INVESTIGATION OF VOLTAGE STABILITY OF WIND FARM DURING CONTINGENT SCENARIO INCORPORATING FACTS DEVICES

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Abstract : One of the imperative requirements of power system operation is to maintain an acceptable voltage during normal as well as stressed operating scenario. This becomes extremely challenging if intermittent source of power generation, i.e. renewable energy sources are integrated with conventional generation based power system. In this context, provision of reactive power support becomes a vital option for voltage secure operation. An attempt has been made in this work to demonstrate the effectiveness of inclusion of shunt FACTS devices in a wind integrated power system. A comparative assessment among different shunt FACTS devices is carried out to depict the most effective voltage secure operation even during contingencies.

Index Terms*: *Voltage security; FACTS devices; Wind Integrated system; Reactive power support..

I. INTRODUCTION

The increasing environmental concern and the limited availability of fossil fuels have attracted attention towards integration of renewable energy driven units with power grid. In this regards, the wind energy emerges as a cleaner and safer alternative [1] to substitute the traditional fossil fuel based energy sources. However, the intermittency nature of wind has several shortcomings from scheduling aspect. Considering this, the concept of reactive power capability limit of DFIG and its impact on voltage stability wind powered system is presented in [1]. The stochastic modelling and stability analysis of the wind integrated power generation under different operational paradigm has been studied by researchers [2-5]. A security constrained optimal power flow (SCOPF) solution of wind-thermal generation system using intelligent techniques is done in [2] where the authors have demonstrated the improvement in system voltage after the installation of static synchronous compensator (STATCOM) even in stressed operating situation. The modelling and combined operation of hydro-thermal-wind (HTW) generation in OPF framework while satisfying a number of constraints is presented in [3]. Issues relating to cost minimization, loss minimization and emission reduction in a system with wind integration is analysed in [4]. Implementation of swarm based and evolutionary algorithm based optimization techniques to hybrid power system operation is done by authors in [5,6]. Studies [7-9] show that, the limitations imposed by the unpredictable wind power on voltage security may be improved by implementing reactive power compensation. The amount of the reactive power produced or absorbed by the wind farm and the grid changes because of the power variation at different wind speed [1, 2, 10]. In a wind powered unit, the power fluctuation can leads to voltage variation at the interconnection point of the grid. This paper focuses on implementation of shunt connected FACTS devices like static var compensator (SVC) and STATCOM with wind farms integrated power system to maintain voltage security. The objectives of implementing shunt compensation [11] in a transmission system are (i) midpoint voltage regulation for line segmentation in order to increase transmittable power in the transmission system, (ii) end of line voltage support requires the compensation of loads having poor power factor. This increases the maximum power transmission capability of the transmission line while improving the voltage instability limits. (iii) Improvement of transient stability margin by increasing the maximum transmittable power in the transmission line. SVC is a shunt connected generator or absorber whose output is adjusted to exchange capacitive or inductive power in order to control reactive power flow [12]. SVC based systems use Thyristor Switched Capacitors (TSC) or Thyristor Controlled Reactors (TCR) with fixed filters employing capacitive/inductive reactive power and harmonic filtering. SVC systems cause harmonic current problems [13,14]while they solve reactive power problems. This requires constant shunt filters or special transformer connections for these systems. The reactive power capability of SVCs is directly related to the source voltage [14] and any decrease in the source voltage reduces the reactive power compensation capability of SVCs. Among many devices in the family of FACTs, STATCOM is one of the fastest responding devices which can regulate the voltage at the node where it is connected by controlling the amount of reactive power flowing to or from the same node. It generates a set of balanced three-phase sinusoidal voltages at the fundamental frequency, with rapidly controllable amplitude and phase angle [14,15]. The objective of installing the STATCOM is to supply the desired amount of reactive compensation to directly regulate the system voltage using converters. These converters do not use any capacitor or reactor banks to produce reactive power. However, they need low pass input filters to suppress the switching frequency harmonics of the converter. STATCOMs are used in transmission systems [18] to control reactive power and to supply voltage support to buses. Transmission STATCOMs are high power systems (20MVAr-100MVAr). STATCOM is installed in distribution systems or near the loads to improve power factor and voltage regulation. This type of STATCOM is called D-STATCOM which is used in medium power systems (up to 5MVAr). STATCOM can control reactive power flow by changing the fundamental component of the converter voltage with respect to the AC bus bar voltage both phase wise and magnitude wise [19].

