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Grid-Tie Wind turbine Energy Conversion System based on PMSG with Model Predictive Control

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Abstract— This article presents a model prescient control (MPC) system for variable speed wind energy transformation framework (VS_WECS) based lasting magnet coordinated generator (PMSG). The prescient control is applied for ideal activity of a PMSG wind turbine (WT). The PMSG is attached to the utility framework through a three-stage consecutive (BTB) converter. The greatest force accessible from the WECS is collected by applying the control calculation to the machine side converter (MSC). The dc-interface voltage guideline is accomplished utilizing the framework side converter (GSC). A model of straightforwardly determined PMSG based variable-speed WECS is created and imitated utilizing MATLAB/SIMULINK climate. The MPC gives great unique execution under wide wind speed variety. The viability of the proposed control approach is approved through broad reenactment results. The THD (total harmonics distortion) of the grid current is maintained under the limit of an IEEE-519 standard.

Keywords: Wind energy, PMSG, model predictive control(MPC), maximum power point tracking.

1. INTRODUCTION

Development of sustainable power frameworks, during late years, adding to limit carbon dioxide discharges and to decrease natural contamination [1]. This development will proceed as nations extend their sustainable activity plans. Therefore, creation of wind energy will further increment around the world. A few arrangements of WECS are utilized, among them, the Doubly Fed Induction Generator (DFIG) in light of VS_WECS have been the prevailing innovation on the lookout Where, DFIG goes about as a wellspring of genuine and responsive forces furthermore it can work with incomplete scale power converter "roughly 30% of machine rating" [2]. On the other hand, as of late, different arrangements of VS_WECS are utilized with bigger limit, lower cost, and higher dependability. Among various generator types, the PMSG has been widely applied because of its related advantages, for example, high productivity, high force thickness, low upkeep cost what's more, acceptable matrix similarity The VS_WECS comprises of a PMSG which is straightforwardly coupled to the WT. The stator windings of the PMSG are attached to the utility network through a consecutive (BTB) full scale converter. Field-arranged control (FOC) and direct-force control (DTC) are applied for machine-side converter (MSC). Then, two standard procedures, the voltage-arranged control (VOC) and direct-power control (DPC), are applied to the lattice side converter (GSC) [2].

The usage of cutting edge control plans improves the VS_WECS execution. Among various progressed control plans, fluffy rationale control and model prescient control(MPC) are the most widely recognized [3]. MPC has a few advantages, forexample, it very well may be utilized with a assortment of frameworks andantagonists, nonlinearities can be handily included, and multi-variable case can be considered in expansion, it relies upon its own forecasts for the subsequent stage. The WT mechanical yield power changes with the breeze speed. Thusly, extraordinary MPPT calculations are utilized to keep up most extreme mechanical force at all wind speed conditions. In this paper, a MPC methodology for PMSG VS_WECS is proposed. The PMSG is attached to the utility lattice at the purpose of basic coupling (PCC) through a three-stage consecutive (BTB) converter. Two control plans are created for machine-and organization side converters.

A shunt capacitor is utilized as a dc-connect between the two converters. The MPC is applied in the MSC to extricate greatest force. Likewise, the MPC is utilized in the GSC to infuse just dynamic force into the network. A tip speed proportion (TSR/λ)calculation is used to keep up the mechanical capacity to its ideal worth. The framework elements are analyzed with the assistance of MATLAB /SIMULINK. This article is set up as follows; area II presents the WECS framework demonstrating. The MPPT procedure applied in this work is talked about in segment III. Area IV examine the control of the MSC and GS. The standards of MPC for MSC also, GSC are examined in area V. The framework results are portrayed and broke down in segment VI. At last, segment VII gives finishes of the work.

2. WIND TURBINE ENERGY CONVERSION SYSTEM

This part portrays the structure of the WECS. It comprises of a three-stage PMSG. A BTB converter is utilized to associate the PMSG to the network as appeared in Fig. 1. The MSC utilizes the MPC to remove most extreme force just as to infuse dynamic power into the network to guarantee solidarity power factor activity

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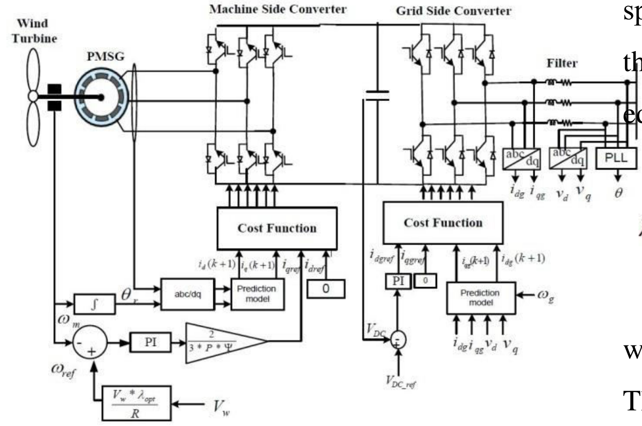

Fig. 1. Wind Energy Conversion System configuration.

