ADVANCED CONTROL TECHNIQUES IN VARIABLE SPEED STAND ALONE WIND TURBINE SYSTEM

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ABSTRACT

This project presents an advanced control strategy for the operation of a direct-drive synchronous generator-based stand-alone variable-speed wind turbine. The control strategy for the generator-side converter with maximum power extraction is presented. The stand-alone control featured is constant output voltage and frequency that is capable of delivering to variable load. The potential excess of power is dissipated. The PI controller in switch mode rectifier can be replaced with fuzzy control technique to improve the output voltage level. The simulation results show this control strategy gives better regulating voltage and frequency under sudden varying load conditions. Dynamic representation of dc bus and small signal analysis are presented. The dynamic controller shows very good performance.

KEYWORDS: *PMSG, boost converter, inverter, driver circuit and PIC/DSP*

I. INTRODUCTION

In this paper to design advance control techniques in variable speed to give continuous Supply to load. Variable-speed wind turbines have many advantages over fixed-speed generation such as increased energy capture, operation at maximum power point, improved efficiency, and power quality [1]. The reliability of the variable-speed wind turbine can be improved significantly by using a direct-drive synchronous generator. PMSG has received much attention in wind-energy application because of their property of self-excitation, which allows an operation at a high power factor and high efficiency [2].

Optimum power/torque tracking is a popular control strategy, as it helps to achieve optimum wind-energy utilization [3]–[7].

The switch-mode rectifier has also been investigated for small-scale variable-speed wind turbine[10], [11].It is very difficult to obtain the maximum voltage level by using PI controller. In order to obtain the maximum output, Fuzzy logic control can be used.

II. BLOCK DIAGRAM

A. Block diagram description

Generator converts the variable speed mechanical power produced by the wind turbine into electrical power. The power produced in the generator having variable frequency and voltage AC power. This Ac power converted into DC power with the help of uncontrolled rectifier. The dc power will be have variable voltage. This variable voltage is boosted to rated level with the help of boosted converter. Boosted dc power is converted into fixed frequency AC power and it is delivered to load. Between load and inverter as storage system with converter and inverter is used to store the energy. This storage system will store the energy at the time of load lesser than maximum level. Also this storage system is used to deliver power to load when the boost converter unable to boost up the voltage.

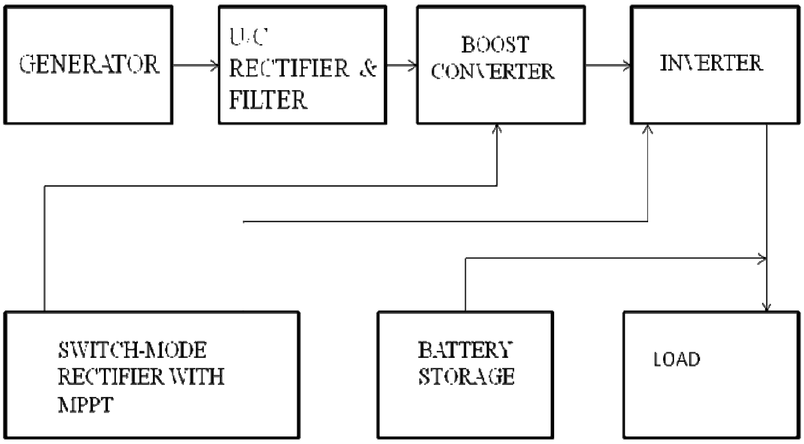

Fig 1. Block diagram of the project

B. Wind-turbine characteristics

The amount of power captured by the wind turbine (power delivered by the rotor) is given by,

$$P_t = 0.5\rho A C_p(\lambda, \beta) \times (v_\omega)^3 = 0.5\rho A C_p \times \left(\frac{\omega_m R}{\lambda}\right)^3$$

where ρ is the air density (kilograms per cubic meter), $v\omega$ is the wind speed in meters per second, A is the blades' swept area, and Cp is the turbine-rotor-power coefficient, which is a function of the tip-speed ratio (λ) and pitch angle (β). ωm = rotational speed of turbine rotor in mechanical radians per second, and

R = radius of the turbine. If the wind speed varies, the rotor speed should be adjusted to follow the change.

