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An Interleaved Boost converter with FLC based MPPT for a PV system

M. Deepika[1], M. Marimuthu[2], B. Paranthagan[3], L.Akila[4]

M.E student, Electrical and Electronics Engineering, Saranathan College of Engineering, Trichy, India[1,4]

Assistant Professor, Electrical and Electronics Engineering, Saranathan College of Engineering, Trichy, India[2,3]

Abstract: In this paper FLC based Maximum Power Point Tracking (MPPT) is proposed to an Interleaved Boost Converter for a Standalone PV system. This topology used to raise the efficiency of the PV power conditioning system. It minimizes switching losses and overall efficiency is increased when compared with the conventional Boost converter. FLC based Maximum power point tracking gives accurate tracking of operating points and fast transient response despite fluctuating atmospheric conditions. The evaluation of the performance has been carried out by using Matlab/Simulink.

Keywords: Conventional Interleaved Boost converter (IBC); Maximum Power Point Tracking (MPPT); Fuzzy logic controller (FLC).

I. INTRODUCTION

Photovoltaic (PV) generation is becoming increasingly important as a renewable source since it offers many advantages such as incurring no fuel costs, not being polluting, requiring little maintenance, and emitting no noise, among others. PV modules still have relatively low conversion efficiency due to the nonlinear V-I and P-V characteristics, which depend on the irradiance, the operating temperature and load condition of the cell.

Therefore, high efficiency is required for the power conditioning system (PCS), which transmits power from the PV array to the load. In general, a single-phase PV PCS consists of two conversion stages (i.e., DC-DC conversion stage and DC-AC conversion stage).

The DC-DC converter is the first stage and it has to control the variation of the maximum power-point of the solar cell output. In other words, modulation of the duty ratio of the DC-DC converter controls maximum power point tracking (MPPT). The most famous one is called Perturbation and observation (P&O) controller. But this method has presents limitations to track maximum power point as fast as possible to reduce oscillations in output power.

In order to increase the overall efficiency of PV power conditioning system, an Interleaved boost converter (IBC) is utilized, which consists of two single phase boost converters connected in parallel with better efficiency for high power applications, and having low conduction loss (I^2R) by splitting the input current path into two and reduced output voltage ripple by doubling the ripple frequency at the output capacitor where two phases are combined. Therefore, the output power of the PV array can be boosted with high efficiency.

The proposed topology uses the Fuzzy Logic based Maximum power point tracking to have a greater degree of control over the PV system to harness optimal energy.

II. PROPOSED TOPOLOGY

A. Block Diagram

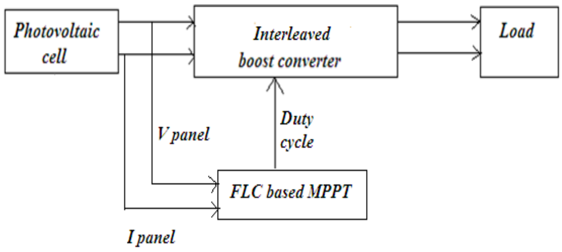

Fig. 1. Block Diagram

In this the insolation is sensed and it is given to the Fuzzy logic controller. And the Fuzzy logic controller will deliver the duty cycle to an interleaved boost converter corresponding to that particular insolation level. An Interleaved Boost Converter consists of two single-phase boost converters connected in parallel. The two PWM signal difference is 180◦ when each switch is controlled with the interleaving method.

Because each inductor current magnitude is decreased according to one per phase, we can reduce the inductor size and inductance when the input current flows through two boost inductors. The input current ripple is decreased because the input current is the sum of each current of inductor.

An interleaved design involving parallel operation of two boost converters was evaluated as a means to reduce the burden on the output capacitor as well as the form factor and weight of the inductor.

Additional benefits of interleaving include high power capability, modularity, and improved reliability of the converter. An interleaved topology, however, improves converter performance at the cost of additional inductors and power switching devices.

