

Implementation of MPPT Controller in Solar PV Using Jaya Algorithm

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Abstract: This paper develops a Jaya-based maximum power point tracking (MPPT) method for photovoltaic (PV) arrays working under variable partial shading conditions. In practice, the Jaya is deployed in the inverter to obtain the optimal voltage setting for MPPT through an efficient iterative interaction with the PV system. A simulation study is conducted to validate the effectiveness of the proposed method in tracking the global maximum power point (GMPP) of PV arrays exposed to various partial shading patterns. A prediction model is incorporated into the iterative search process to guide the update of candidate solutions (operating voltage settings) in the Jaya and such extension is capable of improving the tracking performance. The performance of the proposed method is benchmarked with P&O which is the most frequently utilized optimization algorithm for PV MPPT. Simulation results illustrate that the proposed method requires less iterations to converge to the GMPP and shows higher dynamical tracking efficiency than P&O methods.

Keywords: Boost Converter, Maximum power point tracking, Perturbation and observation, PV Modelling

1. Introduction

The application of photovoltaic (PV) has achieved an exponential rise for past two decades from off-grid to grid connected PV systems. The electric energy produced by the PV array can be utilized in the best way by delivering it directly to utility grid, without using storage system (battery banks) [1]. The performance analysis of newly developed systems requires mathematical functional models for PV module research. Field professionals do not readily adopt these developed systems for minimising failure rate. Therefore, it requires simplified Simulink modelling of PV module for analysis purpose. In the literature [2–11] basic structure of single diode PV system have been represented. For adjusting the I-V curve by using artificial intelligence [12, 13] some authors have put forward some indirect methods. Although interesting but these methods are complex, inapplicable and needs more calculation. Modelling was confined to PV module characteristics simulation in all the above. The mathematical expressions determining the PV module (as well as PV cell) are also represented. For each expression, Simulink model is represented with numerical results for constant irradiation values (1000W/m²) and temperature. When building a new photovoltaic power system it is very important to consider maximum power point tracking (MPPT) as it is required for extraction of maximum power output from a PV array under varying atmospheric conditions

for maximum power output. Many researchers and industry delegates from all over the world have developed several MPPT algorithms. Some of these algorithm like perturbation and observation(P&O) method, fuzzy logic control method, linear approximation method, incremental conductance method, voltage feedback method, hill climbing method, actual measurement method and so on [14], [15]. Appropriate MPPT method along with good weather conditions are required for implementing maximum performance of a photovoltaic system [9]-[11]. This paper mainly focuses on studying and comparing execution efficiency, advantages, disadvantages for two power-feedback type MPPT methods, including perturbation & observation (P&O) and fuzzy logic (FL) methods. For implementation of modelling and simulations tasks, and to compare execution efficiency and accuracy for selected MPPT methods Matlab/Simulink is used in this paper.

2. Designing of PV module

A. Equivalent circuit

The Fig. 1, represents a single diode model which is widely used as compared to other PV module design. In this circuit, R_{sh} is shunt resistance, I is open circuit current of a solar cell, I_0 is diode saturation current, I_{ph} is the light-generated current which depends upon solar radiation and cell temperature, I_{sh} is shunt resistance current which flows through R_{sh} and flows between the n and p layers, R_{se} is series resistance which represents the losses due to flowing current across highly resistive emitter and contacts, V_{oc} is terminal voltage of a solar cell, respectively.

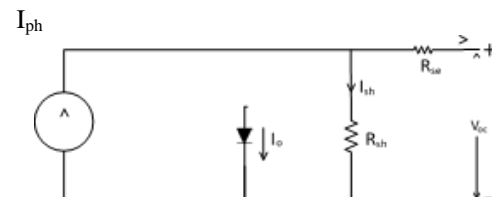


Fig. 1. Solar cell equivalent circuit

In this circuit the mathematical expression for cell current in single diode model is obtained by applying KCL,

$$I = I_{ph} - I_0 - I_{sh} \quad (1)$$

Where,

$$I_{ph} = [I_{sc} + K_i (T_k - T)] * G / 1000 \quad (2)$$

I_{ph} is photocurrent under standard test conditions (STC), with reference solar radiation of $1000 W / m^2$ at solar spectrum of $1.5A$ and reference temperature of solar cell T_k of $25^\circ C$. T is instantaneous solar cell temperature, K_i is current temperature coefficient and G is an instantaneous solar radiation.

