AC DYNAMIC LOAD CONTROL FROM SOLAR ENERGY BY USING PHASE-IN POSITION CONTROL TECHNIQUE

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ABSTRACT

This paper presents the design, control and simulation of multifunctional, two-stage, three- Phase SPV energy conversion system which have been carried out using an control algorithm based on ANF. The ANF has been used for extraction of fundamental part of load current. The reference grid currents are then estimated using all load currents, PV contribution and loss component of VSC, which are further used to generate the switching pulses for VSC. The performance of the system has been demonstrated for harmonics elimination, compensation of reactive power, load balancing and power factor correction. An InCA technique has been used for the electrical MPPT of SPV panels. The performance of the two-stage, three-phase grid-interfaced SPV energy system has been found satisfactory under different dynamics and steady state operating conditions. The THD of grid currents is found well under IEEE-519 standard. A wide range of simulation results has been shown to prove the feasibility of the control approach.

Keyword: *- PV system, MPPT, dynamic load, grid*

1. INTRODUCTION

Due to rising cost of non-renewable sources of energy and also because of environmental concerns caused due to their use Green and low carbon power is an urgent need today. SPV (Solar Photovoltaic) energy conversion systems, in comparison with other renewable sources of energy like wind, tidal etc. are gaining momentum due to increased research in the area, suitable government policies and falling prices. "Solar PV energy conversion systems can be of two types: grid-interfaced and standalone power generating system". Standalone systems increase both capital and maintenance cost of the system, as it require additional energy storage device like batteries for reliable and efficient operation. Whereas in Grid-interfaced solar energy conversion systems integration of any renewable energy source to the electric grid has to fulfill standard power quality requirements so that the grid is not polluted due to such interface. Thus Grid-interfaced solar energy conversion systems do not require any storage device.

The ratio of nonlinear load is increasing in the distribution system like adjustable speed drives, computers, electronic ballasts, etc. due to lot of electronic devices coming in the market."These nonlinear loads inject harmonics rich current into the distribution system, which may cause several other problems like mal-operation of devices connected to the system, overheating of motor-load and distortion in the supply voltage wave form etc". Various custom power devices provide retrofit solutions to these power quality problems. For power quality improvement various series, shunt, hybrid and shunt-series connected devices are proposed in.

The energy scarcity and poor quality of the supplied power are the challenges encountered in the distribution system, these challenges are addressed in the proposed system is a multi-function device. "The proposed SPV energy conversion system is capable of improving the power quality along with the objectives of MPPT" (Maximum power Point Tracking) and feeding that energy into the grid. For feeding active power to the grid PV inverters are limited to use , in the literature many single-stage as well as two stage grid interfaced SPV systems are reported.

Very few grid interfaced SPV systems with reactive power compensation and active power filtering are reported in but they do not provide load currents balancing and also detailed hardware results are not given. However only simulation studies have been presented in SRFT (Synchronous Reference Frame Theory) based control for grid interfaced SPV system with power quality improvement discussed by Verma et al. Because of low pass filters used for filtering the SRF theory based system suffers from poor dynamic response.

Two-stage multifunctional SPV generation systems are presented. A complicated neural network based control approach is used. Here we are discussing about grid-tied systems that utilize batteries for energy storage. We can rely on the batteries to power our “critical loads” when grid is absent. Critical loads generally consist of refrigerators, freezers, well pump, some lighting circuits, etc. The batteries are most often maintained in a ‘float’ charge where the battery is maintained at full capacity waiting for that critical moment, when we have a grid-tied system with battery backup.

One knows that how batteries are traditionally incorporated into grid-tied systems, why strictly grid-tied systems are most often used. To gain higher efficiencies, we focus on a newer type of battery based system that couples the PV on the AC side of a battery based system. As they are very simple and efficient vast majority of solar PV systems installed today are strictly grid-tied systems and they do not utilize batteries for energy storage. The least amount of components are required for the system. They are the solar array, a utility-interactive inverter (to convert the solar modules DC current to AC current) and installation components for a code compliant system.

The excess energy produced goes onto the electrical grid virtually spinning the utility meter backwards instead of storing the electrical energy in a battery bank. A credit that is subtracted from the energy consumed every month is stored as the energy that is delivered to the grid. Often times when the credit amount reaches a certain monetary value set by the utility, the utility will cut the system owner a check and the energy delivered to the utility exceeds the amount of energy consumed by the home or business.

When the connection between the grid and the solar PV is interrupted due to a power outage or other event, since there is no energy storage on site there is no way to utilize the energy from the solar array. Because of the higher efficiency that it delivers and least expensive this system is most often used.

When grid is absent, some people opt for a system that utilizes batteries to store energy for those events as not being able to use your solar array during a power outage can be frustrating. The amount of times that backup power is needed is generally few and the utility is reliable in most areas around Wisconsin. Due to the number of components and complexity of the system investing in a PV system with battery backup from the get go has always been the most expensive system.

