Transient Stability Analysis of Wind Turbine Based Micro Grid using ETAP Software

Vijaya Rai
M. Tech (Power System)
Amity University, Noida, India

Sumeet Sehrawat
Assistant Professor,
Amity University, Noida, India

Kamlesh Pandey
Assistant Professor,
Amity University, Noida, India

Abstract— **As the wind energy is becoming most popular renewable energy source, the increasing use of wind power in distribution system can greatly affect voltage stability of the system during transients and sudden change in load. There has been a tremendous increase in demand for the application of doubly fed induction generators (DFIG) in wind power plants in last four years. This paper demonstrates the issues of grid- loss reduction of distribution systems which uses DFIG-WTs and stability of system has been examined by doing some simulations using ETAP software. This paper uses available models of two different turbine technologies: DFIG-wind turbine and Synchronous generator. This paper investigates the stability of wind turbine interconnected to micro-grid under many operational conditions.**

Keywords— Transient stability, doubly- fed induction generator (DFIG), distribution systems, Synchronous wind generator, grid loss reduction

I. INTRODUCTION

IN the recent years many countries have experienced a big expansion at wind farms buildings as wind energy is a clean, renewable and indigenous energy resource. The studies and researches to determine the behaviour of a power system when connected with wind turbines, by transient disturbances that may cause loss of generation stability, are among the main factors responsible for the technical viability of implementing this kind of technology.

Wind power capacity is annually added over 20% in recent five years because of its relatively low MWh cost. Wind power could be combined with appropriate reactive power compensations to improve the operational voltage stability of the electricity distribution systems during sudden load change. Some of the often-quoted benefits include the following [1]:

1) Emergency backup during sustained utility outages.
2) Voltage support.
3) Grid loss reduction.
4) Improved utility system reliability.
5) Distribution capacity release.
6) Potential utility capacity addition deferrals.

On the other hand, the integration of wind power may cause some additional problems in voltage and frequency regulation, reactive power compensation, power quality (e.g., flicker and harmonics) and protection of the distribution systems. Therefore, reactive power compensations are very important to wind turbines. For reactive power compensation a shunt capacitor is connected in system model used for simulation.

II. DOUBLE-FED INDUCTION GENERATOR AND SYNCHRONOUS GENERATOR

The utilization of double-fed induction generators, DFIG, has become a feasible and efficient alternative for energy generation, once the primary energy source is not controlled. Its viability and efficiency is due to the converters capacity of controlling the machine rotor field excitation, as shows Figure1. Other advantage of this kind of technology is the reduction of converters costs, once its rated power is around 30% of the machine rated power [2]. The DFIG consists of a wound rotor induction generator and AC/DC/AC IGBT-based PWM converter. It is equipped with pitch control system.

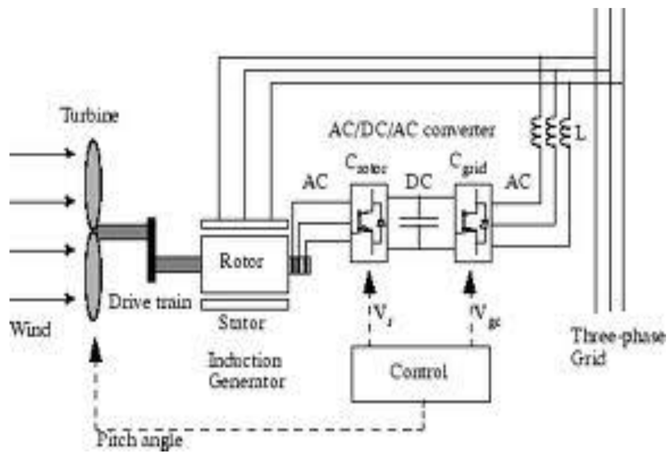

Fig 1. Double-fed induction generator with converters.

Besides the DFIG another technology largely used is the synchronous wind turbine. These synchronous generators are connected by means of converters in series with the network, in variable speed scheme, as shows Figure 2. The speed can be varied by varying pitch control angle of rotor.

