International Journal of Emerging Technology in Computer Science & Electronics (IJETCSE)
ISSN: 0976-1353 Volume 22 Issue 1 – MAY 2016.

A CONSTANT EFFICIENT POWER CONTROL IN SMART POWER GRIDS

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***Abstract*--This paper publics was detailed design and modeling of grid integrated with the Photovoltaic Solar Power Generator. As the Photovoltaic System uses the solar energy as one of the renewable energies for the electrical energy production has an enormous potential. The PV system is developing very rapidly as compared to its counterparts of the renewable energies. The DC voltage generated by the PV system is boosted by the DC-DC Boost converter. The utility grid is incorporated with the PV Solar Power Generator through the 3-Phase PWM DC-AC inverter, whose control is provided by a constant current controller. This controller uses a 3-Phase, phase locked loop (PLL) for tracking the phase angle of the utility grid and reacts fast enough to the changes in load or grid connection states, as a result, it seems to be efficient in supplying to load the constant voltage without phase jump. The complete mathematical model for the grid connected PV system is developed and simulated. The results verify that the proposed system is proficient to supply the local loads.**

Index key: DC-DC Boost converter, PV, DC-AC inverter, PLL

I. INTRODUCTION

Renewable energy is the energy which comes from natural resources such as sunlight, wind, rain, tides and geothermal heat. These resources are renewable and can be naturally replenished. Therefore, for all practical purposes, these resources can be considered to be inexhaustible, unlike dwindling conventional fossil fuels. The global energy crunch has provided a renewed impetus to the growth and development of Clean and Renewable Energy sources.

Apart from the rapidly decreasing reserves of fossil fuels in the world, another major factor working against fossil fuels is the pollution associated with their combustion. Contrastingly, renewable energy sources are known to be much cleaner and produce energy without the harmful effects of pollution unlike their conventional counterparts.

The tapping of solar energy owes its origins to the British astronomer John Herschel who famously used a solar thermal collector box to cook food during an expedition to Africa. Solar energy can be utilized in two major ways. Firstly, the captured heat can be used as solar thermal energy, with applications in space heating. Another alternative is the conversion of incident solar radiation to electrical energy, which is the most usable form of energy. This can be achieved with the help of solar photovoltaic cells or with concentrating solar power plants.

II. LITERATURE REVIEW

The continuous increase in the electrical energy with the clean environment needs the decentralized renewable energy production. The increasing energy consumption may overload the distribution grid as well as power station and may cause the negative impact on power availability, security and quality. The only solution to overcome this problem is integrating the utility grid with the renewable energy systems like solar, wind or hydro. The grid can be connected to the renewable energy system as per the availability of renewable energy sources. Recently the solar and wind power generation systems are getting more attention because solar energy is abundantly available, more efficient and more environment friendly as compared to the conventional power generation systems such as fossil fuel, coal or nuclear.The PV systems are still very expensive because of higher manufacturing cost of the PV panels, but the energy that drives them -the light from the sun- is free, available almost everywhere and will still be present or millions of years, even all non-renewable energy sources might be depleted. One of the major advantages of PV technology is that it has no moving parts. Therefore, the PV system is very robust, it has a long lifetime and low maintenance requirements. And, most importantly, it is one solution that offers environmentally friendly power generation. The disadvantage of the PV system is that it can supply the load only in sunny days. Therefore, for improving the performance and supplying the power in all day, it is necessary to hybrid the PV system into another power generation systems or to integrate with the utility grid. The integration of the PV system with the utility grid requires the PWM voltage source converter for interfacing the utility grid and results some interface issues. A current- controlled power conditioning system has been developed and tested. This prototype sources 20 kW of power from a photovoltaic array with a maximum power point tracking control. The disadvantage of this system is the need of high bandwidth current measurement transducers (dc to several times the switching frequency), and the need for relatively high precision in the reference signal generation. Power electronic systems can also be used for controlling the solar inverter for interfacing the Solar Power Generation system with the grid.

