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REACTIVE POWER COMPENSATION AND VOLTAGE-STABILIZATION FOR WIND POWER IN A WEAK DISTRIBUTION NETWORK

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Abstract -One of the most promising alternate sources of energy is wind energy. Energy of the wind is converted to electrical energy in wind farms and is then connected to a weak distribution network to supply local loads. Most wind farms use induction generators for electricity generation. These induction generators draw excessive reactive power for their operation and this causes shortage of reactive power in the system and leads to voltage collapse. This problem is simulated on PSCAD/EMTDC platform. For static compensation, capacitor banks are used and for dynamic compensation, Static Var Compensators (SVCs) are used.

Keywords- *Induction Generators, Wind Farms, Reactive Power Compensation, , Dynamic Compensation, SVC, Capacitor Bank, PSCAD/EMTDC.*

I. INTRODUCTION

Wind energy is the kinetic energy associated with the movement of large masses of air. Wind energy is available for longer periods and is harnessed as mechanical energy using wind turbines. The mechanical power is used as input to the induction generators to generate electricity.

Wind energy is harnessed in wind farms. Modern wind turbine generation system are employs variable speed wind generators. But over the former years fixed speed induction generator were installed. Hence still it is matter of interest to investigate fixed speed squirrel cage induction generator with power system. [1] A typical wind farm consists of many fixed speed wind turbine generation system. The mechanical input to the generator is provided using wind turbines, whose output is governed by wind turbine governors, each of these being controlled by their own control system. The ideal wind speed required for most wind turbines will be between 5 m/s and 25m/s. The wind farm is connected to distribution network using a transmission line and transformer. The most important characteristic of such an induction generator is that it draws reactive power from the grid for its operation. This is undesirable for the network, as it creates a reactive power deficit, leading to voltage dip at the generator bus. This largely affects the local loads i.e. the loads connected directly to the generator bus. The induction generator also slows down the voltage restoration process, and this might lead to voltage collapse.

Dynamic compensation device Static Var compensator (SVC), a combination of thyristor-controlled reactors can provide suitable compensation. The SVC responds faster than conventional compensators and hence is suitable for providing dynamic compensation. SVC does not contribute for short circuit currents and requires less maintenance.

In this paper, the analysis of the reactive power management of a wind farm consisting of fixed speed wind turbines is carried out. The capability of Static Var compensator (SVC) in reactive power compensation and voltage restoration in wind farms connected to weak distribution network is analyzed. A fault is simulated in the system and the system is analyzed with and without the use of compensation. The simulations are carried out on PSCAD/EMTDC platform.

II. SYSTEM UNDER CONSIDERATION

The block diagram of the system under consideration is shown in figure. The network consists of a 33kV distribution system fed from a 132kV grid. The distribution system consists of a wind farm, transmission line and step-up transformer. The 9MW wind farm is modeled as six 1.5MW wind turbines connected to fixed speed induction generators. The transmission line is a 50km line, connecting the generators to the low voltage side of the 62.5MVA, 132/33kV step-down transformer. Pitch angle control is enabled for the wind farms.

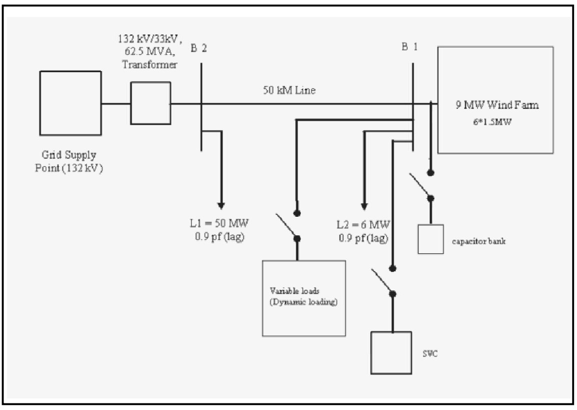

Fig-1: Single line diagram of the system

The ratings of each component are as follows:

a. Generator: 9MW (6 generators, each of 1.5MW capacity)

