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Analysis of Hybrid Solar PV Connected with Three Phase AC Supply and Battery Bank Charging Facility

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ABSTRACT

This paper works on the modelling of Solar PV connected with the boost converter for boosting output voltage from the Solar panel and an option for the battery charging arrangement is provided from the booster side DC output for the charging facility of a battery bank. An Inverter has been connected for the three phase supply to the grid or load. The gate pulse has been generated for the IGBT based inverter and a filter arrangement has been provided to reduce the harmonic distortions in the transmission line. The output voltage & current as well as active and reactive power has been explored and analyzed. The simulation has been done on a Matlab software and simulation results obtained and analyzed. The output voltage & current as well as active and reactive power has been explored and analyzed. The Simulink results represents that the proposed model is able to synchronize with grid system, which has matching frequency and amplitude.

KEYWORDS: *Maximum power point tracking system (MPPT), Pulse Width Modulation (PWM), Insulated gate bipolar transistor (IGBT), Total harmonic distortion (THD), Solar Panel, Battery Bank*

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INTRODUCTION

The global demand for energy in all spheres of human civilization has increased manifold in the last few decades. The alarming rate of energy consumption leading to energy crisis is an important issue in need of immediate attention. Moreover, government has formed new industrial regulations to go green to ensure environmental protection. In the present scenario, exploring renewable and alternative energy sources is gaining prime importance. Harnessing sustainable energy is a promising research area that deals with the issues of the environment and global warming. Efforts are on for extracting clean, green and renewable energy from the sun, wind, water, and biomass across the globe. Another key issue is energy efficiency, i.e. extracting the maximum benefits from the existing energy sources. UN Secretary General Ben Ki Moon is urging the investors to at least double their clean energy investments by 2020 to ensure a safer and prosperous future for the ensuing generations [1].

The impact of improvements in energy intensity is revealed by trends in its components. Between 1990 and 2019, global GDP increased by a factor of 2.5, while global total energy supply grew by two-thirds.17 Consistent improvements in global energy intensity, which fell by more than a third between 1990 and 2019,signal trends in the decoupling of energy use from economic growth. Improving energy efficiency at scale will be a key factor in achieving affordable, sustainable energy access for all. Stronger government policies on energy efficiency are needed to bring the target within reach. [2]

Fig 1- Annual rate growth of Energy Intensity by sector

As per the above graph we can see that from the last three decades the annual energy intensity of the consumers sector wise has been increasing continuously and this will a major challenge in the upcoming decades to meet this increasing demand of electricity. This is the reason that the governments of various countries creating such programs to make the use of renewable source of energy as much as possible by using various schemes in a vast range and to achieve the targets for the generation of electricity by the use of renewables and reduction of carbon emission.

Financing techniques has also been used to promote the use of green energy and by using various tariff schemes and attractive options for the consumers to use this kind of energy and majorly spreading the awareness for this. So we should adopt the most convenient and cheapest way for generation transmission and distribution. In order to get an optimum power generation hybrid electricity is used so that increase in price may get compensated by the use of renewable assets.

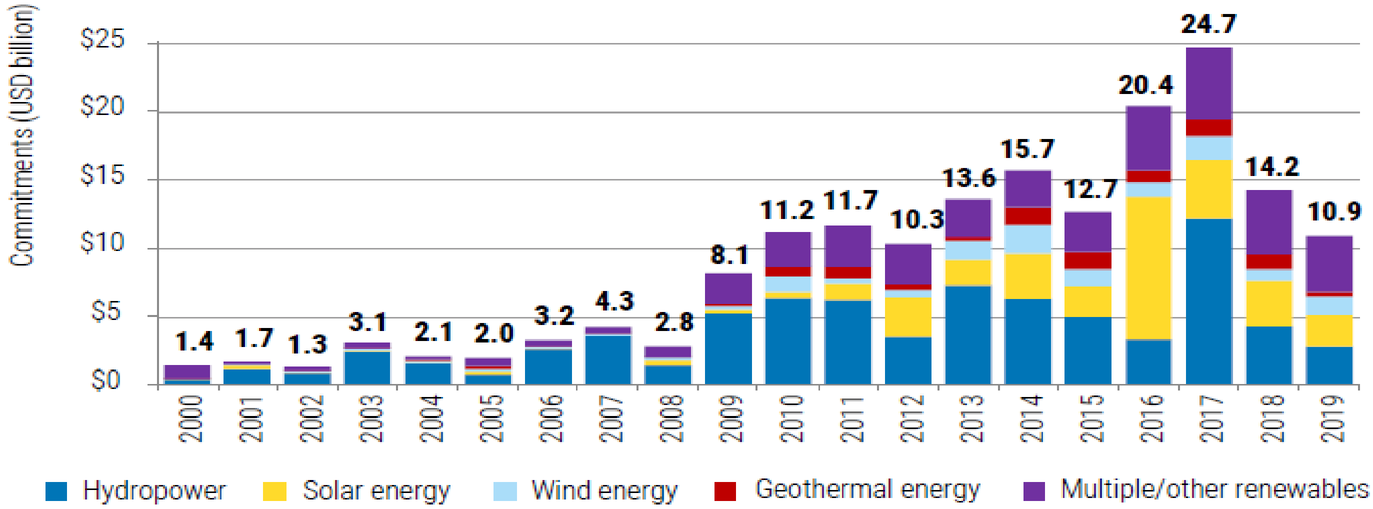

Fig 2- Financial commitments for renewable energy productions

The warming of global surface is increasing 0.6 degree Celsius per century. This warming caused by huge release of carbon dioxide and carbon monoxide. This causes acid rain, depletion of ozone layer and radioactive emission these effects can be minimized by searching some effective solution, this solution also include energy conservation with improved energy efficiency.

