Implementation of Fuzzy Logic Based MPPT Controller for Solar Photo Voltaic Application

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Keywords: Solar Photovoltaic Array (SPV), MPPT, Zeta Converter, Brushless DC Motor (BLDC).

Abstract: In this work, a straightforward water pumping system that is driven by a BLDC motor and fed by a solar photovoltaic array is proposed. Because of its smaller size, quieter operation, and increased dependability, BLDC motors are used. A solar photovoltaic array serves as the source of energy for the motor. The maximum power is extracted and the zeta converter switch is regulated by means of maximum power point tracking or MPPT. A solar array's voltage is increased via a zeta converter. VSI switching pulse is generated by the electronic commutation of the BLDC motor. In this instance, an incremental conductance approach is utilized in conjunction with a fuzzy-based MPPT controller, and the outcomes are compared. MATLAB / SIMULINK software is used to simulate the proposed system and examine its simulation results.

1 INTRODUCTION

Today the rate of consumption of energy is increasing more rapidly due to increase in population, communication network, industries, transportation, etc. Development and success of any country is mainly depends on uninterrupted power supply. However, the availability of conventional fossil fuels (such as oil, natural gas, coal, gasoline, and diesel) is declining, leading to an energy dearth. Using energy from renewable sources to supplement fossil fuel consumption is one alternative (Sujata S Naik et al., 2019).

There are numerous varieties of sources of sustainable energy, such as solar, wind, hydro, and tidal energy. Among all these sources of renewable energy, solar energy is unique in that as it produces power that is free of cost, non-toxic, and always clean. Additionally, the price of SPV panels is declining nowadays, which draws more attention to the use of solar photovoltaic applications (Kumar R et al., 2014). Both residential and commercial applications based on renewable energy employ this technology. Water pumping is the most efficient and affordable use of all application-based SPV systems for generating electricity from solar photovoltaic arrays (Chandani Sharma et al., 2014).

Typically, in general run of the things simple, affordable, and effective motors are employed for water pumping applications. Direct current motors and induction motors are primarily utilized for pumping load applications due to their easy availability and outstanding performance under all load conditions, However, when these motors are utilized for solar photovoltaic applications, they overheat and require elaborate controls because of low motor voltage (A. Shahin et al., 2010, H Kukde, 2017). Consequently, in low voltage situations, dependable and efficient motors are needed to overcome these issues; brushless DC motors are utilized in these applications.

The term "brushless direct current motor" (BLDC) refers to a motor without any brushes (R. Saxena et al, 2008) Due to the lack of brushes and a commutator, brushless DC motors have several advantages: longer life, reduced inertia from minimal friction, increased efficiency, increased dependability, and a high maximum speed (AbolfazlHalvaeiet., 2005, T. Esram et al., 2007)

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2 METHODOLOGY

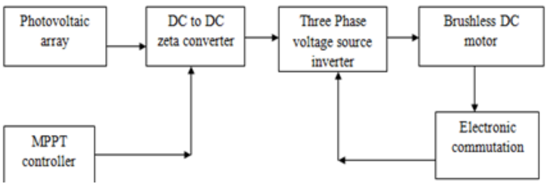

Fig 1: Block representation of the proposed system.

2.1 Maximum Power Point Tracking

The voltage at which a solar module generates the most electricity is known as its maximum power point. The main goal of MPPT is to determine the highest power that a photovoltaic panel can generate under various environmental conditions, such as temperature, sun irradiation, and solar cell temperature (M. Lokanadham et al., 2012)

2.2 Incremental Conductance MPPT (Inc MPPT)

The basic tenet of the incremental conductance method is that the power curve of a solar array has a zero slope at the highest power point (Nandini. D et al., 2017). In order to measure the output voltage and current of the solar array, this method employs voltage and current sensors. Using this technique, the PV array's voltage is adjusted based on the voltage at the source of the most power. This is dependent on the photovoltaic module's incremental and instantaneous conductance (T. Esram.et al., 2007). A comparison is made between the array conductance (I/V) and the incremental conductance (dI/dV). When (I/V) = (dI/dV), there is a maximum output yield; at the maximum power point, dP/dV = 0 (Nandini. D et al., 2017, M. Lokanadham et al., 2012).

