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Optimization of Power Quality for PV Solar System based Grid using STATCOM

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Abstract: **PV to grid connected with reactive power control through the STATCOM perform in MATLAB/Simulink 2015a. A grid connected photovoltaic system is becoming increasingly important for the solution in renewable energy. This work proposed as a PV to grid connected system. This work processed in two stages where, stage one is the DC-DC boost converter with MPPT (Maximum power point) tracking and second stage is the rectifier which is further connected with grid with reactive power control. Also the DC bus is useful to balance the bus voltage. For rectifier stage used a H-bridge topology which is reduce the switched count and other parameters. After this stage levelled output passes through designed LCL filter which gives AC output and connected to grid. This work simulates at a 2 kW power rating and use a PV module as 1 parallel and 8 series connected string at specific module. With open circuit voltage Voc is 36.3V. There are 8 module are connected in series so the equivalent output voltage near about 290V.**

Index Terms – **GRID, STATCOM, H-bridge, MPPT**

I. INTRODUCTION

Alternative green energy sources are becoming increasingly popular as the demand for electricity continues to rise. One of the most promising renewable green energy technologies used as an alternative power source is photovoltaic (PV) power generation. For improved performance, PV integration into the load necessitates power electronic converter support. Due to the widespread use of power electronics converters in stand-alone and grid-based systems, their complications are rapidly evolving [1].

Distributed smart grid-based energy generation systems will replace the current centralized and large grid-dependent electric power system in a sustainable future. In order to accomplish this, the world is increasingly utilizing renewable energy sources like fuel cells, solar, wind, and tidal power [2, 3].

Power electronics are necessary for utilizing renewable energy sources like wind and solar. As the power created by photovoltaic (PV) framework is DC, to change over it into AC power converters are required. Similarly, a generator with a high efficiency is required to convert wind energy. Additionally, power converters contribute to an improved waveform by reducing harmonics and achieving a high power factor. The development of technology over time, particularly the development of power electronics applications, has resulted in numerous specialized comforts and prudent benefits; However, it has also added new challenges to the power system operation concern. Power systems are increasingly operating at - and occasionally exceeding - their maximum execution limits in order to increase resource use, driven by testing ecological requirements, the expansion of the energy market, and the privatization of the power supply industry [4, 5].

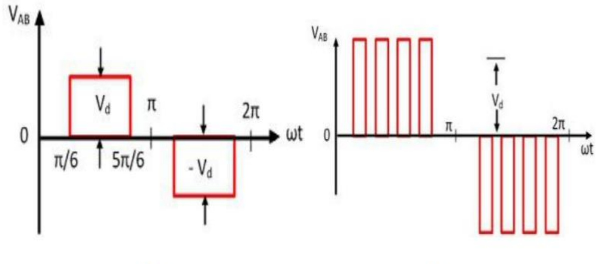
The system's safe and dependable operation in relation to various components of power system operation needs to be maintained in order to prevent genuine utility issues from occurring in these circumstances. The enthusiasm for finding, portraying, or more importantly, in estimating system conduct develops consistently due to the fact that the nature of electrical power—such as the voltage provided by the utility or the client-infused current—has evolved into a crucial component. In order to maintain stable system performance, alternative methods are required to identify power quality issues before they occur due to the widespread use of electronic loads in distribution networks. Electric utilities try to meet the requirement that power distribution systems should work with pure sinusoidal waveforms on a regular basis [6].

However, the proximity of harmonics in the power system indicates a threat to delicate equipment like PCs, power electronic loads, and adjustable speed drives, among others. These kinds of equipment are constantly acquainting distortion with the constant state current and voltages during their typical operation. Due to these circumstances, attention needs to be paid to the nature of electrical power and the problem of voltage and current harmonic distortion. As a possible arrangement, efforts to establish relentless state harmonic points of confinement as guidelines for electrical systems with power devices or other nonlinear loads were developed. Harmonic currents are constrained by gauges, influencing the voltage waveform [7, 8].

