Investigation of Various Voltage Sag Analyses in Wind Farm through SVC

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Abstract

In this study, the systems connect wind farm various voltage sag wind Farm DC link voltage, system buses voltage examined. For study of various transient stability 7.2 MVAr Static Var Compensator (SVC) is used. In the wind farm examined, 6 MW Double Feed Induction Generator (DFIG) is used. Also it examined 3 phase fault, induction motor, both 3 phase fault and induction motor together in wind farm. The results achieved have proved that SVC yield good results when used in terms of transient stability of the system. , SVC was found to be effective and successful for eliminating instability in a very short period of time.

1. Introduction

In the years come, it will be focusing on maintain power system stability, for example at short circuit fault and nonlinear load, ensuring power supply safety and other important tasks as amount of wind power is drastically increasing. This situation makes it necessary to find solutions with respect to maintain dynamic stability of the power system with large amount of wind power and reliable operation [1]. These problems have been solved through power electronics drivers included in Flexible AC Transmission systems (FACTS). FACTS devices consists of Static Synchronous Compensator (STATCOM), Static VAR Compensator (SVC), Static Synchronous Series Compensator (SSSC), Thyristor Controlled Series Compensator (TCSC) and UPFC respectively. There are several studies on the use of SVC devices related to the wind farms. It has been observed that SVC was utilized in order to meet the need for reactive power in the wind farm which produces active power [2]. SVC has been effect in ensuring voltage and reactive power coordination in wind farm [3]. Stall control has a great importance in transient stability in wind farm [4]. SVC has been improve in ensure voltage stability in wind farm has been possible thanks to the reactive power support of SVC [5]. STATCOM and SVC known as parallel compensator have been found to reliability in transient stability analysis in wind farm [6]. The point at which transient stability is important is dynamic power response in wind farm. Using STATCOM and SVC, instability of the dynamic power response has been eliminated in a short time period [7]. STATCOM and SVC have been found to be quite effective in torque control at different compensation rates and low voltage ride through analysis [8]. It has been found that the improvement of load parameter and voltage profile in wind farm has been possible depending on the usage of STATCOM and SVC [9]. Another usage analysis of STATCOM and SVC is static and dynamic load analysis. The system has been found achieve stability with different load models in operation with usage of parallel FACTS devices in a short time in wind farm [10]. In this study 3 phase fault, induction machine in operation, wind farm DC link bus voltage that will come out as a result of two circumstances happening simultaneously and voltage variation analysis of the buses in the system through SVC have been investigated. It has been found that SVC can improve the instability cases both in induction machines and 3 phase fault in a short time.

2. Double Feed Induction Generator (DFIG)

Two voltage fed converters are inserted back-to-back in the rotor circuit, which connect the slip ring terminals the ac supply network. By adjustment of the switching of the Insulated Gate Bipolar Transistors (IGBT) in both converters, the power flow between the rotor circuit and the supply can be controlled both in magnitude and in direction. This is effectively the same as connecting a controllable voltage source to the rotor circuit. A typical scheme of a DFIG equipped wind turbine is shown in Fig. 1.

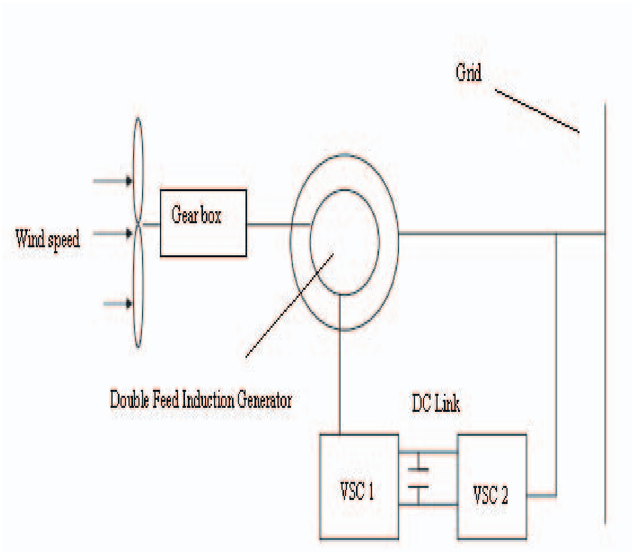

Fig. 1. DFIG equipped circuit modeling

The DFIG can be regarded as a traditional induction generator with a nonzero rotor voltage [11]. The doubly fed induction generator is the most commonly used machine for wind power generation. The rotor terminals are fed with a symmetrical three-phase voltage of variable frequency and amplitude. Using the generator convention, the following set of dynamic equations results [12].