V-I Characteristics

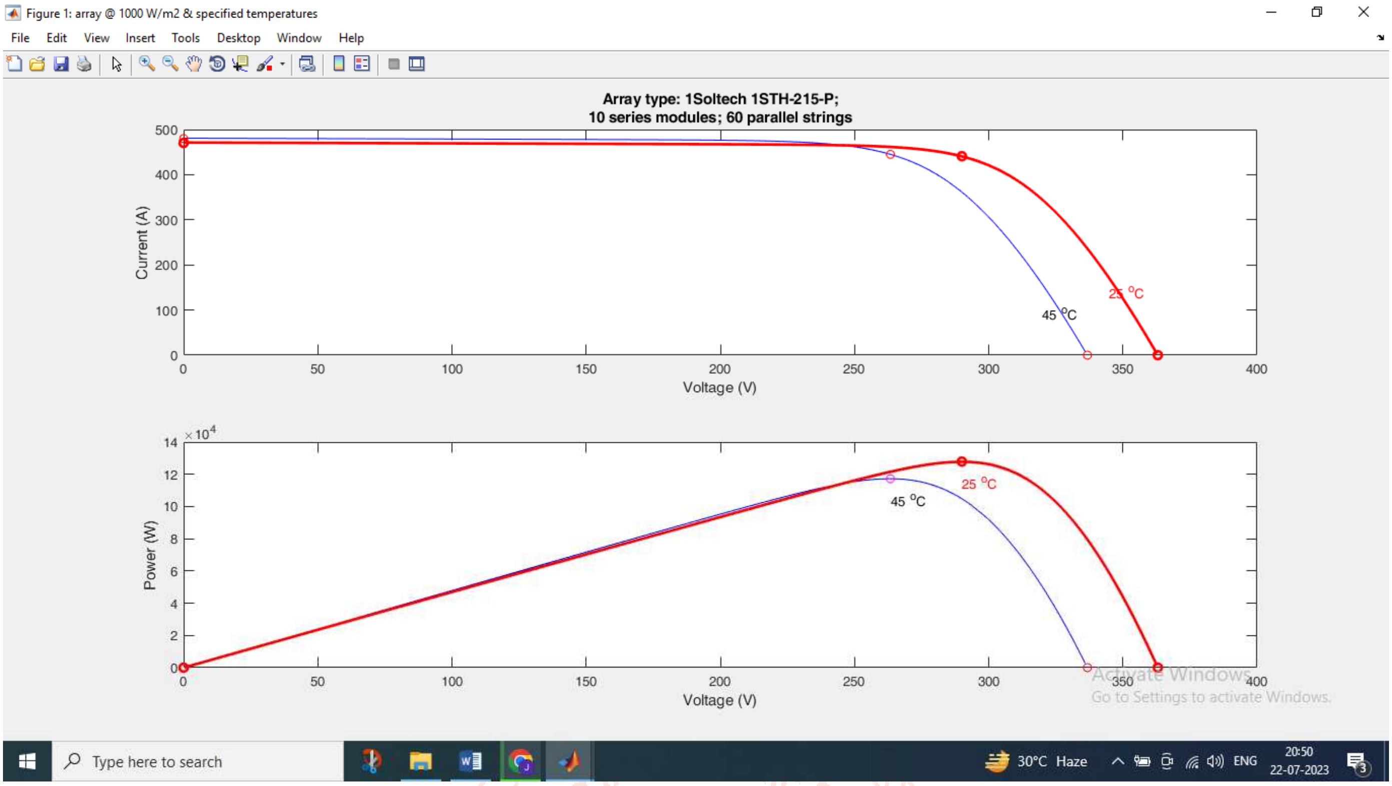

Fig 3- V-I Characteristics for the 1000W/m2

By taking variation in the solar irradiations we can see the selected solar panel VI characteristics, In fig 3, if the irradiation will be 1000 watt per meter square the characteristic of the selected panel is shown similarly from the fig 4 we can see if the variation in irradiance like 500 watt per square meters the characteristics of voltage and current is described, all these graphs plays a vital role in maximum power point tracking.

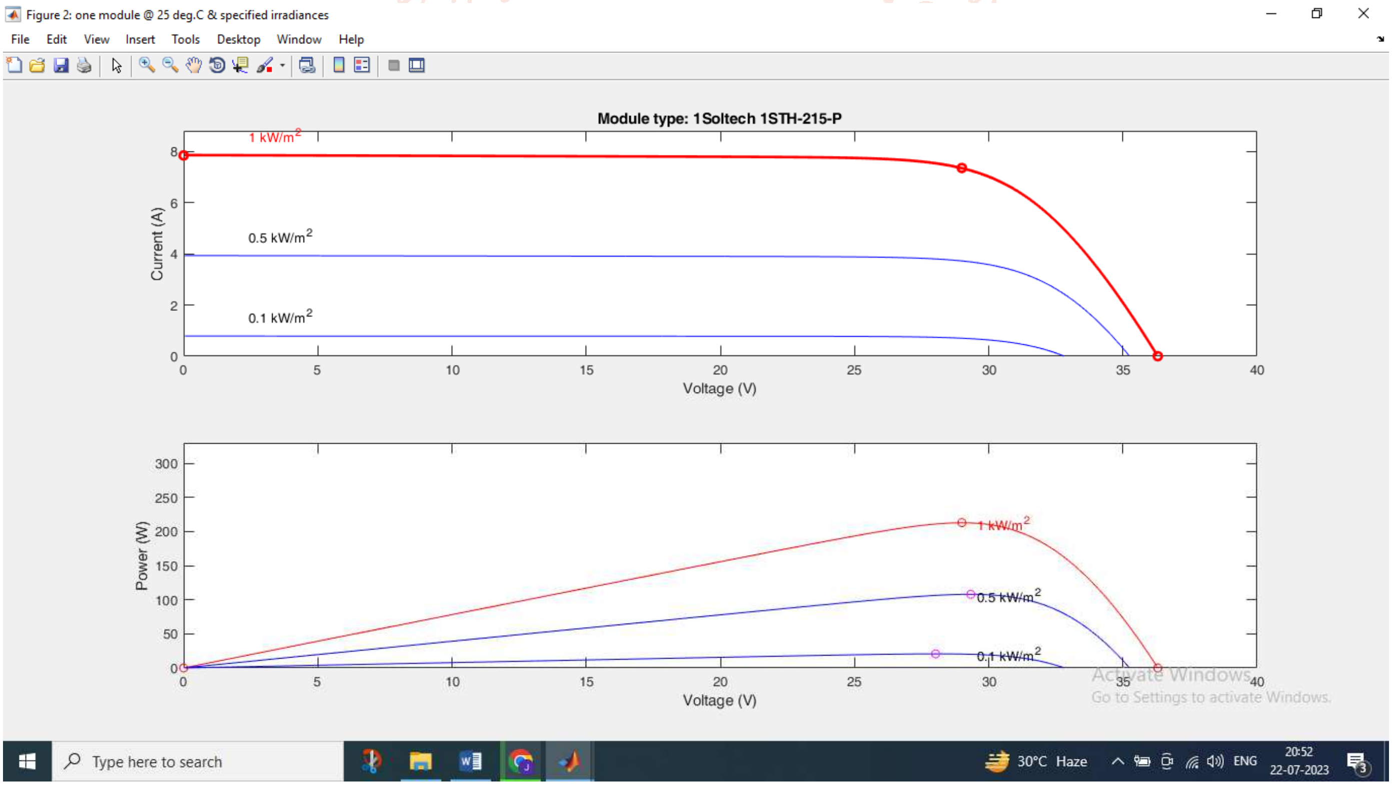

Fig 4- V-I Characteristics for the 1000W/m2, 500W/m2, 100W/m2

MODELLING OF PV ARRAY

Electrical Model of photovoltaic cell

Implements a PV array built of strings of PV modules connected in parallel. Each strings consists of strings connected in series. Parallel strings 60 and series connected modules per strings 10. With open circuit voltage 37.14V and short circuit current 8A.

