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A RECONFIGURABLE SOLAR CONVERTER: A SINGLE-STAGE POWER CONVERSION PV-BATTERY SYSTEM

Abdul Kalam[1], Mr. Zafar Khan[2]

[1] *Student, M.Tech, Department of Electrical & Electronics Engineering, Al-falahUniversity, (India)*

[2]*Assistant Prof., Department of Electrical & Electronics Engineering, Al-falahUniversity, (India)*

ABSTRACT

In This paper introduces a new converter called reconfigurable solar converter (RSC) for photovoltaic (PV)-battery application, particularly utility-scale PV-battery application. The main concept of the new converter is to use a single-stage three phase grid-tie solar PV converter to perform dc/ac and dc/dc operations. This converter solution is appealing for PV-battery application, because it minimizes the number of conversion stages, thereby improving efficiency and reducing cost, weight, and volume. In this paper, a combination of analysis and experimental tests is used to demonstrate the attractive performance characteristics of the proposed RSC.

Keywords: RSC, Solar Energy, PV Controller, Battery System, MATLAB, Reactive Power.

I. INTRODUCTION

Normally in India, Grid system is very traditional (old) one. So the reliability and efficiency is low. Power Gird system is Generation Transmission and Distribution. It is like one way communication. It inter-links one to one. This may lead to affect the system, when the fault occurs in any of the system line. Power transmission is limited. Information technology between the power systems is very poor. We can't create a flexible electric power system because of absences of intelligent and co-operating resources. This poor power system will leads to more power losses. And we can't penetrate non-traditional power generation such as Renewable energy system into our power system. This paper presents that the emerging trend of smart grids. Smart grid is nothing but normal grid but it inter link grid with many micro grid. And also it is like two way communication. How it is possible to get a two way communication? This is possible by connecting more number of micro grids with it. So, now clear that we are using more number of generating unit, we have more reliable control and information technology is used to improve the grid's efficiency. In the traditional grid has low efficiency and one way communication. Generating stations are very minimum and long transmission is lead to more power losses. Normal dc source can be boosted and inverted for AC load. Many drawbacks are discussed in above paragraph itself. So let us see the existing technique which is under

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process in power system. A DC GRID consisting of a solar panel as an energy source, a storage unit, and some dc and local ac loads. The solar panel is associated with a series blocking diode *DS* to avoid reverse power conduction. As the dynamic behaviors of all the different units of GRID are not uniform, they are interfaced to a common dc bus using power electronic converters. In this the GRID has three different power converter stages are used to interface the renewable energy source, energy storage unit, and the local ac loads in the system to the dc bus.

II. SOLAR ENERGY

Photovoltaic cell is a device used to convert solar energy into electrical energy. They generate electricity when they absorb the sunlight .Photovoltaic cells are made of semiconductor devices and when these absorb photons present in the sunlight free electrical charges are generated which can be collected on the contacts present on the surfaces of the semiconductors. Photovoltaic cells are not like heat engines, so do not require to operate at high temperature, they usually operate at room temperature as they are adapted to the weak energy flux of solar radiation. There theoretical efficiency is of the order of 45%. Their efficiencies decrease very rapidly with the increase in temperature. Photovoltaic cells are famously known for power generation in space craft in which the silicon solar cells is most widely developed. The silicon cell has a crystal of silicon on which the doping material is concentrated to form a semiconductor. The efficiency of the photo cell is defined as a power developed per unit area of array divided by solar energy flux in the free space.

