FUZZY BASED BOOST CONVERTER CONTROL FOR WIND ENERGY CONVERSION SYSTEM

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Abstract- In this paper the operation of wind turbine system with fuzzy based boost converter control is proposed. Generally this system consists of wind turbine, variable-speed permanent-magnet synchronous generator (PMSG), AC-DC converter (bridge rectifier+boost converter), battery, and a single phase inverter. Fuzzy logic controller is introduced in the boost converter to maintain constant output voltage. Energy storage devices are required for power balance and power quality in stand-alone wind energy systems. The power can be effectively delivered and supplied to the loads, subject to an appropriate control method. The whole proposed system is developed using MATLAB simulink software.

Key Words: **Energy storage, real-time control, variable-speed permanent-magnet generators (PMSG), fuzzy logic controller (FLC), power quality, power balance.**

1. INTRODUCTION

OVER THE past few years, research into the use of renewable energy sources (RESs), such as wind, photovoltaic, and hydropower plants for electricity generation has been the subject of increased attention. In the case of wind energy conversion systems (WECSs), the interest is also focused. small units, used to provide electricity supply in remote areas that are beyond the reach of an electric power grid or cannot be economically connected to a grid. While large wind turbines reached their technological maturity, small-scale WECSs have to be further optimized in order to achieve integration in flexible micro grids (MGs) and increased reliability. Clusters of MGs, linked through power and data exchange highways, play a similar role in the smart grid as the power generators do in classical power systems. However, the higher flexibility of the MGs and the easier integration of RES make them more attractive. The WECSs are the most favored alternatives for supplying electricity in stand-alone cases at this moment due to the fact that wind energy is relatively easily harnessed, the maintenance required by the wind turbine generators is reasonable, and there is no fuel cost. Several electrical machines can be used to implement the electromechanical energy conversion and control, each of which presents different advantages and disadvantages. For small-power wind systems operating in remote and isolated areas, the study of permanent-magnet synchronous generators (PMSGs) has been the subject of much research. PMSGs are particularly interesting in low-power wind energy applications, due to their small size and high power density. The primary advantage of PMSGs is that they do not require any external excitation current. A major cost benefit in using the PMSG is the fact that a diode bridge rectifier may be used at the generator terminals since no external excitation current is needed. The system topology used in this paper is based on a PMSG connected through a diode bridge rectifier and a boost converter to the dc link for small- and medium-power ranges. Due to the highly variable nature of the wind, the utilization of an energy storage device such as a battery can significantly enhance the reliability of a small stand-alone wind system. Integrating an appropriate energy storage system in conjunction with a wind generator removes the fluctuations and can maximize the reliability of the power supplied to the loads. In the autonomous system, the wind power converter may be operated to maximize the wind energy converted into electricity. The captured energy is supplied to the load directly, the difference between the wind power generation and user consumption being directed to or supplied by the battery energy storage device connected via the power electronic interface. The lead–acid batteries (LABs) are the dominant energy storage technology, with their advantages of low price, high unit voltage, stable performance, and a wide range of operating temperature. The LABs hence constitute an exciting challenge, as major components in the development of the stand-alone wind energy systems.

II. SYSTEM CONFIGURATION

The proposed stand-alone wind power system supplies single-phase consumers at 230 V/50 Hz. It is designed for a residential location, and it is based on a 2-kW wind turbine equipped with the following: 1) a direct-driven PMSG; 2) an ac/dc converter (diode rectifier bridge +boost converter with fuzzy control); 3) a LAB storage device; 4) an inverter; 5) a transformer; and 6) resistive loads. The wind power is converted into the mechanical rotational energy of the wind turbine rotor. A wind turbine cannot "completely" extract the power from the wind. Theoretically, only 59% of the wind power could be utilized by a wind turbine but for the 2-kW wind turbine system analyzed in this paper, the real power coefficient is 39%. The wind turbine rotor is connected to the wind generator, thus converting the mechanical energy into electrical energy. The generator's ac voltage is converted into dc voltage through an ac/dc converter. The rectifier is matching the generator's ac voltage to the dc voltage, while the boost converter provides the required level of constant dc voltage. As fuzzy based boost converter control is used the stability will be increased. The dc output voltage is fed to the battery bank and through an inverter further to the load. The voltage should stay constant for various wind speeds. When the wind speed is too high, the power excess supplied by the wind turbine is stored in the battery. When the wind speed is low, the generator, together with the battery bank, can provide sufficient energy to the loads. The dc loads are supplied directly from the dc circuit. At high speeds, the turbine control system stops the energy production. The same protection is activated also in the case when the battery is fully charged and energy production exceeds consumption. At low wind speeds, load shedding is used to keep the frequency at the rated value. The storage system is composed of a LAB and a full-bridge single-phase inverter that converts the dc voltage of the battery to ac voltage. Furthermore, this voltage is applied to a single-phase transformer, which boosts up the voltage to 230 V. The inverter controls the power transfer.