II. INVERTER

Based on the input source, inverter circuits are typically categorized as voltage source inverters (VSI) or current source inverters (CSI).Medium voltage and high power applications require VSI technology most effectively [7].The CSI is mostly used in applications that use a lot of power and can protect the system from short circuits. Based on the control strategies used, the VSI can be divided into two categories: Square wave (SW) and pulse-width modulated (PWM) inverters. PWM inverters are more popular and have a wider range of applications than the other. The dc input voltage must remain constant in PWM inverters;

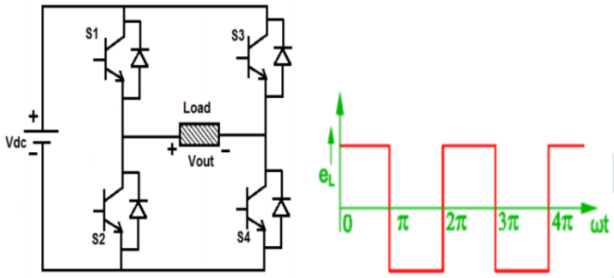
Furthermore, the inverter must be used to regulate the frequency and magnitude of the AC output voltage [8].The AC output voltage is shaped using a variety of PWM schemes to more closely resemble a sinusoidal waveform, as shown in figure 1.



(a) (b)

Fig. 1: PWM and Square Wave Inverter waveform

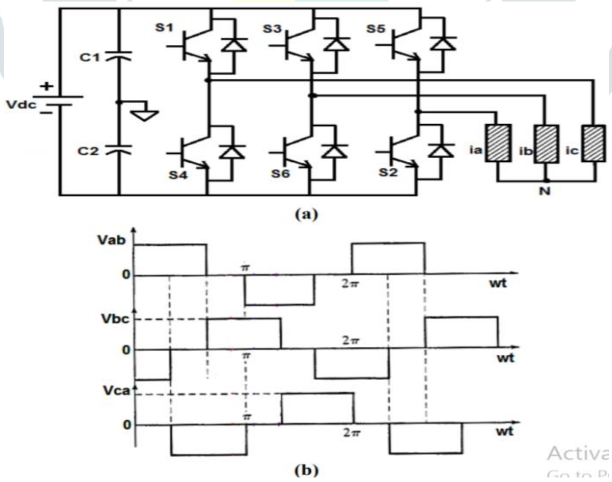
Because these inverters technically divide the DC bus voltage into two parts, the DC bus's midpoint may not be available for many applications. In most three-phase, four-wire systems, this point is used to keep the circuit's neutral current at zero [8].



(a) (b)

Fig. 2: (a) Single Phase Full Bridge VSI circuit (b) AC Output Voltage

There are three ways to set up the traditional 2-level VSI circuit: Circuits for a single phase half bridge, a single phase full bridge, and a three phase full bridge. One source, two switches, and two anti-parallel diodes are all present in a single phase half bridge inverter [9].The inverter circuit is created by combining these switches and anti-parallel diodes. The load is connected between two legs in a single phase full bridge circuit, as depicted in Figure 3. The three-legged three-phase inverter, also known as the six-pulse inverter, is depicted in Figure 3a and Figure The three-phase line-to-line voltage waveform is shown in Figure 3(b). Two modes of operation exist for each leg: The voltage at the output is +Vdc when the top switch is ON. The output voltage is –Vdc when the bottom switch is on. Additionally, when both switches in one leg are turned ON, a short circuit may occur. Therefore, a three-phase VSI can operate in a total of 23 or 8 switching states [9].



(b)

Fig. 3: (a) Three phase VSI circuit (b) Waveform of Line to Line Voltage

When the two-level or conventional VSI is used in high-voltage and high-power applications, there are a few drawbacks. For instance, in applications for electric utilities; The six pulse converter must use devices connected in series to block the DC bus voltages because the power handling capacity of six pulse inverters is greater than the rating of individual power switching devices [10].The dynamic and static voltage sharing can only be controlled by limiting the number of devices connected in series. In order to guarantee that all switching devices equally share the voltage, snubber circuits are used to control the device's shutoff time. The coordination between turning on and turning off semiconductor devices in long strings becomes more difficult. In this design, only a small number of devices can be connected in series successfully, resulting in poor device utilization. As a result, the snubber circuit loses a lot of money as well.

