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Performance Comparison of STATCOM & SVC in Reactive Power Control Strategy for Wind Farm

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Abstract *– In this paper the wind farm reactive power control strategy introduced by the STATCOM and SVC. First, the STATCOM system and its application in power systems and wind farms is shown. Second, the SVC system and its application in power systems and wind farms is shown. Then wind farm and a STATCOM and a SVC are modeled. Finally, strategies to control the reactive power delivered to the grid is shown in times of need. The results of the implementation of the control strategy are demonstrated by simulation. All results, obtained in the MATLAB software simulation.*

Keywords*: Doubly-Fed Induction Generator (DFIG), Wind Farm, Reactive Power Control*

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INTRODUCTION

Wind energy has been tested very much in the past few decades. Also in Europe, with a capacity of 34 gigawatts of wind farms installed. When the cost of wind energy production can be significantly reduced its importance. The developing world needs clean energy and away from fossil fuels progress [1]. Significant growth in wind energy cycle energy system depends on structural and regulatory changes in the energy sector, increased awareness of environmental and technological development and demonstration of wind power generation systems in electric networks. Technological development in the field of wind power is a significant challenge in its evolution. Fluctuating wind power Flicker factor is delivered wind farm electrical network. Therefore, the development of systems to improve voltage stability, frequency stability and power quality research in the field of wind power is very important [2]. Continuity of the double-fed induction generators in wind turbines, frequency and voltage stability through individual control of active and reactive power improves. However, the electric power delivered to the grid by the wind farm will create many disadvantages. Some of these include [2-3-4]:

- Flicker: The sensitivity of the human eye when it makes sense refers to changes in light intensity. The maximum sensitivity of the human eye to light changes in frequency range from 5 to 15 Hz. Changes caused by changes in wind power.
- The oscillation frequency due to oscillation power.
- Harmonic emissions due to the power electronic converters in wind turbines.
- Voltage fluctuation caused by the aerodynamic aspects of wind turbines.

Promote the accumulation of wind farms in the electrical network Flexible AC Transmission Systems (FACTS) are widely used. The FACTS STATCOM system is one of them. A number of studies have shown that transient and steady-state stability can be improved by controlling the voltage of the junction of the wind farm to the grid. STATCOM system voltage stability by reactive power regulator, which stimulates [5]. Task STATCOM, absorb or inject reactive power in the electrical grid connection of wind farms to reduce and prevent voltage drop voltage grid. Compared to other systems, such as reactive power compensation capacitors in parallel, FACTS devices are very expensive. FACTS devices react faster and stronger wind farm voltage to the show. But shunt capacitance response was weak and it is not unable to control the voltage at the connection point of the wind farm [6]. The STATCOM reactive power independently of the actual voltage at the connection point provides. Though STATCOM is expensive. In [7], A STATCOM $\pm 80MVAr$ capacity to improve power transfer capacity distribution is installed. In [4], STATCOM is used to reduce the effect of Flicker. In [8], a STATCOM in a station with a capacity of 220 kW $\pm 50MAVr$ improve the stability of power transmission and distribution line capacity is used. In [9], A SVC $\pm 256MAr$ improve the transient stability of ac power systems with using Fuzzy

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Logic Controller. In Ahmadi Kamarposhti et al. [10] research, a comparison between the SVC, STATCOM, TCSC and UPFC controllers for static voltage stability evaluated by continuation power flow method is performed. In this paper, different control strategies for a STATCOM and SVC reactive power is applied to the wind farm is shown. This paper consists of a 9-bus network, including generators, DFIG wind farm and FACTS devices (STATCOM or SVC).

Description of STATCOM

STATCOM system is a static synchronous generator connected in parallel as a static equalizer and capacitive or inductive output current can independently control voltage. A charged capacitor acts as a source of direct current. In this process, a power converter AC / DC power supply provides a regulated output so as to produce a controllable three-phase voltages. Systems connected to the grid by a transformer is shown in Figure 1.

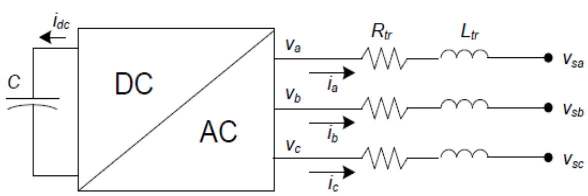

Fig. 1 - The Description of STATCOM

This system and its ability to provide rapid response at the junction voltage control by reactive power compensation is determined. STATCOM can be used to filter out the harmonics, improve transient stability and dynamic voltage and voltage drop, voltage collapse, voltage mode, constant improvement, improved clones reactive power flow and improve transient adverse used. The STATCOM voltage conditions to help wind farms, voltage regulation, power factor and stability on power load. STATCOM operating principle is as follows:

- If it is $v = v_s$(in per unit values), the current does not pass R_{tr} and L_{tr}.
- If $v > v_s$, current passes from R_{tr} and L_{tr}. Thus, impedance, inductance, and phasor current is perpendicular to V and Vs. The STATCOM capacitive reactive current is injected into the grid.
- If $v < v_s$, the current passes from the Rtr and Ltr. In this case the flow is opposite before, so that would indicate that the STATCOM absorbs reactive power from the grid.

STATCOM reactive power flow between the grid voltage and the voltage of the power converter is determined. The operation area of STATCOM is shown in Figure 2 [11].

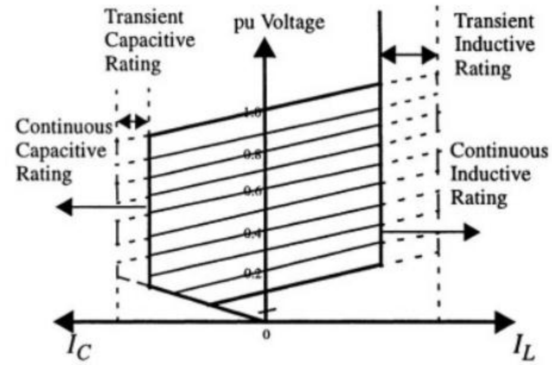

Figure 2: The operation area of STATCOM

Description of SVC

The SVC has been used for reactive power compensation since the mid 1970's, firstly for arc furnace flicker compensation and then in power transmission systems. The SVC results in the following benefits:

- Voltage support,
- Transient stability improvement, and
- Power system oscillation damping.

Although many versions of SVC's exist, the most common one usually employs switched capacitors and Thyristor controlled reactors (TCRs). The Var output can be varied continuously and rapidly between capacitive/inductive values. It maintains the steady state and dynamic voltage at a bus within bounds, and has some ability to control stability [9], but not much to control active power flow. The description of SVC and operation area of SVC shown in Figure 3 and 4, respectively [11].