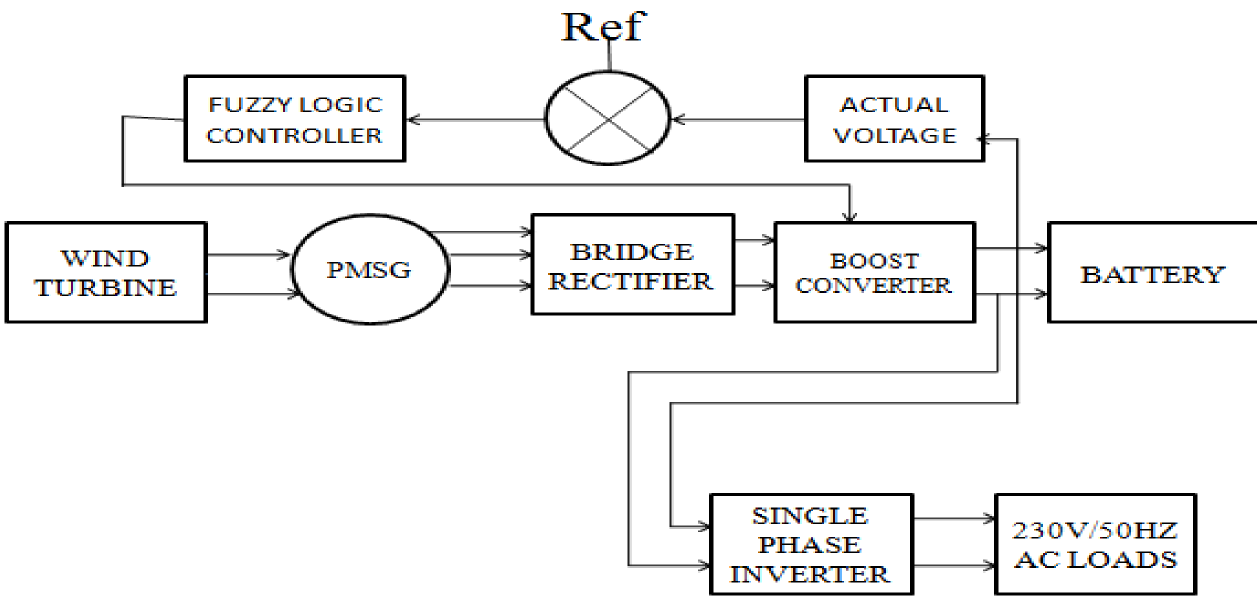

Fig. 1. Proposed Fuzzy based WECS

III. WIND TURBINE MODEL

The model is based on the steady-state power characteristics of the turbine. The stiffness of the drive train is infinite and the friction factor and the inertia of the turbine must be combined with those of the generator coupled to the turbine. The conversion efficiency of the system from wind power to electrical power is given by the product of the power coefficient the gearbox (if present) efficiency, alternator efficiency and power-electronic converter efficiency. It is limited to a maximum of 0.59 (Betz limit). Overall efficiency is defined as the average conversion from energy available in the wind to electrical energy produced. The output power of the turbine is given by the following equation.

$$P_m = C_p(\alpha,\beta)\frac{\rho A}{2}V_{wind}^3$$

A generic equation is used to model c_p (α, β) is,

$$C_{p(\alpha,\beta)} = C_1\left(\left(\frac{C^2}{\alpha_i}\right) - C_3\beta - C_4\right)e^{\frac{-C_5}{\alpha i}} + C_6\alpha$$

