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Power Comparability Analysis of DFIG and SCIG based Wind Farm

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ABSTRACT

The rapid depletion of conventional sources for power generation necessitates the need of renewable energy power plants. Renewable sources primarily wind and solar are available free of cost and counts for cleaner source of energy thereby reducing environmental concern. The potential of wind energy needs to be harnessed effectively for optimum power generation. Present research aims at comparison of wind power performance characteristics utilizing squirrel cage induction generator (SCIG) and doubly fed induction generator (DFIG) focusing on load flow analysis, active power at various wind speeds and reactive power analysis. The simulation and analysis pinpoints the suitable generator at various wind speeds to consummate for selection in a distinct wind farm. The evaluation consisted identical operating conditions and control schemes.

Keywords: Power generation, SCIG, DFIG, wind farm.

I. INTRODUCTION

Renewable energy has emerged to be a dominant option for power generation in India. Wind, solar, hydro are the majorly subsidized sources for the rise of depletion from conventional sources of energy. Out of these sources, wind energy continues to grow its popularity in renewable energy sector [1]. Wind energy consumes low cost for generating same amount of electrical energy; hence emphases are targeted towards wind power generation in terms of its sustainability, efficiency and reliability of the system.

In this paper, the vital objective was to compare the wind power performance characteristics of DFIG and SCIG for a particular wind farm. The analysis included load flow analysis for nominal wind speed, active power analysis at various wind speeds, and reactive power analysis at grid side of the system. Various analyser programs help in analysis of wind farm containing wind turbine generator [2], before actual implementation for any corrective action. With advanced technology and efficiency in computation of wind generator model, ETAP (Electrical Transient Analyser Program) software was opted most appropriate for the comparative analysis of both generators simulated in the wind farm. The single line diagram of wind farm was simulated in ETAP. The wind farm consisted of 20 WTG's each of 2.1 MW constituting total capacity of 42 MW, internally connected through cables. Variable rotor resistance induction generator (Type 2) and limited variable speed generator with back to back partial converter (Type 3) also known as DFIG were modelled for a wind farm. 132 kV voltage level at Bus 1 was monitored for analysis. The load flow analysis using advanced Newton-Raphson method was simulated for wind speed range from 4 m/s to 14 m/s with cut-in speed at 4 m/s for choice of wind generator for various speeds depending on wind power output.

II. METHODS AND MATERIAL

1. An Outline of the Wind Farm

Wind farm with 3 Networks constituted capacity of 42 MW. Network 1 comprises 12.6 MW, Network 2 of 14.7 MW and Network 3 of 14.7 MW. Individual wind generator's capacity is 2.1 MW. Grid (U1) system operates at 132 kV through parallel operated transformers. Transformer (T1) bay further connects two parallel connected Networks (1 and 2) at 33 kV, while transformer (T2) bay connects one Network (3) at 33 kV. Each wind generator is coupled to a step up transformer of 2.5 MVA, 0.69/33 kV.