$$u_{ds} = p\psi_{ds} - w_1\psi_{qs} - r_s i_{ds} \quad (1)$$

$$u_{qs} = p\psi_{qs} - w_1\psi_{ds} - r_s i_{qs} \quad (2)$$

$$u_{dr} = p\psi_{dr} - w_s\psi_{qr} - r_r i_{dr} \quad (3)$$

$$u_{qr} = p\psi_{qr} - w_s\psi_{dr} - r_r i_{qr} \quad (4)$$

Flux equation,

$$\psi_{ds} = -L_s i_{ds} + L_m i_{dr} \quad (5)$$

$$\psi_{qs} = -L_s i_{qs} + L_m i_{qr} \quad (6)$$

$$\psi_{dr} = -L_r i_{dr} + L_m i_{ds} \quad (7)$$

$$\psi_{qr} = -L_r i_{qr} + L_m i_{qs} \quad (8)$$

Electromagnetic torque and motion equation,

$$P = (T_m - T_e) / J \quad (9)$$

$$T_e = \frac{3}{2} N_p L_m (i_{qs} i_{dr} - i_{ds} i_{qr}) \quad (10)$$

$$w_s = S w_1 \quad (11)$$

$$\frac{d\theta_r}{dt} = w_r \quad (12)$$

where, the subscript s and r respectively represent stator quantity, and rotor quantity L_s and L_r are stator self-inductance and rotor self inductance respectively, L_m is mutual inductance between stator and rotor T_m and T_e are input torque and electromagnetic torque respectively, J is rotational inertia, P is differential operator , N_p is number of pole pairs, w_1, w_r and w_s are synchronous angular velocity, rotor angular velocity and slip angular velocity respectively, S is slip ratio, θ_r is stator flux phase angle [13].

3. Static Var Compensator (SVC)

SVC can be considered as the combination of a capacitor and a thyristor controlled reactor. The fundamental frequency SVC equivalent circuit as a function of the thyristor's firing angle is shown in Fig. 2.

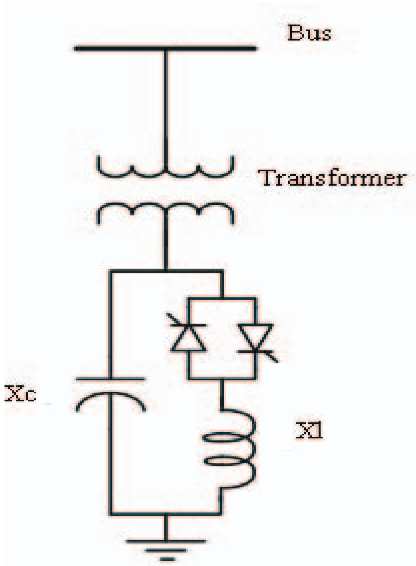

Fig. 2. SVC circuit modeling

The quantities in Fig. 2 are defined as follows δ is the firing angle of thyristor, X_C is the reactance of capacitor, X_L is the reactance of inductor, X_T is the reactance of transformer, V_i is the bus voltage phases at bus i, and I_i is the injected current phases at bus i. The effective reactance of SVC can be described as,

$$X_{SVC} = \frac{XcX_L}{X_C / \pi(2(\pi - \delta) + \sin 2\delta) - X_L} \quad (13)$$

And the equivalent reactance of SVC including transformer is given by,

$$X_i = X_T + X_{SVC} \quad (14)$$

Thus, the reactive power at the installed SVC bus can be written as,

$$Q_i = -B_i V_i^2 \quad (15)$$

where $B_i = -1 / X_i$ and V_i denotes the magnitude [14].