IV.PMSG MODEL

The dynamic model of PMSG is derived from the two-phase synchronous reference frame in which the *q*-axis is 90◦ ahead of the *d*-axis, with respect to the direction of rotation. The electrical model of PMSG in the synchronous reference frame. where subscripts *d* and *q* refer to the physical quantities that have been transformed into the *d*–*q* synchronous rotating reference frame; *Ra* is the armature resistance; *ωe* is the electrical rotating speed which is related to the mechanical rotating speed of the generator as *ωe* = *np* · *ωg*, where *np* is the number of pole pairs; and *ψ*PM is the magnetic flux of the permanent magnets. The electromagnetic torque can be derived, as shown below

$$Te = 1.5np\,[(Ld - Lq)idiq + \psi PMiq]$$

and the electromagnetic torque can be regulated by *iq* as

$$Te = 1.5np\psi PMiq.$$

V.FUZZY BASED BOOST CONVERTER MODEL

The unidirectional boost converter achieves an interface between the battery and the rectifier capacitor and ensures the rapid transfer of power. When *V*dc ≥ *Vb*, the boost converter is not working, and the current provided by the generator is channeled through the bypass Schottky diode *Ds*.It is assumed that there is no power loss in the converter. The input and output signals of the boost converter are modeled by two controlled current sources The reference current (*I* Lconv) is supplied by the maximum power point tracking (MPPT). The error between the reference current and the measured current (*I*Lconv) is applied to a proportional integrator (PI) regulator. The output of the regulator is summed with the positive voltage reaction, which realizes *V*dc/*Vb*. The modulation factor *D* is obtained, which is used as a reference for the PWM generator, The modulation factor provides the control signal for the converter's switching device *ST* . In order to control the generator current and to provide over speed limitation, our research team proposed in a control method which is applicable to the dc boost converter block diagram analyzed . Also, the operation of the PMSG rectifier is characterized by variable frequency and variable voltage, as the wind turbine rotor speed varies.

For building a fuzzy block, four main components are needed:

1. *Fuzzification*: It can convert the input into information that which the inference mechanism use to activate and apply the rules.
2. *Rule Base:* It contains the description that how to get the good control.
3. *Inference Mechanism*: It evaluates that which rules of control are relevant to use in this scenario, and
4. *De-Fuzzification:* It can interface that converts the inference mechanism's conclusion into the control input to the system.

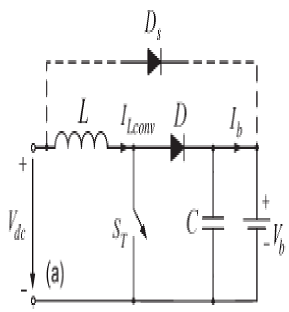

Fig. 2. Boost converter circuit configuration.

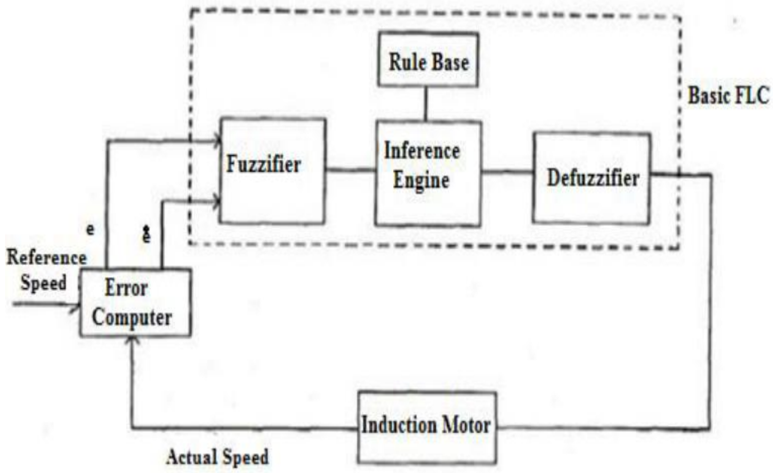

Fig. 3. Block diagram for fuzzy based boost converter.

The Two inputs should be given to the fuzzy controller of the boost converter. First input is the error in output voltage e[i]= Ref-ADC[i], where ADC[i] is the converted digital value of the ith sample of output voltage and „Ref" is the digital value corresponding to the desired output voltage. The second input ce[i] = e[i] - e[i-1], is the difference in the error of the ith sample and the error of $(i-1)th$ sample.

