TEST Engineering & Management

January - February 2020
ISSN: 0193 - 4120 Page No. 11578 - 11582

Simulation and Modelling Of Wind Energy Generator for Smart Grid

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Article Info
Volume 82
Page Number: 11578 - 11582
Publication Issue:
January-February 2020

Article History
Article Received*: 18 May 2019*
Revised*: 14 July 2019*
Accepted*: 22 December 2019*
Publication*: 21 February 2020*

Abstract

In this paper the authors present a steady state model of wind generator. The operating characteristics Tip-speed-ratio (TSR) and Cp (Power coefficient) of the wind turbine over varying wind speeds (WSs) have been presented for the wind turbine specifications. Also the DFIG Induction generator model has been presented with the mathematical equations for stator and rotor voltages and currents respectively as a function of the electrical equivalent circuit parameters, slip and mechanical power out of the turbine (as an electrical power output of the turbine in MW). Further the variation in the stator and rotor active and reactive power output with the variation in the WS (m/s) have been presented.As, the wind turbine normally stay away from the grid terminals, so we need to consider the transformer and cable impedance for calculating the terminal voltage of the Grid (PCC), the variation in the terminal voltage with the variation of the WS have been studied. The proposed work is carried on MATLAB. Further the developed model of the wind generator and its performance has been tested on a real-time WS time-series data available from MNRE (India).

Keywords: *Wind turbine model, Squirrel cage induction generator(SCIG) and DFIG wind generators characteristics, Real time data, Grid connected wind generating system, Radial Distribution System (RDS)*

I. Introduction

With present scenario of growing power demand and with the usage of different types of electronic loads, there is a need for smart utilization of power generation resources, i.e, renewable energy resources like solar and wind power generation. Much research has been done in the wind energy generator models, like SCIG which is a fixed speed wind generator. As the wind is Intermittent, so many authors have developed different models of variable speed wind generators with power electronic converters connected on the generator side as well as on the grid side for efficient Integration of wind energy generating system with the Grid. Here, in this paper the authors propose a basic model of SCIG and DFIG wind generators and their characteristics with the variation in the WSs. The feasible operation ranges of wind generators have been identified for the range of variations in the WSs, further these obtained three-dimensional graphs helps the operation engineers to know the maximum mechanical power being converted into electrical energy for a particular WS and for the specified turbine and generator parameter values. Also the developed models have been tested on the real-time data from MNRE.

There are different types of wind generators, with Type-1 wind generator being fixed speed with the variation in the wind of 1%, is an SCIG. Type-2 generator is a wound rotor induction generator with a wind variation tolerance of 1-10%. Type-3 wind generator is a DFIG with the wind variation tolerance of 30%. Type-4 wind generator is a PMSG with a wind variation tolerance of 30%, which achieves a 100% efficiency [6].

Here, the developed SCIG and DFIG generators models have been connected to a 33-Bus RDS, at 18th and 30th bus and the improvement in the voltage profile and the reduction in total active power losses of the system is been obtained.

II.Wind Turbine Model

The main components in wind energy conversion system are illustrated in figure1. The system includes a rotor with turbine blades, an electric generator, a power electronic converter, a transformer for connecting to grid [1].

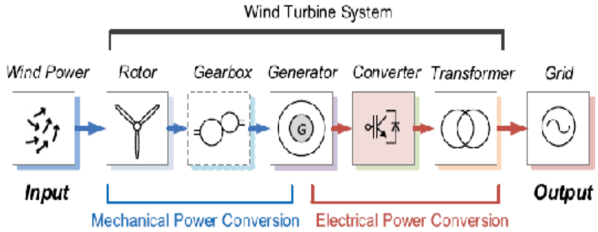

Fig.1: Power conversion stages in a wind turbine system

The power obtained from wind is given by the following equation [2].

$$P_w = \frac{\rho}{2} C_p A V_w^3 \text{ .... (1)}$$

Where ρ is density of air,

$$C_p = C_1\left(C_2 - C_3 \times \vartheta - C_4 \vartheta^x - C_5\right)e^{-C_6}$$

The considered parameter values are

$C_1 = 0.5$; $C_2 = 116/\lambda_i$; $C_3 = 0.4$; $C_4 = 0$; $C_5 = 5$; $C6 = 21/\lambda_i$

Where $\frac{1}{\lambda_i} = \frac{1}{\lambda + 0.08\vartheta} - \frac{0.035}{\vartheta^3 + 1}$

Figure 2 and figure3 represents the three dimensional plots of mechanical power output of the wind turbine for variation of the WS, power coefficient and Tip speed ratio.