A) Wind Turbine.

At the point when wind is applied to the turbine the yield mechanical power drives the rotor of the generator. For a variable speed WT, the yield mechanical force and force are given by

$$P_m = \frac{1}{2}\rho A C_p(\lambda,\beta) V_w^3 \quad (1)$$

$$T_m = \frac{P_m}{\omega_m} = \frac{1}{2}\frac{\rho A C_{p(\lambda,\beta)} V_w^3}{\omega_m} \quad (2)$$

where is the turbine yield power (in Watts), T_m is the mechanical force of turbine (in Nm), C_p is the turbine power coefficient (dimensionless), ρ is the air thickness (in kg/m^3), A is the region cleared by the turbine cutting edges (in m^2), V_W is the breeze speed- Wind velocity (in m/s), and w_m is the mechanical rakish speed of the turbine (in rad/s).

The turbine power coefficients C_p, portrays the force extraction effectiveness of the WT. It is a nonlinear capacity of both tip speed proportion λ and the edge pitch point β. The tip speed proportion λ is a variable communicates the proportion of the straight speed of the tip of edges to rotational speed of WT, as follows:

$$\lambda = \frac{\omega_m R}{V_w} \quad (3)$$

where R is the range of the turbine cutting edge. There are numerous various variants of the fitted conditions for C_p [12]. This paper characterizes C_p as follows:

$$C_p(\lambda,\beta) = C_1\left(\frac{C_2}{\lambda_i} - C_3\beta - C_4\right)e^{\frac{-C_5}{\lambda_i}} + C_6\lambda \quad (4)$$

$$\frac{1}{\lambda_i} = \frac{1}{\lambda + 0.08\beta} - \frac{0.035}{1+\beta^3} \quad (5)$$

In this work, accepting fixed rotor pitch, the pitch point β is set to zero. The turbine coefficients,C_1 – C_6, are distinctive for fixed and variable speed WTs. Be that as it may, a MPPT calculation is reasonable just for variable speed WTs and the approximated coefficient esteems are given as: C_1 = 0.5167, C_2 = 116, C_3 = 0.4, C_4=5, C_5 = 21, and C_6 = 0.0068 [13]. The connection among C_p and λ when β rises to zero degree is appeared in Fig. 2.

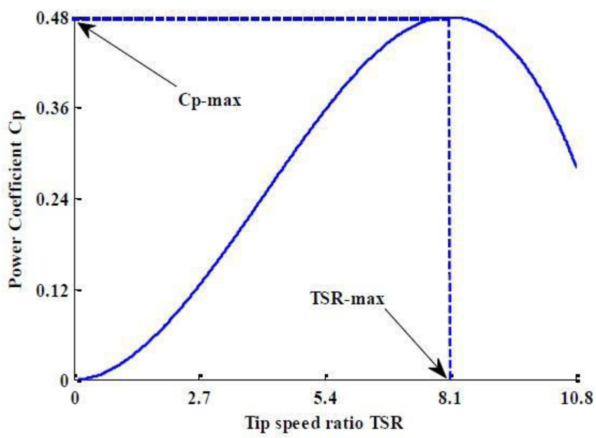

Fig. 2. Power coefficient (C□) vs. tip speed ratio (TSR/ λ).

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The ideal C_p esteem is about 0.48 at λ = 8.1. Greatest accessible force collecting from turbine can be accomplished when the turbine runs at the ideal, C_p . Fig. 3 shows the produced mechanical force versus the turbine rotor speed with wind speed variety. There is a novel MPP for each wind speed that changes with the variety of wind speed. To extricate the most extreme accessible force from the WT, the regulator must follows the ideal force bend with wind speed variety, see Fig. 3.

