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Comparative Study of Wind-Energy Conversion System on Fixed-speed and Variable Speed in Synchronization to Grid

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Abstract: This Paper provides a comparative study of important parameters to be taken into account if considering Wind-Energy-Conversion system. The effects of variable wind speed are observed for grid in term of introducing harmonics and power losses to the system. The model of wind energy conversion system is incorporated with doubly-fed induction generator, constructed in MATLAB Simulink. This also marks the importance of Variable speed Wind turbine Control strategies [3]. The Wind farm is able to produce the rated power of 9MW, by operating 6 turbines of 1.5MW.

Keywords: Wind Energy Conversion system, Doubly Fed Induction Generator and control strategies.

I. INTRODUCTION

Wind power resources are now receiving attention of the World energy sector. In the early stages, the wind-energy conversion systems were equipped by generators, intended to operate at constant speed and can be connected directly to the grid [1]. The revolutionary change in the power electronics has emerged as an aiding technique to synchronize the fixed-grid frequency with the variable frequency of the generator by means of AC-DC-AC Power converters. The use of these power converters made turbine capable of to run efficiently at all wind speeds, but at the same time injects harmonics into the grid with more extra power losses [3]. However, the improved ability of producing more maximum power output while generating minimal mechanical stress provides major advantages to Variable-Speed wind energy conversion system over Fixed speed system.

II. PROBLEM STUDY AND MODELLING

A. Variable Wind-Speed effects

Since, the irregularities in the wind cause a barrier in harnessing wind energy. The mechanical equation describes the targeted effect.

$$P_m = \frac{1}{2} C_p \rho A V^3 \qquad \text{Eq. (1)}$$

where, C_p is the power co-efficient that gives the fraction of kinetic energy which is converted into mechanical energy by the wind turbine. ρ is the density of the of air, A is the swept area and V is the wind speed.

The Eq. (1) clearly illustrates that the amount of energy to be harness is directly proportional to the cube of wind speed. Hence, a small variation in wind speed can cause a larger impact on the amount of power.

B. Modelling Considerations

The built-in MATLAB Model of wind turbine was been taken as a base model so that initial know-how of simulation design and modelling perspective can be observed. The three-phase source can be used to generate the voltages of 120kV which is step down to 25kV transmitted through Pi-line of 30km and then further step down to 575 volts to be synchronize with the Wind energy conversion system. The model initially consists of several flaws and outdated scenarios (related to this problem), so the model is modified and all the flaws are corrected according to the results we required.

The model is completed in the following steps.

- Modelling of a grid to distribution end.
- Modelling of wind farm having 6 turbines of 1.5MW with double fed induction generator.
- Integration of grid with the wind farm.
- Configuring simulation setting according to the model characteristics.

C. Variable-Speed Data sets

The data sets for observing the pattern of the wind-speed are collected by an open-source website of Los-Angeles. The Data-set consist of 17520 samples taken at the instant of 15 minutes. (Temperature, wind direction and Humidity are also included in dataset).

D. Variable Speed Input

To fed the variable input continuously, **Look-up table** is considered. The lookup table is the mapping of input values to output values in form of an array. The lookup table plots the varying behavior of wind-speed, fed an input as shown in figure 1.

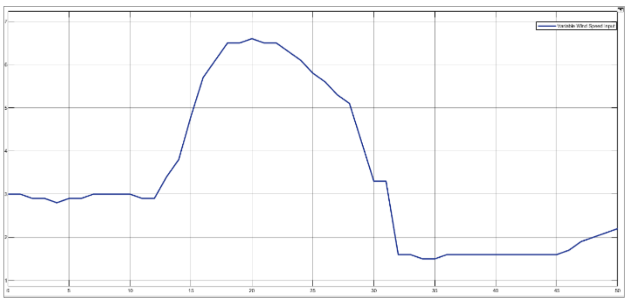


Fig. 1: Variable Wind Speed using look-up table.

III. WAVEFORMS AND COMPARISON

A. Wind-Energy Conversion System on Fixed Speed

Operating the synchronized system at a fixed-speed of 10m/s results in smooth current and voltage waveform after synchronization, on generation and distribution end, however distribution end voltage is observed with some negligible spikes which can be shown in fig. 2.

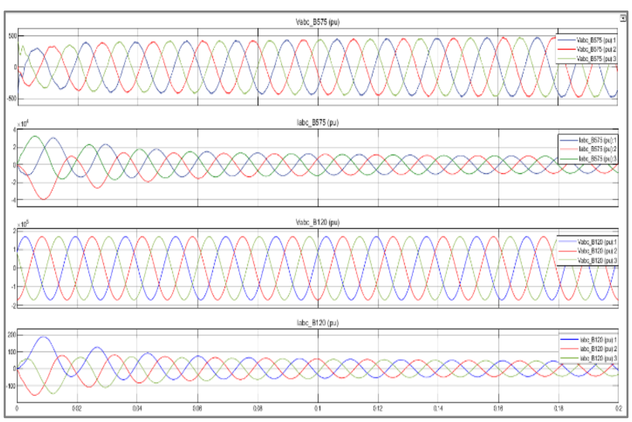
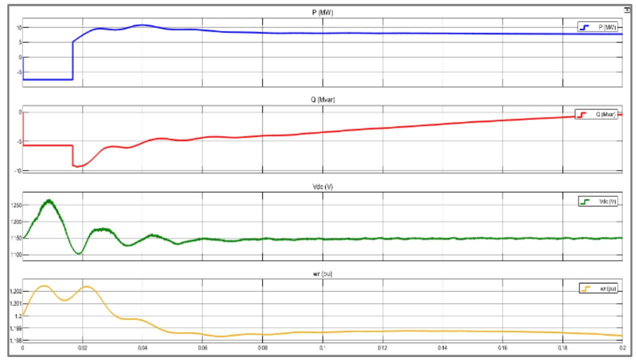