III. SOLAR PHOTOVOLTAIC SYSTEM

The PV system normally uses solar panels, which is in arrays. There are many types of PV system, starting from a cell up to arrays.

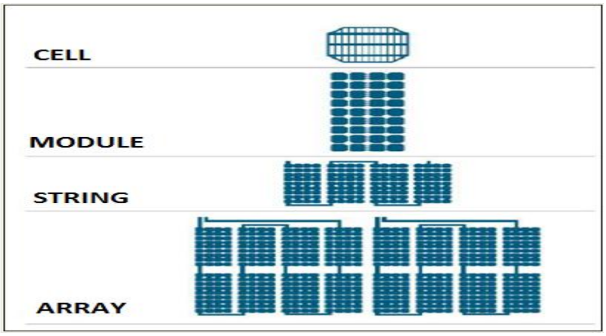

Figure 1: The PV from cell to module

Photovoltaic's is a technology that generates direct current (DC) electrical power measured in Watts (W) or kilo Watts (kW) from semiconductors when they are illuminated by photons. As long as light is shining on the solar cell, it generates electrical power. When the light stops, then the electricity also stops. Solar cells never need recharging like a battery. Some have been in continuous outdoor operation on Earth or in space for over 30 years.

PHOTOVOLTAIC CELL

A photovoltaic cell or photoelectric cell is a semiconductor device that converts light to electrical energy by photovoltaic effect. If the energy of photon of light is greater than the band gap then the electron is emitted and the flow of electrons creates current.

PV MODULE

Usually a number of PV modules are arranged in series and parallel to meet the energy requirements. PV modules of different sizes are commercially available (generally sized from 60W to 170W). For example, a typical small scale desalination plant requires a few thousand watts of power.

3PV MODELING

A PV array consists of several photovoltaic cells in series and parallel connections. Series connections are responsible for increasing the voltage of the module whereas the parallel connection is responsible for increasing the current in the array.

IV. CONVERTERS

Converters serve as an interface between the source and load as shown in Figure 2. It convert one type or level of a voltage or current waveform to another and classified by the relationship between input signal and output signal.

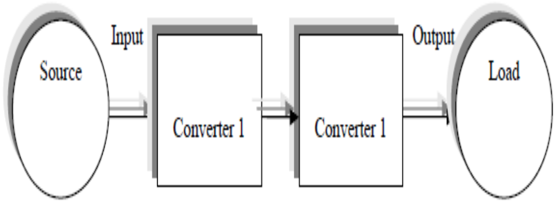

Figure 2: Two converters are used in a multistep process.

Converter circuits capable to operate in different mode, depending on electronic circuit used, high frequency switching semiconductor and applied control system. Thus, converters are capable to operate in multiple stages in a process with different type of converter involve.

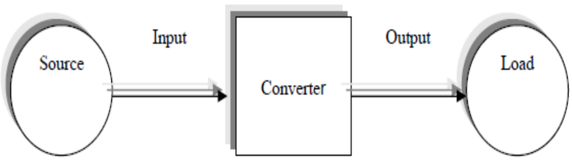

Figure 3: Basic converter system General overview of DC-DC converter

DC-DC converters are used to convert the unregulated DC input to a controlled DC output at a desire voltage output. It classified as a regulator as it useful when a load requires a specified dc voltage or current but the source is at a different or unregulated dc value. DC-DC converters include buck converters, boost converters, buck-boost converters, Cuk converters and full-bridge converters. The DC-DC converter is considered as the heart of the power supply, thus it will affect the overall performance of the power supply system. Switched DC-DC converters offer a method to increase or decrease an output voltage depend on application or system. DC-DC converters may be operated in two modes, according to the current in its main magnetic component, inductor. The current fluctuates but never goes down to zero is called Continuous Conduction Mode (CCM) and Discontinuous Conduction Mode (DCM) occur when the current fluctuates during the cycle, going down to zero at or before the end of each cycle.

