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Engineering

PERFORMANCE ANALYSIS OF FUZZY CONTROL STRATEGY FOR BOOST AND QUADRATIC BOOST CONVERTER USED IN PHOTOVOLTAIC SYSTEM

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ABSTRACT Fuzzy based quadratic DC-DC boost converter with Maximum power point tracking(MPPT) ability for high step-up ratio is proposed. This system consists of a quadratic boost converter with high step-up ratio and fuzzy logic based maximum power point tracking controller. Quadratic boost converter(QBC) provides high step-up function with robustness and stability. It is achieved with low duty ratio while compared with traditional boost converter. The Fuzzy logic controller (FLC) has two inputs and one output. The output power and output voltage of the photovoltaic (PV) panel are selected as input variables, and the change in duty cycle is determined as output variable. The performance of the proposed system is compared with FLC based MPPT for boost converter. FLC based MPPT for quadratic boost converter has fast transient response for rapidly changing atmospheric conditions and reaches the MPP. Additionally, the FLC based MPPT algorithm reduces the oscillation of the converter output power at the MPP. This topology is demonstrated using MATLAB/Simulink and the performance is analyzed.

KEYWORDS : Maximum Power Point(MPP), Fuzzy Logic Controller(FLC), Quadratic Boost Converter(QBC), Photovoltaic(PV)

INTRODUCTION

Rapid growing energy demand makes photovoltaic an alternative source to overcome this issues. The important advantage of renewable energy sources is to mitigate the rising concern about CO_2 emissions and global warming. PV based electricity generation can be exponentially increased by two methods[6,7]. One method is designing new, high efficient, low cost PV cells and modules and other method is by using appropriate power electronics converter topologies and control strategy.

DC-DC converter improves the output voltage obtained from renewable energy sources. Voltage gain can be improved by using boost converter. But in the case of boost converter switching frequency is limited, hence the output voltage is reduced. This problem can be mitigated, by combining the components of two boost converter by using single switch[1]. This proposed system is known as quadratic boost converter, which improves the switching frequency and output voltage of converter.

PV output vary with environmental effects such as the solar irradiation, ambient temperature, pollution of the PV module surface, shadowing etc. Since environmental conditions vary seasonally and on a daily basis. Due to these parameter changes, the amount of produced power also changes.

MPPT is an electronic system that operates the photovoltaic modules in a manner to extract maximum power from the system[6,7]. MPP is a operating point at which maximum power can be extracted from the system. Many algorithms have been suggested for MPPT action[11]. Most commonly used algorithms for MPPT are P and O and INC. Artifical intelligence based fuzzy logic MPPT is a new approach. Among the different artifical intelligence methods fuzzy handles with a simple structure[10]. Output of the FLC is continuously adjusting the duty cycle of the converter, so that the PV always works in the MPP. Thus new topology is attractive especially when it is applied for tracking the MPP in PV systems.

There are different converter topologies with high step up capabilities. High step-up converter is obtained with coupled-inductor technique [2].

Efficiency of this technique is low, and leakage-inductor energy of the coupled inductor will cause voltage spike on the switch and increases switching losses.

High conversion ranges can be provided by the combination of conventional boost converter with switched capacitors. High step-up voltage gain can also be achieved with two cascaded boost converters[8]. It needs two controllers and two active switches. Quadratic boost converter which is structurally similar to two cascaded boost converters has been proposed to provide high voltage conversion ratio[1].

BOOST CONVERTER

Boost converter is also referred as step up converter. Used to step up the given input to a desired value. The working of a boost converter can be explained with two modes of operation. The circuit diagram of boost converter is shown in figure 1.

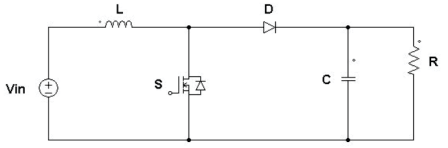


Figure 1: Circuit diagram of boost converter

In mode 1 operation figure 2 (a), switch S is ON then the inductor L gets charged. The inductor current gradually decreases. Diode D is reverse biased and blocks the flowing current. Capacitor C discharges and load current remains the same.

