MODELING AND ANALYSIS OF MPPT AND BUCK BOOST CONVERTER FOR SOLAR POWER APPLICATION

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Abstract—

PV system is widely adapted to the forefront in electrical power applications such as grid connected and stand-alone systems in recent years for efficient operation of photovoltaic system. It is necessary to use a maximum power point tracking (MPPT) system to extract maximum power from a PV panel, irrespective of the temperature, irradiation conditions and electrical characteristics of the load. This project has presented the mathematical modeling of photovoltaic module and development of power converter using MATLAB/SIMULINK to simulate the basic operation of MPPT based DC-DC converter. The algorithm chosen for simulation was incremental conductance algorithm among the various MPPT algorithms studied. The algorithm would ensure maximum power point tracking by controlling the mosfet of buck-boost converter by varying its duty ratio. The TMDSSOLAR (P/C) EXPKIT is programmed as per the requirement based on different working conditions and by using graphical user interface in the software tool overall operations and performance are monitored and tabulated. To compare the various characteristics obtained from simulation model study, a solar cell & solar RELAB hardware model which is a scaled down model of solar system, is used. Solar RELAB hardware model is controlled using LABVIEW graphical user interface. This validate that the work done on solar RELAB and TMDSSOLAR(P/C)EXPKIT can be scaled to a higher rating solar system which further is an answer to a sustainable energy.

IndexTerms- MPPT,PV,SolarRElab,TMDSSOLAR(P/C)EXPIT

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I. INTRODUCTION

Due to the nonlinear relationship between the current and the voltage of the PV cell, it can be observed that there is a unique Maximum Power Point (MPP) at a particular environment, and this peak power point keeps changing with solar illumination and ambient temperature. An important consideration in achieving high efficiency in PV power generation system is to match the PV source and load impedance properly for any weather conditions, thus obtaining maximum power generation. Therefore, the system needs a Maximum power point tracking (MPPT) which sets the system working point to the optimum and increases the system's output power

In most common applications, MPPT with DC to DC converter is inserted between the PV module and load to achieve optimum matching. By using an intelligent algorithm, it ensures that the PV module always operates at its MPP. Several MPPT algorithms have been proposed in different literatures like Perturb & Observe (P&O), incremental conductance, constant voltage, constant current and fuzzy based algorithms.[1] These techniques differ in many aspects like complexity, convergence speed, hardware implementation, sensor requirement, cost, range of effectiveness and need for parameterization.

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II. OBJECTIVE

The main aim of this work is to use the solar power with MPPT technique. An attempt has been made to design solar panel with MPPT controller and DC - DC converter which switches in between buck and boost topology depending upon the input voltage and the switching signals from the MPPT algorithm. It uses a multi objective control algorithm wherein, the system is classified into various states based on operating conditions of the PV array and the load to generate the Pulses Width Modulation (PWM) pulses. By judging the state and setting the related control goal, the power will be balanced to satisfy the MPPT control.

III. STUDY ON TMDSSOLAR (P/C) EXPITSOALR KIT

Main control program is developed on PLC programming the solar panel or Photovoltaic (PV) panel, is a DC source with a nonlinear V vs I characteristics. A variety of power topologies are used to condition power from the PV source so that it can be used in variety of applications such as to feed power into the grid (PV inverter) and charge batteries. The Texas Instruments C2000 microcontroller family, with its enhanced peripheral set and optimized CPU core for control tasks, is ideal for these power conversion applications. The solar explorer kit shown in Fig 2 has different power stages that can enable the kit to be used in a variety of these solar power applications. The input to the solar explorer kit is a 20 V DC power supply that powers the controller and the supporting circuitry. A 50W solar panel can be connected to the solar explorer kit (typical values Vmpp 17V, Pmax 50W). However, for quick demonstration of the power processing from the solar panel, a PV emulator power stage is integrated on the solar explorer kit along with other stages that are needed to process power from the panel. Using a Piccolo-A device integrated on the board lessens the burden of the controller used to control the solar power conditioning circuit control of the PV panel. Thus, the board uses two C2000 controllers, a dedicated Piccolo-A device is present on the baseboard and used to control the PV emulator stage. The device on the DIMM100 control CARD is used to control the DC-DC Boost, DC-AC and DC-DC Sepic stage. [2] Fig 2shows the solar explorer kit block diagram.Fig 1 Block Diagram of Experimental setup