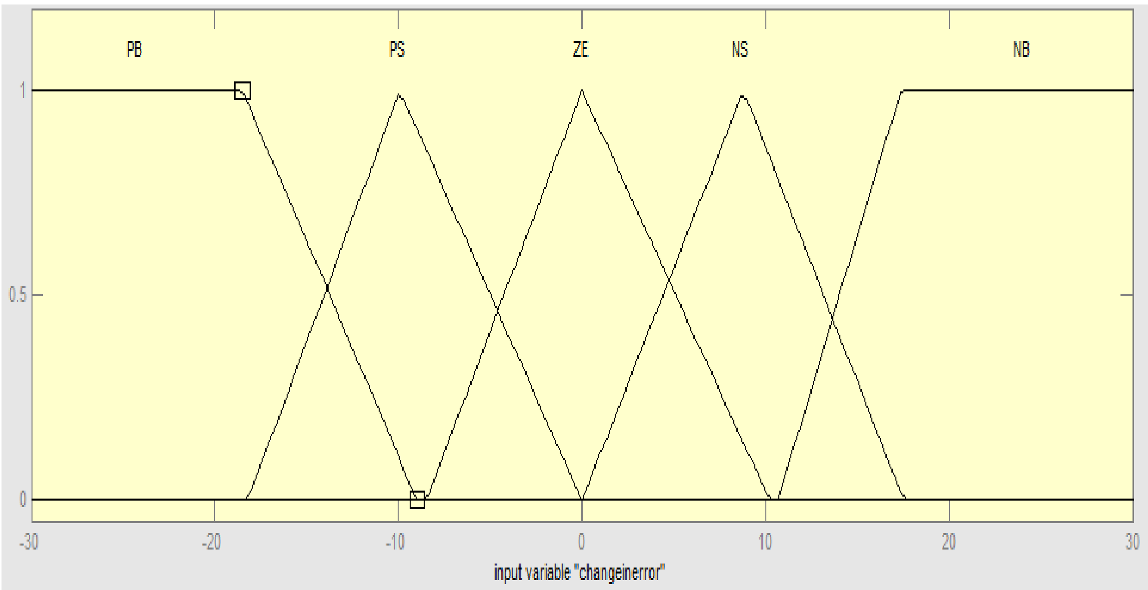

Fig 4.plot of membership function for change in error

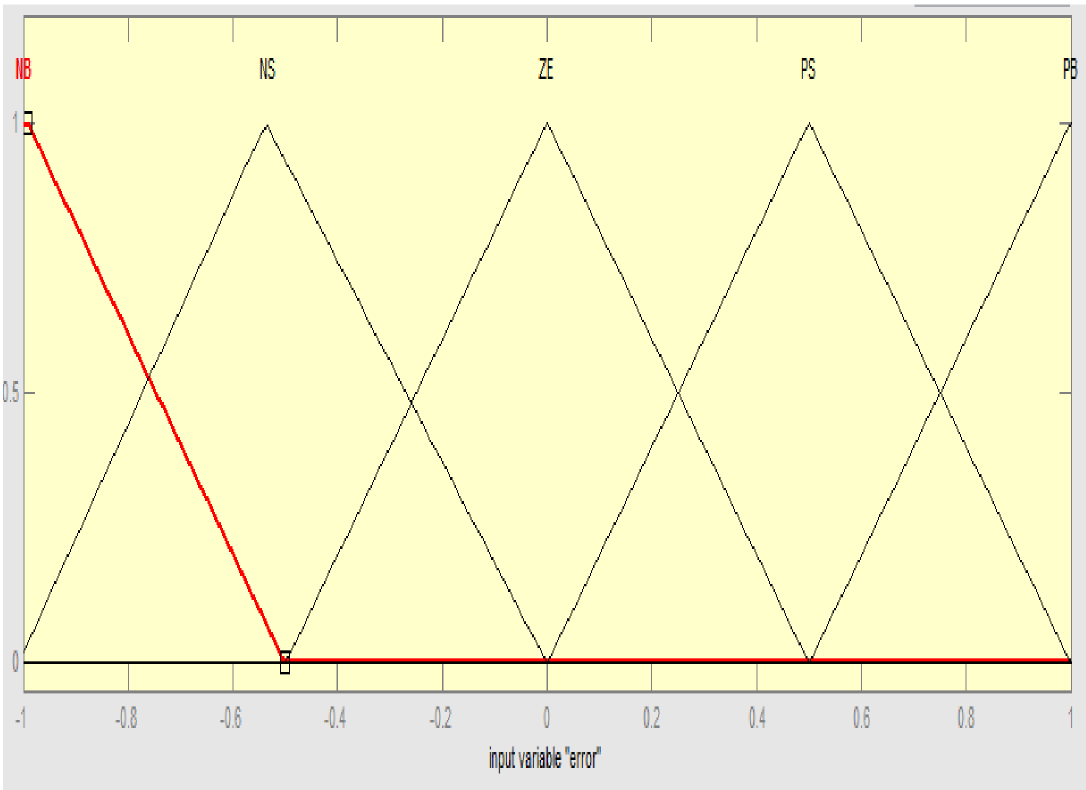

Fig 5.plot of membership function for error

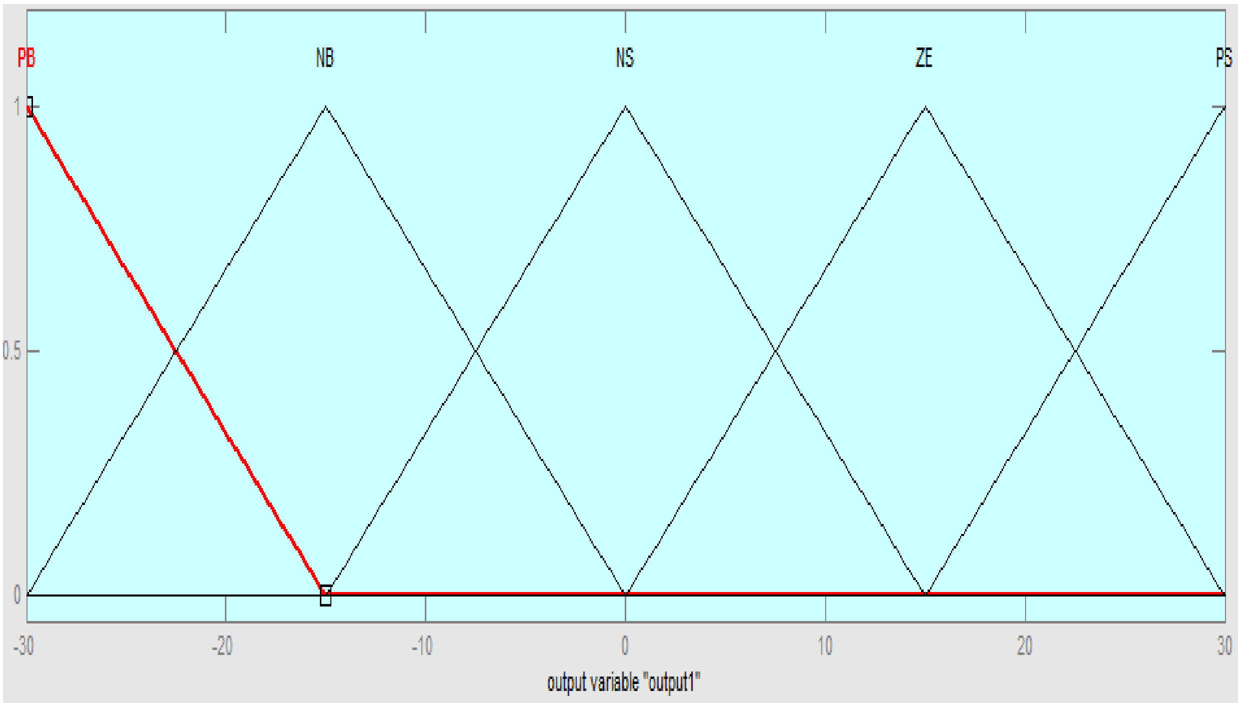

Fig 6.plot of membership function for output

PB	PS	NB	ZE	NS
NB	PB	PS	NS	ZE
NS	NB	PB	PS	ZE
ZE	NS	NB	PB	PS
PS	ZE	NS	NB	PB

Table 1.fuzzy rules for boost converter

VI. PERFORMANCE ANALYSIS

The output voltage, simulation, fuzzy rules are discussed in this section. Simulation results shows boost converter operation with fuzzy based control. MATLAB simulation was utilized to perform the simulation for the analysis.