In mode 2 operation figure 2 (b), switch S is OFF. The energy stored in the inductor L changes its polarity and discharges through the diode D. The diode D is forward biased. Capacitor C supplies voltage to load and load current remains constant.

Conversion ratio of the boost converter is given by,
$V_o = V_{in}/D$,where V_o is Output voltage, V_{in} is Input voltage, D is duty ratio.

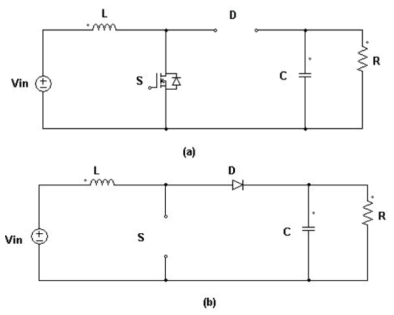


Figure 2: (a) Mode 1 operation of boost converter
(b) Mode 2 operation of boost converter

TABLE – 1 OUTPUT ANALYSIS OF BOOST CONVERTER

Duty Ratio	Quadratic Boost Converter				
	Input Voltage (V)	Input Current (A)	Output Voltage (V)	Output Current (A)	Efficiency
0.2	10	0.3	13.54	0.1354	61%
0.5	10	1.85	35.35	0.3535	67%
0.7	10	10.5	88.26	0.8826	74%

QUADRATIC BOOST CONVERTER

Quadratic boost converter is a two stage boost converter with single switch topology. This converter contains high conversion ratio. The working of Quadratic boost converter can be explained with two modes of operation. The circuit diagram of Quadratic boost converter is shown in figure 3.

In mode 1 operation figure 4 (a), switch S is ON. Diode D_1 and D_3 is at OFF state. Input supply current flows through inductor L_1 and diode D_2. Inductor L_1 receives energy from power supply and inductor L_2 gathers energy from C_2.

In mode 2 operation figure 4(b), switch S is OFF. Diode D_1 and D_3 is at ON state, diode D_2 at OFF state. Capacitor C_1 and C_2 is charged by inductor L_1 and L_2 . Inductors supply the load energy demand.

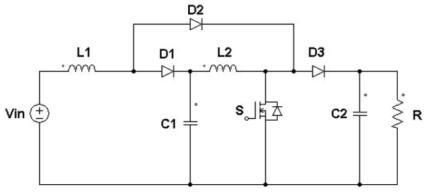


Figure 3: Circuit diagram of QBC

Conversion ratio of the Quadratic boost converter is given by, $V_o = V_{in}/(1-D)^2$, where V_o is Output voltage, V_{in} is Input voltage, D is duty ratio.

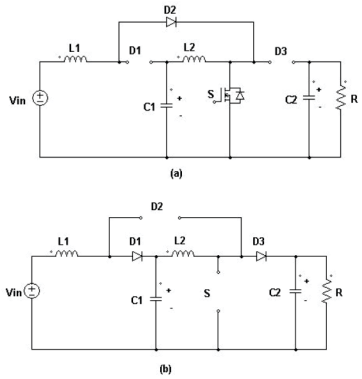


Figure 4: (a) Mode 1 operation of QBC
(b) Mode 2 operation of QBC

TABLE – 2 OUTPUT ANALYSIS OF QBC

Duty Ratio	Quadratic Boost Converter				
	Input Voltage (V)	Input Current (A)	Output Voltage (V)	Output Current (A)	Efficiency
0.2	10	0.3	13.54	0.1354	61%
0.5	10	1.85	35.35	0.3535	67%
0.7	10	10.5	88.26	0.8826	74%

FUZZY BASED MPPT ALGORITHM

In this paper Mamdani type fuzzy controller is used for maximum power point tracking. The figure 5 shows the basic illustration of FLC. FLC contains four basic components they are fuzzification, knowledge base, inference engine and defuzzification. Fuzzifier transforms the crisp data in to linguistic labels and membership values using knowledge base. After this process, inputs are called fuzzy inputs. Inference engine generates verbal judgements regarding fuzzy inputs. IF-THEN rules are knowledge base to generate fuzzy outputs. Defuzzifier converts fuzzy output to crisp values. Knowledge base consists of input and output membership functions, and rules is one which defines the relation between inputs and outputs.

