Optimizing Grid-Connected Inverter Performance Through Voltage Stability Control

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Abstract:- Everyday, non-renewable energy sources are being depleted while energy use rises. In response to these arguments, we ought to generate more renewable energy. But a big problem with renewable energy is that its production is weather-dependent. In overcast and unfavorable weather, the energy generated on the grid side is insufficient to match the demand on the load side. The primary load-side issues may be non-linear loads that lower the energy network's power quality or excessive or unmanaged energy demand. When compared to the production of renewable energy, energy sources that are connected to the grid through an electronic converter or inverter have quite different operating characteristics. The stability of the grid and solutions to the grid-to-transmission-line stability issue are the main topics of this study. The benefits of using inverters in a power system from the grid to the transmission line with MPPT and PI controllers are examined in this article. A robust control system with an inverter-equipped PI controller and MPPT addresses the main problem.

Keywords:- *IGBT; Boost Converter; PI Controller; MPPT; PV Array.*

I. INTRODUCTION

The ability of a power system to sustain constant voltages at each bus after experiencing a disruption from a specific initial operating condition is known as voltage stability. When electricity is transported between the generation and load sites via a transmission network, voltage drops or losses happen. These voltage drops are within the grid's allowed bounds under typical operating conditions. In this case, problems could be caused by excessive or unmanaged energy production, as that which occurs on a partially cloudy day. Nonlinear loads or excessive or uncontrolled energy consumption may be the main causes of problems on the load side. Voltage stability is the capacity of a power system to keep all of its buses operating at constant voltages even when there is a disruption from a certain initial operating condition. There are drops or losses in voltage. [1] When a network for transmitting electric power has connections between its generating and load sites. These voltage dips occur within the permitted limits of the grid when it functions normally. However, due to disruptions, spikes in power consumption, or other system changes, the bus voltages may deviate materially from the acceptable operating range (established by power system operators or grid code), rendering operator intervention or automatic control ineffective in reversing the deviation. [2]

➢ *Aims*

This research aims to provide a practical approach that evaluates voltage security and uses information from a power system model to suggest corrective actions. The particular tasks that need to be finished in order to accomplish this thesis are:

- We can obtain a reliable output by adjusting the constant voltage.
- It is also possible to modify the boost converter output value to achieve the required voltage.
- A PI controller is utilized in order to stabilize the voltage output.

The research's primary goals are to evaluate voltage stability using MPPT and treat noiseless output voltage using an LC filter. To get satisfactory outcomes from the MPPT and PI controller, it is important to precisely simulate the system using the MATLAB program.

II. LITERATURE REVIEW

We read a paper which published in 2008, an examination of voltage stability and control in distribution networks with distributed generation (DG) is presented in this research. Distribution systems with and without synchronous and induction machines (DG) are assessed for their potential operation characteristics in terms of steady state voltage and reactive power regulation. It is looked into how the DG affects different voltage stability processes. [1] This paper examines the stability issue of the grid-connected voltage-source inverter (VSI) using LC filters. It shows that, when a traditional proportional-integrator (PI) controller is utilized for grid current control, potential variations in grid impedance have a major impact on the stability of the system. The tracking performance and disturbance rejection capability of the PI controller are lowered as a result of having to reduce its low frequency gain and bandwidth in order to maintain system stability when the grid's inductive impedance rises. [3] The examination of a hybrid PV-battery/super capacitor system and the detailed presentation of active power control in MATLAB/Simulink for a novel topology are mentioned.

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Investigating research in the literature more thoroughly is the first step. This paper looks at the advantages and disadvantages of super capacitors for active photovoltaic power regulation. Super capacitors used in active PV power regulation won't cost more since, as shown, using them on the load side reduces the storage system's cost. [4] By speeding up battery aging and increasing efficiency, super capacitors can also save costs in other ways. A novel architecture for HESS is proposed to lower PV peak power and share PV power. Reference [5] by calculating the areas and borders of a power system, one may predict its stability condition and prescribe preventive actions to bring the system back to stability. [6]

III. MATERIALS

Here, we're utilizing a lot of components.

- *PV Array*

The whole power-generating system is a photovoltaic array, which can consist of any number of PV modules and panels. The maximum DC power output (watts) of PV modules and arrays defines their functionality under Standard Test Conditions (STC). In our setup architecture, the PV array serves as the input.[7]

Fig 1 PV Array

- *Boost Converter*

The boost converter is used to "step-up" an input-Voltage to a higher level that is required by a load. This unique characteristic is made feasible by storing energy in an inductor and transferring it to the load at a higher voltage. Here, the voltage is being raised via the boost converter.

