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20-Sim Bondgraph for Solar Home Applications

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Abstract: Designing of solar generation for home applications using MATLAB/sim electronics and Bond Graph model 20- sim used in this paper. The devices required for home applications are solar panel, irradiance and temperature insists as input and generates DC as output to the solar panel. As the solar panels generates DC output but our home requires 240 v AC supply, to convert this DC to AC power electronic device inverter requires. This inverter converts DC to pulsating AC supply. To convert pulsating AC to pure AC needs LC filter. The output DC of solar depends upon temperature and irradiance, no more the temperature is not constant depends on atmosphere varying from morning to evening at afternoon only maximum temperature, high power attains and at morning and evening low temperature, low power attains but any time the home needs constant power supply to the load for 24 hours for this purpose boost converter requires for continuous supply. The device Boost converter is connected between solar panels and inverter. Instead of boost converter the device Transformer can also be used between LC filter and load. The cost of transformer is high and requires more space but in boost converter only inductor, diode, capacitor, one switch uses and obtains continuous supply, reduces the ripple factor. First all the devices solar panel, boost converter, single phase inverter are designed individually and combined by using MATLAB/ sim electronics and Bond Graph 20-sim for both software applications better output waveforms are obtained.

Keywords: *Bond Graph, solar panel, boost converter, 1-Φ inverter.*

I. **Introduction**: Multiple software packages are available to perform simulation in mathematical of complex physical systems to get accurate model. The following are the graphical approaches Block Diagram, Signal Flow Graph and Bond Graph model. Block Diagram, Signal Flow Graph models provides mathematical equations with pictures but do not give much insight into the topology of the system. Bond Graph is used for modeling and simulates multidisciplinary systems and well established for graphical method displays the structure of state space equations and provides algorithmic way of extraction for computer simulation [1]. These advantages have encouraged simulation industry to develop software Bond Graph as a primary modeling. But in this paper equation model is not considered.

This paper commences the Bond Graph 20-sim development for Photovoltaic Solar Home Applications. To develop this first PV Modules, Boost converter, Single phase Inverter are designed by using MATLAB/sim electronics components then in 20-Sim Bond Graph Model components.

The first section consists of MATLAB/ Simulink and 20-Sim, description of Bond Graph. The second section describes PV Modules, Boost Converter, 1 - ϕ Inverter [10]. The third section deals with the results of both MATLAB/ Sim Electronics and 20 – sim Bond Graph has obtained the same, and the fourth section consists of Conclusion.

I. Modeling: Simelectronics is a part of the Simulink physical modeling family. Simelectronics essentially consists of simscape blocks. To build a system level model with electrical blocks, a combination of simelectronics and simscape blocks of Simulink are used [2]. By using this MATLAB/simelectronics PV modules/solar modules, Boost Converter, Single phase inverter, LC filter and Load has been designed and output waveforms of figures have obtained and discussed below

A. **20-sim:**

20-sim is a simulation software package program and commercial modeling for multi domain dynamic systems developed by control lab for the development of control systems. In this models can be entered as equations, block diagrams, physical components and bond graphs [9]. 20-sim models can be created graphically, similar to drawing an engineering scheme. It consists of 2 windows i.e., editor and simulator. The editor contains a model library tree from this the elements are dragged out and dropped to the drawing canvas to construct the required models. If the model is ready the simulator is used to run program and analyzes [3].

B. Description of Bond Graph:

The description of physical system analyzes the exchange of energy by the engineering tool is the Bond graph (BG). This BG involves devices, connections of directed power transfers and causality strokes. The symbol of BG is indicated by an half arrow shown in fig (1) which represents power flow or energy flow. Each Bond consists of two variables i.e., flow and effort variables [4].The causality represents the direction of flow variable by a stroke near the element. The power is the product of flow and effort variables describes the energy flow. It was introduced by Henry Paynter in 1961.

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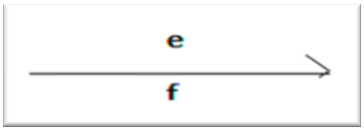
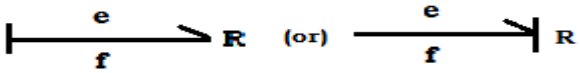
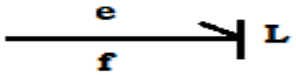
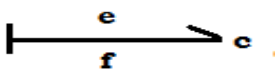
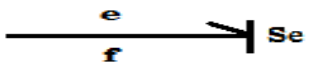
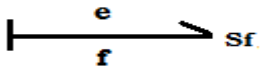
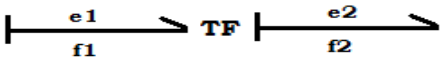
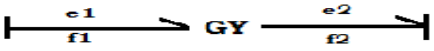
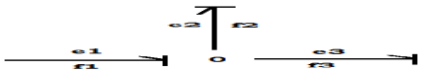
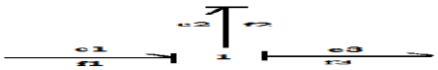


FIG (1)

BG is a unified graphical method and represents in various domains i.e., hydraulic, thermal electrical etc., Table (1) BG represents inter disciplinary systems with one act of symbols for various disciplines with a variation in causality.

