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Modeling and Simulation of Fuzzy Logic Based Controller With Proposed DC to DC Converter for Photovoltaic Module

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Abstract - *This paper presents an intelligent control method to track the maximum power point from a photovoltaic system irrespective of changes in temperature and irradiance. The objective of controller to increase tracking efficiency and to simultaneously solve the inherent drawbacks in conventional maximum power point tracking algorithms. First for the purpose of comparison and because of its proven good performance the INC(incremental conductance) technique is introduced and then its parameters have been compared with the proposed FLC(fuzzy logic controller).An optimized FLC using mamdani type fuzzy inference system is proposed. The MPPT (maximum power point tracking) algorithm is implemented with proposed Cuk converter to increase the converter output from the PV panel. The Cuk converter has low switching losses and the highest efficiency among non-isolated DC-DC converters. It can also provide a better output-current characteristic due to the inductor on the output stage. Experimental test has been done for multichanges in irradiance, temperature by keeping voltage and current as main sensed parameter. Results show that cuk converter produces higher output voltages and gives better efficiency than the conventional boost converter. The design is accomplished and verified using matlab/simulink software.*

Key words*:* **Cuk converter, Fuzzy logic controller, Incremental conductance algorithm, Maximum power point tracking.**

I. INTRODUCTION

The increasing demand for energy, the continuous reduction in existing sources of fossil fuels and the growing concern regarding environment pollution, have push mankind to explore new technologies for the production of electrical energy using clean, renewable sources such as solar energy, wind energy etc.[1-3]. There are inherent problems with Photovoltaic modules like rapid change in insulation conditions, high initial establishment cost and low conversion efficiency. To overcome the problems it is necessary to optimize the design of Photovoltaic system components. A photovoltaic generation system should operate at its maximum power point (MPP) to increase the system efficiency [4-6]. However the MPP also changes with irradiation level and temperature due to nonlinear characteristics of PV modules. To overcome this many MPPT algorithms have been developed [7-9]. Recently Fuzzy logic has been applied in tracking the MPP of PV systems as it has the advantages of being robust, simple in design and minimal requirement for accurate mathematical modeling. However fuzzy methods depend on a careful selection of parameters, definition of membership functions and fuzzy rules. In the proposed system initially the photovoltaic panel has been replicated with the help of mathematical equations in simulink. Then a photovoltaic subsystem with Cuk converter has been designed. After that the simulink model with MPPT controller working on the principle of Incremental conductance algorithm has been modeled and the efficiency of this model with the fuzzy model was compared by considering various conditions of temperature and irradiance.

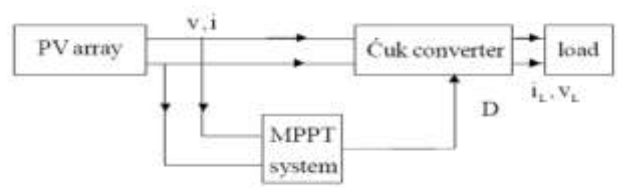

Fig -1: Simple model of proposed system

The simple model of the proposed system has been shown in Fig.1[4]. A Maximum Power Point tracking system contains a PV array, which is a solar panel formed with an array of solar cells. The power that is outputted by the PV array is given as input to the Cuk Converter circuit. Cuk Converter operates based on the commands of the MPPT System. The parameters of PV array like Current (I) and Voltage (V) are given as input to the MPPT System. Based on these parameters the MPPT system generates the output pulses. These pulses are used for switching purpose in the Cuk Converter, which controls the output power at the Cuk-Converter thus controlling the output power of the whole System.

2. MODELLING OF PV MODULE IN SIMULINK

A PV Subsystem is similar to a PV Module. A 5w panel is selected for experimentation whose specifications are listed in table 1.