DC-DC converter switching

There are two switching condition that need to be applied, that is when ON and OFF as shown in Figure . When ON, Output voltage is the same as the input voltage and the voltage across the switch is 0V. When OFF, Output voltage = 0V and current through the switch = 0A. In ideal condition, power loss = 0W since output power equal to input power shown in figure 4.

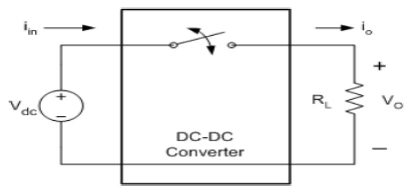

Figure 4: Switching of DC-DC converter.

MAXIMUM POWER POINT TRACKING ALGORITHMS

An overview of Maximum Power Point Tracking

A typical solar panel converts only 30 to 40 percent of the incident solar irradiation into electrical energy. Maximum power point tracking technique is used to improve the efficiency of the solar panel. According to Maximum Power Transfer theorem, the power output of a circuit is maximum when the The venin impedance of the circuit (source impedance) matches with the load impedance. Hence our problem of tracking the maximum power point reduces to an impedance matching problem. In the source side we are using a boost convertor connected to a solar panel in order to enhance the output voltage so that it can be used for different applications like motor load. By changing the duty cycle of the boost converter appropriately we can match the source impedance with that of the load impedance.

Perturb & Observe

Perturb & Observe (P&O) is the simplest method. In this we use only one sensor, that is the voltage sensor, to sense the PV array voltage and so the cost of implementation is less and hence easy to implement. The time complexity of this algorithm is very less but on reaching very close to the MPP it doesn't stop at the MPP and keeps on perturbing on both the directions. When this happens the algorithm has reached very close to the MPP and we can set an appropriate error limit or can use a wait function which ends up increasing the time complexity of the algorithm. However the method does not take account of the rapid change of irradiation level (due to which MPPT changes) and considers it as a change in MPP due to perturbation and ends up calculating the wrong MPP. To avoid this problem we can use incremental conductance method.

Perturb & Observe Algorithm

The Perturb & Observe algorithm states that when the operating voltage of the PV panel is perturbed by a small increment, if the resulting change in power P is positive, then we are going in the direction of MPP and we keep on perturbing in the same direction. If P is negative, we are going away from the direction of MPP and the sign of perturbation supplied has to be changed.

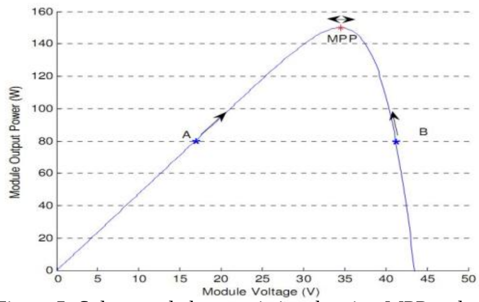

Figure 5: Solar panel characteristics showing MPP and operating points A and B

Therefore, we can move towards the MPP by providing a positive perturbation to the voltage. On the other hand, point B is on the right hand side of the MPP. When we give a positive perturbation, the value of P becomes negative, thus it is imperative to change the direction of perturbation to achieve MPP. The flowchart for the P&O algorithm is shown.

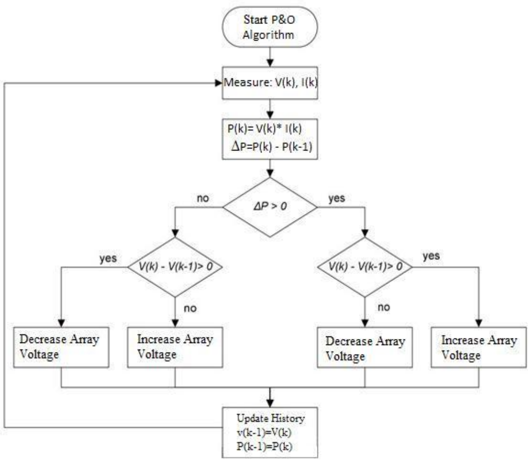

Figure 6: Flowchart of Perturb & Observe algorithm

Limitations of Perturb & Observe algorithm

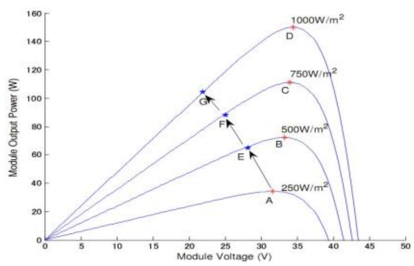

Figure 7: Curve showing wrong tracking of MPP by P&O algorithm under rapidly varying irradiance