Fig. 2: Waveform of grid parameter (Current and Voltages at generation and distribution end) on fixed speed



The operation of wind farm at constant speed can also be observed in fig. 3. Where, constant active and reactive power is achieved,

Fig. 3: Waveforms of Wind Farm operating at Fixed Speed

The numeric steady state results will be given in table 1.1 as follow, extracted from the PowerGui block.

Table 1.1. Steady-state results at fixed speed

Grid Parameter	
• **Distribution Voltage**	476.5 V
• **Distribution Current**	2000 A
• **Grid Voltage**	17979 V
• **Grid Current**	50A
Wind Farm Parameter	
• **Active Power**	6MW
• **Reactive Power**	0.02 MVar
• **DC Voltage**	1150

B. Wind-Energy Conversion System on Variable Speed.

Operating the model on variable wind speed injects harmonics and incurs extra power loss [3]. Also, spikes at distribution voltage can be seen clearly now, increased with the increasing variation of wind speed which can be shown in fig 4.

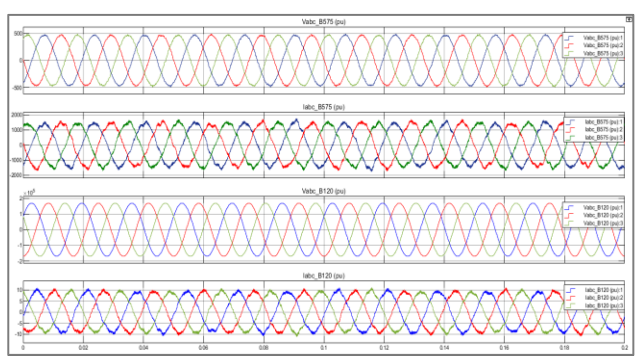


Fig. 4: Waveform of grid parameter (Current and Voltages at generation and distribution end) on variable speed

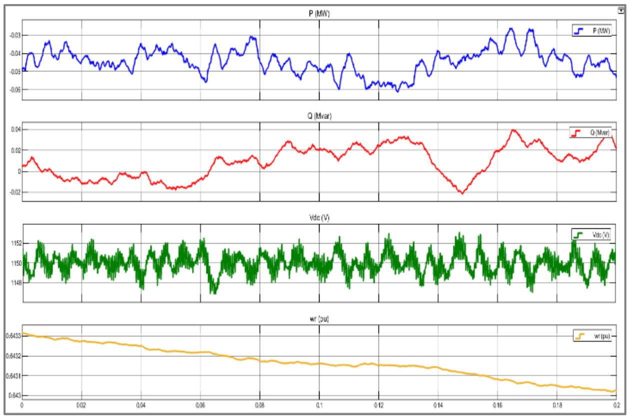


Fig. 5: Waveforms of Wind Farm operating at Variable Speed

In term of wind farm, the effect of variable wind speed will be shown in Fig. 5.

Table 1.2. Steady-state results at variable speed

The numeric steady state results will be given in table 1.2 as follow, extracted from the PowerGui block.

Grid Parameter	
• **Distribution Voltage**	500 V
• **Distribution Current**	1277 A
• **Grid Voltage**	16970 V
• **Grid Current**	12A
Wind Farm Parameter	
• **Active Power**	40kW
• **Reactive Power**	0.03 MVar
• **DC Voltage**	1150

IV. CONCLUSION

A. Discussion

The papers aim to discovers the effect of wind farm on integration to the grid in term of harmonics in currents and fluctuation in voltages. The fixed speed wind energy conversion systems intend to produce heavy mechanical stresses. Hence, to deal with variable wind speed. Power converters are to be equipped with the generators so that turbine can run efficiently at all speeds. In this regards, different controlling strategies and techniques [1] are being used. The grid at fixed speed is experiencing negligible changes in smooth waveforms however harmonics can be clearly observed in the currents and spiky voltages at distribution end in case of Variable wind speed.

Since, comparing the numerical results in table 1.1 and table 1.2, Major power loss in variable speed wind energy conversion system with high ripples in DC voltage can be observed on side of power converters. That contributes in the high harmonic currents of the grid [3]. However, it can be observed that no instance of customer announcing and equipment failure can be seen.

B. Future Work(s)

Since, wind-energy conversion system at variable speed is more preferable because of its improved power quality. This aided the concept of Maximum Power Point tracking to harness the optimal amount of energy thorough wind turbines at all speed [5]. The majorly accountable techniques are artificial neural network and machine learning [6] [9] [10]. Several approaches are taken into account with complex engineering techniques. Similarly, several variable controlling strategies are in discoveries to make this aspect of harnessing wind energy feasible [1].

V. REFERENCES

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