Table1: Specifications of PV module considered for experimentation

V_{OC}	I_{SC}	Power	Rated Voltage(Vmax)	Rated Current(Imax)	Power oleran ce	N_p	N_s
21.06 V	1.39 A	20 W	17.40 V	1.20A	±5%	9	4

These parameters are measured at (STC) standard test conditions) 1000w/meter^2 and at 25^0 C.we have replicated the PV Panel in simulink using mathematical equations. The voltage-current characteristic equation of a solar cell is given as

$$I=I_{PH}-I_S[\exp q(V+IR_S)/kT_CA)-1]-(V+IR_S)/R_{SH} \quad (1)$$

Where I_{PH} is a light-generated current or photocurrent, I_S is the cell saturation of dark current, q (= 1.6 ×10^{-19}C) is electron charge, k (= 1.38 ×10^{-23}J/K) is a Boltzmann's constant, T_C is the cell's working temperature, A is an ideal factor, R_{SH} is a shunt resistance, and R_S is a series resistance. The photocurrent mainly depends on the solar irradiance and cell's working temperature, which is given as

$$I_{PH}=[I_{SC}+K_I(T_C-T_{Ref})]\lambda \quad (2)$$

Where I_{SC} is the cells short-circuit current at a 25°C and 1kW/m2, K_I is the cells short-circuit current temperature coefficient, T_{Ref} is the cell's reference temperature, and λ is the solar irradiance in kW/m2. On the other hand, the cell's Saturation current varies with the cell temperature, which is given as

$$I_s=I_{RS}(Tc/Tref)^3\exp[qEg(1/T_{ref}-1/Tc)/kA \quad (3)$$

Where I_{RS} is the cell's reverse saturation current at a reference temperature and a solar radiation Eg is the band gap energy of the semiconductor used in the cell. In general, the PV efficiency is insensitive to variation in R_{SH} and the shunt-leakage resistance can be assumed to approach infinity without Leakage Current to ground hence Equ 1 can be written as

$$I=I_{PH}-Is[\exp(q(V+IRs)/kTcA)-1] \quad (4)$$

Since a typical PV cell produces less power, the cells must be connected in series-parallel configuration on a module to produce enough high power as shown in Fig.2. A PV array is a group of several PV modules which are electrically connected in series and parallel circuits to generate the required current and voltage. The equivalent circuit for the solar module arranged in N_P parallel and N_S series.

$$I=NpI_{PH}NpIs[\exp(q(V/Ns+IRs/Np)/k)] \quad (5)$$

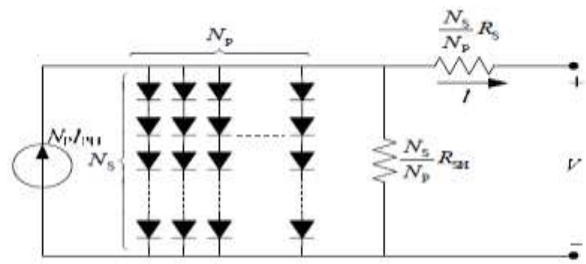

Fig -2: General model of a PV cell

The reverse saturation current can be obtained based on following equation

$$I_{RS}=Isc/[\exp(qVoc/NskATc)-1] \quad (6)$$

These equations can be implemented in simulink environment using blocks that perform mathematical operations.

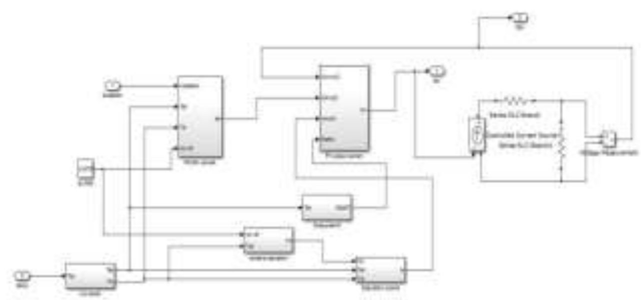

Fig -3: PV Module Block in simulink environment

The modeling of PV module in simulink environment is implemented as shown in Fig.3. Equ(2) is implemented using the mathematical blocks summers, multipliers in the Photon Current block as shown in the Fig.4.

