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Maximizing Output Power of a Solar Panel via Combination of Sun Tracking and Maximum Power Point Tracking

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ABSTRACT

Energy is the basic needs for human comforts and day to day activities. Energy is the key factor for social and economic developments in today scenario. Now a day's global warming is the main problem of developing counties, due to the nonstop combustion of fossil fuels all over the world, creating environmental hazards and reducing conventional energy sources. This scenario is contributing to the need to search for an new renewable source of energy, which is clean and available in excess. Due to the huge impetus in the government policies on the development of solar energy, it is acting as a main alternative renewable energy source. The solar energy is popular due to easy maintenance, cleanliness, sustainability, and zero noise characteristics. Therefore, Photo-Voltaic module supplying loads with and without Maximum Power Point Technique (MPPT) is applied in the current studies to find the best results. Since the Photovoltaic array output is known to be affected by radiation of sun and temperature, which makes is compulsory to find out an effective method to draw out maximum power from Photo-Voltaic cell modules. In my work, Perturb and Observe (P&O) algorithm is selected because of its easy implementation Solar energy is the clean and eternal source of energy till the end of the world. In this paper main focus is how to improve the efficiency of solar based power generation .Solar energy is variable depends upon the time and the atmospheric condition and hence output of the solar cell is directly proportional to the insulation level and inversely proportional to cell temperature and also the cell never operates at maximum power.

KEYWORDS: *STATCOM, MPPT, Solar photovoltaic, Sun tracker*

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1. INTRODUCTION

Electric energy has been proved to be the most versatile form of energy which can be converted and utilized in any form and way, in the same way any form of energy could be converted and conserved as electric energy. Fossil fuels are main source of electric but due to their irreversible nature, they are being extinguished at an alarming speed[2]. In this age, every country wholly agrees that electric energy is an essential factor in the economic development of the country[3]. The advancement of technical progress, rapid industrialization and the necessities regarding the modern world has transformed electric energy into an important asset. Increase in its production runs parallel to the better and comfortable lifestyle and accumulation of wealth, In this century, resources of energy and its proper use will be a leading issue and they have been discussed many times in recent years along with natural resource depletion, the increasing demand for latest energy resources and its environmental effects. To meet the power demand in the world, renewable energy is the best alternative source[4]. But the injection of renewable power in to grid creates some power quality issues and parameters of the electrical power grid fall down the standard values[32]. As it is clear from the latest review of literature now all agree that the greenhouse gas producer's causes severe destruction to environment. International surveys conclude that all the countries tremendously support the utilization of renewable energies like tidal energy, wind energy, solar power[6]. At international level, in around 30 countries, renewable energy sources are fulfilling their energy supply up to more than 20 %. It is also noticed that the national renewable energy market is increasing rapidly and expected to rise tremendously in coming years. Some places and countries like Norway and Iceland produce 100 % energy from renewable energy resources and similarly many other nations are trying to meet the benchmark of 100% renewable energy production like government of Denmark is going for 100 % switching from current energy sources to renewable energy to meet their energy supply (heating /cooling, mobility and electricity) by the end of year 2050[33].Use of photovoltaic (PV) cell powered power systems connected with grids has been increasing exponentially during the last ten years[9]. This sharp growth is pushed by a genuine concern about changes in climate, reduction in cost of PV system and rebates/tax incentives. The major limitation of electrical power supply (coming from Sun) is that the generation of power is not uniform all through the day and it keep changing with changing atmospheric conditions. Also, efficiency of PV cells is very low in converting solar energy into electrical energy and in the span of 9-17%. So, to overcome these constraints, MPPT is a necessary part of a solar photo voltaic (PV) system, which is tied to Grid. It always ensure that maximum available power is drawn

out of the Gird Connected Photo Voltaic panel at each and every conditions and directed to the AC grid, which is ideally assumed as an infinite sink of power[11]. This important characteristic helps in improving dynamic response and efficiency of the grid connected PV system. In our literature, distinct MPPT algorithms are presented and two of them are mostly used. One is "Perturb and Observe (P&O)" and the other one is "Incremental Conductance". Some MPPTs are impressively fast and accurate but special design is needed and knowledge of particular subjects for e.g. fuzzy logic.

2. Modeling and Simulation of Grid Connected PV System

When light energy is changed into electrical energy, it is called solar power generation. Many units and panels are connected electrically in parallel-series combination to produce the required power. By using the result of photoelectric effects, the light is directly changed into electric current[12]. Depending upon the light transferred per unit area, the Photovoltaic range generates direct current. With the help of inverter or universal bridge, the dc power is being converted into ac power having phase and frequency. In my thesis, eight photoelectric modules are being used.. The quality and electrical behavior is determined on light and temperature. The maximum boundary of solar flow is 1000 W/m²[38].

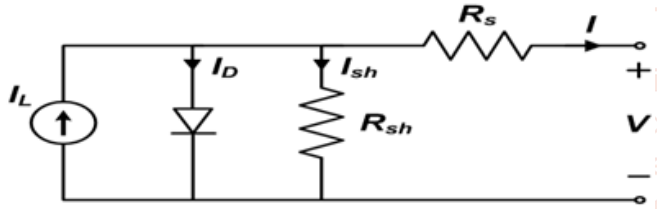

Figure-1 Equivalent circuit diagram of PV system with series and parallel resistance

Boost converter is one of the most favored converters for MPPT application, because almost all of the solar PV module output voltage is lower than the required external load voltage. However, the switching component in the buck converter is placed in the Input side and series with the input voltage, which will stop the flow of current within the system[35].

It will definitely cause energy losses during the solar power generation process. Hence boost converter is most efficient and economical [12].

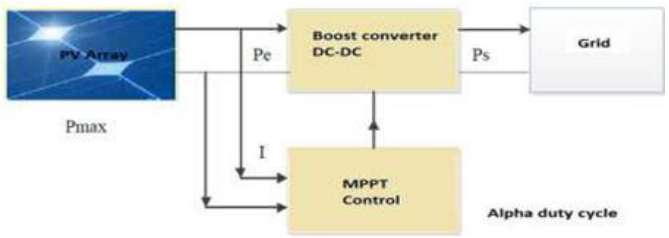

Figure-2 Proposed block diagram of grid connected solar system

3. Modeling of Solar Cell with STATCOM:

A Basic grid-connected Photo Voltaic system includes a PV array together with inverter unit, near the point of use for generating energy for residential purpose[18]. The major technical roadblock that can put the limit to widespread Photo Voltaic use is the quick changes in the output power of Photo Voltaic systems induced by cloud transients. These events can cause fluctuations in Voltage which give rise to too much use of voltage regulation instruments and light flickering [36].