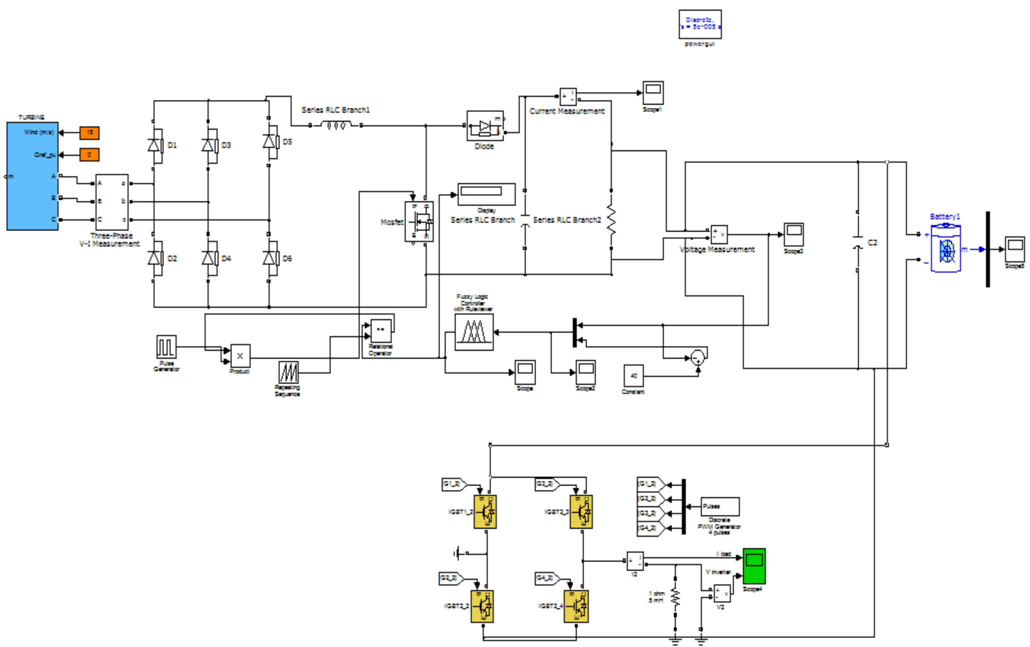

Fig. 6..MATLAB/SIMULINK diagram of the proposed fuzzy based WECS.

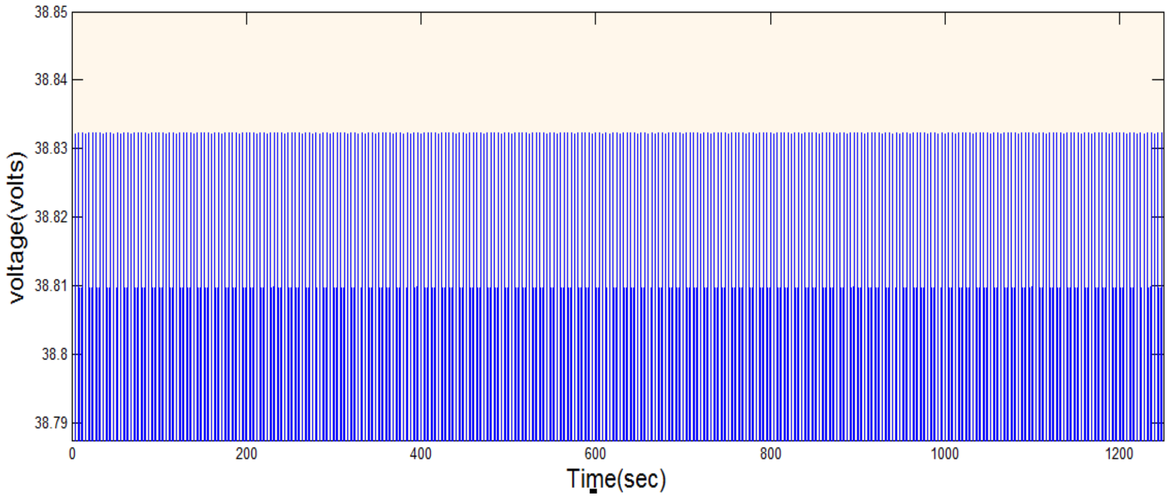

Fig. 7. Output of fuzzy based boost converter

The input which is given to boost converter is 12v and the output which we are getting is 38V. here the input voltage is boosted. This is the output for boost converter.