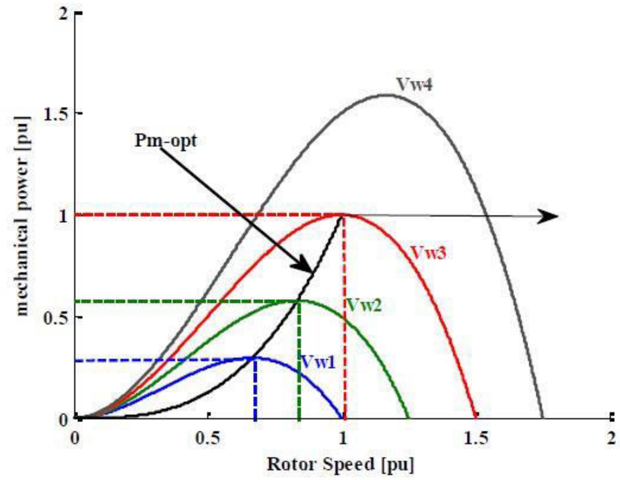

Fig. 3. Generated mechanical power vs. rotor speed at different wind Speed

B) Permanent Magnet Synchronous Generator Model

The voltage conditions of a three-stage PMSG communicated in the rotor reference outline utilizing an all-inclusive Park change as

$$V_d = R_s i_d + L_d \frac{di_d}{dt} - L_q \omega_e i_q \quad (6)$$

$$V_q = R_s i_q + L_q \frac{di_q}{dt} + L_d \omega_e i_d + \psi \omega_e \quad (7)$$

where V_d and V_q speak to the stator voltages in the (d, q) hub, i_d and i_q speak to the flows in the (d, q) hub, R_s speaks to stator opposition, L_d, L_q speak to the (d, q) pivot inductances, $\omega_e = p\omega_m$ (p is number of post sets, ω_m speaks to the turbine rotor precise speed) and ψ is the perpetual transition linkage.

The developed torque of the PMSG can be expressed as:

$$T_e = \frac{3}{2} p \psi i_q \quad (8)$$

The mechanical equation of the PMSG is given by:

$$T_m = T_e + f\omega_m + J\frac{d\omega_m}{dt} \quad (9)$$

where f is the rubbing coefficient, J is the absolute snapshot of inactivity, T_m is the mechanical force created by a WT and T_e is electromagnetic force of PMSG.

3. MAXIMUM POWER POINT TRACKING TECHNIQUES

where w_{ref} is the reference rotor speed, λ_{opt} is the ideal TSR, R is the edge span and V_w is the breeze speed. It is clear that the TSR control is a basic MPPT technique however incredibly dependent on the exactness of the breeze speed estimation utilizing an anemometer which adds to the framework cost

$$\omega_{ref} = \frac{\lambda_{opt} * R}{V_w} \quad (10)$$

From Eq. (9) the control of generator speed can be accomplished by the control of electromagnetic force. Besides, from Eq. (8) the electromagnetic force is relative to the q-pivot current of PMSG, consequently the rotor speed

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can be constrained by changing the q-pivot current of PMSG.

$$i_{qref} = \frac{2}{3 * P * \Psi} * T_{em} \quad (11)$$

4. CONTROL OF MACHINE SIDE AND GRID SIDE CONVERTERS.

Two levels BTB converter goes about as a rectifier on the MSC and inverter on GSC. The MSC is utilized to change the rotor speed to its ideal qualities at various breeze speeds. Also, the WT works at greatest force under wind speed varieties. The MSC comprises of two circles, the external circle is used to change the rotor speed through a PI regulator and the inward circle is for the d-pivot and q-hub stator flows to its reference esteems through a MPC. Then again, the GSC is utilized to keep up the dc-interface capacitor voltage to its reference esteem. Likewise, the GSC is utilized to control the genuine and responsive force. The inside control circle is for power control through the MPC. The outer circle controls the dc-interface capacitor voltage through a PI regulator.

5. MODEL PREDICTIVE CONTROL.

The MPC contains a wide group of regulators. The regulator predicts and appraises the impending conduct of factors for a restricted skyline of time. At that point, the regulator chooses the ideal incitations by limiting the expense work, g. The working standards of MPC are summed up in Fig. 4 and is finished up in three stages as follows:

1. Build a model for the framework to anticipate the future conduct of factors until a skyline as expected.
2. A cost work is applied that speaks to the ideal conduct of the framework.
3. The ideal activation is gotten by limiting the cost work.