Solar irradiance variability is recorded by the help of pyranometer with a data logger. In many studies, where we want to calculate the AC power feeded into the grid by Photo Voltaic systems, we use solar irradiance variability[19]. But these two variables, in reality, are not ideally proportional to each other and also not synchronized in time due to delays found within the controls and circuit elements of inverter. A standard utility interactive Photovoltaic system as shown in Fig. 5.1, it is observed that the difference between output power variability and solar radiation that may be produced by the buffer capacitor and MPPT is negligible. Therefore, the differences in solar irradiance are reliable indication of power fluctuations[31].

Solar PV system captures the sunlight and directly converts it into electricity. The solar cell output is mainly depends on two factors which are variable in nature that is, ambient temperature and irradiation. Change in these two factors affect the output of the solar cell either increase or decrease. The modeling requires the mathematical equations explaining and defining the physical characteristics of the PV cell. Fig. represents PV cell's equivalent circuit[36].

$$I = I_{PVcell} - I_{0cell}\left[\left(\exp\left(\frac{q(V+iR_s)}{nkT}\right) - 1\right) - \left(\frac{V + IR_s}{R_p}\right)\right] \quad (1)$$

Incident photocurrent is calculated by the temperaturesT_1 and T_2.

$$I_{PVcell} = I_{PVcell} + (T - T_1)K_0 \quad (2)$$

$$I_L(T) = I_{SC_{T1}}\left(\frac{G}{G_{nom}}\right) \quad (3)$$

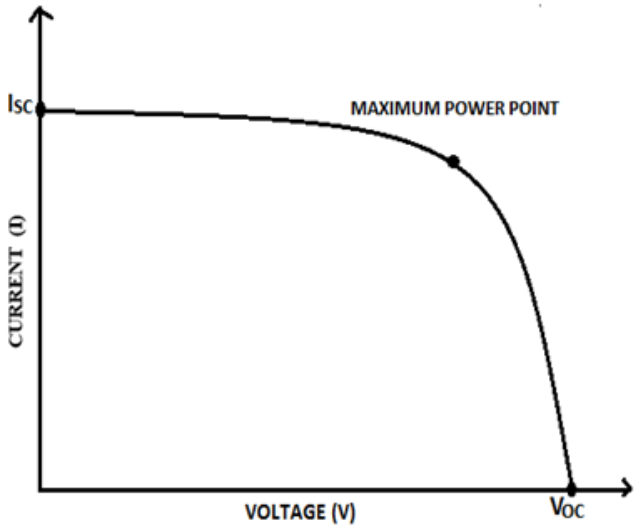

Figure- 3 V - I characteristic of a solar cell

$$K_0 = (I_{SC_{T1}} - I_{SC_{T2}})/(T_2 - T_!)$$

G_{nom} is the reference solar radiation and current solar radiation is represented by G.

During the dark, the cell is inactive and behaves like diode. The shunt resistance and internal resistance of the solar cell are denoted by R_p and Rs respectively. The maximum power (for a given resistive load) is given by

$$P_{Max} = I_{Max} * V_{Max} \quad (4)$$

Solar cell's efficiency can be defined by

$$\eta = \frac{P_{Max}}{P_{Min}} = \frac{(V_{Max} * I_{Max})}{A * G} \quad (5)$$

Here, A represent area of the cell whereas is the incident solar radiation on cell

To measure the quality of the solar cell, we use Fill Factor (FF). The FF should be more than 0.7. It is inversely proportional to the cell temperature.

$$FF = \frac{(I_{SC} * V_{OC})}{(V_{Max} * I_{Max})} \quad (6)$$

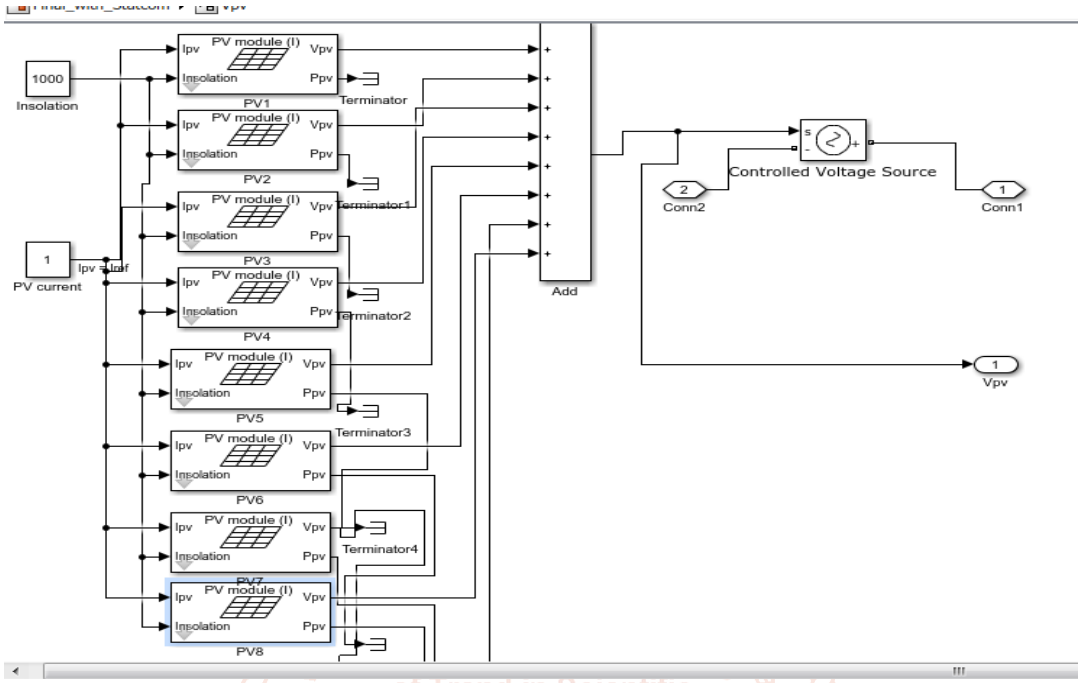

Figure-4 SIMULINK of photovoltaic modules

In this work, it is a successful way to get the electric power by incorporates the Hybrid solar/wind generating system and then controlled and changed with the help of static compensator which contain wind power/voltage stabilization and harmonic filtering. The simulation circuit will contain all sensible components of the system[21].

STATCOM is a shunt connected compensation tool having the capacity of introducing or absorbing the reactive power. It also boosts the steady state and transient stability systems. The important parts involves Voltage source Inverter (VSI), DC Capacitor, Signal Generation, Coupling Transformer and Control Circuit. Its output can be changed to control the different parameters of power system[22]. It is considered as solid state switching converter because having the capacity of Introducing or absorbing real and reactive power at its output terminals when it is actually assigned from solar/wind hybrid input terminal system[32]. The three phase output ac voltage generated after using STATCOM is in phase with the identical ac voltage through leakage reactance [23]. The DC side of the voltage source converter is connected to a DC capacitor transmits the input current. No power will be distributed to the system if the AC terminal voltage will turns equal to the output voltage of the VSI[27]. The performance of STATCOM will be in capacitive mode if the output voltage will be significant than ac output voltage [24-32]. Likewise STATCOM will operate in Inductive mode if ac output voltage is more than output voltage of VSI.

