High gain DC-DC converter for photovoltaic applications using fuzzy logic MPPT controller

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Abstract—As the advancement in power electronics technology, the solar photovoltaic energy is recognized as an important renewable energy resource because it is abundant and pollution free. Efficiency of photovoltaic system is increased by using Maximum Power Point Tracker (MPPT). A number of algorithms are developed to track the maximum power point efficiently. Mostly MPPT algorithms suffer from drawback of being slow or wrong tracking. Introduction of intelligent MPPTs in PV systems is very promising. This research proposes an intelligent control method for the maximum power point tracking (MPPT) of a photovoltaic system under variable solar radiation conditions. Here in this paper, intelligent control method uses a Fuzzy Logic Controller applied to a Super-Lift Luo converter device in which the output voltage increases in Geometric progression. The effectiveness of proposed algorithm is validated by simulation using Matlab/Simulink and is compared to those obtained by the conventional methods. The result concludes that fuzzy logic control provides a better output compared to that of conventional method.

Keywords—Photovoltaic, MPPT, Luo, Fuzzy logic controller

1. INTRODUCTION

Photovoltaic power generation using solar cells that can convert solar light energy directly to DC electricity promises to be a clean, widely applicable renewable energy source. Researchers have shown great interest on photovoltaic (PV) technology over the past decades. Advancement in cell efficiency and system reliability has given wide acceptance of PV power technology for both standalone and grid interactive power generation[1]. Sustainable growth of photovoltaic power generation throughout the world is also reducing dependence and pressure on fossil fuel considerably. The output current vs. voltage curve of a photovoltaic cell shows a non-linear characteristic. From this nonlinear relationship, it can be observed that there is a unique point, under given illumination and temperature, at which the cell produces maximum power, the so-called maximum power point (MPP).

One of the major concerns in the power sector is the day to day increasing power demand but the unavailability of enough resources to meet the power demand using the conventional energy sources [6]. The continuous use of fossil fuels has caused the fossil fuel deposit to be reduced and has drastically affected the environment depleting the biosphere.
and cumulatively adding to global warming. Demand has increased for renewable sources of energy to be utilized along with conventional systems to meet the energy demand. The growing demand on electricity, the limited stock and rising prices of conventional sources such as coal, petroleum etc., has led to the use of renewable energy sources. Utilization of renewable energy resources is the demand of today and the necessity of tomorrow. With advancement in power electronic technology, the solar photovoltaic energy has been recognized as an important renewable energy resource because it is clean, abundant and pollution free. The extraction of maximum available power from a photovoltaic module is called Maximum Power Point Tracking and is done by Maximum Power Point Tracking Controller. The efficiency of the photovoltaic system may be substantially increased by using Maximum Power Point Tracker (MPPT). A number of algorithms are developed to track the maximum power point efficiently. Among all MPPT methods, Perturb and Observe (P&O) method and Incremental Conductance method are most commonly used. Most of the existing MPPT algorithms suffer from the drawback of being slow tracking. Due to this the utilization efficiency is reduced.

A typical solar panel converts only 30 to 40 percent of the incident solar irradiation into electrical energy. Maximum power point tracking technique is used to improve the efficiency of the solar panel. According to Maximum Power Transfer theorem; the power output of a circuit is maximum when the Thevenin impedance of the circuit (source impedance) matches with the load impedance. Hence the problem of tracking the maximum power point reduces to an impedance matching problem. In the source side, a boost converter is connected to a solar panel in order to enhance the output voltage so that it can be used for different applications like motor load. By changing the duty cycle of the boost converter appropriately, the source impedance can be matched with that of the load impedance.

The efficiency of a solar cell is very low. In order to increase the efficiency, methods are to be undertaken to match the source and load properly. One such method is the Maximum Power Point Tracking (MPPT)[3]. This technique is used to obtain the maximum possible power from a varying source. MPPT techniques are applied on various PV applications such as space satellite, solar vehicles and solar water pumping etc. Several methods are presented for maximum power point tracking (MPPT) from photovoltaic system such as Perturbation and Observation (P&O) method, Incremental Conductance method, Open Circuit Voltage method, Short Circuit Current method, Feedback of power variation with voltage technique, Feedback of power variation with current technique, Fuzzy Logic Controller based method etc.