Table (1)

PORTS	ELEMENTS	SYMBOLS
One Port	Resistance(R)	
	Inductance(L)	
	Capacitance(C)	
	Voltage Source(Se)	

	Current Source	
Two Port	Transformer(TF)	
	Gyrator	
Multiport	S-Junction	
	P-Junction	

II (A). **Implementing solar panels**: In this 21 century renewable energy resources like solar energy has a great demand among those energies in the world. A solar cell absorbs light energy and converts it into electrical power and is made of semiconductor material (Silicon or Germanium). No potential is applied, but current flows through the load and develops an electrical power. As solar energy is a green and conventional energy generates electric power from sunshine. A PV cell or solar cell generates a voltage of 0.5 to 0.8 volts and current 7.34A [8]. To conduct this experiment in the laboratory with PV cells consumes more time and costly. This problem can be solved by simulation techniques used to simulate the behavior of PV cells under different conditions. Among several simulation software's 20-sim Bond Graph and MATLAB/simelectronics are used for the study of solar cells and constructed PV modules. The five parameter model of PV cell is shown in fig (2). To get more output voltage the solar cells are connected in series as modules as shown in fig (2a). The number of modules is formed as arrays and developed by using the blocks of MATLAB/simelectronics and simscape shown in fig (2b). The PV module blocks are connected with current sensor and voltage sensors this measures current and voltage across PV modules. Irradiance and temperature blocks are connected to the PV model as shown in fig (2c) and its designed 20-sim BondGraph model shown in fig (2d) and its VI and PV characteristics simulation results are obtained by simulation.