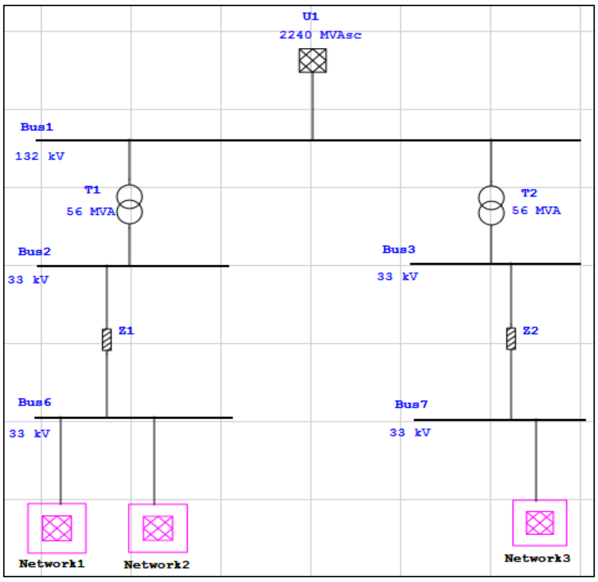

Figure 1. Single line diagram of the Wind Farm

2. Wind Turbine Generators

Recent technology implements four types of generators namely, fixed speed induction generator (Type 1), variable rotor resistance induction generator (Type 2), variable speed doubly fed induction generator with partial back to back converters (Type 3) and variable speed asynchronous generator with full converter system (Type 4) [3]. In this paper, emphases are given only on Type 2 and Type 3 generators. Type 2 generator usually eliminates the use of slip ring and brush assembly reducing the cost of the generator. The variable rotor resistance is a controlled parameter [4]. Using controlled variable rotor resistance, the power output operates limitedly near synchronous speed. The generator is simple in construction, reducing cost of converter and maintenance. This type absorbs reactive power from grid during fault condition and hence requires reactive power compensation [5].

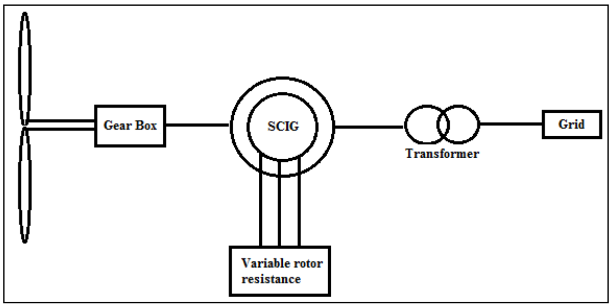

Figure 2. Block diagram of SCIG

Type 3 generators consist of stator and rotor connected directly to grid only the difference is stator connected through transformer while rotor connected through feedback consisting back to back partial scale converters [6]. Today, almost 80% of the wind farms incorporate DFIG type generators [7]. The major advantage of DFIG lies in its ability to operate at very low and at high wind speeds. The reactive power is fed into the grid avoiding absorption of power from the grid and thereby voltage disturbance is reduced, hence the need for reactive power compensation is over-ruled [8].

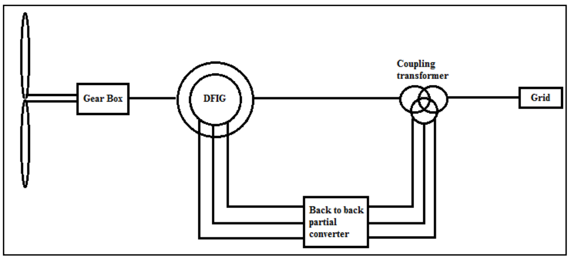

Figure 3. Block diagram of DFIG

III. RESULTS AND DISCUSSION

1. Simulation And Discussion

A. Active Power Flow Analysis at Nominal speed

In ETAP, load flow analysis module was used for a general active power flow for individual network. The load flow analysis was executed through advanced Newton-Raphson method. Load flow analysis was carried out at nominal wind speed. Active power for SCIG at Grid was around 39987 kW (40 MW), while for DFIG it was 40400 kW (40.4 MW). Fig. 4 indicates SCIG power output and Fig. 5 indicates DFIG power flow towards the grid. DFIG proves to be more efficient than SCIG with optimised power flow towards the grid with reduction in losses.

Table I. Active Power Comparison At Nominal Speed

Network	Actual (MW)	Simulation (MW)	
		SCIG	DFIG
Network 1	12.6	12.0	12.1
Network 2	14.7	14.0	14.2
Network 3	14.7	14.0	14.1
Total (At Grid)	42.0	40.0	40.4

