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Perfomance Enhancement of PV System Using Luo Converter and FLC Based P&O MPPT

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Abstract: In our present scenario, solar energy is one of the quite attractive pollution free, essentially inexhaustible and broadly available renewable energy source as a future energy supply. But the main drawbacks associated with PV systems are (i) low output panel voltage (ii) low power conversion efficiency. This paper presents the use of a super lift low converter with FLC based P&O MPP tracking control to alleviate the above said problems. Incorporation of luo converter with a PV system ensures the high step up voltage conversion with lesser ripples and high power density. Furthermore, to enhance the power conversion efficiency, we introduced a modified FLC based P&O MPPT.

Key words: Photovoltaic(PV) · Fuzzy logic control (FLC) · Maximum power point tracking (MPPT) · Perturb & Observe (P&O) (key words)

INTRODUCTION

A PV system converts the sunlight energy into electricity. PV panels are used to track the solar energy and convert it into electricity. But solar panel has merely 30-40% efficiency only. The PV module also exhibits nonlinear V-I characteristic curves because of changing temperature, irradiation levels. In order to improve the efficiency, we use super lift luo converter which increases the output voltage level in power series stage by stage. Perturbation and Observation (P&O) can track the Maximum Power Point (MPP) all the time and is widely used in PV systems because of its simplicity and ease of implementation. However, it presents drawbacks such as slow response speed, oscillation around the MPP in steady state and even tracking in the wrong way under rapidly changing environmental conditions. In order to overcome these drawbacks and improve the P&O tracking, this paper proposes a fuzzy based MPPT [1] technique Hence it necessitates an effective, robust control approach with a goal of designing a controller and confirming stability in every working stage of the converter viz. Initial start-up, dynamic responses (line and load variations) and the effect of component variation etc.

PV Cell Modelling: A Solar cell is basically a p-n junction device and works on the principle of photo-electric phenomenon. Fig. 1 represents the equivalent circuit model of PV cell. This circuit includes a light generated source, diode, a series resistance Rs and a parallel resistance Rsh.

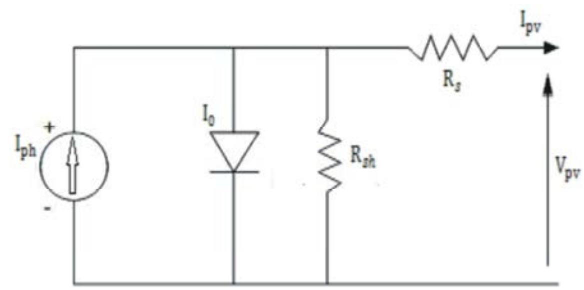

Fig. 1: Equivalent Circuit of PV Cell

The characteristic equation for a photovoltaic cell is given by (1)

$$I_{pv} = I_{ph} - I_0\left[\exp\left(\frac{q(V_{pv} + R_s I)}{nKT}\right) - 1\right] - \frac{V_{pv} + R_s I}{R_{sh}} \quad (1)$$

Iph is expressed by(2):

$$\mathbf{I_{ph}} = [\mathbf{I_{SC}} + \mathbf{K_1}(\mathbf{T} - \mathbf{T_r})]\frac{\mathbf{G}}{\mathbf{1000}} \quad (2)$$

The reverse saturation current I_0 depends on temperature T as fol shows:

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$$I_o = I_{rs}\left(\frac{T}{T_r}\right)^3 \exp\left[\frac{qE_g}{nK}\left(\frac{1}{T_r} - \frac{1}{T}\right)\right] \quad (3)$$

where,
Ipv and Vpv are the output current and voltage of pv cell,
n is the ideality factor(1.6),
k is the Boltzmann's constant(1.3x10^-23Nm/k),
T is the cell's operating temperature in Kelvin,
q is the electron charge(1.6e-19 coloumbs),
I_0 is the reverse saturation current and
Iph is photo generated current,
Tr is the reference temperature,
Kt is the cell's short-circuit current temperature coefficient,
I_{SC} is the short circuit current at Tr and
G is the irradiation in W/m^2,
Irs is the saturation current at the reference temperature,
Eg is the band gap energy of the semiconductor used in photovoltaic cell.