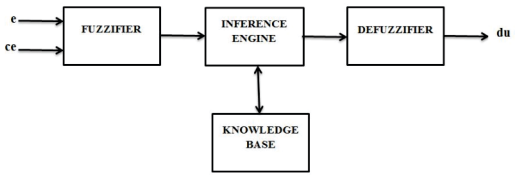


Figure 5: Basic illustration of FLC

TABLE – 3 RULE BASE

	CHANGE IN PV POWER (dp/dt)							
CHANGE IN PV VOLTAGE (dv/dt)		NL	NM	NS	Z	PS	PM	PL
	NL	NL	NL	NM	Z	PM	PL	PL
	NM	NL	NM	NM	Z	PM	PM	PL
	NS	NL	NM	NS	Z	PS	PM	PL
	Z	Z	Z	Z	Z	Z	Z	Z
	PS	PS	PS	PS	Z	NS	NM	NL
	PM	PM	PM	PS	Z	NS	NM	NL
	PL	PL	PL	PM	Z	NM	NL	NL

FUZZY LOGIC FLOW CHART IN MPPT

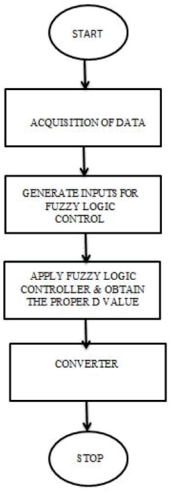
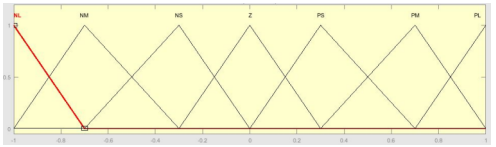


Figure 6: Flow chart for FLC

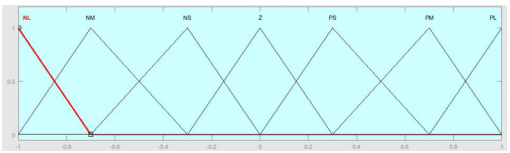
Table 1 shows the rule base of FLC for MPP. Rule base is for fast tracking speed and for reduced oscillations. The main advantages of this method are it is independent of the mathematical model of the system, ability to handle system non-linearities and accurate tracking of MPP in presence of varying climatic conditions. Disadvantage of this controller is that its effectiveness depends on the error calculation and on the rule base for fuzzy interence mechanisms. Figure 6 shows the flow chart of fuzzy based maximum power point tracking.

PROPOSED SYSTEM

Proposed system combines the advantages of QBC and FLC. QBC seems to be a better solution for high step up nature. FLC based MPPT unit results in fast, robust and stable operation. FLC contains two inputs and one output to track MPP of PV system. Change in output power (dP/dt) and the change in output voltage (dV/dt) of the PV system are selected as inputs of the FLC. The input and output membership functions are shown in figure 7.



(a)



(b)

Figure 7: (a) Input membership functions change in output power (dP/dt) and change in output voltage (dV/dt)
(b)Output membership functions change in duty ratio

The output of FLC is used to change duty ratio. Rule base is for fast

tracking speed and for reduced oscillations. Defuzzification is done by using center of gravity method. The circuit diagram of the proposed system is shown in figure 8.

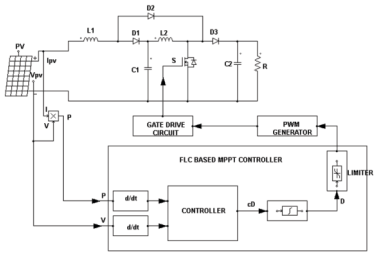


Figure 8: Circuit diagram of the proposed system

SIMULATION MODELS AND RESULTS

Boost converter is simulated with the input voltage of 18V. The switching frequency used is 1 kHz. The simulation model for the boost converter is given in figure 9. The design values of boost converter are L=870µH, C=2.034mF, R=50Ω. If $_{in}$=18V, D=0.5 then the output voltage is given by 36V for the duty cycle 0.5 whereas the simulation output is 35.2V for the same input voltage. The simulation output of boost converter is shown in figure 10.