The first aim of using SVC, is to control the bus voltage that is SVC connected. By using an appropriate auxiliary control signal, it can also provide damping of the system oscillations as discussed [15]. We use the Phasor Model of the SVC, to control bus voltage of motor without and 3 phase fault using any supplementary control, as shown in Fig. 3

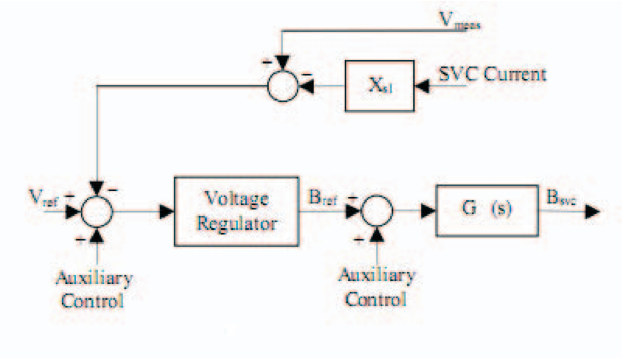

Fig. 3. SVC controller modeling

The SVC current may be obtained by multiplying Bref and Vmeas or measured by a CT. The voltage regulator is often integral control and provides B to make the error signal zero in the steady state [16].

4. Simulation of Study

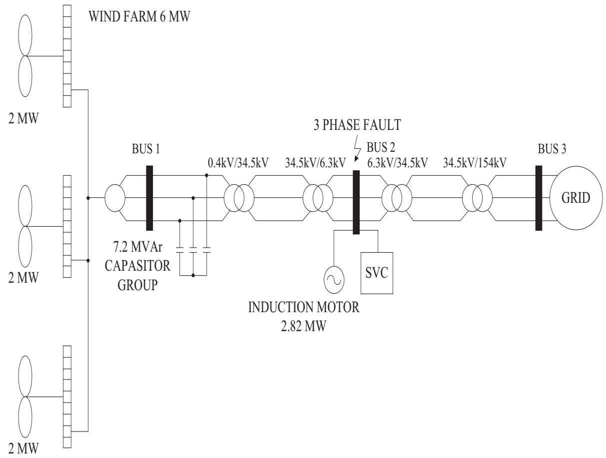

Fig. 4. Simulation system modeling

In this study, 400V, 50 hz and 6 MW wind farm is used .The wind farm generates power with the induction generator in it. The wind farm produces voltage regulation dependent on the voltage value of capacitor included in the back to back convertor .with the control of the system frequency depending on the convertor, network voltage is assured to be equal. Moreover, thanks to a booster transformer, voltage was raised from 400 volt to 34.5 KV. Network voltage and frequency values are regarded to be 154 KV 50 hz. In the network, the voltage was reduced from 154 KV to 34.5 KV with the use of transformer as in the wind farm. Moreover 34.5 KV transformers converted 6.3 KV. In the system, number 3 bus is connected to the network, number 1 bus is connected to wind farm, and number 2 bus has been examined as the bus that is involved in the area where the network and wind farm has been converted to 34.5 KV. In this simulation study, SVC 7.2 MVA has been used. The part to which wind farm has been attached a capacitor group with 7.2 MVAr. The aim is to analyze the circumstances in which number 2 bus is 3 phase fault; induction machine with 2.82 MW get into operation; and both 3 phase fault and induction machine get into operation, through SVC. Time required for the induction machine to outage and 3 phase fault to get into operation is between 0.2 and 0.35 seconds. In the second plan; however, induction motor gets in and outage within 0.3 and 0.4 second. The parameter values wind farm and SVC have taken on. In this study are shown on table 1.

Table 1. System parameter values

Wind Farm	*
Grid voltage regulator gains	Kp=1.25 , Ki=300
Power regulator gains	Kp=1, Ki=100
DC bus voltage regulator gains	Kp=0.02, Ki=0.5
SVC	*
SVC voltage	6.3 KV
Shunt Converter power	7.2MVA
DC link nominal voltage	1.2 KV

5. Simulation Results

Regarding the results, Induction machines connection to system with use of SVC in wind farm and DC voltage variations, buses voltage variations during 3 phase fault have been shown on figures 5-6-7 and 8.

