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Fuzzy Logic Based MPPT for Wind Energy System with Power Factor Correction

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Abstract: *Two factors that provide a quantitative measure of the power quality in an electrical system are Power Factor and Total Harmonic Distortion. The amount of useful power being consumed by an electrical system is predominantly decided by the PF of the system. Benefits from improvement of Power Factor include Lower energy and distribution costs, reduced losses in the electrical system during distribution, better voltage regulation and increased capacity to serve power requirements. This Paper presents a Power factor correction for a Wind generation system. As we know that where ever there is power conversion there is power factor problem. As wind energy system consists of rectifier and Inverter there is a Power Factor problem also. The rectifier used in this topology is a Boost type of Rectifier. For extracting maximum power from the wind system, MPPT algorithm is also used in this system. The proposed system has High Power Factor, Low Harmonic Distortion. The wind generator is used as the main power source and lead-acid batteries as the auxiliary power source. The proposed system adopts power factor correction to achieve unit power factor and Maximum Power Point Tracking to implement available maximum power, thus to improve the overall system performance. In addition, the bidirectional converter provides charging and discharging compensation to dc bus by controlling the duty cycle of switches.*
Keywords: *wind generator; bi-directional dc/dc converter; the maximum power point tracking; three-phase power factor correction.*

I. Introduction

The diminishing reserves of fossil fuels, together with the associated environmental effects are encouraging more research in renewable clean energy. These renewable clean energy alternatives include solar energy, hydro energy and wind energy. The need to extract the maximum power available in the wind, research is taking place in numerous fields related to wind energy production. Intelligent control techniques are considered among the most important dimensions for the turbine efficiency and hence the control techniques enhancement has direct contribution to the better performance of wind turbines.

In this paper the new concept for the energy conversion system of the wind turbine (WT) is proposed. It is the result of the effort to further improve the WT energy conversion system based on the permanent-magnet generator similar to the one described. The system comprises (Fig. 1) a grid connected permanent magnet synchronous generator (PMSG), a small series converter (20% of rated power) in the star point of the open winding PMSG and an optional gearbox (GB). The series converter provides damping to the system in case of input power and/or grid disturbances. The design belongs to the category of fixed speed designs, but in comparison with those based on induction generators it proposes to use more efficient PMSG.

II. Fuzzy Logic Controller

As shown in Figure 1, the FLC system consists of 3 components. They are fuzzification, the rule base, and defuzzification. Fuzzification, the first component of the FLC, converts the exact inputs to fuzzy values. These fuzzy values are sent to the rule-base unit and processed with fuzzy rules, and then these derived fuzzy values are sent to the defuzzification unit. In this unit, the fuzzy results are converted to exact values using centre of area method. In Figure 3 and 4, the error and the error variation of the input data of the FLC's input variables are shown. Triangle membership functions were used. These functions are called NB, NM, S, PM, and PB, and the data vary between –1 and 1 as seen in the Figures. The triangle membership function is defined as,

$$\mu_{MU(x)} = \max(\min(\frac{x-x1}{xT-x1}, \frac{x2-x1}{x2-xT}), 0)$$

The output space of the FLC is shown. These data also vary between –1 and 1. In Table 1, the rules of the FLC are given. Due to the 5-ruled input variables, there are 25 rules in total.