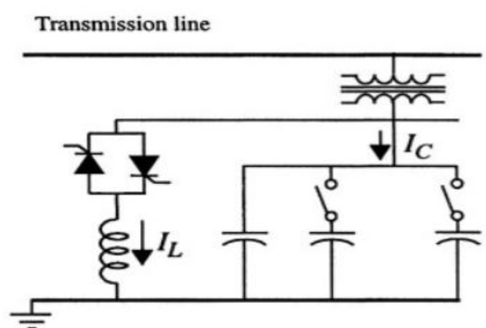

Fig. 3 - The Description of SVC

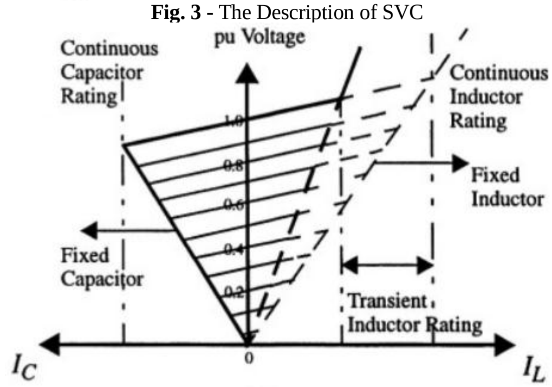

Fig. 4 - The operation area of SVC

In Table 1, a comparison between SVC and STATCOM is done from various perspectives [12].

Table 1
Comparison between SVC and STATCOM

Items	SVC	STATCOM
Compensation Accuracy	Good	Excellent
Control Flexibility	Good	Excellent
Reactive Power Capability	Leading/Lagging (Indirect)	Leading/Lagging
Control	Discontinues	Continues
Harmonics	Good	Good

By comparing the I-V characteristic curves of STATCOM and SVC shown by Fig.5, we note that the quantity of the reactive power compensation provided by the STATCOM is more important than the SVC and the operating zone of the STATCOM is larger than the SVC [9].

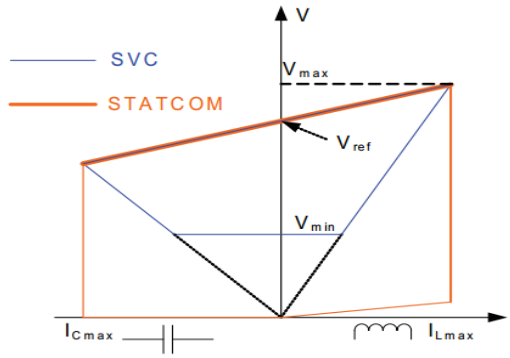

Fig. 5 - I-V characteristic of SVC and STATCOM

DESCRIPTION OF SYSTEM

With using MATLAB software simulation environment, a 9-bus network with synchronous generators, variable load and a wind farm which has a 10MVA STATCOM has been modeled. Fig 6 shows the overall scheme.

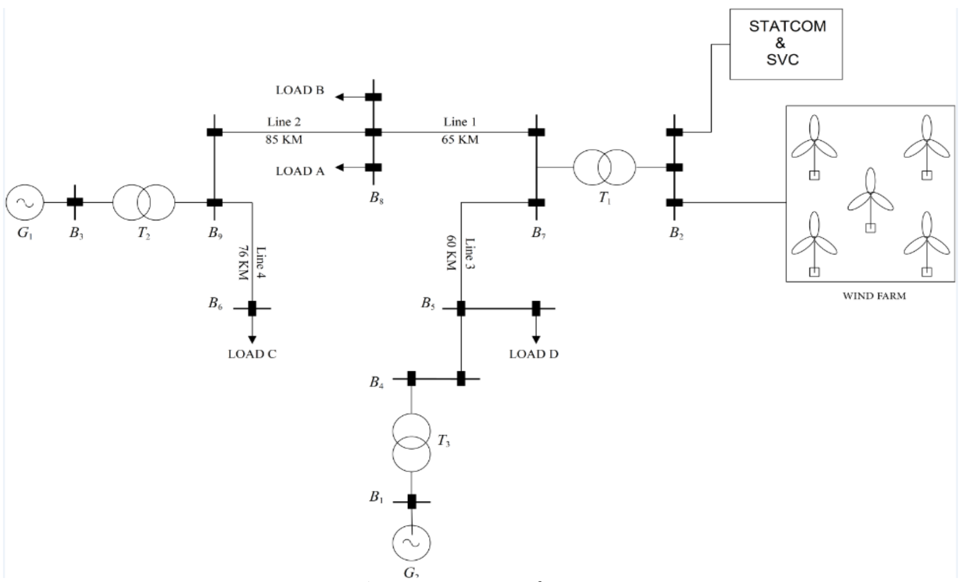

Fig. 6 - Description of System

Strategies for reactive power control

The main objective of this paper is to compare the performance of SVC and STATCOM when the electrical grid with DFIG generators and certain parts of the network voltage fluctuates. To do this, at a certain moment, a load capacity of 60MVAr electrically connected to the network. When the new load is connected to the electrical grid, causing voltage drop at all buses networks. To offset the voltage fluctuation, the wind farm has the ability to generate reactive power. The reactive power referenced by the wind farm control is proportional to the voltage deviation at the connection point of the wind farm about a constant set point. The demand for power can be supplied by a generator or a STATCOM (or SVC). Therefore, control strategies are presented as follows:

I. Wind turbines are working with a unity power factor and STATCOM is the only element that injects reactive power.

II. A proportional dispatch of reactive power between wind turbines and STATCOM.

III. When the STATCOM system reaches its maximum capacity, wind turbines delivers reactive power.

As mentioned previously, when the new load is connected to the electrical grid, causing voltage drop at all buses networks. To avoid this voltage drop in the electrical network, STATCOM (or SVC) injects reactive power into the grid. Now consider the first case. In the first case wind turbines are working with a unity power factor and STATCOM (or SVC) is the only element that injects reactive power. Then we reach the following conclusions.