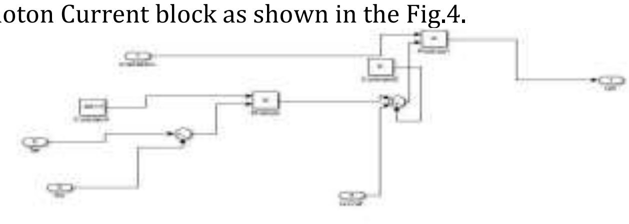

Fig -4: Photon current block

The I_{sc} reference value is the value that is given on the panel at a particular test condition. Here, in our case it is

0.075A because the I_{sc} value as per the panel specification is 0.3A and we have 4 cells in parallel in the panel. So, for each cell 0.075A will be the I_{sc} Value. Equ (3) is implemented in the Saturation Current block and all the required inputs for it are processed in C to Kelvin block and Reverse Saturation Block. Equ(6) is implemented in the reverse saturation block which is later given as input to the saturation current block. Equ(5) is implemented in the PV output current block whose inputs are all the previous values calculated in Fig.4.

3. MODELING OF DC-DC CUK CONVERTER IN SIMULINK

Photovoltaic panel generated voltage is fed to the converter and Cuk converter output connected to the load. By varying the duty cycle the voltage gain of Cuk converter can be set higher or lesser than unity. Although the buck–boost configuration is cheaper than the Cuk converter but it has limitations such as high peak and discontinuous input current, poor transient response and efficiency. The Cuk converter has low switching losses and the highest efficiency among non-isolated DC-DC converters. It can also provide a better output-current characteristic due to the inductor on the output stage. The practical circuit of Cuk converter using diode and MOSFET is shown in Fig.5

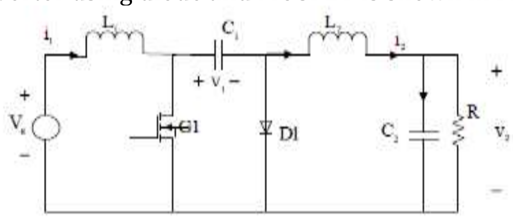

Fig -5:Cuk Converter Using Diode and MOSFET Switch

The values of the inductors and capacitors are calculated using the following expressions
$L_1 = (1-k)^2R/2kf$, $C_1 = k/2fR$
$L_2 = (1-k)R/2f$, $C_2 = 1/8fR$

Where Resistive load, R = 100Ω; k is duty cycle which is 0.5 and Switching frequency, f=1kHz.Basing on the above equations, the values obtained to produce maximum output are listed as Input inductor L1 = 5mH; Capacitor C1 (PV side) = 10μF; Filter inductor L2 = 5mH; Capacitor C2 (filter side) = 8mF

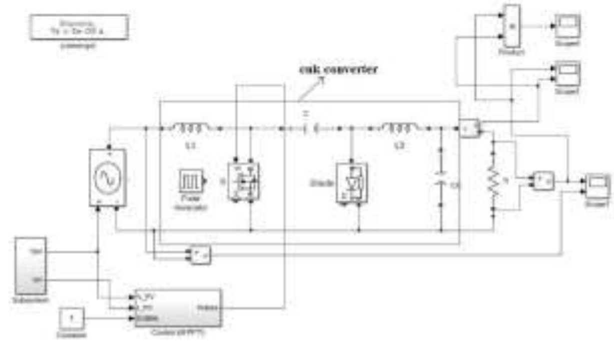

Fig -6: Simulink Model of CUK Converter

Fig.6.depicts the modeling of CUK converter. The PWM pulses generated in the MPPT block is fed as input to the IGBT diode. The IGBT(Insulated-Gate Bipolar Transistor) diode is 3-terminal semiconductor device used as an electronic switch. It provides high efficiency and fast switching. It is designed in order to turn on and off rapidly.