$$dP/dV = VdI/dV + I(V) \quad (1)$$

$$dI/dV = -I(V)/V \quad (2)$$

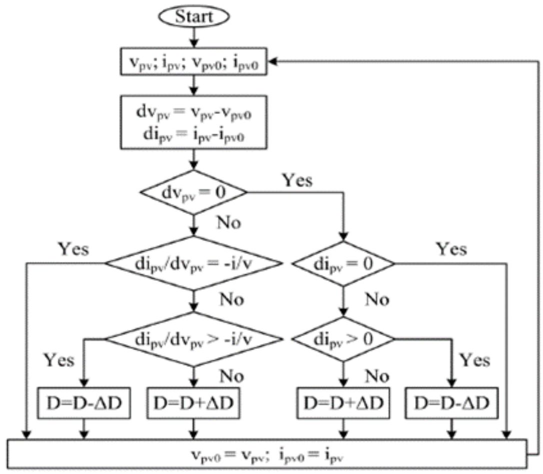

Fig 2: Inc MPPT flow chart.

2.3 Fuzzy Logic MPPT

A novel technique for regulating MPPT to determine peak power is fuzzy logic. To implement fuzzy logic control, three fundamental modules are needed: fuzzification, deffuzification, and inference engine (T. Esram et al., 2007).

Fuzzification is the systematic approach of changing a computational input variable into a linguistic one. Fuzzy controllers use duty cycle as its output, which is employed to control DC-DC converters. The input variables are error and change in error. To produce a fuzzy output, the inference engine applies the rule to a fuzzy input. NB (negative big), NS (negative small), ZE (zero), PS (positive small), and PB (positive big) are the five fuzzy levels that are employed. Language variable attributed to change in duty cycle for various combinations of E and CE. Fuzzy rules' main objective is to change the duty cycle in order to move the operational stance to the maximum power point. During defuzzification, the fuzzy logic controller's output is changed from a linguistic variable to a numerical variable value using the membership function(T. Esram et al., 2007).

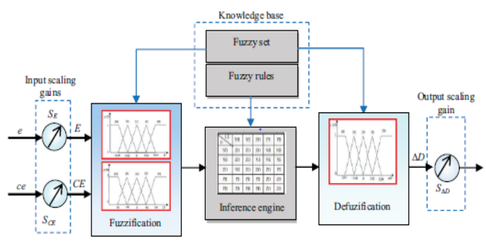

Fig 3: Configuration of Fuzzy Logic Controller.

2.4 Zeta Converter

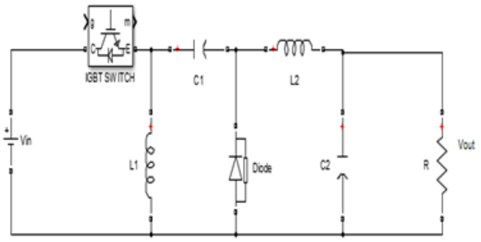

Fig 4: Circuit diagram of Zeta Converter.

The zeta converter is a fourth order DC-DC converter made up of a switch, a diode, two inductors, and two capacitors. This converter has ability to transform an input voltage into an output voltage that is not inverted. It has aptness to work in both step-up and step-down modes(Sujata S Naik et al., 2019, Nandini. D et al., 2017).

$$Vout = Vin * (D/ (1-D)) \quad (3)$$

2.5 Implementation

The electrical power required by the motor-pump is generated by a solar array. The motor receives this power from zeta converter and VSI. The MPPT controller receives data from the solar photovoltaic array and utilizes it to modify the zeta converter's duty cycle to maximize power. A switching pulse produced will switch an IGBT of the converter by the pulse generator via maximum power point controller. Here, the duty cycle of the zeta converter can be altered to function in either step-up (boost) or step-down (buck) mode. The converter used in this work is operating in boost mode, which boosts the output value from the SPV array. So that regulated output at the converter can be obtained. The DC output power of the converter is converted into AC power by the voltage source inverter and then sent to BLDC motor. By operating the VSI in 120-degree conduction mode, commutation losses can be minimized. The switching pulse for VSI is provided by hall signals of a BLDC motor.