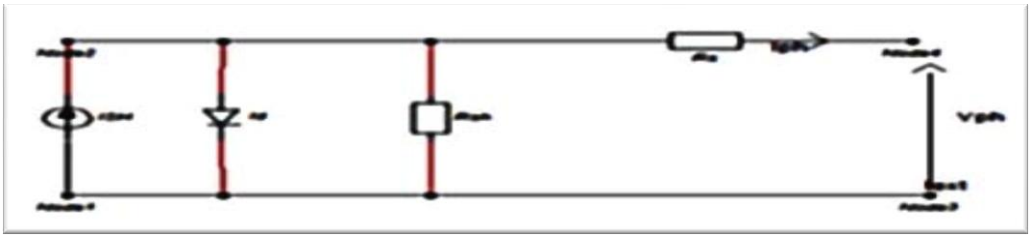


FIG (2) PV cell

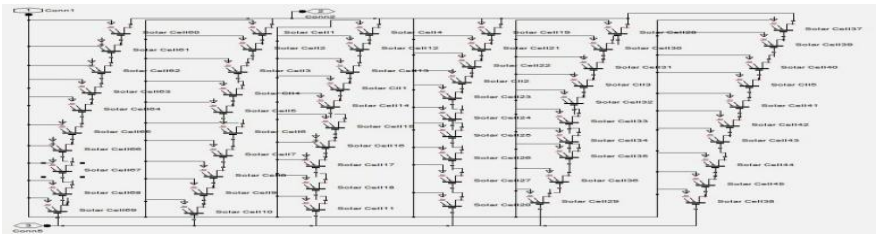


FIG (2a) Solar cells in series and parallel

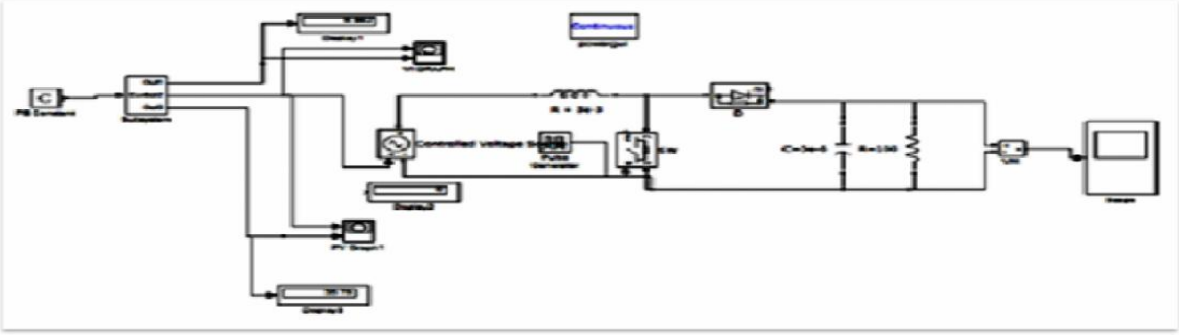


FIG (2b) PV modules

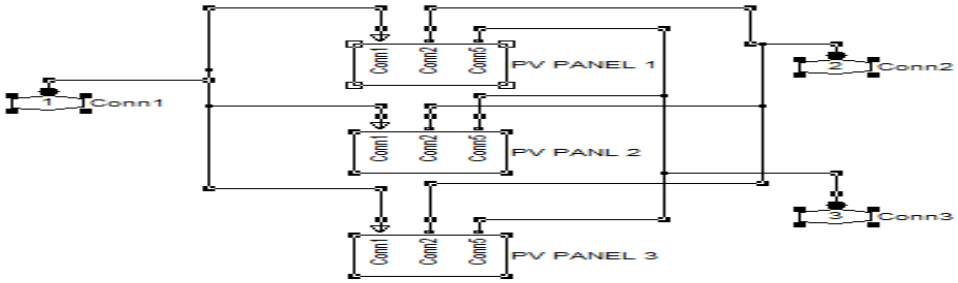


FIG (2c) Design of PV cell MATLAB/simelectronics

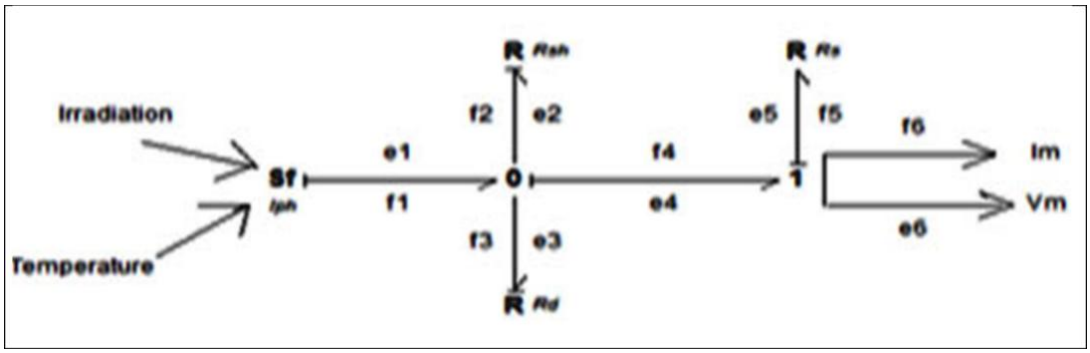


FIG (2d) Design of PV cell 20 sim Bond Graph

B. Boost Converter: A Boost converter is a DC to DC power converter used to step up or step down voltage. In this step up converter is used where it steps up the output voltage (while steps down the current) from its input supply. Among many sources solar panels are used as input supply [7]. It consists of at least one or two semiconductors (a diode and a MOSFET) and one storage element either a capacitor filter (reduces the voltage ripples) or inductor (changes in current by increasing or decreasing the energy stored in the magnetic field) or two in combination.

Operation: The Boost converter is shown in fig (3) when the switch is closed (on state), current flows through the inductor in clock wise direction and stores magnetic field energy.

When the switch is opened (off state), the magnetic field stored energy reduces the current towards the load as the impedance is higher. These results two sources in series cause higher voltage to charge the capacitor through the diode D. In this stage capacitor will be in parallel with the load to charge to this combined voltage.

The Boost converter electrical circuit is shown in fig (3) for PV system [6]. The generation of maximum power for Boost Converter is from PV system where it consists of components with specifications as voltage v=120v, inductor L= 3e-3H, capacitor C =3e-6MF, R = 100Ω, MOSFET switch is chosen to operate in continuous conduction mode. This DC-DC Boost converter is connected between PV Modules and Single Phase Inverter. This Boost Converter is modeled and simulated by MATLAB/sim electronics and is shown in fig (3a) and its bondgraph model in figure (3b).The output waveforms for both MATLAB/simelectronics and 20 sim Bond Graph are obtained same and its simulation results are displayed in section III.