B. Module Reverse Saturation Current (I_{rs})

Module reverse saturation current, I_{rs} , is expressed as,

$$I_{rs} = I_{sc} / [exp(q * V_{oc} / N_s * k * A * T) - 1] \quad (3)$$

Where q is the electron charge ($1.6 \times 10^{-19} C$), V_{oc} is Solar module open-circuit voltage ($21.24V$), N_s is the number of cells connected in series (36), A is the ideality factor ($A=1.6$). and k is the Boltzmann constant ($k= 1.3805 \times 10^{-23} J/K$).

C. Module Saturation Current (I_0)

Variation of module saturation current I_0 takes place with respect to cell temperature. It is expressed as, $I_0 = I_{rs} [T/Tr]^{3 * exp[q * E_{g0} / A * k * ((1/Tr) - (1/T))]}$ (4) Where E_{g0} is the band gap energy of semiconductor (For polycrystalline Si at $25^\circ C$, $E_{g0}=1.1 eV$). Simulation of equation (4) has been done and represented in Fig. 4. Here, the inputs are module reverse saturation current, module operating temperature and reference temperature.

D. Module Output Current (I_{pv})

The PV module output current of single diode model is I_{pv} represented in Fig. 1 is described by a basic equation and is expressed as,

$$I_{pv} = N_p * I_{ph} - N_p * I_0 [exp\{q * (V_{pv} + I_{pv} * R_{se}) * N_s * A * k * T - 1\}] \quad (5)$$

E. Simulink Model of I_{pv}

Inputs for this model are insolation, V_{PV} is varied from 0 to $21.5V$. With the help of setup shown in Fig. 5, Simulink model of I_{pv} is simulated.

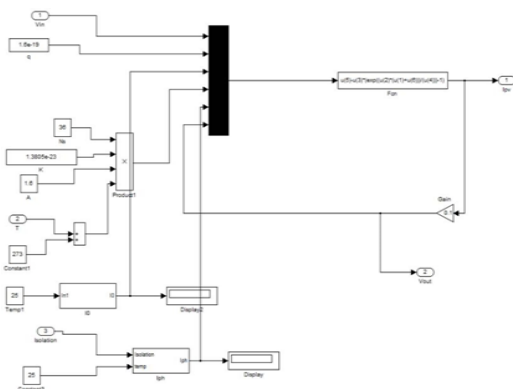


Fig. 2. Simulation module output current I_{pv}

To get the I-V and P-V characteristics of I_{pv} model under varying irradiation with constant temperature and constant irradiation with varying temperature, simulation steps have been discussed in details.

3. PV maximum power extraction system design

The PV module output power changes significantly as there is variation in irradiation and temperature. To extract the maximum power of from solar photovoltaic module and transfer this power to the load, the maximum power point (MPPT) algorithm is used [15]. To transfer the maximum power of the PV module to the load, a DC-DC converter is used as shown in Figure 14, which acts as an interface between the load and the module. Here, step up/step down type DC-DC Converter is used. The load impedance as seen from source side is changed by varying the duty cycle of PWM control signal and hence it coincides with the maximum power point of the source to transfer the maximum power.

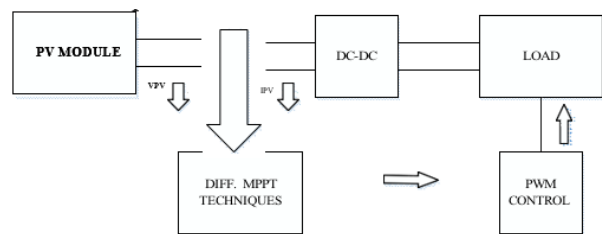


Fig. 3. Block diagram of the DC-DC converter for MPP operation

A. Power electronic circuit

To obtain the maximum performance of the maximum power point, PV modules are always used with DC-to-DC converters. Buck, boost, and buck-boost are types of converters used for this purpose. For grid-connected applications boost converter is used whereas buck-boost configuration is used for battery charging applications. Fig. 4. represents the configuration of boost converter and it is composed of load resistance R, filter capacitor C, diode D, control switch S, boost inductor L, and DC input voltage source V_s .

