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Solar Fed DC-DC Boost Converter using Fuzzy Logic Controller

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Abstract—*This paper presents the solar-fed DC-DC boost converter regulated by a Mamdani Fuzzy Logic Controller. The Objective of this methodology is to develop a fuzzy logic controller on a solar-fed DC-DC boost converter using MATLAB@Simulink. The output voltage of the boost converter is controlled by providing a gate pulse through a fuzzy logic controller. The proposed system consists of developing a fuzzy logic controller to generate PWM pulses with the required duty cycle for the boost converter's MOSFET to maintain a constant output voltage. The converter's duty cycle is adjusted continuously to achieve the required output voltage. This proposed system is designed as an adaptive control approach that does not rely on explicit mathematical modelling. The simulation results show that the voltage output can be controlled for the boost DC-DC converter by using this system.*

Index Terms— *Solar Fed DC-DC Boost Converter, Mamdani Fuzzy Logic Controller, MATLAB@Simulink, Pulse Width Modulation (PWM).*

I. INTRODUCTION

The increasing penetration of photovoltaic (PV) systems demands high-performance power-conditioning units capable of regulating the inherently nonlinear and time-varying output of solar sources. Variations in irradiance, temperature, and load conditions cause significant fluctuations in PV voltage and power. A DC–DC boost converter is a power electronic converter used to step up a low input DC voltage to a higher regulated output voltage. It is widely employed in photovoltaic systems to elevate the variable solar source voltage to the required load or storage level. This project proposes a solar-fed DC–DC converter using a Fuzzy Logic Controller (FLC) modelled in MATLAB/Simulink. The boost converter performs regulated voltage conversion, while the fuzzy controller dynamically adjusts the PWM duty cycle based on error and change in error signals. The proposed adaptive system does not require precise mathematical modelling and effectively handles converter nonlinearity, parameter uncertainty, and rapid operating-point variations.

II. PROPOSED MODEL

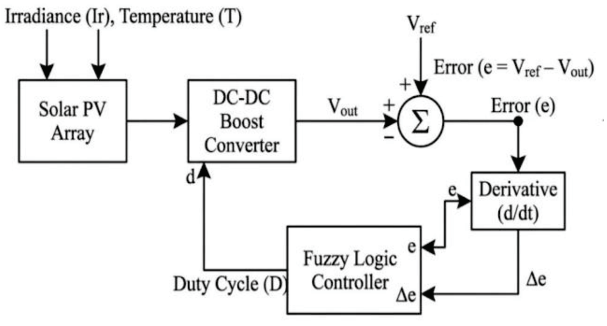

Fig 1. Block diagram of a fuzzy logic controller for a solar-fed DC-DC boost converter.

The proposed system represents a closed-loop architecture integrating a photovoltaic (PV) source, a DC–DC boost converter, and a Mamdani-type fuzzy logic controller. The PV array, driven by irradiance and temperature, exhibits nonlinear I–V characteristics, producing a variable DC input to the converter. The boost converter operates in continuous conduction mode, where the duty cycle (D) governs both voltage step-up and impedance transformation, thereby influencing the PV operating point and power extraction. The output voltage (V_{out}) is continuously measured and compared with a reference voltage (V_{ref}) to generate the control error $e=V_{ref}-V_{out}$.

The error signal and the change in error signal are the inputs to the fuzzy logic controller. The FLC implements a nonlinear control surface through rule-based inference. It allows the controller to adapt to different operating conditions without requiring a precise mathematical model of the system. Based on the inference mechanism, an incremental adjustment to the duty cycle is generated, which modulates the PWM signal driving the converter switch. This closed-loop interaction ensures continuous adaptation of the converter dynamics to compensate for PV variability and load-induced disturbances.

III. SOLAR PV ARRAY

The solar PV array is the combination of multiple solar panels connected in a mix of series and parallel configurations. In this proposed work, we use a PV array with variable irradiance and constant temperature. The irradiance that we are giving to the PV array is a "Time-varying Irradiance Signal". And the Time-varying Irradiance Signal is shown in Fig.2.