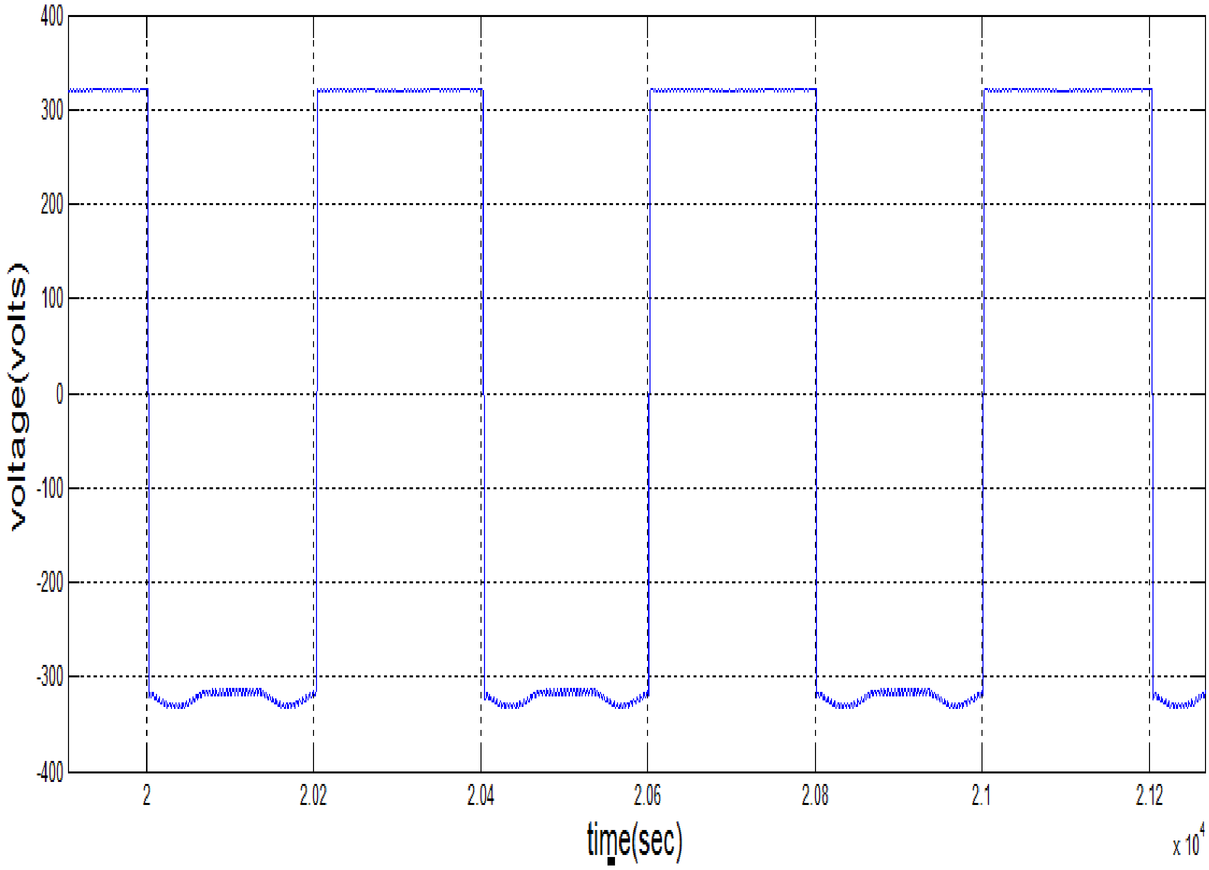

Fig. 8.output of fuzzy based wecs(230-240V)

Thus the output voltage with fuzzy based boost converter wind energy conversion system is 230-300V which is suitable for single phase systems.

VII. CONCLUSION

Design of a fuzzy logic controller on boost dc-dc converter by using MATLAB has been successfully achieved. Here the 12 V input for the boost converter is increased into 38.5V. The fuzzy logic controller shows the better performance compared to without using fuzzy logic controller. Using a closed loop circuit with fuzzy logic controller, it is confirmed that the boost dc-dc converter gives a value of output voltage exactly as circuit requirement

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