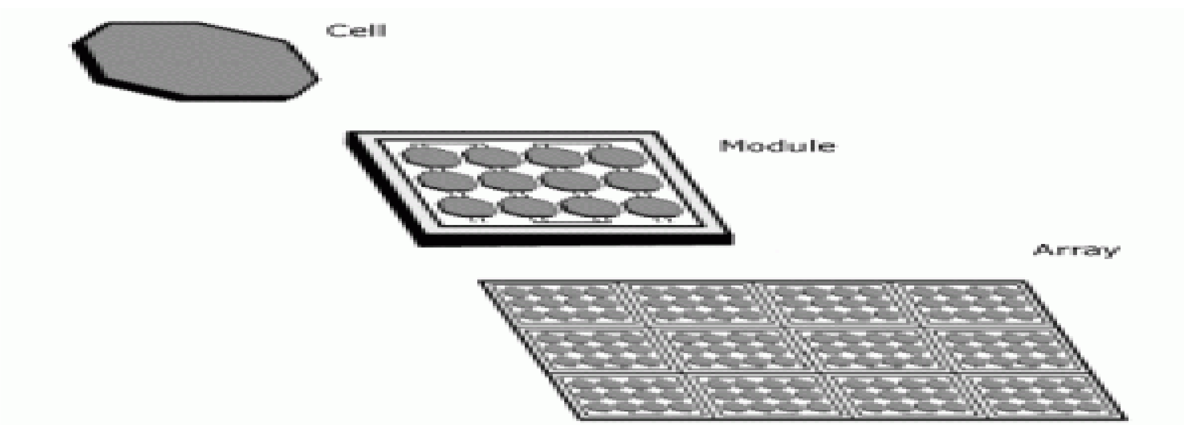

Fig 1: PV Module Array

Photo- current of the module:

$$I_{ph}= [I_{scr} + K_i(T-298)] * \lambda/1000$$

Reverse saturation current of the module:

$$I_{rs} = I_{scr} / [\exp (qV_{oc}/N_S KAT)-1]$$

Saturation current module I_o;

$$I_0 = I_{rs} \left[\frac{T}{T_r}\right]^3 \exp\left[\frac{qE}{BK} \left\{\frac{1}{T_r} - \frac{1}{T}\right\}\right]$$

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III. RSC SYSTEM

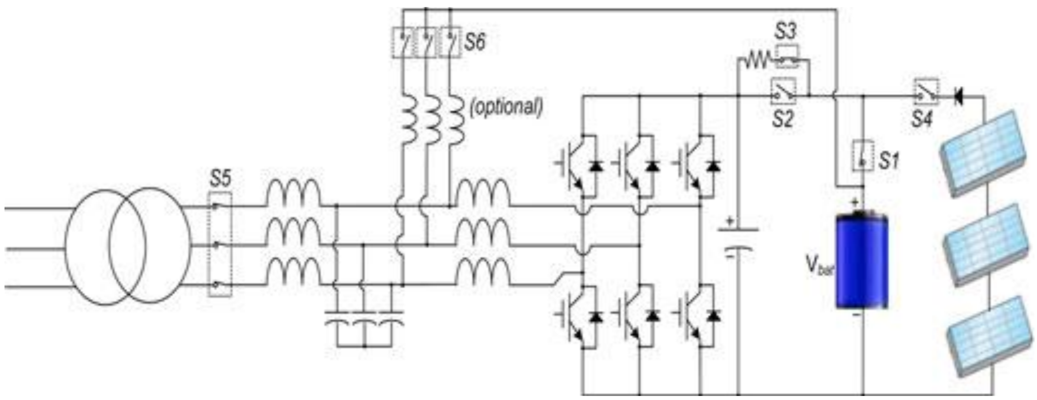

Fig. 2 The schematic of the proposed RSC

The RSC has some modifications to the conventional three-phase PV inverter system. These modifications allow the RSC to include the charging function in the conventional threephase PV inverter system. Assuming that the conventional utility-scale PV inverter system consists of a three-phase voltage source converter and its associated components, the RSC requires additional cables and mechanical switches, as shown in Fig. Optional inductors are included if the ac filter inductance is not enough for the charging purpose.