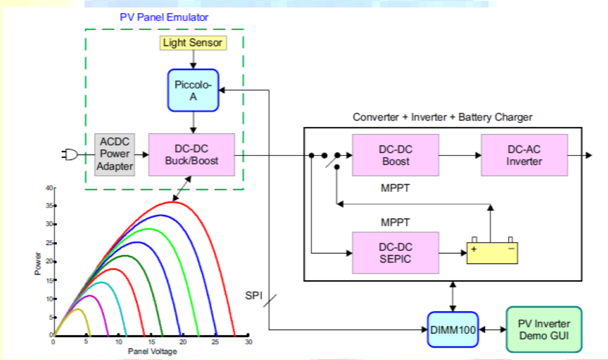

Fig.1: Solar Explorer Kit Overview

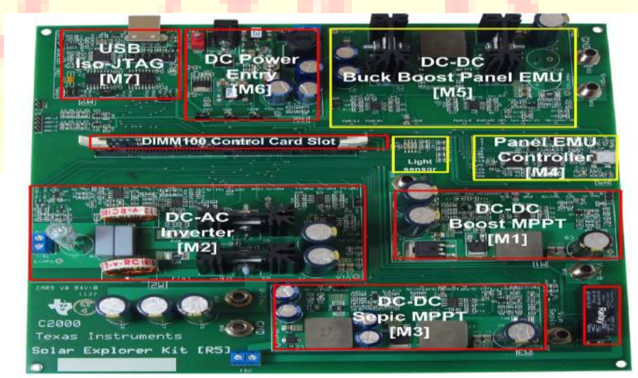

Fig.2.: Macro Block on Solar Explorer Kit

IV. MODELLING AND SIMULATION

Mathematical modeling of photovoltaic cell/ module and development of power converter using Matlab/Simulink is presented in this chapter in order to simulate the basic operation of MPPT based controller. Simulation is explained in further parts with detailed model

DETAILED BLOCK DIAGRAM OF SIMULATION

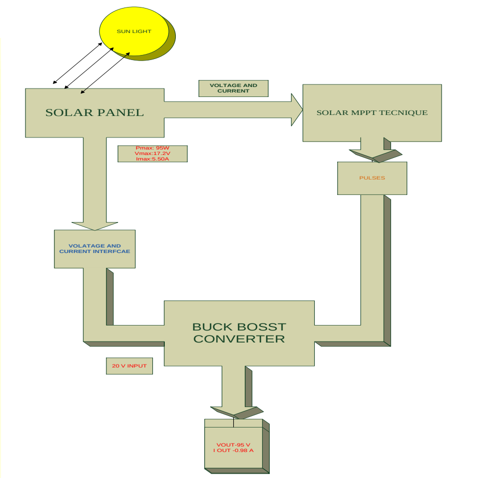

Fig.3: Detailed bloc diagram

A. Model of a photo voltaic (PV) cell

The solar cell is modeled by a current source and inverted diode connected parallel to it. It also has series and parallel resistance as shown in Fig 4[3]

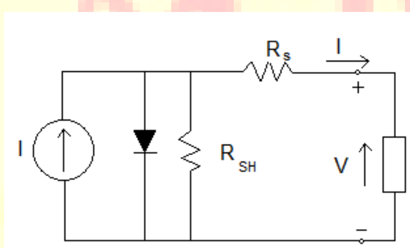

Fig.4: Single diode model of a PV cell

From the Fig 4, the output voltage (V) and current (I) of a solar cell can be expressed as:

$I = I_L - I_o\{\exp\left(\frac{V+IR_S}{\alpha}\right) - 1\}$Where, IL is light current, Io is saturation current and is the thermal voltage timing completion factor of the cell.[3]

$$I = N_p \left\{ I_{ph} - I_n \left(\exp\left(\frac{q(V+IR_s)}{AKTN_s} - 1 \right) \right) \right\} \text{Where, } I_{rs} = I_n \left(\frac{T}{T_r} \right)^3 \exp\{ \frac{E_G}{AK} (\frac{1}{T_r} - \frac{1}{T}) \};$$

q = charge of an electron (1.6 x 10-9C);

K = Boltzmann's constant (1.38 x 10-23J/˚K);

A = diode ideality factor (1.92);

T = cell temperature;