2.6 Photovoltaic Array

The photovoltaic Array is modelled by using one diode model. Series resistance Rs used to build solar cells is coupled in series with a parallel combination of current sources made up of diodes and shunt resistance Rsh.

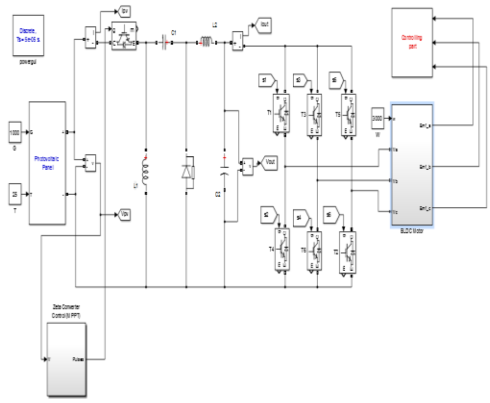

Fig 5: Proposed System's Matlab Model.

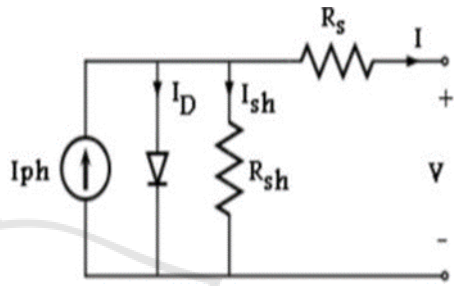

Fig 6: Equivalent photovoltaic cell circuit.

$$\text{Diode Current } (Id) = [e^{(V/NS+I*RS/NS)/VT*C}-1]\ IS\ NP \quad (4)$$

$$\text{Shunt Current}(Ish)=(V+I*Rs)/Rp \quad (5)$$

$$\text{Terminal Voltage}=k*Top/q \quad (6)$$

$$\text{Phase current } (Iph)=[(TopTref)k+Isc]Irr \quad (7)$$

$$(Is)=Irs(Top/Tref)(q*1.12/k*N)(1/Top1/Tref) \quad (8)$$

$$\text{Load current } (I)=Iph*NpIsh \quad (9)$$

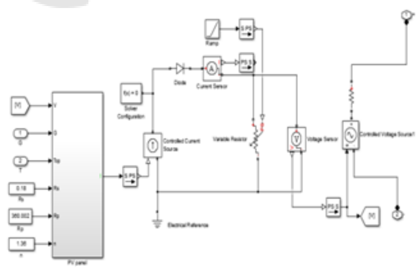

Fig 7: Simulink model of SPV panel.

2.7 Simulink Model BLDC Motor

Simulink model of BLDC motor built with Matlab program is displayed in Fig 12. The three-phase winding BLDC motor receives power from a VSI, with each phase offset by a 120-degree angle.

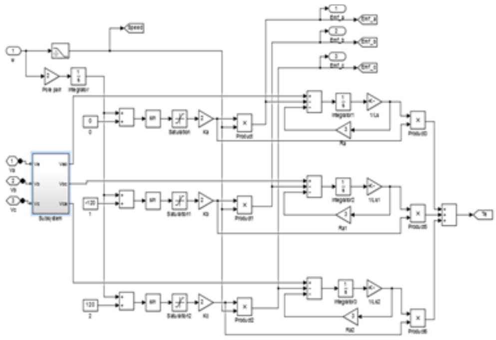

Fig 8: BLDC motor Simulink model.

3 RESULT AND DISCUSSION

At 1000W/m2 solar irradiation, conduction of a solar photovoltaic array supplied BLDC motor employing a zeta converter is examined. And maximum power can be tracked by using MPPT controller. The curve of the array voltage with respect to time is shown in Fig. 9. As seen in graph, the array voltage begins at a low beginning value and gradually rises as motor speed increases. Once the motor speed reaches a constant value, the array voltage then stays constant.

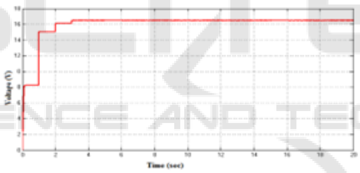

Fig 9: PV panel Output voltage.