4. MODELING OF INCREMENTAL CONDUCTANCE MPPT ALGORITHM IN SIMULINK

The incremental conductance method can perform maximum power point tracking under rapidly varying irradiation conditions with higher accuracy than the Perturb and observe method[5]. The sampling frequency is decreased due to the higher complexity of the algorithm compared to the P&O method[6,7]. So we have to mitigate with a trade-off between complexity and efficiency. Hence we go for Incremental Conductance.

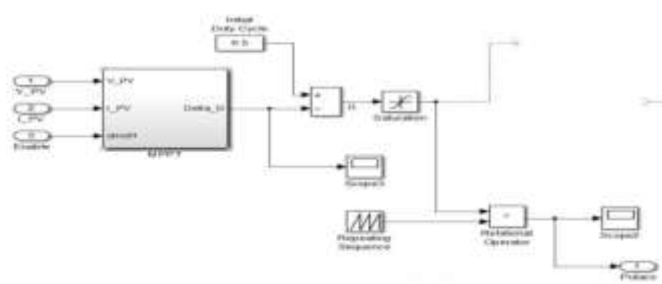

Fig -7: PWM signal generation

The MPPT block in the above Fig.7 has the algorithm implemented. The output of the MPPT block is duty cycle which is a constant. This value is compared with the initial duty cycle which is given a constant value of 0.5 so that it does not go to saturation stage. The duty cycle is compared with the repeating sequence to generate PWM pulses which is given as input to the CUK converter. The on/off PWM signal acts as a switch that switches ON and OFF the

CUK converter. The incremental conductance algorithm implementation is shown in the Fig.8.

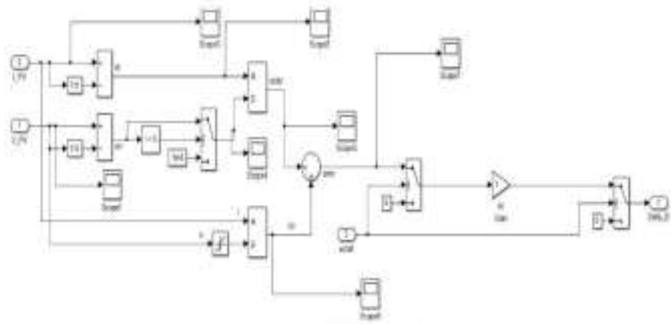

Fig -8: Incremental Conductance Algorithm using Simulink

5. MODELING OF FUZZY LOGIC BASED MPPT CONTROLLER IN SIMULINK

The proposed Fuzzy Logic Controller is implemented using the fuzzy logic toolbox of Simulink. The Fuzzy logic controller uses the fuzzy logics to make the decisions and to control the output of the controller. The main components in fuzzy logic based MPPT controller are fuzzification, rule-base, and inference and defuzzification as shown in Fig.9.

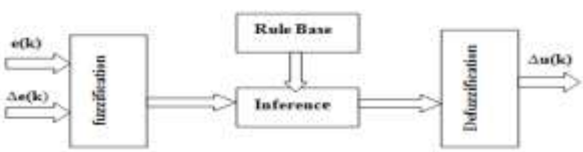

Fig -9: Fuzzy Logic block diagram

The fuzzy inference in the proposed model is carried out by using Mamdani's method, and the defuzzification uses the centre of gravity to compute the output of FLC which is the change in duty cycle. Based on the rule set and the membership functions we define for the inputs and output, the fuzzy logic controller will produce the output. Here all the inputs and outputs are defined as a range of values rather than a particular value. This makes Fuzzy logic MPPT algorithm more efficient than other algorithms. It generates more output power, less fluctuations and faster response.