Irs = cell reverse saturation current at

Tr = cell reverse temperature (28˚C);

EG = band gap energy of semiconductor (1.11eV);

Iph = photocurrent given by the equation:

$$I_{ph} = \{ I_{scr} + K_i (T - T_r) \} \frac{S}{100};$$

ISCR = cell short circuit current at Tr and radiation;

Ki = short circuit current temperature coefficient;

S = solar radiation (mW/cm2);

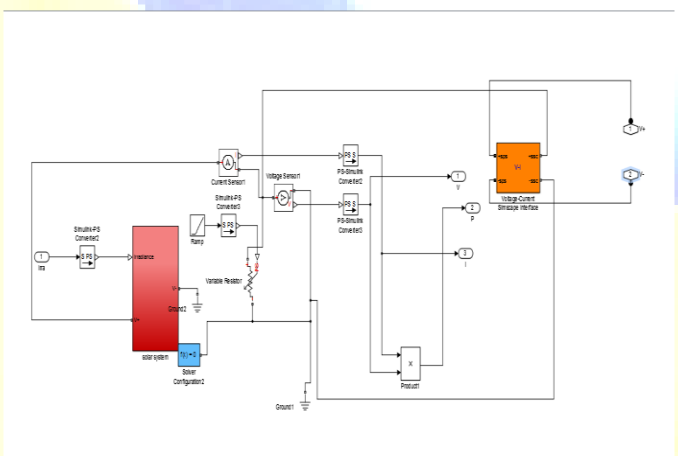

Fig.5: solar panel model in MATLAB-SIMULINK

B.MPPT TRACKING ALGORITHM

The photovoltaic array power output is sensed and assessed by controller and adjusts it for further interfaced in order to obtain optimum operating condition. The inverter is used as the power conditioner

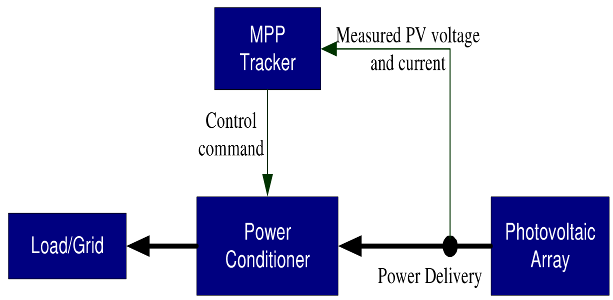

Fig.6 Block diagram of Maximum power tracking system

Flow chart of Incremental conductance method

Comparative study on MPPT techniques shows that the incremental conductance algorithm which is used for simulation performs well under rapidly changing atmosphere conditions and has good accuracy and efficiency.[4][5] Flow chart of the incremental conductance algorithm is shown in Fig\.7

MPPT Control Algorithm, The power output characteristics of the PV system as functions of irradiance and temperature curves are nonlinear and are crucially influenced by solar irradiation and temperature. Furthermore, the daily solar irradiation diagram has abrupt variations during the day, under these conditions, the MPP of the PV array changes continuously; consequently the PV system's operation point must change to maximize the energy produced. An MPPT technique is therefore used to maintain the PV array's operating point at its MPP. There are many MPPT methods available in the literature; the most widely-used techniques are described in the following sections, starting with the simplest method [6][7]

Incremental Conductance Method

The Incremental Conductance (IC) algorithm is based on the observation that the following equation holds at the MPP where IPV and VPV are the PV array current and voltage, respectively. When the optimum operating point in the P-V plane is to the right of the MPP,

$(dIPV/dVPV) + (IPV/VPV)<0$,

Whereas when the optimum operating point is to the left of the MPP,

$(dIPV/dVPV) + (IPV/VPV)>0$. Therefore the sign of the quantity (dIPV/dVPV) + (IPV/VPV)

Indicates the correct direction of

Perturbation leading to the MPP. Through the IC algorithm it is therefore theoretically possible to know when the MPP has been reached, and thus when the perturbation can be stopped. The IC method offers good performance under [8] [9]

Rapidly changing atmospheric conditions.