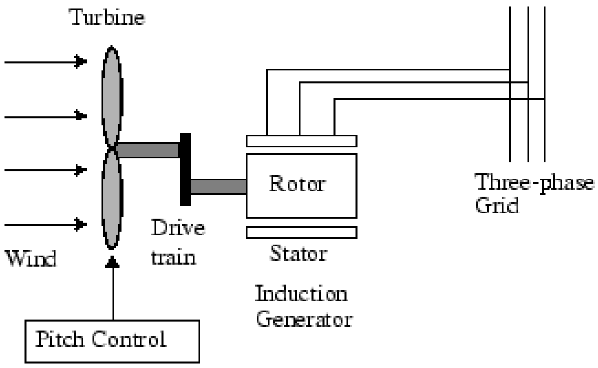

Fig 2. Scheme of synchronous wind turbine

With the recent development in power electronics, the DFIGWTs become very popular. Comparing to traditional squirrel-cage induction generator wind turbines, the major advantages of DFIG are that they can operate in a higher wind speed range and produce or consume reactive power through the magnetization provided by the rotor-side converter.

III. SYSTEM MODEL

A single line diagram of the system used for simulation is shown in figure 3 to investigate the stability of wind turbines interconnected to micro grid during sudden short circuit event. This system contains 13.8 kV, three feeder distribution sub system which is connected to a large network through a 69 kV radial line and substation transformer. Table 1 represent the load parameters.

TABLE I
Feeder Loads and their Impedances

	Maximum Power (MW + MVA r)	**Equivalent Impedence (ohm)**
FEEDER 1	0.9 MW, 0.67 MVAr 2.5 MW, 1.5 MVAr	146.62+ j98.00 93.26+ j62.38
FEEDER 2	3.6 MW, 2.3 MVAr	37.65+ j45.15
FEEDER3	1.2 MW, 1.6 MVAr 1.4 MW	123.64+ j114.02 256