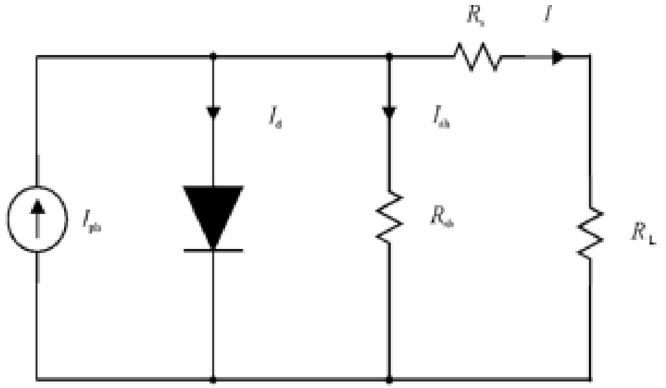

Fig --5: P-V cell Model

$I = I_D - I_{RP} - I_{ph}$ .... (1)

$I = I_{ph} - I_0 - \left[exp\left(\frac{V+IRs}{V_T}\right) - 1\right] - \left[\left(\frac{V+IRs}{R_p}\right)\right]$......... (2)

$I = n_p I_{ph} - n_p I_{rs} - \left[exp\left(\frac{q}{KTA} * \frac{V}{n_s}\right) - 1\right]$.......... (3)

$I_{rs} = I_{rr}\left[\frac{T}{T_R}\right]^3 exp\left(\frac{qE_G}{KA}\left[\frac{1}{T_r} - \frac{1}{T}\right]\right)$.....................(4)

$E_G = E_G(0)\frac{\alpha T^2}{T+\beta}$.. (5)

$I_{ph} = [I_{scr} + K_i(T - T_r)]\frac{s}{1000}$............................(6)

Where, Iph is the Insolation current, I is the Cell current, I0 is the Reverse saturation current, V is the Cell voltage, Rs is the Series resistance, Rp is the Parallel resistance, VT is the Thermal voltage (KT/q), K is the Boltzmann constant, T is the Temperature in Kelvin, and q is the Charge of an electron. [3]

BOOST CONVERTER

The PV system generates DC voltage in all the variable conditions of solar radiations. The generated voltage is low and variable and it must be somewhat high and constant at the input of inverter. So we need a boost converter device to boost the voltage as well it try to maintain constant boosted voltage.

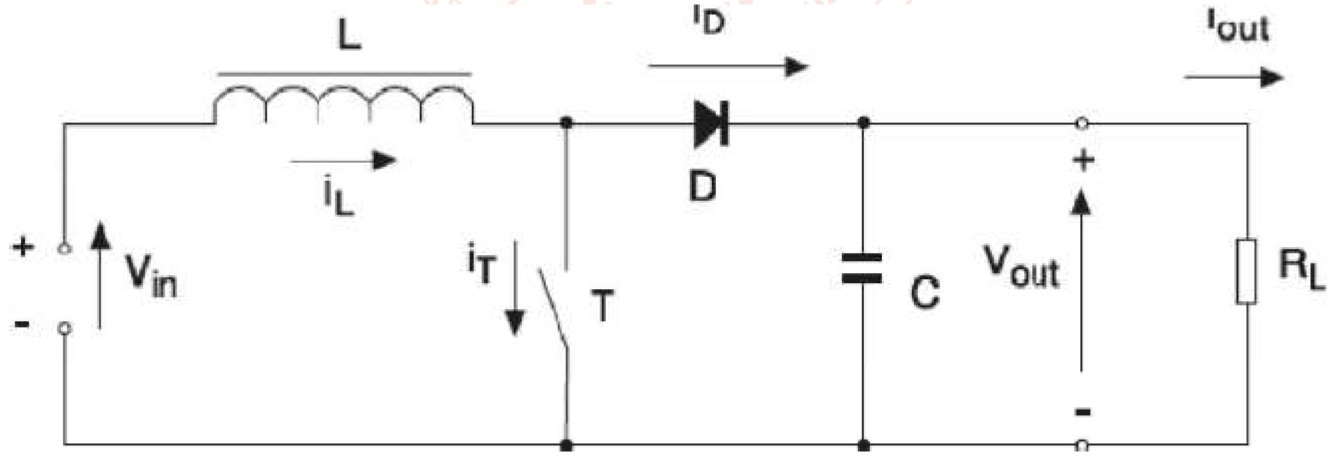

Fig -6: Circuit diagram of boost converter

The Fig. 6 shows a step up or PWM boost converter. This consists of a dc input voltage source VIN; boost inductor L controlled switch T, diode D, filter capacitor C and load resistance RL. When the switch S is in on state, the current in the boost inductor increases linearly and the diode D is off at that time, when the switch s is turned off, the energy stored in the inductor is released through the diode to the output RC circuit. The transfer function for the boost converter is [4]

METHODOLOGY

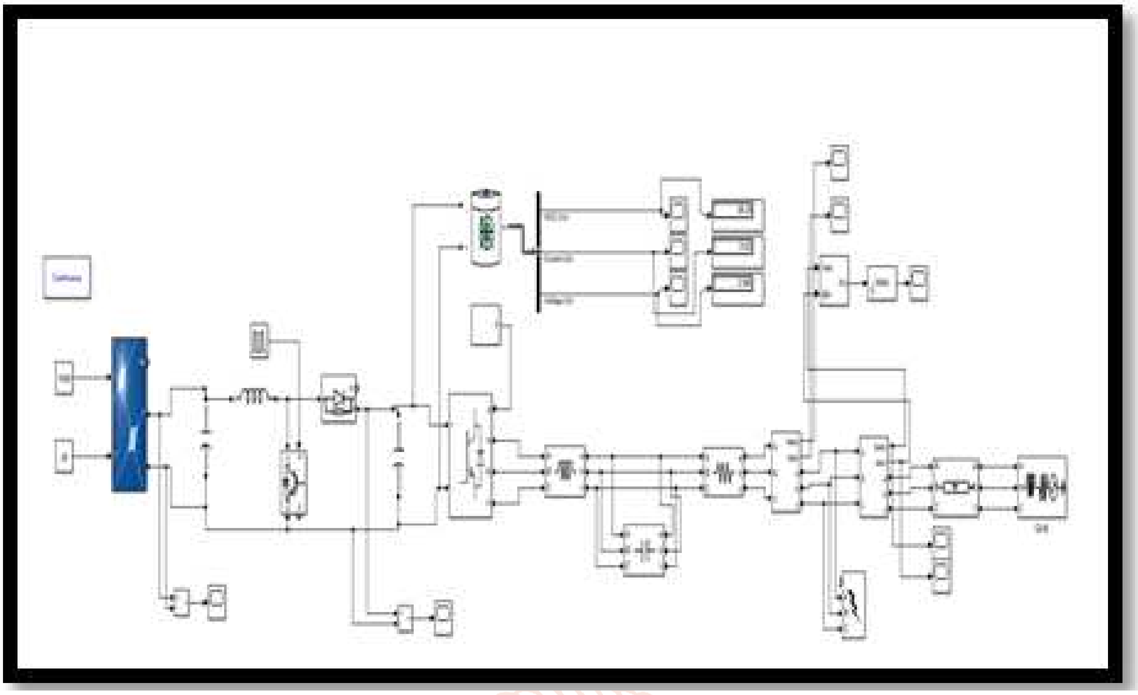

Fig -7: Proposed Model

In this work a model has been designed with 60 strings and 10 strings connected in series parallel combination and after the successful boosting of the voltages from the solar panels and then connected to the inverter and then supplied to the three phase grid and a battery arrangement also been done before the inverter so that the charging of battery can be done parallel side. The battery arrangement may be used as a storage battery bank and will be used in a better analytical manner.