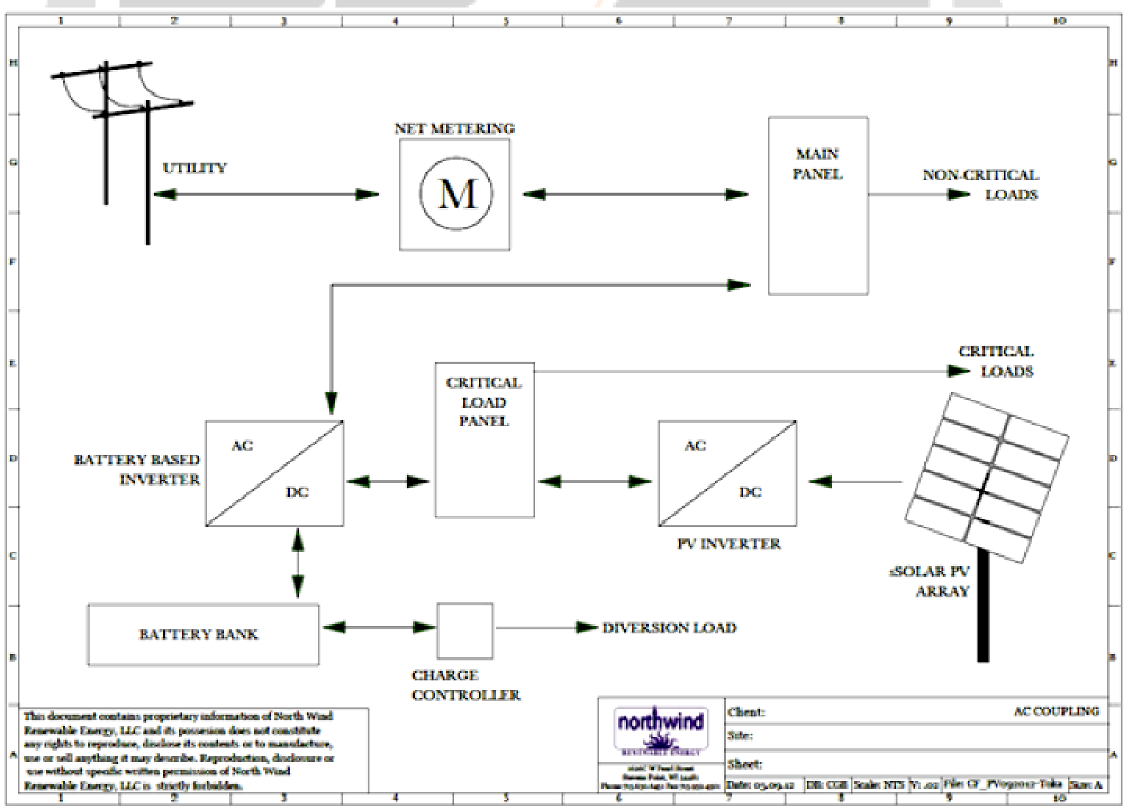


Fig:1. AC coupled PV system

Instead of diverting it to dump loads or wasting that energy, you had the best of both worlds being able to have off-grid capability and be able to sell excess energy (after batteries were charged up) to the utility. A charge controller is used to manage the energy from the PV array to effectively charge the battery ,Traditionally a PV array is connected or ‘coupled’ to the DC side of a battery-based system . “The array is wired at a lower voltage to better match the battery bank”. Many battery inverters will sell excess PV power to the grid when the battery is full. There are more efficiency losses in the system as a whole (when compared to a strictly grid-interactive inverter) in this configuration.
During off-grid operation only ‘critical loads’ are powered. The system added to an existing PV system can be very cost effective and give the peace of mind that backup power offers. “The configuration of the PV array doesn’t need to be changed at all and only the battery-based inverter, battery bank, battery management components and a ‘critical load’ panel need to be added”. Most importantly the high efficiency of the grid-tied inverter is maintained. It may be only once or twice a year when the battery system is asked to perform its crucial task and the other 360 days of the year you can utilize your PV at a very high efficiency, powering your loads and selling excess power to the grid. With the traditional DC coupled array during those other 360 days you may be wasting ¼ of your array potential only operating at 75%. Solar is hands down a very rewarding investment. AC coupling allows you to have an even more rewarding experience by giving you the battery backup capacity when the grid is absent while utilizing your existing, high efficiency PV array. We’d love to retrofit all of the central Wisconsin grid-tied systems out there, so give us a call.
In designing a solar power system for the cabin at Enota, we are using the newest most cost-efficient technology. However, to understand new more efficient methods we researched past projects. By doing so, we can learn from others mistakes and hardships. By understanding the difficulties we will face, we can be better prepared for them. The following are two examples and tips from other solar projects [1]. Looking through some do-it-yourself documents we found the detailed experience of Shane from Rock river. Shane wanted to become more self-sufficient and decided to start with a solar system consisting of 4, 190 watt solar panels. He documents his experience very thoroughly on this website and has a few tips we can take from it. Shane says he lowered his average monthly electric bill by half in just two steps [2].B His first step was to change the incandescent light bulbs to compact florescent and second was installing timed power strip son the electronic devices with phantom loads. “A phantom load is when a device is plugged into the wall and is turned off but still uses power when turned off [3].” The rest of the installation is mostly straight forward and standard but he offers oneother tip about panel positioning. “It is recommended to tilt your panels to equal your latitude and then for winter months add 15 degrees to the tilt and in Summer Subtract 15 degrees from the tilt [4].” Bob Goodsell undertook a project similar to ours, installing a PV system with battery backup [5]. One of the major disadvantages to Bob’s design was that he did not incorporate net metering, or selling power back to the grid [6]. During sunny days when the batteries were completely charged, the rest of his power was just wasted. Our system is designed to have the capability to net meter, thus selling excess power back to the power company [7]. Another issue Bob ran into is the overheating of his solar panels. “The conversion of sunlight to electricity is dependent on the temperature of the panels”. If the panels get too hot, the output will go down. He used the solar shingles directly mounted on his roof, with no air gap behind them and no aluminum frame to dissipate heat. Because of this, his output in May was higher than in July. Our system utilizes panels with aluminum frames to help dissipate heat. Also, both mounting options have sufficient air gap under the panels, keeping them at a normal temperature. Also, Bob used flooded non-sealed batteries. Thus he has to maintain the water level of these batteries to prevent damage or battery failure, as well as vent dangerous fumes out of his house. Our system uses sealed batteries, so there is never any off gassing or need to check any fluid levels [8] S. Yuvarajan et al proposed a fast and accurate maximum power point tracking (MPPT) algorithm for a photovoltaic (PV) panel that uses the open circuit voltage and the short circuit current of the PV panel [8]. The mathematical equations describing the nonlinear V-I characteristics of the PV panel were used in developing the algorithm.

The MPPT algorithm is valid under different insulation, temperature, and level of degradation. The algorithm is verified using MATLAB and it is found that the results obtained using the algorithm were very close to the theoretical values over a wide range of temperature and illumination levels. The maximum deviation in the maximum power was less than 1.5% for the illumination levels and temperatures normally encountered by a commercial PV panel. The complete derivation of this MPPT algorithm was presented [9]. It is seen that the algorithm is faster than other MPPT algorithms like perturbation and observation (P&O) and more accurate than approximate methods that use the linearity between voltage (current) at maximum power point and open-circuit voltage (short-circuit current).Prof. Dr. IlhamiColak, et al. have modeled three separate solar farms that provide [10]. 15 kW power for each farm using Mat lab Simulink real-time analysis software [11]. Energy conversion was performed with maximum power point tracking (MPPT) algorithms in each converter using Perturb and Observe

(P&O) structure. These were collected in DC bus bar with parallel connection of converters over inter-phase transformers (IPT). The voltage was applied to a full bridge inverter to generate 3-phase AC voltages at the output of inverter which was controlled with sinusoidal pulse width modulation (SPWM) scheme [12]. S. G. Tesfahunegn et al. designed a new solar/battery charge controller that combines both MPPT and over-voltage controls as single control function [10]. A small-signal model of lead acid battery was derived in detail to design the employed dual-loop control configuration. Case studies were then conducted, in SIMULINK/SIMPOWER, to evaluate the performance of the designed controller in terms of transient response and voltage overshoot [13].