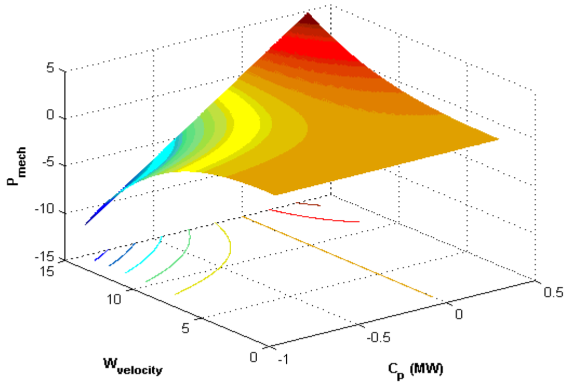

Fig 2:Mechanical power output of the wind turbine for variation of the WSand power coefficient.

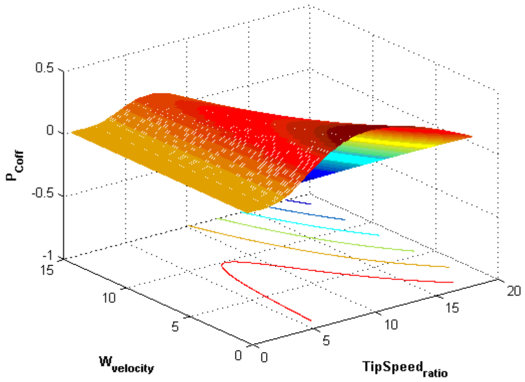

Fig3:Three-dimensional plot of variation of mechanical power output of the wind turbine with the variation in the WSs andTip-speed Ratio.

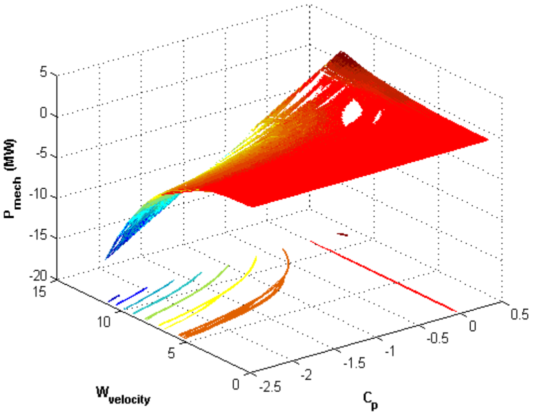

Fig.4: Mechanical power output of the wind turbine for variation of the WSand power coefficient [source:mnre]

wind generator electrical equivalent circuit [2] is shown in fig:3

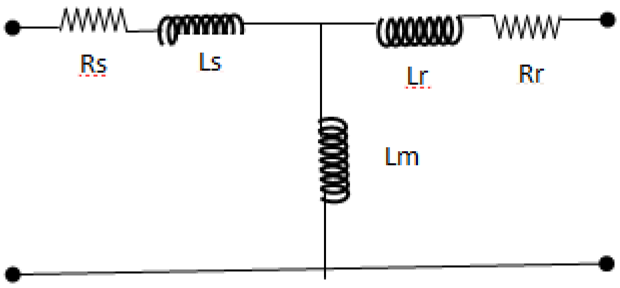

Fig3: Steady state equivalent circuit of DFIG

Rs = 0.02;Xs = 0.1;Rr = 0.018;Xr = 0.18;Xm = 3.2;V = 0.92;

The Thevenin's equivalent impedance seen at the input terminals

$$Z_{th} = \frac{((Rs + j\times Xs)\times j\times Xm)}{(Rs + j\times Xs + j\times Xm)} \ldots\ldots\ldots\ldots\ldots(2)$$

Open circuit voltage of the generator at the input terminals is

$$V_{th} = \frac{V\times(j\times Xm)}{(Rs + j\times Xs + j\times Xm)} \ldots\ldots\ldots\ldots\ldots\ldots(3)$$

The equivalent resistance of the circuit

$$R_{th} = real(Z_{th})$$

The equivalent reactance of the circuit

$$X_{th} = imag(Z_{th})$$

Wind generator stator current

$$I_s = \frac{V_{th}}{\sqrt{\left(R_{th} + \frac{Rr}{s}\right)^2 + (X_{th} + Xr)^2}} \ldots\ldots\ldots\ldots(4)$$

Where the initial terminal voltage considered is V = 0.92 p.u.