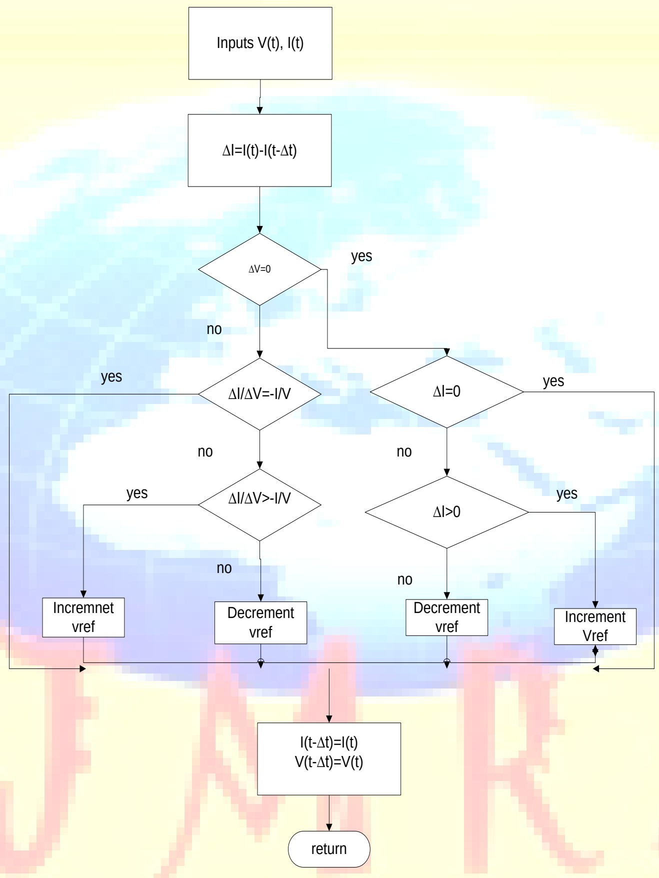

Fig..7: Flowchart of the incremental conductance method

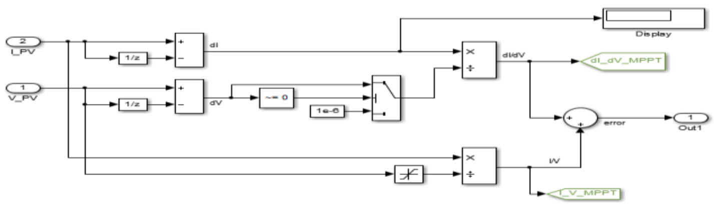

Fig.8: MATLAB-Simulink model implementing incremental conductance method

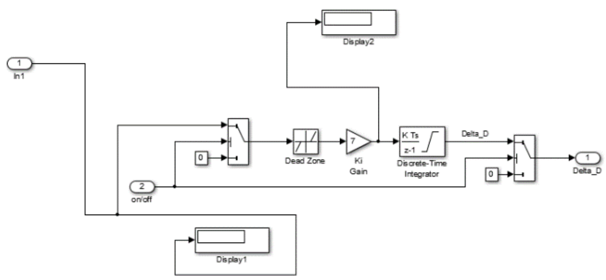

Fig.9: MATLAB-Simulink model of pi controller for MPPT model

Fig 8 and Fig 9 shows the Simulink model of incremental conductance algorithm along with PI controller The MPPT model shown in Fig 8 tracks the MPP of the PV array by comparing incremental conductance with instantaneous conductance. The duty of the algorithm is to search a suitable duty cycle at which the incremental conductance equals to instantaneous conductance so that the PV system always operates at its maximum power point

MPPT block shown in Fig 10 incorporates the Simulink block of incremental conductance algorithm shown in Fig 8 and Fig .9 to generate pulses for switching the MOSFET in the buck-boost converter[10]

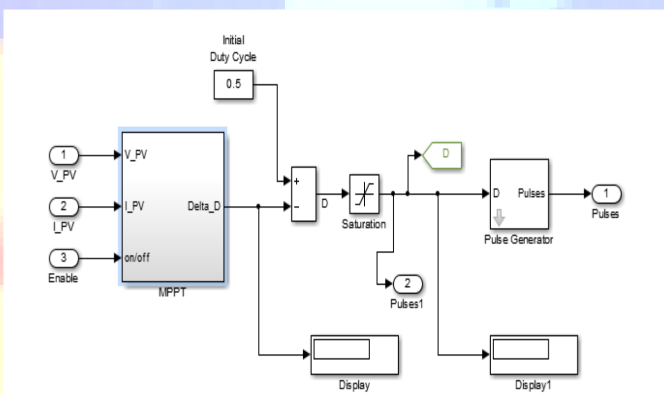

Fig.10: Pulse generator using MPPT block *Modeling and for buck boost converter*

Usually the output voltage of the DC-DC buck boost converter is greater than the input voltage of the converter. It is a converter operated basically by changing the switch mode to ON or OFF positions. The circuit diagram of the buck-boost converter is shown in Fig11 below [11]