The designed controller was demonstrated to have good transient response with only small voltage overshoot. Yuncong Jiang et.al. Present an analogue Maximum Power Point Tracking (MPPT) controller for a Photovoltaic (PV) solar system that utilizes the load current to achieve maximum output power from the solar panel [14]. Comparing to the existing MPPT controller circuitry which requires multiplication of the sensed PV panel voltage and current to yield panel power, the cost and size of the proposed circuit was reduced. The tracking performance of the proposed MPPT controller was validated by simulation results. ArashShafie et al proposed a novel MPPT algorithm mainly for battery charging applications which were considered constant voltage type loads. This was achieved mainly with output current maximization [12]. This technique benefits from advantages such as very simple current controller and also circuit topology independency. This provides high efficiency for energy conversion with low cost for low power, low cost applications. A new hybrid PV model was introduced for simulation purposes. Finally, simulation results will be provided confirming the validity of the algorithm. Solar photovoltaic (PV) systems have been an area of active research for the last few decades to improve the efficiency of solar PV module. The non-linear nature of IV curve of solar PV module demands some technique to track the maximum voltage and maximum current point on IV curve corresponding to Maximum Power Point (MPP)[11].

The proposed MPPT technique was much more robust in tracking the MPP even under the frequent changing irradiance conditions and was less oscillatory around the MPP as compared to P&O. The technique was verified using MATLAB/SIMULNK and simulation results show a clear improvement in achieving the MPP when subjected to change in irradiance

2. GRID CONNECTED SYSTEM

When connecting a home energy system to the electric grid, research and consider equipment required as well as your power provider’s requirements and agreements. | Photo courtesy of Solar Design Associates, Inc. Many people prefer the advantages that grid-connection offers, even renewable energy systems are capable of powering houses and small businesses without any connection to the electricity grid. During the periods (daily as well as seasonally) like when the sun is shining, the water is running, or the wind is blowing, a grid-connected system allows you to power your home or small business with renewable energy. Any excess electricity you produce is fed back into the grid. Eliminating the expense of electricity storage devices like batteries, electricity from the grid supplies your needs when renewable resources are unavailable. In addition, power providers (i.e., electric utilities) in most states allow net metering, an arrangement where the excess electricity generated by grid-connected renewable energy systems "turns back" your electricity meter as it is fed back into the grid. If you use more electricity than your system feeds into the grid during a given month, you pay your power provider only for the difference between what you used and what you produced. When thinking about connecting your home energy system to the electric grid some of the things you need to know. They are :

- Equipment required to connect your system to the grid
- Grid-connection requirements from your power provider
- State and community codes and requirements

In order to safely transmit electricity to your loads and comply with your power provider's grid-connection requirements, you will need to purchase some additional equipment, aside from the major small renewable energy system components. You may need the following items:

- Power conditioning equipment
- Safety equipment
- Meters and instrumentation.

Because grid-connection requirements vary, you or your system supplier/installer should contact your power provider to learn about its specific grid-connection requirements before purchasing any part of your renewable energy system. Page on balance-of-system gives the equipment requirements for small renewable energy systems.

2.1 Grid-Connection Requirements from Your Power Provider:

Currently, requirements for connecting distributed generation systems—like home renewable energy or wind systems—to the electricity grid vary widely. But all power providers face a common set of issues in connecting small renewable energy systems to the grid, so regulations usually have to do with safety and power quality, contracts (which may require liability insurance), and metering and rates. Try contacting your state utilities commission, state utility consumer advocate group (represents the interests of consumers before state and federal regulators and in the courts), state consumer representation office, or state energy office, if your power provider does not have an individual assigned to deal with grid-connection requests. To learn about its specific requirements, you will need to contact your power provider directly.

2.2Addressing Safety and Power Quality for Grid Connection:

Power providers want to be sure that your system includes safety and power quality components. These components include switches to disconnect your system from the grid in the event of a power surge or power failure (so repairmen are not electrocuted) and power conditioning equipment to ensure that your power exactly matches the voltage and frequency of the electricity flowing through the grid.

2.3 Contractual Issues for Grid-Connected Systems:

You will probably need to sign an interconnection agreement with your power provider, when connecting your small renewable energy system to the grid. Power providers may require you to do the following in your agreement:

- **Carry liability insurance** -- Liability insurance protects the power provider in the event of accidents resulting from the operation of your system. Most homeowners carry at least $100,000 of liability through their homeowner insurance policies (although you should verify that your policy will cover your system), which is often sufficient. Be aware, however, that your power provider may require that you carry more. Some power providers may also require you to indemnify them for any potential damage, loss, or injury caused by your system, which can sometimes be prohibitively expensive.
- **Pay fees and other charges** -- You may be asked to pay permitting fees, engineering/inspection fees, metering charges (if a second meter is installed), and stand-by charges (to defray the power provider's cost of maintaining your system as a backup power supply). Identify these costs early so you can factor them into the cost of your system, and don't be afraid to question any that seem inappropriate.

In addition to insurance and fees, you may find that your power provider requires a great deal of paperwork before you can move ahead with your system. However, power providers in several states are now moving to streamline the contracting process by simplifying agreements, establishing time limits for processing paper work, and appointing representatives to handle grid-connection inquiries.

