COMPARATIVE ANALYSIS OF DIFFERENT MPPT TECHNIQUES FOR
SOLAR PV SYSTEM

Pushprajsinh Thakor¹, Aakashkumar Chavada², Bhargviben Patel³

¹PG Scholar, Dept. Electrical Engineering, TITS Modasa, Gujarat, India
² PG Scholar, Dept. Electrical Engineering, TITS Modasa, Gujarat, India
³ PG Scholar, Dept. Electrical Engineering, TITS Modasa, Gujarat, India

Abstract: This paper presents a comparative analysis of control methods to extract the maximum power and to track the maximum power point (MPP) from photovoltaic (PV) systems under changeable environmental conditions. The PV system consists of a solar module and a DC/DC converter, in this case a boost converter, connected to a load. The maximum power point tracking (MPPT) algorithms compared are the perturb and observe (P&O) method, the Ripple Correlation control (RCC) and fuzzy logic control (FLC) technique. The parameters considered for the comparison are the efficiency of the MPPT algorithm taking into account the extracted power from the PV system, steady and dynamic response of the system under changeable conditions such as the temperature and the irradiance and the signals ripple. The methods have been compared and the algorithm with the best results has been implemented in a MATLAB simulation platform.

Keywords: PV System, Boost converter, MPPT methods

I INTRODUCTION

The energy demand and the number of distributed generation systems are growing all over the world last years. For that reason, it is essential the use of renewable energy systems in addition to the conventional ones, [1]. Among renewable energy systems, solar energy is one of the most widespread due to the fact that it is clean, inexhaustible and free.

The solar cell turns the solar light into electricity. There are two types of PV systems, the isolated systems and the grid connected systems. The PV system connected to the electrical network consists of solar cells connected together in series or parallel to get a PV module, obtaining output voltage or output current greater than a unique solar cell, a DC/DC converter to regulate the PV module output voltage in order to achieve the maximum power point and a DC/AC converter to transfer energy to the AC side [2].

There are various topologies of DC/DC converters, In this work, a boost converter is designed to regulate the solar module output voltage depending on the requirements, controlling the switch of the DC/DC converter to obtain the desired input voltage value to track the MPP.

II SYSTEM CONFIGURATION

The energy supplied by the PV panel depends on the environmental conditions, such as the irradiance and the temperature. Besides, there is only one MPP for each value of solar radiation and temperature and, in that point, the maximum power is extracted from the solar cells, If the PV system works at the MPP, the efficiency of the system is greater.

![Fig: 1 Basic block diagram of MPPT in PV system](image-url)
III. PV SYSTEM

This section describes the model of the photovoltaic system: the PV modules and the DC/DC converter, connected to a DC load, to regulate the voltage that gives the MPP.

A. Solar cells

A solar cell converts the solar light to electricity by means of the photovoltaic effect. It is a p-n junction made with semiconductor material. The equivalent circuit model of the solar cell consists of electronic devices such as a current source, a diode and two resistors, one in series and one in parallel, as it is shown in Fig. 2.

\[ I = I_{ph} - I_0 \left[ \exp \left( \frac{V + I R_s}{V_T} \right) - 1 \right] - \left[ \frac{V + I R_s}{R_P} \right] \]

Where, \( I_{ph} \) = The PV module saturation current (A)
\( I \) = Output Current of a PV modules (A)
\( I_0 \) = Reverse Saturation Current
\( V \) = Output Voltage of a PV modules (V)
\( R_s \) = Series Resistance of PV modules
\( R_p \) = Parallel Resistance
\( V_T \) = Thermal Voltage

Being \( V \) the voltage of the solar cell in V, \( I_{ph} \) the light generated by the photons and \( I_0 \) is the saturation current, both in A. In order to adjust the model with the losses, two resistors have been added, \( R_s \) represents the ohmic losses and \( Rsh \) models the current leak in a parallel way, both measured in \( \Omega \).

The voltage generated by a solar cell is about 1 V and it is essential to connect cells in series and in parallel to create PV modules in order to supply the desired power.

B. DC/DC Boost Converter

A topology of the DC boost converter is shown in Fig. 3. It is modelled in two modes of operation, which are given by the operation state of the switch. The output variables are inductor current \( I_l \) and the capacitor voltage \( V_c \) [6].

When the switch is on (closed), the inductor stores the energy from PV array and the load is supplied only by the capacitor (Fig. 4) [5].

When the switch is off (open), the inductor current flows to the load and the stored energy of the inductor is transferred to the capacitor and the load (Fig. 5) [5].

IV. MPPT ALGORITHMS

The MPPT algorithms are responsible for achieving the maximum power point even when there are changeable
environmental conditions in order to increase the efficiency of the PV system. There are plenty of techniques for the tracking, the most used method, the P&O, is compared with the RCC and FLC.