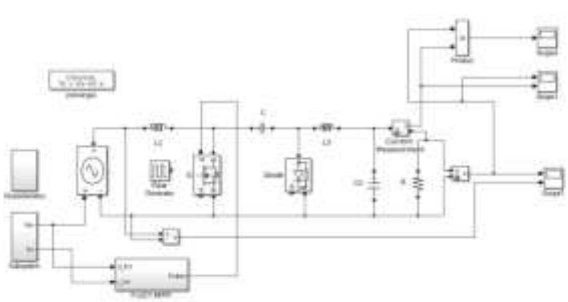

Fig -10: Fuzzy MPPT Simulink Model

The simulink model of fuzzy MPPT is shown in Fig.10.The MPPT block as shown in Fig.6 has been replaced with a fuzzy controller block to compare the operation of both controllers.

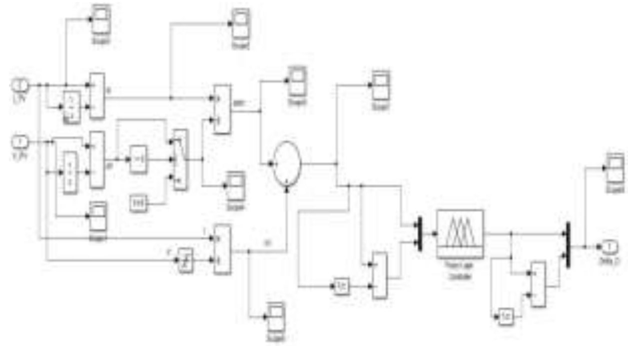

Fig -11: MPPT Block in Fuzzy logic MPPT

The main block in Fig.11 is Fuzzy logic Controller (FLC). A Fuzzy logic controller has two inputs namely Error (E) and Change in Error (CE). It has an output which is the duty cycle ratio. As we considered conductance as the measuring parameter the error is given by E= ΔI/ΔV +I/V and Change in Error is given by CE= E (K) –E (K-1). This is done using FIS Editor as shown in Fig.12.

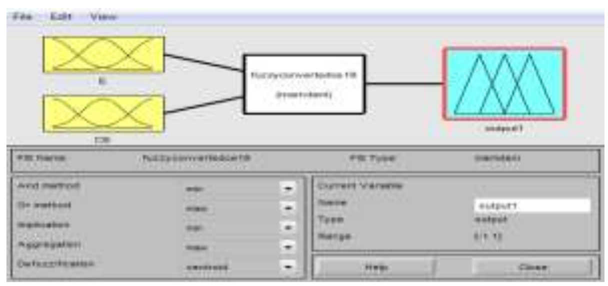

Fig -12: FIS Editor

6. RESULTS

Fuzzy logic systems consist of knowledge base, based on "if then rule set" and inference structure called fuzzy inference system. The fuzzy inference system combines fuzzy rules into a mapping function between input with it's output of the system using fuzzy reasoning methods The possible range is divided into 5 regions as *NB*-Negative big; *NS*-Negative small; *ZE*- Zero equal; *PS*-Positive small *PB*-Positive big hence there will be a 25 rule set. The rule set with membership functions as Error(E),Change in error(CE) at input and output duty cycle of the cuk converter are shown in Fig.13.

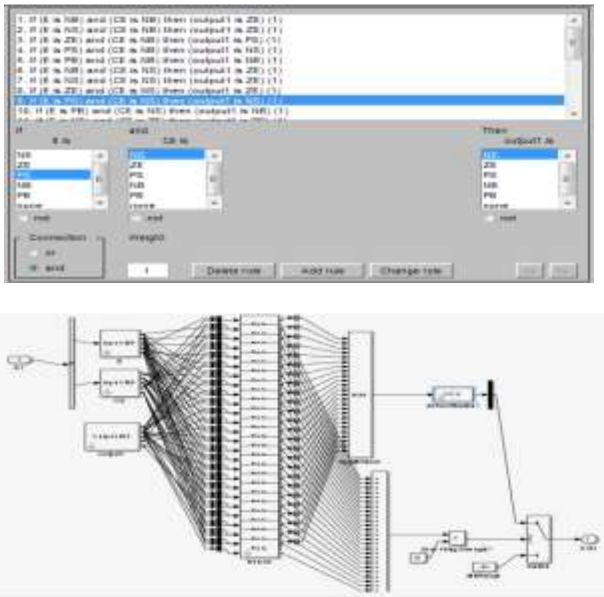

Fig -13: Defining rules in FIS editor with input membership functions E, CE and output membership function as Duty cycle.