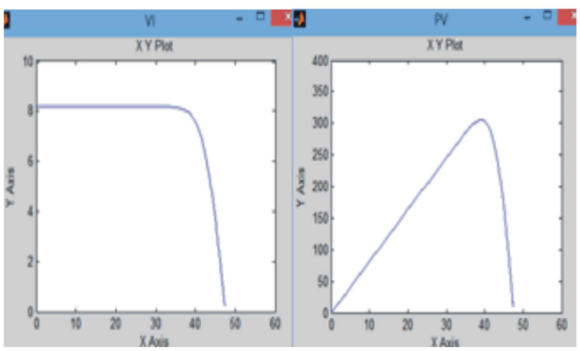

Fig. 2: P-V and I-V characteristics of simulated PV module

Maximum Power Point Tracking: There is a need to implement an MPPT algorithm to track changes insolation levels and to extract the maximum power from the solar PV panel, because the power generated by the panel is significantly affected by variations in irradiation, temperature and panel voltage by giving a non-linear characteristic. "An MPPT system can be defined as an electronic device that makes the PV panel to operate in such way that it delivers all the power it can produce".

The MPP varies depending on the irradiation and cell temperature, therefore, appropriate algorithms must be developed to track the MPP and to maintain the operation of the system as close as possible at this point. The MPPT plays the role of impedance matching adapter, i.e., it forces the impedance at the terminals of the PV panel to the value that produces maximum power from the panel. By changing the duty cycle of the luo converter appropriately the source and load impedance are matched together. Fig -3 shows the characteristics of MPP curve.

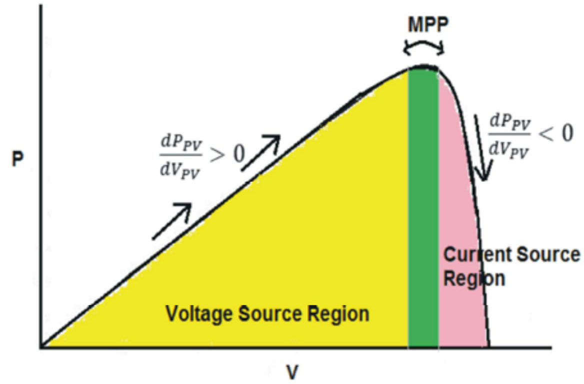

Fig. 3: MPP curve

From Fig. 3 we understand,

- On the left side of Maximum power point, $\frac{dP_{PV}}{dV_{PV}}$ the slope is positive
- On the right side of Maximum power point, $\frac{dP_{PV}}{dV_{PV}}$ the slope is negative
- A Region near to maximum power point, $\frac{dP_{PV}}{dV_{PV}}$ the slope is zero.

There are many MPP algorithms out that we prefer to use a P&O method because of its simplicity and easy implementation. In this method voltage and current is measured continuously. The Function of the algorithm is given by:

- In the voltage source region, $\frac{dP_{PV}}{dV_{PV}} > 0$ then D=D + ΔD
- In the current source region, $\frac{dP_{PV}}{dV_{PV}} < 0$ then D=D - ΔD
- At MPP, $\frac{dP_{PV}}{dV_{PV}}$ =0 then D=D (no change)

But this algorithm produces power with some ripples and oscillations. Furthermore, when environmental condition (insolation levels) changes suddenly, this method probably fails to track the MPP. To conclude this problem P & O method is implemented with the Fuzzy logic [2] controller, which is used to generate a duty cycle for the Luo converter. The fuzzy logic controller have proved to Robustness around the operating point, Good dynamic performance in the presence of input voltage variations and Invariant dynamic performance in the presence of varying operating conditions.

FLC Based MPPT: This method uses the inputs from P&O algorithm which are change in power and change in voltage. Fuzzification comprises the process of converting the numerical crisp inputs into linguistic fuzzy sets using fuzzy membership functions. After fuzzification of inputs the resulting fuzzy sets have to be compared with rules base. A set of “IF premise THEN consequent “is called rules base which is designed in accordance with designer’s system knowledge and expertise. For proposed FLC the inference used is sugeno method associated with wtaver deffuzification method.

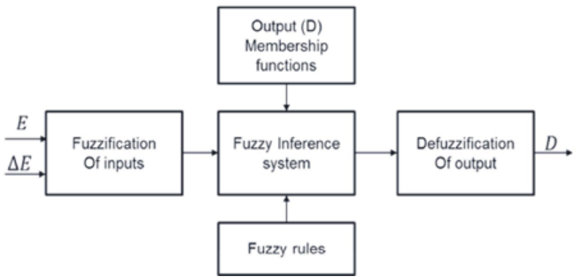

Fig. 4: Fuzzy logic controller

The inputs to the fuzzy system are error, E and change in Error, ΔE given by;

$$e(K) = \frac{p(k) - p(k-1)}{V(k) - V(K-1)}$$

$$ce(K) = e(K) - e(K-1)$$

The output duty ratio D = D + ΔD, the ΔD value will be based on the fuzzy inputs and fuzzy rules.