IV. OPERATION MODES OF THE RSC

All possible operation modes for the RSC are presented in Fig. 3. In Mode 1, the PV is directly connected to the grid through a dc/ac operation of the converter with possibility of maximum power point tracking (MPPT) control and the *S*1 and *S*6 switches remain open. In Mode 2, the battery is charged with the PV panels through the dc/dc operation of the converter by closing the *S*6 switch and opening the *S*5 switch. In this mode, the MPPT function is performed; therefore, maximum power is generated from PV. There is another mode that both the PV andbattery provide the power to the grid by closing the *S*1 switch. This operation is shown as Mode 3. In this mode, the dc-link voltage that is the same as the PV voltage is enforced by the battery voltage; therefore, MPPT control is not possible. Mode 4 represents an operation mode that the energy stored in the battery is delivered to the grid. There is another mode, Mode 5 that the battery is charged from the grid. This mode is not shown in Fig. 3.

1. Control of the RSC in the DC/AC Operation Modes (Modes 1, 3, 4, and 5)

The dc/ac operation of the RSC is utilized for deliveringpower from PV to grid, battery to grid, PV and battery to grid, and grid to battery. The RSC performs the MPPT algorithm todeliver maximum power from the PV to the grid. Like the conventionalPV inverter control, the RSC control is implementedin the synchronous reference frame. The synchronous referenceframe proportional-integral current control is employed. In a reference frame rotating synchronously with the fundamental excitation, the fundamental excitation signals are transformed into dc signals. As a result, the current regulator forming the innermost loop of the control system is able to regulate ac currents over a wide frequency range with high bandwidth and zero steady-state error. For the pulse width modulation (PWM) scheme, the conventional space vector PWM scheme is utilized presents the overall control block diagram of the RSCin the dc/ac operation. For the dc/ac operation with the battery, the RSC control should be coordinated with the battery management system (BMS)

2. **Control of the RSC in the DC/DC Operation Mode (Mode 2)**

The dc/dc operation of the RSC is also utilized for deliveringthe maximum power from the PV to the battery. The RSC inthe dc/dc operation is a boost converter that controls the currentflowing into the battery. In this research, Li-ion batteryhas been selected for the PV-battery systems. Li-ion batteriesrequire a constant current, constant voltage type of charging algorithm.In other words, a Li-ion battery should be charged ata set current level until it reaches its final voltage. At the finalvoltage, the charging process should switch over to the constantvoltage mode, and provide the current necessary to holdthe battery at this final voltage. Thus, the dc/dc converter performing performing charging process must be capable of providing stable control for maintaining either current or voltage at a constant value, depending on the state of the battery. Typically, a few percent capacity losses happen by not performing constant voltage charging. However, it is not uncommon only to use constant current charging to simplify the charging control and process.The latter has been used to charge the battery. Therefore, from the control point of view, it is just sufficient to control only the inductor current. Like the dc/ac operation, the RSC performs the MPPT algorithm to deliver maximum power from the PV to the battery in the dc/dc operation. Fig. 7 shows the overall control block diagram of the RSC in the dc/dc operation. In this mode, the RSC control should be coordinated with the BMS,

V. DESIGN CONSIDERATIONS AND MODIFICATIONS TO THECONVENTIONAL THREE-PHASE PV CONVERTER

One of the most important requirements of the project is that a new power conversion solution for PV-battery systems must have minimal complexity and modifications to the conventional three-phase solar PV converter system. Therefore, it is necessary to investigate how a three-phase dc/ac converter operates as a dc/dc converter and what modifications should be made. It is common to use a *LCL* filter for a high-power three-phase PV converter and the RSC in the dc/dc operation is expected to use the inductors already available in the *LCL* filter. There are basically two types of inductors, coupled three-phase inductor and three single-phase inductors that can be utilized in the RSC circuit. Using all three phases of the coupled three-phase inductor in the dc/dc operation causes a significant drop in the inductance value due to inductor core saturation. Table I presents an example of inductance value of a coupled three-phase inductor for the dc/dc operation, which shows significant drop in the inductance value. The reduction in inductance value requires inserting additional inductors for the dc/dc operation which has been marked as "optional" in Fig. 2. To avoid extra inductors, only one phase can perform the–dc/dc operation. However, when only one phase, for instance phase B, is utilized for the dc/dc operation with only either upper or lower three insulated-gate bipolar transistors (IGBTs) are turned OFF as complementary switching, the circulating current occurs in phases A and C through filter capacitors, the coupled inductor, and switches, resulting in significantly high current ripple in phase B current. To prevent the circulating current in the dc/dc operation, the following two solutions are proposed;