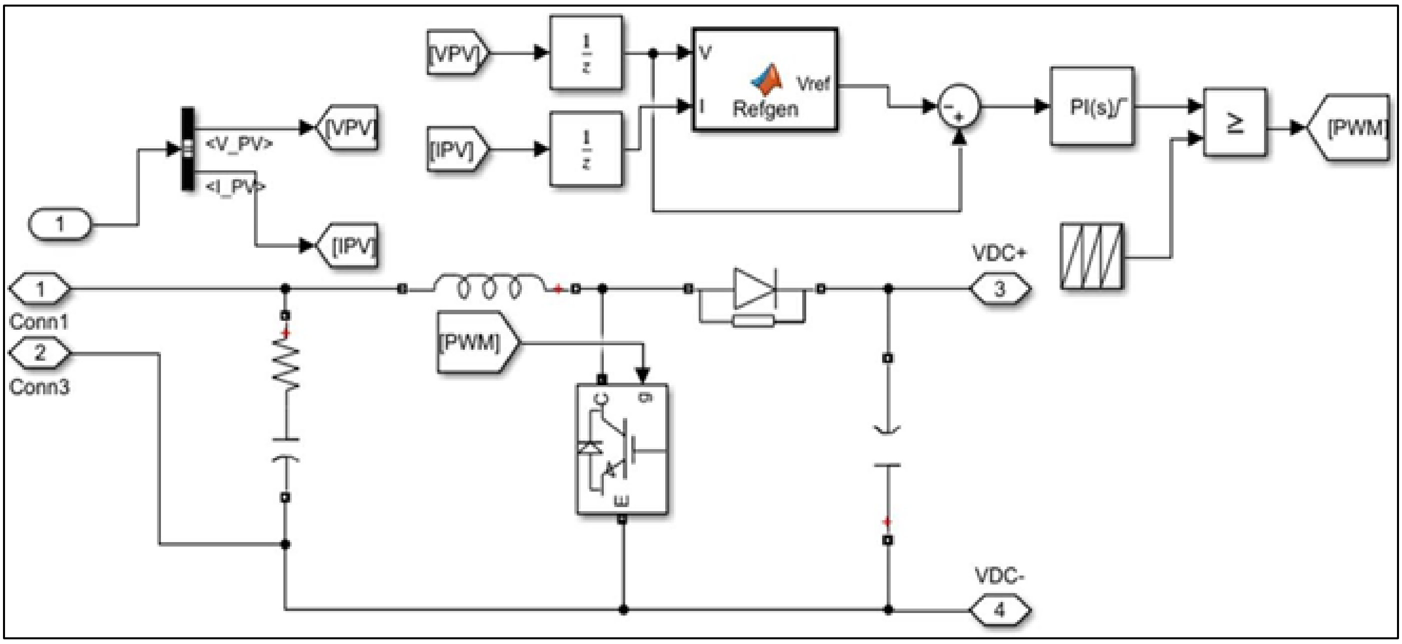

Fig 2 BOOST Converter

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- *Inverter*

We use some IGBT and connect them to the boost converter's PWM port to create the inverter.

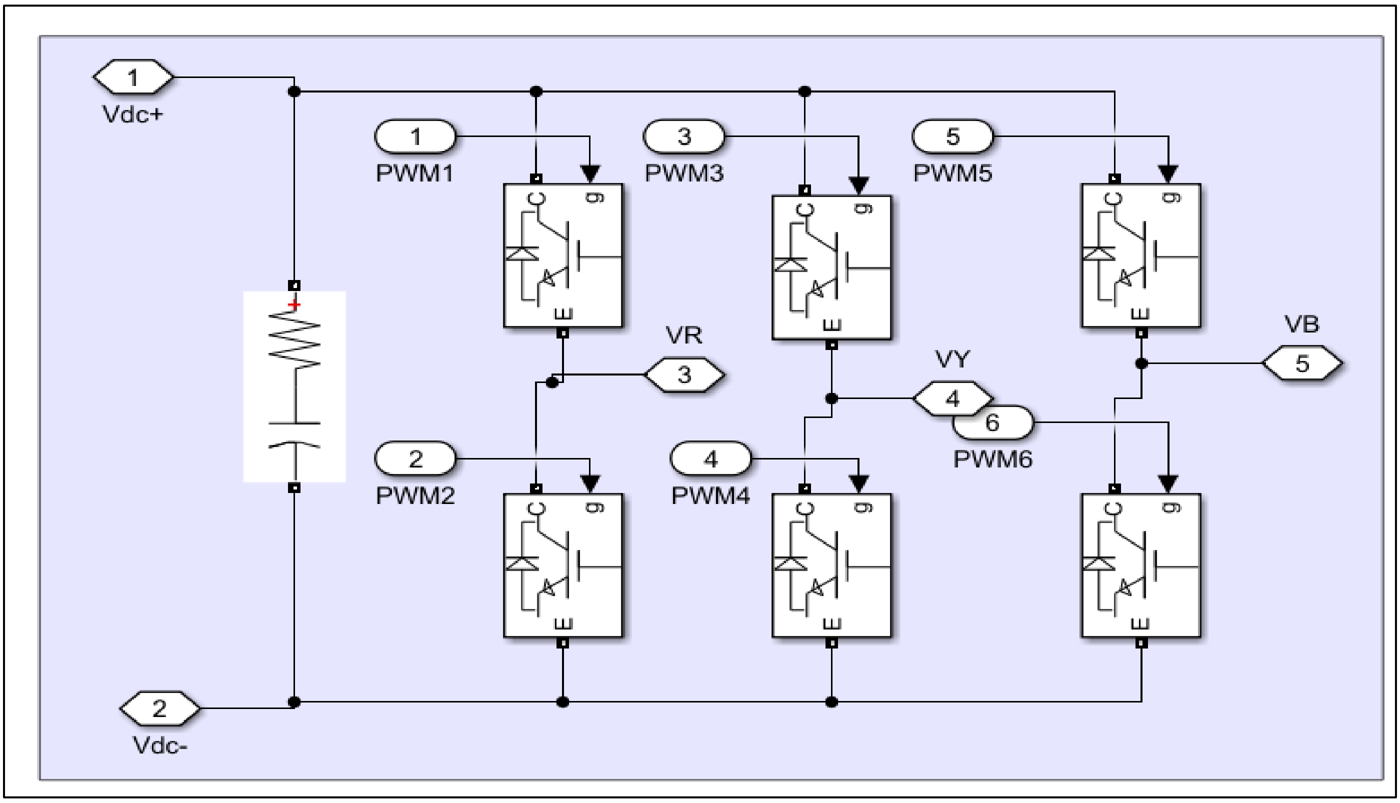

Fig 3 Inverter

- *Advanced Voltage Transformation Block*

Through the Park Transform block, the time-domain components of a three-phase system in an abc reference frame are converted into direct, quadrature, and zero components in a rotating reference frame. The active, reactive, and system powers can all be preserved by the block in the ABC reference frame by utilizing an invariant version of the Park transform. In a balanced system, zero is the same as the zero component.[8]

