Maximum Power Point Tracking Technique to Wind Energy Conversion System Driven by PMSG

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***Abstract*—This paper presents a maximum power point tracking (MPPT) technique for a wind energy conversion system (WECS) through a direct driven permanent magnet synchronous generator (D-PMSM) fed to a grid of 380A.C Volts. The proposed system uses a two back-back IGBT based power converters. In the proposed system, a given wind turbine generates the output optimum speed command for speed control loop of rotor flux oriented vector controlled scheme at grid side power converter with the instantaneous active power as its input. The optimum reference speed command tracks the maximum power points for the WECS are generated in accordance with the variation of active power output due to the change in the command speed generated by the controller. The two power control techniques with a 2MW direct driven variable speed PMSM for WECS are modeled and simulated in MATLAB using Simulink and Sim Power System set tool boxes.**

Keywords ---wind-energy-conversion system (W.E.C.S), maximum power tracking point (MPPT), permanent magnet synchronous generator (PMSM) .

I. INTRODUCTION

Many countries are aware with global warning problems. One of the main problems is the pollution from burning fossil fuels to produce energy. Then the solution of this problem is to produce the clean energy .So more attention and interest have been paid to the utilization renewable energy sources, like solar, hydro, wind, biomass etc... Wind energy is the fastest growing and most promising renewable source among them due to economically variable [8].

A MPPT control is achieved by using stator frequency derivative and power mapping technique [2]. The MPPT curves for the power mapping are established by running several experiments at various kinds of winds at different speeds. In this paper a MPPT controller proposed to generate optimum speed command for the speed control loop of the machine side converter control system enables the optimal output power. Optimum power flow algorithm is proposed, which uses the fact that $\frac{dP_m}{d\omega} = 0$ at maximum power point [4]. The algorithm quickly changes the speed command according to the magnitude and direction of change of active power.

A wind sensor less MPPT controller for variable wind speed is proposed in this paper. The proposed technique does not requires the knowledge of turbines parameters, wind speed and air density. It requires only the instantaneous active power as its input and generates as its output the optimum reference speed for the vector controlled machine side converter control system in order to enable the system to track maximum power lines.

II. CHARACTERISTIC EQUATIONS OF VARIABLE WIND TURBINE

The fallowing equations describe the wind turbine characteristics.

$$P_m = \frac{1}{2}.\rho.A.v^3.C_P(\lambda,\beta) \quad (1)$$

$$\lambda = \frac{R.\omega}{v} \quad (2)$$

$$C_P(\lambda,\beta) = 0.5176\left(\frac{116}{\lambda_i} - 0.4\beta - 5\right)e^{\frac{-21}{\lambda_i}} + 0.068\,\lambda \quad (3)$$

$$\frac{1}{\lambda_i} = \frac{1}{\lambda+0.08\beta} - \frac{0.035}{\beta^3+1} \quad (4)$$

Wind turbine torque equation is

$$T_m - T_e - F.\omega = J\frac{d\omega}{dt} \quad (5)$$

Where P_m- mechanical output power of wind turbine(W) , ρ- density of air (kg/m^3), A-turbine swept area(m^2), v -wind speed(m/sec) , R - turbine radius (m) , $C_P(\lambda,\beta)$ power coefficient of wind turbine , ω- turbine angular velocity(rad/sec) , β- blade pitch angle(deg), λ-tip speed ratio the rotor blade tip speed to wind speed , T_m-shaft mechanical torque , T_e -electromagnetic torque ,F – combined viscous friction of rotor and load and J is combined inertia of rotor and load.

The maximum value of C_P is achieved at 0.48 for β=0 degree and for λ =8.1 is shown in Fig.1 .The particular value of λ is called the nominal value.

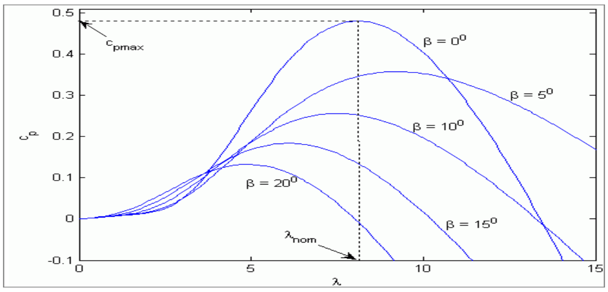

Fig.1.Coefficient of power C_P versus tip speed ratio, λ (TSR)

III. PRINCIPLE OF OPERATION

In this paper, a 2MW D-PMSM with 2 MW wind turbine is considered to simulate the results of WECS in MATLAB software. In Fig.2 it is evident that, for any particular wind speed, there is a rotational speed ω_m that corresponds to the maximum power lines. When the wind speed changes, the rotational speed is controlled to fallow the maximum power lines. In the proposed algorithm, the value of optimum speed is calculated without measuring wind speeds. In the Flow chart Fig.3, the proposed MPPT controller shows how it tracks the maximum power point[1].

