Modeling and Analysis of Soft-Switched Interleaved Boost Converter for Photovoltaic System

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Abstract- *The global demand for electrical energy is constantly increasing while the production of fossil fuel based energy is declining and therefore the obvious choice of clean energy source which is abundant and could provide security for the future development is sun's energy. This paper presents the modeling and analysis of soft-switched interleaved boost converter for photovoltaic (PV) system with various maximum power point tracking (MPPT) techniques. The availability of solar energy varies widely with ambient temperature and different atmospheric conditions and hence the maximum power point (MPP) of PV system is not stable. Therefore, a MPPT controller is needed to operate the PV at its MPP. The both MPPT techniques fuzzy logic controller (FLC) and genetic algorithm (GA) are used to track MPP and it's implemented in a soft switched interleaved boosts converter. The performance comparison is made for these algorithms in terms of parameters like global peak, tracking speed and power extraction. The effectiveness of the proposed system is proved with the help of simulation. The simulation is performed in MATLAB/Simulink. From the simulation results, it shows that the proposed GA algorithm works properly to track the maximum power for PV system, estimate projected efficiency and to achieve high dynamic performance of the proposed system.*

Keywords- Photovoltaic Array (PV), Genetic Algorithm (GA), Maximum Power Point Tracking (MPPT), Soft-Switched Interleaved Boosts Converter.

I. INTRODUCTION

Today, the energy demand is moving on increasing toward generating power with renewable energy source that may be dispersed in a wide area, and most of them are renewable, as they have greater advantages due to their environmentally friendly nature. Photovoltaic (PV) energy has augmented interest in wide range of electrical power applications, since it is considered as a basically limitless and generally on hand energy resource with the focus on greener sources of power particularly for distant locations where utility power is engaged [1-4]. The solar can be used by all in universe which doesn't need more investigations of producing electricity [5-7]. Photovoltaic energy has increased interest in electrical power applications, since it is considered as a basically limitless and generally on hand energy resource.

However, the output power induced in the photovoltaic modules depends on solar irradiance and temperature of the solar cells. This makes the extraction of maximum power a complex task. The efficiency of the PV generation depends on maximum power extraction of PV system. Therefore, to maximize the efficiency of the renewable energy system, it is necessary to track the maximum power point of the PV array [8].

The PV array has a single in service point that can supply maximum power to the load. This point is called the maximum power point (MPP). The locus of this point has a nonlinear distinction with solar irradiance and the cell temperature. Thus, in order to operate the PV array at its MPP, the PV system must contain a maximum power point tracking (MPPT) controller.

Many MPPT techniques have been reported in the literature. The P&O method is an iterative algorithm to track the MPP by measuring the current and voltage of the PV module. This algorithm is easy to implement but the problem of oscillation of operating point around MPP is unavoidable and implementation of PWM control as discussed in [9-10]. INC method presented in [11] is most widely used method. It tracks the MPP by comparing instantaneous conductance to the incremental conductance.

Recently artificial intelligence methods which include Fuzzy and Neural Network have been applied to track. The fuzzy logic controllers have the advantages of robustness, simplicity in design and it does not need accurate mathematical model. The selection of parameters and membership function in fuzzy logic is not easy as it needs expert knowledge and experimentation as discussed in [12-14].

From all the above analysis, conclude that the objective of this paper is to analyze two different MPPT algorithms: fuzzy logic controller (FLC) and genetic algorithm (GA) being used to extract the maximum DC power from PV module various isolation and cell temperature. The functional block diagram is shown in Fig. 1.

II. PV ARRAY MODELING

In this model, the PV array used in the proposed system is 72 multi-crystalline silicon solar cells in series able to provide 150W of maximum power PV module and it is simulated as per datasheet. The single exponential model is shown in Fig 2.

