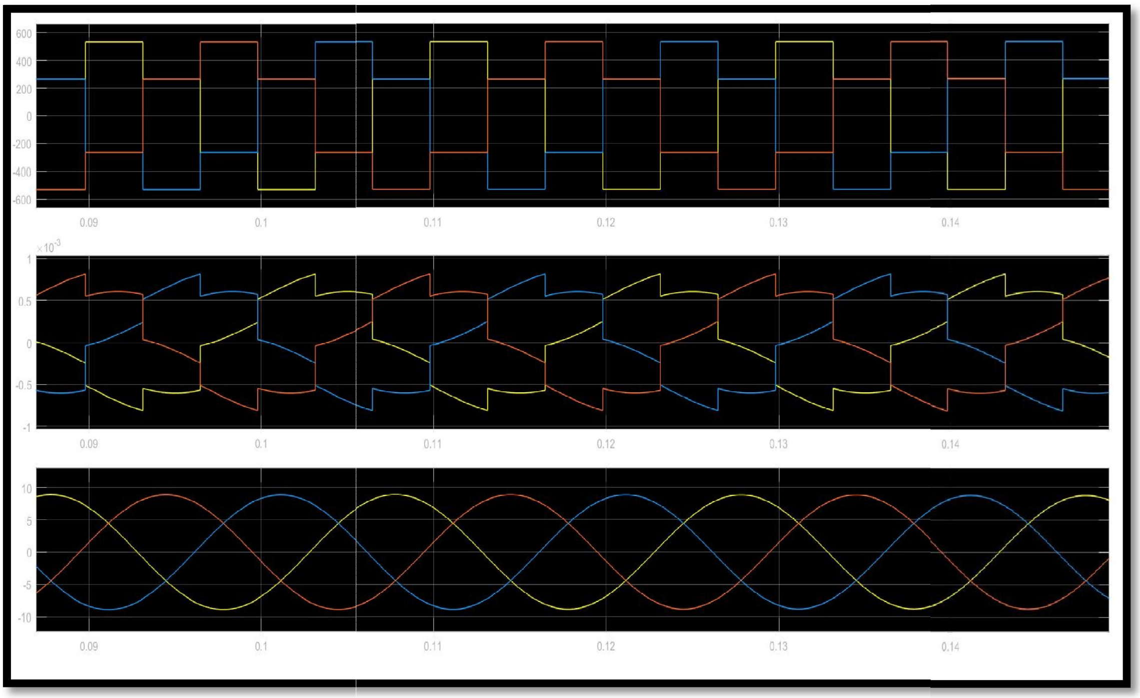

Fig.5 STATCOM Voltage, Injected Voltage, Wind Current.

Fig. 5 shows a controlled voltage profile after a certain load variation, and, therefore, a variation in load current can also be seen. After every switching operation in the MG system, the voltage profile is maintained with the PID Controller.

Voltage controlloop with PID controller has been used to control STATCOM. A Pulse Width Modulation (PWM) method has been adopted asthe control strategy of STATCOM. Different comparative studyregarding stabilization of a wind farm has been performed usingdifferent approach (i.e. wind farm with capacitor bank and STATCOM or using STATCOM along with Proportional–integral–derivative (PID)controller) during wind speed change.Comparison of result shows that STATCOM with PIDcontroller offers better performance with enhanced stability.

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