The target optimum torque can be given by

$$T_{m\_opt} = K_{opt}\left(\omega_{m\_opt}\right)^2.$$

The mechanical rotor power generated by the turbine as a function of the rotor speed for different wind speed is shown in Fig. 2.

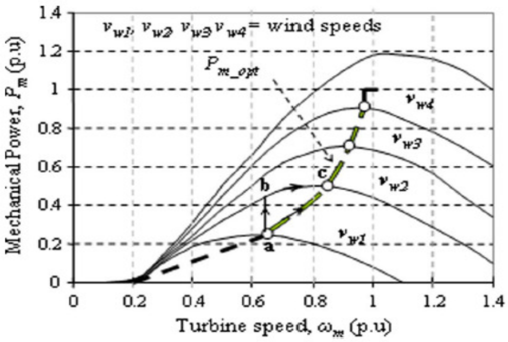

Fig 2. Mechanical power generated by the turbine as a function of the rotor speed for different wind speeds.

The optimum power is also shown in this figure. The optimum power curve (*P*opt) shows how maximum energy can be captured from the fluctuating wind. The function of the controller is to keep the turbine operating on this curve, as the wind velocity varies.

It is observed from this figure that there is always a matching rotor speed which produces optimum power for any wind speed. If the controller can properly follow the optimum curve, the wind turbine will produce maximum power at any speed within the allowable range.

III. System Overview

Fig. 3 shows the control structure of a PMSG-based stand alone variable-speed wind turbine which include a wind turbine, PMSG, single-switch three-phase switch-mode rectifier, and a vector-controlled PWM voltage-source inverter. A constant dc voltage is required for direct use, storage, or conversion to ac via an inverter.

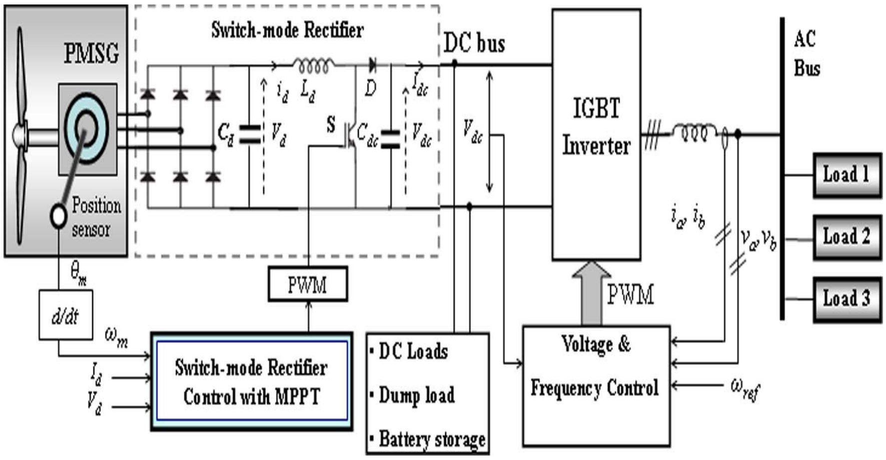

Fig 3. Control structure of a PMSG-based stand-alone variable-speed wind turbine.

In this paper, a single-switch three-phase switch-mode rectifier is used to convert the ac output voltage of the generator to a constant dc voltage before conversion to ac voltage via an inverter. The single-switch three-phase switch-mode rectifier consists of a three-phase diode bridge rectifier and a dc to dc converter.