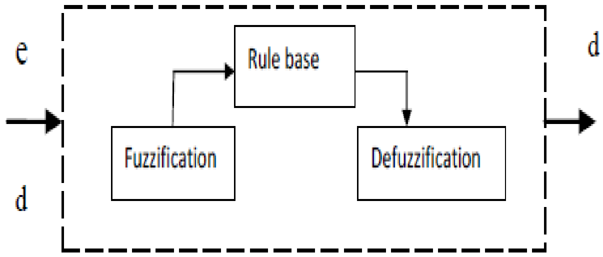

Fig 1: Basic configuration of a FLC

Table 1. Fuzzy rule base

e/de	NB	NM	S	PM	PB
NB	NB	NB	NM	NM	S
NM	NB	NM	NM	S	PM
S	NM	NM	S	PM	PM
PM	NM	S	PM	PM	PB
PB	S	PM	PM	PB	PB

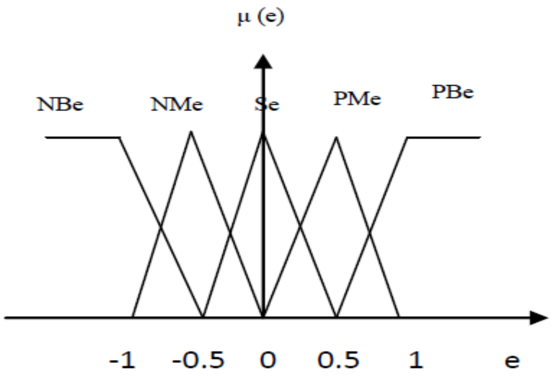

Fig 3: Error membership functions

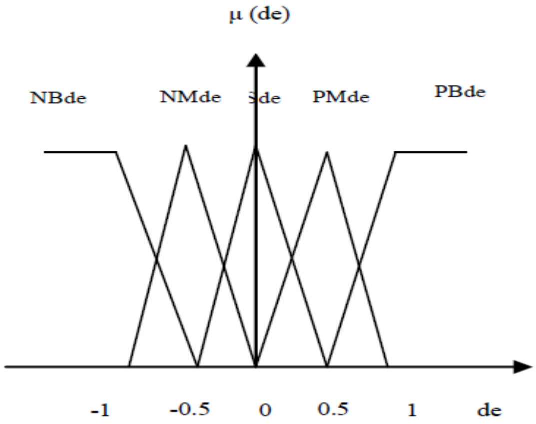

Fig 4: Variation of error membership functions

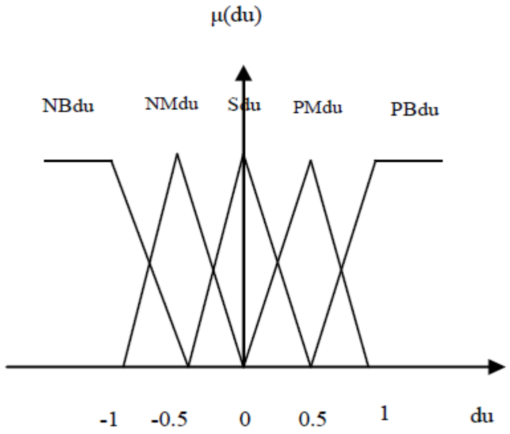

Fig 5: Output space

Topologies Of The Proposed System

The proposed wind power generation converter system mainly uses PMSG to provide electricity to the load and employs a lead-acid battery to avoid the wind power provide electricity to the load intermittently. The lead-acid can not only absorb extra energy but also provide energy to the load. Fig.6 shows the topologies of the proposed system that consists of three phase ac/dc full-bridge semi controlled rectifier, SEPIC converter, bi-directional dc/dc converter and bridge dc/ac inverter. The proposed system improves the harmonic distortion and the power factor that makes the wind full generator to reduce the noise [1]-[5] and the balances three phase. The system with power electronic technology achieves higher efficiency and stability[6]. Each converter operating is introduced as following. To improve the output of current harmonics and power factor of the wind generator, the rectifier is employed. The semi controlled rectifier is similar to a boost converter. The currents corresponding to the inductors (L1, L2, L3) are increase when the switches (S1, S2, S3) are turned on, and the corresponding diodes (D1, D2, D3) conduct when the switches(S1, S2, S3) are turned off. The power flow is transferred from wind generator to the rectifier. Table I shows the six intervals