A three phase bridge six pulse converter has been used of the PWM pulse generation for the IGBT based inverter. The parameters taken in the model is shown in figure below.

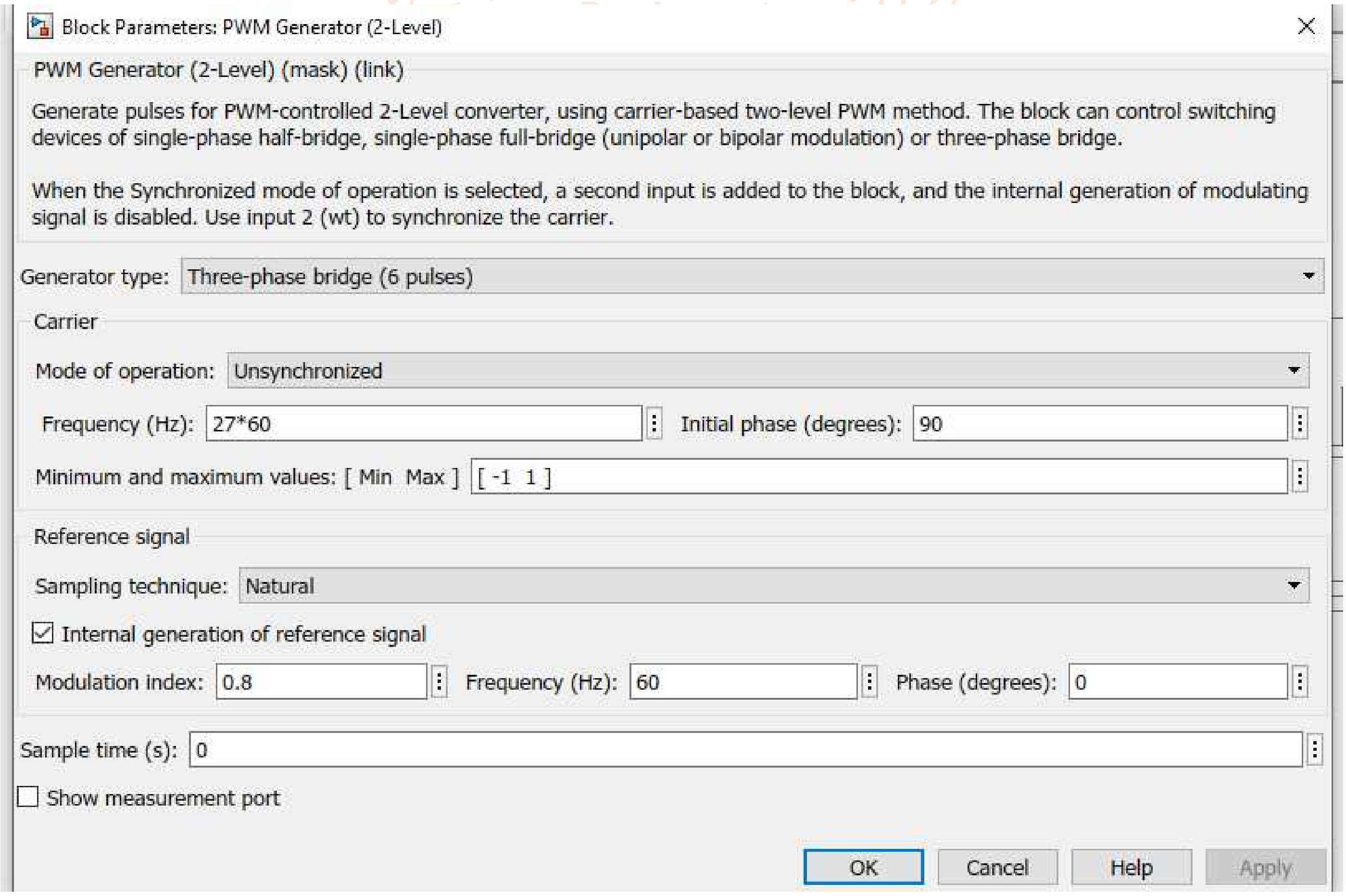

Fig -8: PWM pulse inverter parameters

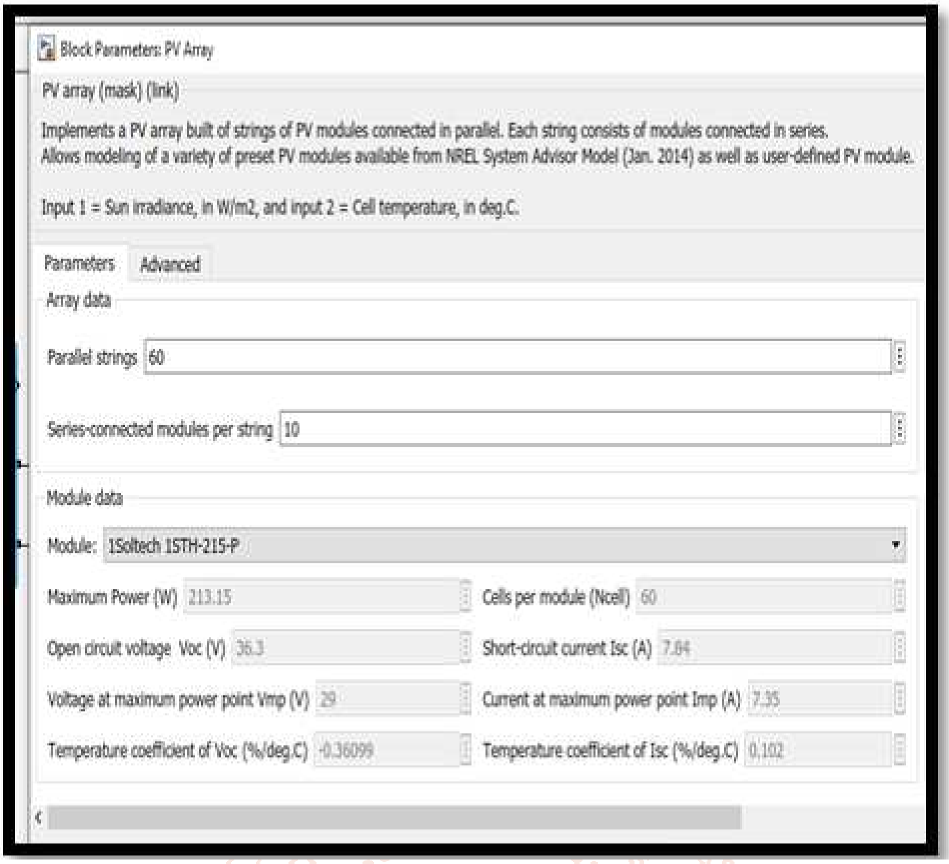

Fig -9 Solar Panel Parameters

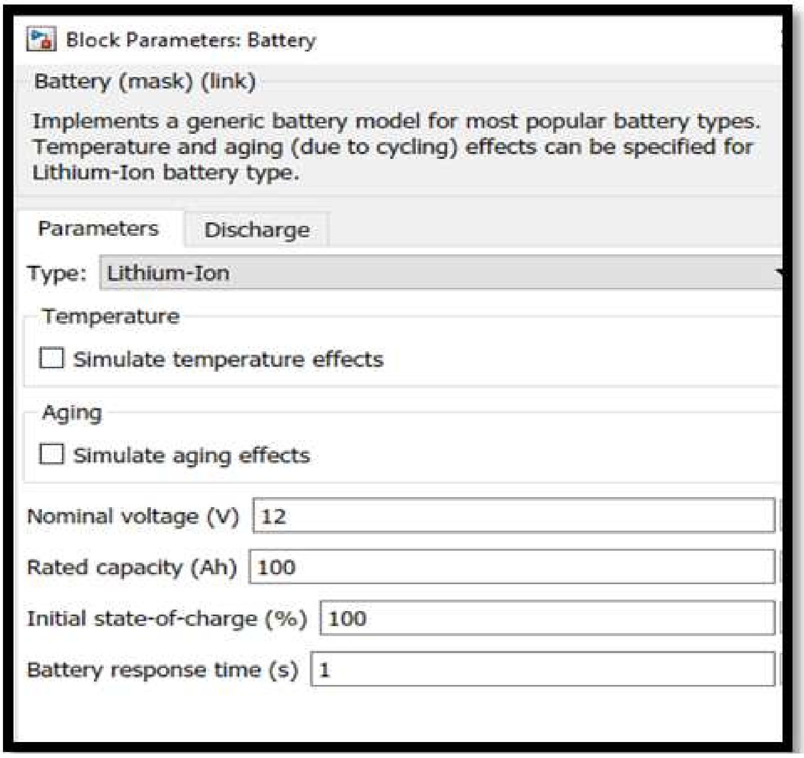

Fig -10 Battery Parameters

Transmission line

A transmission line of three phase PI section line has been selected with the values of frequency selected 50Hz, with positive and zero sequence resistance of 0.01273 ohms per km and zero sequence resistance of 0.3864 ohms per km, positive and zero sequence inductances of henry per km of 0.9337e-3 and 4.1264e-3. The model consists of one set of RL series element connected between input and output terminals and two sets of shunt capacitances lumped at both ends of the line.

In the grid side a three phase source has been modelled with star ground phase to phase voltages of 400 volts and frequency 50 Hz with base voltage phase to phase rms value with 25e-3.