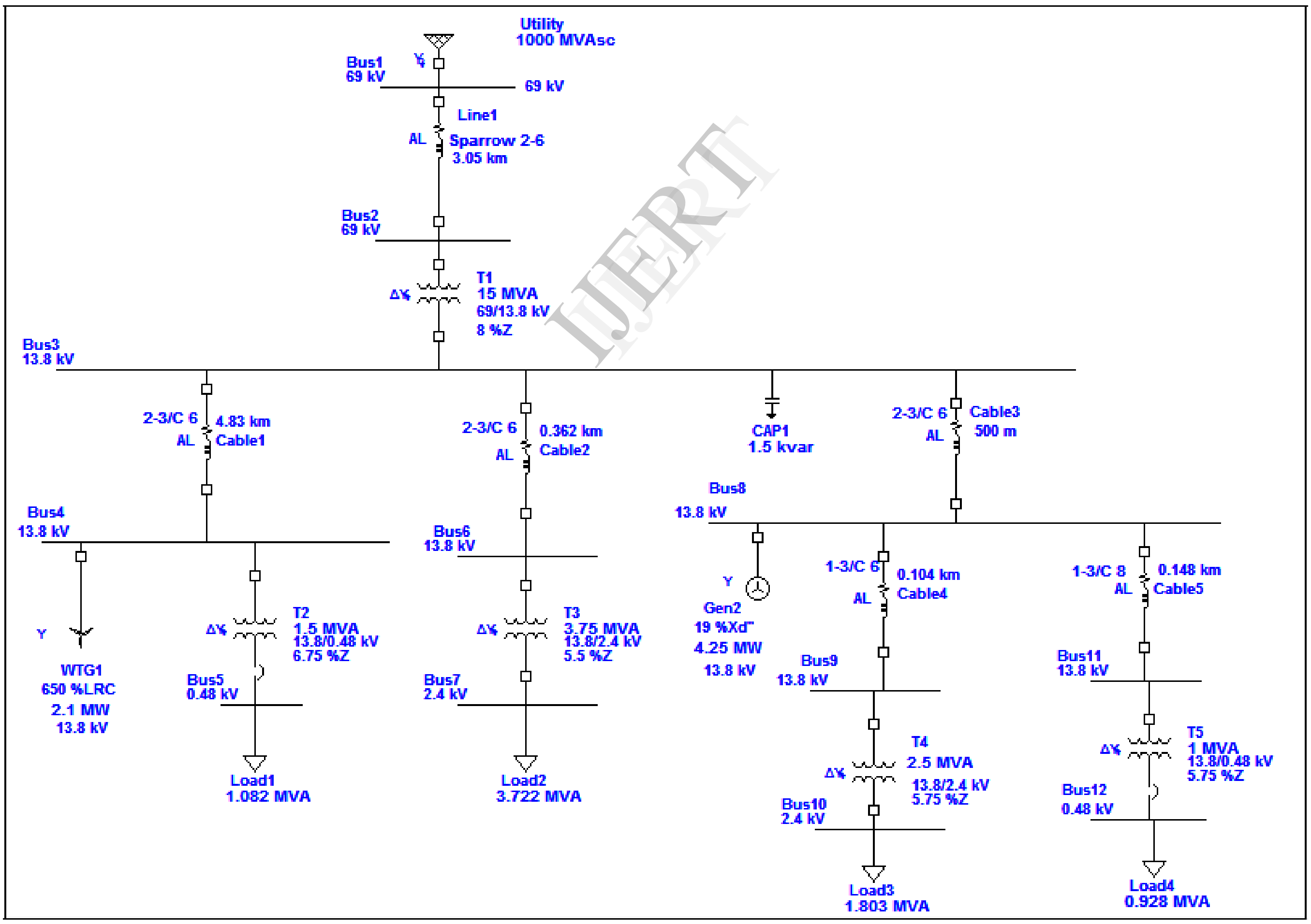

Fig 3. System model

To maintain the voltage and frequency regulation the 13.8 kV distribution sub-station is equipped with three- phase fixed shunt capacitor-bank. The grid is connected to another end of 69 kV, 1000 MVA short circuit capacity bus through a transformer. A combination of linear and non linear loads (L1 to L4) is supplied through three radial feeders of the subsystem. The system includes one DG unit (5 MVA) at feeder 1which is a synchronous machine and two turbines i.e., synchronous wind generator (5 MW) and DFIG 2.5 MW) at feeder 2 and feeder 3 respectively.

IV. METHODOLOGY AND SIMULATION

After building the system model in ETAP and choosing the integration technique between the two turbines the evaluation can be started by performing various simulations. Later, these simulation results should be compared for the coherency of results obtained by using two different turbine schemes with micro grid.

A. Basic case studies with a single DFIG-WT connected to test system

Short circuit is activated at bus 4 at time t = 0.2 sec and cleared at time t = 0.3 sec. The simulations of 2 sec include electromagnetic transients in the models, but saturation is not included.

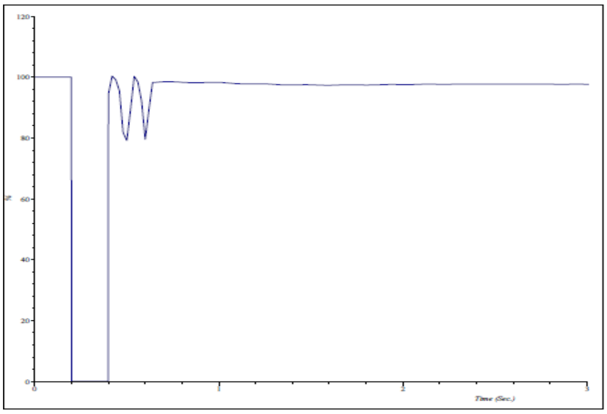

Fig 4.Bus 4: Line-Ground Voltage (kV)

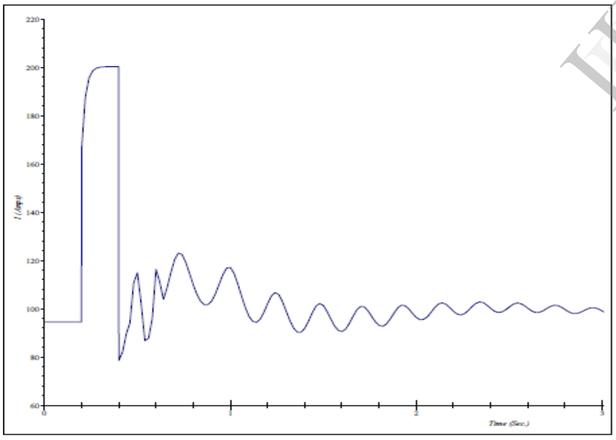

Fig 5.Bus 4: Short-circuit Current (kA)