Rotor current and voltage in terms of the terminal voltage and the parameters of the generator is

$$I_r = \frac{V - Rs\times I_s - j\times w_s\times L_s\times I_s}{j\times w_s\times L_m} \ldots\ldots\ldots\ldots\ldots\ldots(5)$$

$$V_r = (j\times s\times w_s\times L_m\times I_s) + I_r\times(Rr + j\times s\times w_s\times L_r) \ldots\ldots\ldots\ldots\ldots\ldots \quad (6)$$

The sator active power, rotor ctive power and stator reactive power are computed as

$$P_s = real(V\times I_s^*) \ldots\ldots\ldots\ldots\ldots\ldots(7)$$

$$P_r = real(V_r\times I_r^*) \ldots\ldots\ldots\ldots\ldots\ldots \; (8)$$

Where Ir, Vr, Pr are the rotor current, voltage and active power and Is, Vs, Ps are the respective stator quantities.

The corresponding characteristics curves of the wind generator DFIG model have been obtained with the variation of the WS form 1 m/s to 25 m/s.

Based on above equations a MATLAB program has been written and generator stator active and reactive power, mechanical power developed vsWS are calculated and results are shown in fig:4, fig,5, fig.6 and fig.7..

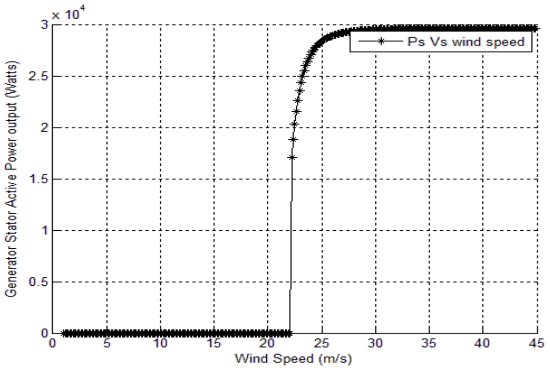

Fig-4: Generator stator active power Verses WS

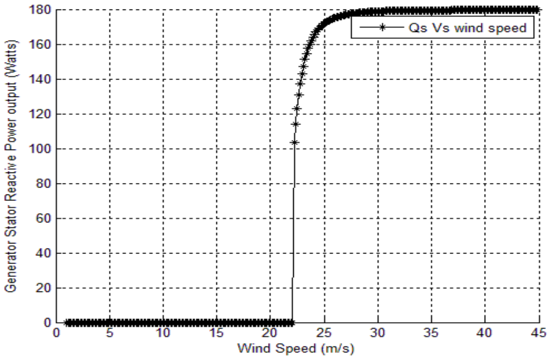

Fig-5: Generator stator reactive power Verses WS

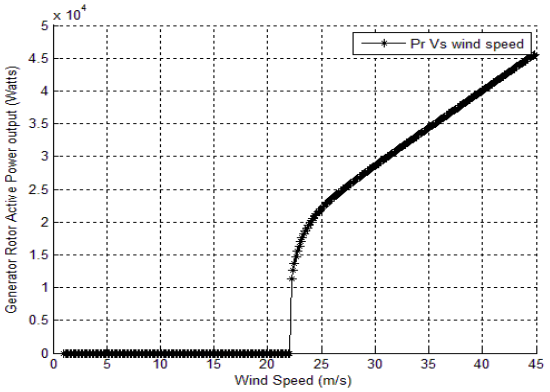

Fig-6: Generator rotor power Verses WS

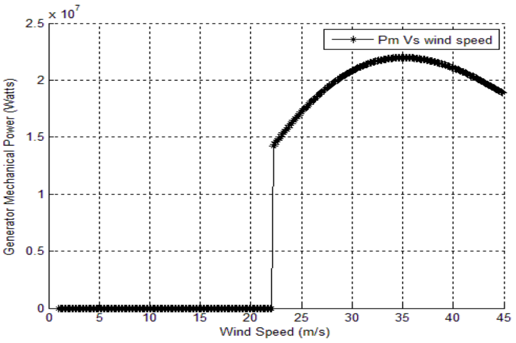

Fig-7: Mechanical power developed Verses WS

Generator stator power loss and generator rotor power loss vs.WS are determined and depicted in figures8 and 9.and efficiency is calculated as per equation (9).

$$\%\eta = \frac{(P_s + P_r)}{P_m} \times 100\% \;\ldots\ldots\ldots\ldots\ldots\ldots \quad (9)$$

The efficiency curve of the generator for variation the WSs has been presented in figure10.