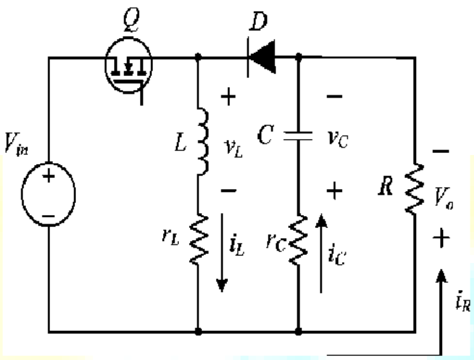

Fig.11: DC-DC Buck Boost converter circuit diagram

The V_{in} and V_o in equation (3) denotes the input and output voltage of the converter respectively. In order to operate the DC-DC buck boost converter in continuous mode, the minimum capacitance and inductance required in order to generate continuous current is expressed as below

$$L_{min} = \frac{(1-D)^2 R}{2f} \quad (1)$$

$$C_{min} = \frac{D}{Rf(\Delta V_0/V_0)} \quad (2)$$

$$V_0 = \frac{D}{1-D} V_{in} \quad (3)$$

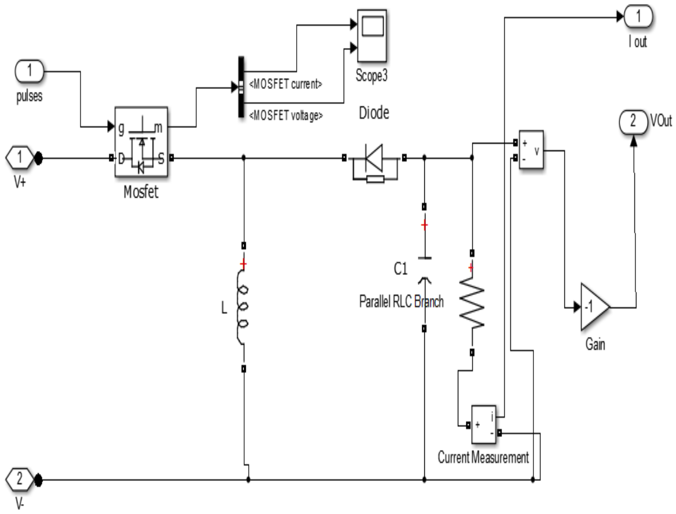

Fig.4.14: Simulink model of buck boost converter

V. *MATLAB –SIMULINK* MODEL RESULTS

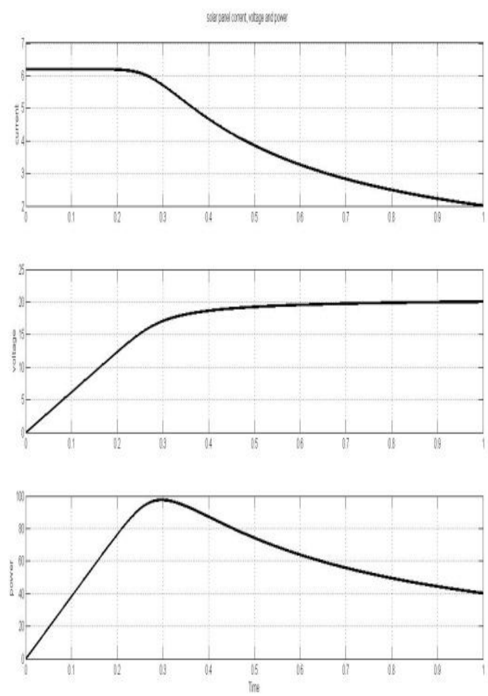

Fig .12: output of solar panel current, voltage and power

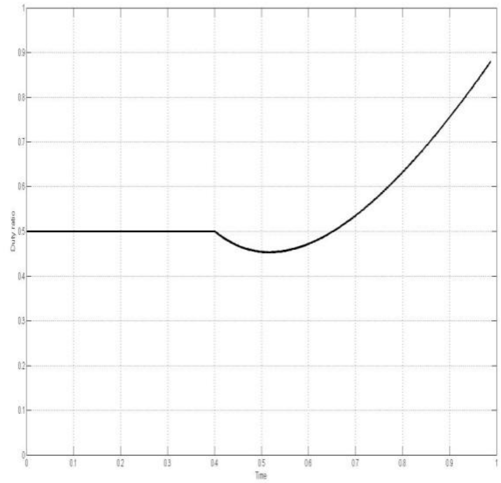

Fig.13:variation of duty ratio

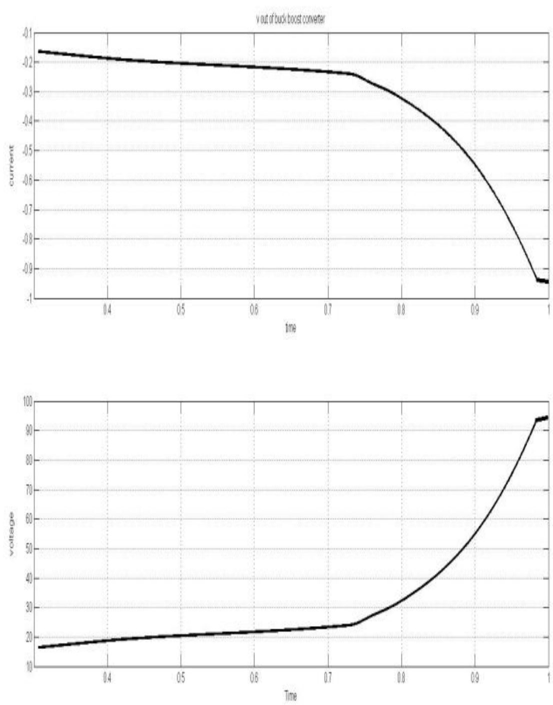

Fig.14: Output voltage across the buck boost converter

