Comparative Study of Control Algorithms Through Different Converters to Improve the Performance of a Solar Panel

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A B S T R A C T
This article aims at comparing two controls to follow the maximum power point, making use of DC-DC converters for PV uses. All transformers operate continuously. To fulfil maximum power, we will exploit two MPPT controls: a traditional perturb – observe ‘P&O’ and a smart one – the fuzzy logic ‘FL’. The goal of this article is two-fold: to scrutinize the efficiency of DC-DC transformers (Boost, Buck, Cuk and SEPIC), and to assess the outcomes of the simulation. For the construction of models and simulations, the Matlab / Simulink environment is employed.

1. Introduction

There has been recently a crucial advancement in renewable energies. With its permanent potential and without adverse effect on the external environment, new energies are an adequate and affordable technique for development. The main lines of research concerning the conversion of new energies are as follows: recovery of basic energy, mechanical transformation, electrical transformation, electricity production, conversion, and injection into the network. The main axis is to determine the quality of “green” energy generation [1, 2].

Transformers DC-DC are an essential constituent in power generation. These converters are chiefly used in connection with batteries, wind turbines, hybrid systems, solar panel. Transformers DC-DC are to match the tension between the input stage and the output stage of a system. In this work we will make a comparison between different converters: Boost, Buck, Sepic and Cuk for two commands perturb – observe 'P&O' and fuzzy logic 'FL', in order to obtain the maximum power of a solar panel source for meteorological variations conditions [3, 4].

2. Modeling of Photovoltaic System

The fundamental element of the solar panel is the semiconductor, consisting of many cells mounted in shunt or mounted in cascade. The photovoltaic cell is schematized by a circuit: a parallel resistance, a series resistance, and a single diode, represented in figure 1 [5].

\[ I_{ph} = \left( I_{sc} + K_I (T_c - T_{ref}) \right) \frac{G}{G_{ref}} \]  \hspace{1cm} (1)

whereby \( K_I \) is the temperature coefficient [%/K]; \( I_{sc} \) is the short intensity current [A]; \( T_c \) is the module temperature [K], \( G \) is the sunlight solar effect [W/m²]; \( T_{ref} = 298 \) K and \( G_{ref} = 1000 \) W/m². [6, 7]
The formula giving the electrical intensity \( I \) is:

\[
I = I_{ph} - I_d - I_{sh}
\]

whence

\[
I = I_c + I_s = \frac{G}{G_m} - I \left[ \exp \left( \frac{q(V + RI)}{NKT} - 1 \right) \right] \frac{(V + RI)}{R_n}
\]

where
\( I_{ph} \) the short electrical intensity,
\( I_c \) the electrical intensity saturation of the diode;
\( q \) the elementary charge of the electron \((1.60 \times 10^{-19} \text{ C})\); 
\( V \) the diode tension \((\text{V})\); 
\( K \) the Boltzmann’s universal constant \((1.38 \times 10^{-23} \text{ J/K})\); 
\( T \) the temperature,
\( N \) Ideality factor of the diode,
\( R_c \) the cascade resistance,
\( R_{sh} \) is the parallel resistance,

\section{3. Prepare Transformers DC-DC analysis}

The transformers DC-DC is a very important element in power generation of a solar panel. It is a block between the load and the photovoltaic panel that allows to extract the maximum power for the panel.

The transformers DC-DC consists of a capacitor, a diode, an inductor, commanded switch (controlled by PWM signal) and uncontrolled switch.

\subsection{3.1. Buck Transformer}

The buck transformer makes it possible to reduce the input tension \([8]\).

\[
V_0 = DV
\]

where \( D \) represents the duty cycle.

\subsection{3.2. Boost transformer}

The boost transformer allows to increase the input tension \([9, 10]\).
Figure 6 shows the structure of the Perturb – Observe command [14,15].