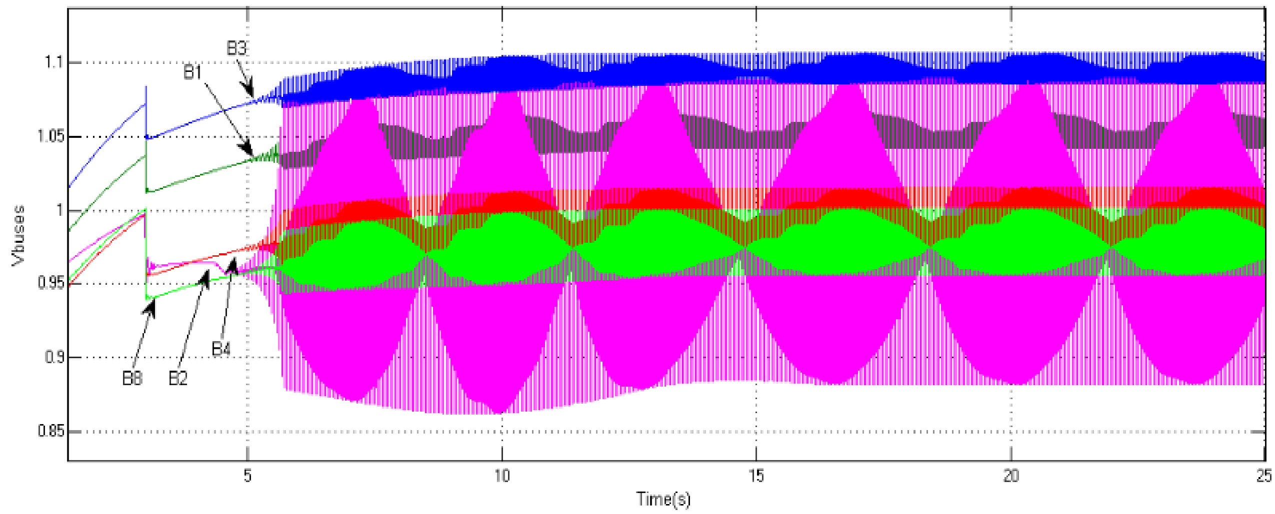

Fig. 7 - Voltage Buses without using of FACTS devices

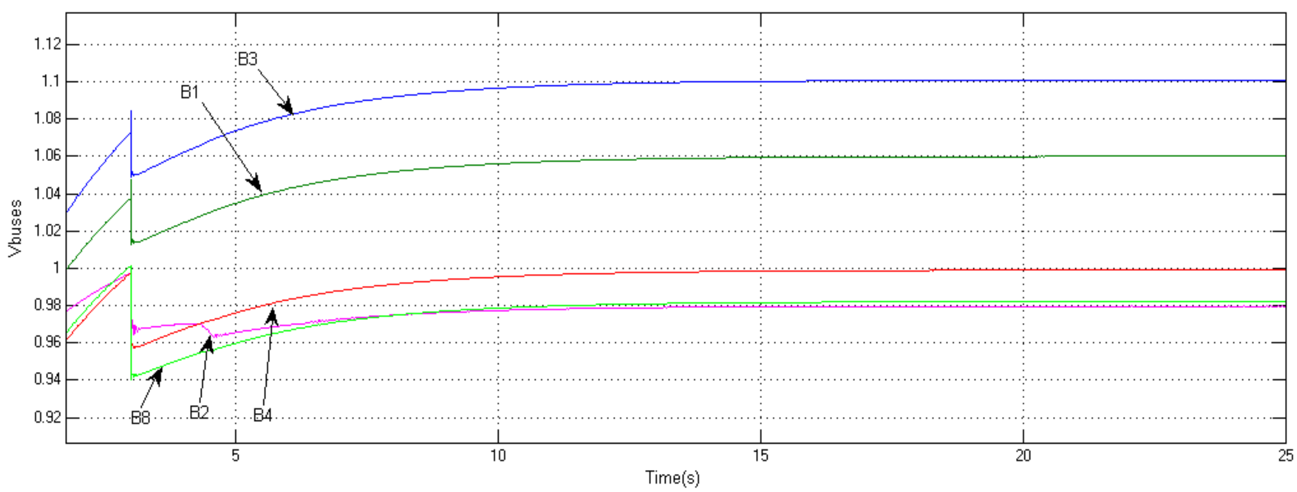

Fig. 8 - Voltage Buses with using STATCOM

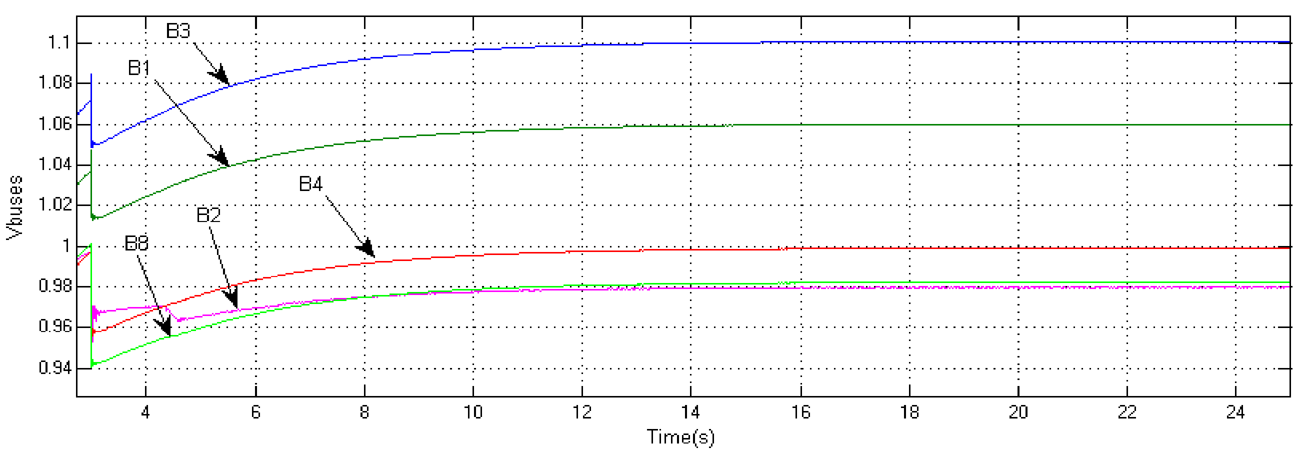

Fig. 9 - Voltage Buses with using SVC

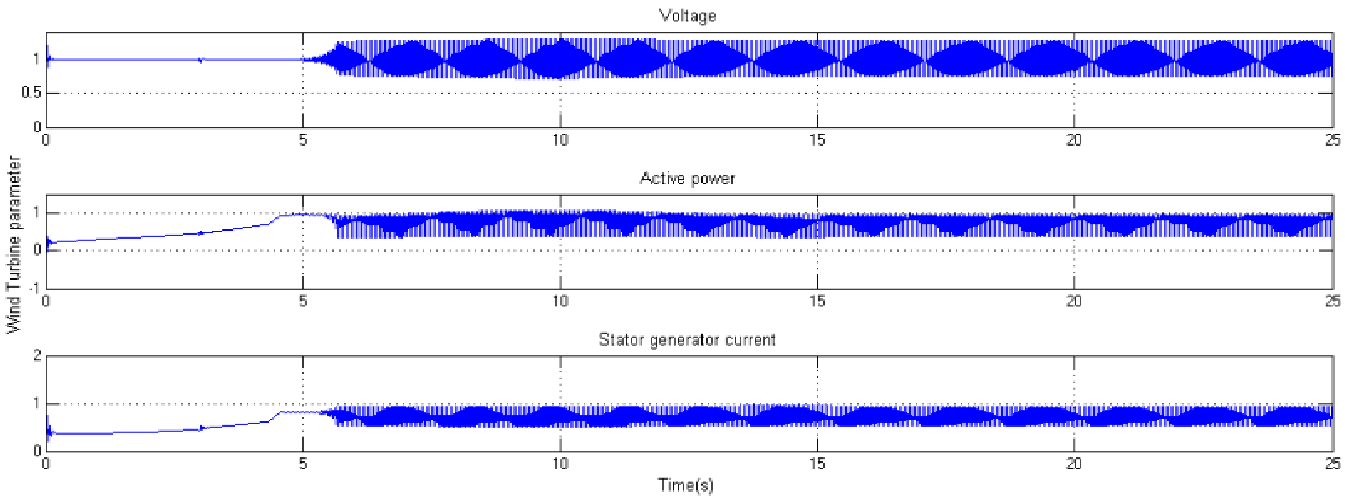

Fig. 10 - Voltage, Active Power and Stator Current of Bus 2 without using of FACTS devices