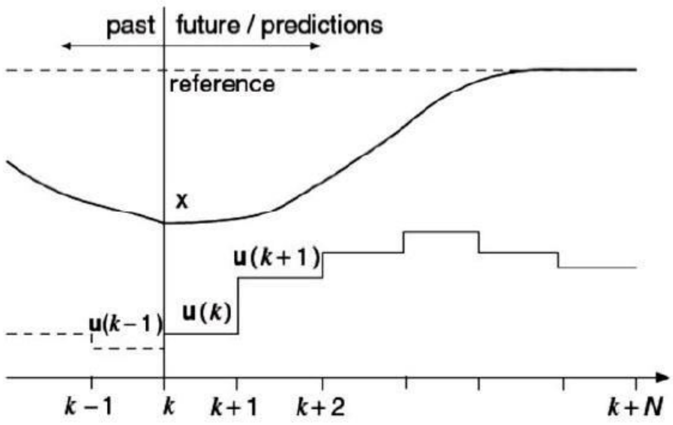
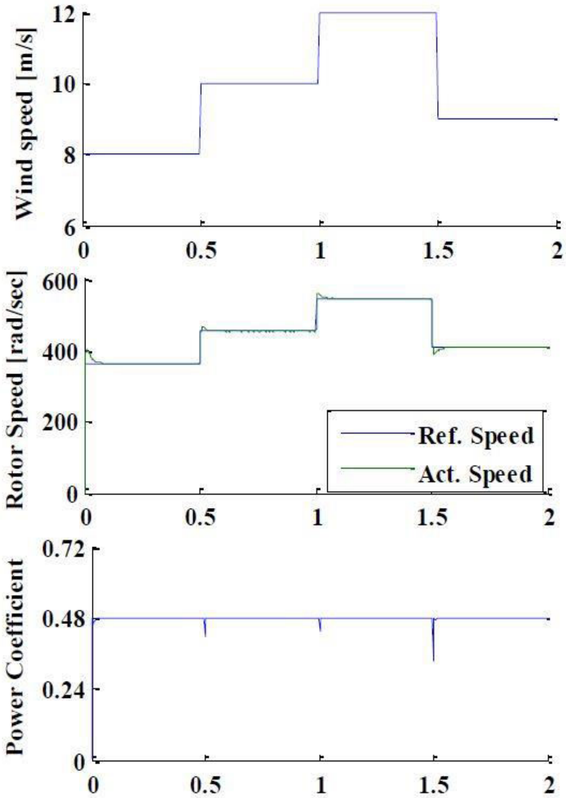


Fig. 4. Basic principles of MPC

6. SIMULATION RESULTS

To show the legitimacy and viability of the framework, reproduction results have been completed by Matlab/Simulink programming. The boundaries of the framework under examination are given in the Appendix. To consider the qualities of the TSR calculation in following the MPP under various variety in the breeze speed.

It is accepted that the breeze speed profile differs all over as a stage work with mean breeze speed of 10 m/sec. Fig. 5 speaks to the real wind speed, the deliberate and reference generator speed, the real and greatest mechanical force, the turbine's capacity coefficient, the turbine tip speed proportion and the force of the PMSG. Clearly the regulator gives a decent following of the genuine and reference estimations of the rotor speed. The distinction in force between the decided electrical and mechanical forces is exceptionally little. On the other hand, it very well may be seen that the framework works at the ideal force coefficient esteem (0.48). Additionally, the tip speed proportion arrives at greatest worth (8.1). Likewise, the turbine force T_m and generator force T_e are harmonize well. The framework side converter regulator is inspected under step changing wind speed profile. Fig. 6 shows the dc-interface voltage, the framework voltage and current, the network power and the power factor. The regulator controls the genuine estimation of dclink voltage to the reference level. Then again, to accomplish solidarity power factor, the framework voltage and current are kept in-stage. The infused dynamic force has a stage change as per the adjustment in the breeze speed, though the receptive force is zero to accomplish solidarity power factor.