III. PROPOSED METHODOLOGY

When compared to the situation that exists currently, the demand for electricity is greater. Green Energy-based Distributed Generators (DG) are playing a crucial role in electric power systems in order to meet global power demand. Utilities and power engineers are currently most concerned about power pollution. Non-linear loads, also known as distorted or sensitive loads, are to blame for problems with power quality like a low power factor, voltage variations, harmonics, and an excessive demand for reactive power, among other things.in the system of electrical distribution. In the electrical power systems, Active Filters play a major role in reducing quality-related concerns. The use of a photovoltaic (PV) solar farm as a PV-Statcom in a grid-integrated wind-pv system to improve the quality of electric power and the system's power transfer capacity during the day and night was the primary focus of this paper. The PV solar farm only produces real power during the day, and it is completely idle at night.
The loads on the power feeders are much lower at night than they are during the day, but wind farms generate a lot of power because of the higher wind speeds, which causes the power from PCC to flow back toward the main grid source. which causes voltage variations in grid-integrated systems to typically be less than 5%.Voltage source converter-based PV-Statcom can change the dynamic and responsive power at the measure point (PCC) in electrical dissemination framework, to keep the framework voltage inside as far as possible to enhance the nature of force in network tie proposed framework. The PV-statcom's fundamental structure is depicted in Figure 4.

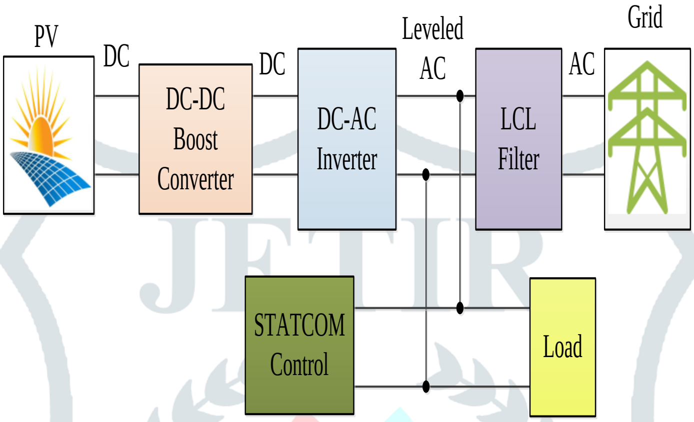


Fig. 4: Basic block diagram of the PV STATCOM

Designing of H-bridge Rectifier
In this work proposed an H-bridge rectifier which is suitable to connect PV and transmit a power to the grid. Proposed rectifier generates a three-level at the input of the rectifier as V_{dc}, 0, -$V_{dc.}$ Proposed topology is represented in figure 5. This topology has 4 switch and 1 capacitors as a dc-bus capacitor which is connected after the first stage which is AC-DC boost converter. Levelled voltage as a three-level voltage occurs at the input terminal of the rectifier.