A filter arrangement is required for the smooth output waveforms and the reduction of harmonic distortions.

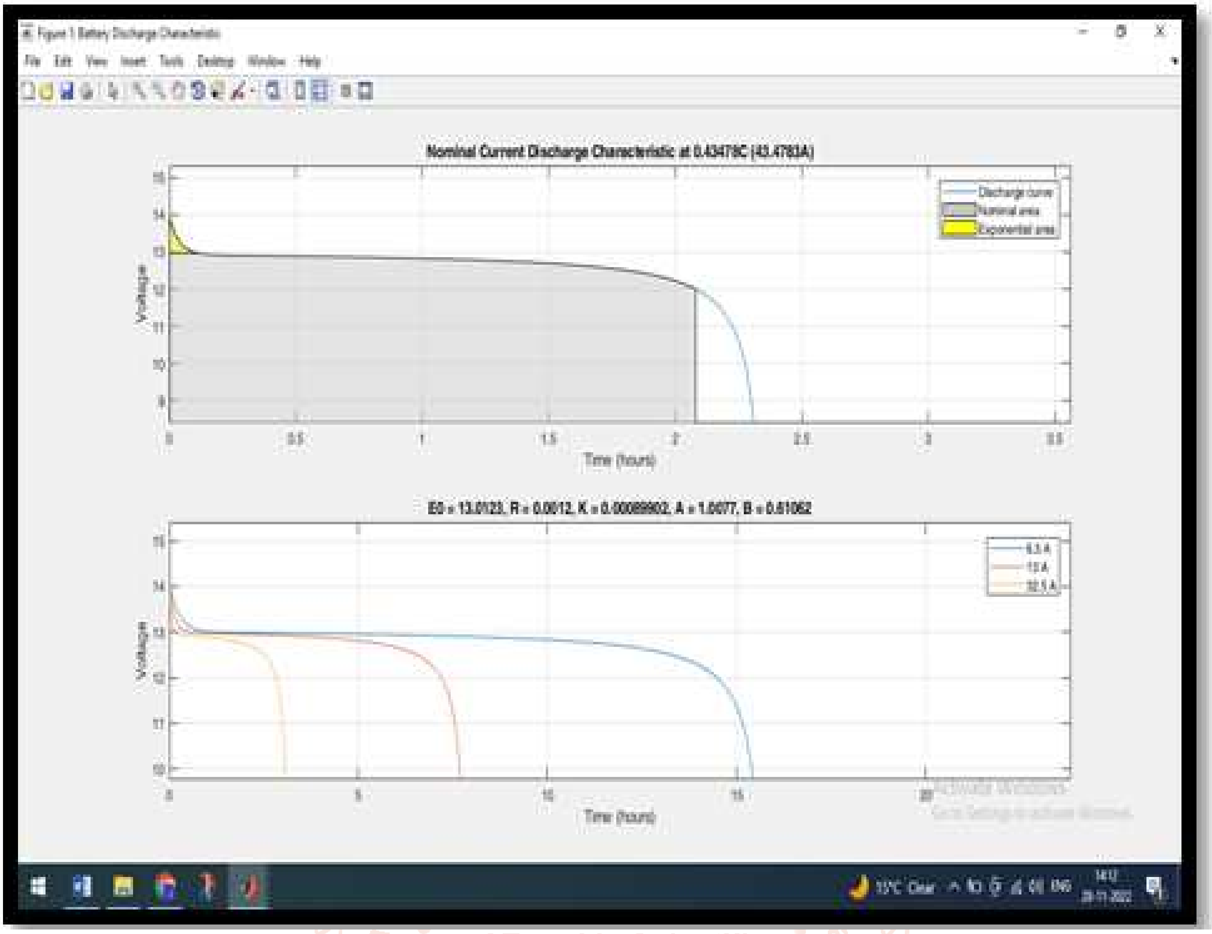

Fig -11: Battery Discharge Characteristics

For charging one 48 volt 12 AH battery the required watt hour will be=576 watt hour. Considering 30% losses required the required watt hour will be=748.8 watt hour. The watt-hour is divided by the panel generation factor of site 4.5, so the total watt peak needed to charge one 48 volt battery will be 748.8/4.5=166.4-watt peak. If 110wattpeak is the available module then 166.4/110=02 modules will be required to charge 48 volt battery. The size of the inverter should be 25% bigger than the total load due losses in the inverter.so 576×1.25=720 watt inverter is at least required to charge one 48 volt battery at 1C rate. For 48 volt system, 02 days of autonomy and 60% depth of discharge the required AH capacity for solar battery will be 47AH at least. [10]