The output of the switch-mode rectifier can be controlled by controlling the duty cycle of an active switch (such as IGBT) at any wind speed to extract maximum power from the wind turbine and to supply the loads. A vector-controlled IGBT inverter is used to regulate the output voltage and frequency during load or wind variations. Voltage drop due to sudden fall in wind speed can be compensated by the energy-storage system. During wind gust, the dump-load controller will be activated to regulate the dc-link voltage to maintain the output load voltage at the desired value.

IV. CONTROL OF SWITCH-MODE RECTIFIER WITH MAXIMUM POWER EXTRACTION

The structure of the proposed control strategy of the switch mode rectifier is shown in Fig. 4. The control objective is to control the duty cycle of the switch ***S*** in Fig. 2 to extract maximum power from the variable-speed wind turbine and transfer the power to the load. The control algorithm includes the following steps.

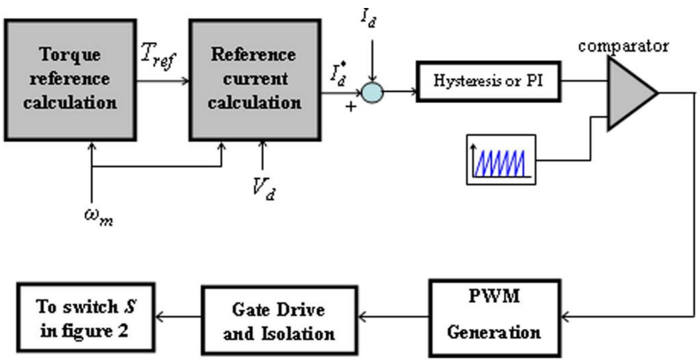

Fig 4. Control strategy of the switch-mode rectifier.

1) Measure generator speed ωg.
2) Determine the reference torque (Fig. 4) using the following equation:

$$T_g^* = K_{\text{opt}}(\omega_g)^2.$$

3) This torque reference is then used to calculate the dc current reference by measuring the rectifier output voltage *Vd* as given by

$$I_d^* = \left(T_g^* \times \omega_g\right)/V_d.$$

4) The error between the reference dc current and measured dc current is used to vary the duty cycle of the switch to regulate the output of the switch-mode rectifier and the generator torque through a proportional–integral (PI) controller.

The generator torque is controlled in the optimum torque curve as shown in Fig.5 according to the generator speed.

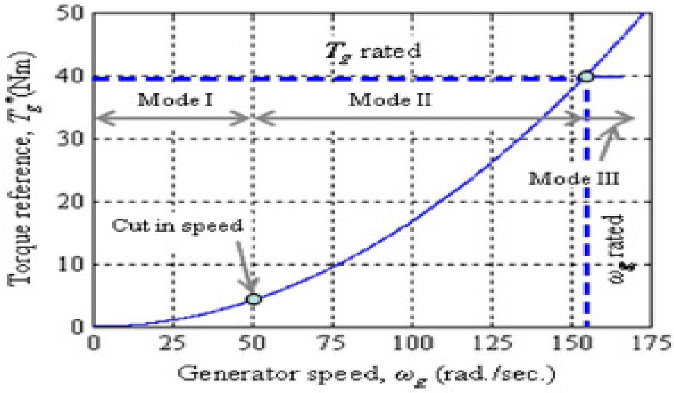

Fig. 5. Generator torque reference versus speed.

If the PMSG is operating at point "**a**" and the wind speed increases from *vw*1 to *vw*2 (point "**b**"), the additional power and, hence, torque causes the PMSG to accelerate. Finally, the generator will reach the point " **c**" where the accelerating torque is zero. A similar situation occurs when the wind velocity decreases. In the proposed method, the wind speed is not required to be monitored, and, therefore, it is a simple output-maximization control method without wind-speed sensor (anemometer).