II. SYSTEM UNDER CONSIDERATION

For independent control of real and reactive power as well as to utilize the inherent reactive power capability limit, the generator used in the wind turbine is a doubly fed induction generator (DFIG) [1,16]. A basic introduction to DFIG may be described as follows. The DFIG is commonly used in variable-speed large wind turbines. The DFIG has the ability to provide precise speed control and good power factor with a converter that is rated as low as 25% of the machine power rating. Due to its numerous advantages, such as improved power quality, high energy efficiency and controllability, reduced power converter rating, etc., the variable-speed wind turbine using a DFIG is becoming popular for large power generation from wind. The rotor terminals of the induction machine are connected to the four-quadrant power electronic converter capable of supplying both real and reactive powers from the grid to the rotor as well as supplying power from the rotor to the grid [17]. There are two different converters used in the DFIG configuration. The converter connected to the rotor of the induction generator is the generator side known as Rotor Side Converter (RSC) and the one connected to the grid side is known as the Grid Side Converter (GSC). Both of these power electronics converters have different functions and they are interconnected with a common DC link capacitor. The RSC controls the real and reactive power output of the machine and the GSC maintains the DC link voltage at its set point. The GSC is connected to the grid via a transformer that steps up the voltage to the grid. The stator side of the induction generator is also connected to the grid via a step up transformer. The point of interconnection with the grid is the point used to measure the active and reactive power output of the wind farm. For reliable operation of the system, additional reactive power can be injected by incorporating a compensating unit. The RSC of the DFIG injects suitable magnitude and phase of voltage in three phase rotor windings via the slip rings and brushes.

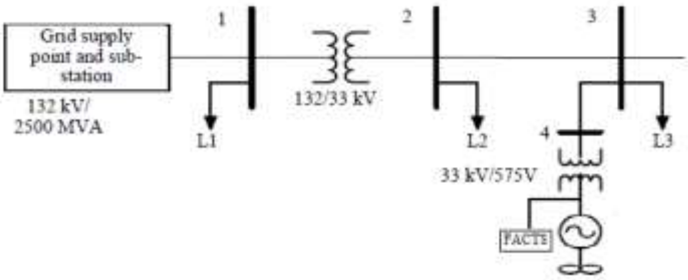

Fig.1. Layout of power network under consideration.

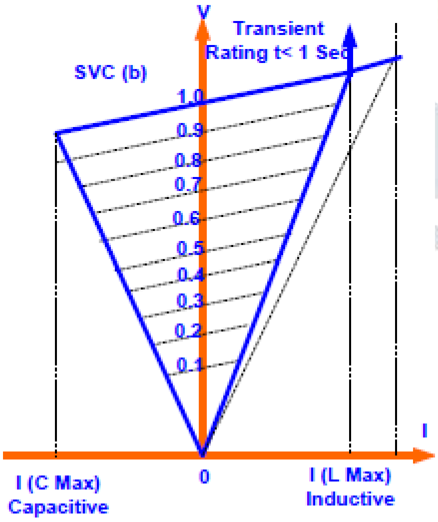

Fig.2. V-I Characteristics of SVC

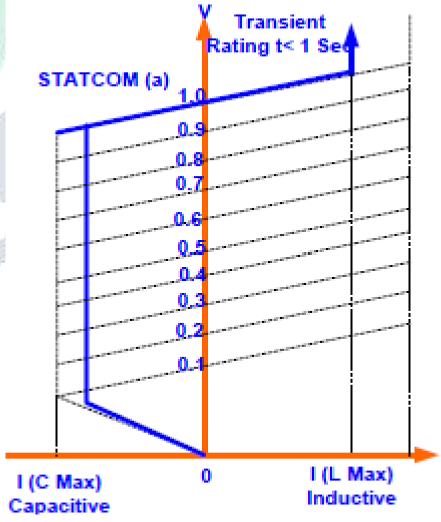

Fig.3. V-I Characteristics of STATCOM

For the analysis of voltage stability, the system considered in Fig.1 is intentionally subjected to LG fault. In three different case studies the performance of the wind integrated power system is analyzed. Those are

1. System operation without FACTS devices
2. System operation with SVC
3. System operation with STATCOM

The capacity of the SVC and STATCOM use in the simulation studies is 20 MVAr. The V-I characteristics of SVC and STATCOM is shown in Fig.2 and Fig.3 respectively.