In a situation where the irradiance changes rapidly, the MPP also moves on the right hand side of the curve. The algorithm takes it as a change due to perturbation and in the next iteration it changes the direction of perturbation and hence goes away from the MPP as shown in the figure 7.

However, in this algorithm we use only one sensor, that is the voltage sensor, to sense the PV array voltage and so the cost of implementation is less and hence easy to implement. The time complexity of this algorithm is very less but on reaching very close to the MPP it doesn't stop at the MPP and keeps on perturbing in both the directions.

INVERTER

The word 'inverter' in the context of power-electronics denotes a class of power conversion (or power conditioning) circuits that operates from a dc voltage source or a dc current source and converts it into ac voltage or current. The 'inverter' does reverse of what ac- to-dc 'converter' does **(refer to ac to dc converters)**.

Even though input to an inverter circuit is a dc source, it is not uncommon to have this dc derived from an ac source such as utility ac supply. Thus, for example, the primary source of input power may be utility ac voltage supply that is 'converted' to dc by an ac to dc converter and then 'inverted' back to ac using an inverter.

Here, the final ac output may be of a different frequency and magnitude than the input ac of the utility supply.

The nomenclature 'inverter' is sometimes also used for ac to dc converter circuits if the power flow direction is from dc to ac side. However in this lesson, irrespective of power flow direction, 'inverter' is referred as a circuit that operates from a stiff dc source and generates ac output. If the input dc is a voltage source, the inverter is called a voltage source inverter (VSI) .

GRIDINTERFACING INVERTER

To reduce the overall cost of the system the DC link of both hydro and solar power plant is integrated. To feed the AC load or to inject the real power to the utility grid the DC-AC powerconversion is carried out using the grid interfacing bridge inverter.

The phase voltages of the VSI denoted as Vha(t), Vhb(t), and Vhc(t). The phase potentials of the utility grid denoted Vga(t), Vgb(t), and Vgc(t). The currents flowing through the VSI denoted as Iha(t), Ihb(t), and Ihc(t), while the DC-link current and voltage of the solar system are denoted as Idc(t), and Vdc(t) respectively.

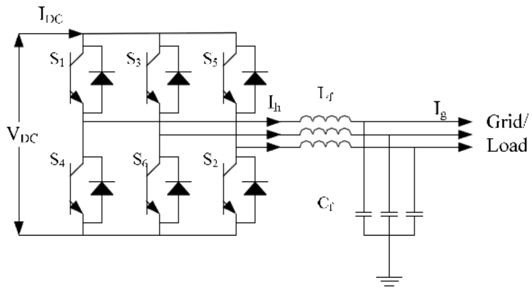

Figure 8: Simplified circuit of the grid interfacing inverter.

BATTERIES

Batteries are often used in PV systems for storing energy produced by the PV array during day time and supplying it to electrical loads as needed (during night time or cloudy weather). Moreover, batteries are also needed in the tracker systems to keep the operation at MPP in order to provide elec-trical loads with stable voltages. Nearly, most of the batteries used in PV systems are deep cycle lead-acid. These bat-teries have thicker lead plates that make them tolerate deep discharges. The thicker the lead plates, the longer the life span. The heavier the battery for a given group size, the thicker the plates and the better the battery will tolerate deep discharges.

All deep cycle batteries are rated in ampere-hour where Ampere-hour (AH) capacity is a quantity of the amount of usable energy it can store at nominal voltage. For example an ampere-hour is one ampere for one hour or 10 A for one-tenth of an hour and so forth. A good charge rate is approximately 10% of the total capacity of the battery per hour (i.e. 200 ampere-hour battery charged at 20A). This will reduce electrolyte loss and damage to the plates. A PV system may have to be sized to store a sufficient amount of power in the batteries to meet power demand during several days of cloudy weather. This is known as "days of autonomy".