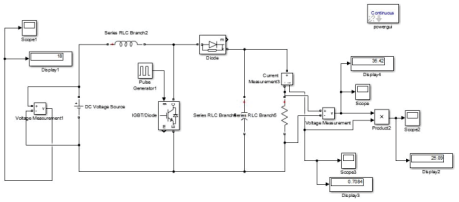


Figure 9: Simulink model of boost converter

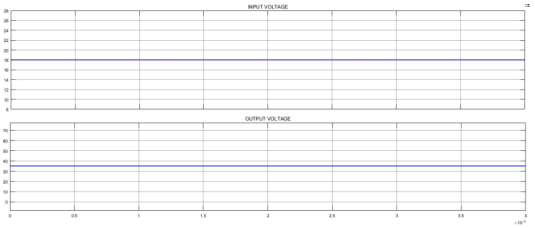


Figure 10: Input and output voltage of boost converter

QBC is simulated with the input voltage of 18V. The switching frequency used is 1 kHz. The simulation model for QBC is given below in figure 11. The design values of QBC are L_1=1mH, L_2=2.2mH, C_1=47µF, C_2=75µF, R=50Ω. If $_{in}$=18V, D=0.5 then the output voltage is given by 72V for the duty cycle 0.5 whereas the simulation output is 69V for the same input voltage. The simulation output of QBC is shown below in figure 12.

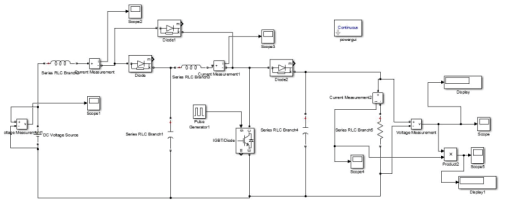


Figure 11: Simulink model of Quadratic boost converter

The fuzzy logic controller based MPPT for boost converter model is shown in figure 13. System consists of the PV array, boost converter and FLC based MPP tracking. The maximum power point voltage, current and power of this panel at 25 ° C are given as V_{MP}=23 V, I_{MP}=7.27A and P_{MP}= 167.21 W, respectively. The PV array consists of two strings and each one has 3 series connected PV panels. The input voltage applied to the system is 69V, the resulting output voltage is 138V and output power is 380W. The simulatiom results of FLC based MPPT for boost converter is shown in figure 14.

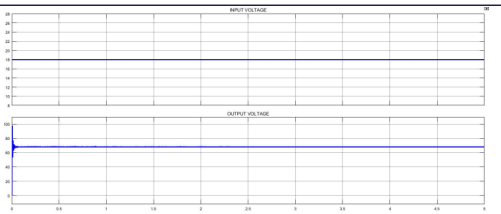


Figure 12: Input and output voltage of quadratic boost converter

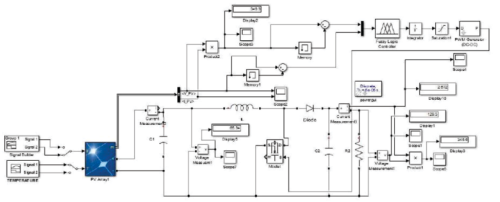


Figure 13: Simulink model of FLC based MPPT for boost converter

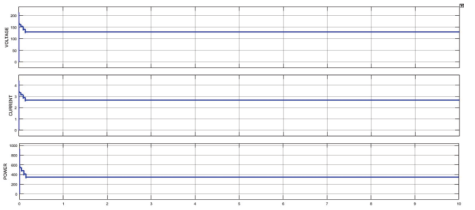


Figure 14: Output voltage,current and power of FLC based MPPT for boost converter

The fuzzy logic controller based MPPT for quadratic boost converter model is shown in figure 15. System consists of the PV array, QBC and FLC based MPPT controller. The input voltage applied to the system is 69V, the resulting output voltage is 230V and output power is 850W. The simulatiom results of FLC based MPPT for Quadratic boost converter is shown in figure 16.