RESULTS

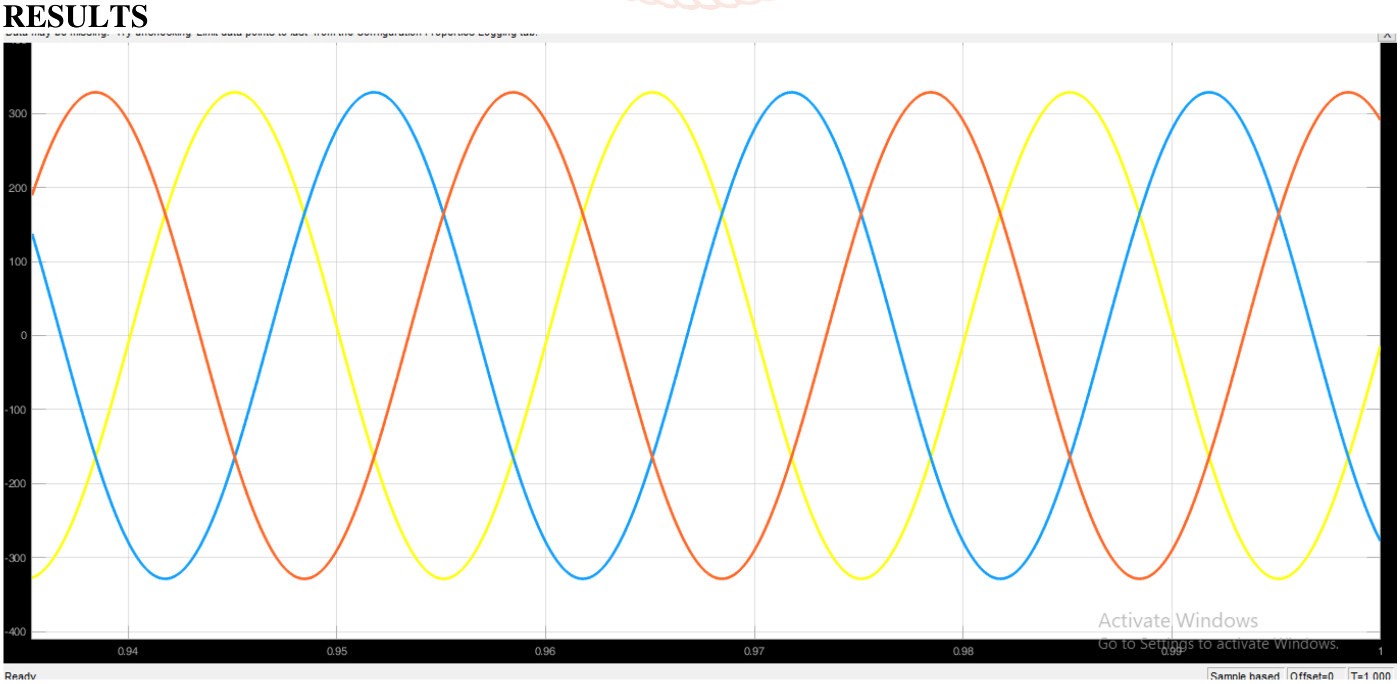

Fig -12: Three Phase Voltage

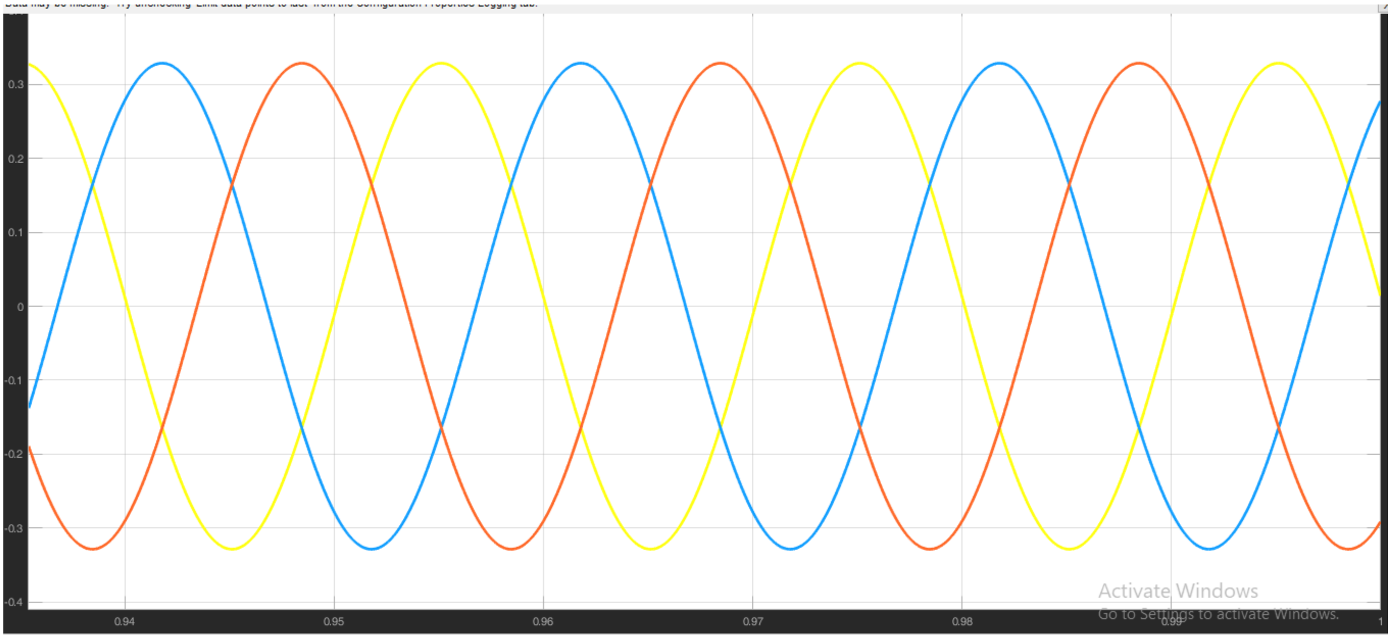

Fig -12: Three Phase Current

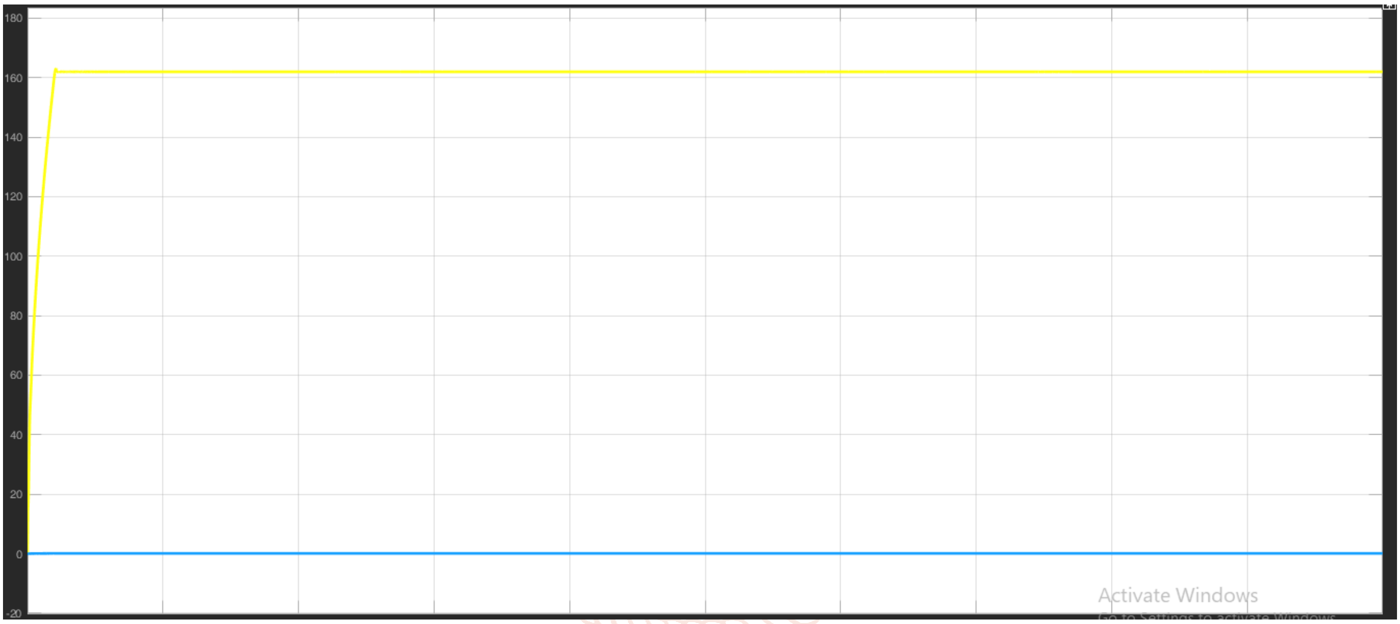

Fig -13: RMS value of PQ

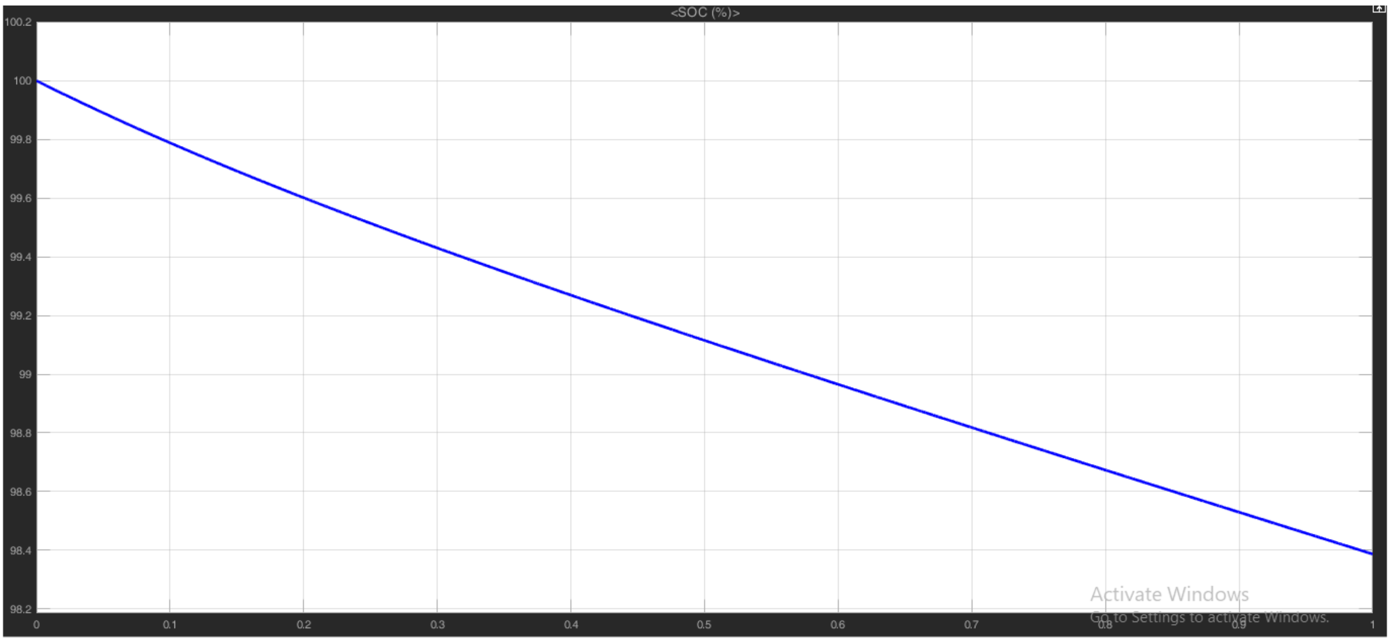

Fig -16: SOC of battery

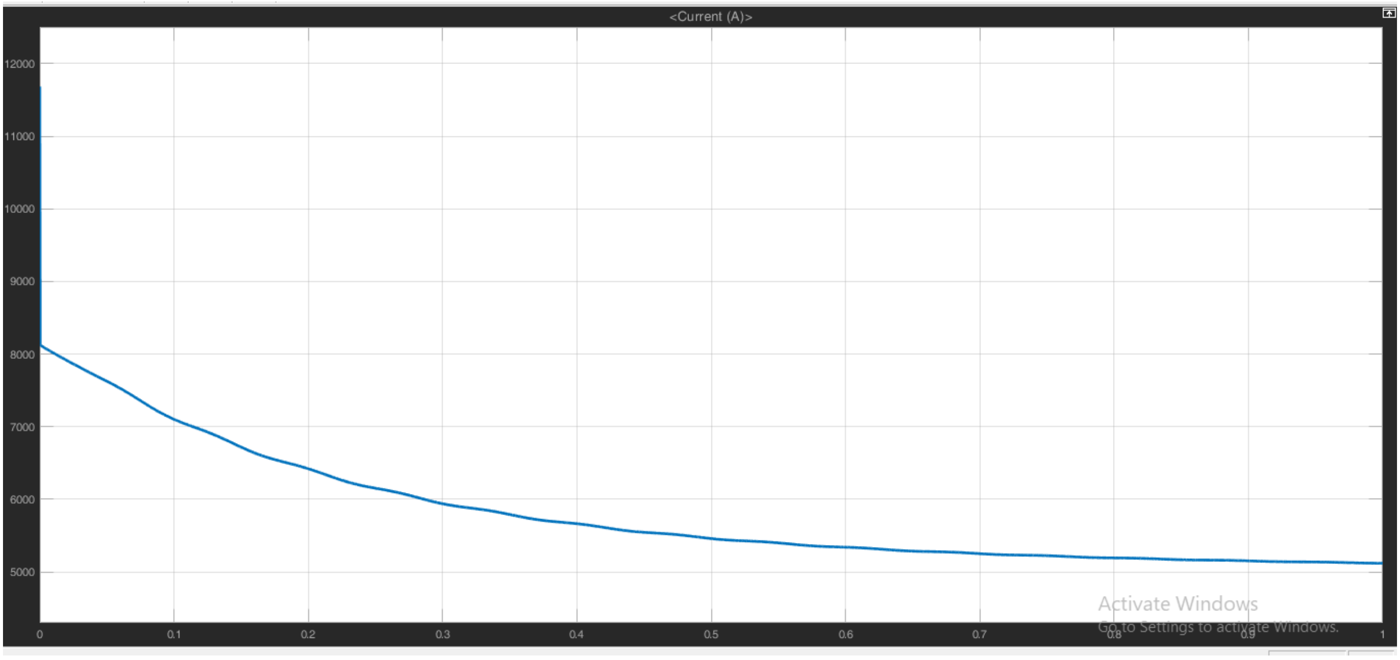

Fig -16: Current of battery

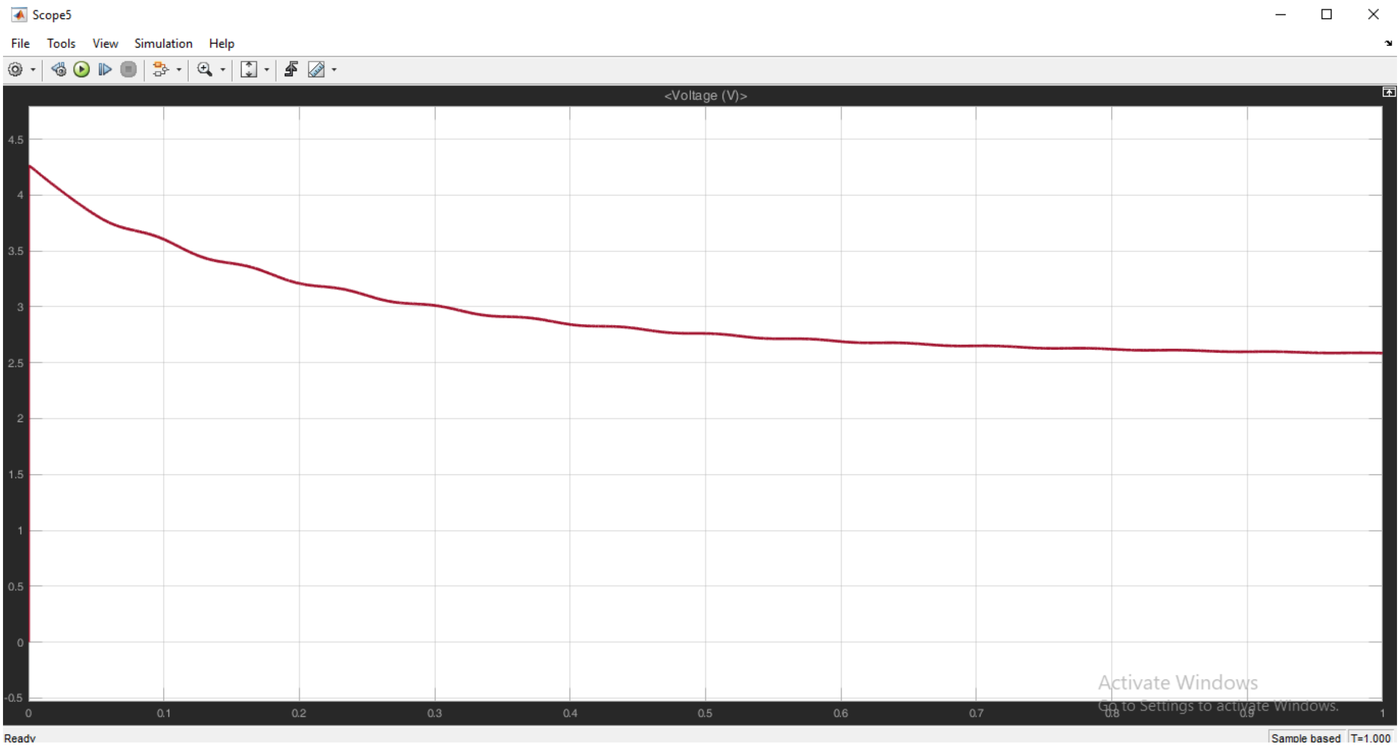

Fig -16: Voltage of battery

Now a days global warming is a major issue and every program related to the green energy and clean energy related to the renewable energy generation and its better use. Various research is going on to make a much better system to extract maximum power from the solar with the minimum installation cost. Our approach also works on the same aim that generation and connection with the three phase grid will be the successful completion of the project but as the battery storage is also one of the challenge so the hybrid connection trying to build to work in a switching manner.

Major aim is to reduce carbon footprints and now a days solar PV also installing in the commercial as well as residential buildings.

CONCLUSION

In this work a system has been proposed for the simulation of a solar panel with strings connected in series parallel combination to produce the DC output and get boosted by the booster arrangements and then the connections has been provided for the battery bank charging facility as well as the connections given to the inverter for the supply of the three phase electrical grid along with a transmission line with the suitable specific values of all the components required. A filter arrangements also been done for the harmonics reduction. The simulation results shows that the output voltage and current waveforms are smooth sinusoidal waveforms and ready to supply grid as well as loads. The battery characteristics and voltage, current measurements also done in the simulation and found to be in a desirable range.

FUTURE SCOPE

In the current work only the modelling and connections has been established for the three phase supply and battery charging system. The future works can be based on the climatic analysis and future forecasting analysis of the solar radiations in any particular geographical location and other parameters consideration. The control system also been designed for the maximum power point tracking works also in progress so a better control system to extract the maximum power from irregular radiations is a major challenge for all of us and this work needs lots of research.

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