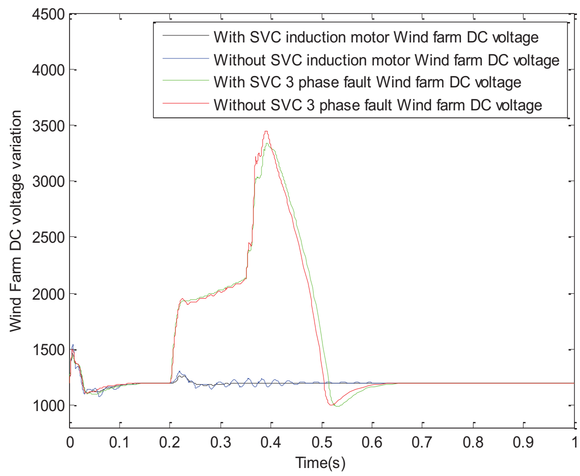

Fig.5. Induction motor connected DC voltage variation in wind farm

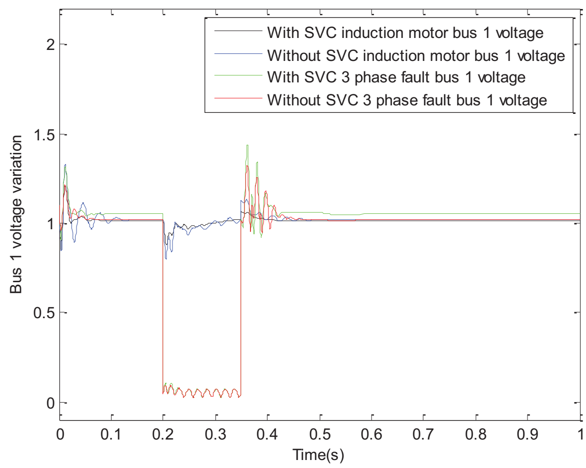

Fig. 6. Induction motor connected bus 1 voltage variation

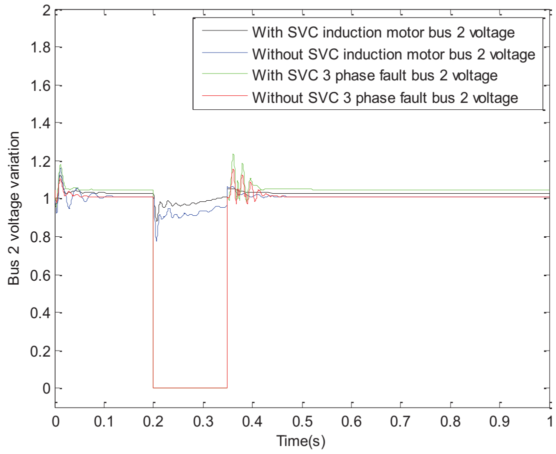

Fig. 7. Induction motor connected bus 2 voltage variation

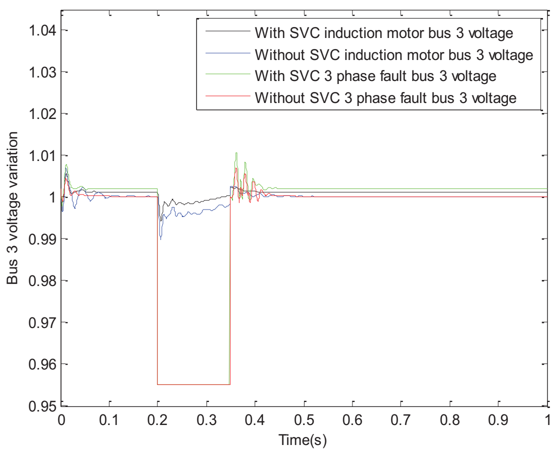

Fig. 8. Induction motor connected bus 3 voltage variation

The effects SVC exert on DC voltage variation during which both induction machine is connected to system and 3 phase fault comes out and buses voltage variations have been shown figures 9-10-11 and 12.

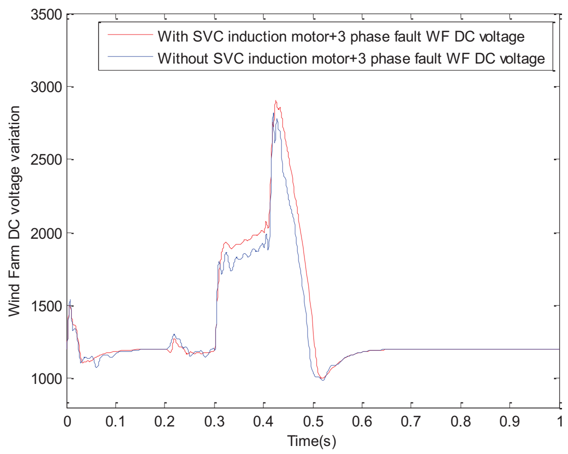

Fig.9. Induction motor connected + 3 phase fault DC voltage variation in wind farm