b. Transformer: 62.5MVA, 132/33kV (step-up)

c. Constant loads: 6MW at 0.9pf lag and 50MW at 0.9pf lag

d. Variable loads: 2MW, 1.5MW, & 0.75MW at 0.9pf lag

III. SIMULATION SET UP IN PSCAD

The test system is modeled on PSCAD/EMTDC platform in three-phase form and represented in single line display.. The simulation is carried out for 10 seconds in the following modes:

i. System with variable loads, without compensation

ii. System with variable load, with compensation

iii. Fault analysis, without compensation

iv. Fault analysis, with compensation

Capacitor bank is connected to generator terminal to compensate reactive power demand of induction generator at steady state. For Dynamic compensations are Static Var compensator (SVC), is connected to generator bus1.

SVC model can be represented with the Equations,[2]

$$V - V_{REF} + X_{SL}I = 0$$

Dynamic loading is condition is simulated using breaker switching logic, which represents the real-time local-load conditions.

In all the cases, the voltage and active and reactive powers at each bus and at the compensator is monitored, and The result of simulation are plotted on the graphs The dynamic responses are investigated for the system subject to a three phase short circuit fault starting at t = 4s and lasting for 0.04 second.

IV. SIMULATION RESULTS

4.1 *System with variable loads, without compensation*

The system has a fixed load of 4MW on bus-1 and 50MW on bus-2. The load variation effect on the dynamic performance of the SVC-compensated Induction generator is studied. The disturbance considered in a step, by addition in load demand at t=2 second, at t=4second and at t=6 second. And removing the load at t=9 second. While removing the load the instantaneous voltage swell caused by surplus reactive power in the system is observed

The load and the bus1 voltage variation are shown in the Fig 1. It is clearly seen that with addition or removal of load, the bus-1 voltage does not remain at 33kV. Fig-1 shows the variation in active power due to change in load (variable load switching) and Fig-2 shows the corresponding change in generation bus voltage.

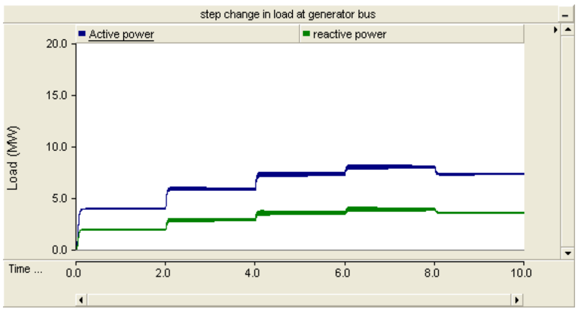

Fig-1: Step change in system load.

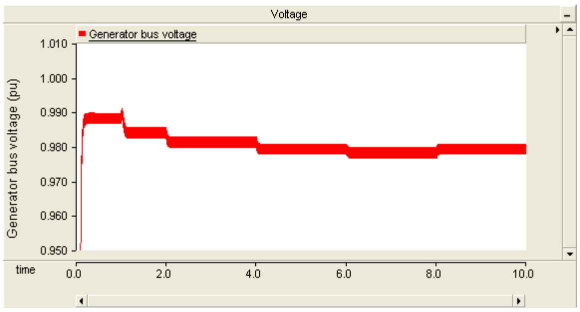

Fig-2: Variation in generator bus voltage due to step change in load (with no reactive power support)

4.2 *System with variable load, with reactive power support.*

When reactive power compensation is used in the system, it is observed that the generator bus voltage remains at 33kV even when the load on the bus has increased or decreased. The graphs of load change and corresponding voltage at bus-1 are shown below in Fig 3 and Fig4.

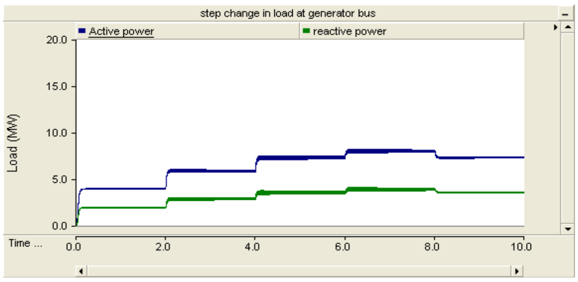

Fig-3: Step change in system load with reactive power support.