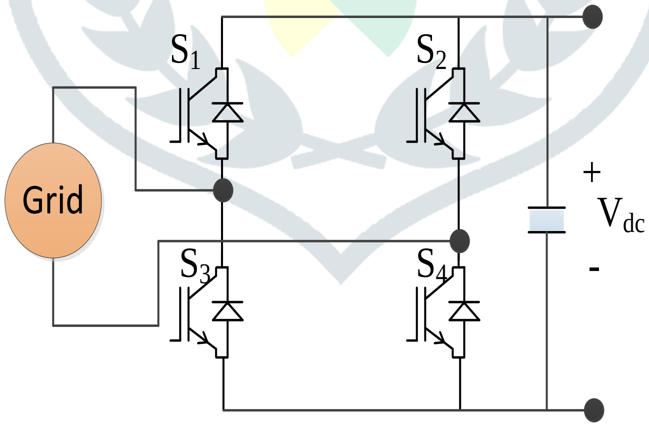


Fig. 5: Proposed H-bridge rectifier topologies

+V_{dc} Level

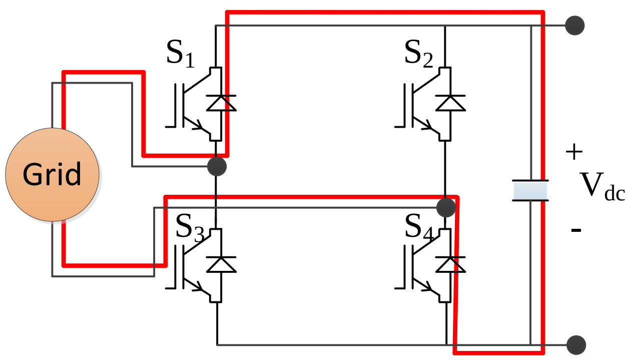


Fig. 6: +V_{dc} Level

By turning ON switch S_1 and S_4 and other switch OFF, capacitors is connected in series through the grid, it gives $+V_{dc}$ voltage at the input of the rectifier. This stage specified in Figure 6.

0 Level

By turning ON switch S_1 and S_2 or S_3 and S_4 and other switch OFF, capacitor is by passed and it gives 0 voltage at the input of the rectifier. This stage specified in Figure 7.

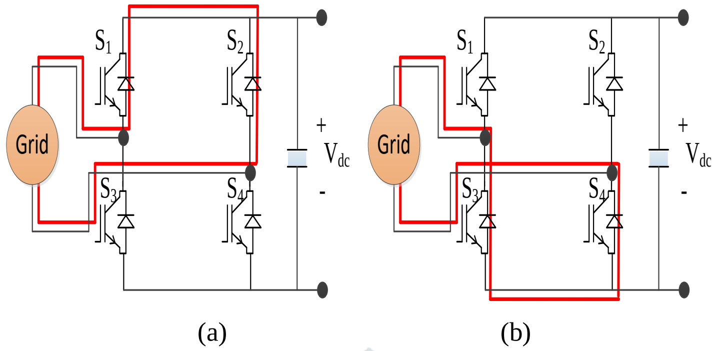


Fig. 7: 0 Level (a) when switch S_1 and S_2 on (b) when switch S_3 and S_4 on

$-V_{dc}$ Level

By turning ON switch S_3 and S_4 other switch OFF, capacitor is connected in series through the load and it gives $-V_{dc}$ voltage at the input of the rectifier. This stage specified in Figure 8.

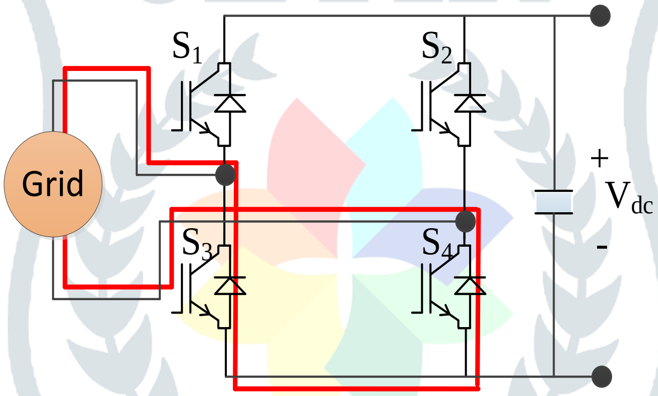


Fig. 8: $-V_{dc}$ Level

IV. SIMULATION RESULT

This work simulates at a 2 kW power rating and use a PV module as 1 parallel and 8 series connected string at specific module. With open circuit voltage Voc is 36.3V. There are 8 module are connected in series so the equivalent output voltage near about 290V. So, specified 290V maximum dc output voltage. Parameters of PV panel depicted in Table 1. Graph plot of current and power with respect to voltage shown in figure 9.

Table 5.1: Parameters of PV

Module	1Soltech 1STH-215-P
Parallel and series module	1 and 8
Module power	213.15 W
Open circuit voltage Voc	36.3V
Voltage at maximum power point	29V
Temperature coefficient of Voc	-0.36099 %/deg.C
Cells per module	60 Ncell
Short circuit current Isc	7.84A
Current at maximum power point	7.35A
Temperature coefficient of Isc	0.102 %/deg.C

STATCOM uses single phases powerful Voltage Sourced Converter as its core. Its voltage output connects system by through reactor or transformer. And regulates AC voltage amplitude and phase of rectifier to absorb or produce reactive power for system.