The voltage gain of boost converter when switch operated with a duty ratio D is expressed as,

$$M_v = V_o / V_s = 1 / (1 - D) \quad (6)$$

Where V_o is output voltage, V_s is input voltage, and D is duty cycle of PWM (pulse width modulation) signal and used to control ON and OFF states of MOSFET.

Table 1
 Electrical Parameters of 250W Panel
 DC-to-DC boost converter component values

Description	Rating
Switching frequency	20 kHz
Power diode	1N5408
MOSFET	IRF P460
Capacitor	330 μF
Resistive Load	50 Ω , 50W
Inductor	120 μH

For value of inductance $L > L_b$, the operation of boost converter is in continuous conduction mode.

$$\text{where, } L_b = (1 - D^2) DR / 2f \quad (7)$$

Where L_b is smallest inductance value required for

continuous conduction. As current supplied to output RC circuit is discontinuous. Therefore, to limit the output ripple voltage a large filter capacitor is required. C_{min} is minimum value of filter capacitor. It supplies output DC current to the load when diode D is off. The smallest value of filter capacitance results in ripple voltage V_c and it is expressed as,

$$C_{min} = DV_o / V_r R F \quad (8)$$

The Table 1 gives the DC-DC boost converter design component values which are used for simulation.

B. Design of MPPT

The Fig. 7 shows the DC-DC converter (with component values in Table 1 and configuration given in Fig. 4, simulation with battery supply.

The solar cell has very low efficiency. Therefore, to boost the efficiency some methods are implemented to balance the source and load properly. Maximum Power Point Tracking (MPPT) method is one of the methods which are used to obtain the maximum possible power from a variable source. It is difficult to use photovoltaic systems to power certain load because the I-V curve in photovoltaic systems is non-linear. So boost converter is used and its duty cycle is varied by using a MPPT algorithm. By the help of simulation with developed circuit model the data is collected for the design of MPPT. The results are represented in Table 2.

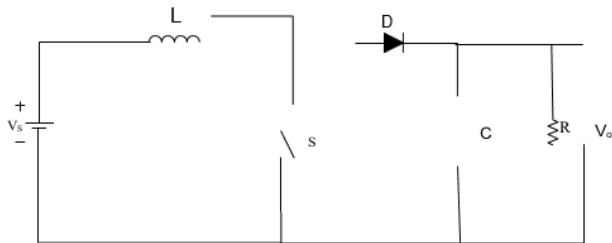


Fig. 4. DC to DC boost converter configuration

C. MPPT techniques

For maximum power point tracking many methods are used. Some of the methods are:

- Constant Current method
- Constant Voltage method
- Parasitic Capacitance method
- Incremental Conductance method
- Perturb and Observe method

D. Perturb and Observe method

It is widely used method. Minimum sensors are used in this method. In this method, sampling of operating voltage is done and operating voltage is changed in a specific direction by using algorithm and therefore it samples dP/dV . The algorithm increases the voltage value towards MPP until dP/dV is negative if dP/dV is positive. This iteration continues until the algorithm arrives at MPP. When there is a large variation in solar irradiation then this algorithm is not suitable. The voltage

perturbs around the maximum power point (MPP) and never actually reaches an exact value.