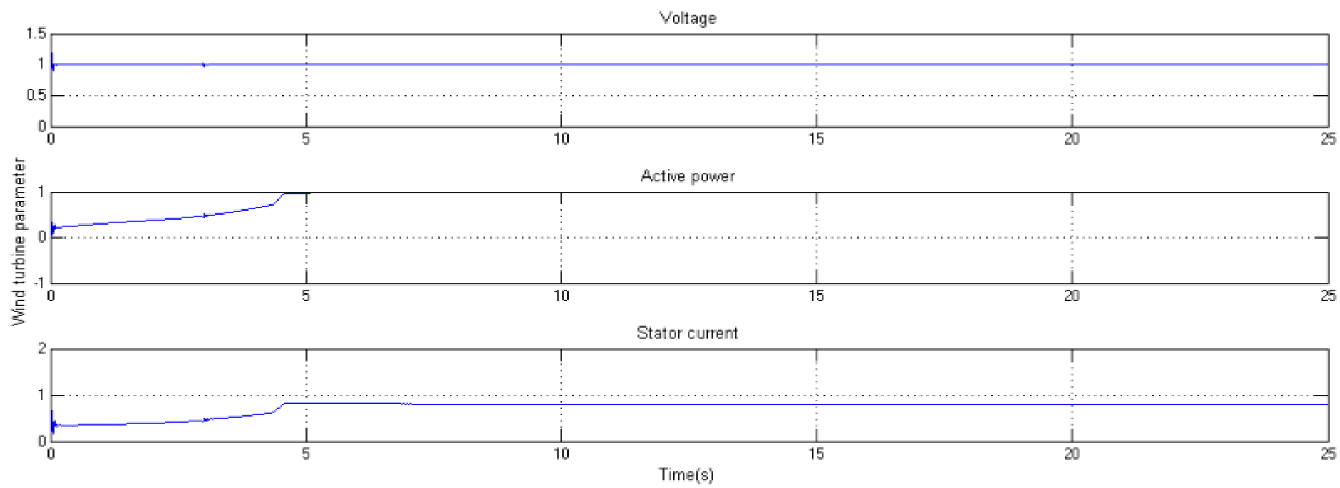

Fig. 11 - Voltage, Active Power and Stator Current of Bus 2 with using STATCOM

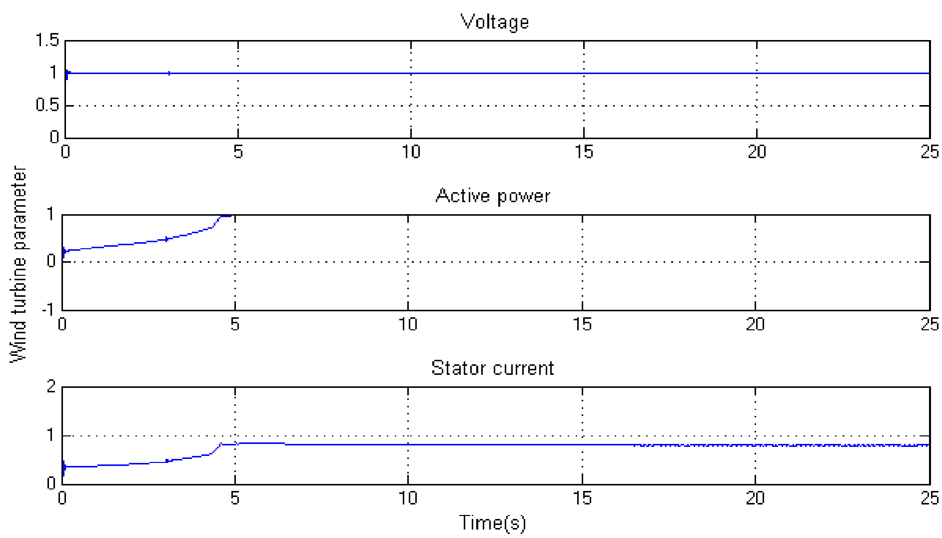

Fig. 12 - Voltage, Active Power and Stator Current of Bus 2 with using SVC

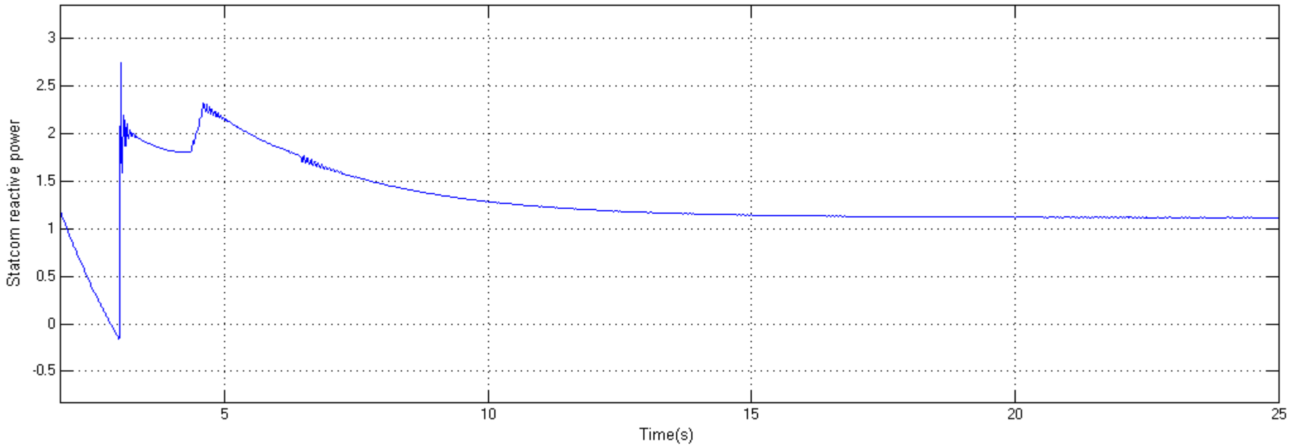

Fig. 13 - STATCOM reactive power

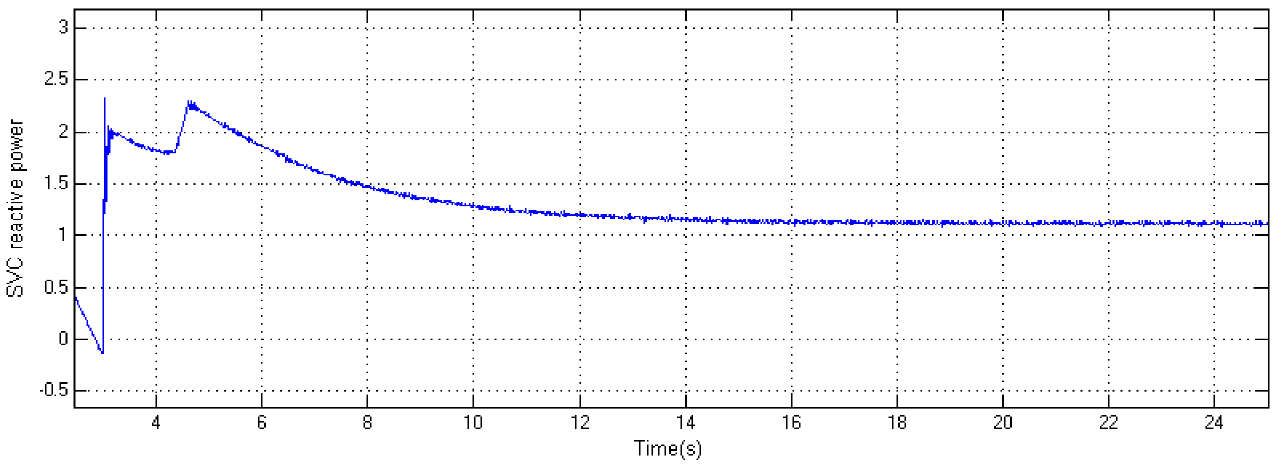

Figure 14: SVC reactive power

In the second case we consider a proportional dispatch of reactive power between wind turbines and STATCOM. Then the following results are achieved.