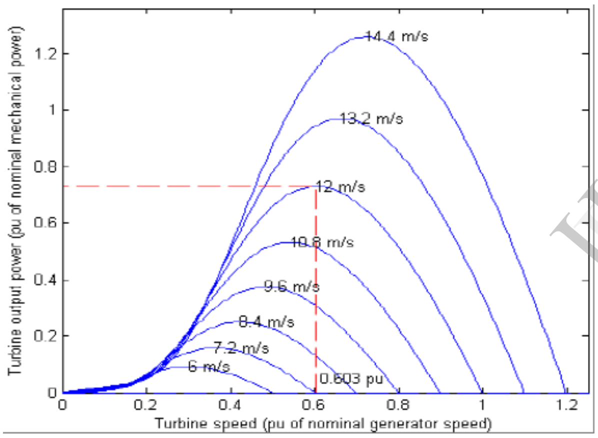

Fig.2. wind turbine power characteristics

The values of K are determined by running several simulations using different values and selecting the ones which gives the best results. If the power in the present sampling instant is found to be increased, i.e. $\Delta P_m(n) > 0$, the command speed ω_r is increased. If the power in present sampling instant is found to be decreased, i.e. $\Delta P_m(n) < 0$, then, the command speed is decremented.

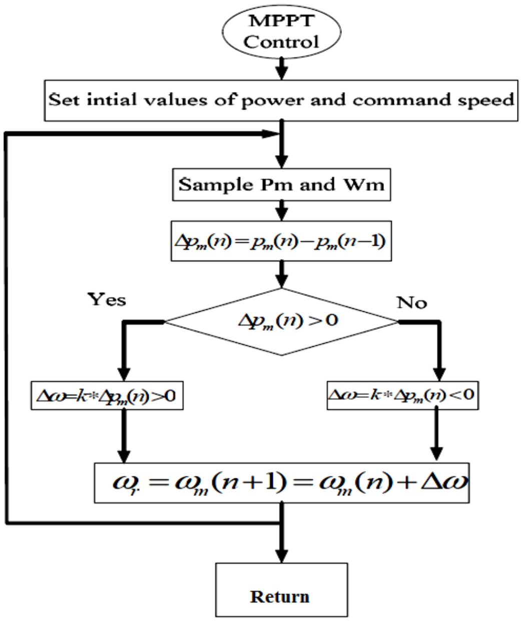

Fig.3.Flow chart diagram of MPPT controller

IV. PROPOSED ELECTRICAL SCHEME OF W.E.C.S & ITS CONTROL STATEGY

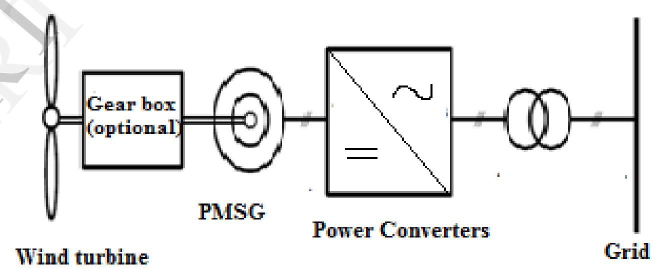

Fig .4. Electrical scheme of proposed W.E.C.S

The proposed electrical system is shown in Fig.4. Two back -to- back power converters are connected between the power generated side and the grid side. They worked as a rectifier at generated side and worked as an inverter at grid side.

The Fig.5 is represents the control scheme of generated side rectifier and is directly connected to the PMSG. Its q-axis current can control the DC link voltage and d-axis stator current can control the reactive power.

The Fig.6 is represents the control scheme of grid side inverter. The inside loop control scheme is same as the generator side rectifier. The q-axis current can control the active power.

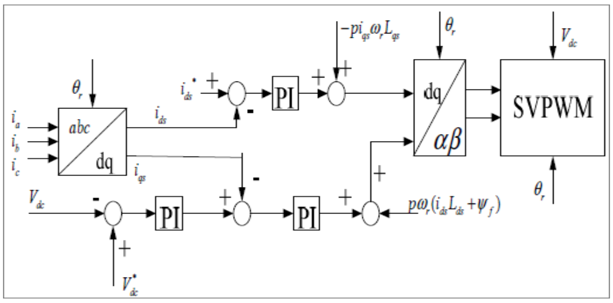

Fig.5.Block diagram of control scheme of generator side rectifier .