Fig 12 shows the current, voltage and power respectively of solar panel , it is observed that current value of 6 Amps starts linearly decreasing at 0.3 sec were the voltage starts increasing to 20 volts In Fig13 shows that MPPT algorithm tries to track the maximum power after 0.4 seconds so that the duty ratio of the converter is changing to track maximum power point as the illumination changes and the maximum power is obtained for a particular value of irradiation.

Fig 14 shows the output across the buck-boost converter where the voltage is boosted to 95V

VI. Experimental setup

Fig.15: Experimental setup of TMS320 solar explorer kit

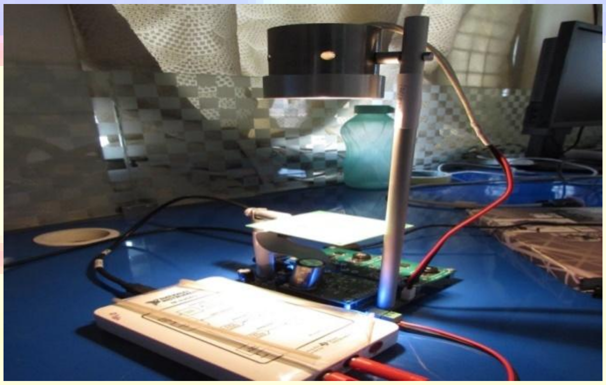

Fig.16 Solar RElab setup model

To compare the charactestics of solar panel the simulation results with hardware model of TMS320SOLAR EXPLORER, the kit is programmed as per the requirements, based on the programming the kit made to work till boost converter. The hardware kit is scale down to smaller rating of 40 Watts shown in Fig 15

VII. RESULTS AND ANALYSIS

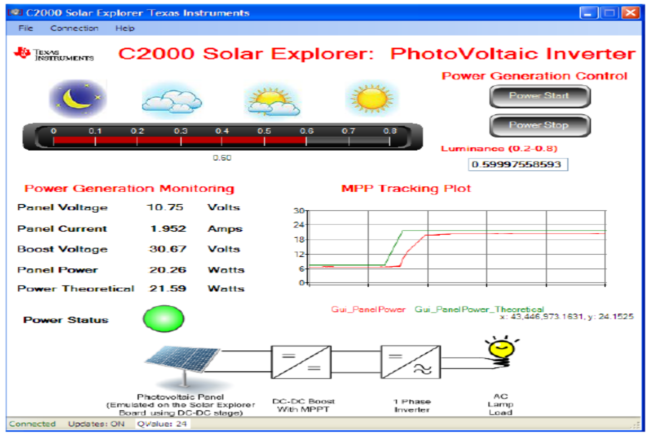

Fig.17: Graphical user interface (GUI)