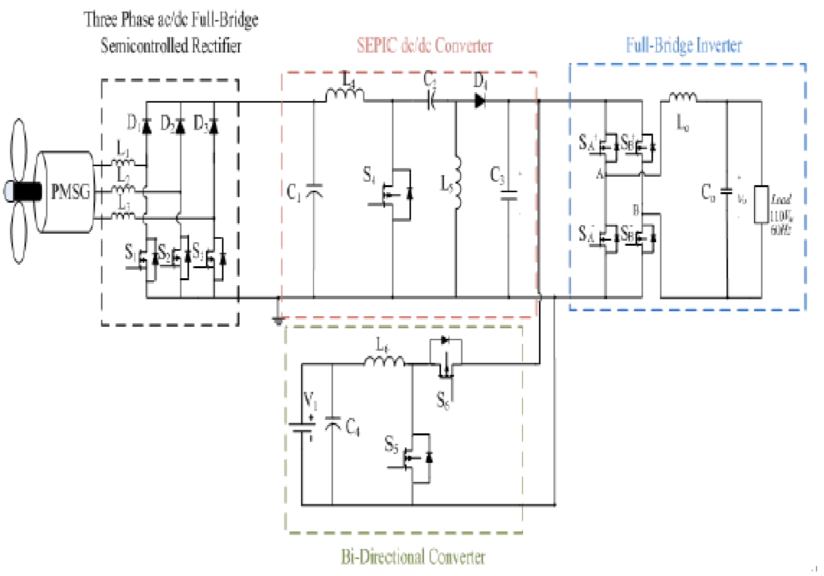

Figure 6. Topologies of the proposed system.

Table I. The condition of input current

interval / current	1	2	3	4	5	6
i_a	+	+	+	−	−	−
i_b	−	−	+	+	+	−
i_c	+	−	−	−	+	+

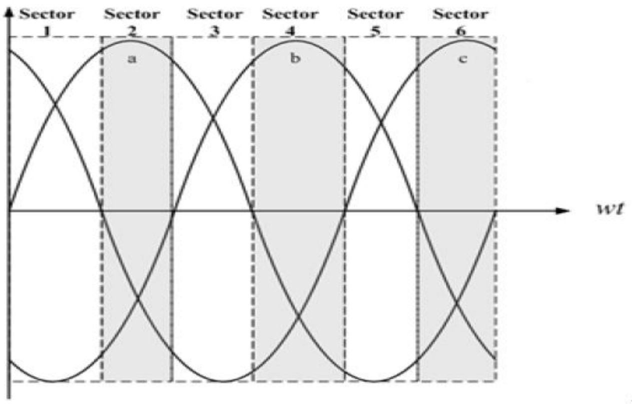

Figure 7. Theoretical waveforms of ia, ib and ic.

of the three-phase input currents. Fig. 7 shows the waveforms of input currents. The dc bus can be compensated fast by the bi-directional converter. According to the different conditions of dc bus, itcan play in the charged or discharged role. In other words, the power flow is variable, and needs to decide the input and on the basis of the circuit current. The converter is applied to a hybrid power system, a fuel cell, an uninterruptible power system or a renewable energy conversion system. These system topologies can not only be compensated but also store energy by the bi-directional converter connected with batteries. The proposed system is employed with the full-bridge inverter, due to its output voltage is twice of the half-bridge inverter under the same input voltage.

III. Control Startegies

A. Fuzzy logic control (Flc) algorithm

The overall control scheme of the proposed system is shownin Fig. 8. In fuzzy logic controller design, one should identify the main control variables and determine the sets that describethe values of each linguistic variable. The input variables of the FLC are the output voltage error, (n), and the change of this error, `e(n). The output of the is the duty cycle of the, d(n), of the PWM signal, which regulates the output voltage. Figs. 9 show the membership functions of the inputs and the outputs of the SEPIC side FLCs.