BATTERY CHARGING

Batteries for PV Systems Stand-alone PV energy system requires storage to meet the energy demand during periods of low solar irradiation and nighttime. Several types of batteries are available such as the lead acid, nickel–cadmium, lithium, zinc bromide, zinc chloride, sodium sulfur, nickel–hydrogen, redox, and vanadium batteries. The provision of cost-effective electrical energy storage remains one of the

major challenges for the development of improved PV power systems. Typically, lead-acid batteries are used to guarantee several hours to a few days of energy storage. Their reasonable cost and general availability has resulted in the widespread application of lead-acid batteries for remote area power supplies despite their limited lifetime compared to other system components. Lead-acid batteries can be deep or shallow cycling gelled batteries, batteries with captive or liquid electrolyte, sealed and non-sealed batteries etc. Sealed batteries are valve regulated to permit evolution of excess hydrogen gas (although catalytic converters are used to convert
as much evolved hydrogen and oxygen back to water as possible). Sealed batteries need less maintenance. The following factors are considered in the selection of batteries.

V. PV APPLICATIONS

- Deep discharge (70–80% depth of discharge).
- Low charging/discharging current.
- Long duration charge (slow) and discharge (long duty cycle).
- Irregular and varying charge/discharge.
- Low self discharge.
- Long life time.
- Less maintenance requirement.
- High energy storage efficiency.
- Low cost.

Battery manufacturers specify the nominal number of complete charge and discharge cycles as a function of the depth-of-discharge (DOD). While this information can be used reliably to predict the lifetime of lead-acid batteries in conventional applications, such as uninterruptable power supplies or electric vehicles, it usually results in an overestimation of the useful life of the battery bank in renewable energy systems. Two of the main factors that have been identified as limiting criteria for the cycle life of batteries in PV power systems are incomplete charging and prolonged operation at a low state-of-charge (SOC). The objective of improved battery control strategies is to extend the lifetime of lead-acid batteries to achieve a typical

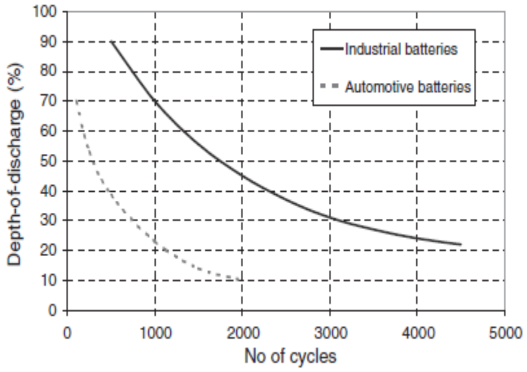

Figure .9. Nominal number of battery cycles vs DOD.

number of cycles shown in Figure. If this is achieved, an optimum solution for the required storage capacity and the maximum DOD of the battery can be found by referring to manufacturer's information. Increasing the capacity will reduce the typical DOD and therefore prolong the battery lifetime. Conversely, it may be more economic to replace a smaller battery bank more frequently.

POWER CONVERTERS FOR WIND ENERGY CONVERSION SYSTEM

The technology of power electronic interfaces for variable speed wind turbines is focused on the following points: Development of high efficiency/high quality voltage source AC/DC/AC converter for a main connection of variable wind turbines, operating with either a permanent magnet, a synchronous or an asynchronous generator. Operation at a power factor around one with higher harmonic voltage distortion less than international standards. The power quality of the electrical output of the wind farms may be improved by the use of advanced static var compensators STATCOM or active power filters using power semiconductors like IGBTs, IGCTs, or GTOs .These kind of power conditioning systems are a new emerging family of FACTS (flexible AC transmission system)converters, which allow improved utilization of the power network. These systems will allow wind farms to reduce voltage drops and electrical losses in the network with out the possibility of transient over voltage at is landing due to self-excitation of wind generators. More over, power conditioning systems equipment with different control algorithm can be used to control the network voltage, which will fluctuate in response to the wind farm output if the distribution network is weak.