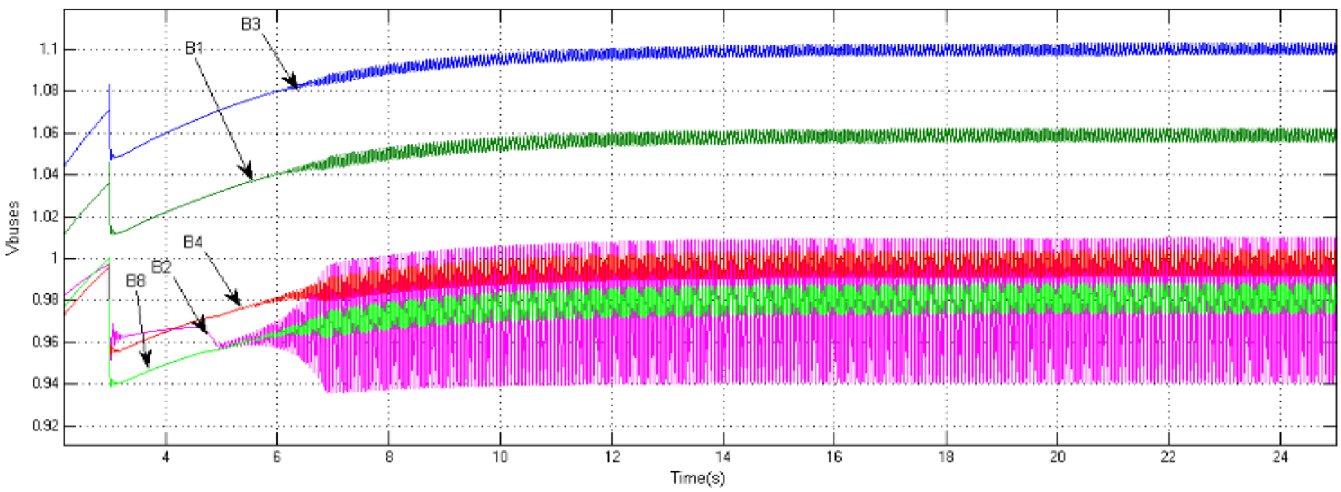

Fig. 15 - Voltage Buses without using of FACTS devices

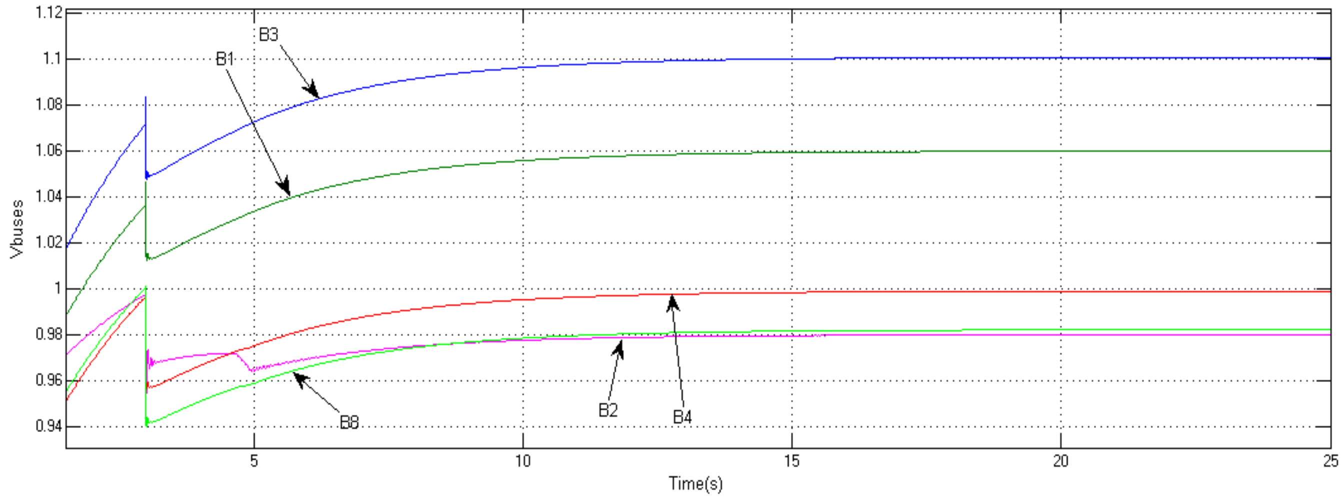

Figure 16: Voltage Buses with using STATCOM

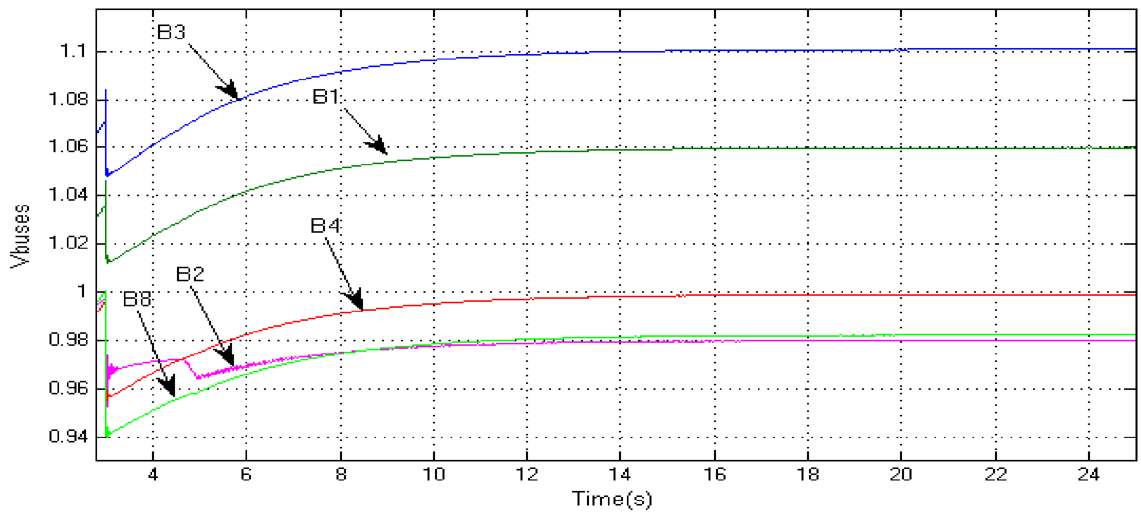

Figure 17: Voltage Buses with using SVC

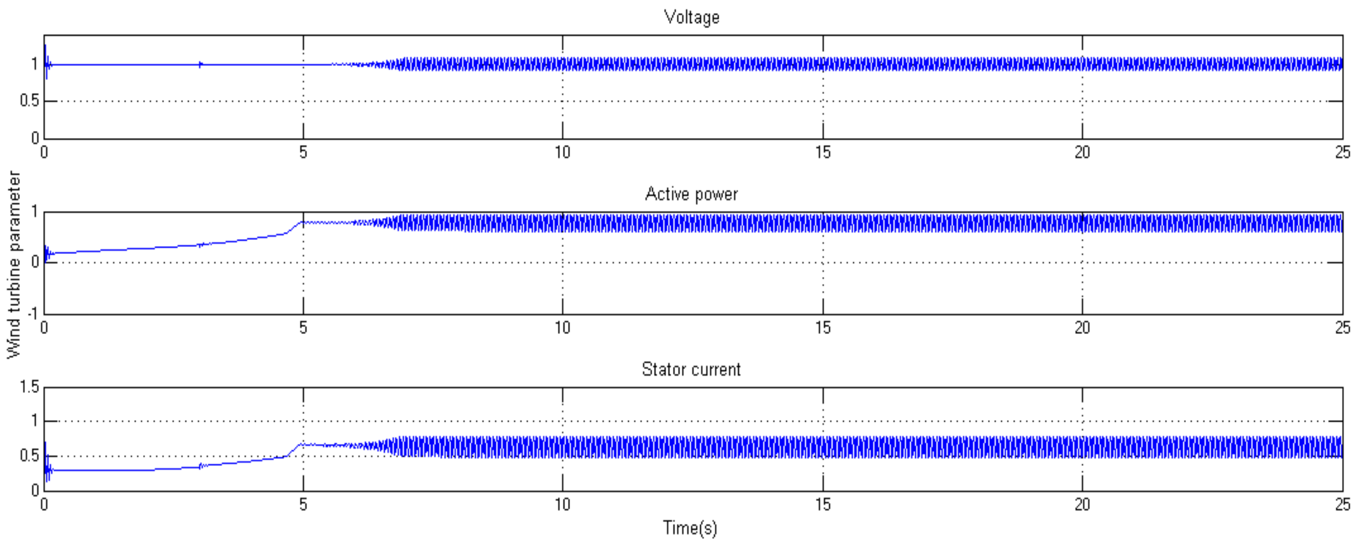

Figure 18: Voltage, Active Power and Stator Current of Bus 2 without using FACTS devices