1) All unused upper and lower IGBTs must be turned OFF;

2) The coupled inductor is replaced by three single-phase inductors.

VI. SYSTEM BENEFITS OF SOLAR PV POWER PLANTWITH THE RSC CONCEPT

The RSC concept provides significant benefits to system planning of utility-scale solar PV power plants. The current state of- the-art technology is to integrate the energy storage into the ac side of the solar PV system. An example of commercial energy storage solutions is the ABB distributed energy storage (DES) solution that is a complete package up to 4MW, which is connected to the grids directly and, with its communication capabilities, can be utilized as a mean for peak shifting in solar PV power plants [33]. The RSC concept allows not only the system owners to possess an expandable asset that helps them to plan and operate the power plant accordingly but also manufacturers to offer a cost-competitive decentralized PV energy storage solution with the RSC. Fig. 4 shows examples of the PV energy storage solutions with the RSC and the current state-of-the-art technology. The technical and financial benefits that the RSC solution is able to provide are more apparent in larger solar PV power plants. Specifically, a large solar PV power plant using the RSCs can be controlled more effectively and its power can be dispatched more economically because of the flexibility of operation. Developing a detailed operation characteristic of a solar PV power plant with the RSC is beyond the scope of this paper. However, different system controls as shown in Fig. 5 can be proposed based on the requested power from the grid operator P_{req} and available generated power form the plant P_{gen}. These two values being results of an optimization problem (such as unit commitment methods) serve as variables to control the solar PV power plant accordingly. In other words, in response to the Request of the grid operator, different system control schemes can be realized with the RSC-based solar PV power plant as follows:

1) system control 1 for $P_{gen} > P_{req}$;
2) System control 2 for $P_{gen} < P_{req}$;
3) System control 3 for $P_{gen} = P_{req}$;
4) System control 4 for charging from the grid

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VII. SIMULATION MODEL

1. Sinusoidal PWM

In multiple-pulse modulation, all pulses are the same width. Vary the pulse width according to the amplitude of a sine wave evaluated at the center of the same pulse. In Sine-PWM inverter the widths of the pole-voltage pulses, over the output cycle, vary in a sinusoidal manner. The scheme, in its simplified form, involves comparison of a high frequency triangular carrier voltage with a sinusoidal modulating signal that represents the desired fundamental component of the pole voltage waveform. The peak magnitude of the modulating signal should remain limited to the peak magnitude of the carrier signal. The comparator output is then used to control the high side and low side switches of the particular pole. Fig. 3 shows an op-amp based comparator output along with representative sinusoidal and triangular signals as inputs. In the comparator shown in Fig. 4, the triangular and sinusoidal signals are fed to the inverting and the non-inverting input terminals respectively and the comparator output magnitudes for high and low levels are assumed to be $+V_{CC}$ and $-V_{CC}$.

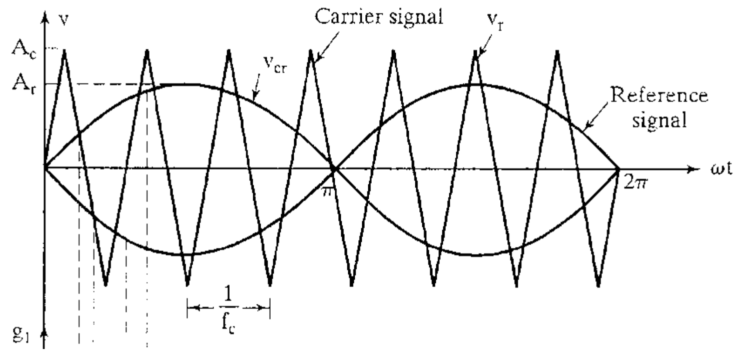

Fig.3 op-amp based comparator output along with representative sinusoidal and triangular signals as inputs