For large power wind turbine applications where it is necessary to increase the voltage level of the semiconductor of the power electronic interface, multilevel power converter technology is emerging as a new breed of power converter options for high-power applications. The general structure of the multilevel converter is to synthesize sinusoidal voltage from several levels of voltages, typically obtained from capacitor voltage sources. Additionally, these converters have better performance and controllability because they use more than two voltage levels.

VI. CONTROL ALGORITHMS

A variable pitch and speed wind turbine is a very complexion-lineal system. The control problem is more difficult to solve because some performance objectives, such as maximum power captured, minimum mechanical stress, constant speed, and power constant counteract each other. To solve this problem, A Fuzzy Logic control has recently been proposed. The Fuzzy Logic controller implements a rule-based structure that can be easily adapted in order to optimize performance control objectives and has been widely used in introduction motor control applications. In, a Fuzzy Logic controller is used to optimize the power captured using maximum power tracking algorithms. Other original structures have been proposed in. The structure implements different control strategies depending on the rotor speed and generates a current torque control action. Presently, more complex control structures are being researched.

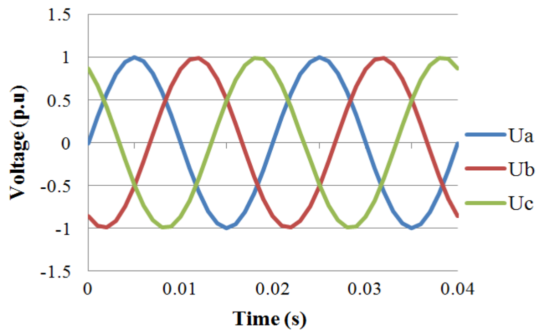

Figure 10. Grid Voltage waveform

VII. MODELING OF SYSTEM

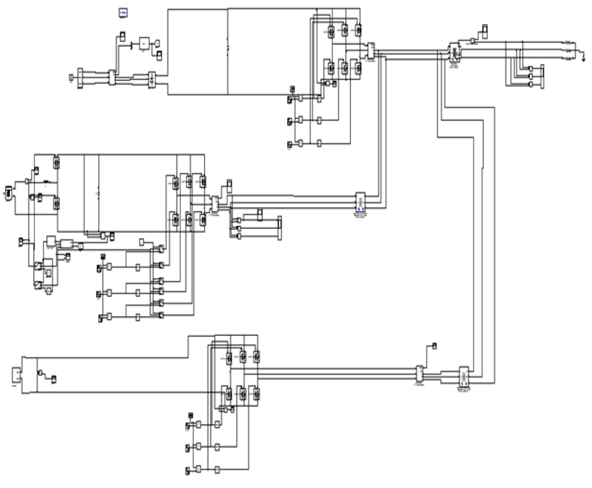

Figure 11: Overall Simulation Model

VIII. SIMULATION RESULTS

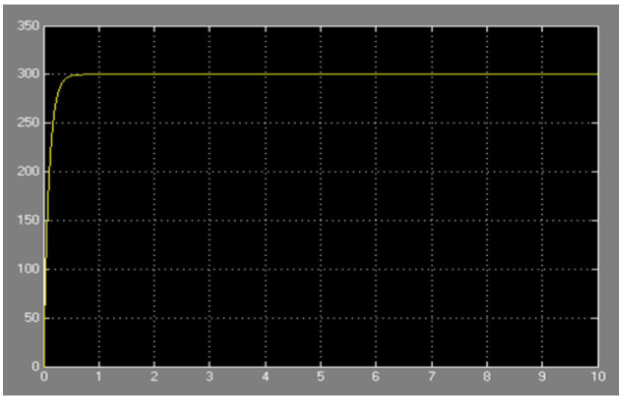

Figure 12: Scope of PV Module