III. SIMULATION, RESULTS AND DISCUSSION

Initially no FACTS device is connected to the system. An intentional LG fault is introduced in the transmission line joining bus 2 and bus 3. Under this situation the variation in system voltage was analyzed. After this analysis, in two different operational paradigms, separately the shunt FACTS devices are connected to the system one after the other. In all these simulations, the wind speed is assumed to be 12 m/s. The voltage variation is represented in Fig.4. From Fig.4 the improvement introduced in the system voltage after the incorporation of STATCOM is clearly observed as compared to the SVC performance. To further test the superiority of STATCOM the system behavior is analyzed in higher wind speed values, those are 15m/sec and 25 m/sec. The result obtained with these wind speed is depicted in Fig.5 and Fig.6 respectively. From Fig.5 the following notion may be drawn. When wind speed was 15m/s, the effect of LG fault on system was observed approximately at t=5sec. Though the effect was prominent on system voltage, still the STATCOM managed to provide comparatively a better voltage security scenario than that of the SVC. But when wind speed was increased to 25m/s, the effect of fault on system voltage during case1 was found to be maximum i.e. in the absence of shunt FACTs devices. At the same time although an improved behavior was observed between SVC and STATCOM, STATCOM managed to provide an improved voltage secure system in comparison to SVC integrated scenario.

In order to evaluate the impact of capacity enhancement of FACTS devices on system operation, in a separate study the capacity of SVC is increased to 40MVAr while the size of STATCOM is still kept as 20 MVAr. With this configuration, the wind integrated system was operated with randomly choosen wind speed i.e. 15m/s and 24 m/s. This is demonstrated in Fig.7-Fig 8. From these figures, it may be noted that performance of a 20 MVAr STATCOM is comparatively better than a 40 MVAr SVC in depicting a relative improvement of system voltage.