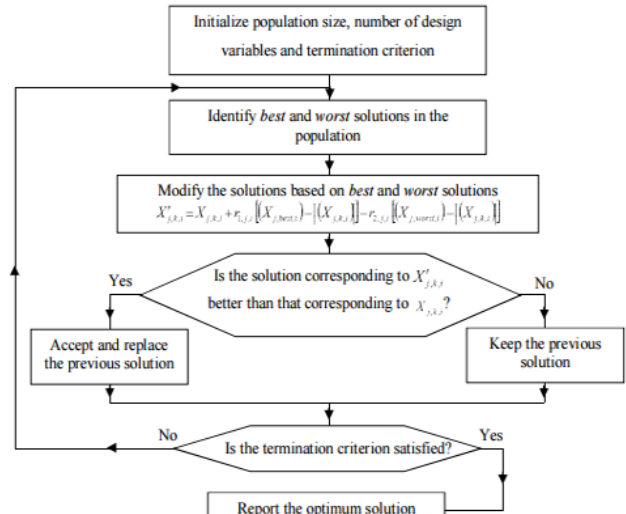


Fig. 5. Flowchart of the Jaya algorithm

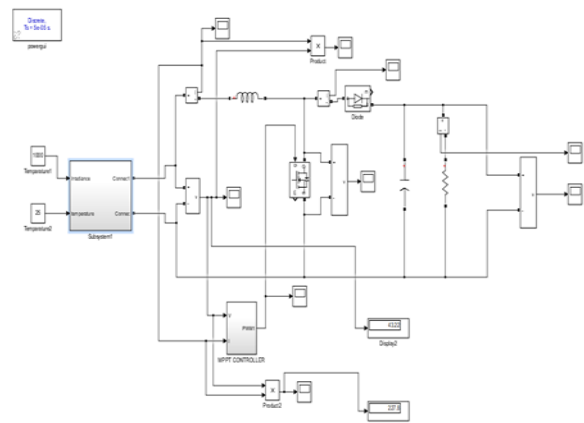


Fig. 6. Simulink diagram

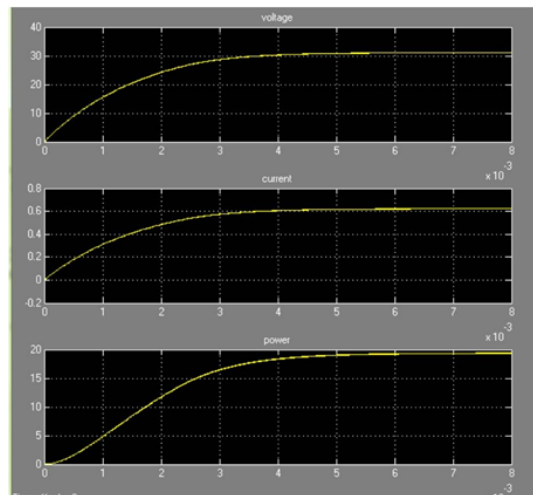


Fig. 7. Simulation results of Jaya MPPT

So fuzzy control algorithm have the ability to improve the tracking performance for both linear and nonlinear loads as

compared with the classical methods. As fuzzy logic does not use complex mathematical equation therefore it is also appropriate for nonlinear control. Figure.10 represents the block diagram of fuzzy logic controller (FLC). The shape of membership functions of the rule base is one of the factor on which the behaviour of a FLC depends.