V. SIMULATION MODEL USING PI CONTROLLER

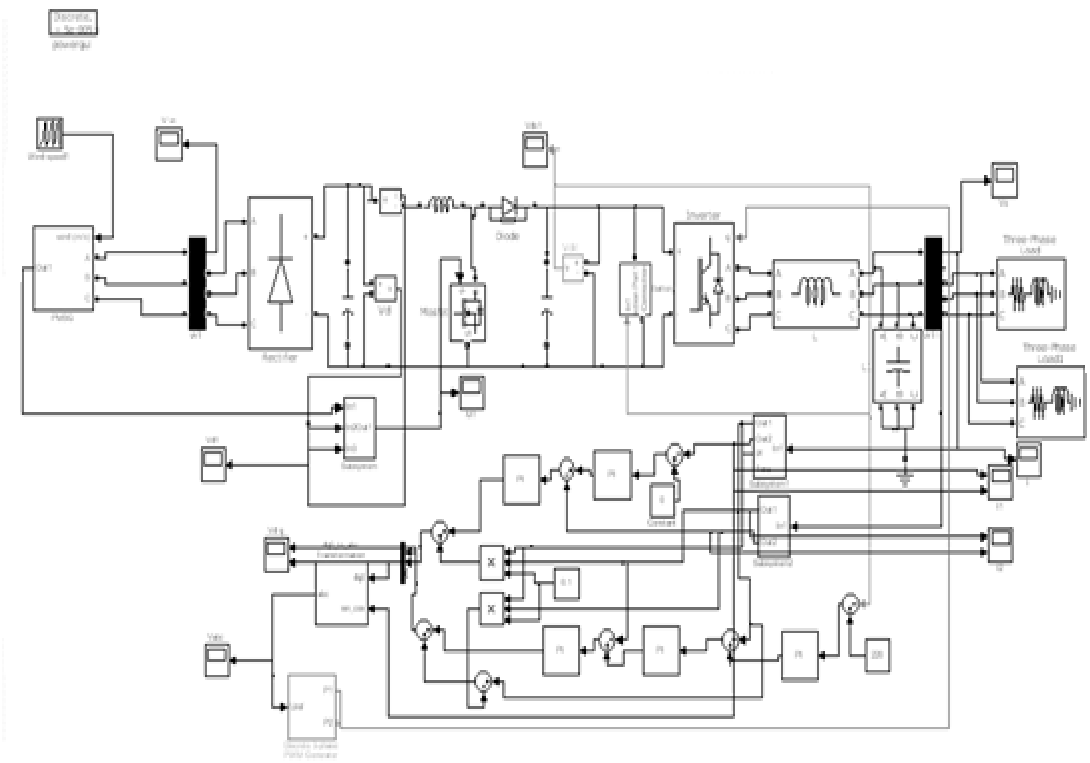

Fig 6. Matlab model of the PMSG based variable-speed wind-turbine system using PI Controller