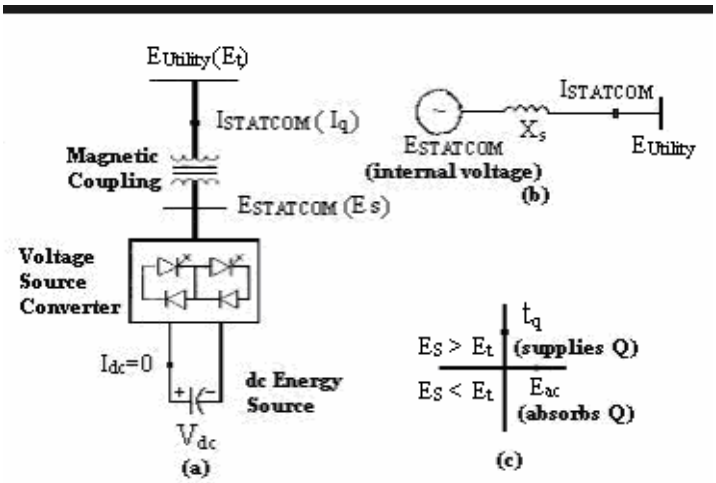

Figure-5 STATCOM

STATCOM has the following dominance over other equipments:

- The transient stability of power system can be upgraded.
- The power oscillation damping in power transmission system.
- Voltage flicker control and Dynamic voltage control in transmission and distribution system.
- Its acknowledgment is fast and less time wasting.

The SIMULINK model of STATCOM is shown in Fig. 4.8.

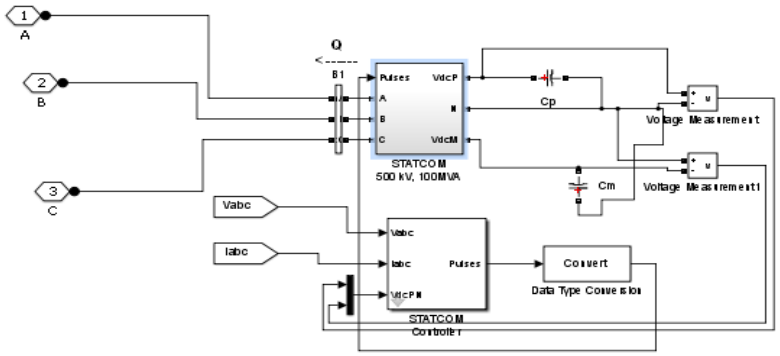

Figure-6 SIMULINK model of STATCOM

4. Implementation of MPPT using a boost converter:

The initially low voltage output obtain we are stepping up to a higher level using the boost converter, though the use of the converter does tend to introduce switching losses[33]. The block diagram shown in Figure-7 representation of boost converter with MPPT

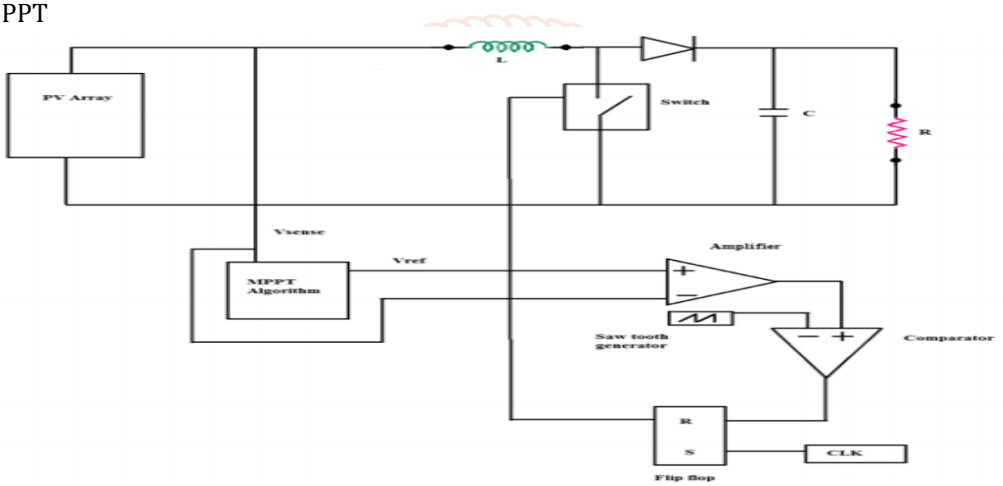

Figure-7 Requisite implementation for MPPT system

MPPT receive signal from solar plate and generate a signal that signal compares with a comparator and it generate error signal again it compares with saw tooth signal and finally it operate on RS fillip flop output of SR fillip flop used for triggering of boost converter .

5. Modeling of PV Subsystem without MPPT:

The Fig. 4.5 below is of PV subsystem without MPPT. The maximum power point is not achieved in this technique and the power from the PV array lost in many folds[33]. The PWM technique is used in this to provide gate pulse to the inverter switches.

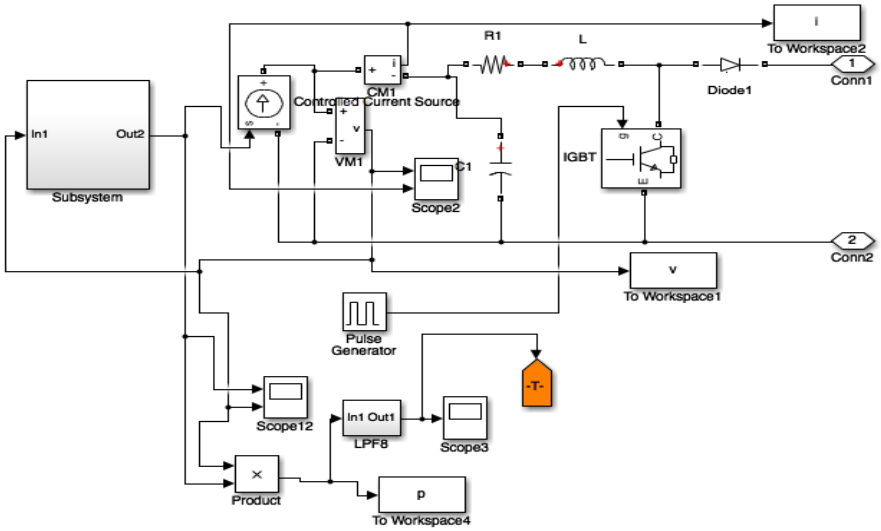

Figure-8 PV Subsystem without MPPT (without controller)

As show in figure-7 solar system with MPPT, MPPT receive signal from solar system and generated output compared with saw tooth and that compared output operate on SR flip flop o to produce a pulse which is used for switching for boost converter and controlling of duty cycle[35].