By varying the irradiance level through GUIas shown in Fig 17, the output across the boost converter is tabulated as shown in table 1

Irradiance W/m^2	Pmpp	Vmpp	Buck boost output	Boost output
1.0	36.02	18.46	25	39
0.9	32.42	16.42	20	35
0.8	28.82	14.68	15	32
0.7	25.22	12.77	114	28

The results are obtain by connecting the MYdaq to the hardware module and the capturing of the data is done through the LABVIEW software, the circuit implemented for MYdaq interface is shown in Fig 18 the captured results across the buck-boost converter and boost converter are show in Fig 19 and 20

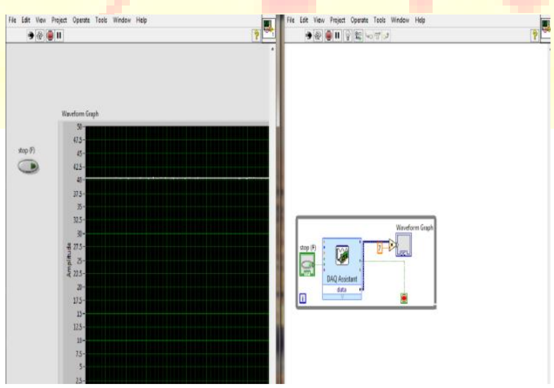

Fig.18 Results obtain through the LABVIEW which is interface with MYdaq

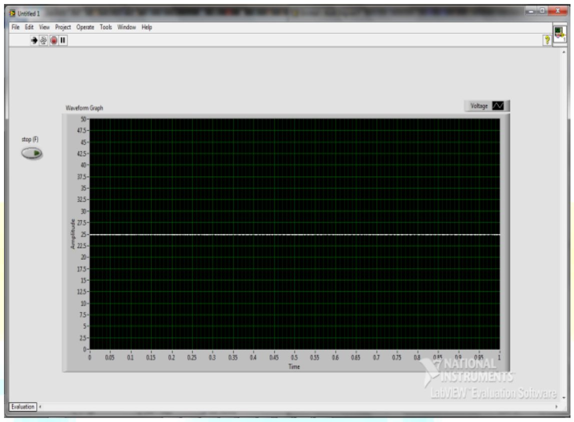

Fig.19 Output voltage across buck-boost converter

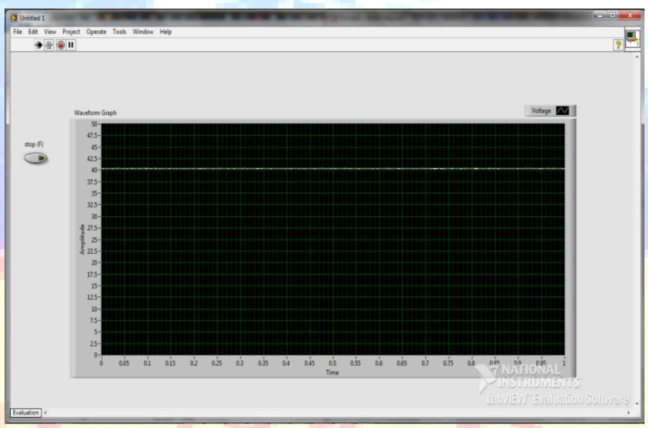

Fig.20 Output across the boost converter

Table.1: variation of parameters by varying irradiance

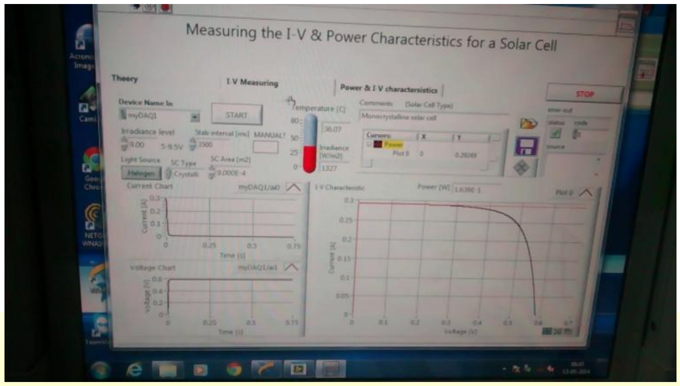

Fig.21: Results obtained when the irradiance level of 0.9

Fig 21 shows the GUI of solar RElab which gives the I-V charactestics of solar cell and also the irradiance can be controlled through the GUI and temperature variation can be seen through the thermometer model