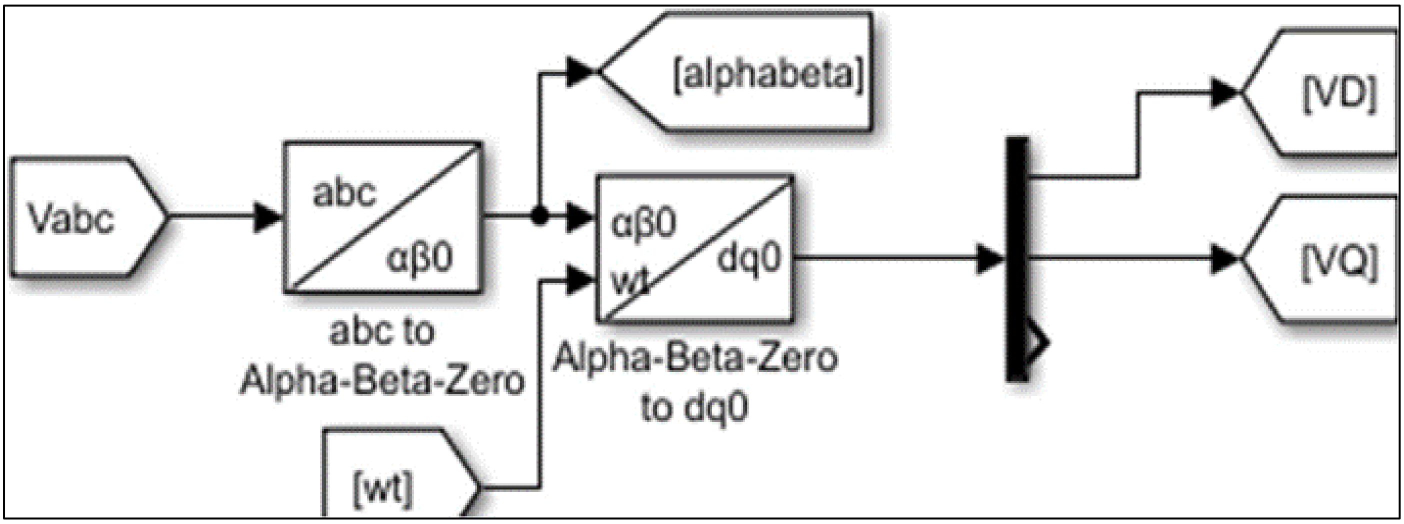

Fig 4 Voltage transformation block

- *PWM Generation Block*

Pulse width modulation (PWM) is a technique used to convert high frequency pulses into low frequency output signals. When an inverter leg rapidly switches between the higher and lower DC rail voltages, its low frequency output can be viewed as the average voltage throughout the course of that switching period.

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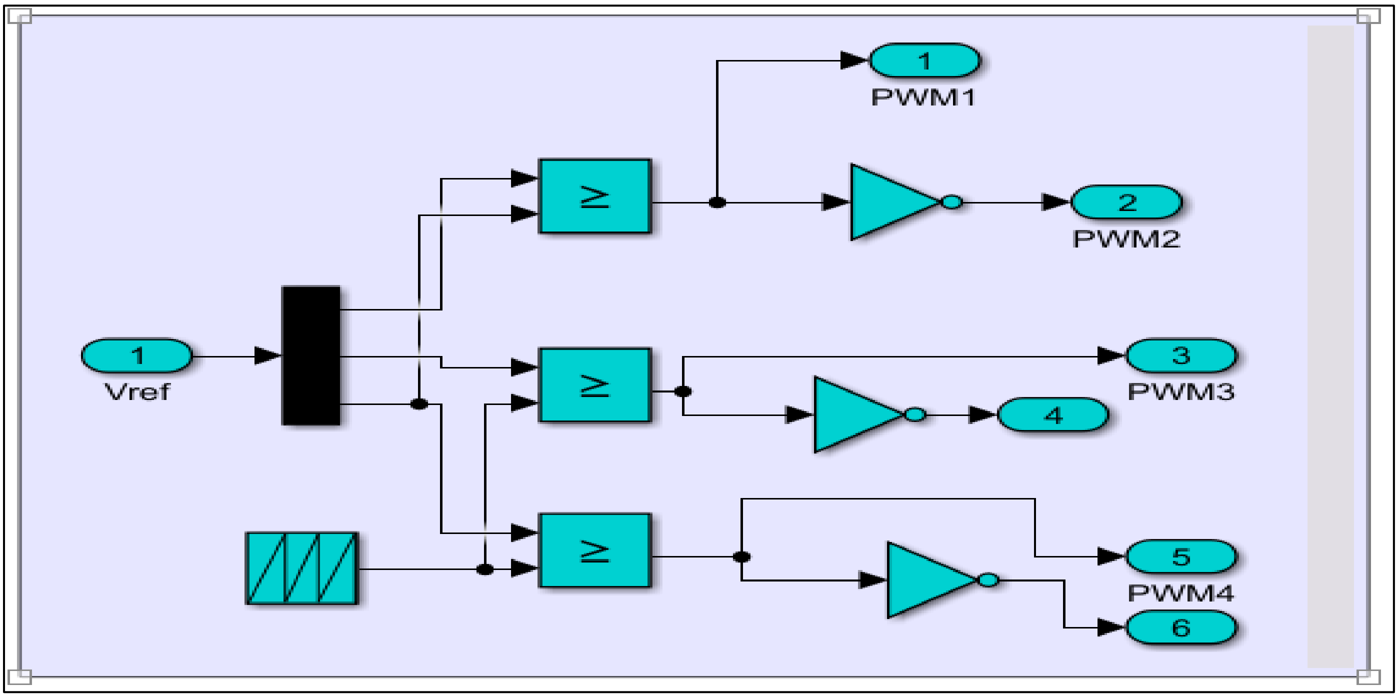