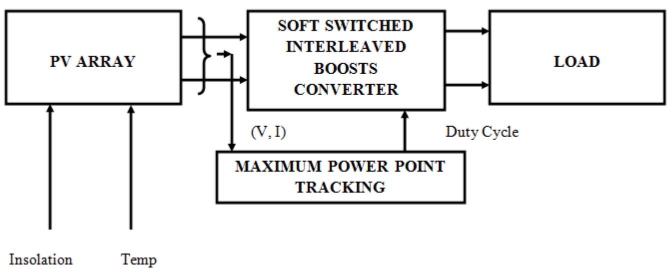

Fig.1 General Diagram of load connected photovoltaic system

In this model, a PV cell is represented by a current source in parallel with a diode and a series resistance, the basic current equation is given in Eq. (1).

$$I=I_{pv,\,cell}- I_{0,\,cell}\{[\exp\,(qv/akT)]-1\} \qquad (1)$$

Where $I_{pv,\ cell}$ is current generated by the incident light (directly proportional to sun irradiation), $I_{0,\ cell}$ is leakage current of the diode, q is electron charge 1.6021e10-19 C, k is Boltzmann constant, T is Temperature of the PN junction, a is Diode ideality constant is explained in [15-16]. To develop embedded simulink model based on current equation and manufacturer's data sheet as per parameter of BP SX 150S model.

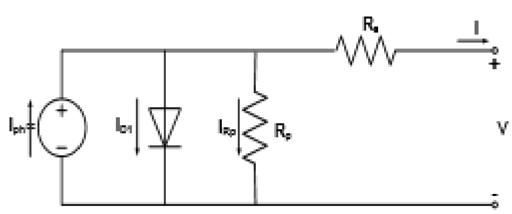

Fig. 2 Equivalent circuit of PV cell

III. FUZZY LOGIC MPPT CONTROL

The sudden changes of climate and the load associated to the panel with fast tracker algorithm is fuzzy logic and its flow chart is shown in Fig. 3.

In this paper the fuzzy inference rule is carried out by using Mamdani's method and the de-fuzzification use the centre of gravity to compute the output of this FLC which is the duty cycle. FLC system has two inputs and one output. The two FLC input variables are the error *E(k)* and change of error Δ*E(k)* at sampled times *k* defined. Where *P(k)* and *V(k)* are the instant power and voltage of the photovoltaic system respectively *E(k)* is zero at the maximum power point of PV array.

The input *E(k)* shows if the operation point at the instant *k* is located on the left or on the right of the MPPT on the PV Characteristic while the input Δ*E(k)* expresses the moving direction of this point. The objective of designed FLC is to track maximum power irrespective of panel voltage variations. Accordingly FLC uses two input variables: change in PV array Power *(*Δ*Pin)* and change in PV array voltage *(*Δ*Vin)* corresponding to the two sampling time instants and determining duty cycle of converter.

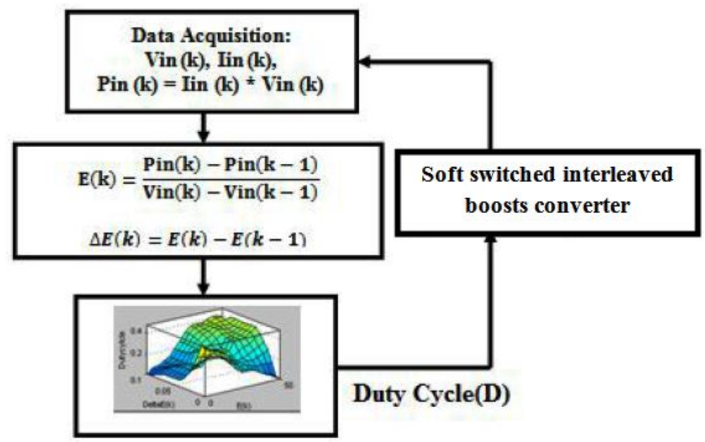

Fig. 3 Fuzzy Logic Control

IV. GENETIC ALGORITHM CONTROL

The genetic algorithm is a method for solving both constrained and unconstrained optimization problems that is based on natural selection, the process that drives biological evolution. The genetic algorithm repeatedly modifies a population of individual solutions. At each step, the genetic algorithm selects individuals at random from the current population to be parents and uses them to produce the children for the next generation.

Over successive generations, the population "evolves" toward an optimal solution. The application of the genetic algorithm to solve a variety of optimization problems that are not well suited for standard optimization algorithms, including problems in which the objective function is discontinuous, non - differentiable, stochastic, or highly nonlinear [17-18].