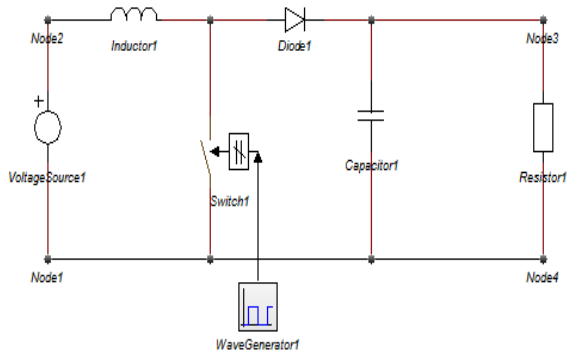


FIG (3) Boost converter

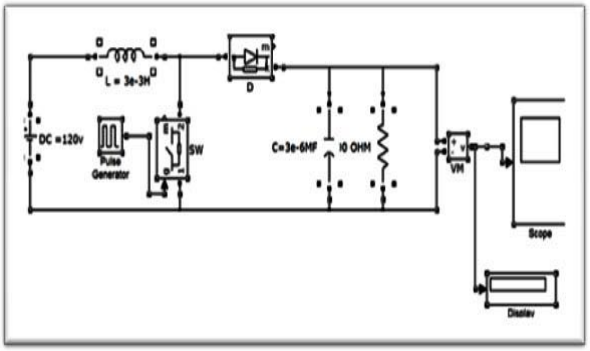


FIG (3a) Boost converter MATLAB/simelectronics

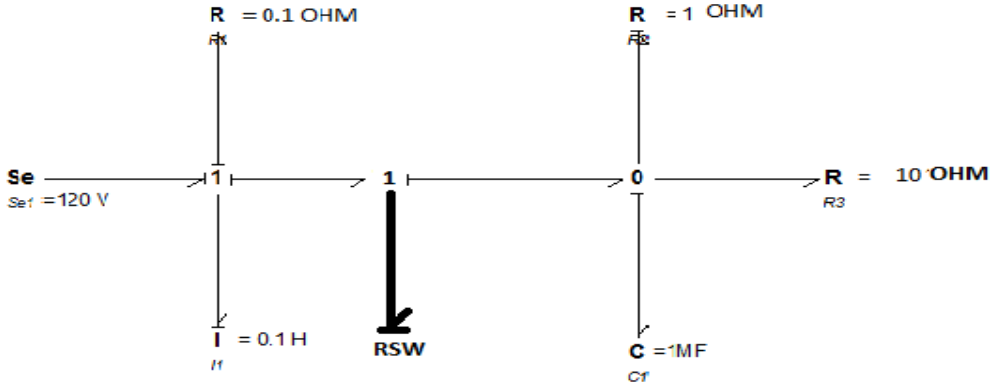


FIG (3b) Boost converter 20 sim Bond Graph

C. PV Panel with Boost Converter: The combination of PV modules and boost converter is designed as shown in figure (3c). where PV modules are given as input source to the Boost converter by constructing MATLAB/simelectronics and Simscape library components with specifications noted above and its desgined 20- sim BondGraph model specifies figure (3d) both of this obtained simulation results shown in section IV.