Fig 5 PWM Generation Block

➢ *Voltage and Current Controller Block*

We use a PI controller, a dq0 to ABC block for the input port for PWM, and 0 for voltage and current, respectively, in our voltage and current controller.

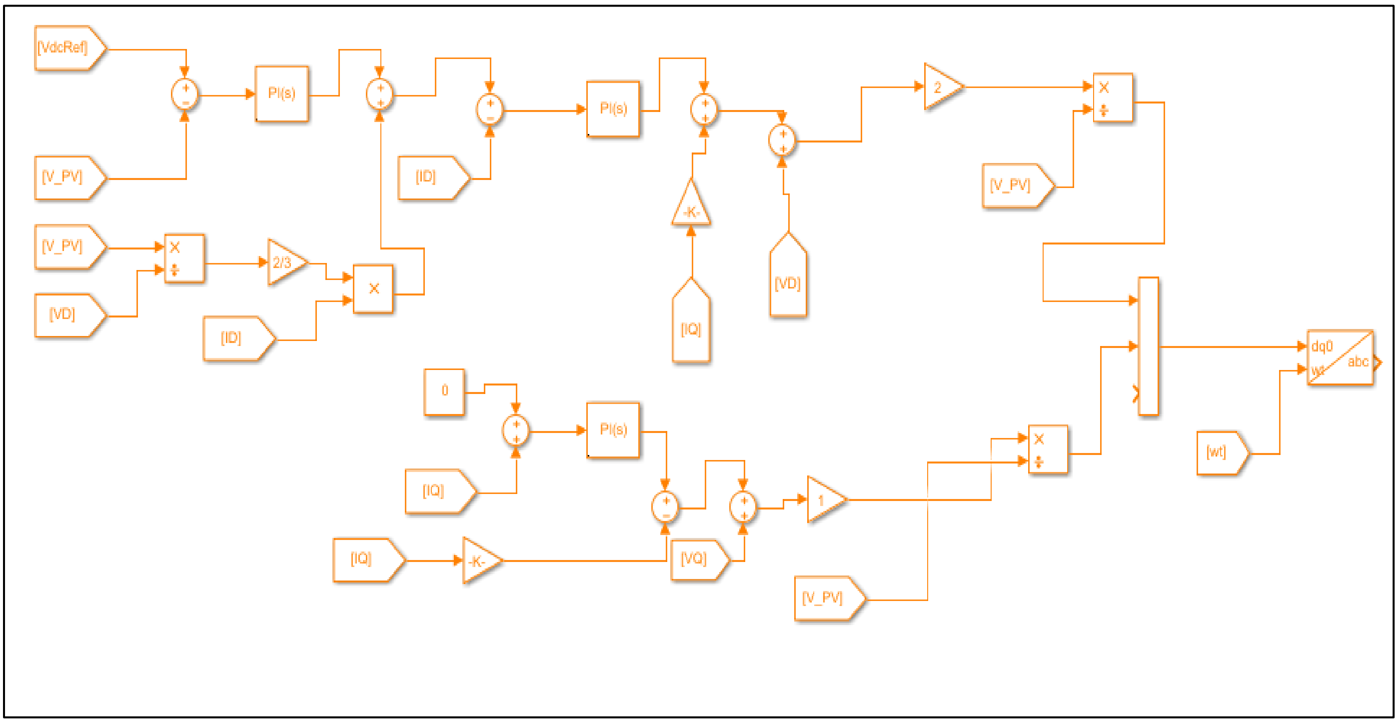

Fig 6 Voltage and Current Controller Block.

➢ *Precision Phase Locked Loop.*

Phase-locked loops (PLLs) are control systems that produce an output signal whose phase is associated with the phase of an input signal. A simple phase-loop loop (PLL) consists of a phase detector, a loop filter, and a voltage-controlled oscillator (VCO). There are several different types; the most basic is an electrical circuit consisting of a variable frequency oscillator and a feedback loop. A phase locked loop, or PLL, needs to be able to detect and measure the phase difference between two signals in order to function properly.