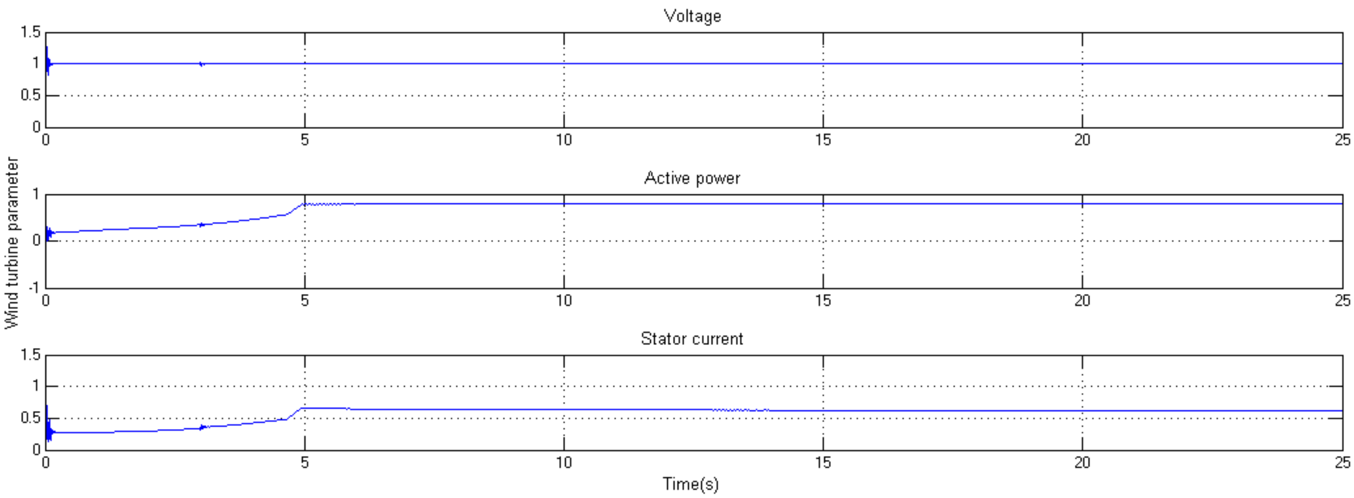

Figure 19: Voltage, Active Power and Stator Current of Bus 2 with using STATCOM

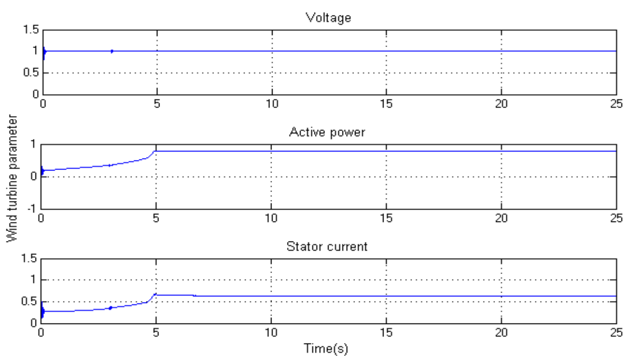

Fig. 20 - Voltage, Active Power and Stator current of Bus 2 with using SVC

Generators reactive power control helps to keep their voltage levels, since practically does not suffer a significant variation during the transient caused by the connection of new load to the system. As the reactive power delivered can tolerate only minor variation. Also to be noted that due to the stator currents are significantly higher due to the reactive current injected.

In the finally case we consider wind turbines delivers reactive power when the STATCOM system reaches its maximum capacity. Then the following results are achieved.