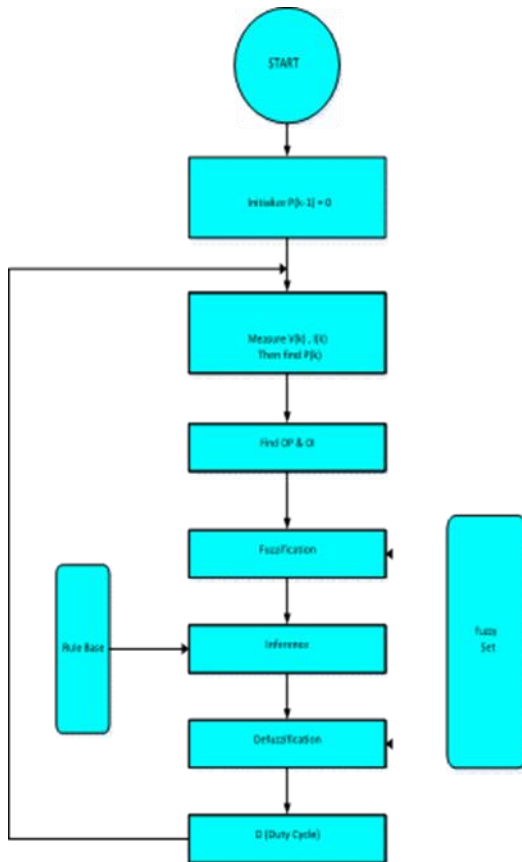


Fig. 8. Flow chart

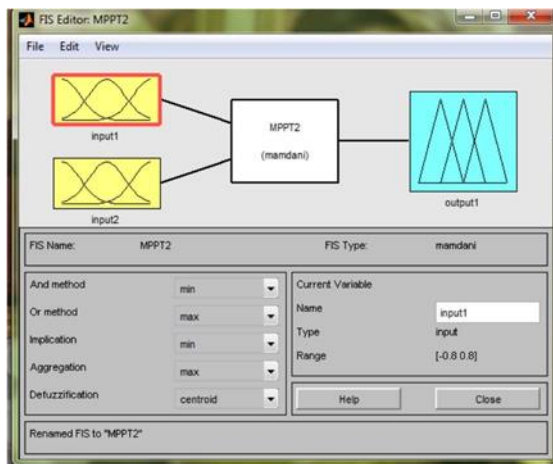


Fig. 9. Fuzzy logic implementation in simulation

When you measure a current using a Current Measurement block, the positive direction of current is indicated on the block icon (positive current flowing from + terminal to – terminal).

Similarly, when you measure a voltage using a Voltage Measurement block, the measured voltage is the voltage of the + terminal with respect to the – terminal. However, when voltages and currents of blocks from the Elements library are measured using the multimeter block, the voltage and current polarities are not immediately obvious because blocks might have been rotated and there are no signs indicating polarities on the block icons.

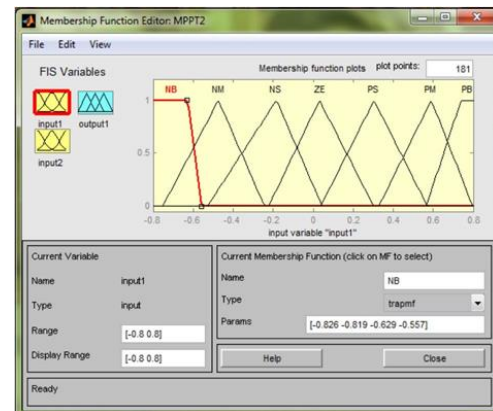


Fig. 10. Fuzzy logic input Error (E)

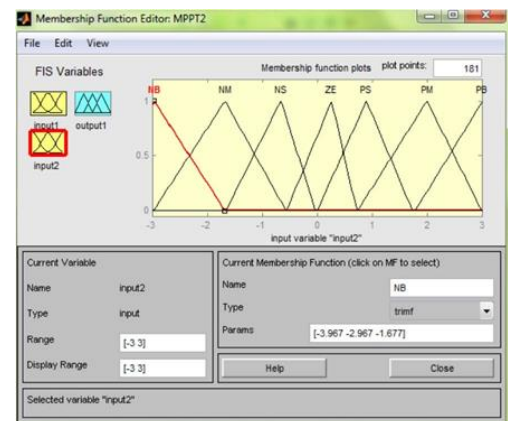


Fig. 11. Fuzzy logic input change of Error (CE)

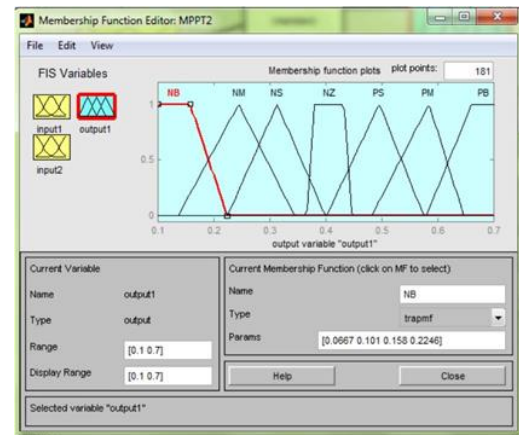


Fig. 12. Fuzzy logic output (D)

Graphic view of the membership function for (a) error signal (b) change of error signal and (c) duty cycle. Different number

of subsets has been used for rule settings of fuzzy logic MPPT. In this case, seven subsets based on forty- nine rules were used. The tuning of forty nine rules represents a better precision and dynamic response but it is time consuming.