2.4Metering and Rate Arrangements for Grid-Connected Systems:

When your renewable energy system generates more electricity than you can use at that moment, the electricity goes onto the electric grid for your utility to use elsewhere,with a grid-connected system. The Public Utility Regulatory Policy Act of 1978 (PURPA) requires power providers to purchase excess power from grid-connected small renewable energy systems at a rate equal to what it costs the power provider to produce the power itself. Through various metering arrangements power providers generally implement this requirement. Here are the metering arrangements you are likely to encounter:

- **Net purchase and sale** -- Under this arrangement, two uni-directional meters are installed: one records electricity drawn from the grid, and the other records excess electricity generated and fed back into the grid. You pay retail rate for the electricity you use, and the power provider purchases your excess generation at its avoided cost (wholesale rate). There may be a significant difference between the retail rate you pay and the power provider's avoided cost.
- **Net metering** -- Net metering provides the greatest benefit to you as a consumer. Under this arrangement, a single, bi-directional meter is used to record both electricity you draw from the grid and the excess electricity your system feeds back into the grid. The meter spins forward as you draw electricity, and it spins backward as the excess is fed into the grid. If, at the end of the month, you've used more electricity than your system has produced, you pay retail price for that extra electricity. If you've produced more than you've used, the power provider generally pays you for the extra electricity at its avoided cost. The real benefit of net metering is that the power provider essentially pays you retail price for the electricity you feed back into the grid. Some power providers will now let you carry over the balance of any net extra electricity your system generates from month to month, which can be an advantage if the resource you are using to generate your electricity is seasonal. If, at the end of the year, you have produced more than you've used, you forfeit the excess generation to the power provider. In an attempt to address safety and power quality issues, several organizations are developing national guidelines for equipment manufacture, operation, and installation (your supplier/installer, a local renewable energy organization, or your power provider will know which of the standards apply to your situation, and how to implement them):

- The Institute of Electrical and Electronics Engineers (IEEE) has written a standard that addresses all grid-connected distributed generation including renewable energy systems. IEEE 1547-2003 provides technical requirements and tests for grid-connected operation. See the IEEE Standards Coordinating Committee on Fuel Cells, Photovoltaics, Dispersed Generation, and Energy Storage for more information.
- Underwriters Laboratories (UL) has developed UL 1741 to certify inverters, converters, charge controllers, and output controllers for power-producing stand-alone and grid-connected renewable energy systems. UL 1741 verifies that inverters comply with IEEE 1547 for grid-connected applications.
- The National Electrical Code (NEC), a product of the National Fire Protection Association, deals with electrical equipment and wiring safety.

Although states and power providers are not federally mandated to adopt these codes and standards, a number of utility commissions and legislatures now require regulations for distributed generation systems to be based on the IEEE, UL, and NEC standards. In addition, some states are now "pre-certifying" specific models of equipment as safe to connect to the state electricity grid.

3. AC COUPLING – CONVERTING GRID TIED PV SYSTEM

With solar panels through better efficiency rates, net metering, plus lower equipment and installation costs,a grid-connection will allow you to save more money: For a fully functional off-grid solar system batteries, and other stand-alone equipment, are required and add to costs as well as maintenance. Therefore, Grid-tied solar systems are generally cheaper and simpler to install. Often more electricity than what you are capable of consuming is generated by your solar panels. Instead of storing it themselves with batteries with net metering, homeowners can put this excess electricity onto the utility grid. How solar power is incentivized, net metering (or feed-in tariff schemes in some countries) play an important role. Without it, residential solar systems would be much less feasible from a financial point of view. Many utility companies are committed to buying electricity from homeowners at the same rate as they sell it themselves. Electricity has to be spent in real time. However, it can be temporarily stored as other forms of energy (e.g. chemical energy in batteries). Energy storage typically comes with significant losses. A schematic diagram of two-stage grid interfaced SPV generating system is shown in Fig.2. The proposed system consists of SPV panels, a dc-dc boost converter, and a three-leg VSC. A two-stage grid connected SPV energy conversion system is used in this work. In first stage, the solar photovoltaic modules are connected in a suitable series-parallel combination to get the desired voltage and current rating from the panels.

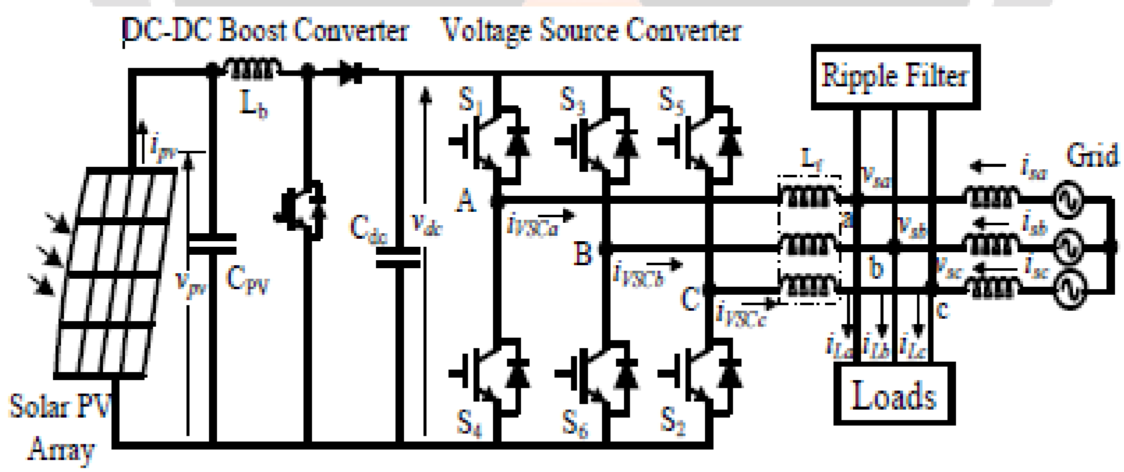


Fig: 2.Two-stage Grid-interfaced SPV generation system

. The load current mainly consists of fundamental, harmonics and dc components. The fundamental portion of load current can be further divided into current in-phase and 90° shifted with respect to respective phase voltage. An adaptive theory-based notch filter [25]-[26] with adaptive frequency is used to estimate the fundamental part of load current of phase“a”(i_{Lfa}), as shown in the block diagram of Fig. 2. An adaptive notch filter (ANF) based control technique is used to estimate.

