Comparative Analysis of MPPT Algorithms for PV Systems Under Partial Shading Conditions

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II. Grid-connected PV system

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1. Introduction

General scheme of a grid-connected PV system
I. Introduction

Maximum Power Point Tracking (MPPT) under uniform irradiance and temperature conditions

MPPT algorithms:
- Perturb and Observe (P&O) technique
- Incremental Conductance (IC) technique
- Constant Voltage (CV) method
- Adaptive P&O technique
- Adaptive IC technique
- P&O with compensation network
- Fuzzy logic
- Artificial Neuron Network
I. Introduction

Characteristic curves under different irradiance and partial shading conditions
I. Introduction

This work presents a performance comparison between different kind of MPPT techniques for grid-connected PV systems under partial shading conditions.

- P&O technique
- Observe, Compare and Perturbed (OC&P) technique
- Fuzzy logic controller

Traditional methods
Algorithm based on modifications of traditional methods
Algorithm based on artificial intelligence
II. Grid-connected PV system

Scheme of the grid-connected PV system
II. Grid-connected PV system

Reference signal generation:

- Algorithm based on Fryze power theory

\[ i_{ref} = \frac{P^* u_g}{U_g^{2RMS}} \]

\[ P^* = P_{PV} - P_{dc} \]

where:

\[ P_{dc} = k_pe + \frac{k_p}{T_i} \int e dt \]

\[ e = U^*_{dc} - u_{dc} \]

Current controller:

- Proportional resonant (PR) damped controller with PWM technique

\[ G_{PR}(s) = k_{pr} + \frac{2k_i\omega_c s}{s^2 + 2\omega_c s + \omega_o^2} \]
III. Maximum Power Point tracking (MPPT) algorithms

I. Perturb and Observe (P&O) technique
III. Maximum Power Point tracking (MPPT) algorithms

II. Observe, Compare and Perturb (OC&P) technique


III. Maximum Power Point tracking (MPPT) algorithms

III. Fuzzy logic controller

IV. Simulation test

Grid-connected PV system

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power at the MPP under STC</td>
<td>1000 W</td>
</tr>
<tr>
<td>Voltage at the MPP under STC</td>
<td>120.4 V</td>
</tr>
<tr>
<td>Current at the MPP under STC</td>
<td>8.3 A</td>
</tr>
<tr>
<td>Input capacitor ($C_{in}$)</td>
<td>10 $\mu$F</td>
</tr>
<tr>
<td>DC-link capacitor ($C_{dc}$)</td>
<td>2200 $\mu$F</td>
</tr>
<tr>
<td>Filter capacitor ($C_f$)</td>
<td>9.2 $\mu$F</td>
</tr>
<tr>
<td>Filter damping resistor ($R_d$)</td>
<td>1.5 $\Omega$</td>
</tr>
<tr>
<td>Boost converter inductor ($L_1$)</td>
<td>10 mH</td>
</tr>
<tr>
<td>Inverter side inductor ($L_i$)</td>
<td>3.7 mH</td>
</tr>
<tr>
<td>Grid side inductor ($L_g$)</td>
<td>180 $\mu$H</td>
</tr>
<tr>
<td>Grid voltage ($u_g$)</td>
<td>120 $V_{rms}$ / 60 Hz</td>
</tr>
<tr>
<td>Switching frequency ($f_s$)</td>
<td>20 kHz</td>
</tr>
<tr>
<td>DC-link reference voltage ($U_{dc}^*$)</td>
<td>300 V</td>
</tr>
</tbody>
</table>
### IV. Simulation test

**PV generator and shading conditions**

![Diagram showing PV generator and shading conditions]

- **0 ≤ t ≤ 4 [s]**
- **4 < t ≤ 6 [s]**
- **6 < t ≤ 8 [s]**
IV. Simulation test

Comparison criteria:

• Convergence time: time required to reach the 95% of the final value of the power at the global MPP after the occurrence of a disturbance.

• Maximum relative error in steady-state between the power delivered by the PV generator ($P_{PV}$) and the power at the global MPP ($P_{MPP}$):

$$\varepsilon = \max \left( \frac{|P_{PV} - P_{MPP}|}{P_{MPP}} \right)$$

• The efficiency of the algorithm in steady-state according to:

$$\eta(t) = \frac{\int_{t_1}^{t} P_{PV}(\tau)d\tau}{\int_{t_1}^{t} P_{MPP}(\tau)d\tau}$$
V. Results

<table>
<thead>
<tr>
<th>Technique</th>
<th>Convergence time [s]</th>
<th>Relative error [%]</th>
<th>Efficiency [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>OC&amp;P</td>
<td>0.412</td>
<td>0.509</td>
<td>above 95</td>
</tr>
<tr>
<td>Fuzzy Logic</td>
<td>0.03</td>
<td>0.178</td>
<td>above 95</td>
</tr>
</tbody>
</table>
VI. Conclusions

- The traditional P&O technique may converge to non-global maximums under partial shading conditions, which depends on the initial reference voltage value and the location of the global maximum.

- The OC&P method and fuzzy logic controller presented an outstanding performance on the tracking of the global maximum under different cases of partial shading conditions with an efficiency above the 95% in steady-state. Between these two algorithms, the fuzzy logic controller presented a faster respond to the global maximum power and smaller relative errors than the OC&P technique once the system has already been initialized.
VI. Conclusions

- The fuzzy logic controller requires a previous algorithm that provides the most suitable ranges for the membership functions, otherwise it could lead to local maximums.

- Regarding the OC&P method, it presented a convergence time less to 0.5 [s], which is feasible for this application. However, this algorithm requires prior knowledge of the number of PV panels in series connection in the PV generator and the number of sub-modules per panel with bypass diodes.
¡THANK YOU!

¡GRACIAS!