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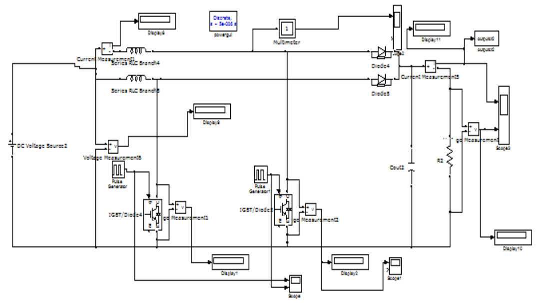

Fig. 2. Simulink model of Interleaved Boost Converter

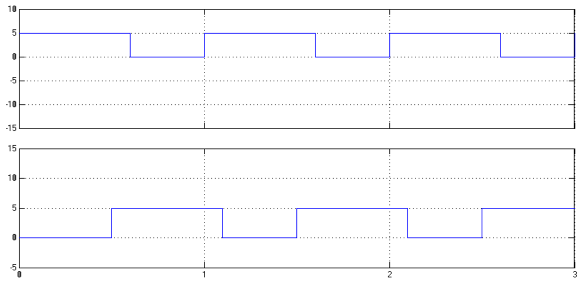

Fig. 3. Pulse generation for Interleaved Boost Converter

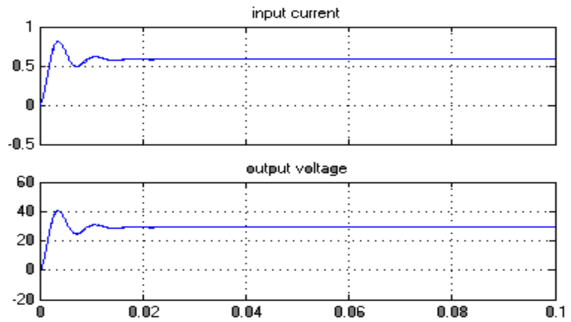

Fig. 4. Input current and Output voltage waveform of IBC

III. MAXIMUM POWER POINT TRACKING

A typical solar panel converts only 30 to 40 percent of the incident solar irradiation into electrical energy. Maximum power point tracking technique is used to improve the efficiency of the solar panel. According to Maximum Power Transfer theorem, the power output of a circuit is maximum, when the impedance of the circuit (source impedance) matches with the load impedance. Hence our problem of tracking the maximum power point reduces to an impedance matching problem. In the source side, an Interleaved Boost Converter is used, which is connected to a solar panel in order to enhance the output voltage so that it can be used for different applications like motor load. By changing the duty cycle of the IBC appropriately we can match the source impedance with that of the load impedance.

A. Perturb and Observe

Perturb & Observe (P&O) is the simplest method. In this we use only one sensor, that is the voltage sensor, to sense the PV array voltage and so the cost of implementation is less and hence easy to implement. The time complexity of this algorithm is very less but on reaching very close to the MPP it doesn't stop at the MPP and keeps on perturbing on both the directions. When this happens the algorithm has reached very close to the MPP and we can set an appropriate error limit or can use a wait function which ends up increasing the time complexity of the algorithm. However the method does not take account of the rapid change of irradiation level (due to which MPPT changes) and considers it as a change in MPP due to perturbation and ends up calculating the wrong MPP. To avoid this problem we can use FLC based MPPT.

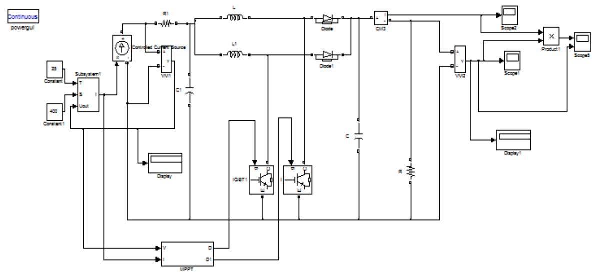

Fig. 5. Design of FLC MPPT on Interleaved Boost converter

B. Fuzzy Logic based MPPT Controller

Unlike Boolean logic which the state value of any variable is either 0 or 1, fuzzy logic allows states between them. More specifically, that's call membership value. The grade of membership value of fuzzy variable can be described in linguistic term. Fuzzy logic control is a control algorithm based on a linguistic control strategy, which is derived from expert knowledge into an automatic control strategy. The operation of a FLC is based on qualitative knowledge about the system being controlled .It doesn't need any difficult mathematical calculation like the others control system. While the others control system use difficult mathematical calculation to provide a model of the controlled plant, it only uses simple mathematical calculation to simulate the expert knowledge.