4. SIMULATION CIRCUITS AND RESULTS

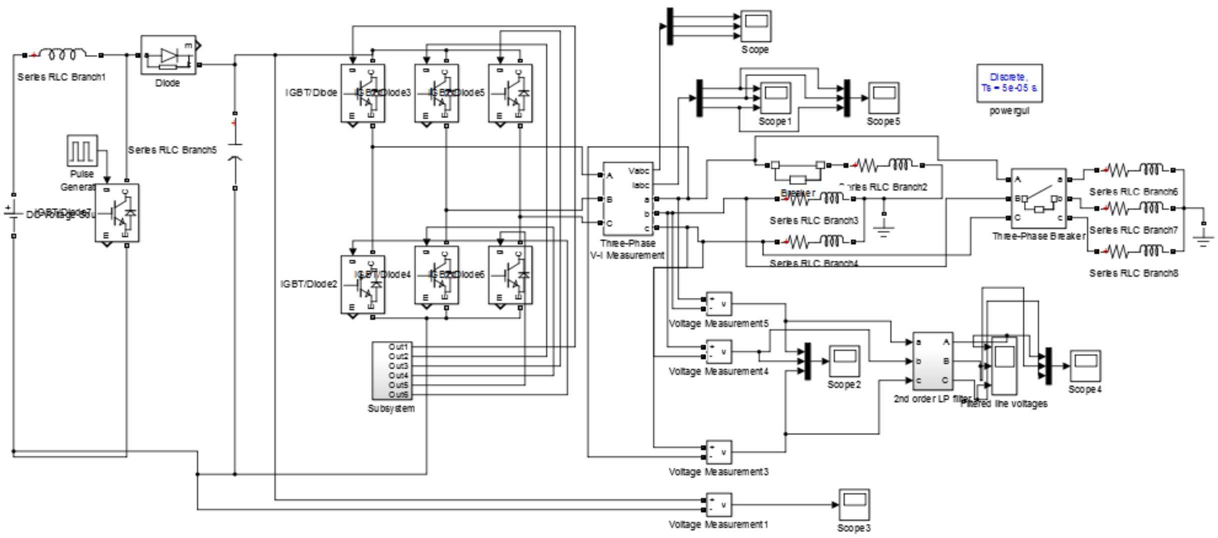


Fig: 3. Simulated circuit of Two-stage Grid-interfaced SPV generating system

4.1 SIMULATED BEHAVIOR UNDER LINEAR LOAD CONDITIONS

A linear load of 25 kW, 0.8 lagging power factor is connected to the proposed system. Performance of the system for a period of 0.35s to 0.5s is shown in Fig. 3. From 0.35s to 0.4s, the load is connected and the load power is more than the power supplied by the PV array so the extra power needed is being supplied by the grid. At 0.4s, one phase of the load is disconnected, this causes the load power to decrease, as a result net power required by load becomes less than the power supplied by the PV array. The surplus power is fed to the ac mains as it is evident from the figure that the phase of the grid current is changed. Under all operating conditions the grid currents are maintained balanced and at unity power factor. The dc link voltage of VSC is also regulated to a constant value.

Using MATLAB Simulink and SPS toolboxes, a two-stage grid-interfaced SPV energy conversion system using three-leg VSC is designed and modeled. The design parameters for the simulated system are given in the Fig.3-4. Under various operating conditions, the performance of the system is simulated. The proposed SPV energy system performance is depicted in the terms of solar PV array voltages $v_{pv,}$ PV array current i_{pv}, PCC voltages v_s , grid currents i_s, Load currents i_{Load}, VSC currents i_{VSC} , and dc-link voltage $v_{dc.}$ For different Operating conditions results are presented.

4.2 SIMULATED BEHAVIOR UNDER NONLINEAR LOAD CONDITIONS

In this case, a three-phase nonlinear load of 20 kW is connected at PCC terminals. Performance of the system for a period of 0.35s to 0.5s is shown in Fig.4. From 0.35s to 0.4s, a load is connected and the load power is less than the power generated by the PV panels, so the extra power is being fed to the grid. Although the load is nonlinear, the grid currents are maintained sinusoidal with current THD (Total Harmonic Distortion) within limit. At 0.4s, one phase of the load is disconnected. This causes the load power to decrease and the load currents become unbalanced in nature.

The effective load after disconnection of phase-c is a single-phase diode bridge rectifier connected between line to line of ac supply system. The load currents after disconnection seem linear as the inductor on the dc side is not sufficient to keep constant current after load disconnection. Under these operating conditions, the grid currents are maintained balanced and at unity power factor w.r.t. grid voltages. The power sharing between the load and ac mains are smooth even at sudden load changes. The transient response of the system is also observed fast and smooth. The electric power grid is in many ways also a battery, without the need for maintenance or replacements, and with much better efficiency rates**.** In other words, more electricity (and more money) goes to waste with conventional battery systems. Additional perks of being grid-tied include access to backup power from the utility grid (in case your solar system stop generating electricity for one reason or another). At the same time you help to mitigate the utility company`s peak load. As a result, the efficiency of our electrical system as a whole goes up.