The MPPT algorithm based on GA Genetic Algorithm (GA) is an optimization system that resembles natural genetics. Using this method, an optimal set of parameters is resolute based on a "survival of the fittest" principle. In fact, there are three basic operators concerned in the look for procedure of a GA: selection, crossover, and mutation. Selection is a method which chooses a genetic material from the current generation's population for enclosure in the next generation's population according to their fitness. Crossover operator combines two chromosomes to produce a new genetic material.

Mutation operator maintains genetic diversity from one generation of population to the next and aims to achieve some stochastic dissimilarity of GA in order to get an earlier convergence to solve this problem customized the algorithm by resetting the first population whenever it detects a variation of irradiance and cell temperature. Accordingly, the GA is reinitialized every time the following two conditions are satisfied as given in Eq. (2) and Eq. (3).

$$|V(K+1)-V(K)| < \Delta V \qquad (2)$$

$$|[Ppv(k+1)- Ppv(k)]/ Ppv(k)|>\Delta P \qquad (3)$$

The chromosomes position corresponds to the desired output voltage at iteration (*k*). The initial population that is composed by chromosomes parents includes four individuals which are applied successively. The initial positions of this population are given by Eq. (4).

$$[P1, P2, P3, P4] = [0.8, 0.6, 0.4, 0.2]\ Voc. \qquad (4)$$

The fitness is the generated power *Ppv*, it is sorted decreasingly, and the criterion of selection is performed by elitism. The crossover step consists of combining two chromosomes parents to produce a child. In fact, this step is based on Eq. (5) and Eq. (6).

$$child\ (k) = r.P\ (r) - (1 - r).P\ (k + 1) \qquad (5)$$

$$child\ (k + 1) = (r - 1).P\ (k) - (r).P\ (k + 1) \qquad (6)$$

where, r is a random number. The relation between the output voltage and the duty cycle of the ISSBC is written as Eq. (7).

$$a(k) = child(k)/Voc. \qquad (7)$$

In this work, to take into account the step of mutation regardless it impact on the convergence of the dynamic response and the apparition of oscillations, and this is due to the sequential aspect of chromosomes. Based on the GA equation MATLAB programmed and embedded in user interface function, initialized in simulation system.

V. SOFT SWITCHED INTERLEAVED BOOSTS CONVERTER

The interleaved boost inverter consists of two single-phase boost inverters that are linked in parallel and inverters operating 180 degrees out of phase with 30 kHz switching frequency. Interleaved converter mode 60 kHz effect is achieved by phase shifting of the two 30 kHz switching signals [19]. Because the inductor ripple currents are out of phase, they cancel each other and the input-ripple current reduce to 12% of that of a conventional boost inverter.

The best input-inductor-ripple-current deletion occurs at 50% duty cycle. Therefore, the interleaved inverters have the wider continuous current mode, the condensed input current ripple and output voltage ripple, and lower switching losses, therefore the output voltage of the solar cell can be boosted with high effectiveness. The soft switched interleaved boosts converter diagram is shown in Fig. 4.

The interleaving technique requires that each converter connected in parallel operates at the same switching frequency. The switching, current and voltage waveform of soft switched interleaved boosts converter diagram is shown in Fig. 5. As seen in Fig. 5, the input current ripple is reduced and the input current ripple frequency becomes 2 times higher than the switching frequency. The operation modes of the proposed Soft switched interleaved boosts converter have voltage are in discontinuous and current are continuous in nature.