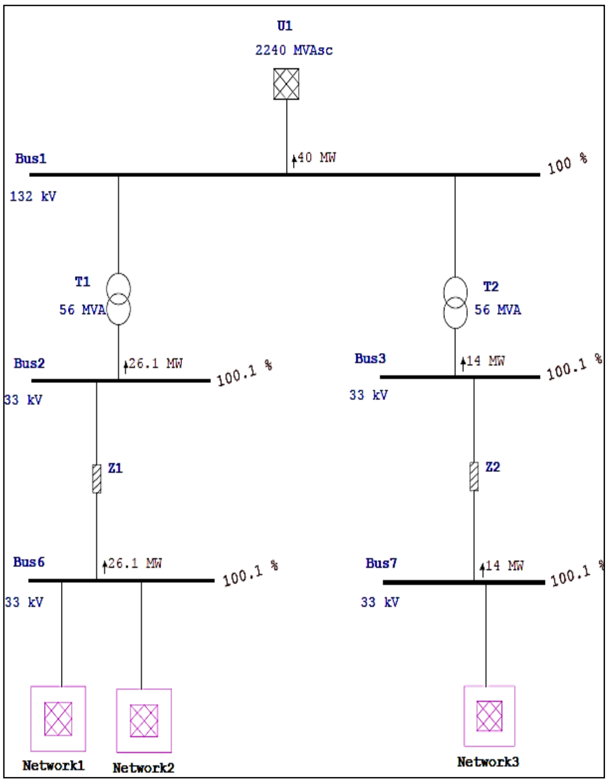

Figure 4. Active power flow for SCIG at nominal speed

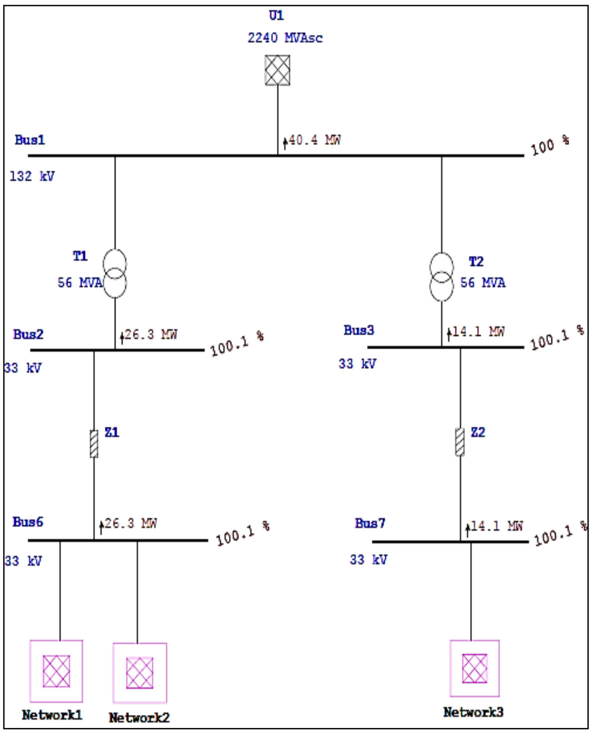

Figure 5. Active power flow for DFIG at nominal speed

B. Active Power at various Wind Speeds

The power extracted from wind varies in direct proportion with the cube of wind speed [4]. The wind turbine generator was operated in Type 2 and type 3 Generic model of ETAP. The wind speed was made to fluctuate from cut-in speed to 14 m/s. The results are mentioned in TABLE II below.

Table II. Comparison of Active Power

Wind Speed (m/s)	Active Power (MW)	
	SCIG	DFIG
4	2.08	2.2
5	5.2	4.3
6	7.78	7.6
7	13	12
8	18.7	17.9
9	26.2	25
10	32.2	31.1
11	34.7	33.2
12	39.3	38.6
13	40.3	40.9
14	41.1	41.8

The simulated analysis indicates the efficiency of SCIG to extract wind power generation at medium wind speeds ranging from 5 m/s to 12 m/s, on the other hand, DFIG extracts power generation at low speed upto 4 m/s, and high speed above 12 m/s upto cut-off speed after which the power extracted remains constant. As the power flow below wind speeds remains the same below wind speeds 4 m/s, it was not considered in the Table II above. Wind power extraction through DFIG grows at faster rate in steps as compared to SCIG. Power extraction at low wind speeds has led for most of wind farms today equipped with DFIG. Due to this advantage, DFIG has led to replace SCIG in proposed wind farms.
The active power curve obtained for SCIG and DFIG is shown in Fig. 6. The nature of graph though looks similar, still SCIG fails to compete DFIG at very low and high wind speeds.