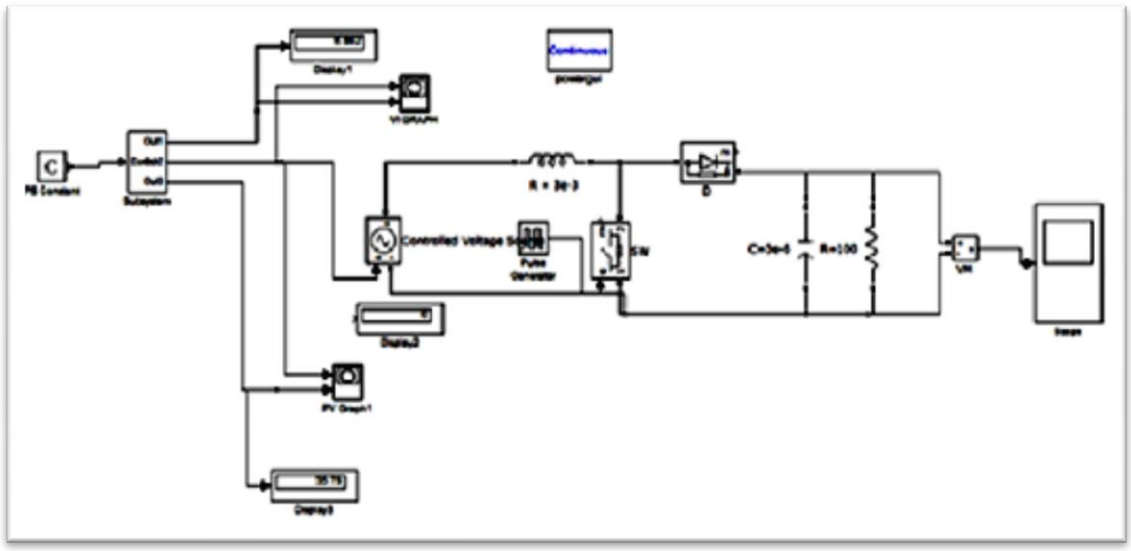


FIG (3c) PV module with Boost converter MATLAB/simelectronics

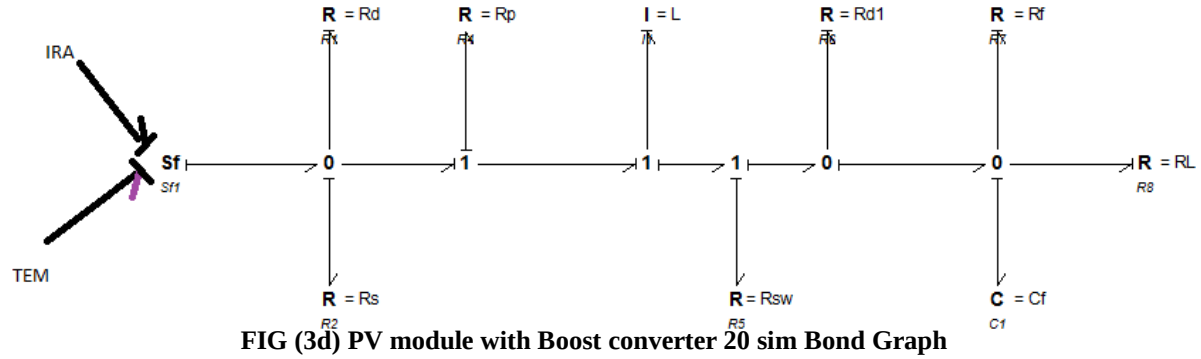


FIG (3d) PV module with Boost converter 20 sim Bond Graph

D. Single- Phase Inverter: The basic role of an inverter is to convert DC power into AC power. This AC power can be supplied to homes, industries using the public utility From the Boost Converter the inverter takes DC as input and converts this into AC.[5] This single phase inverter consists of two phase lead commutations with four switches T1,T3 at one leg and T2,T4 at another leg are designed by MATLAB/simelectronics in one model figure(4) and 20 sim Bond Graph in another model figure (4a) by using their components[6]. When T1, T2 are in switched on positionsT3, T4 are in off positions and vice versa, are connected to the R load. The output waveform obtains as sinusoidal. The values used are Vs=230v, L=30e-6 H, C=5e-6MF,R=100 Ω with four transistor switches connected to their pulse generators.

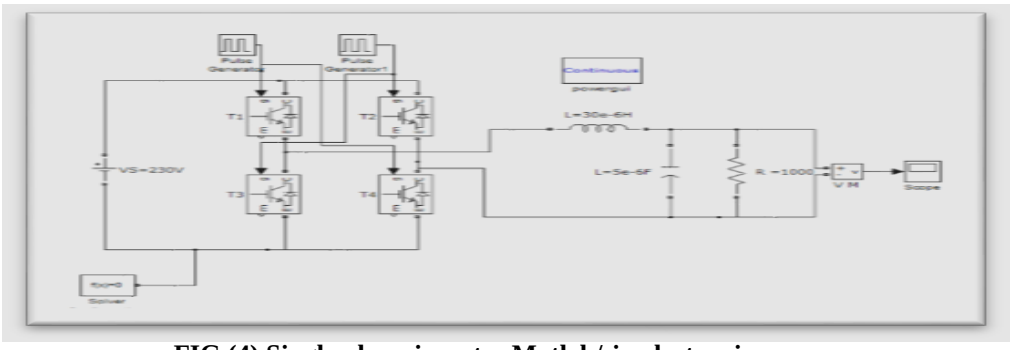


FIG (4) Single phase inverter Matlab/simelectronics

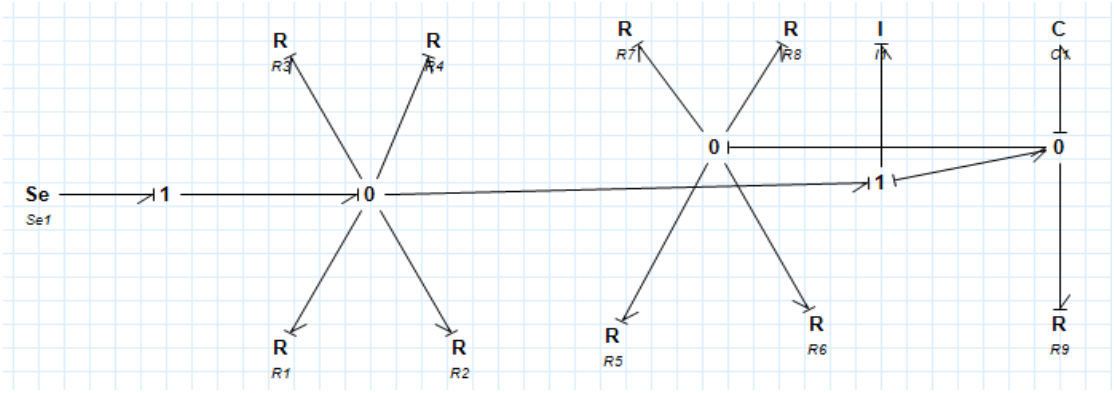


FIG (4a) Single Phase inverter 20 sim Bond Graph

D. **Complete Circuit**: The inverter is connected to the combination of PV modules and Boost Converter. The complete circuit of PV Panel, Boost Converter, Single Phase Inverter and LC filter with load is shown in figure (5) are designed by MATLAB/simelectronics in figure (5) and 20 sim Bond Graph model in figure (5a)[3].The output waveform is obtained as square with some pulsations to overcome these pulsations LC filter has connected and obtained a pure sinusoidal waveform as in simulation results.