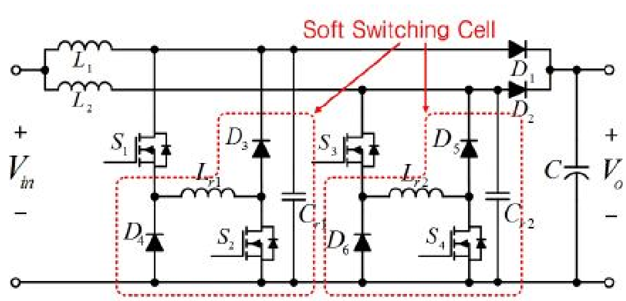

Fig. 4 Proposed Soft switched interleaved boosts converter

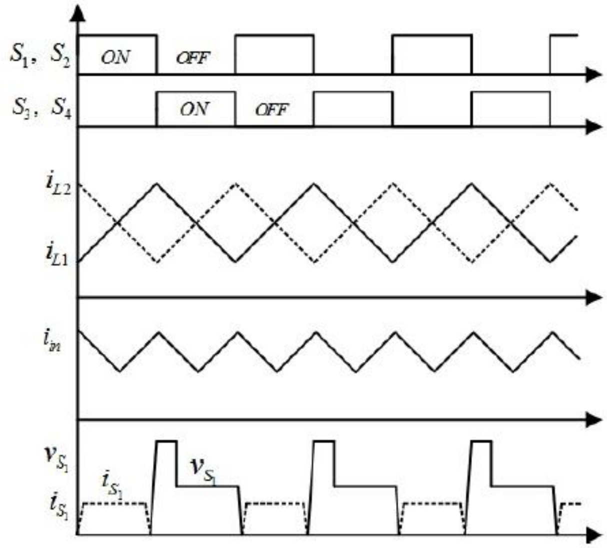

Fig. 5 Switching patterns, voltage and current waveforms.

VI. SIMULATION RESULS AND DISCUSSION

The PV module parameters are obtained from the 150 Watts Multi-crystalline PV Module technical datasheet. All algorithm tests were performed considering the same temperature and irradiation steps. Such parameters are considered at the Standard Test Condition are 1000 W/m^2 and cell temperature of 25 ºC. First the characteristics of the PV module are validated and connected with soft switched interleaved boosts converter, and then the performance of the MPPT techniques under various conditions is evaluated to investigate the output power efficiency. The simulation validation of PV module and converter results of the I-V and P-V characteristics of PV module as a function of irradiation and temperature shown in Figs. 6 and 7. It can be observed quite similar to the 150 watts PV module as per data sheet. The sampling time considered is equal to 0.02*s*, and the switching frequency is chosen equal to the 30 kHz.