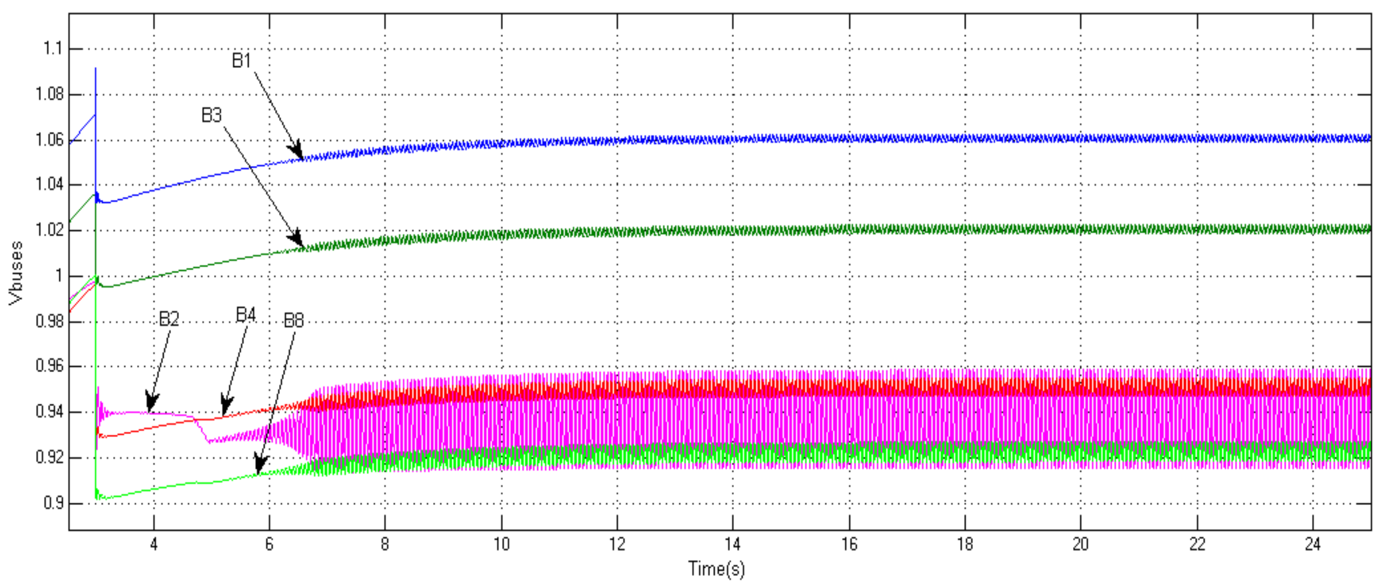

Figure 21: Voltage Buses without using FACTS devices

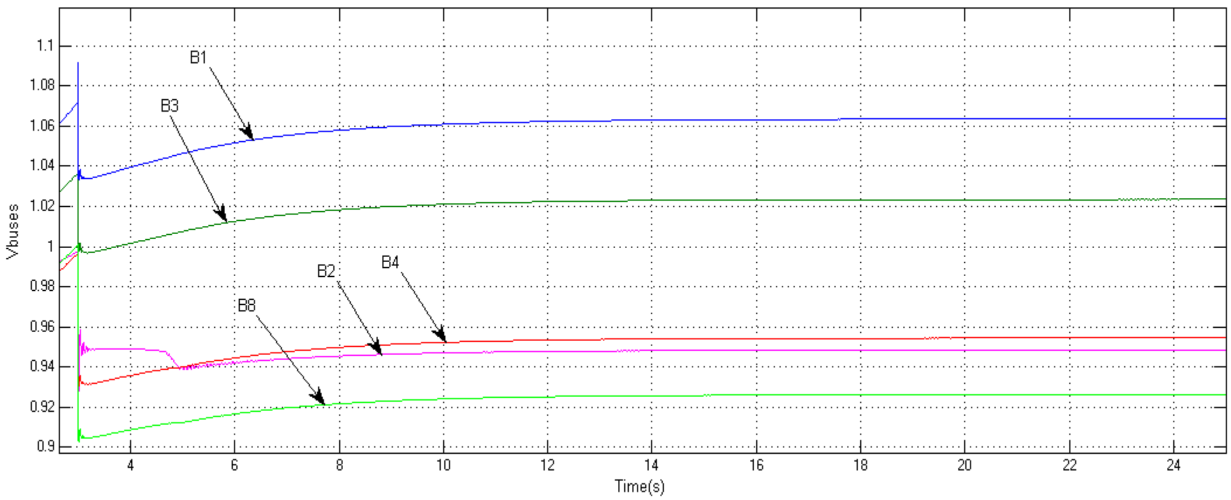

Figure 22: Voltage Buses with using STATCOM

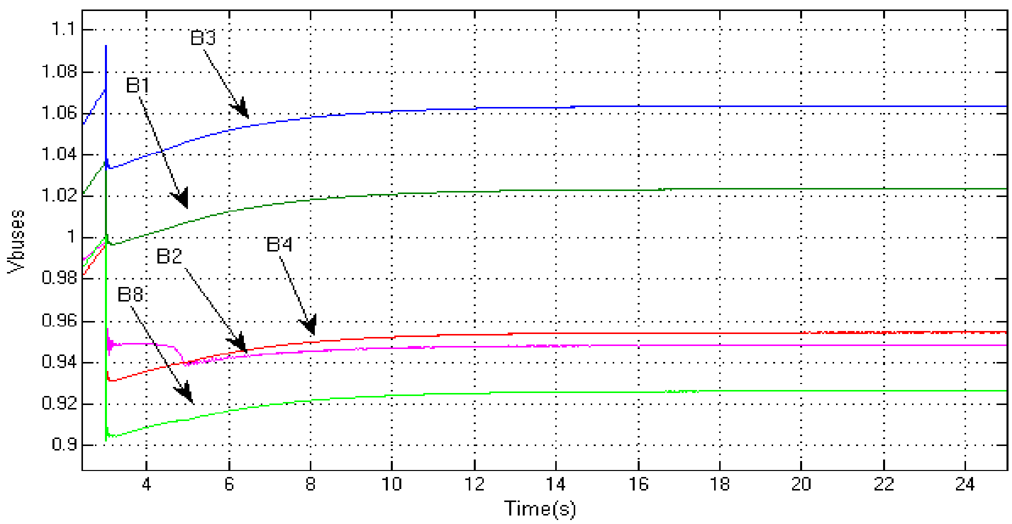

Figure 23: Voltage Buses with using SVC

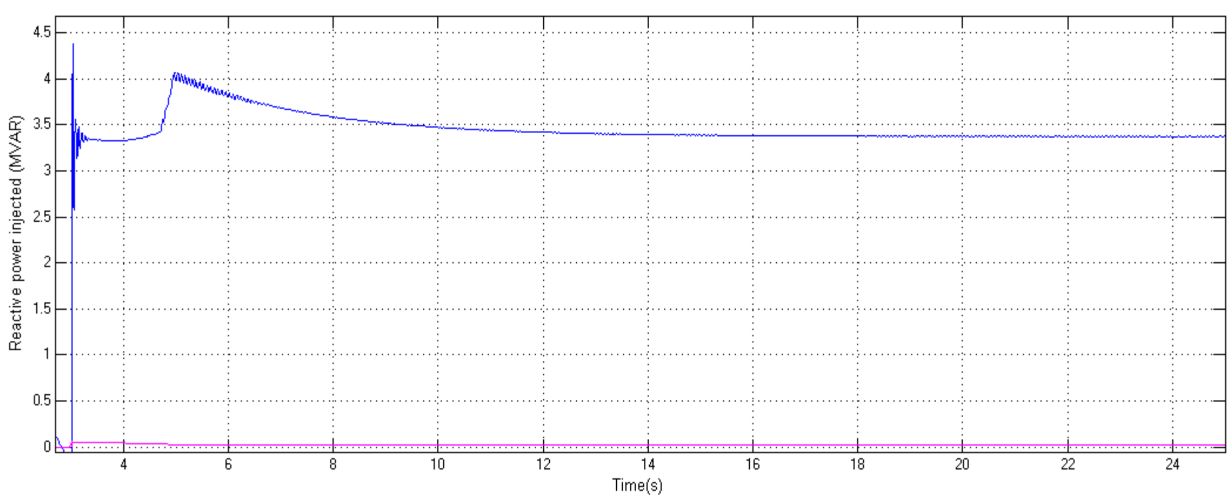