VI. OUTPUT WAVEFORMS

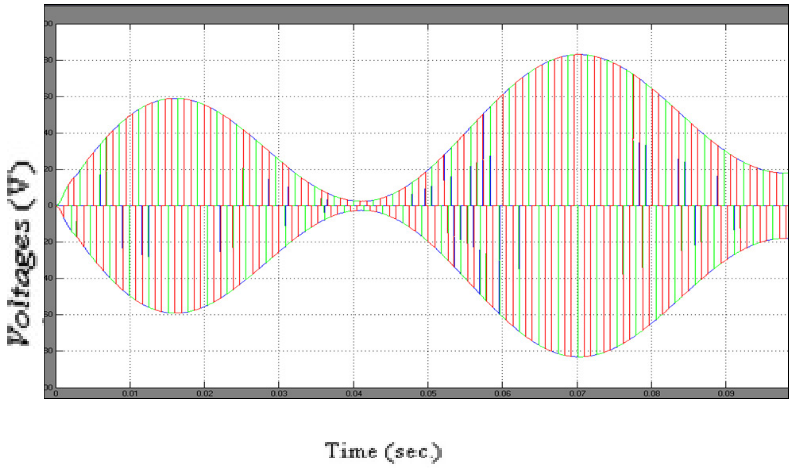

Fig 7.a output voltage of PMSG

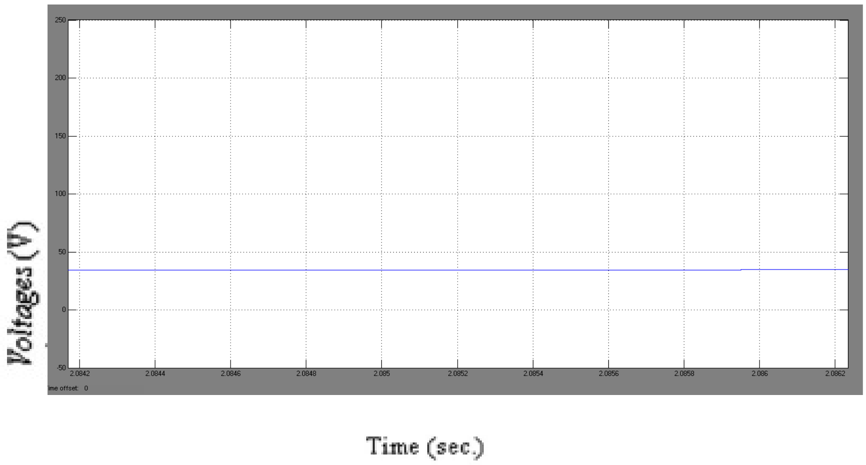

Fig 7.b Output voltage of uncontrolled rectifier

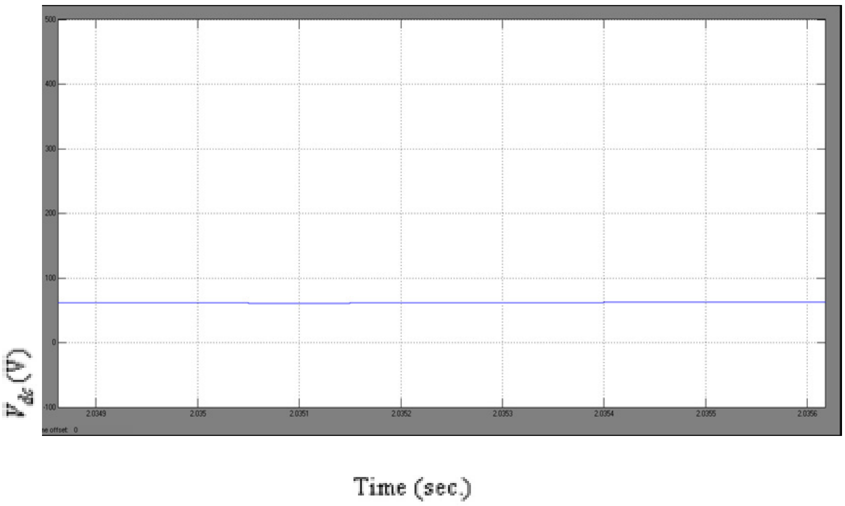

Fig 7.c boosted output voltage.