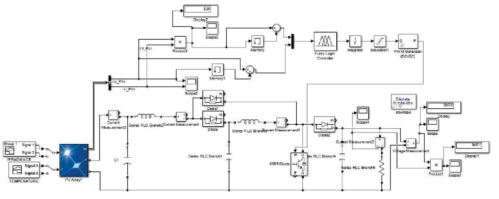


Figure 15: Simulink model of FLC based MPPT for QBC

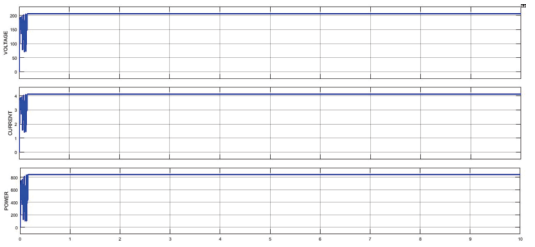


Figure 16: Output voltage,current and power of FLC based MPPT for QBC

CONCLUSIONS

In this work, a quadratic DC-DC boost converter with fuzzy based MPPT ability for high step-up ratio applications is proposed. This strategy assures the stability of the system, as well as a maximum power extraction. The proposed algorithm for MPPT is validated using boost converter and quadratic boost converter, results shows better overall efficiency. The entire system is simulated in Simulink and desired results where validated for effectiveness of proposed MPPT algorithm. QBC provides high voltage conversion ratio with lower duty cycle as compared with conventional boost converters, and provide lower voltage stress and higher efficiency values. The QBC is also more simple, reliable and highly efficient than the cascaded converters because of the second active switch elimination.

REFERENCES:

[1] Ozdemir, Saban, Necmi Altin, and Ibrahim Sefa. (2017),"Fuzzy logic based MPPT controller for high conversion ratio quadratic boost converter." International Journal of Hydrogen Energy42.28, 17748-17759.

[2] Berkovich, Y., and B. Axelrod. (2011), "Switched-coupled inductor cell for DC–DC converters with very large conversion ratio." IET power electronics 4.3, 309-315.

[3] Kumar, R. Selva, et al. (2016), "Design and Comparison of Quadratic Boost Converter with Boost Converter." International Journal of Engineering Research & Technology (IJERT) 5, 877-881.

[4] Ramos-Hernanz, Josean, et al.(2017), "Novel control algorithm for MPPT with Boost converters in photovoltaic systems." International Journal of Hydrogen Energy 42.28, 17831-17855.

[5] Ghamrawi, Ahmad, Jean-Paul Gaubert, and Driss Mehdi. (2016), "New control strategy for a quadratic boost converter used in solar energy system." IEEE International Energy Conference (ENERGYCON) IEEE.

[6] Altin, Necmi, and Saban Ozdemir. (2013), "Three-phase three-level grid interactive inverter with fuzzy logic based maximum power point tracking controller." Energy Conversion and Management 69,17-26.

[7] Ozdemir, Saban, Necmi Altin, and Ibrahim Sefa. (2014), "Single stage three level grid interactive MPPT inverter for PV systems." Energy Conversion and Management 80, 561-572.

[8] Leyva-Ramos, J., et al. (2009), "Switching regulator using a quadratic boost converter for wide DC conversion ratios." IET Power Electronics 2.5, 605-613.

[9] S. Kolsi1, H. Samet, M. Ben Amar (2014),"Design Analysis of DC-DC Converters Connected to a Photovoltaic Generator and Controlled by MPPT for Optimal Energy Transfer throughout a Clear Day", Journal of Powerand Energy Engineering, 2, 27-34.

[10] M.S. At Cheikh, C. Larbes, G.F. Tchoketch Kebir and A. Zerguerras (2007),"Maximum power point tracking using a fuzzy logic control scheme", Revuedes Energies Renouvelables Vol. 10 N3 387 395.

[11] Anurag, A., Bal, S., Sourav, S., & Nanda, M. (2016). A review of maximum power-point tracking techniques for photovoltaic systems. International Journal of Sustainable Energy, 35(5), 478-501.