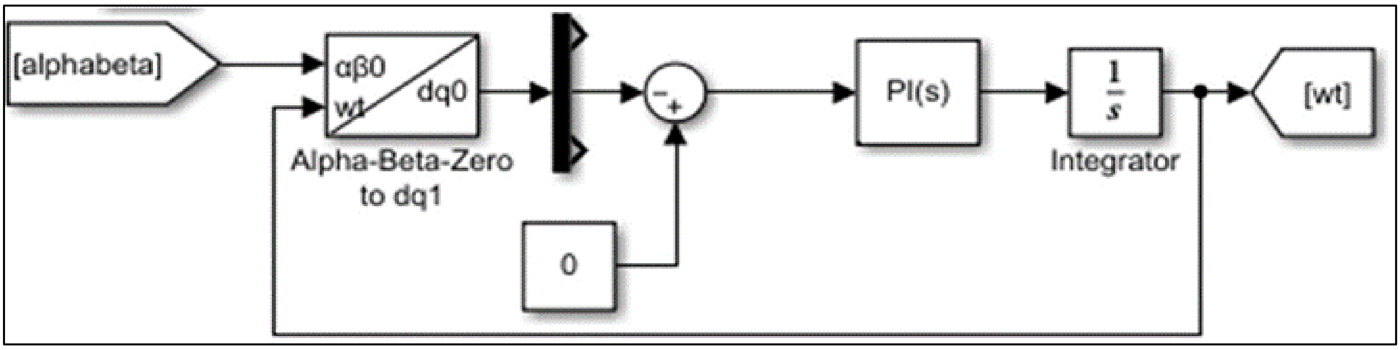

Fig 7 Phase Locked Loop

IV. SYSTEM ANALYSIS

Table 1 PV Array Parameters

PV Array	
Parallel Strings	42
Series connected modules per sting	10
Sun irradiance	1000
Cell temperature in deg	23
PV irradiances (w/m^2)	[100 500 100]
PV Model Aavid Solar ASMS-	165p

Table 2 Series RLC Branch Parameters for Filtering

Series RLC branch parameters for filtering	
RL	R=1e^-3 , L=400e^-6, N=6
Filter Capacity (RC)	N=3, R=1^-3, C=100e^-6

Table 3 BOOST Converter Parameters

BOOST Converter Parameters	
Series RLC Branch	R=1e^-3, C=1000e^- 6
Boost inductor	1.30e^-3
IGBT	N=1
Filter capacity	3235e^-6
MPPT Controller	Output voltage=300
Unit Delay	Sample time=1e^-4
PI controller	P=0.005, I=0.001
Repeating sequence	Time value=[0 0.0002],Output=[0 1]
Source resistance	1e^-6

Table 4 PWM Generation Block Parameters

PWM Generation Block Parameters	
Repeating Sequence	Time Value= [0 0.00005 0.0001] Output values= [-1 0 -1]
Logical operator	NOT gate

Table 5 Voltage Controller Block Parameters

Voltage Controller Block Parameters	
DC voltage	500
PI controller	P=0.25, I=300

➤ *Simulation*

A boost converter is used after the PV array. A boost converter is a type of DC/DC power converter where the voltage is raised from the input (source) to the output (load). We use a voltage measurement to attach a scope to Vdc in order to view the output voltage. Three-phase inverters are used to supply variable frequency power for industrial purposes. Three-phase inverters use PWM to regulate voltage. The inverter is driven by a constant dc voltage, Vdc, and consists of three phase-legs, each of which has two IGBTs. The inverter's switches are controlled by comparing a sinusoidal signal with a triangular signal using SPWM control. While the sinusoidal wave determines the necessary fundamental frequency of the output, the triangle wave

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specifies the switching frequency of the inverter. There are 180 degrees of conductivity in transistors.

The voltage transformation and current transformation blocks of the three-phase inverter are used to regulate its space vector modulation. We are going to use the phase-locked loop to filter this DC signal. The voltage and current controller block is then used. Battery chargers with a fixed output voltage and maximum current are meant to use this circuit. It can be applied to any application where accurate voltage and current regulation is required. Other applications include overvoltage protection and voltage supervisors.

We obtain a set dc voltage from the voltage and current controller block, which converts dq0 to ABC and then to AC. Next, we employ a PWM generating block to produce a PWM signal from our AC signal, which serves as the input signal for the inverter's PWM port.