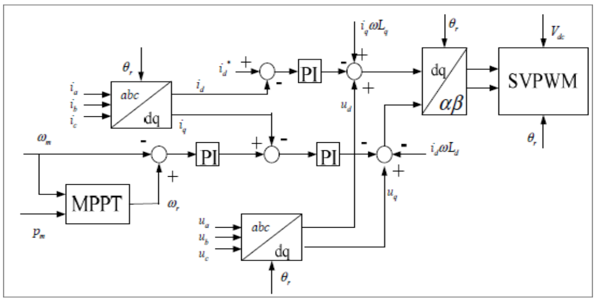

Fig.6.Block diagram of control scheme of grid side inverter

V. MATLAB BASED SIMULATION RESULTS ANALYSIS

The ratings and the specifications of the selected components for the proposed grid coupled wind energy conversion system based on the aforementioned design procedure are used for simulation purpose. The simulation model is developed in MATLAB using Simulink and Sim Power system set toolboxes.

The simulated parameters are listed in the Table.1 and the complete MATLAB based circuit diagram is shown in Fig.7

TABLE.I.SIMULATION PARAMETERS

Parameters	Value
Turbine model	3 Blade Horizontal Axis
Blade angle	$\beta = 0$
Air density	$\rho = 1.225 kg/m^3$
λ_{opt}	8.1
Generation parameter	2MW D-PMSG
Number of poles	60
Rated power factor	0.95
Rated speed	22.5rpm
Inverter	4MW Double PWM
Grid voltage	380A.C V

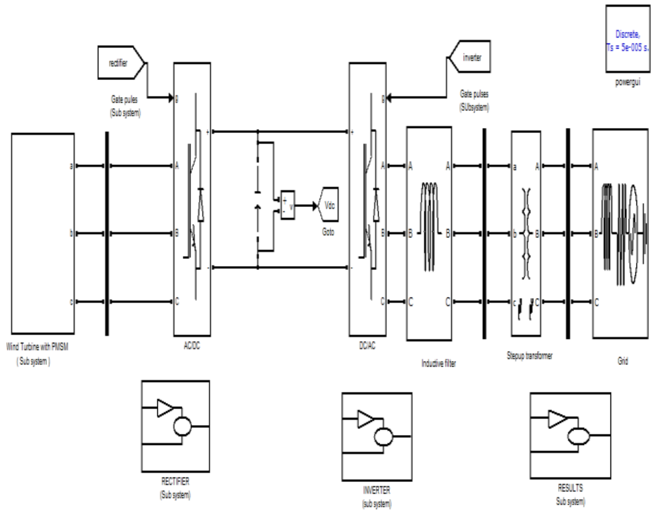

Fig.7. MATLAB based Simulation diagram of W.E.C.S with PMSG

The resultant proposed system studied under various kinds of winds at different wind speeds. Fig.8 shows the MATLAB based results at wind speeds of 8.8 m/s and its corresponding turbine rotor speed (rad/sec), voltage (V), current (V) and output power from the PMSG (W).