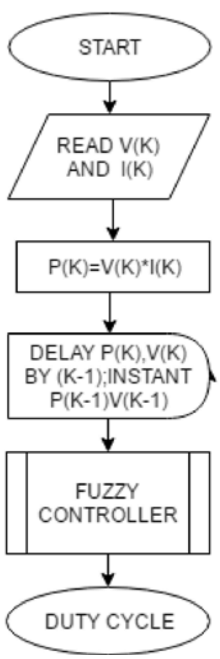

Fig. 5: Flow chart of modified FLC based P&O m

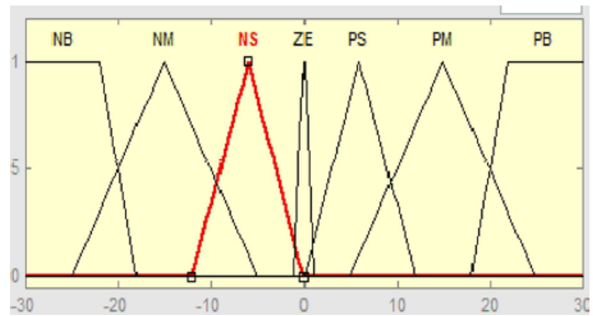

Fig. 6: Membership function of error voltage

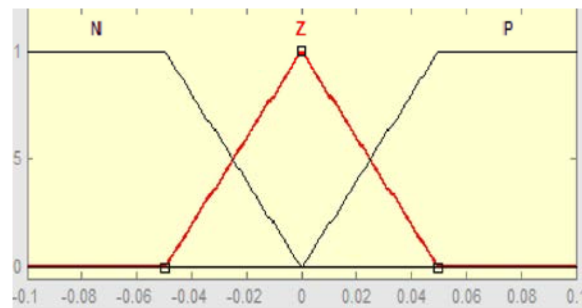

Fig. 7: Membership function for change in error

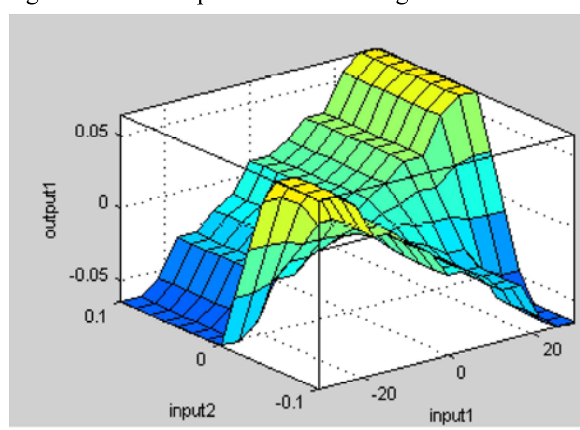

Fig. 8: Surface viewer

Advanced DC –DC Converter

Introduction: The voltage-lift (VL) technique is a popular method that is widely applied in electronic circuit design. VL technique is applied in the periodical switching circuit. Usually, a capacitor is charged during switch-on by certain voltages, e.g., source voltage. This charged capacitor voltage can be arranged on top-up to some parameter, e.g., output voltage during switch-off. Therefore, the output voltage can be lifted higher. Consequently, this circuit is called a self-lift circuit. Analogously, this operation can be repeated many times. Consequently, the series circuits are called re lift, triple-lift circuits, quadruple-lift circuits and so on.

Super Lift Luo Converter: Luo converters are a class of converters providing a high gain with a relatively lesser number of components. Although Luo converters provide a high gain, when cascaded, the gain increases stage by stage only in Arithmetic Progression. In order to solve this discrepancy in the Classical Luo Converters [3], another class of converters called Super-lift Luo Converters was developed. While the positive aspects of the Classical Luo Converters are retained in Super-lift converters, Super-lift converters also have the advantage that the gain in this converter increases in geometric progression, stage by stage.

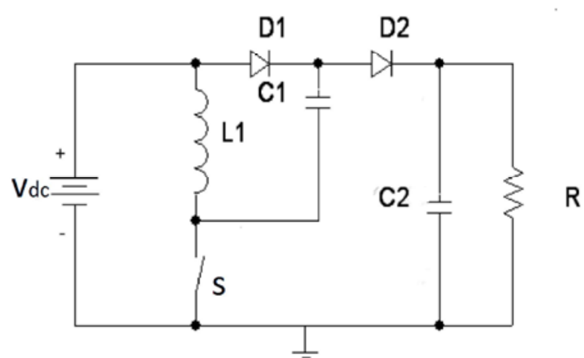

Fig. 9: Super lift luo converter elementary circuit

Mode 1:
During the switch-on period, the voltage across the Capacitor C1 is charged to Vin. The current through Inductor L1 increases with the voltage Vin.