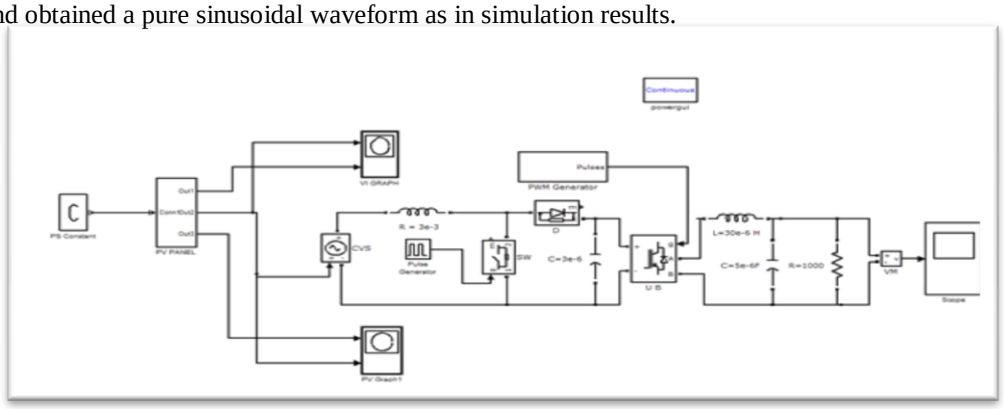


FIG (5) Complete circuit MATLAB/simelectronics

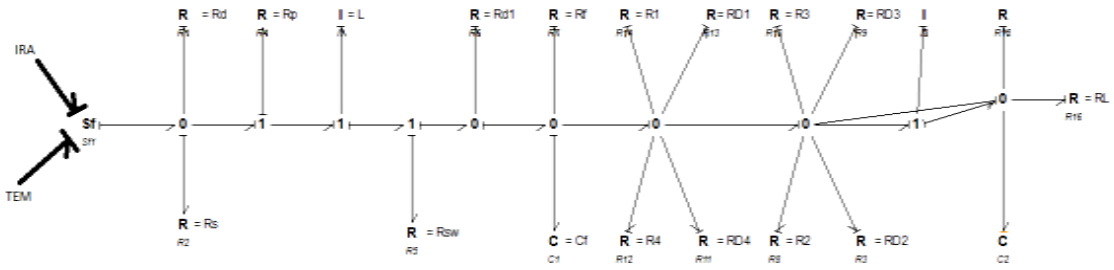
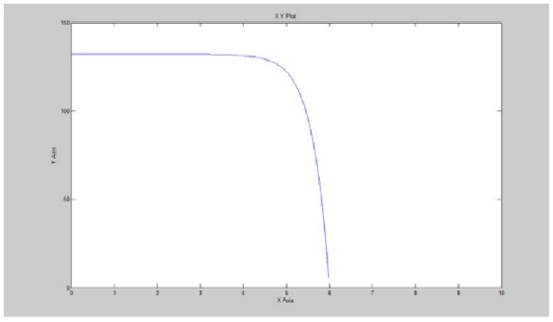


FIG (5a) Complete circuit 20 sim Bond Graph

III. SIMULATION RESULTS : The practical VI curve of PV module obtained as in figure 6(a) and 6(b) for MATLAB/simelectronics and 20 sim Bond Graph with three remarkable points short circuit current (0, Isc),maximum power point (Vmp, Imp) and open circuit voltage (Voc,0)



FIG(6a):VI Characteristics of MATLAB

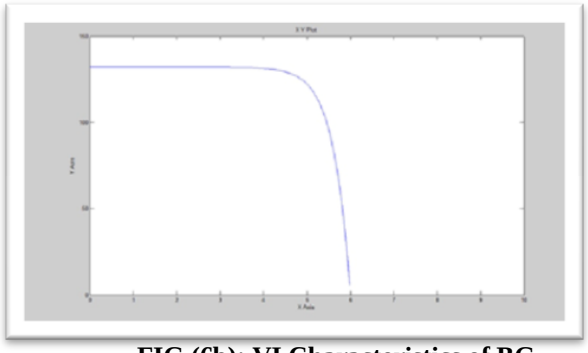


FIG (6b): VI Characteristics of BG

The PV characteristics of pv module consists of figures 6(c) and 6(d) for both models. Where the maximum power obtained as 620 watts