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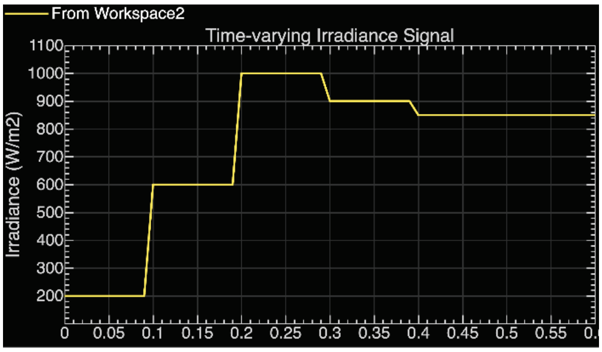

Fig 2. Time-varying Irradiance Signal for Solar PV Array

IV. BOOST CONVERTER

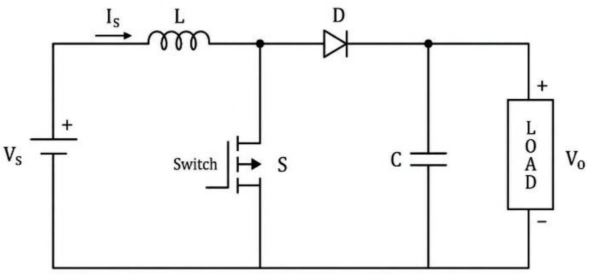

Fig 3. DC-DC Boost Converter

The DC-DC boost converters effectively boost the voltage levels as per our requirement. The basic circuit of the Boosk converter is shown in Fig.3. Here, the MOSFET is controlled by pulses that come from the fuzzy logic controller.

There are 2 modes of operation in the boost converter, and they are explained below

Mode 1: **switch-on**

During the switch-on condition, the MOSFET conducts, and the input voltage appears across the MOSFET. The path taken by the input current is through the source, inductor, switch, and again it flows back to the source. Then the inductor initially gets charged. The capacitor discharges the stored energy and supplies the load, but in the reverse direction.

Inductor voltage : $V_L = V_s$

Inductor current: $\frac{di_L}{dt} = \frac{V_S}{L}$

Capacitor current : $I_c = -I_{load}$

Mode 2: **switch-off**

During the switch-off condition, the MOSFET will not conduct, and the MOSFET branch gets open-circuited. Thus, the input voltage in coordination with the inductor will discharge through the capacitor and load, hence we call it a boost converter. The path taken by the input current and inductor current is through the source, inductor, diode, capacitor, load, and again it flows back to the source. Now the capacitor gets charged.

Inductor voltage : $V_L = V_s - V_o$

Inductor voltage : $\frac{di_L}{dt} = \frac{V_S - V_O}{L}$

V. CONTROLLER DESIGN

A fuzzy logic controller consists of a fuzzifier, a defuzzifier, fuzzy inference system (i.e., rule base, decision-making blocks). A fuzzy logic controller offers an important concept of soft computing with words. Fuzzy language is very close to human language. Fuzzy logic uses linguistic terms such as “low”, “medium”, and “high” to represent system behaviour and make decisions without requiring exact mathematical models.

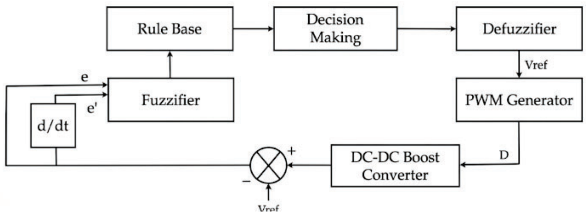

Fig 4. Block Diagram of FLC

The fuzzifier gets an error value (e) and a change in error value(Δe), where a memory block is connected in cascade with Δe to store the previous error value. Thus, the error and the change in error are compared with each other and given to the fuzzifier.

i. *Fuzzification*: The fuzzifier converts precise numerical inputs into fuzzy values which can be described using linguistic terms such as "low", "medium", or "high".

ii. *Rule-base*: Rule-base consist of a set of “if and then” rules like statements in combinations. “If” means condition and “then” means conclusion. Depending upon the error(e) and the change in error(Δe) values, which are given as input to the converter, the rules will be implemented to generate the gate pulse to the converter switch(i.e., MOSFET).