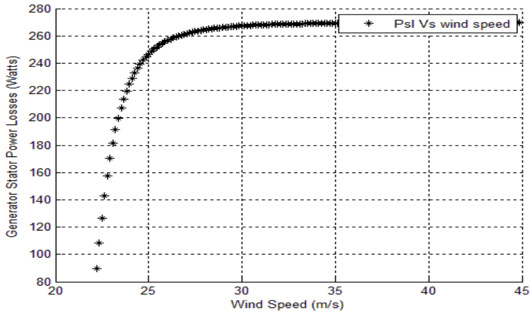

Fig-8: Generator stator power loss Verses WS

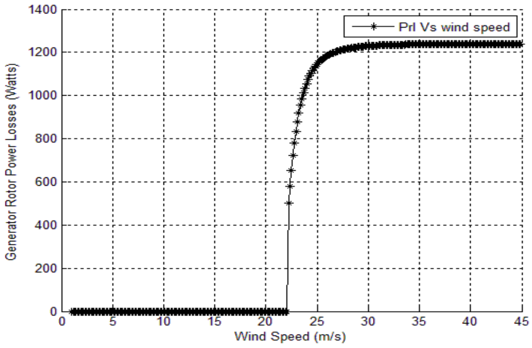

Fig-9: Generator rotor power loss Verses WS

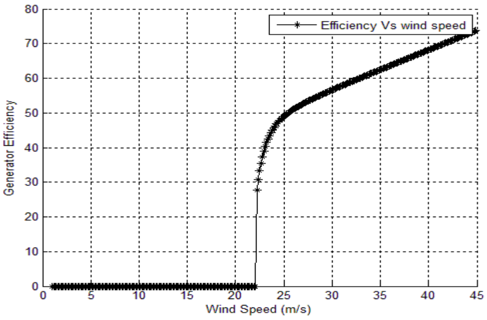

Fig-10: Efficiency Verses WS

The Grid terminal voltage (PCC) has been computed taking the reactance values of the step-up transformer and the cable using Power flow Implementation algorithm [2,5]

Step-1: For the given load and line data identify the distribution networks connection and compute the branch currents (B) form the load currents (I) and the power Injections form the Wind Distributed Generator (WDG) as given by the equations below.

$I = \dfrac{P - j \times Q}{V^*}$ where P and Q are the active and reactive power loads (positive sign)and active power Injections (negative sign) of WDG.

B = BIBC × I

Step-2: Form the obtained branch currents compute the voltage drops of the branches as

VD = Z × B

Step-3: Compute the voltages at each bus, assuming the initial voltage at each load bus as 1.0 p.u without WDG.

Step-4: Find the voltage at the bus where WDG is connected with power flow solution, and substitute it as 'V' in the calculation of V_{th} and I_r equations.

Step-5: Obtain the characteristic plots of Is, Vs, Ps and Ir, Vr, Pr form the wind generator equation (1-9) given above section.

Step-6: The terminal voltage of WDG and the active power injections are updated and the power flow solution of the RDS computed to get the improvement in the voltage profile of the system

The methodology is applied to 33 distribution network.

The developed model of the wind generator has been installed at 18th and 30th bus of the 33-bus RDS, and the corresponding improvement in the system voltage profile has been presented infigure11 and figure12

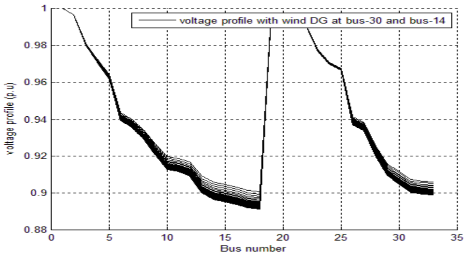

Fig-11: Voltage profile with wind generators (DFIG) at Bus-30 and Bus-14 with the WS variation form (1-32 m/s)

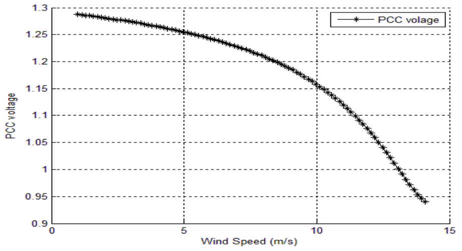

Fig-12: Point of common coupling (PCC) voltage at the wind generator bus-30

III. Conclusion

Here a novel approach is used to identify the optimal velocity of the wind at which the maximum amount of mechanical power is obtained. For which the authors have found the feasible ranges of velocity of at which the maximum power output of the turbine can be extracted. The characteristics of the wind generator for variation in the wind velocity have been presented. Also the developed model of the wind power turbine has been tested by connecting the wind generator on 33-Bus RDS. The improvement in the voltage profile of the system has been presented.

IV. References

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