Due to the expensive of the PV cell manufacturing process and comparative it has low energy conversion efficiency, the maximum power point tracking technique is one of the very crucial for finding the peak operating point or highest power that is to be find out from PV array[33]. A MPPT is one of the important algorithm which adjust the solar power interfaces and also achieve the highest feasible power harvest, in the duration of moment to moment changes of light level, temperature, shading, and the PV module characteristics.[32] The purpose of this MPPT algorithm is to adjust solar operating voltage, which is close to the MPPT under the changing of atmospheric conditions [27]. PV generation is reliable and it has no moving parts therefore, its maintenance and their operating costs are very less and PV modules are the basics for the solar photovoltaic (PV) power generation unit. Electricity is generated by cells of a solar PV system, which are from solar energy and these are on depend of photoelectric effect. The electricity can be received directly by solar energy conversion in PV systems. The PV cell is one of the main building blocks of PV system and it is based on semiconductor materials device which can convert the solar energy in to DC[21].

6. Effect on nature:

In hybrid system we are using SPV with grid no other source used in the paper. My work deal with the generation of energy which lead to generation electric energy with minimum cost without damaging nature. Because SPV generation technology reduce the CO_2 emission by replacing fuels in power generation in industry and transportation.

Life cycle CO_2 emission is much lower than fossil fuels. The life cycle balace also consider to be important factor in the best generation and transportation.

Based on analysis done by IEA, RNPG same 1.7 Gt of CO_2 emission in 2008.

According to IEA analysis BRICS country will same CO_2 emission roughly 5.3 Gt in year 2030 by using RNES.

For decrease in total CO_2 emission if use SPS at the place of thermal power plant for same power output can be calculated for n year.

$$\textbf{Same in } CO_2 = \sum_1^n E_t N_t \alpha_t \beta_t \quad (7)$$

E_t = Electric Energy;

n_T = Sunny Day;

α_t = Amount Fuel use for produced of 1 unit electric energy in TPP;

Economical Effect:

Amount of revenues cane be calculated by

$$\textbf{Revenues} = \sum_1^n E_t \lambda_t \text{ price} \quad (8)$$

E_t = Energy produce by SPS for t time;

λ_t = Fuel we use for produce 1 unit energy in TPP

Price = cost of 1 unit fuel.

Thus SPS is so the economical and environmental benefits.