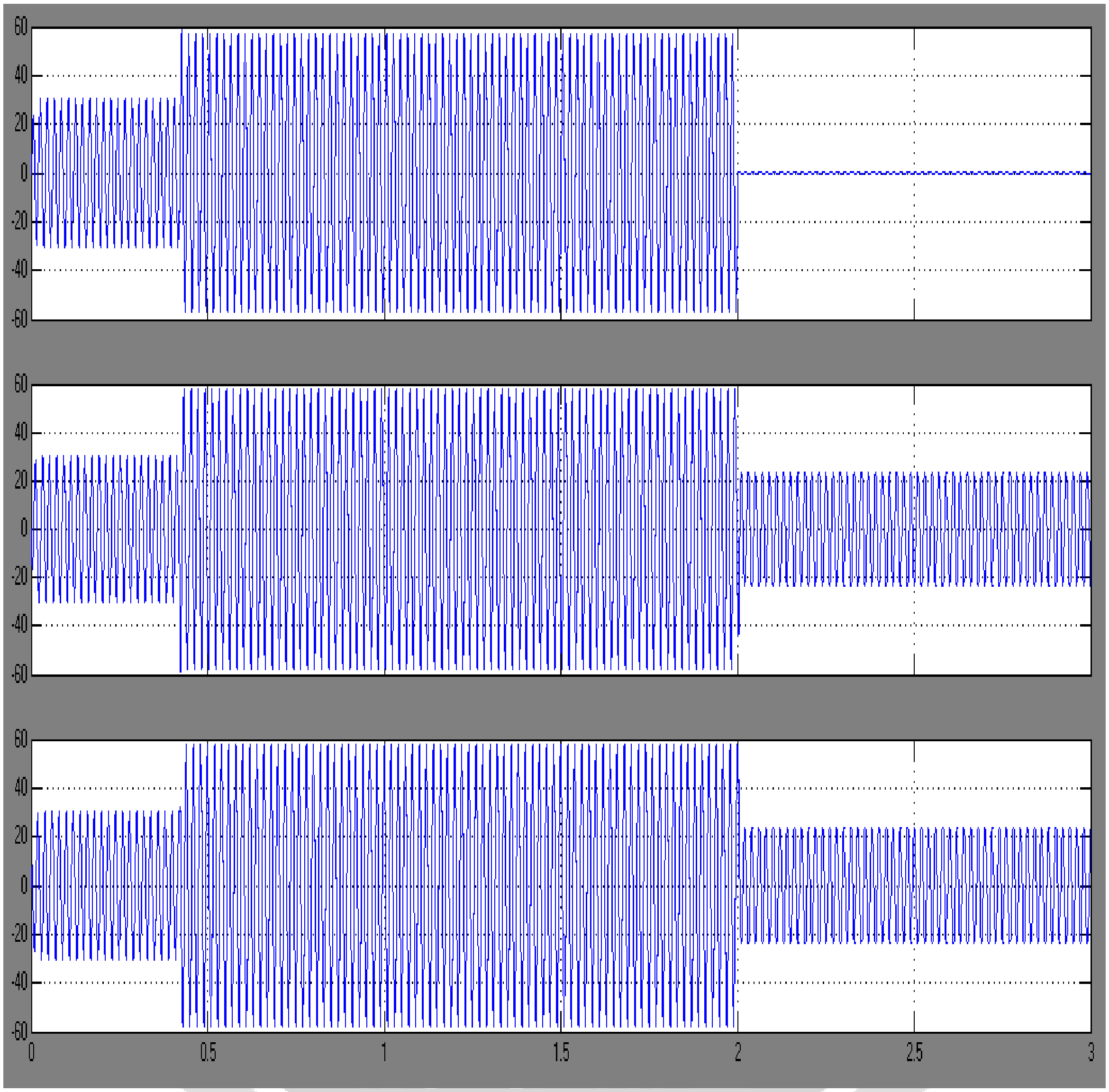


Fig: 4. Simulated results of Two-stage Grid-interfaced SPV generating System

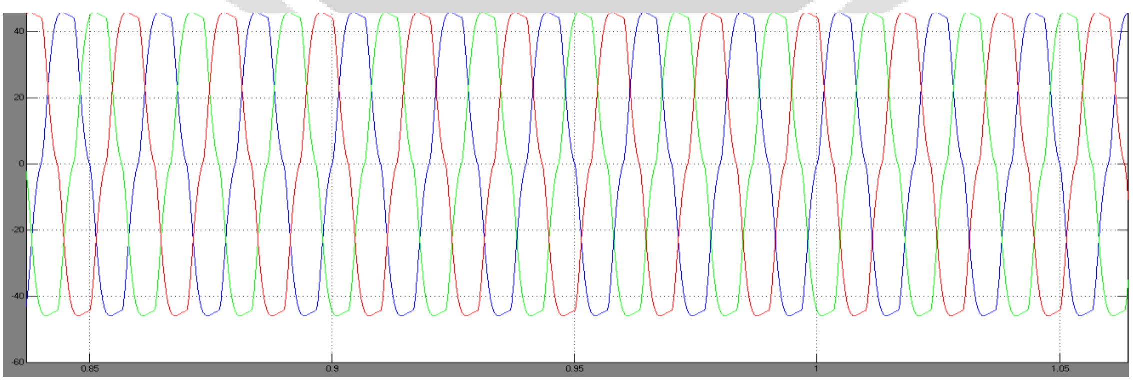


Fig: 5. Simulated results of Two-stage Grid-interfaced SPV generating System

4.3 EXTENSION CIRCUIT AND RESULTS

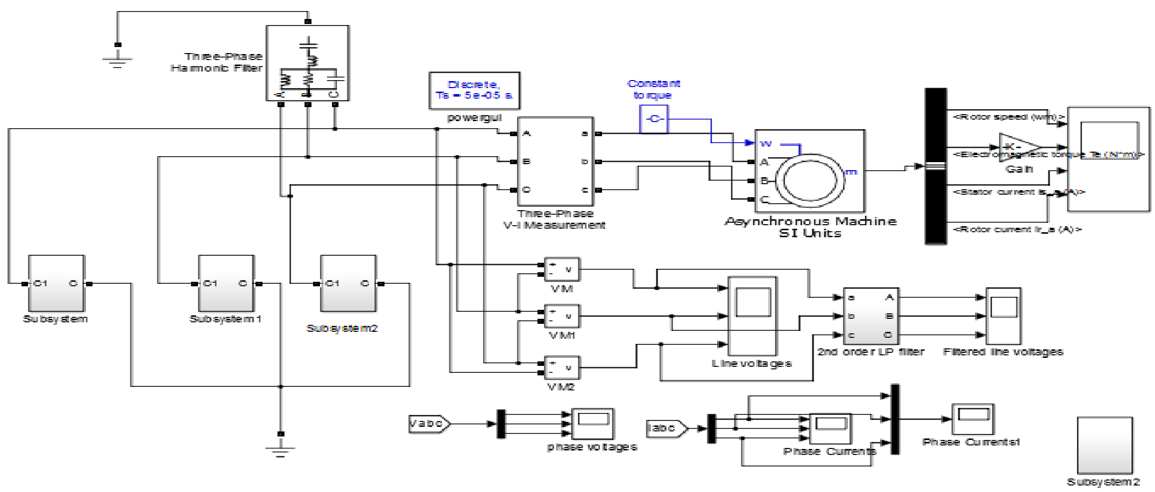


Fig: 6.Simulated circuit of AC Dynamic load control from solar energy by using phase-in position control technique