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When the load voltage (i.e., converter output) is higher than the input, then the duty ratio of the MOSFET is decreased and vice-versa. This change in the gate pulse takes place with the help of fuzzy rules. Table-I shows the fuzzy rules.

Table-I: Fuzzy Rules for e & Δe w.r.t Duty ratio

D		e						
		PB	**PM**	**PS**	**Z**	**NS**	**NM**	**NB**
Δe	**NB**	Z	PS	PM	PB	PB	PB	PB
	NM	NS	Z	PS	PM	PB	PB	PB
	NS	NM	NS	Z	PS	PM	PB	PB
	Z	NB	NM	NS	Z	PS	PM	PB
	PS	NB	NB	NM	NS	Z	PS	PM
	PM	NB	NB	NB	NM	NS	Z	PS
	PB	NB	NB	NB	NB	NM	NS	Z

- PB (Positive Big)
- PM (positive Medium)
- PS (Positive Small)
- Z (Zero)
- NS (Negative Small)
- NM (Negative Medium)
- NB (Negative big)

These whole rules are framed to form membership functions like a triangular functions or a trapezoidal functions. In the proposed work, we are using triangular functions as membership functions for both e & Δe. Hence, the resultant function is also a triangular function. Those functions are shown in Fig. 5 .1, 5.2, 5.3.

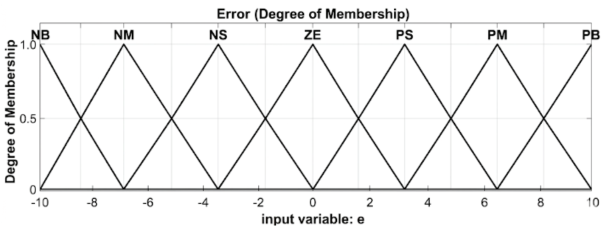

Fig 5.1. Membership Functions for Input Variable: e

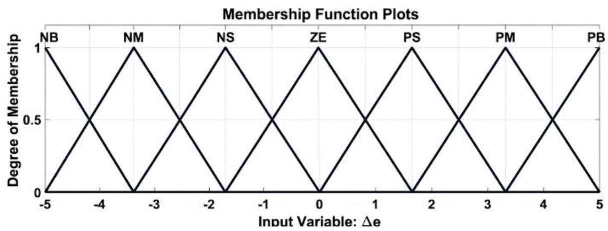

Fig 5.2. Membership Functions for Input Variable: Δe

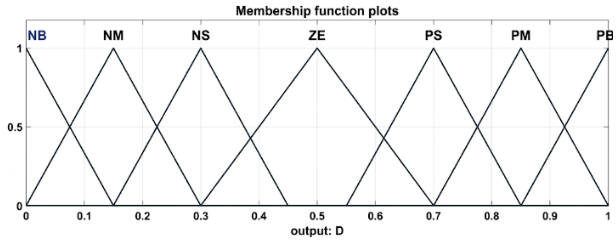

Fig 5.3. Output Membership Functions for output: D

iii. *Decision Making*: Thus, we can see that the output D (Duty ratio) is generated with respect to all the fuzzy rules and membership functions through the fuzzy inference system.

iv. *Defuzzification*: It is the reciprocal function/action of the fuzzification. It converts the linguistic terms into precise numerical terms, which the system can understand.

VI. SIMULATION

The Simulink model of a Solar Fed DC-DC boost converter using Fuzzy Logic Controller is shown in Fig. 6.