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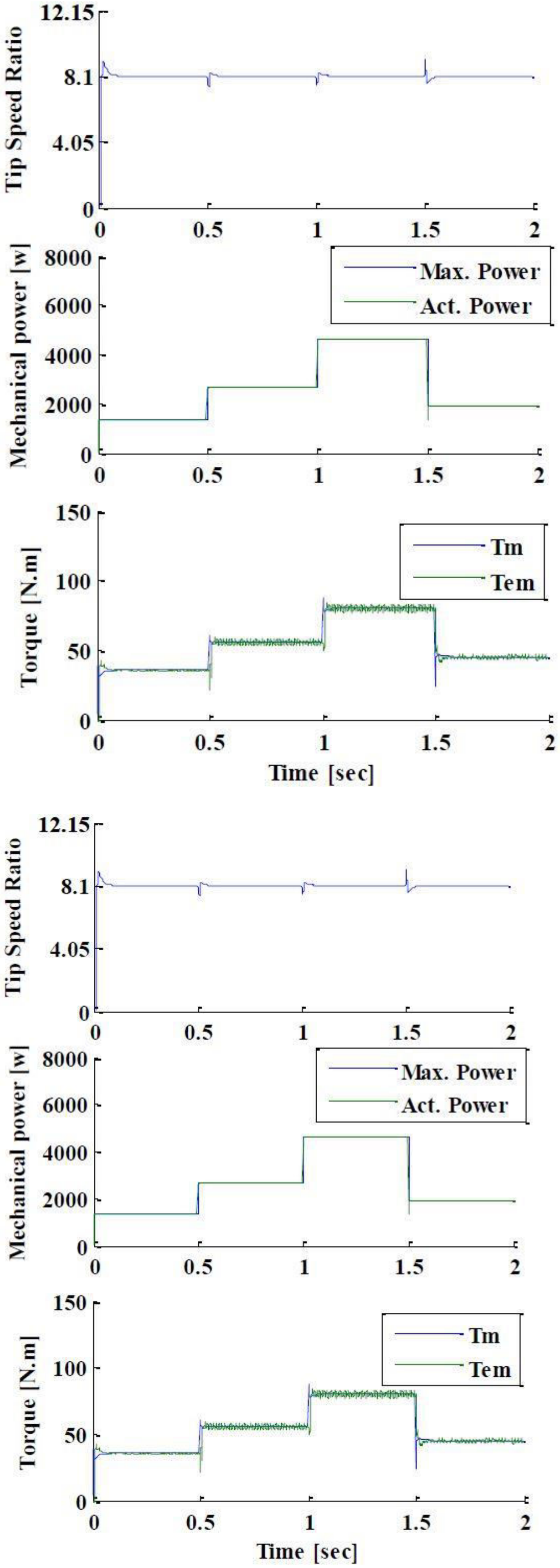

Fig. 5. MSC simulation results

7. CONCLUSIONS.

This paper presents the control of lattice tie WECS dependent on the MPC control methodology. Besides, the primary thought of the MPPT regulator has been examined as far as the change of the PMSG rotor speed as indicated by quick wind speed. The force control is figured it out through MPC where the q-pivot current is utilized to control the rotational speed of the generator as indicated by the variety of wind speed. Likewise, the MPC has been demonstrated as a decent force regulator in framework side. PC reproductions have been done to assess the viability of the MPC. The outcomes demonstrated that the MPC has exact following execution at various breeze speed.

REFERENCES

[1] M. Liserre, R. Cardenas, M. Molinas, and J. Rodriguez, "Overview of multi-MW wind turbines and wind parks," IEEE Transactions on Industrial Electronics, vol. 58, pp. 1081-1095, 2011.

[2] R. Cardenas, R. Peña, S. Alepuz, and G. Asher, "Overviewof control systems for the operation of DFIGs in wind energy applications," IEEE Transactions on Industrial Electronics,vol. 60, pp. 2776-2798, 2013.

[3] P. Cortés, M. P. Kazmierkowski, R. M. Kennel, D. E. Quevedo,and J. Rodríguez, "Predictive control in power electronics and drives," IEEE Transactions on Industrial Electronics, vol. 55,pp. 4312-4324, 2008.

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www.ijiemr.org

[4] A. Linder, R. Kanchan, R. Kennel, and P. Stolze, Modelbased predictive control of electric drives: Cuvillier, 2010.
[5] J. Rodriguez and P. Cortes, Predictive control of power converters and electrical drives vol. 40: John Wiley & Sons, 2012.
[6] Z. Zhang, H. Xu, M. Xue, Z. Chen, T. Sun, R. Kennel, andC. M. Hackl, "Predictive control with novel virtual-fluxestimation for back-to-back power converters," IEEE Transactions on Industrial Electronics, vol. 62, pp. 2823-2834, 2015.
[7] S. Vazquez, J. I. Leon, L. G. Franquelo, J. Rodriguez, H.A. Young, A. Marquez, and P. Zanchetta, "Model predictive control: A review of its applications in power electronics," IEEE Industrial Electronics Magazine, vol. 8, pp. 16-31, 2014.
[8] E. Koutroulis and K. Kalaitzakis, "Design of a maximum power tracking system for wind-energy-conversion applications," IEEE Transactions on Industrial Electronics, vol. 53, pp. 486-494, 2006.
[9] A.-R. Youssef, M. A. Sayed, and M. Abdel Wahab,"Control Scheme of Five-Phase PMSG Based Wind Turbine for Utility Network Connection."