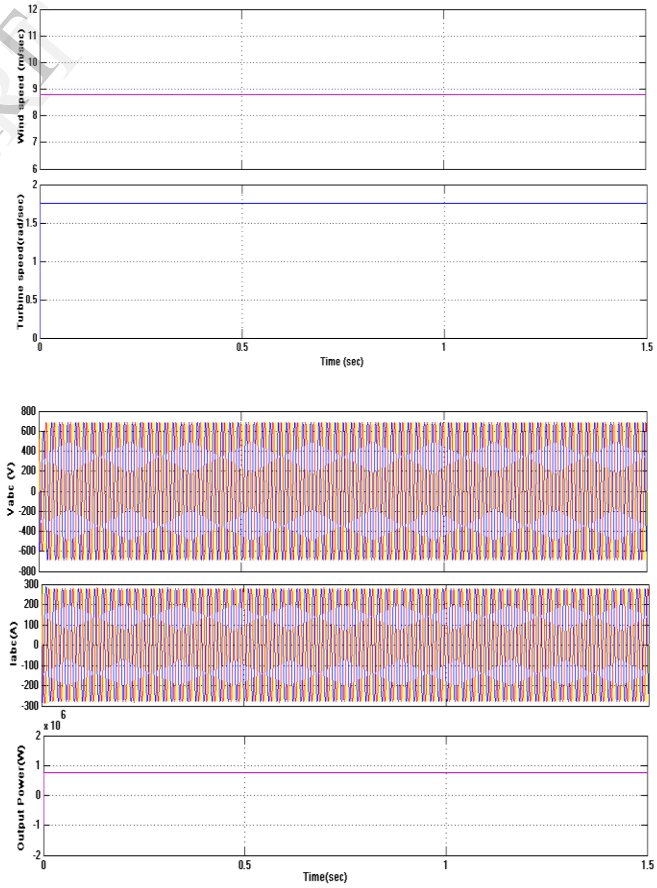

Fig.8. MATLAB based simulation results at wind speed of 8.8 m/sec

Now check the dynamic response of the proposed system with the fallowing conditions

(1) Ramp wind, when t = 1s, the wind speed varies from 6.2 m/s to 9.2 m/s gradually; shown in Fig.9
(2) Gust wind, when t = 0.85s, a gust wind with a bursts out amplitude of 9.1 m/s bursts out; shown in Fig.10.

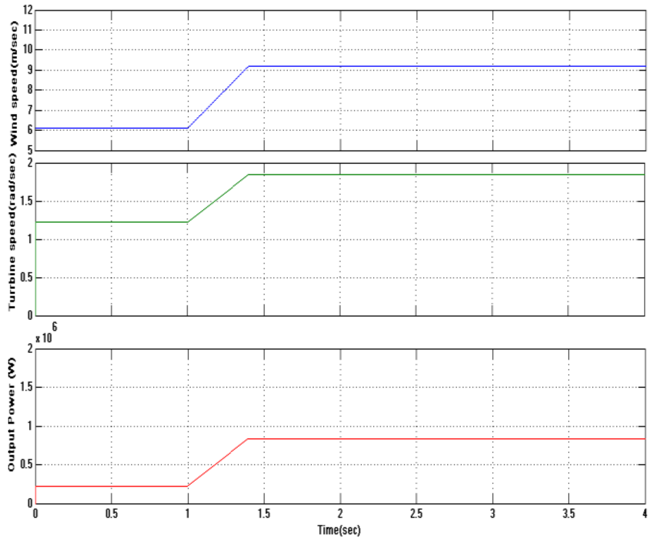

Fig.9. MATLAB based simulation results under ramp wind conditions

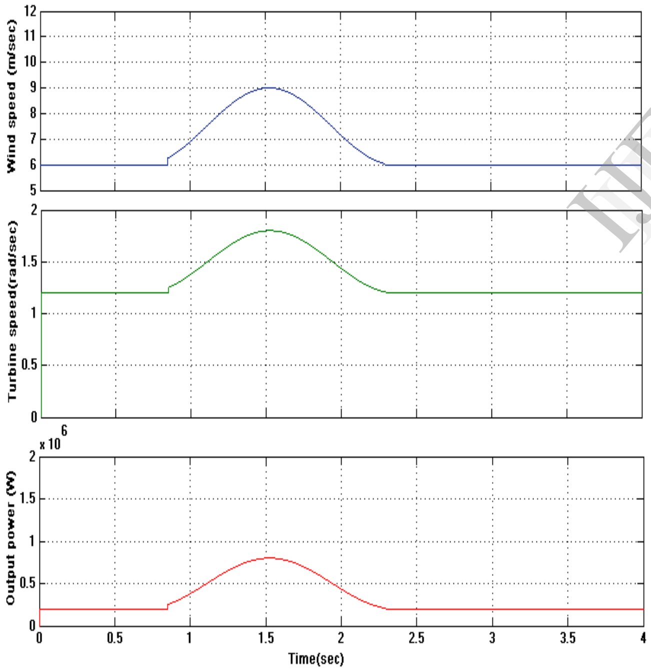

Fig.10. MATLAB based simulation results under gust wind condition

Even though the sample is 0.1s, there must be some delay between ω_m and ω_r it is obvious from the results of simulation that the turbine speed and the power can follow the varying of wind closely and smoothly. In all, the proposed algorithm can achieve MPPT under the dynamic and shifty input wind conditions.

VI. CONCLUSION

The paper proposes a MPPT control technique to the WECS with PMSG, in theory analysis and the MATLAB based simulation results proves that the control technique responds very quickly to input values, i.e. ., variable wind conditions to fulfil the MPPT technique in the grid connected wind energy conversion system and also this paper gives an idea to utilizes these technique in practical production.

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