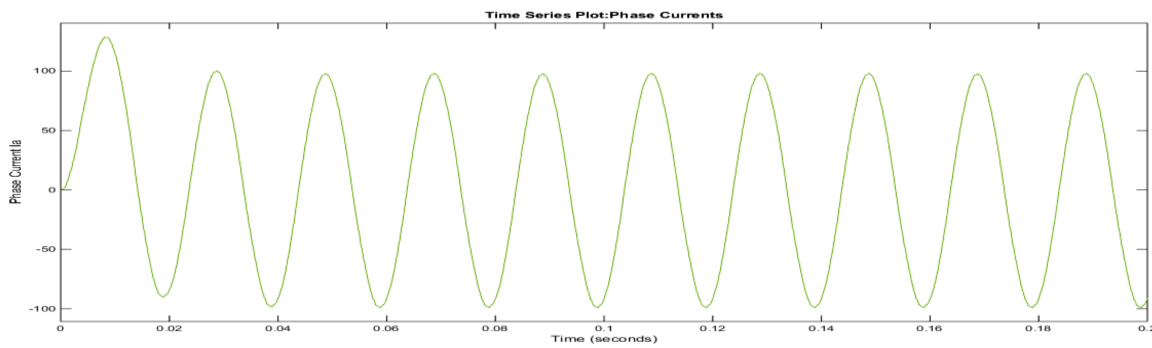
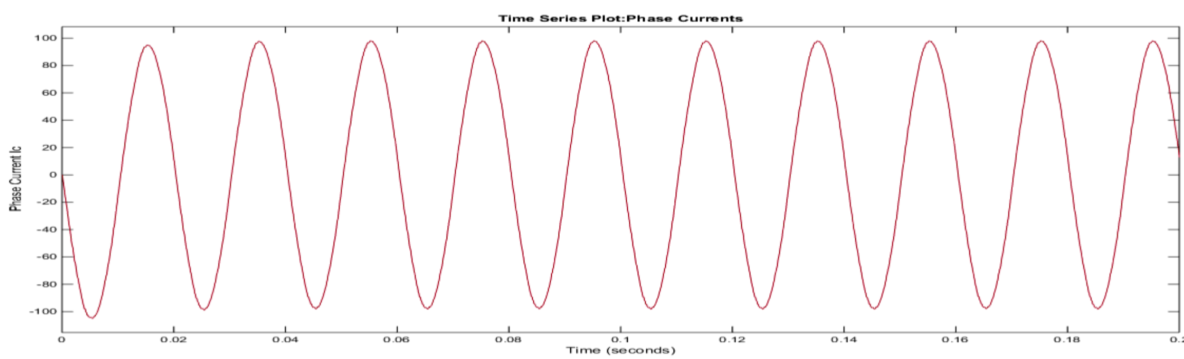


Fig-7:.Simulated performances of AC Dynamic load control from Solar Energy by using Phase-In Position control technique



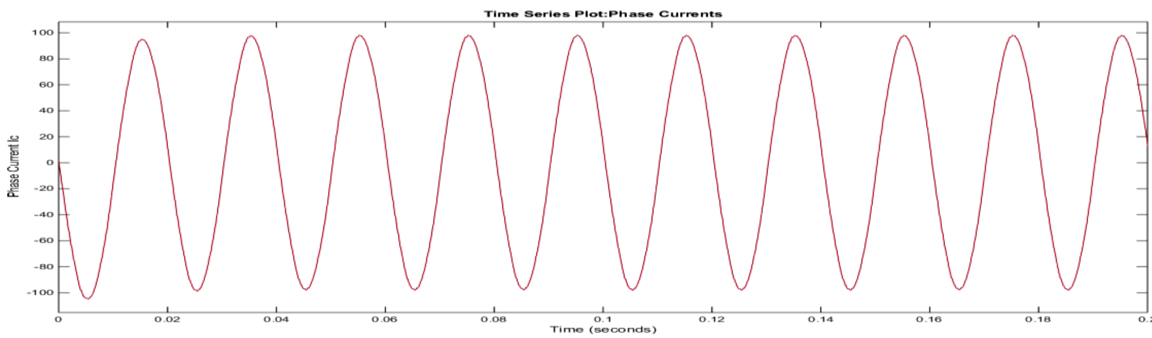


Fig:8 (a).Plot of Phase Currents VS Time(seconds)

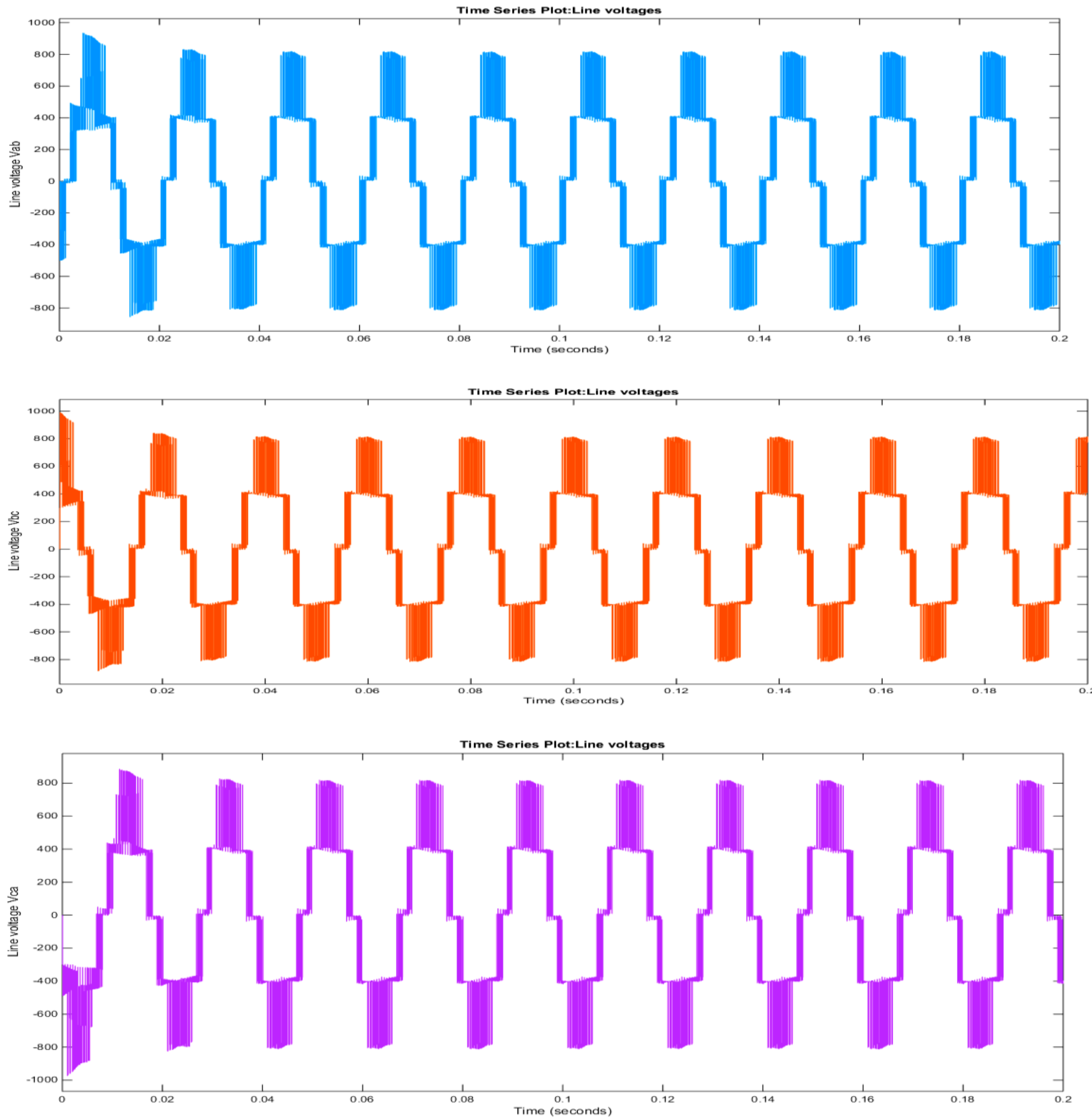


Fig-9 .Plot of Line voltages VS Time(seconds)