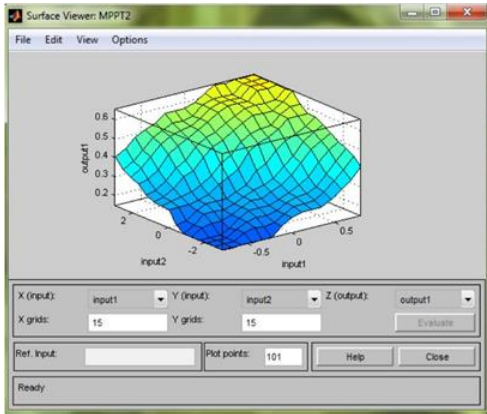


Fig. 13. Fuzzy logic rule view

4. Results of simulation and discussion

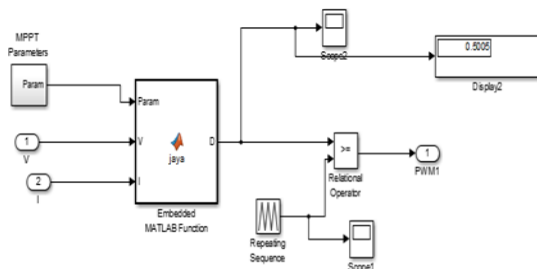


Fig. 14. Simulink model of fuzzy logic MPPT

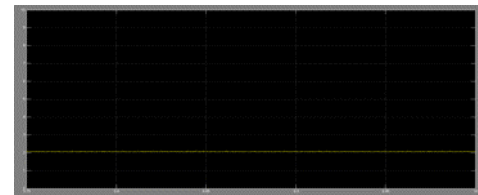
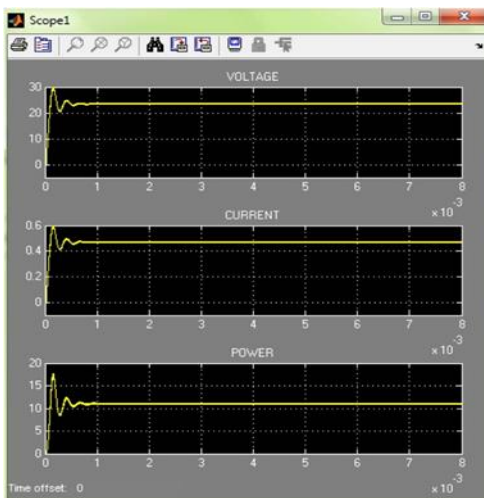


Fig. 15. Result of pulse

The proposed model of Fuzzy MPPT based solar PV system is realized in the MATLAB SIMULINK environment which is represented in Fig. 14. Here a comparison has been made with traditional P&O technique and fuzzy MPPT technique under the operating conditions, accepting constant temperature and an isolation of 1000 W/m². In P&O technique, the incremental current step size uses the appropriate value that is processed by trial and error technique. Current control and FLC are two important parts of MPPT control.

Table 2
 Comparison between different MPPT systems

Different MPPT system	Simulation run time 8 msec					
	V _{in}	I _{in}	P _{in}	V _{o/p}	I _{o/p}	P _{o/p}
JAYA	12.4	2.55	30.8	29.8	0.65	17.88
FUZZY	12.4	2.55	30.8	24.2	0.51	12.35

5. Conclusion

The proposed method of MPPT is faster in comparison to conventional JAYA method when parameters like output voltage, output current and efficiency are compared. From Table 2, it is clear that the system performance can be improved by proposed MPPT technique using fuzzy logic. The proposed technique can be implemented in the real PV system for future work.

References

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