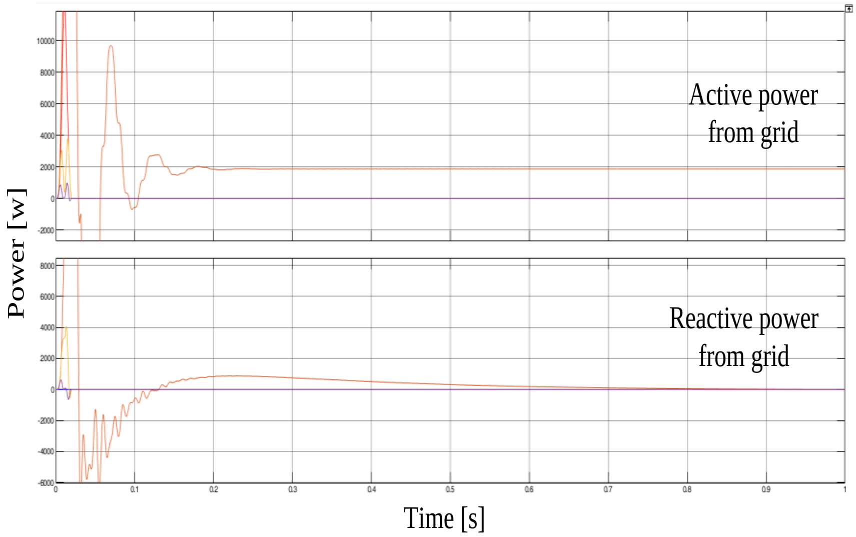


Fig. 9: Active power 2kW drown from the grid and reactive power 0

By the single-phase power measurement module justified the grid power, rectifier power and delivered power to the load. In this figure verified that load absorbs active power from the grid and reactive power from the STATCOM. From figure 9 it is clear that active power drawn by the grid and reactive power is zero.

It is fulfilled by the STATCOM that is shown by figure 10. That is 1.8kW as a active power and similarly 1.8kW as a reactive power it is required to load. Figure 11 shows the active and reactive power fulfilled and drown by the rectifier where the reactive power is 2kW and active power is zero. So its operation mitigates the requirement of the reactive power to the load.