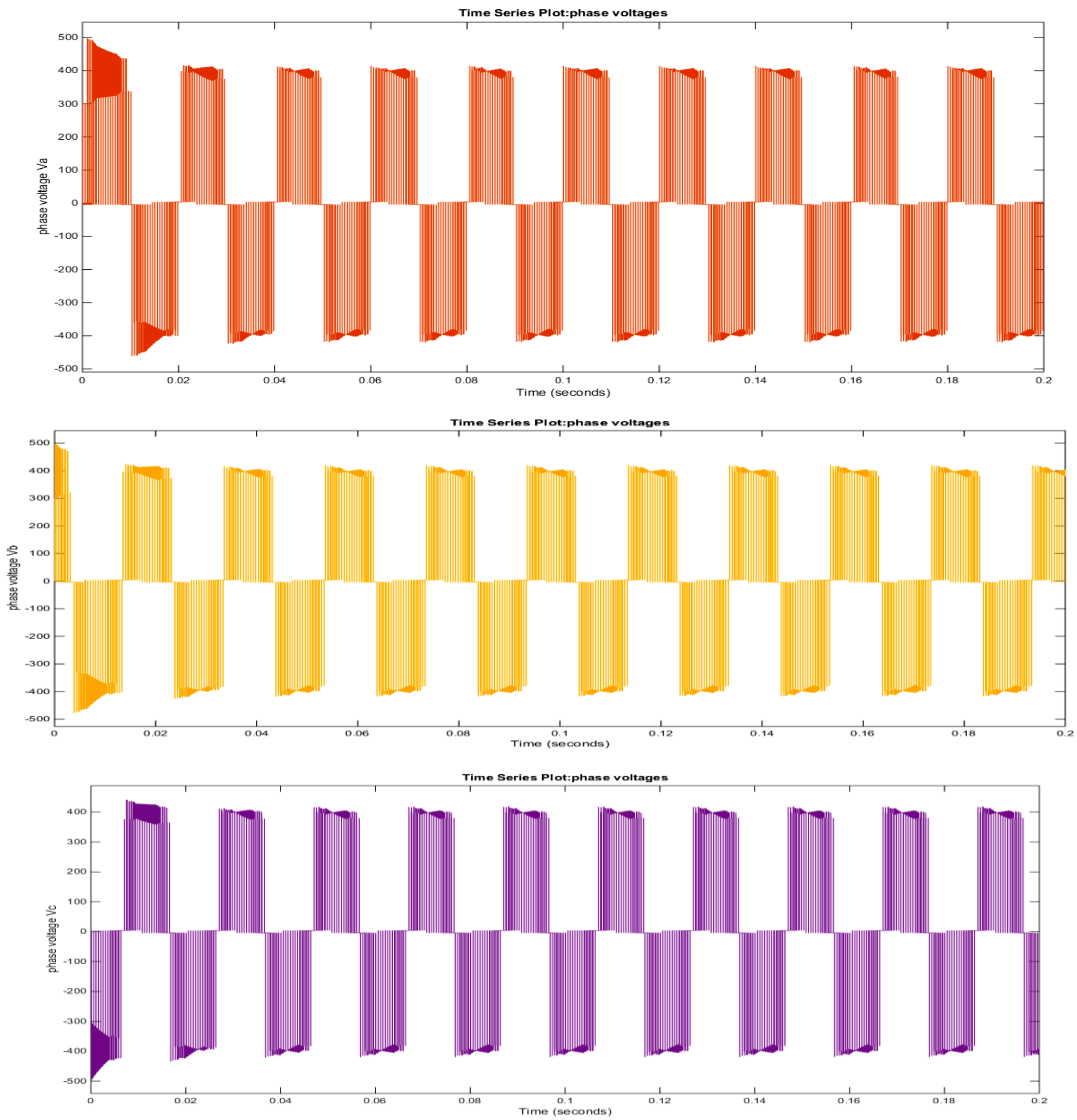


Fig:**10**. Plot of Phase Voltages VS Time(seconds)

5. CONCLUSIONS

The design, control and simulation of multifunctional, two-stage, three- Phase SPV energy conversion system have been carried out using an control algorithm based on ANF. The ANF has been used for extraction of fundamental part of load current. The reference grid currents are then estimated using all load currents, PV contribution and loss component of VSC, which are further used to generate the switching pulses for VSC. The performance of the system has been demonstrated for harmonics elimination, compensation of reactive power, load balancing and power factor correction. An InCA technique has been used for the electrical MPPT of SPV panels. The performance of the two-stage, three-phase grid-interfaced SPV energy system has been found satisfactory under different dynamics and steady state operating conditions. The THD of grid currents is found well under IEEE-519 standard. A wide range of simulation results has been shown to prove the feasibility of the control approach. Based on our calculations we recommend the medium system. We chose the medium system because it meets the power requirements needed to power everything in the cabin so long as the oven and water heater are replaced. This is the most cost effective solution. However, if the capital is not available for new appliances the small system would be sufficient for powering the small appliances and lighting as well as give an educational model. Also, the small system could be upgraded to a larger system at some point in the future. The Pros and cons of the MPPT algorithms It is noted that perturb and observe and incremental conductance is superior to all other MPPT algorithms. Though fuzzy and neural networks are developing in the present days, the efficiency remains high in perturb and observe and Incremental conductance methods. The converters such as buck, boost, buck-boost, buck converters are being used in MPPT systems. PWM inverters are used for grid interconnection and standalone AC loads. The selection of converters is based on the load connected to the system. The ripples in dc voltage and current also influence the selection of converters. With the above mentioned converters and MPPT algorithms, solar panels can be configured to feed any kind of load. The vast development in improving efficiency of MPPT algorithms can encourage domestic generation of power using solar panels.

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