The requirement for the application of a FLC arises mainly in situations where:

1. The description of the technological process is available only in word form, not in analytical form.
2. It is not possible to identify the parameters of the process with precision.
3. The description of the process is too complex and it is more reasonable to express its description in plain language words.
4. It is not possible to precisely define these conditions.

A fuzzy logic controller has four main components as shown in Figure:
1. Fuzzification
2. Inference engine
3. Rule base
4. Defuzzification

1. Fuzzification

The first step in designing a fuzzy controller is to decide which state variables represent the system dynamic performance must be taken as the input signal to the controller. Fuzzy logic uses linguistic variables instead of numerical variables. The process of converting a

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numerical variable (real number or crisp variables) into a linguistic variable (fuzzy number) is called fuzzification.

2. Rule base

A decision making logic which is, simulating a human decision process, inters fuzzy control action from the knowledge of the control rules and linguistic variable definitions. The rules are in "If Then" format and formally the If side is called the conditions and the Then side is called the conclusion. The computer is able to execute the rules and compute a control signal depending on the measured inputs error (e) and change in error (ce). In a rule based controller the control strategy is stored in a more or less natural language. A rule base controller is easy to understand and easy to maintain for a non-specialist end user and an equivalent controller could be implemented using conventional techniques.

3. Inference engine

Inference engine is defined as the Software code which processes the rules, cases, objects or other type of knowledge and expertise based on the facts of a given situation. When there is a problem to be solved that involves logic rather than fencing skills, we take a series of inference steps that may include deduction, association, recognition, and decision making. An inference engine is an information processing system (such as a computer program) that systematically employs inference steps similar to that of a human brain.

4. Defuzzification

The reverse of Fuzzification is called Defuzzification. The use of Fuzzy Logic Controller (FLC) produces required output in a linguistic variable (fuzzy number).