2. Modulation Index

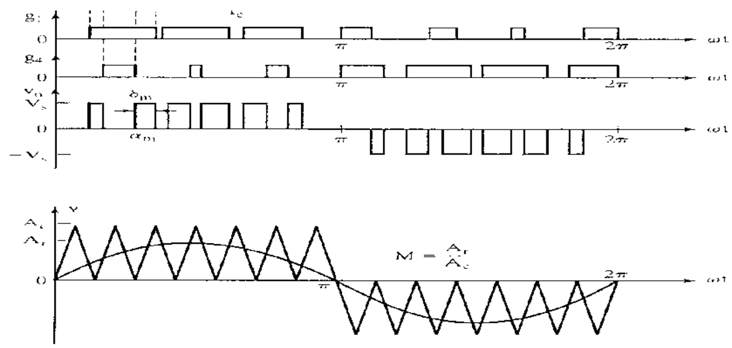

Fig. 4The Triangular and Sinusoidal Signals

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VIII. SIMULATION DESIGN

A simulation design modulation technique as shown in Fig.5 is implemented in MATLAB SIMULINK with the help of pulse generators Sinusoidal PWM is generated. A modified circuit of the system ie Closed switched Boost inverter is also designed.

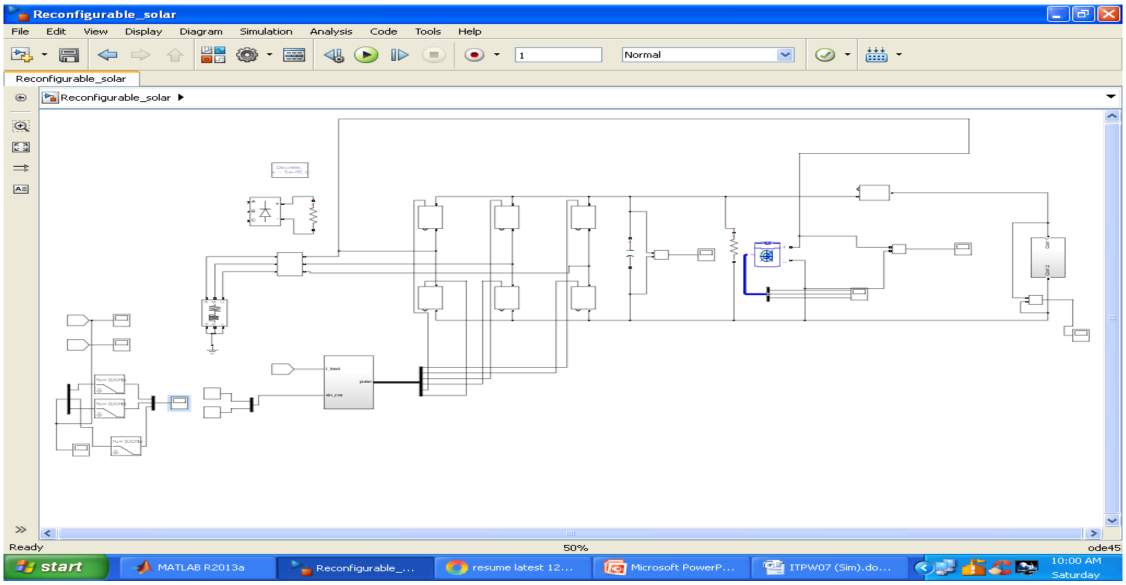

Fig.5Model of Reconfigurable Solar Converter System

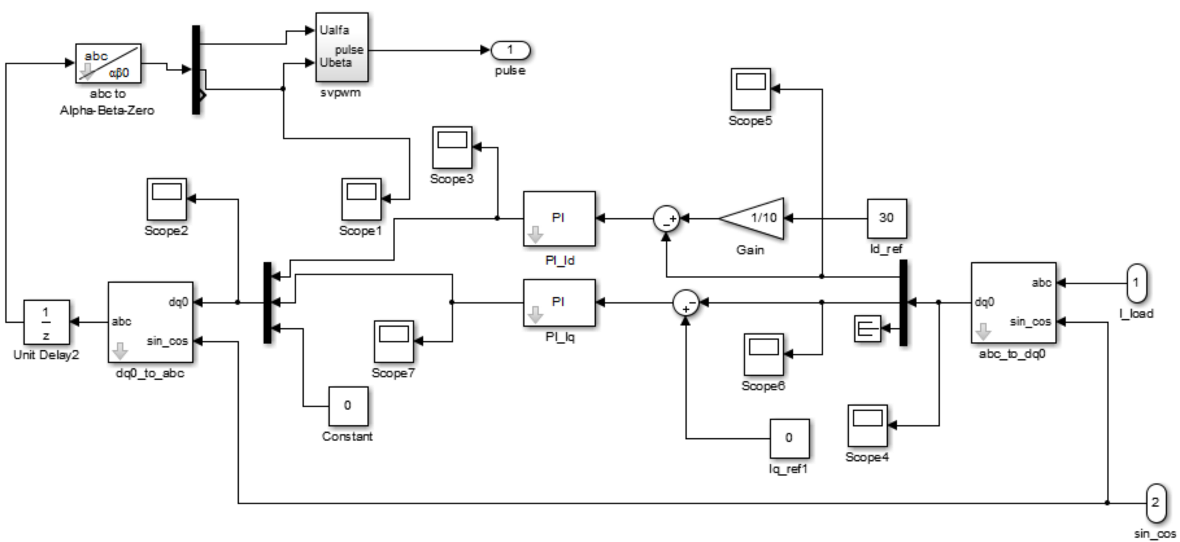

Fig. 6 Model of Inverter Controlling System

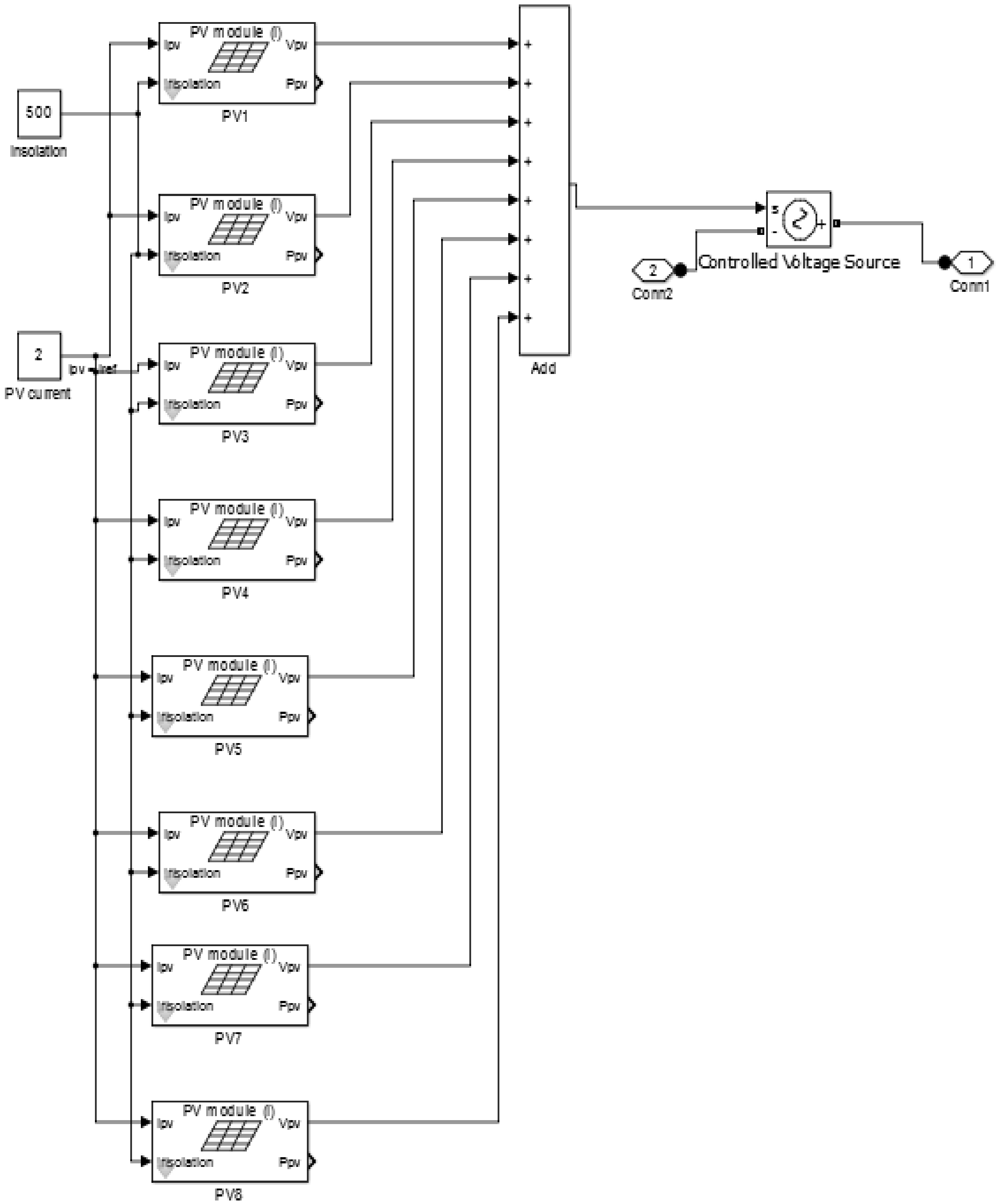

Fig.7 Modelof Solar Plant

IX. RESULT

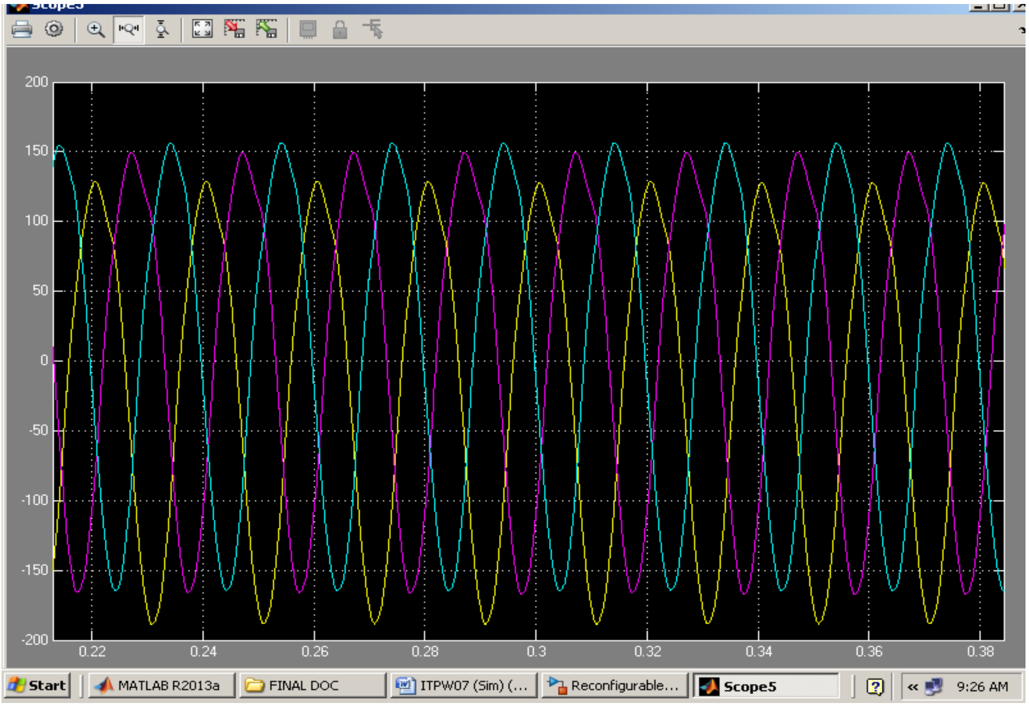

Fig.8 Inverted Voltage of Solar Plant

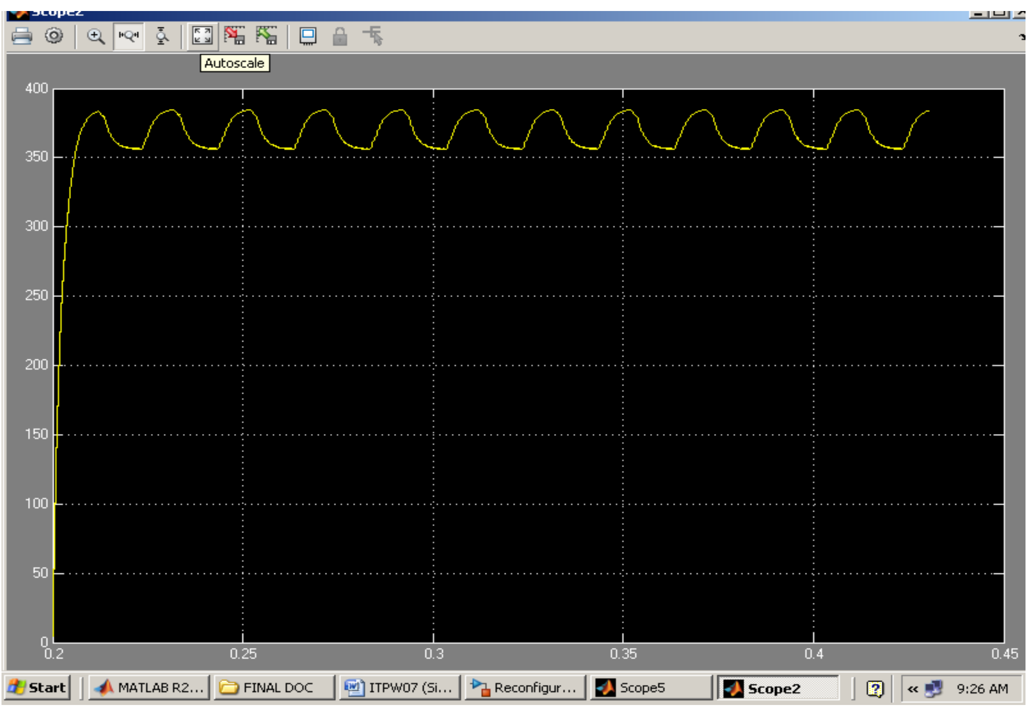

Fig. 9 DC Voltage of Solar Plant

X. CONCLUSION & FUTURE SCOPE

There are various Ares in India where supply of electricity is a really big issue. That can be resolved by using this model. This type of system will be very helpful in the region where grid supply is not continuous. We can give a continue supply to region either by using grid, Battery or directly from Solar plan without having any kind of discontinuity due to any reason. The system can be used operate a more than one load because of two different output is getting. And also DC output can be inverted and fed to AC load. We discussed more about Nano micro and smart grid. We can also improve the high voltage DC transmission and very high frequency AC transmission. We can also introduce resonant concept to reduce the switching losses and soft switching is done. This may reduce the distortion and improve the entire system efficiency.

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