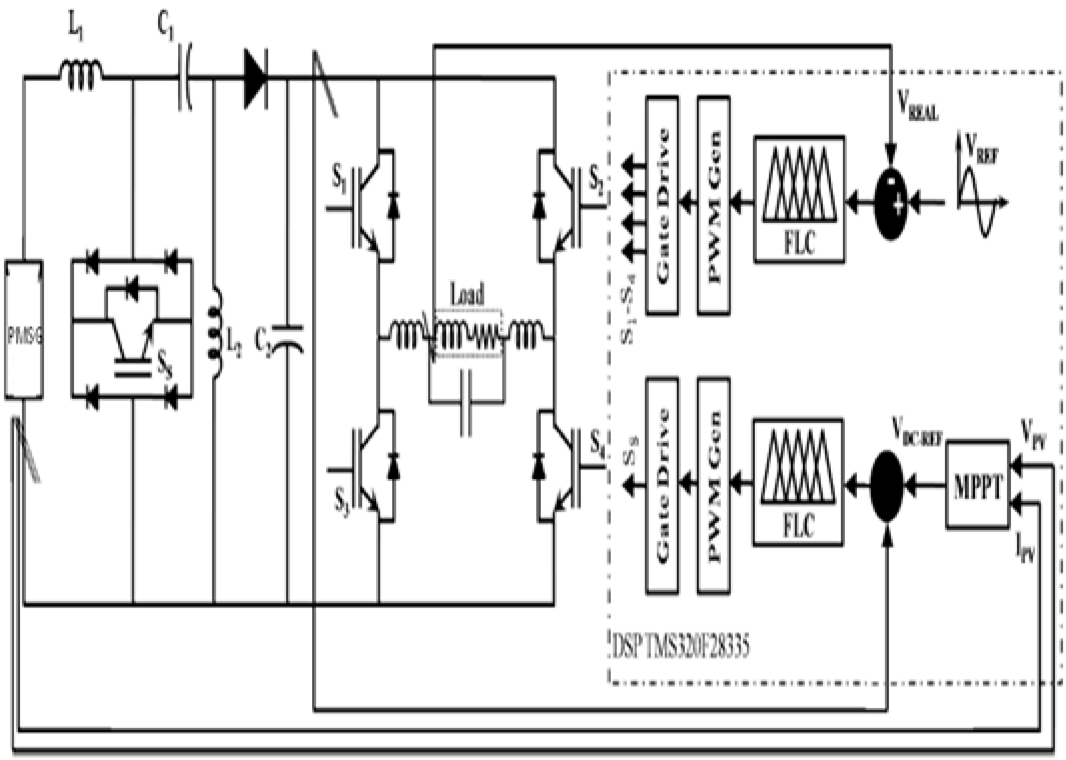

Fig. 8. Overall control scheme for the proposed FLC based MPPT scheme for SEPIC converter.