A. Perturb and Observe (P&O)

The advantage of this method is that it is simple and easy to implement and it is the most used algorithm. The P&O is based on the variation of the PV module output voltage, controlling the duty cycle of the DC/DC converter, and comparing the power supplied by the solar cells in the current instant of time with the power obtained in the previous instant of time, [9]. If the power of the current cycle is greater than the previous one, the voltage must be modified in the same way, increasing or decreasing it, whereas if the power is lower than the previous power, then the voltage must be varied in the opposite way, increasing or decreasing it as well. When the MPP is reached, the control algorithm oscillates around the maximum power. The flowchart of the P&O is shown in Fig. 6.

RCC correlates the time derivative of time varying PV array power P with the time derivative of the time varying PV array current I or voltage V to derive the power gradient to zero, thus reaching MPP.

B. Ripple correlation control (RCC)

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B. Ripple correlation control (RCC)

The switching action of power converter imposes

C. Fuzzy Logic Control (FLC)

MPPT using Fuzzy Logic Control gains several advantages of better performance, robust and simple design. In addition, this technique does not require the knowledge of the exact model of system. The main parts of FLC, fuzzification, rule-base, inference and defuzzification, are shown in Fig. 8.

In the proposed system, the input variables of the FLC are the change in PV array power (∆P_{pv}) and the change in
PV current (ΔIpv), whereas the output of FLC is the magnitude of the change of boost converter current reference (ΔIref).

In the proposed design, the universe of discourse for the first input variable (ΔPpv) is assigned in terms of several linguistic variables by using seven fuzzy subsets, which are denoted by NB (negative big), NM (negative medium), NS (negative small), Z (zero), PS (positive small), PM (positive medium) and PB (positive big). The membership functions for the variable are shown in Fig. 9.

The error equations for ΔPpv and ΔIpv are given as follows:

\[
E = \frac{P(k) - P(k - 1)}{V(k) - V(k - 1)}
\]

\[
ΔE = E(k) - E(k - 1)
\]

V. SIMULATION RESULTS

A. Perturb and Observe (P&O)

B. Ripple correlation control (RCC)

C. Fuzzy Logic Control (FLC)

D. Output Power Comparison of MPPT Techniques

VI. CONCLUSION
In this work, three MPPT algorithms have been simulated to be compared, the P&O algorithm, the RCC control and the fuzzy logic (FLC) controller.

All the methods have rapidly tracking under changeable environmental conditions. The P&O has two disadvantages, the signals ripple involves small oscillation about the MPP voltage leading to power losses and it can reach a local maximum instead of a global maximum in some cases. The other two methods avoid local maximum and have smooth transient response and gives the more output power compare than P&O. Ripple correlation control (RCC) gives slightly better result than P&O. Regarding the efficiency of the MPPT, the fuzzy logic control (FLC) achieves better result compare than other methods.

VII. APPENDICES

A. Parameters for Solar Photovoltaic System

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td>Number of cells</td>
<td>36</td>
</tr>
<tr>
<td>Ns and Np</td>
<td>1</td>
</tr>
<tr>
<td>Open circuit voltage</td>
<td>19.1 volts</td>
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<tr>
<td>Short circuit current</td>
<td>2.5 Amp.</td>
</tr>
<tr>
<td>Series Resistance</td>
<td>0.18 Ohms</td>
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<tr>
<td>Shunt Resistance</td>
<td>360.002 Ohms</td>
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<tr>
<td>Ideality factor</td>
<td>1.36</td>
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<tr>
<td>Temperature</td>
<td>25°C</td>
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<tr>
<td>Irradiance</td>
<td>1000 W/m²</td>
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</tbody>
</table>

B. Parameters for DC-DC Boost converter

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td>R</td>
<td>10 Ohms</td>
</tr>
<tr>
<td>L</td>
<td>0.005 H</td>
</tr>
<tr>
<td>C</td>
<td>12000 μF</td>
</tr>
<tr>
<td>fsh</td>
<td>10 kHz</td>
</tr>
<tr>
<td>D</td>
<td>0.86</td>
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C. Comparison an output results

<table>
<thead>
<tr>
<th>Output</th>
<th>P&amp;O</th>
<th>RCC</th>
<th>FLC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current</td>
<td>2.476(A)</td>
<td>2.451(A)</td>
<td>2.272(A)</td>
</tr>
<tr>
<td>Voltage</td>
<td>9.197(V)</td>
<td>12.3(V)</td>
<td>15.34(V)</td>
</tr>
<tr>
<td>Power</td>
<td>22.77(W)</td>
<td>30.15(W)</td>
<td>34.75(W)</td>
</tr>
</tbody>
</table>

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REFERENCES