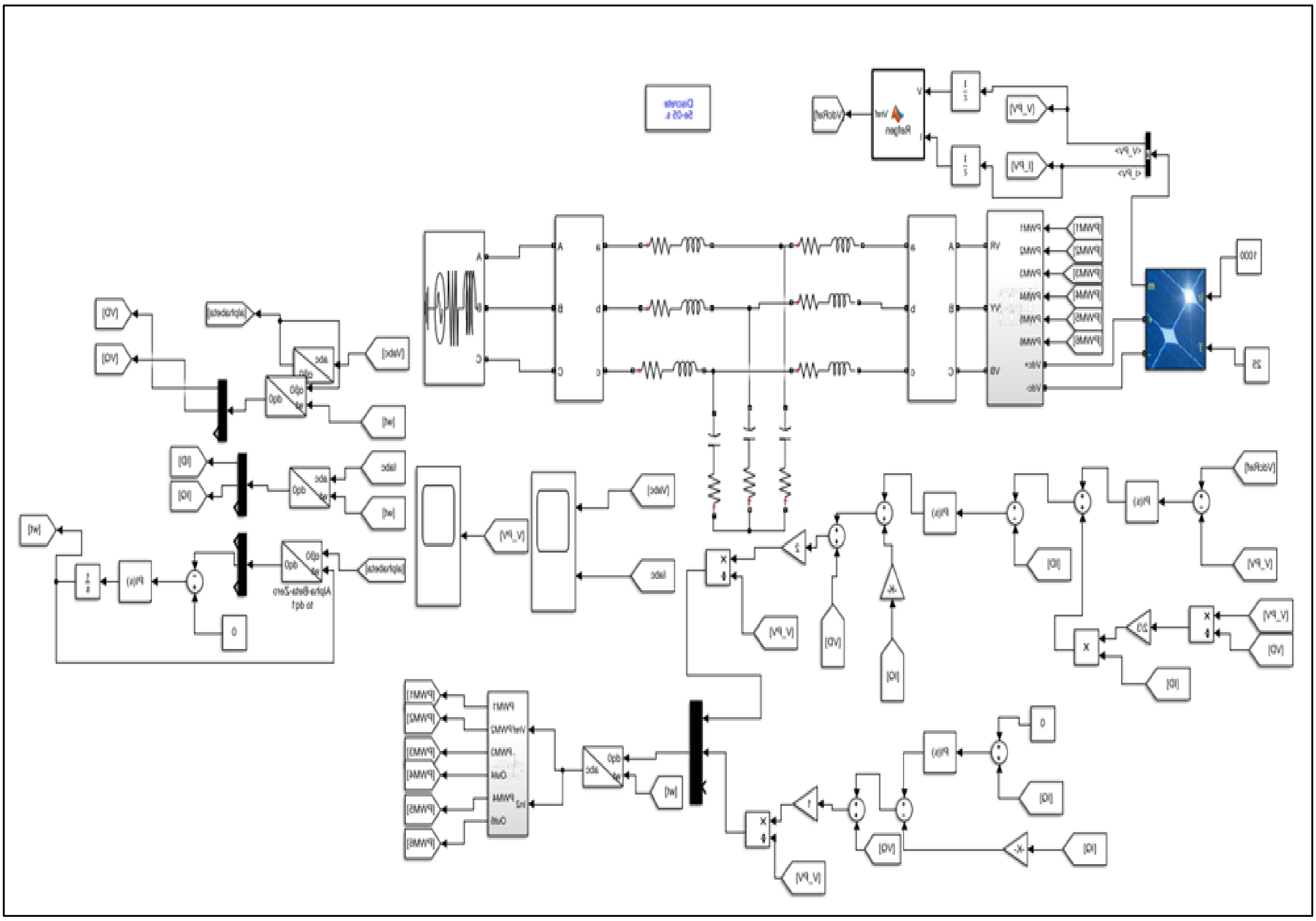

Fig 8 Inverter Connection Diagram

V. SUMMARY

We aim to showcase our design's voltage stability. We are using a BOOST converter in the model to raise the voltage. Another difficulty that manufacturers of high frequency boost converters must face is stability. Electromagnetic fields radiating between circuit components at MHz frequencies can cause both positive and negative feedback, especially in surface mount layouts where the circuit components are relatively close to one another. In order to increase stability and guard against oscillation brought on by unexpected positive feedback, a parallel capacitor is added. Next, the PWM inverter is employed. The method known as pulse-width modulation alters each pulse in a pulse train's width in direct proportion to a tiny control input.

VI. RESULTS

The PV source parameters are set up to provide this energy from PV panels, and the PV array model is constructed in compliance with vendor catalogs. The load, output voltage, and switching signal received from the MPPT output of the boost converter define the PV output voltage, which is set around the MPPT.

For 0.5s, run the simulation. We use a scope with Vdc to view the output voltage of the BOOST converter, and we use another scope with Vabc and Iabc to view the final output voltage and current.

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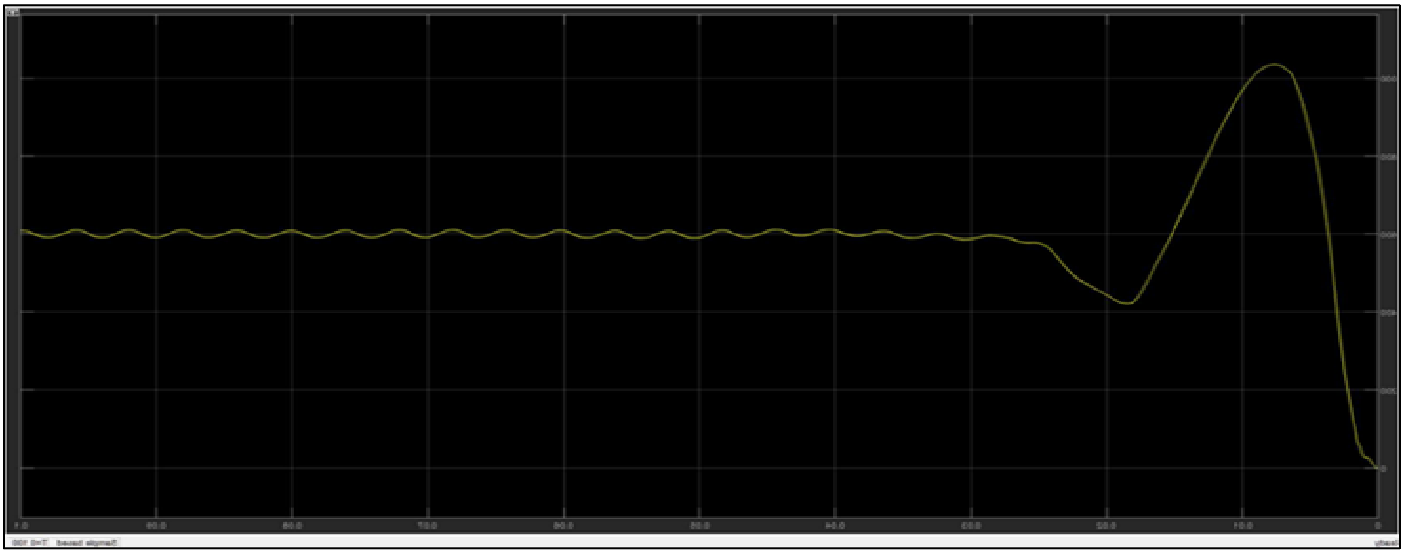