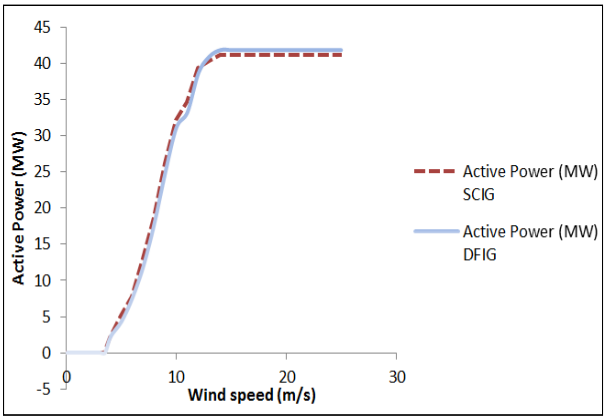

Figure 6. Active power curve comparison of SCIG and DFIG

C. Reactive Power Analysis

The reactive power plays an important role in performance of the system. SCIG draws reactive power from the grid for its excitation [9].

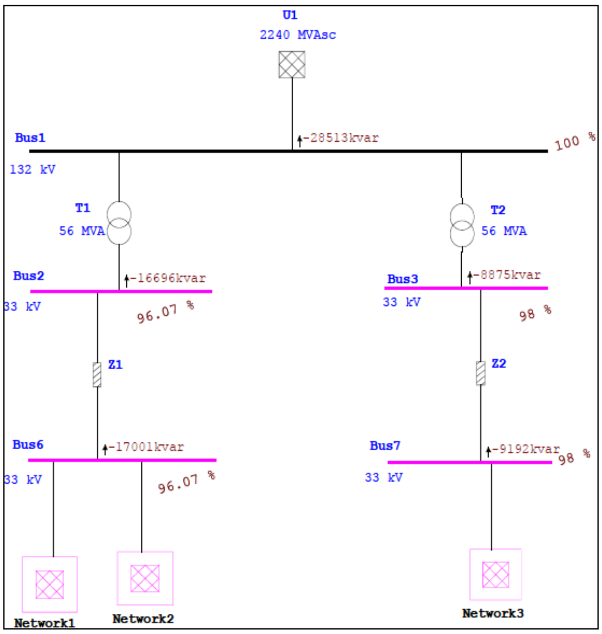

Figure 7. Reactive power drawn by SCIG from the Grid

The load flow analysis indicates clearly the absorption of reactive power by the wind turbine generators from the grid as seen in Fig. 7 above. The total reactive power drawn from the grid is 28.513 Mvar, of which Network 1 and 2 consume 16.696 Mvar and Network 3 consumes 8.875 Mvar. The negative sign indicates that the direction is opposite i.e., towards the wind turbine generators.

The need was felt to compensate the reactive power to optimize the output and improve the efficiency of the system. To validate this, a capacitor bank was designed with requisite parameters to reduce the reactive power withdrawn from the grid and hence maintaining stability of the system.