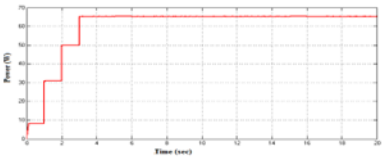

Fig 10: PV panel Output power.

3.1 Incremental Conductance MPPT

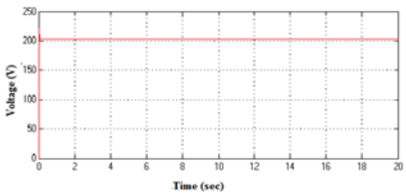

Fig 11: Converter Output voltage using Inc MPPT.

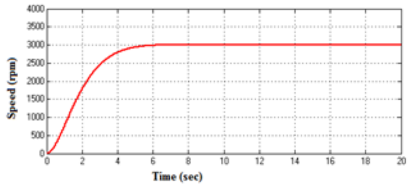

Fig 12: Motor Speed using Inc MPPT.

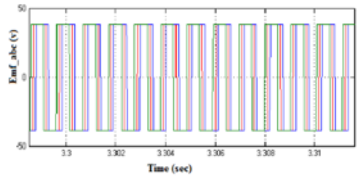

Fig 13: Emf_abc using Inc MPPT.

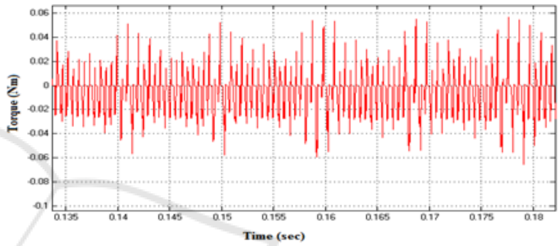

Fig 14: Motor torque.

3.2 Fuzzy MPPT

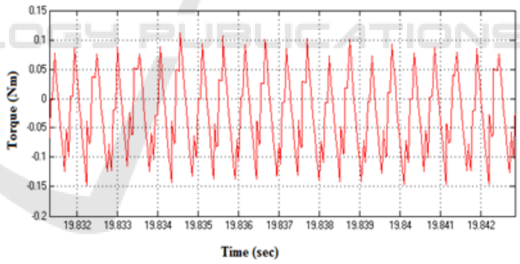

Fig 15: Output voltage of converter using Fuzzy MPPT.

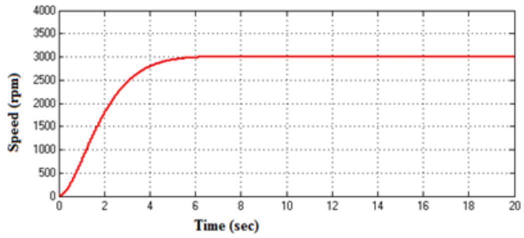

Fig 16: Speed of BLDC motor using Fuzzy MPPT.

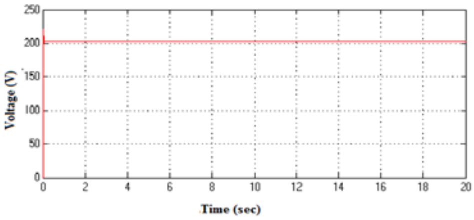

Fig 17: Motor torque.

4 CONCLUSION

A straightforward solar photovoltaic array with a BLDC motor based on a Zeta converter has been proposed to power a water pumping system. In order to power the motor, a photovoltaic array, a circuit made up of one diode-equivalent solar cells is used as the input source. This array has numerous advantages, such as being free, clean, and non-polluting.

Fuzzy based MPPT controller is used to run the converter switch and extract the maximum power from the solar panel; the results are compared with the incremental conductance approach. It can be noticed that Fuzzy based MPPT gives better results, and time taken to achieve speed response is fast. Here Zeta converter is used because of its various advantages such as circuit is simple, fast response, wide range of power tracking. And for boosting the photovoltaic array output voltage zeta converter is used.

The absence of brushes in brushless motors results in improved performance characteristics, eliminating the drawbacks of standard brushed DC motors. Electronic commutation is used in Brushless DC motors to execute commutation, and the motor's speed is controlled without the use of an additional control circuit. The proposed system is created using MATLAB / SIMULINK software. To validate the suggested system, output waveforms of PV panel, the zeta converter, and the Brushless DC motor are shown.

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