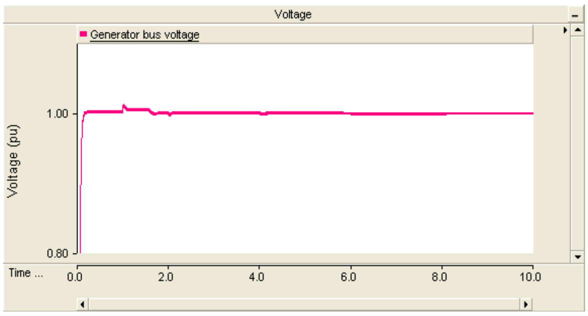

Fig-4: generator bus voltage due to change in load with reactive power support.

4.3 *Fault analysis, without compensation*

When a three phase to ground fault is simulated on the transmission line, it is observed that when the fault is cleared at 4.04 seconds, a time lag for the system to restore the bus voltage to the prefault value is observed from simulation result shown in the Fig 5. A very large dip in voltage was seen between 4 and 4.04 seconds due to the fault.

Recovery time for generator bus voltage is 0.04 seconds.

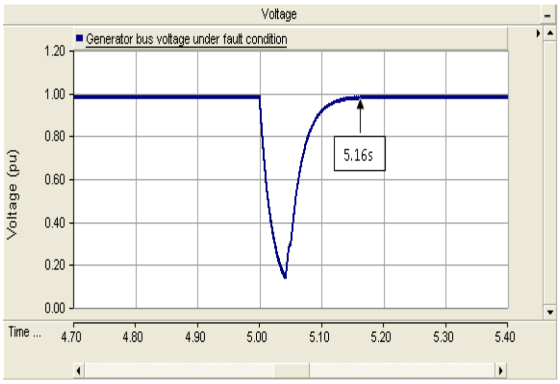

Fig-5: Generator bus pre-fault & post fault voltage with Out compensation.

4.4 *Fault analysis, with compensation*

When a SVC is connected to the bus-1 and the fault is simulated, it is observed that the time taken by the system to restore the value of the generator bus voltage to the original value is reduced. Recovery time for generator bus is 0.13 seconds

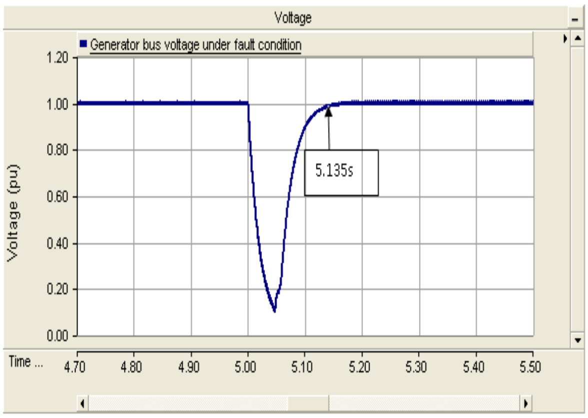

Fig-6: Generator bus pre-fault & post fault voltage with compensation

V. CONCLUSIONS

From the results obtained, the following conclusions were made:

i. When a wind farm is connected to a weak distribution network, due to the excessive reactive power drawn by the generators, the generator bus voltage dropped below the tolerance limit.

ii. When a dynamic compensator is used, the bus voltage is observed to be within the tolerance limits.

iii. The compensator supplied the reactive power deficit and hence stabilized the voltage at the bus.

iv. The time taken by the system to restore the bus voltage to the nominal value after the fault is cleared, is more without compensation, and is reduced when compensator was connected to the generator bus.

This paper presents the analysis of a wind farm connected to a weak distribution network. SVC capability to compensate the reactive power under dynamic load conditions, and fault voltage is also analyzed.

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