- Inductor, L charges
- Capacitor C1 charges to Vin
- Capacitor C2 supplies the load
- Diode D2 is off
- Diode D1 is ON

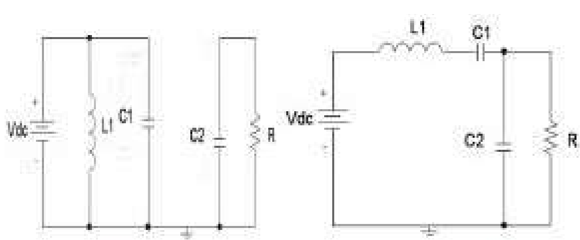

Fig. 10: Mode 1 and Mode 2 circuit operation

Mode 2:
During the switch-off period, the current through the inductor decreases. The capacitor C2 is charged through Vin, VC1 and VL1.

- Inductor current flows to C1
- Capacitor C2 charges
- Diode D2 is ON
- Diode D1 is Off

The output voltage is calculated by the formula,

$$V_0 = \frac{2-G}{1-G} V_{in} \tag{7}$$

The average output current is,

$$I_0 = \frac{1-G}{2-G} I_{in} \tag{8}$$

The voltage transfer gain is,

$$K = \frac{V_0}{V_{in}} = \frac{2-G}{1-G} \tag{9}$$

The duty cycle of conduction period is,

$$G = \frac{t_{on}}{t_{on}+t_{off}} = \frac{t_{on}}{T}. \tag{10}$$

Table 1: Parameters to Design the Prposed System

Parameters	Symbol	Value
Input Voltage(from panel)	V_{in}	45V
Output Voltage	V_o	220V
Inductor	L	100µH
Capacitors	C_1, C_0	5µF, 100µF
Nominal switching		
Frequency	f_s	100kHz
Load resistance	R	100 ohm
Maximum power	P_o	320W
Panel voltage at MPP	V_{mp}	47V
Panel Current at MPP	I_{mp}	8.2A

Simulation Study: A detailed simulation study is performed for the designed system in MATLAB R2013a/Simulink platform.

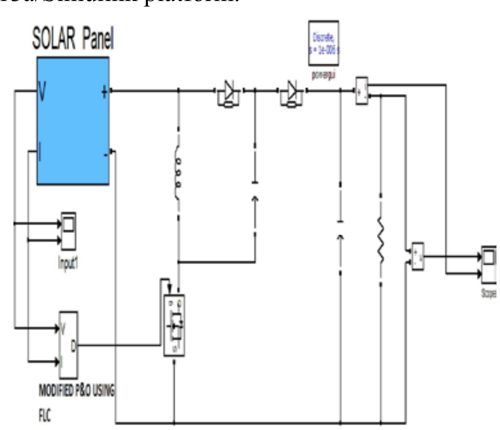

Fig. 11: Overall Simulink model of the proposed model

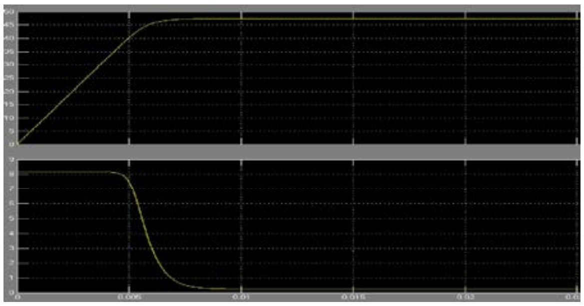

Fig. 12: Input voltage and current to the converter from the panel

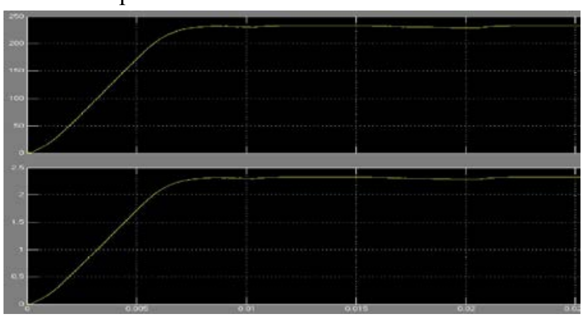

Fig. 13: Output voltage and current from the luo converter

CONCUSION

With the increasing demand of renewable energy sources, we have proposed super lift series of luo converter and an intelligent control strategy of MPPT using the FLC which is typically used in PV System. Simulation results show that the proposed MPPT can track the MPP faster when compared to the conventional P&O method and the luo converter converts the voltage from 45V to 220V providing high voltage gain in each stage. In conclusion, the proposed System with the super lift converter and MPPT using fuzzy logic can improve the performance of the system. For the future work, we intend to implement the proposed technique in the real PV system.

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