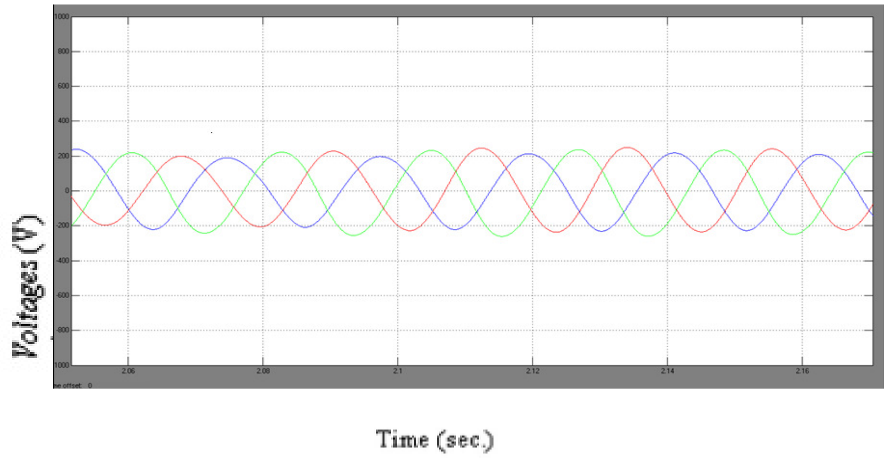

Fig 7.d load voltage

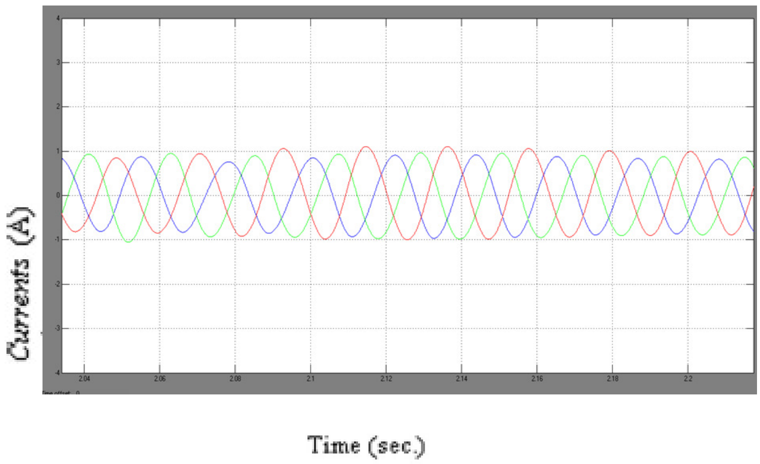

Fig 7.e load current

VII. FUZZY LOGIC CONTROLLER

A control strategy for a rectifier with variable speed direct driven permanent magnet synchronous generator. The fuzzy logic controller is used to track generator speed with varying wind speed to optimize turbine aerodynamic efficiency in the outer speed loop. The voltage space vector PWM in field-oriented control is adopted in the control of the generator side converter. By means of the field-oriented control, the highest efficiency of wind turbine can be reached.
The Fuzzy controller of inner current loop is used instead of the traditional PI controller to improve the performances of current loop. Both simulation and experiments have been conducted to validate the performance.

TABLE- FUZZY-RULE-BASED MATRIX

Change in error / Error	NB	NM	NS	Z	PS	PM	PB
NB	NVB	NB	NM	NS	Z	PS	PM
NM	NVB	NB	NM	NS	PS	PM	PB
NS	NVB	NB	NM	NS	PS	PM	PB
Z	NB	NM	NS	Z	PS	PM	PB
PS	NB	NM	NS	PS	PM	PB	PVB
PM	NB	NM	NS	PS	PM	PB	PVB
PB	NM	NS	Z	PS	PM	PB	PVB