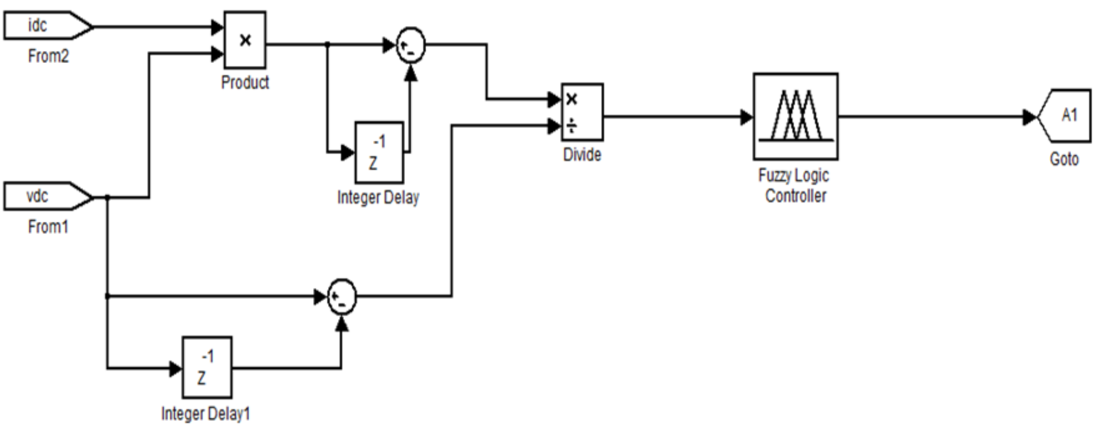

Fig9: simulation of fuzzy logic algorithm

IV. Bi-Directional Batery

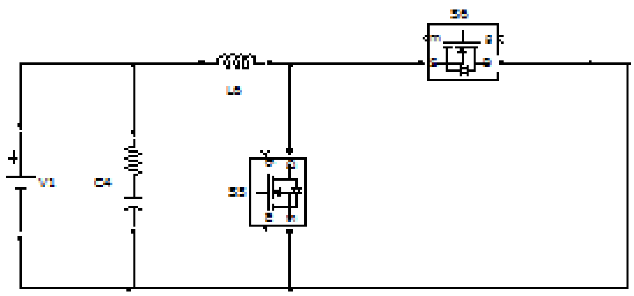

Fig:10 bi-directional battery.

The bi-directional transfer of power between the mains power grid, and the increasingly sophisticated and sensitive battery packs present in renewable energy systems and electric vehicles, commonly requires an additional high frequency converter to maintain the correct voltage conditions for both the mains grid and the battery or storage device. Common circuits use several converter stages, as well as safety isolation circuitry, making the power conversion system bulky, expensive, and inefficient. The increased complexity reduces system reliability. As overall ratings increase, these drawbacks become progressively less tolerable The invention is a new circuit topology for single phase and three phase applications with reduced complexity and fewer bulky, expensive components. The system is galvanically isolated safety while offering bi-directional power flow without separate equipment – so that sophisticated battery optimization procedures for fast charging and life extension are enabled. High efficiency cell balancing is included Competitive Advantages•No large passive components, decreasing cost ,size and weight,Fewer high frequency switching stages, improving efficiency and reducing complexity ,Galvanic isolation for safety at high voltages,Advanced input/output controls for voltagebalancing and other applications.

V. Experimental Results

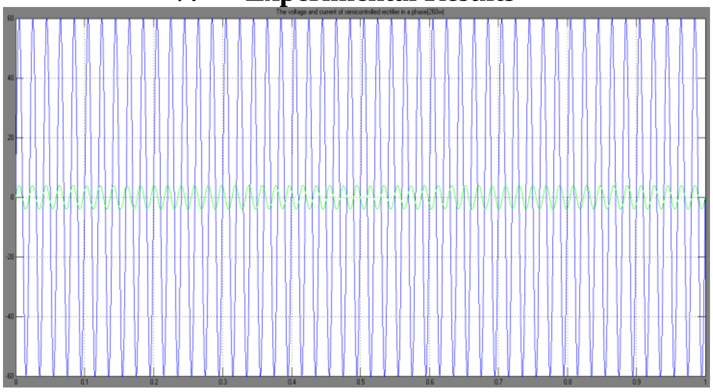

Fig: 11. The input voltage and current of semicontrolled rectifier in a phase (260W).

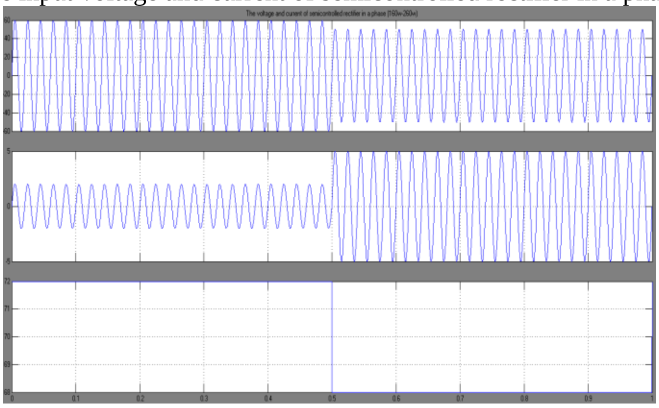

Fig12. The input voltage and current of semicontrolled rectifier in a phase (160W-260W).