7. Results:

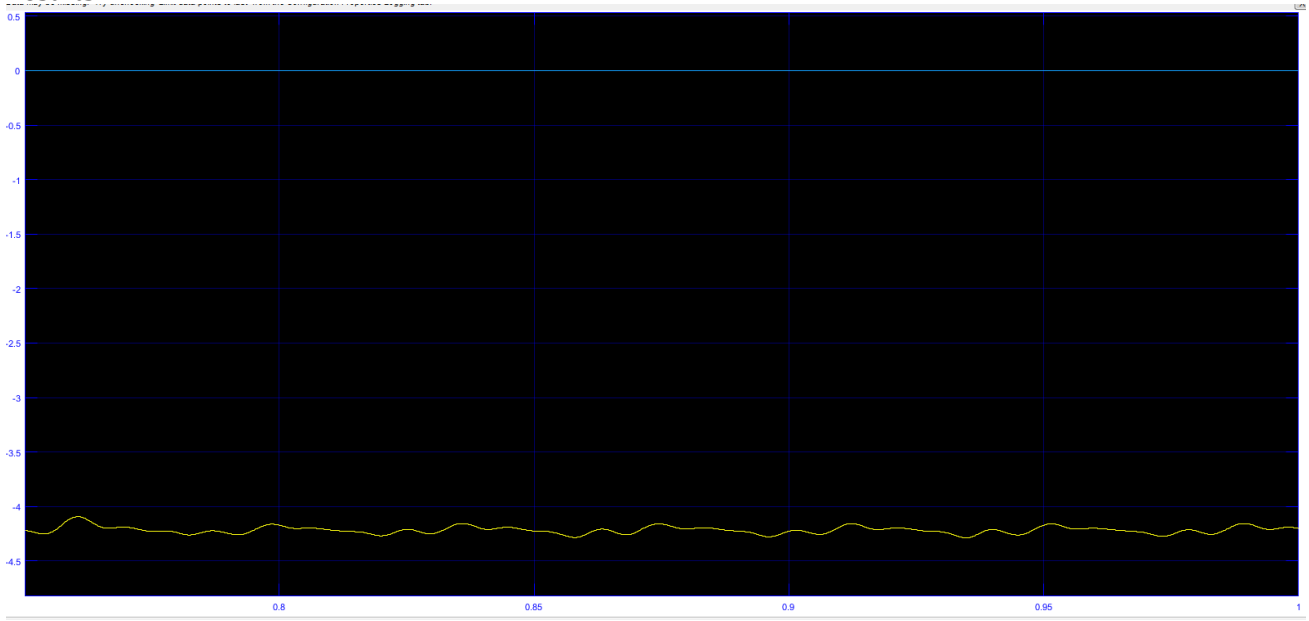

Figure-9 Power share by grid

Figure-10 Graph tan Ø

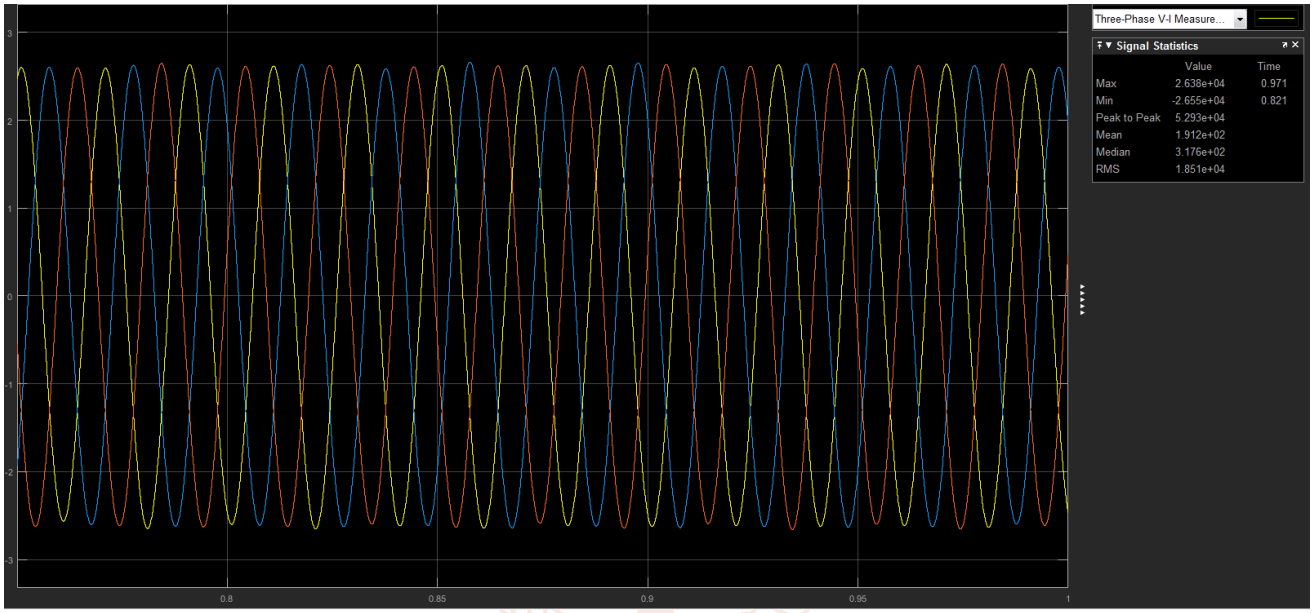

Figure-11 Grid Voltage

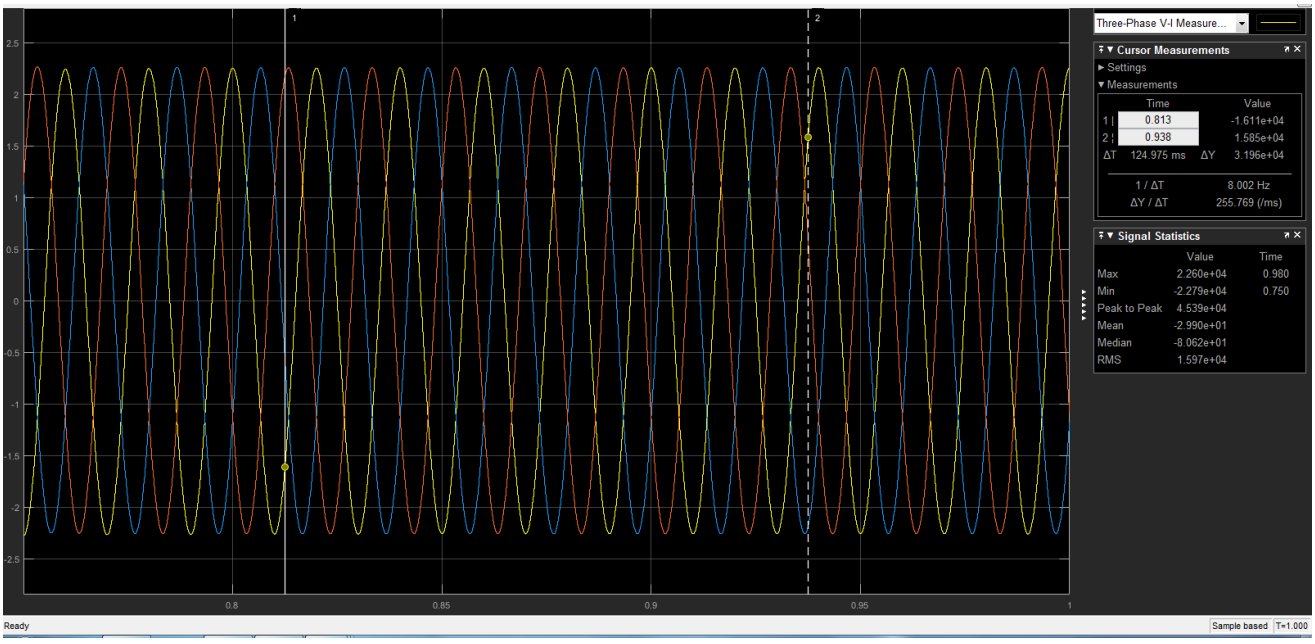

Figure-12 Grid current

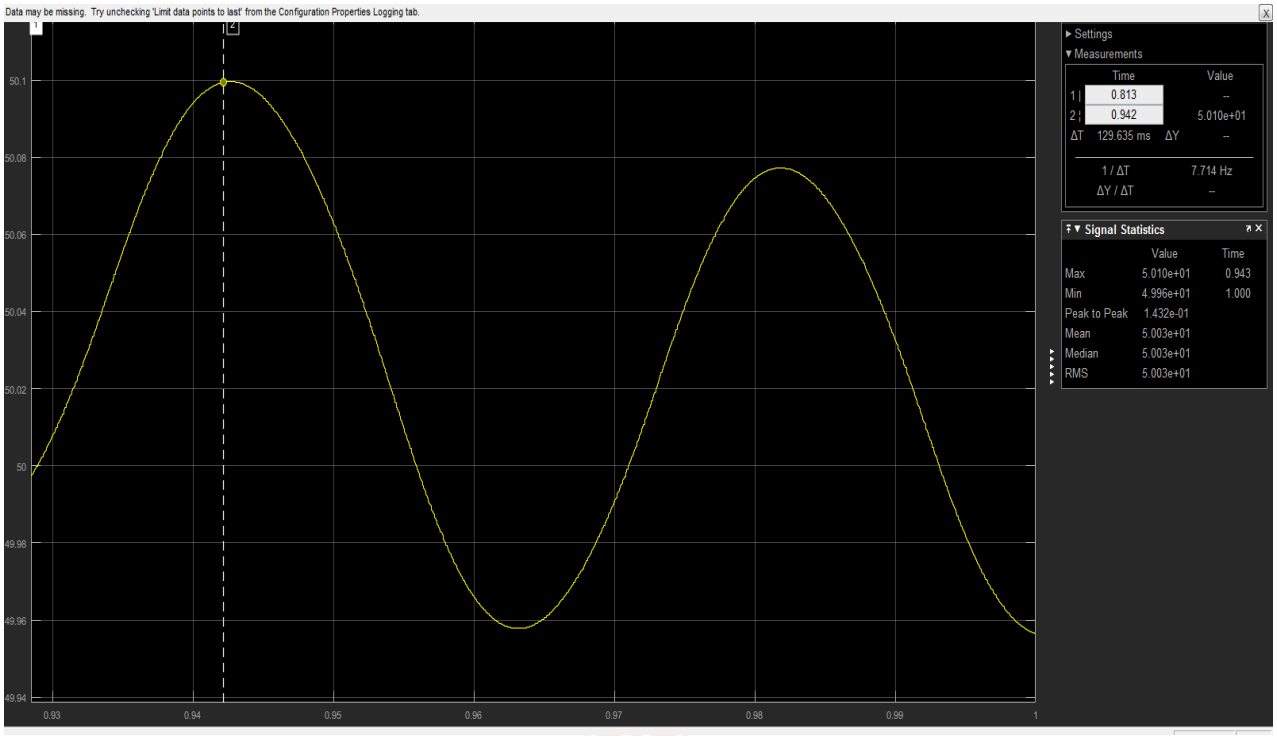

Figure-13 Grid frequency

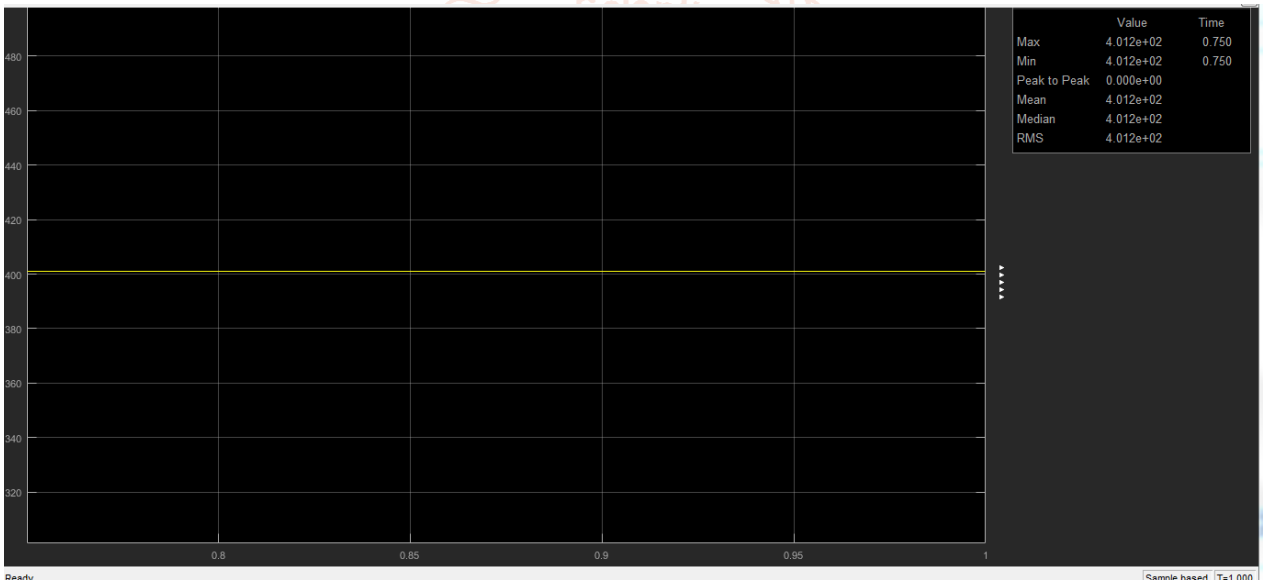

Figure-14 PV voltage

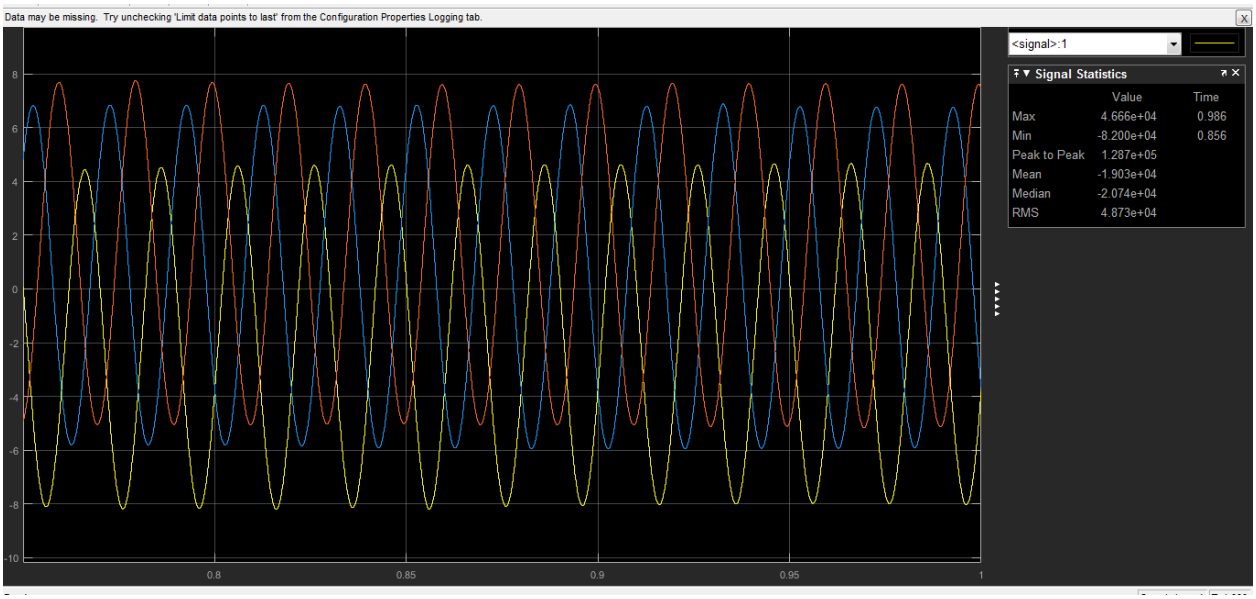

Figure-15 Current drown by load

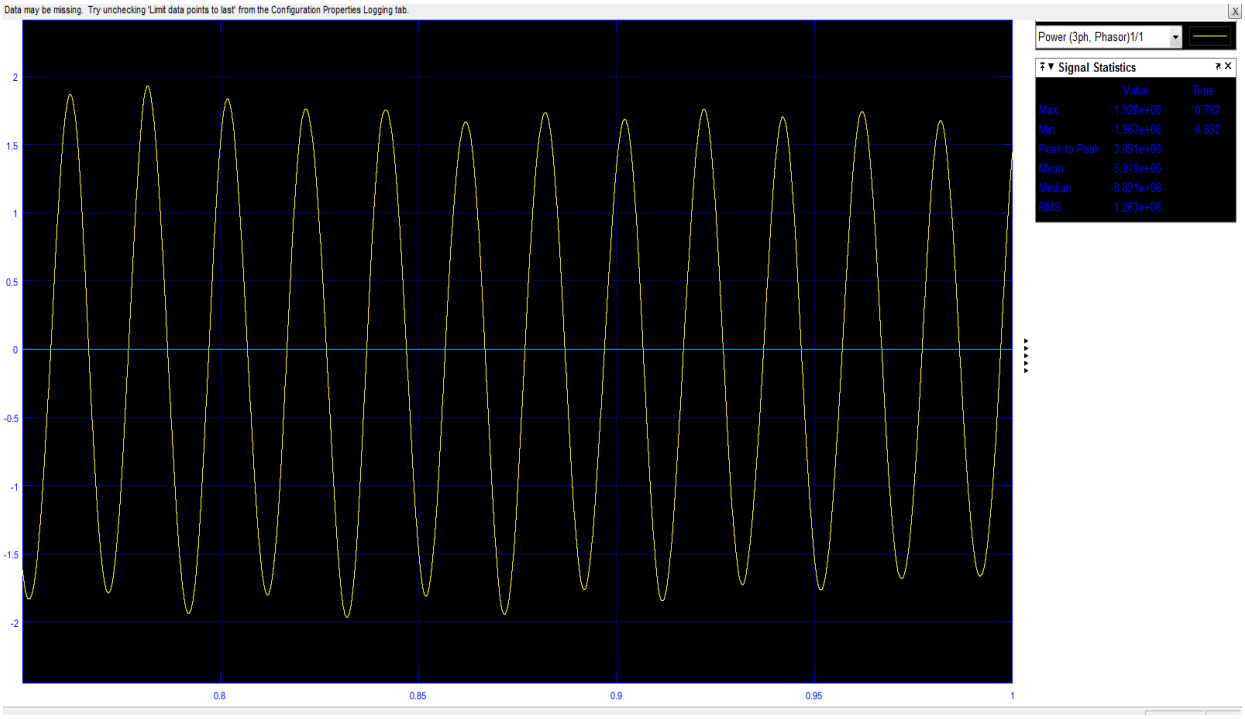

Figure-16 Active power given by PV

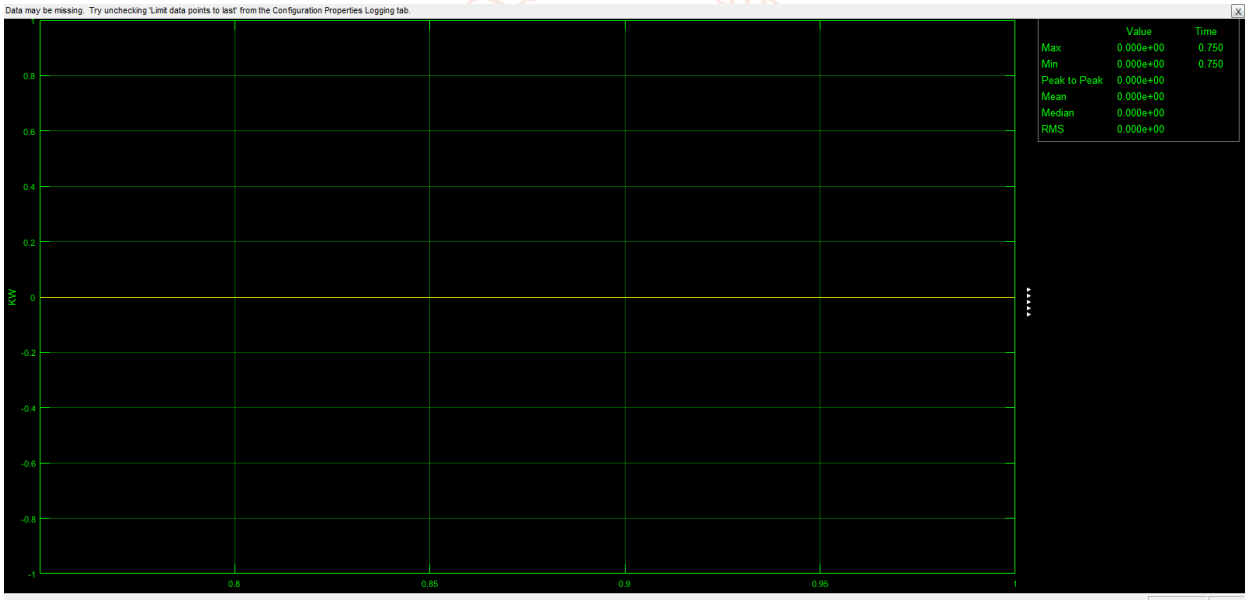

Figure-17 Reactive power at inverter terminal

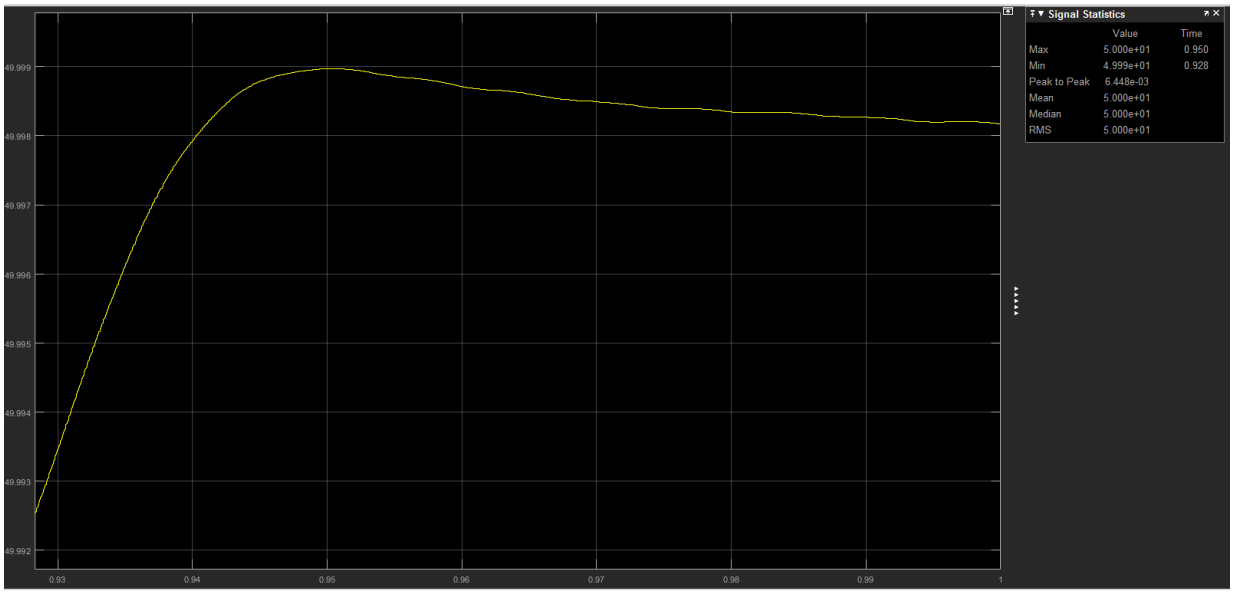