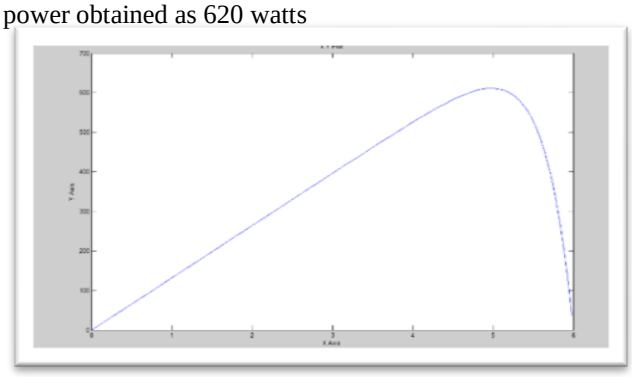


FIG 6(c) PV characteristics of

MATLAB/ simelectronics

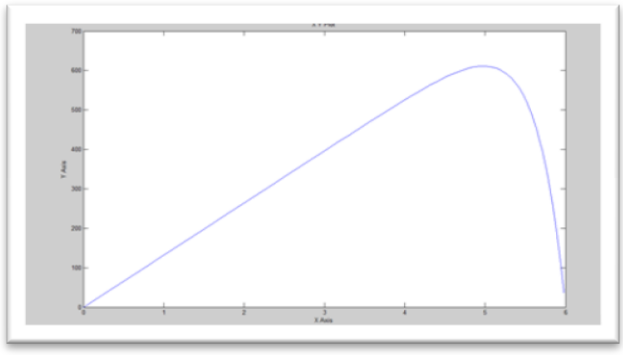


FIG 6 (d) PV characteristics of

20 sim BondGraph

The Boost converter output waveform specifies figure 6(e) and 6(f) where the output voltage is double than the applied input voltage for the values noted above for MATLAB/simelectronics and 20 sim BondGraph. The curve is plotted across voltage Vs time.

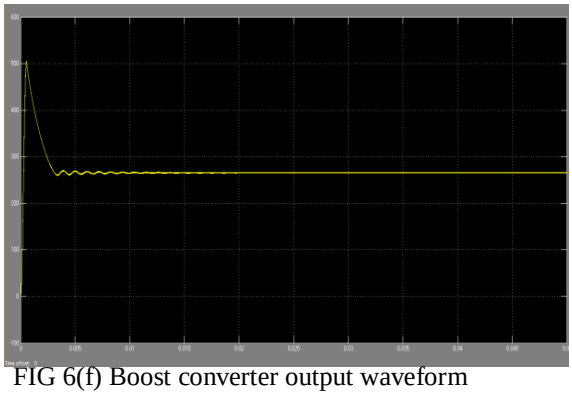
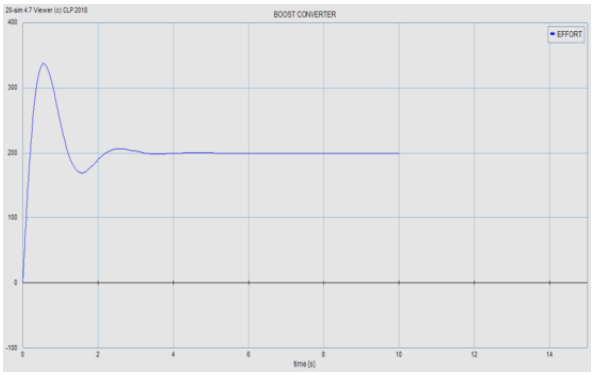


FIG 6(f) Boost converter output waveform

MATLAB/simelectronics



20-sim BondGraph

The single phase inverter output waveform describes below fig's 6(h) and 6(g) where the maxium voltage obtained as 220v for both MATLAB/Simelectronics and 20-Sim BondGraph.

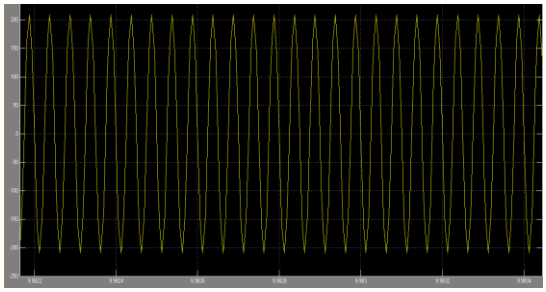


FIG 6(g) Single Phase Inverter output waveform

MATLAB/Simelectronics

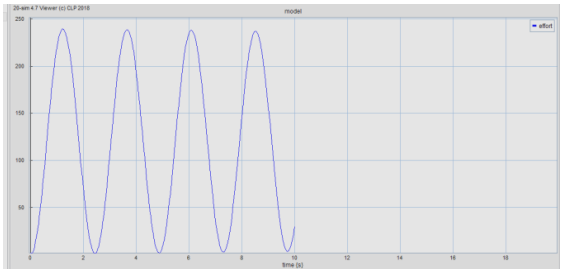


FIG 6(h) Single Phase Inverter output waveform

20-sim BondGraph

The output waveforms for the combination of PV modules, Boost converter and single phase inverter both models without LC filter consists below figures 6(i) and 6(j).The waveform has obtained as square did not get pure sinusoidal waveforms.