The response from all fuzzy rules for the given input is combined together and is given as input to defuzzification process. The Rule Viewer presents a roadmap of the entire fuzzy inference process. It contains the input and output windows and each window have a vertical slider. By dragging the slider, the outputs for the corresponding current input values are displayed on the top of the window. The Surface Viewer is a three dimensional curve that displays the mapping of 3 parameters. The entire mapping between the inputs and the output can be seen in a single plot. The FIS Rule view and surface view are shown in Fig.14.

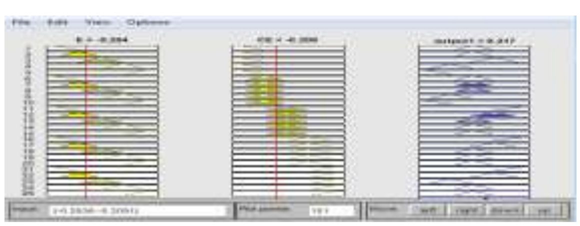

Fig -14: FIS Rule view

The performance of the proposed model is evaluated with a random variation in both temperature and irradiance. Temperature variation is over a range of 10^0c to 75^0c and irradiance variation is over a range of $100 w/m^2$ to $1200 w/m^2$.The input signal applied is shown in Fig.15 and the outputs obtained are shown in Figs.16-17 for voltage and current respectively. The converged response of characteristics of PV module is shown in Fig.18 where the maximum output power is 8.33W. The response of FLC controller is shown in Fig.19 where the maximum output power is 18.51W.