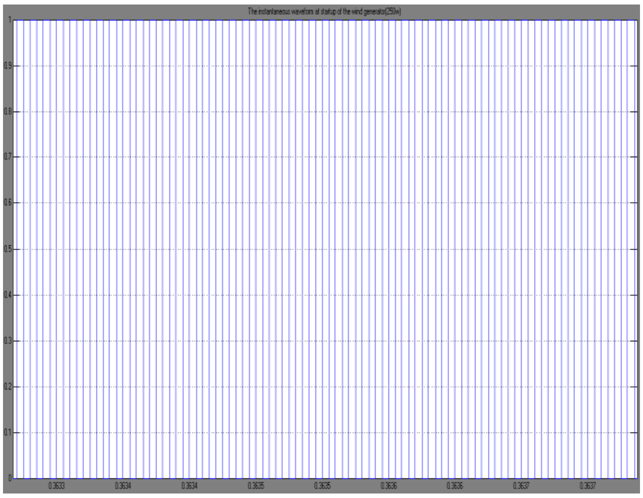

Fig 13. The instantaneous waveform at the startup of the wind generator(250w)

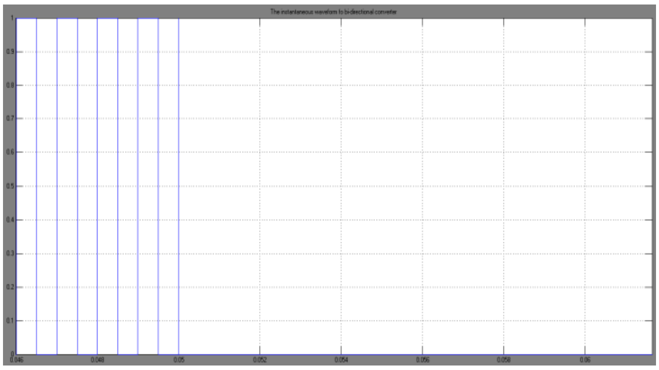

Figure 14a. The instantaneous waveform of bi-directional converter

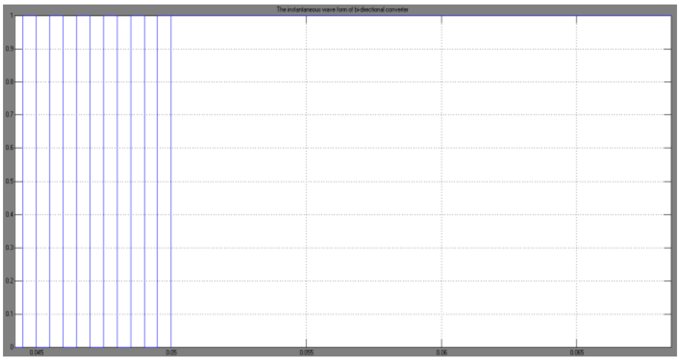

Figure 14b. The instantaneous waveform of bi-directional converter

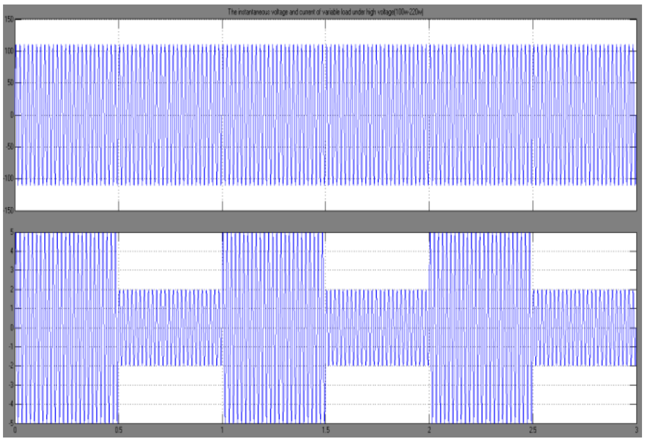

Figure 15. The instantaneous voltage and current of variable load under high voltage (100W-220W).

VI. Conclusion

The implementation of power conversion system (220W) for wind generator is presented in this paper. In the control strategy, the system achieves high stability and available maximum power point by using fuzzy logic controller. With the proper control of the wind generator, the output power will be balanced effectively. A dc bus hysteresis detection mechanism is designed to control the battery; therefore, the power flow between the battery and the dc bus can be controlled. At the last, the feedback controller can compensate the output of the inverter accurately while input voltage or output load changes.

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