VIII. Simulation Diagram using Fuzzy Controller

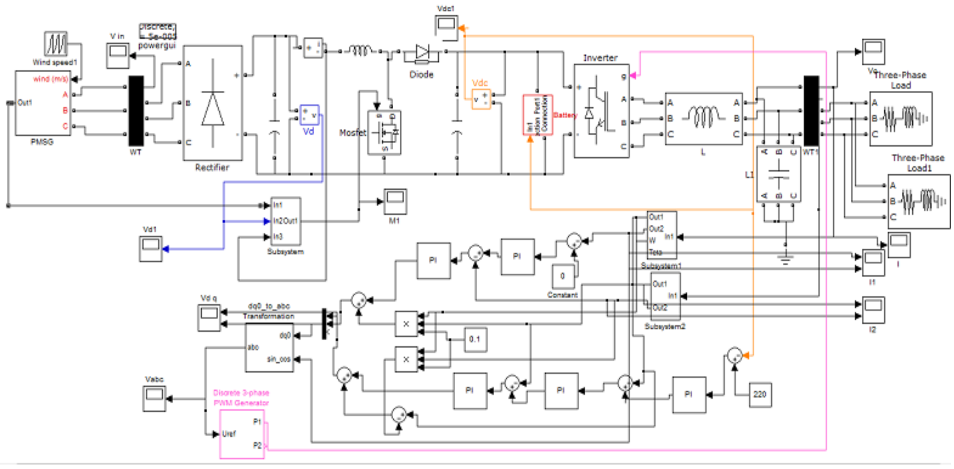

Fig 8. Matlab model of PMSG based variable-speed wind-turbine system using Fuzzy logic controller.

