On the use of sun trackers to improve maximum power point tracking controllers applied to photovoltaic systems

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Outline

- Introduction
- Maximum Power Point Tracking control techniques
- Perturb & Observe technique
- Sun tracker equipment
- Simulation and experimental results
- Conclusion and future work
The Berlin Declaration 2007 was adopted at the end of The European Forum for Renewable Energy Sources (EUROFORES) in its 7th Interparliamentary Meeting on Renewable Energy which took place on October 2007.

Regarding the use of renewable energies that declaration expects that in 2020 the 20% of total energy consumption in the EU will be based on renewable energies.
The prospects of growth in the photovoltaic market

- Strong dependence on country policies
- Massively investing in new production capacities
- Research on new materials

Capacities in the EU (2008): 9,533,25 MWp

<table>
<thead>
<tr>
<th></th>
<th>Capacity (MWp)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Germany</td>
<td>5351</td>
</tr>
<tr>
<td>Spain</td>
<td>3404</td>
</tr>
<tr>
<td>Poland</td>
<td>1,6</td>
</tr>
<tr>
<td>Lithuania</td>
<td>0,055</td>
</tr>
<tr>
<td>Estonia</td>
<td>0,02</td>
</tr>
<tr>
<td>Latvia</td>
<td>0,006</td>
</tr>
</tbody>
</table>

2010 estimation: 16000 MWp
Main drawbacks of photovoltaic plants

- High cost of photovoltaic cells
- Low energy conversion efficiency cells

Some solution

- Sun trackers (electro-mechanical equipment)
- MPPT control techniques (converter control)
The converter control forces the PV module to work at Maximum Power Point.
Main MPPT control techniques

- Voltage control (VMMPT)
- Current control (CMMPT)
- Hill climbing (HC)
- Perturbation and Observation (P&O)
- Incremental conductance method (InC)
- Others:
  - Fuzzy logic control
  - Neural network
  - Ripple correlation control (RCC)
  - Current sweep
P&O control technique

- **Power feedback method**
- MPPT is achieved when \( \frac{dP}{dV} \) is zero (P&O)
- Condition independent of solar radiation and temperature
- Deviation in case of changing weather
- Could oscillate around MPP

<table>
<thead>
<tr>
<th>Perturbation</th>
<th>Change in power</th>
<th>Working</th>
<th>Next Perturbation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positive</td>
<td>Positive</td>
<td>Left to MPPT</td>
<td>Positive</td>
</tr>
<tr>
<td>Positive</td>
<td>Negative</td>
<td>Right to MPP</td>
<td>Negative</td>
</tr>
<tr>
<td>Negative</td>
<td>Positive</td>
<td>Right to MPP</td>
<td>Negative</td>
</tr>
<tr>
<td>Negative</td>
<td>Negative</td>
<td>Left to MPP</td>
<td>Positive</td>
</tr>
</tbody>
</table>
P&O application

- Low complexity
- Easy to implement
- Easy to improve
- Boost converter
P&O flow chart

Start

Sense v(k) and i(k)

Calculate p(k)

p(k) - p(k-1) > 0

p(k) - p(k-1) = 0

p(k) - p(k-1) < 0

v(k) - v(k-1) > 0

v(k) - v(k-1) = 0

v(k) - v(k-1) < 0

v_{ref} = v_{ref} - \Delta v

v_{ref} = v_{ref} + \Delta v

v_{ref} = v_{ref} - \Delta v

v_{ref} = v_{ref} + \Delta v

Return
# P&O study cases

<table>
<thead>
<tr>
<th>Case</th>
<th>Conditions</th>
<th>Position</th>
<th>Control action</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>$\Delta p_K &gt; 0$, $\Delta v_K &gt; 0$</td>
<td>Left of MPP</td>
<td>Increase $\delta$</td>
</tr>
<tr>
<td>2</td>
<td>$\Delta p_K &gt; 0$, $\Delta v_K &lt; 0$</td>
<td>Right of MPP</td>
<td>Decrease $\delta$</td>
</tr>
<tr>
<td>3</td>
<td>$\Delta p_K &lt; 0$, $\Delta v_K &gt; 0$</td>
<td>Right of MPP</td>
<td>Decrease $\delta$</td>
</tr>
<tr>
<td>4</td>
<td>$\Delta p_K &lt; 0$, $\Delta v_K &lt; 0$</td>
<td>Left of MPP</td>
<td>Increase $\delta$</td>
</tr>
</tbody>
</table>

Case 1: $v(k) > v(k-1)$ and $p(k) > p(k-1)$
Sun tracker bloc diagram

The controller holds the PV array in the best position regarding the sun location
Sun tracker main parts

- Light sensors (2): LDRs shadow sensors
- Microcontroller: Cycle of 5’
- Drivers (2): DC-DC Full bridge converter
- Motors (2): Permanent magnet DC motor
- Power supply: Battery + charger
Simulation results

Simulation of Power – voltage (red) and current – voltage (blue) characteristics of a PV module **BP350U** for different radiation levels at constant cell temperature.

Technical data
- Max. Power: 50 W
- Voltage at \( P_{\text{max}} \): 17.5 V
- Current at \( P_{\text{max}} \): 2.9 A
- \( I_{\text{SC}} \): 3.17 A
- \( V_{\text{OC}} \): 21.8 V
- Rated power: 50 W
- Nom. voltage: 12 V
- Limited warranty: 25 years

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Experimental results

2 axis sun tracker system
Experimental results

Power comparison between Sun tracker (blue) and fixed oriented (red) systems

Energy increase of 50%

Own consumption (sun tracker equipment) is about 1%
Experimental results

Radiation and temperature comparison between Sun tracker (blue) and fixed oriented (red) systems
Conclusion

- Development of renewables energies is strongly dependent on EU policies and industrial capabilities.
- EU target for 2020 is to achieve 20% of total energy consumption based on renewable energies.
- EU target for 2010: 6000 MWp (PV systems only)

- Different techniques to achieve MPPT have been presented.
- A Sun tracker system has been developed.
- Simulation and experimental results show good behavior.
- MPPT control and sun tracker improve efficiency of PV systems.
Future work

- Improve the algorithm used in previous P&O application
- Improve sun tracker application. New mechanical structure
- Complete the experimental comparison with other MPPT control techniques using the actual PV system

- Assembly of a new PV plant of 3.4 kWp
- Application of MPPT control techniques and sun trackers to the new plant
Thank you very much for your attention

Solar farm “El cortijo del cura” in Antequera (Spain):
20000 m² and 2.0 MWp (2008)