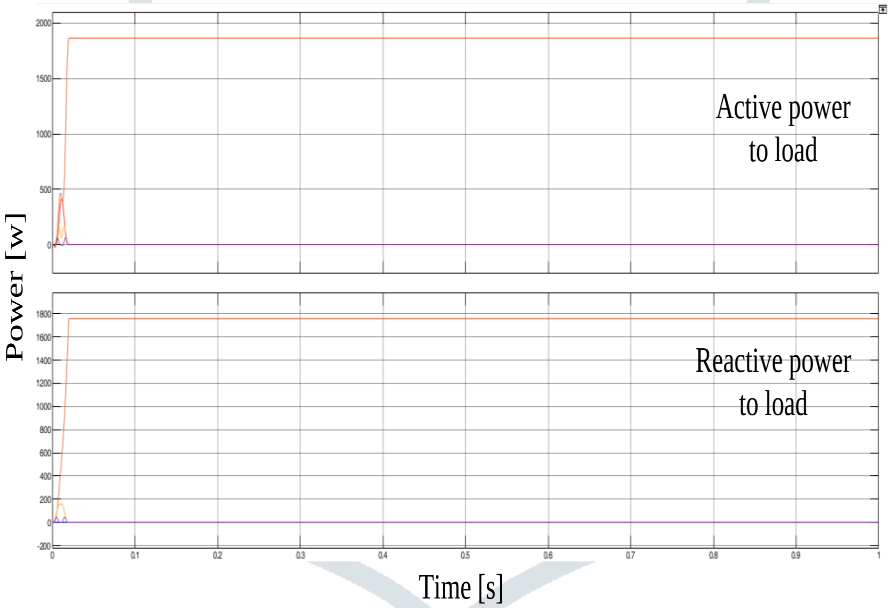


Fig. 10: Active power and reactive power to the load

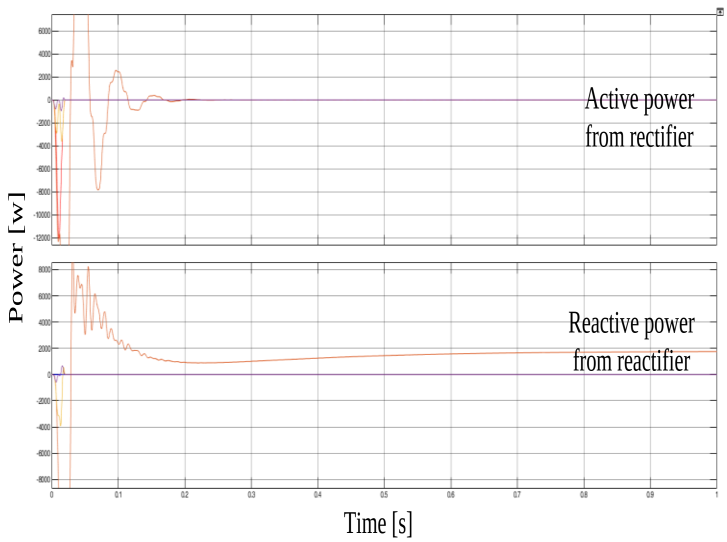


Figure 11: Active power and reactive power from the rectifier

Grid voltage and current

This figure shows the single-phase grid voltage and current. Main concern of the STATOM application is clearly stated the active power absorb from grid and reactive power absorb from inverter. In this figure clearly seen that grid voltage and grid current are in phase that means unity power factor (PF). So, in case of unity power factor phase difference between voltage and current is zero that means cosΦ = 1. It's represented to active power drown from the grid with remove all harmonics of the current by using filter and get ripple free current as shown in figure 12.

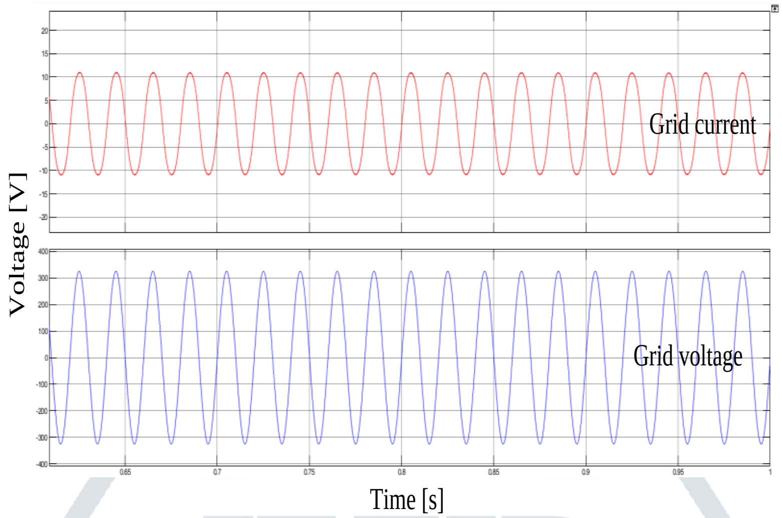


Figure 12: Grid voltage and grid current with unity power factor

V. CONCLUSION

For connection of renewable energy source to the grid required a power electronics converter. PV system generates a power in a form of DC so here required an inverter which is convert this dc power to the levelled AC power. It is a second stage of the proposed system in this stage convert DC voltage into the levelled AC voltage and cascaded T-type inverter used in this stage. By using of single T-type inverter generates a three-level at the output although cascaded of three modules through T-type inverter generates seven-level at the point of levelled AC output.

Application of STATCOM represents the three-phase load achieve reactive power from the inverter not from the grid. Inverter current 90° phase shifted from the grid voltage so in this case power factor (PF) is zero. That means sinΦ = 1, its representation for reactive power. By using filters, we can achieve current without harmonics and achieve ripple free rectifier current and grid current.

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