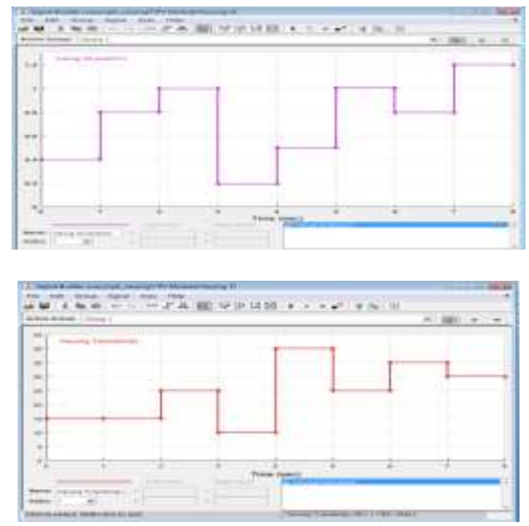

Fig -15: Test condition with varying irradiance and temperature

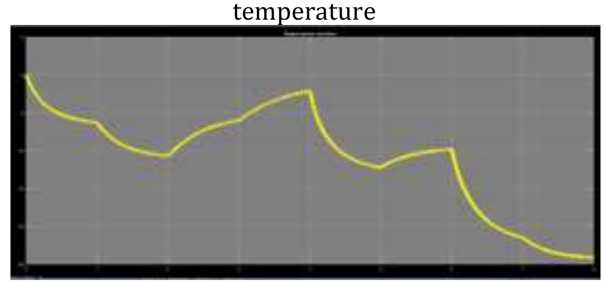

Fig -16: Output Voltage with varying irradiance and temperature for FLC

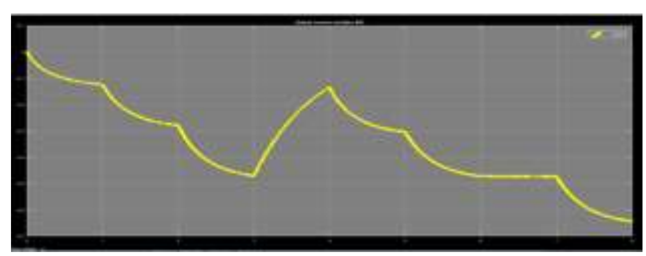

Fig -17: Output Current with varying irradiance and temperature for FLC

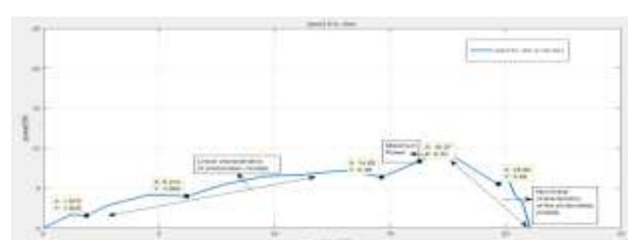

Fig -18: Converged response of Photovoltaic module

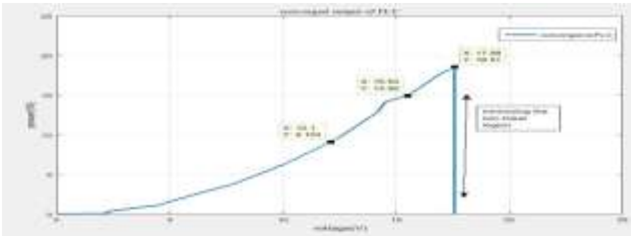

Fig -19: Converged response of Fuzzy logic controller

7. CONCLUSIONS

According to the proposed model we can observe that the Fuzzy Logic controller to attain maximum power using cuk converter achieves higher output power. Moreover the nonlinearities in the output power are minimized by adopting the proposed controller. The replacement of normal DC-DC converters with Cuk converter has reduced switching losses and the highest efficiency among non-isolated DC-DC converters.

REFERENCES

1. R.Kempener, P.Komor , A.Hoke, "Smart Grid and Renewables: A Guide for Efefctive Deployment.," International Renewable Energy Agency: IRENA, Masdar, 2013
2. P. Suskis and I. Galkin, "Enhanced PV Panel Model for MATLAB-Simulink Enviornment Considering Solar Cell Junction Capacitiance," in Industrial Electronics Society, IECON 2013 – 39th Annual Conference of the IEEE, pp. 1613-1618.
3. S.Mekhilefa,, R. Saidurb, A. Safari, "A Review on Solar Energy Use in Industries," Renewable and Sustainable Energy Reviews, vol. 15, p. 1777–1790, 2011.
4. Vladimir V.R.Scarpa,Simone Buso,Giorgio,Spiazzi,"Low Complexity MPPT technique Exploiting the PV module MPP locus characterization",IEEE Transactions on Industrial Electronics,vol.56,Issue 5,pp1531-1538,May 2009.
5. Manwell J.F, Rogers A. Hayman G., Avelar C.T., McGowan J.G., Hybrid2 A Hybrid System Simulation Model – Theory Manual, Renewable Energy Research Laboratory, Department of Mechanical Engineering, University of Massachusetts,1998, pp 105-117.
6. M. Bodur and M. Ermis, Maximum power point tracking for low power PV solar panels, in Proc. IEEE Electro Tech. Conf., 1992, vol.2, pp. 758–761.
7. K.S.Tam, P.Kumar, M.Foreman, "Enahncing the Utilization of Photovoltic Power Generation by Superconductive 3978xtremum Energy Storage.," IEEE Transactions on Energy Conversion, vol. 4, no. 3, pp. 314-321, 2002.
8. A.Denault, M.Hebabi, "Canadian Energy Security. What Does Energy Security Mean For Canada?," Capstone seminar on Canada and Renewable Energy, Canada's security and Intelligence Community., Ottawa, 2009-10.
9. J. H. R. Enslin, D. B. Snyman, Simplified feed-forward control of the maximum power point tracker for PV applications, Proc. Int. Conf. IEEE Power Electron. Motion Control, 1992, vol. 1, pp. 548–553.