Fig 9 Output result of Boost converter (sun irradiance 1000w/m^2)

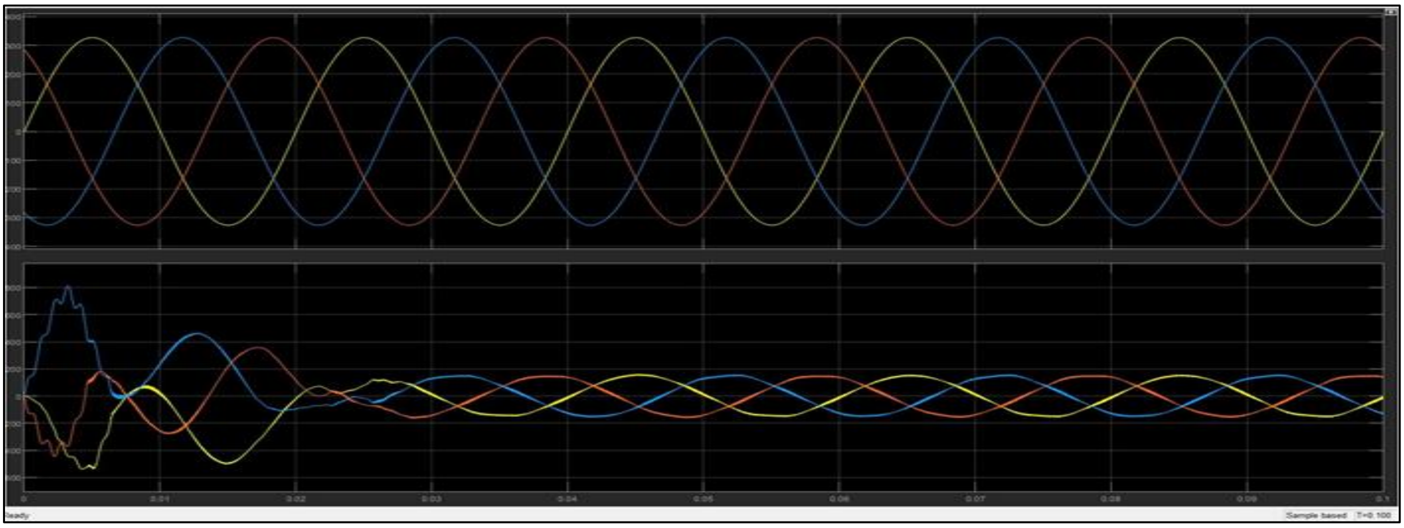

Fig 10 Output result of voltage and current (sun irradiance 1000w/m^2)

When the cell temperature is 25 degrees and we use 800 w/m^2 of solar radiation. Figure 9 displays the boost converter result, and Figure 10 displays the voltage and current ultimate output result.

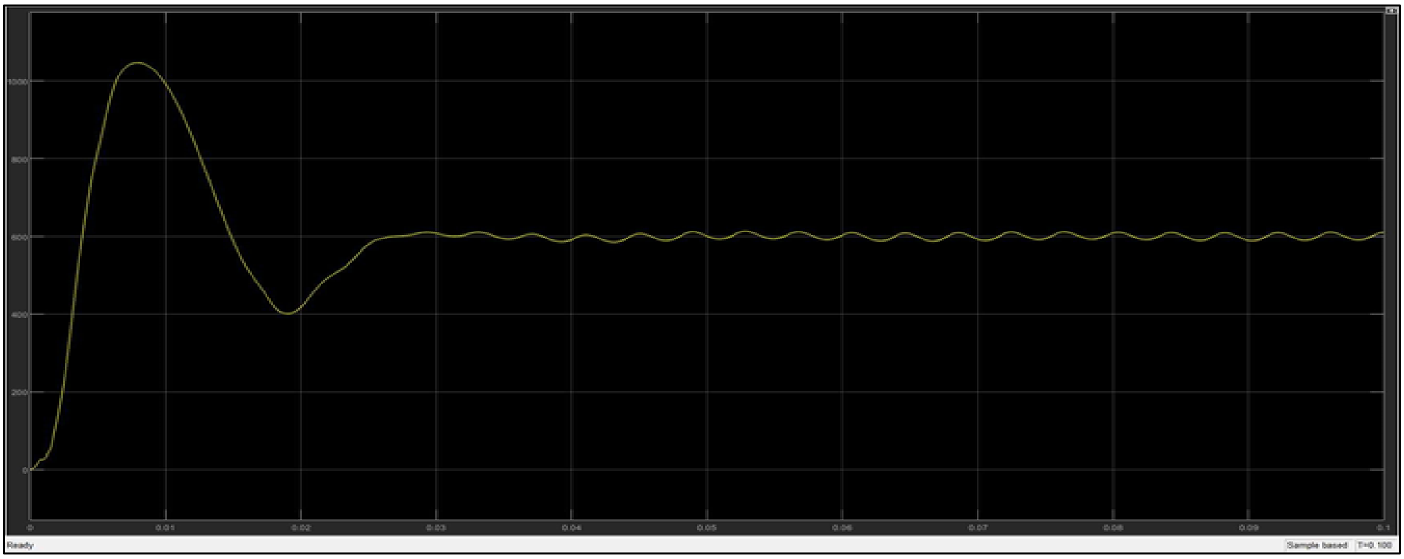

Fig 11 Output result of Boost converter (sun irradiance 800w/m^2)