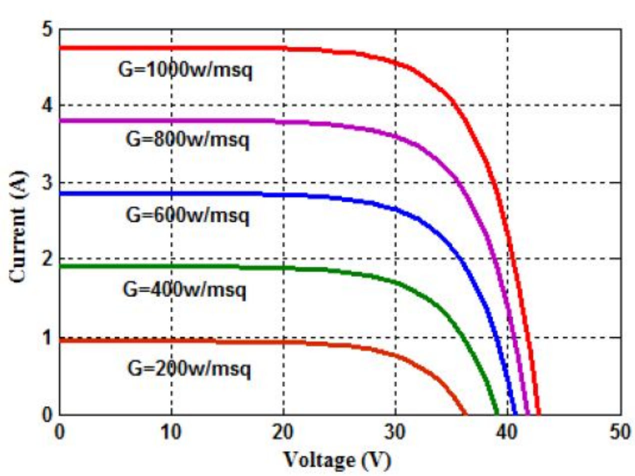

Fig. 6 I-V curve of solar radiation

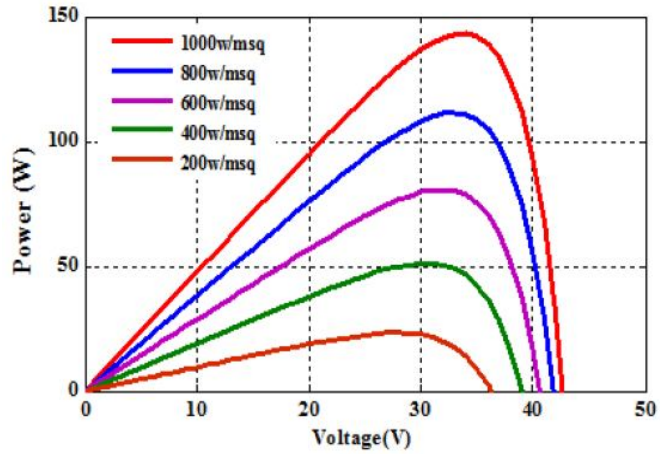

Fig. 7 P-V curve of solar radiation

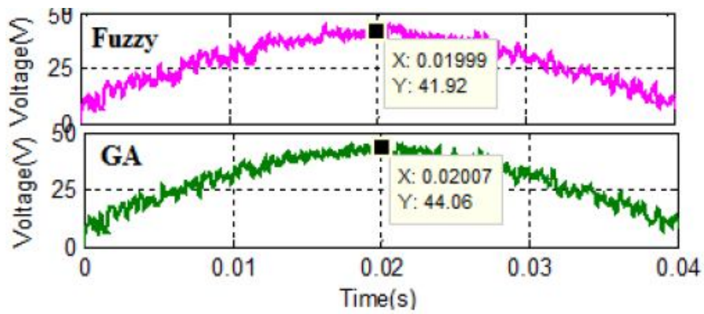

Fig. 8 Simulation of slowly changing irradiance with fuzzy and GA MPPT algorithm

The simulation result of slowly variation with ripple irradiation, in view of a real condition, the solar irradiance varies from a certain minimum value to the maximum value and then goes down to a different minimum value. A parallel pattern is also appropriate for the PV cell temperature. To simulate a real time situation, the solar irradiance and temperature is different consequently as shown in Fig. 8. The solar irradiance is varied from nearly 200 to 200 *W/m* with a peak value of 1000 W/m^2 and with a 4% ripple. The temperature is varied from 15 º*C* to 55 º*C* and back to 15 º*C*.
The simulation result of dynamic varying the solar radiation, the simulations are carried out of two techniques under dynamically changes solar irradiations at temperature of 25 º*C*. Fig. 9 shows the isolation variation of the proposed system.

Fig. 10 shows output voltage of sudden changes in solar irradiation from 600 to 1000 W/m^2. The fuzzy power is equal to 59.03 at 600W/m^2 and the GA power extracted 62.28 watts at 600 W/m^2 fast responses to reach the new MPP after solar irradiation changes. Higher power extracted from GA controller compare to fuzzy controllers.

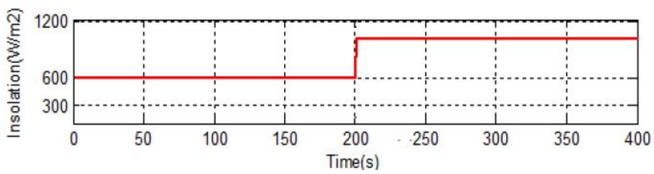

Fig. 9 Simulation of isolation variation of proposed system

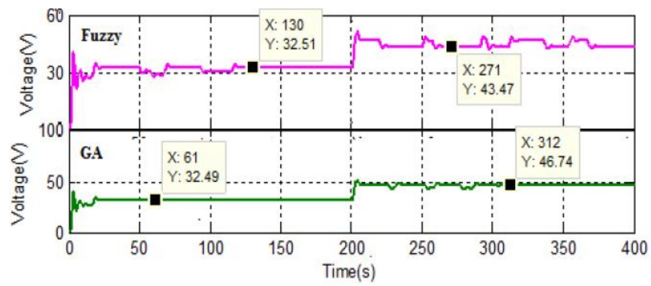

Fig. 10 Simulation of dynamic variation of irradiation with fuzzy and GA MPPT algorithm

VII. CONCLUSION

The modeling and analysis of soft-switched interleaved boost converter for photovoltaic system is implemented. The configuration for the proposed system is designed and simulated using MATLAB/Simulink. Due to the importance of PV systems especially in green energy field, this paper introduces an efficient identification method for maximum power point (MPP) function for photovoltaic (PV) module using fuzzy logic controller and the genetic algorithm (GA). The proposed GA algorithm shows good dynamic performance to track the MPP of the PV even under the rapid change of the irradiation and cell temperature. The soft switched interleaved boosts converter can be more efficient than the conventional converter. The soft switched interleaved boosts converter with GA can provide the overall efficiency of about 98% which is higher than other algorithms due to decreasing the frequency of operation and switching losses and the response time is also less as compared to other algorithms. The results obtained are encouraged to use the soft switched interleaved boosts converter with GA in applications such as PV generation system. The simulation result also proves the effectiveness of the proposed genetic algorithm which uses maximum power point tracking. The results clearly show that the proposed topology can effectively work as a genetic algorithm based maximum power point tracking for photovoltaic system.

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