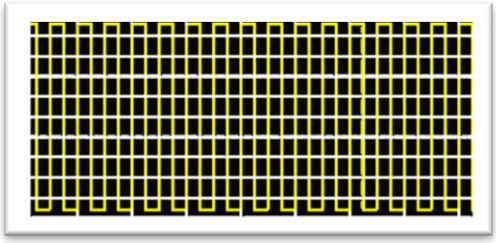


FIG 6(i): Output waveform without LC filter

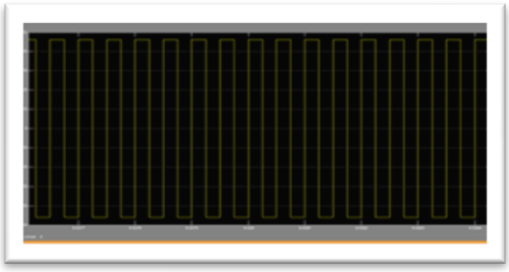


FIG 6(j): Output waveform without LC filter 20-sim

The output waveforms for the combination of PV modules, Boost converter and single phase inverter both models with LC filter consists below figures 6(k) and 6(l).The waveform has obtained as pure sinusoidal waveform with output double than the given input supply which is this voltage for our home applications.

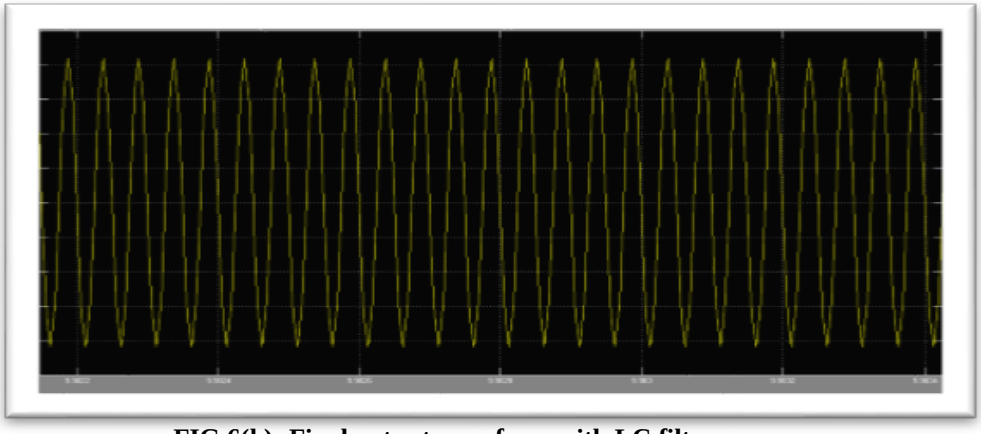


FIG 6(k): Final output waveform with LC filter

FIG 6(l): Final output waveform with LC filter 20-sim

IV. Conclusion:

The main aim of this paper is to develop the Bond Graph 20-sim Model for Photovoltaic Solar Home Applications. The assemble of three individual models described before are coupled and formulated for the complete proposed mode. Different simulations have been made in order to validate the proposed model.

Simulation model of a solar cell has developed in 20-sim Bond Graph and MATLAB/simelectronics using solar cell and other interfacing blocks. To obtain the traditional responses of current and power verses voltage are formulated and obtained a static response for the PV module. The current and voltage increase with the increase in irradiance and temperature is considered as constant. To develop the power the solar cells are connected in series and this series combination of solar cells are connected as parallel and forms as modules. The responses of PV and IV characteristics are presented in figures 6 (a & b) and 6 (c & d) have been simulated by considering the same irradiance and temperature of the PV module.

The open loop schematic circuit of Boost converter for continuous conduction with sensors is used. The MOSFET transistor and the diode are modeled as two conversely ideal switches. A fault in this electronic component leads to failure and degradation of its performance in a power distributed system. For both cases MATLAB/simelectronics and 20-sim the port variables are determined by real measurements are simulated.

A single phase inverter basic MOSFET diode pair behaves likes an ideal switch and results in complementary binary states consisting of two identical half bridges or columns. The inverter model is used to simulate the supply to the load providing with the control signals. The circuit components and variables represented for both cases are observed same at any moment.

The unique causal Bond Graph with fixed causality can be formulated for systems with communications just using junctions and MTF's as ideally switching (no power consuming) Bond Graph elements has successfully modeled and simulated in order to demonstrate the suitability and the properties of the proposed results.

o the design of the PV Modules, Boost Converter, 1 - Φ Inverter by using MATLAB/ simelectronics and Bond Graph 20-sim model and obtained the better results for both for the Development of Bond Graph for Photo Voltaic Solar Home Applications. Where they obtained output voltage is higher than the input which is necessary for home applications.

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