In P&O method, the operating voltage is sampled and the algorithm changes the operating voltage in the required direction. The iteration is continued until the algorithm finally reaches the MPP. This technique is simple to implement but the major drawback is the occasional deviation from the maximum operating point in case of rapidly changing atmospheric conditions. The Incremental Conductance (Inc-Con) algorithm is based on the fact that the slope of the curve power vs. voltage (current) of the PV module is zero at the MPP, positive (negative) on the left of it and negative (positive) on the right. This method tracks rapidly under varying irradiation conditions more accurately than P&O method. It requires complex and costly control circuits. Fuzzy Logic based controllers overcome the disadvantages of conventional methods in tracking maximum power point. Fuzzy Logic based controller is simple to implement gives better convergence speed and improves the tracking performance with minimum oscillations. The FLC based MPPT controls the duty cycle of the dc-dc converter in standalone system using change in slope of P-V curve as input and change in voltage as output [4].

II. OPERATION OF SUPER-LIFT LUO CONVERTER
Super Lift Luo converter increases voltage transfer gain in geometric progression[2]. Super lift Luo converter performs voltage conversion from positive voltage source to positive load voltage and provides increased voltage output [3]. Fig 2,3,4 shows working modes of super lift Luo converter. Voltage across C1 capacitor is charged to $V_{dc}$. Current $i_{L1}$ flowing through $L_1$ inductor increases with $V_{in}$ during switching ON period $DT$. Current $i_{L1}$ decreases during switching OFF period $(1-D)T$ [7].

![Fig.2 Elementary Circuit Diagram](image-url)
Fuzzy logic arose from a desire to incorporate logical reasoning and the intuitive decision making of an expert operator into an automated system. The aim is to make decisions based on a number of learned or predefined rules, rather than numerical calculations. Fuzzy logic incorporates rule-based structure in attempting to make decisions [5]. However, before the rule-base can be used, the input data should be represented in such a way as to retain meaning, while still allowing for manipulation. Fuzzy logic is an aggregation of rules based on the input state variables condition with a corresponding desired output. A mechanism must exist to decide on which output or combination of the different outputs will be used since each rule could conceivably result in a different output action. Fuzzy logic can be viewed as an alternative form of input-output mapping [8].

\[
\Delta_{kL} = \frac{Vin}{L} DT = \frac{(Vo - 2Vin)}{L} (1-D)T \\
\frac{Vo}{Vin} = 2 - D \\
\frac{T_L}{Vin} = \frac{LAI}{(Vo - 2Vin)} \\
\frac{VinD}{fAI} \\
\Delta Vc = \int_{0}^{t} I_{odt} \\
C = \frac{Vo(1-D)}{fRAVc}
\]

III. FUZZY LOGIC

Fuzzy logic control is a convenient way to map an input space to output space. Fuzzy logic uses fuzzy set theory, in which a variable is a member of one or more sets, with a specified degree of membership. Recently fuzzy logic controllers have been introduced in the tracking of the MPP in PV systems.
They have the advantage to being robust and relatively simple to design as they do not require the knowledge of the exact model. They do require in the other hand the complete knowledge of the operation of the PV system by the designer.

IV. SIMULATION OF SUPERLIFT LUO CONVERTER WITH OUTPUT

Simulation of superlift luo converter is performed for pv system with parameters listed below:

<table>
<thead>
<tr>
<th>Parameters to Design Superlift Luo Converter</th>
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<tbody>
<tr>
<td>Parameters</td>
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<tr>
<td>Input voltage to converter</td>
</tr>
<tr>
<td>Output Voltage</td>
</tr>
<tr>
<td>Inductor</td>
</tr>
<tr>
<td>Capacitor</td>
</tr>
<tr>
<td>Capacitor</td>
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<tr>
<td>Switching frequency</td>
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<tr>
<td>Load resistance</td>
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<td>Duty ratio</td>
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![Fig.7 Simulink Model](image)

![VI. SIMULATION RESULTS](image)

Fig. 8 Input Voltage
Hardware components used are as follows:
1. Solar Panel (12 V, 35 Watts)
2. Super-lift Luo converter
3. Microcontroller (DSpic)
4. Rectifier (AC to DC)
5. Transformer (Step down 12V)
6. DC motor (24V)

IX. CONCLUSION

The Super-Lift Luo converter performs the voltage conversion from the source to the load. The controlling action is quick and responsive. The application of this converter in solar PV system produces voltage increasing in geometric progression. It produces output of 73V for the input of 12V from the solar PV system which is six times of the input voltage. The converter has proved to robust around the operating point and good dynamic performance in presence of varying input voltage.

REFERENCES


Fig.9 Output voltage

VIII. EXPERIMENTAL SETUP

Hardware components used are as follows:
1. Solar Panel (12 V, 35 Watts)
2. Super-lift Luo converter
3. Microcontroller (DSpic)