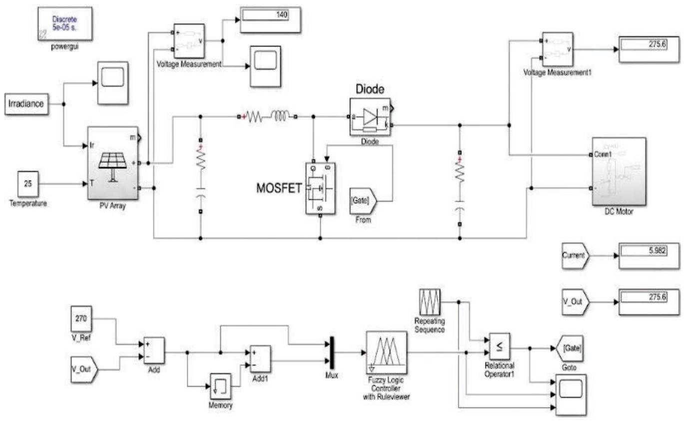

Fig 6. Simulink Model of Solar Fed DC-DC boost converter

Table-II: DC-DC BOOST CONVERTER PARAMETERS

Parameters	Values
Input Voltage (Vs)	140V
Ripple Current	0.15A
Resistance (Ohms)	8Ω
Inductance (milli henry)	22.7
Capacitance (Farads)	83µ
Back Emf (Load)	230V

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VII. RESULTS

The output waveforms are shown in the following Fig.7.1, 7.1, 7.3. Fig. 7.1 contains 3 wave forms (i.e., Relation Operator, Fuzzy Logic Controller, Repeating Sequence). The triangular pulse is compared with the fuzzy wave and generates the gate pulse for the converter

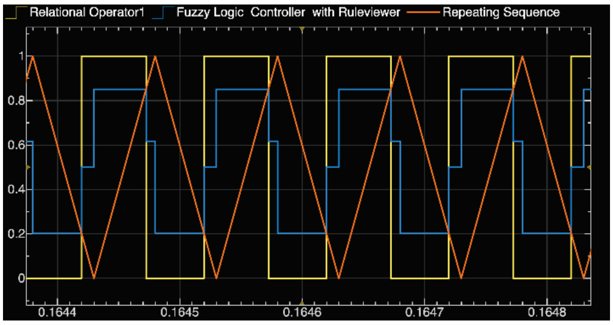
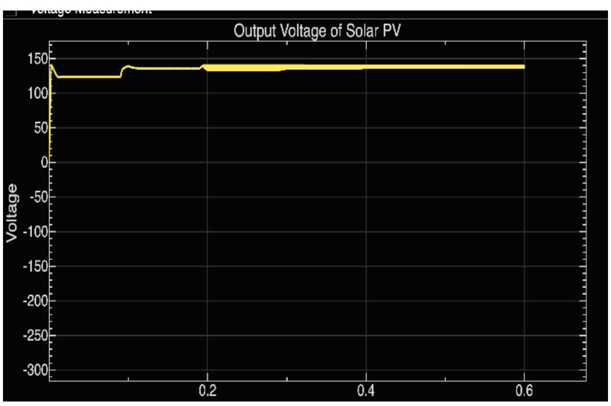
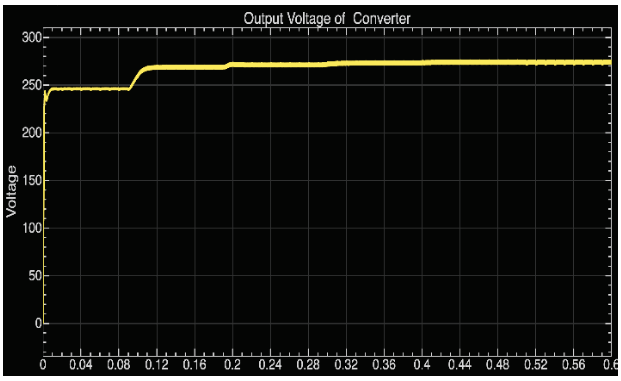


Fig 7.1. Generation of PWM Gate Pulse by Comparing





VIII. CONCLUSION

In this proposed work, Solar Fed DC-DC Boost Converter using Fuzzy Logic Controller is built and implemented using MATLAB@Simulink. The output waveforms prove that the PV array output is boosted by the boost converter with respect to Fuzzy Logic Controller, which adapts to the change in irradiance and generates the gate pulses to the converter. So, for the dynamic condition the proposed model is designed to be adaptive in nature.

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