Figure-18 Grid frequency without shunt reactor

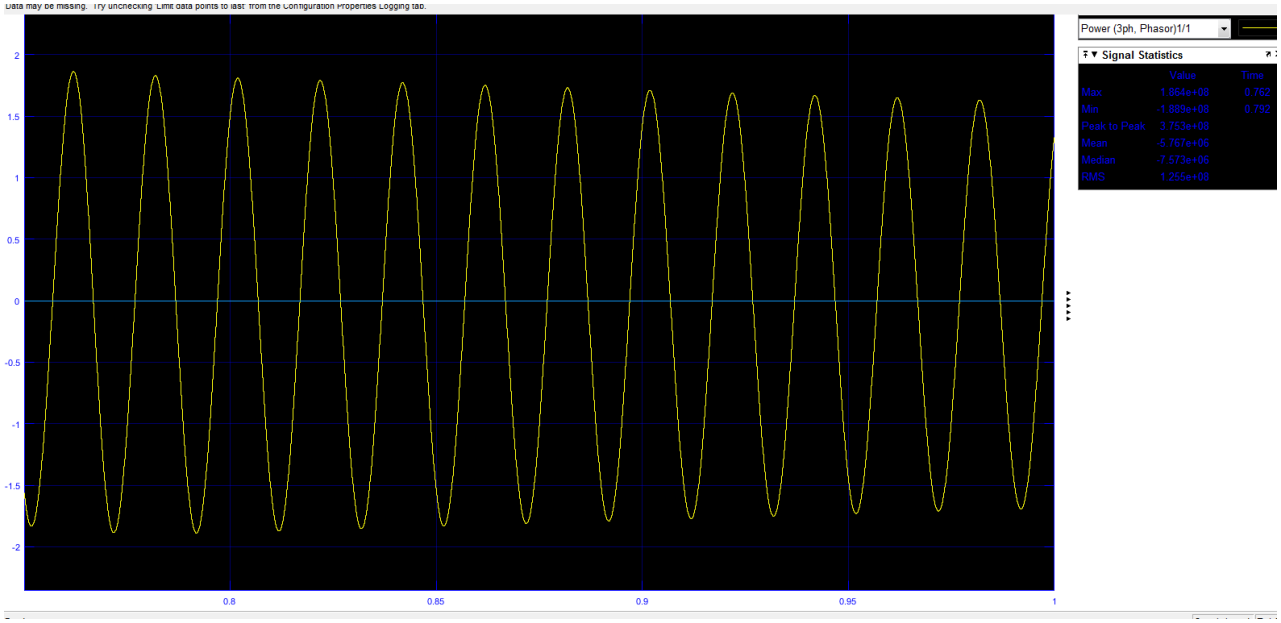

Figure-19 Active power inverter end Without shunt reactor

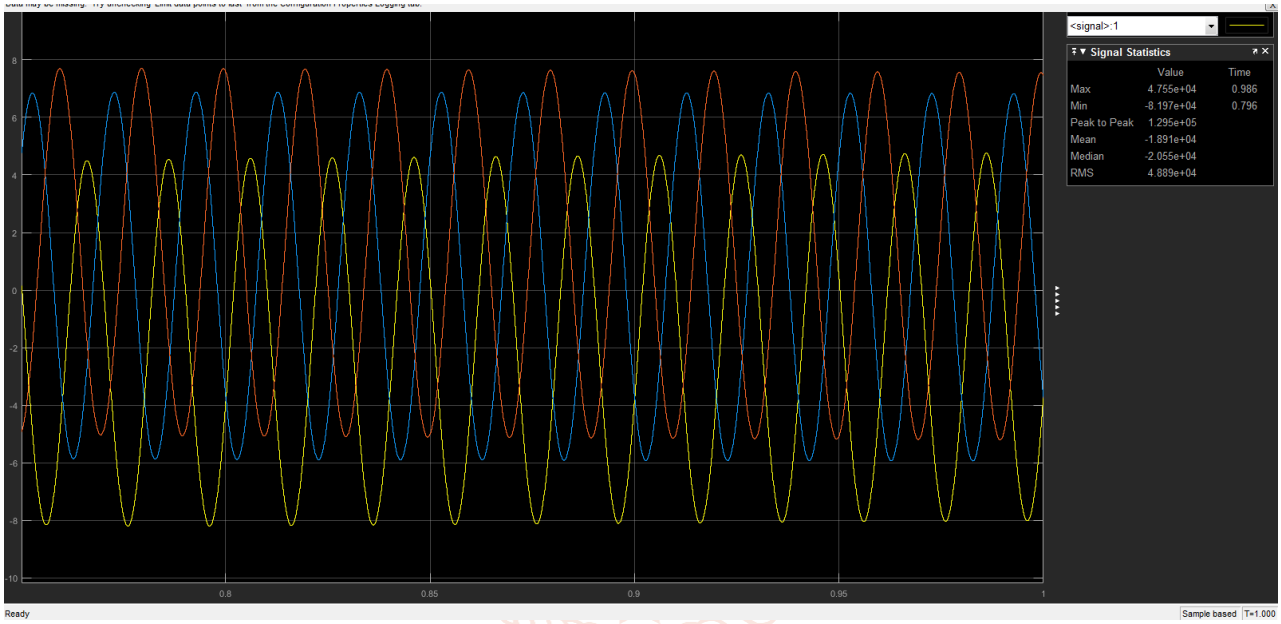

Figure-20 -3 phase current drown by load without shunt reactor

8. Conclusion:

The hybrid PV/grid system with STATCOM is being examined with the help of MATLAB/SIMULINK. STATCOM upgrades the performance of power system and make it balanced as shown in different wave forms. The voltage stability of the STATCOM is shown by changing the inductive load which adjusts the load side voltage and current almost same. The ac supply from hybrid PV/grid system is being provided to grid which is unbalanced and includes harmonics. To assemble it stabilized and balanced. STATCOM 100Mvar has been used in distribution network and the bus feeder is about 100km. The output of STATCOM is connected in parallel with 1.25/25 KVA step up delta-star transformer. A filter bank is supplied at the end of STSTCOM output to digest the harmonics. The principal side of this transformer is fed with Voltage source Inverter and 3000 µF Capacitor is used as a dc voltage source for inverter. STATCOM plays a crucial part for controlling the bus voltage by generating or absorbing it. STATCOM will act as Inductive mode, if the secondary voltage is lesser than the bus voltage and it will act as capacitive mode if bus voltage is lower than secondary voltage. The output range of PV system is 401V dc. Here eight solar plates (each having rating 50 volt) are connected in series. Three phase RLC has been connected to compensate reactive power as per demand of solar system. Finally output (voltage & current) become distortion free. so we can conclude that wave form of voltage and current obtain by STATCOM is more symmetric and don't have harmonics (having very less harmonics) with improved pf.

9. Acknowledgement:

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