When fault occurs, there is a large variation in the voltage during transients and positive sequence current transients are also very high. However these variations cannot be prevented but due to the combination of DG (synchronous generator), it injects the maximum reactive power in the system and voltage returns to its normal range. When the fault occurs the reactive power is supplied by the DG unit. The real and reactive power of main grid is not much affected by the fault at bus 4 on observing figure 6 and 7.

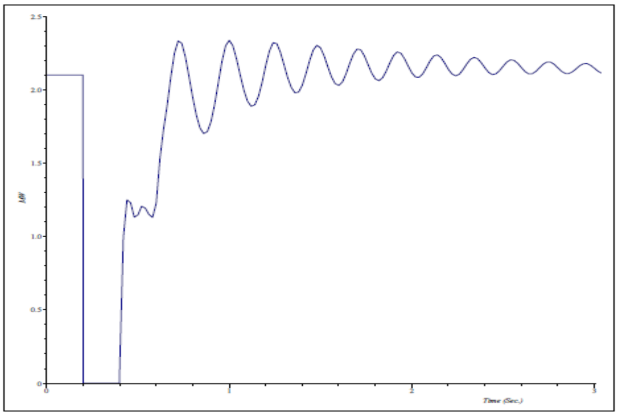

Fig 6.DFIG: Active Power (MW)

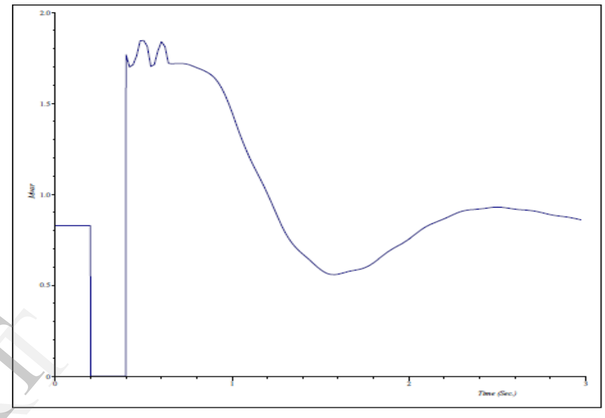

Fig 7.DFIG: Reactive Power (Mvar)

B. Case studies with a single Synchronous- WT connected to test system

Now synchronous wind turbine is connected to the micro grid and short circuit event is defined on the bus 8 for time t = 0.2 sec and cleared at t = 0.3 sec and simulation is run for 2 sec. The simulation results obtained are very similar to that of DFIG conneted system and are shown as below.
In this scheme the current variation is high in comparison to voltage. The pre-fault voltage condition is kept to be identical to that of case A. This is done by setting the voltage reference for the excitation system and compensating capacitor equal to the grid normal voltage at the point of connection and voltage recover effectively.

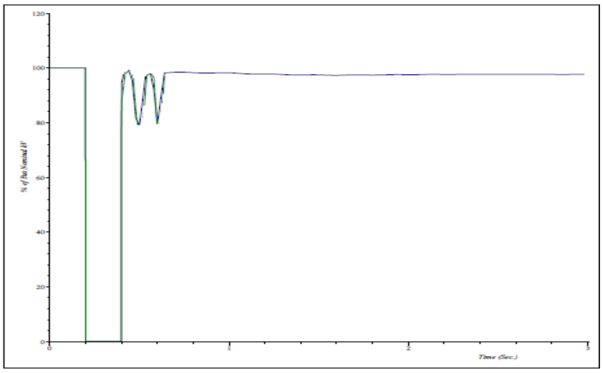

Fig 8.Bus 8: Line-Ground Voltage (kV)