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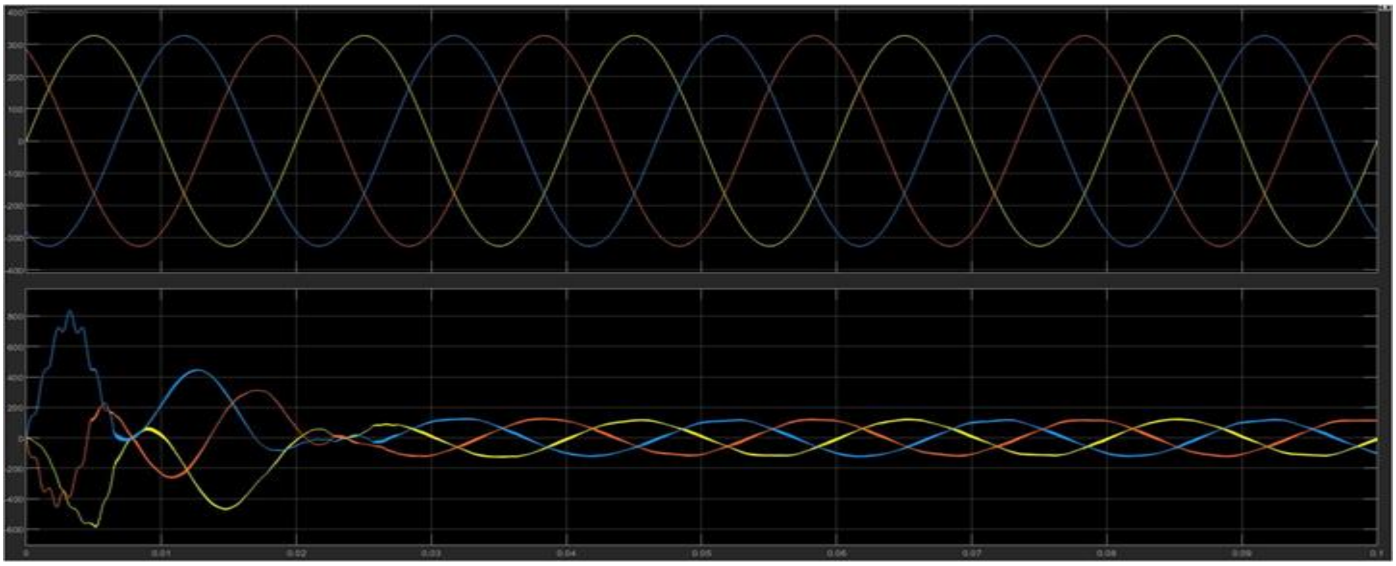
Fig 12 Output result of voltage and current (sun irradiance 800w/m^2)

- *Effective Resource and Cost Management*

The least expensive PWM controllers are as low as $18. Those with additional features may cost $220 or more. MPPT controllers give additional capability and can range in price from $52 to over $1,000, depending on the features. However, since MPPT controllers alter voltage and current, you can save money by using lower-gauge electrical wire to connect your panels and batteries if there is a significant distance between them.

Furthermore, because MPPT controllers have the ability to convert a solar array's higher output to a battery's lower voltage, a battery has the capacity to store more solar energy. This will increase its efficiency, maybe shorten the payback period of the more costly system, and increase your ability to rely only on solar energy.

VII. CONCLUSIONS

Non-renewable energy sources are being depleted while energy use rises. In response to these arguments, we ought to generate more renewable energy. But a big problem with renewable energy is that its production is weather-dependent. In overcast and unfavorable weather, the energy generated on the grid side is insufficient to match the demand on the load side. The primary load-side issues may be non-linear loads that lower the energy networks' power quality or excessive or unmanaged energy demand. When compared to the production of renewable energy, energy sources that are connected to the grid through an electronic converter or inverter have quite different operating characteristics.

These sources behave differently within the network as a result. Since this type of generation is heavily integrated into the electrical grid, it is necessary to update the theories and methods for designing, constructing, and operating power systems and inverters. If not, providing a reliable power supply and power quality that meets technical standards could be difficult. The stability issue between the grid and transmission line is resolved in this study by concentrating on the grid's side stability problem.

This research examines the benefits of using MPPT and PI controllers with inverters in a power system that runs from the grid to the transmission line. A dependable control system that tackles the main problem with the PI controller and MPPT with inverter. The suggested grid system, the inverter, the MPPT model in the BOOST converter, and the LC filter are built in MATLAB/Simulink. To determine the tracking response of the set power references, a series of simulations were performed utilizing various step changes in the active and reactive power references for the grid-connected MPPT in the BOOST converter and the PI controller in the inverter model. The efficacy of the control system—which was designed to better power quality and track the set benchmarks—was shown by the simulation results.

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