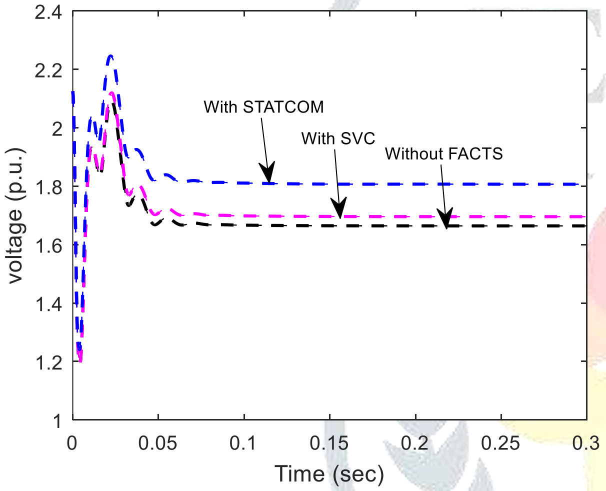

Fig.4. System voltage variation subjected to LG fault for wind speed 12m/s

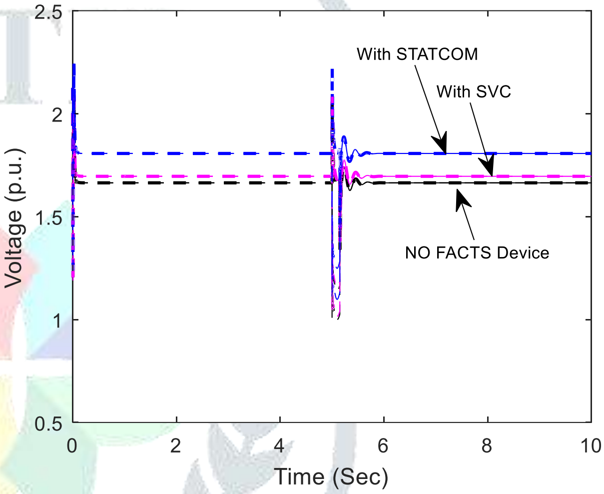

Fig.5. System voltage variation subjected to LG fault for wind speed 15m/s

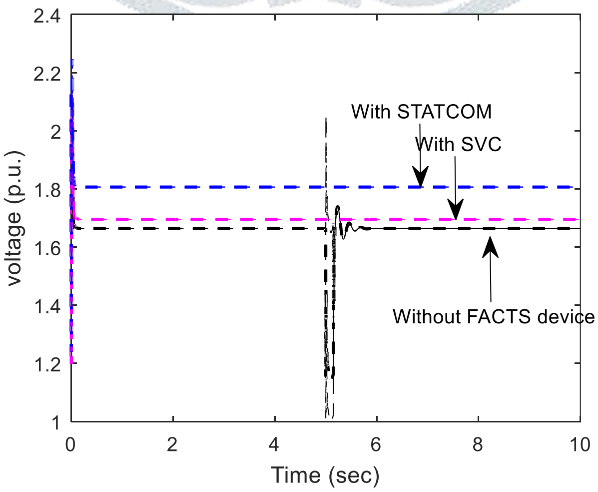

Fig.6. System voltage variation subjected to LG fault for wind speed 25m/s

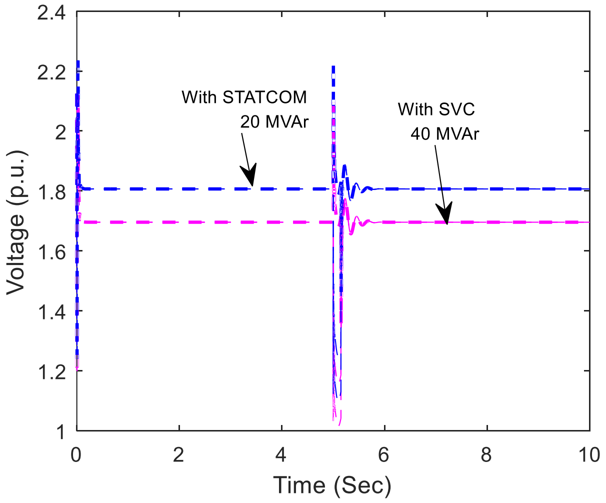

Fig.7. Comparison between shunt FACTs devices of different capacities when wind speed is 15m/s.

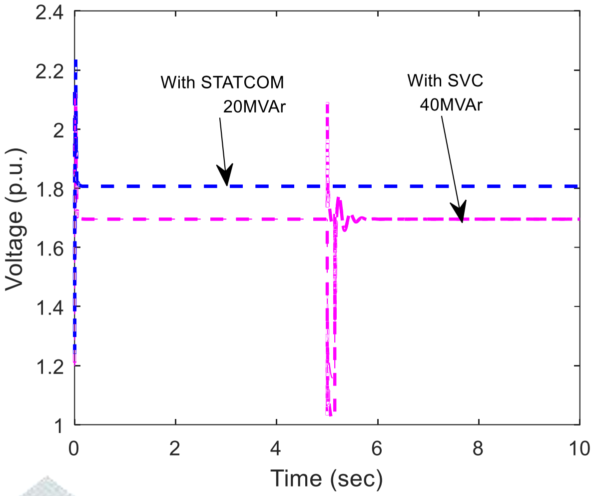

Fig.8. Comparison between shunt FACTs devices of different capacities when wind speed is 24 m/s..

IV. CONCLUSION

An attempt is made in this work to investigate the impact of STATCOM and SVC on voltage security of wind integrated power system following network faults. In this regards, a comparison is made between system without any FACTs devices, system with STATCOM and system with SVC. Along with this a number of comparisons are also made between the performances of the two devices at random wind speed. The system operation was analysed under different wind speed with different capacity of shunt FACTs devices, so that proper assessment of system voltage w.r.t wind power intermittency can be avaluated. After a series of simulations, it was distinctly demonstrated that irrespective of changing wind speed and power, the STATCOM can provide better reactive power support to maintain a steady and superior voltage for system operation. Both SVC and STATCOM considerably improve the system stability during and after disturbances as compared to system without FACTS devices. Besides this, it was observed that a STATCOM can provide improved voltage response than an SVC having a rating approximately twice the rating of STATCOM. Also incorporation of STATCOM depicted a superior performance, in terms of security and stability of the system under consideration.

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