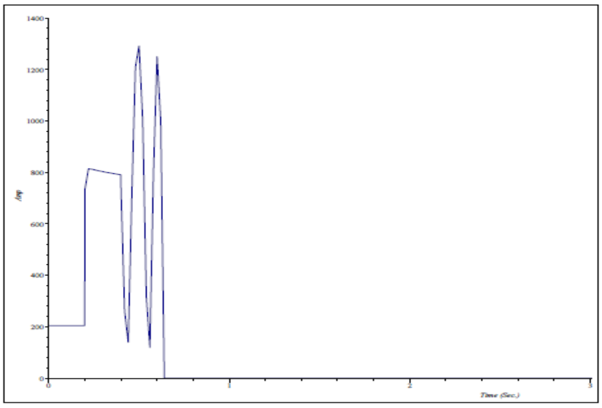

Fig 9.Bus 8: Short-circuit Current (kA)

The capacity of wind turbine is 5 MW and wind speed play a major role in this case. For simulation pupose the wind speed can be varied between 8 m/s to12m/s. The wind speed is varied by varying pitch angle between 3.5 to 4.5 mechanical degrees [4]. Again current variations are very high in first figure and voltage during transient event goes to a very low value .The trends in reactive and real power is slightly different due to the wind turbine itself was supplying compensating VARs.

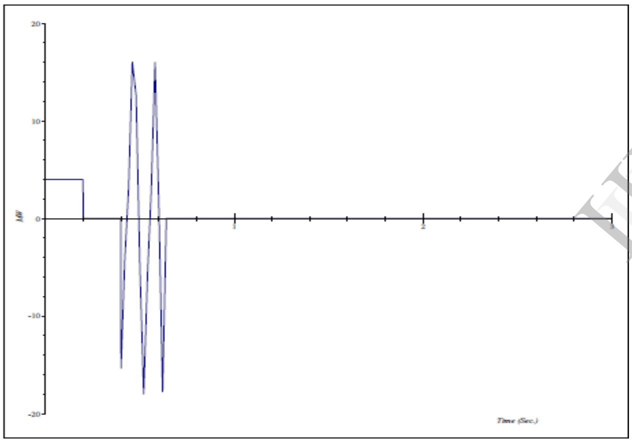

Fig 10.Synchronous Generator: Active Power (MW)

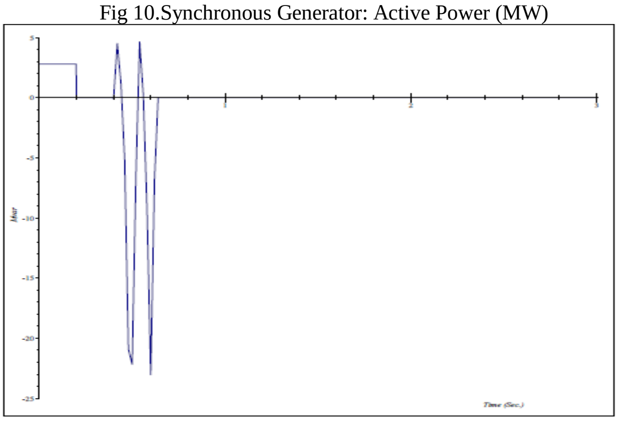

Fig 11.Synchronous Generator: Reactive Power (Mvar)

V. DISCUSSION AND CONCLUSION

Two assumptions are made in the given study model. First, the study model of micro-grid is assumed to be balanced, i.e., no single phase loads or unbalanced three phase loads are considered. Secondly, the DG unit within the micro-grid, do not exhibit any dynamic interactions [3]. It is seen in figure 4 that the current transients caused by short circuit are very high, but also very strongly damped. Another observation is that the behaviour after the short circuit is the same with pre fault values which shows that no protection relays are tripped by the fast transients and long term stability is not affected.

The result obtained by simulation showed that the similarities of the results obtained by the two different evaluation schemes indicate the validity of increase in transient stability of micro grid by the use of doubly fed induction generator to compose the wind farm. The implemented wind farm model can be easily extended to model other large wind farms which have been validated for fault free operation.

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