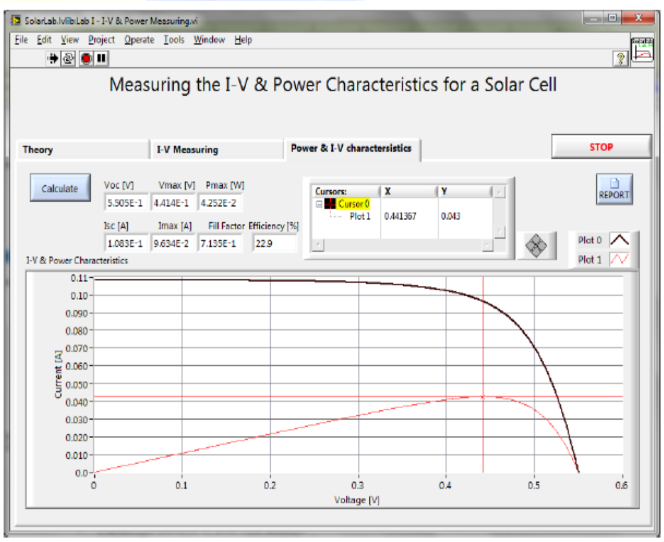

Fig.22 I-V and Power-Measuring Interfaces

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IRRADIANCE(W/m^2)	I_{sc} (A)	V_{oc} (V)
1000	**0.98**	**95**
900	**1**	**94**
800	**1.2**	**91**
700	**1.05**	**93**
600	**1.2**	**95**
500	**0.98**	**94**
400	**0.99**	**92**

The above Fig 22 shows the V-I and power charactestics obtained from the solar RElab of a single solar cell where the results show the similar charactestics obtained in simulation model of solar panel in MTALAB- Simulink, the obtained simulation results V-I and V-P curve are shown in Fig 12 and compared with the solar RElab V-I and P charactestics results are validated

Table.2: various values obtained at different valves of irradiance

The above table 2 shows the different values of Isc and Voc at different vales of irradiance by simulation and is tabulated as above and these results are compared with the tabulated values of solar explorer hardware module

VIII. CONCLUSION

The present work includes mathematical modeling of photovoltaic module and development of power converter using MATLAB/SIMULINK to simulate the basic operation of MPPT based DC-DC buck-boost converter. The algorithm chosen is incremental conductance method and simulation studies performed and compared with various MPPT algorithms.Theincremental conductance method has ensured maximum power point tracking is obtained by varying the duty ratio of switching pulses given to the MOSFET of buck-boost converter.

The TMDSSOLAR (P/C) EXPKIT is programmed as per the requirement based on different working configuration and by using graphical user interface in the software tool overall operations and performance is monitored, tabulated and compared the voltage across the boost converter with the simulation results.

To compare the various characteristics obtained from simulation model like V-I, V-P charactestics, solar RELAB hardware model which is a scaled down model of solar PV module, is used. Solar RELAB hardware model is controlled using LABVIEW graphical user interface. This validate that the work done on solar RELAB and TMDSSOLAR(P/C)EXPKIT can be scaled to a higher rating solar system which further is an answer to a sustainable energy.

VIII.FUTURE SCOPE OF WORK

Present simulation model can be implemented in hardware design with battery charging circuit and inverter so that it can be used for home application and also it can used for other solar power applications.

Future work can be extended to a larger rating to make this as supply power to the electrical grid through an inverter. This feature will be very useful in many applications like, remote locations requiring small quantities of power to run lighting, pumps and other applications such as low power motor drives. Furthermore, it can be coupled with an uninterruptible power supply system in commercial buildings.

The proposed simulation can be extended to use in a hybrid system where the microcontroller performs simultaneously the MPPT control of more than one renewable energy source. Also the hybrid solar charger can be made with solar PV panels and utility grid chargers to keep the batteries charged using either or both of the two sources while maximizing the usage of the available solar energy from the installed panels.

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