IX. Output Waveforms

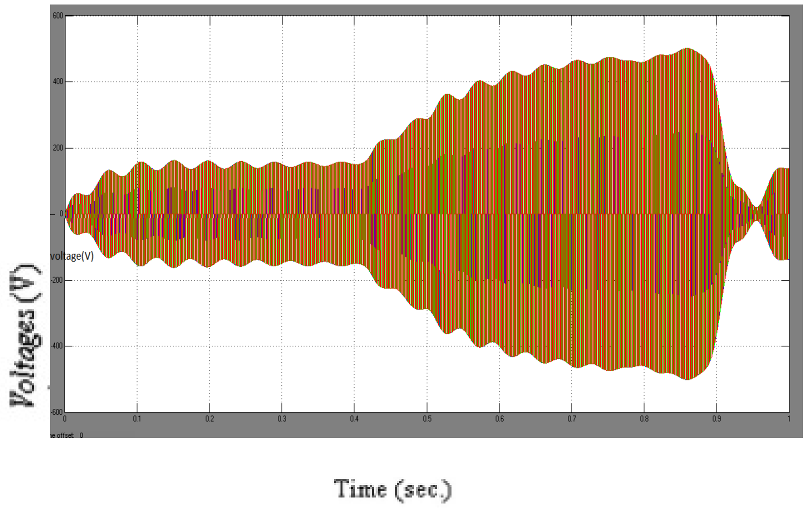

Fig 9.a output voltage of PMSG

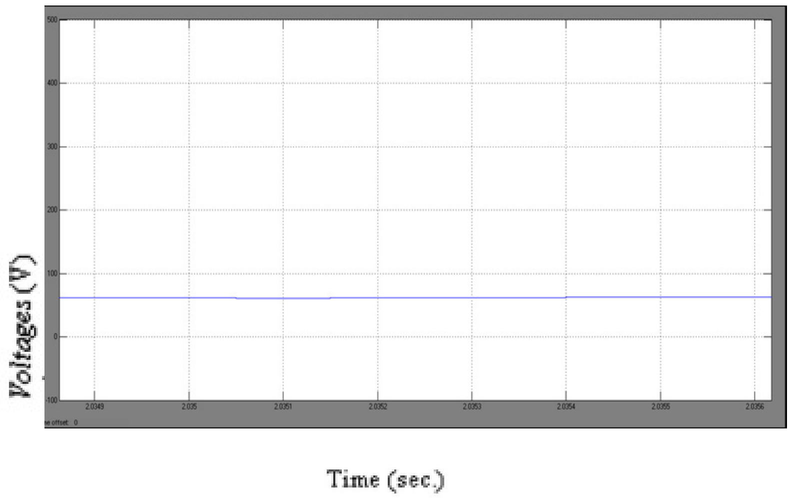

Fig 9.b Output voltage of uncontrolled rectifier

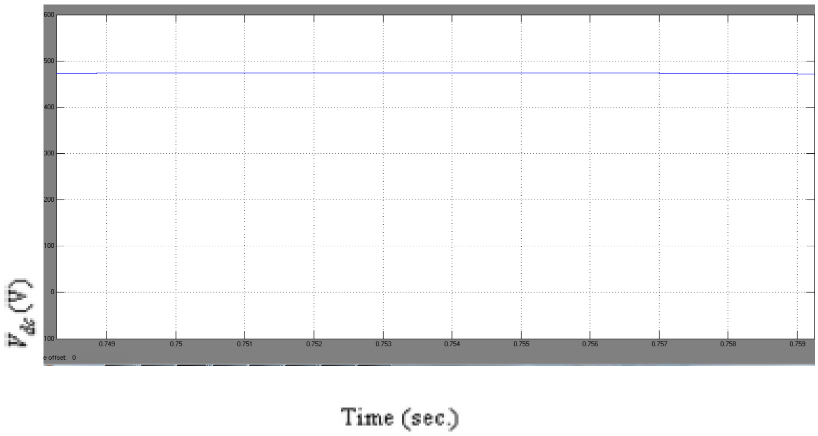

Fig 9.c Boosted Output voltage

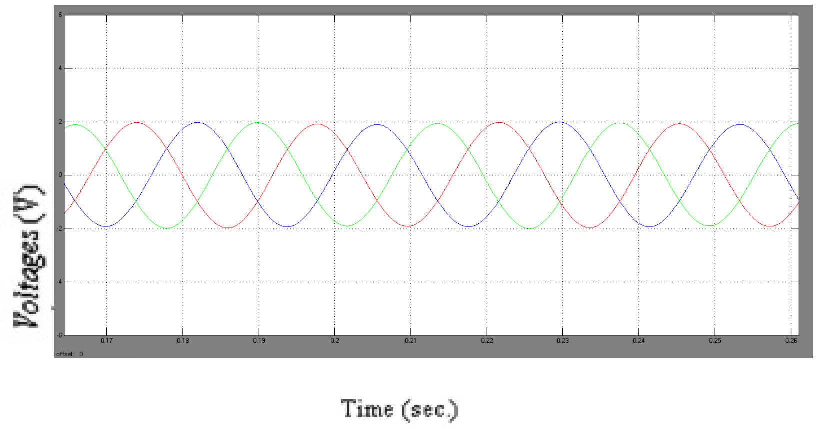

Fig 9.d load voltage

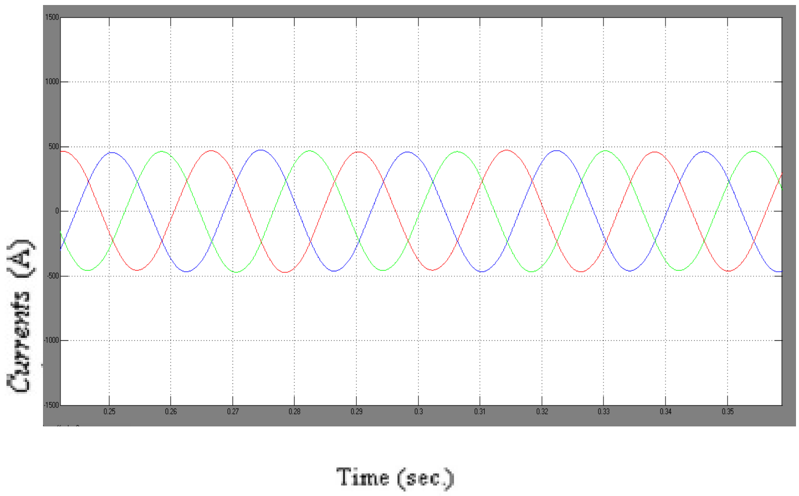

Fig 9.e load current

X. CONCLUSION

A control strategy for a direct-drive stand-alone variable speed wind turbine with a synchronous generator has been presented in this project. The controller is capable of maximizing output of the variable-speed wind turbine under fluctuating wind. The generating system with the proposed control strategy is suitable for a small-scale stand alone variable-speed wind-turbine installation for remotearea power supply .The simulation results has proves that Regulating the o/p voltage & frequency under sudden load variations and typical wind movement.

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Author's Biography

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