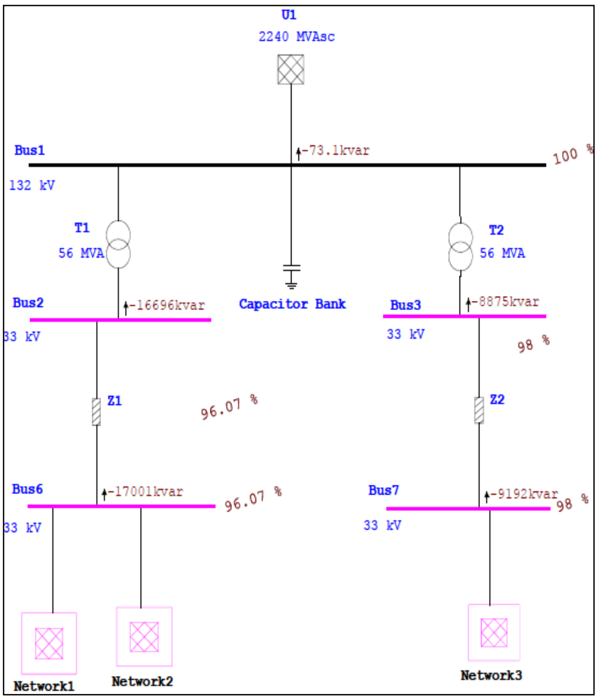

Figure 8. Reactive power compensation with capacitor bank

Fig. 8 clearly indicates the successful compensation of reactive power through capacitor bank at Bus 1 at 132 kV voltage level. It was also analysed that proper sizing of capacitor bank was needed without violating the Indian Grid Codes for the overall system stability including economy as well. After using capacitor bank the reactive power withdrawn from the grid reduced to 73.1 Kvar.

In DFIG, there is no need for reactive power compensation unlike SCIG as both stator and rotor are connected to the grid balancing frequency and voltage. Analysis studied indicated the similar results supplying reactive power to the grid instead of consuming it. Fig. 9 indicates the reactive power supplied to the grid. It supplies 22.5 Mvar to the grid, of which Network 1 and 2 constitute 15.9 Mvar and Network 3 constitutes 9.35 Mvar. It is also observed that the Bus voltages are within Indian Grid Codes limits.

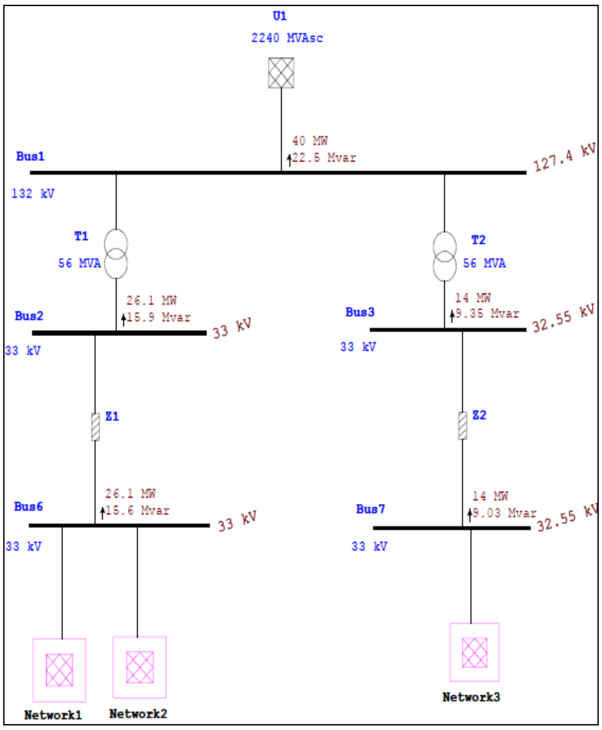

Figure 9. Reactive power supplied by DFIG to the Grid

IV. CONCLUSION

The analysis indicates the potential of DFIG for wind speeds above 12 m/s. This concludes the high wind power output of DFIG at very high wind speeds with additional advantage at low wind speed like 4 m/s. The active power flow analysis at nominal wind speed benefits DFIG with optimum output than SCIG. The reactive power analysis was of prime importance whose results indicated the ability of DFIG to supply reactive power to the Grid compared to SCIG absorbing high amount of reactive power from the grid. Thus, need of compensation devices like capacitor bank, SVC's and STATCOM are required. Most appropriate compensation is provided by capacitor bank which is cheaper as compared to other compensation devices. Hence, the results analysed under similar operating conditions of SCIG and DFIG for a particular wind farm credits DFIG especially for analysis of active power at low and high wind speeds, load flow and reactive power analysis.

V. REFERENCES

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