4.2 Fuzzy – Logic ‘F-L’

The ‘F-L’ technique is used in a point tracking system maximum MPPT power, this technique offers the importance of being a powerful technique and relatively simple to develop and it does not require exact specification of the model to be regulated. The ‘F-L’ technique is more suitable for non-linear systems than photovoltaic systems. The process of this technique is executed in three blocks: Fuzzification, defuzzification and inference. This figure supplies the clue 7 [16].

![Figure 7: ‘F-L’ diagram](image)

The ‘F-L’ diagram input parameters are: the variation of the error CE and the error E giving by the formula:

\[
E = \frac{P(k) - P(k - 1)}{V(k) - V(k - 1)} \quad (8)
\]

\[
CE = E(k) - E(k - 1) \quad (9)
\]

5. Simulation and Results

Under Matlab Simulink environment the PV system is modeled. In this block we find mainly: the equivalent diagram of the converter, the command used and a PV system predefined in Matlab simulink.

![Figure 9: Diagram Block of the Perturb—Observe and fuzzy—Logic commands for the different transformers processed](image)
Figure 9 presents an overview of all blocks: photovoltaic panel, DC-DC converter, MPPT commands, irradiation data et temperature data.

The Solar panel used in the simulations is P20-TDC-36-20W.

Table 2: P20-TDC-36-20W

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>No-Load tension $V_{OC}$ (V)</td>
<td>21.20</td>
</tr>
<tr>
<td>Tension at maximum power $V_{mp}$ (V)</td>
<td>17.20</td>
</tr>
<tr>
<td>Short-intensity current $I_{sc}$ (A)</td>
<td>1.280</td>
</tr>
<tr>
<td>Current at maximum power $I_{mp}$ (A)</td>
<td>1.170</td>
</tr>
<tr>
<td>Puissance maximum (W)</td>
<td>20.0</td>
</tr>
<tr>
<td>The Coefficient of temperature of $V_{OC}$ (%/deg.C)</td>
<td>0.360990</td>
</tr>
<tr>
<td>Coefficient of temperature of $I_{sc}$ (%/deg.C)</td>
<td>0.0650</td>
</tr>
</tbody>
</table>

Figures 10 and 11 depicts the change of the real solar radiation the and temperature data over a day.

Figures 12, 13, 14 and 15 enumerates the outcomes of the different transformers: Boost, Buck, CUK and SEPIC, using as a technique the Perturb and Observe.

**Figure 10:** The change of temperature

**Figure 11:** The change of solar radiation

**Figure 12:** Power with Perturb-observe technique for the Boost transformer

**Figure 13:** Power with Perturb-observe technique for the Buck transformer

**Figure 14:** Power with Perturb-observe technique for the Sepic transformer

**Figure 15:** Power with Perturb-observe technique for the Cuk transformer

For the second simulation figures 16, 17, 18 and 19 the fuzzy logic command was used.

**Figure 16:** Power with ‘F-L’ technique for the Boost transformer
Figure 17: Power with ‘F-L’ technique for the Buck transformer

Figure 18: Power with ‘F-L’ technique for the Sepic transformer

Figure 19: Power with ‘F-L’ technique for the Cuk transformer

Figure 20: Evolution of power for the four transformer with Perturb-Observe

Figure 21: Evolution of power for the four transformer with ‘F-L’

Figure 22: The best power produced with Perturb-Observe and fuzzy-logic

In the Perturb-Observe technique simulation context, the power of photovoltaic panel in the Sepic transformer – is maximal with regard to other transformers, but it is more stable in the boost transformer.

In the ‘F-L’ technique, the power photovoltaic panel in the Buck transformer generate more power compared to other transformers; it is also more stable, but in Boost transformer context.

6. Conclusion

This article studied two maximum power point tracking techniques – a traditional Perturb-Observe and a smart one: ‘F-L’ control to obtain the maximum power of the panel photovoltaic.

In this work, four DC-DC transformers are used to improve the quality of the MPP tracking by analyzing the power produced and the stability of each converter.

Simulation results gives an overview of the power evolution for a temperature and solar effect irradiation data for a day.

References