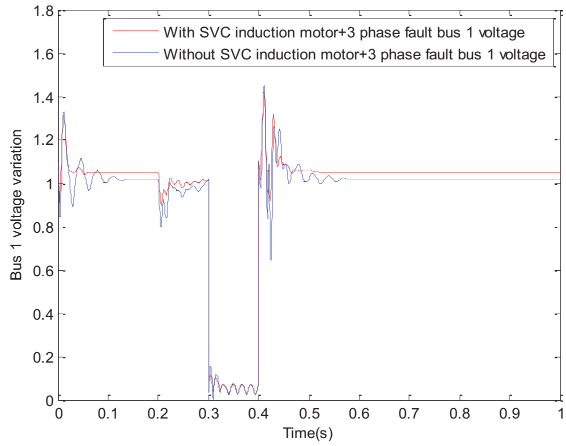

Fig.10. Induction motor connected + 3 phase fault bus 1 voltage variation

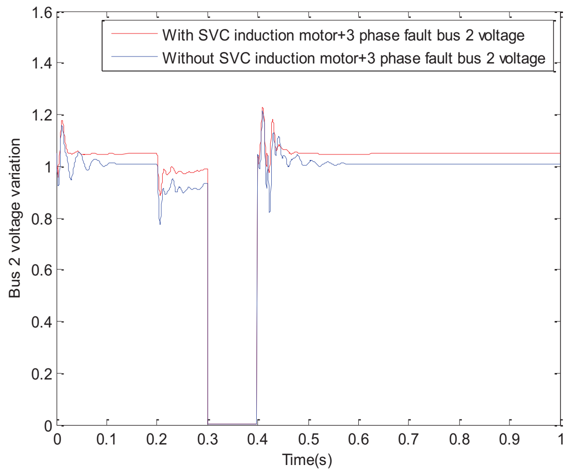

Fig. 11. Induction motor connected + 3 phase fault bus 2 voltage variation

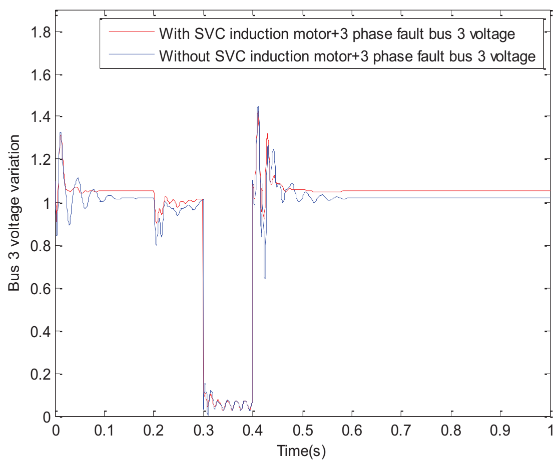

Fig. 12. Induction motor connected + 3 phase fault bus 3 voltage variation

Regarding the results, buses voltage and system time responses have been shown table 2 numerically.

Table 2. Simulation numeric results

*	Induction motor connected	3 phase fault	Induction motor+3 phase fault	Time Response
Wind Farm DC voltage	+	-	-	0.4
Bus 1 voltage	+	-	-	0.4
Bus 2 voltage	+	-	-	0.4
Bus 3 voltage	+	-	-	0.4
Wind Farm DC voltage	-	+	-	0.6
Bus 1 voltage	-	+	-	0.6
Bus 2 voltage	-	+	-	0.6
Bus 3 voltage	-	+	-	0.6
Wind Farm DC voltage	-	-	+	0.65
Bus 1 voltage	-	-	+	0.65
Bus 2 voltage	-	-	+	0.65
Bus 3 voltage	-	-	+	0.65

In the light of those results, the voltage sag conditions that may occur as a result of SVC use in wind farm can be controlled in a short time period. The oscillations in 3 phase fault have achieved stability in time response. It has been found SVC use in various transient stability analyses that might occur in wind farm is improving DC voltage and buses voltage**.**

5. Conclusion

It has been found that system can achieve stability in a short time depending on normal operation in terms of oscillation stability time and time response in 3 phase fault analysis. At the time when induction machine was connected to achieved stability in a short time. When 3 phase fault and the connection at induction machine fell on the same time period; however, it was found that the systems achieved stability in a shorter time span depending on normal operation of SVC. Furthermore it was found in this study that SVC increased buses voltage 1.05 p.u. values.

6. References

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