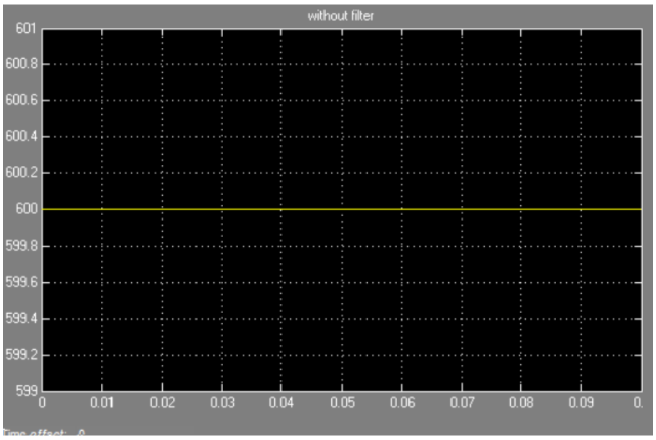

Figure 13: Scope of Boost Converter

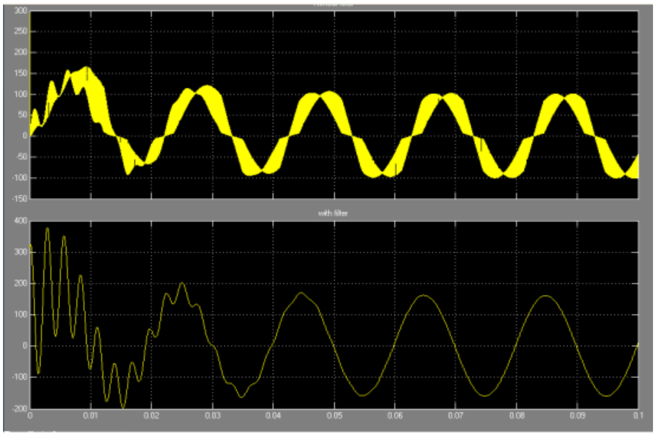

Figure 14: Scope of Overall System

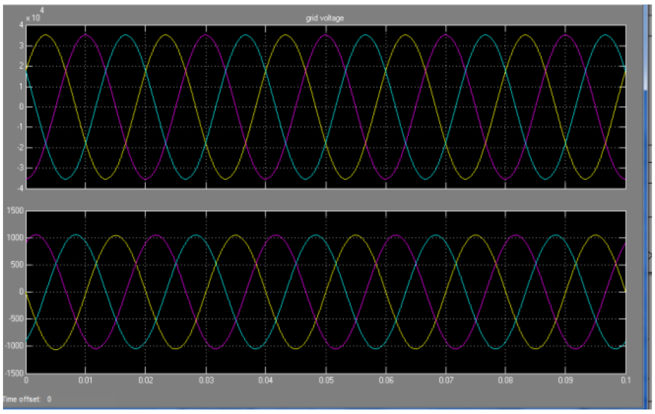

Figure 15: Grid Output Time Vs Voltage

IX. CONCLUSION

The proposed CNSPG problem is an original formulation which may be viewed as a preliminary attempt to model and control the exchange of power in a network of micro grids and grids considered as a system of systems. Its main originality is the use and the exchange of information and forecast of energy production and consumption on the whole set of micro grids. The main limitation of the approach is the hypothesis to know in real time the status of all storage devices in a centralized way. In the future, it is reasonable to assume that power networks will become more similar to an Internet network where grids may be on-line or not, and will be controlled by decentralized autonomous devices. In addition, even with the presence of a centralized controller, the communication system can operate at a much slower speed: routine status information to the central controller will most likely be updated only once every several minutes. Another limitation of the current work is the fact that no lower and upper bounds are introduced for the control and state variables, as it may be required by the infrastructural elements. The adequacy of their values, as defined by the control law, could be obtained by an appropriate tuning of the parameters in the cost function. Thus, new research efforts should be devoted to model the information flow in the network, and the related effects of delays in data acquisition, both in a centralized and in a decentralized decision making approach.

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