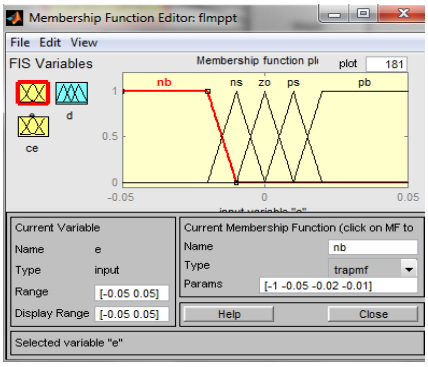

Fig. 6. Membership function of input variable error

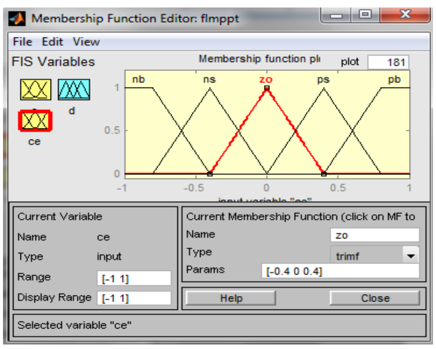

Fig. 7. Membership function of input variable change of error

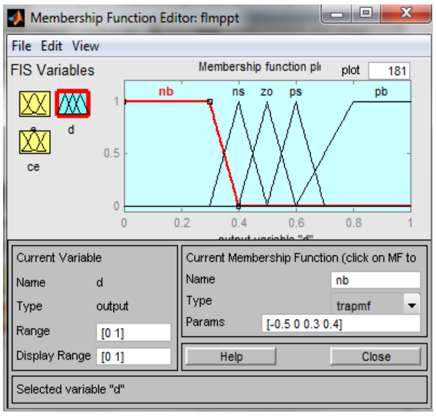

Fig. 8. Membership function of output variable duty cycle

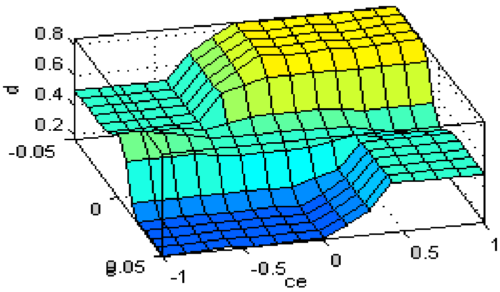

Fig. 9. Surface analysis of FLC based MPPT

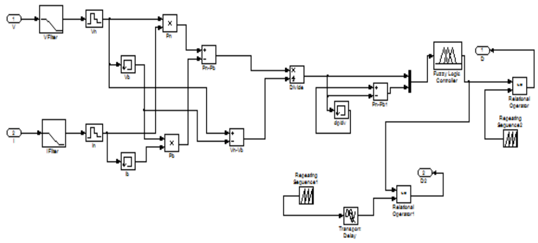

Fig. 10. Design of FLC based MPPT

IV. RESULTS AND DISCUSSIONS

In this section, simulation results for Interleaved Boost converter with FLC based MPPT are shown. The results are analyzed based on output voltage ripple, input current ripple and output voltage deviation. The simulation had been test for variable insolation ranges from 100(W/m^2) Volt to 1000(W/m^2).

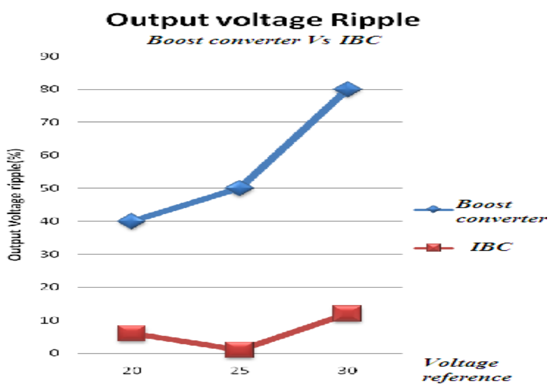

Fig. 11. Comparision of output voltage ripple for IBC and Boost converter

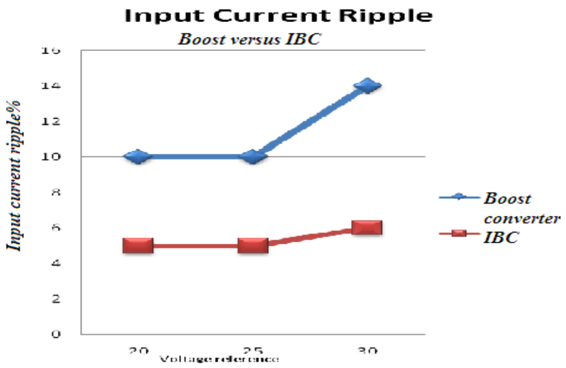

Fig. 12. Comparision of Input Current ripple for IBC and Boost converter

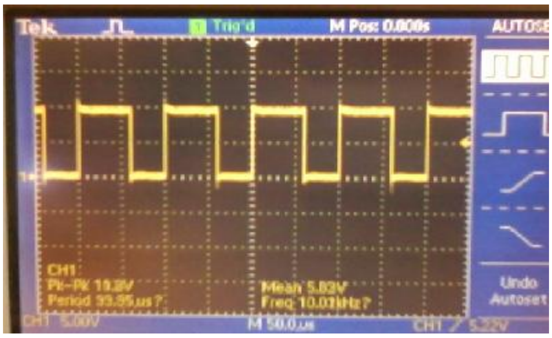

Fig. 13. Pulse generation using driver for IBC

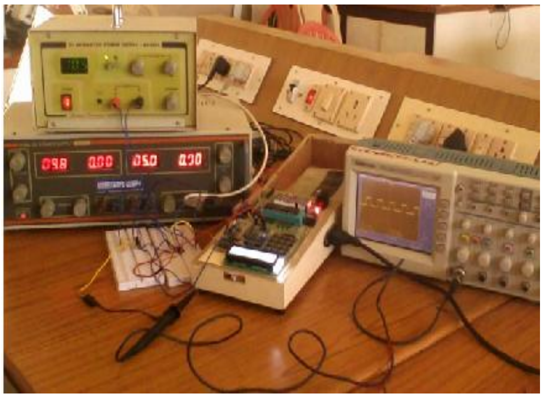
Fig. 14. Pulse generation using microcontroller for IBC

V. CONCLUSION

The proposed Interleaved Boost Converter having less output voltage ripple and input current ripple, as a result the filter requirements will be less. A fuzzy based MP point tracking is developed for the IBC- supplied PV system. The transient response is much higher than all other algorithms. This will make the resulting system to settle at new operating point very sooner.

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