Figure 24: Wind farm and STATCOM reactive power injected to the grid

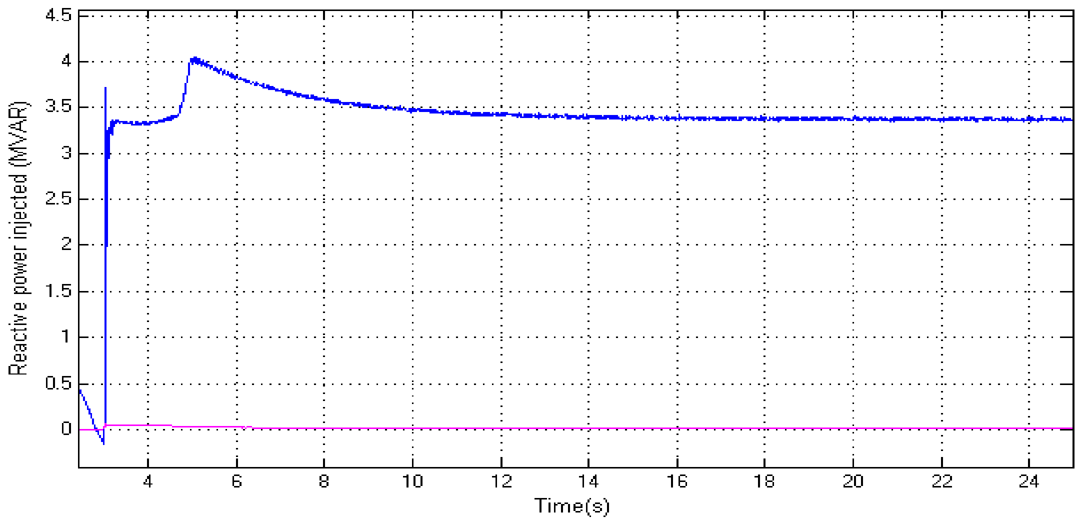

Figure 25 - Wind farm and SVC reactive power injected to the grid

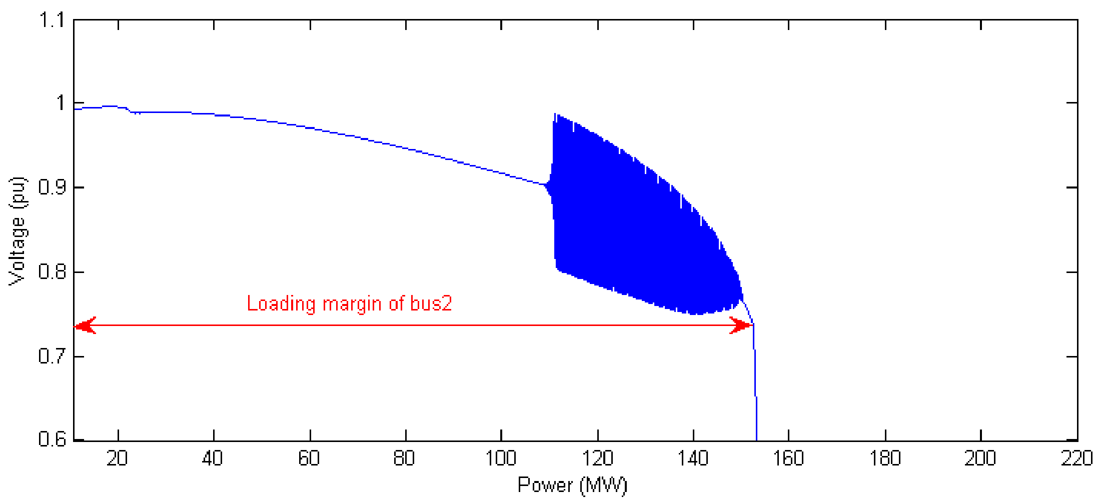

Figure 26: P-V curve in Bus 2 with reactive power injection of STATCOM

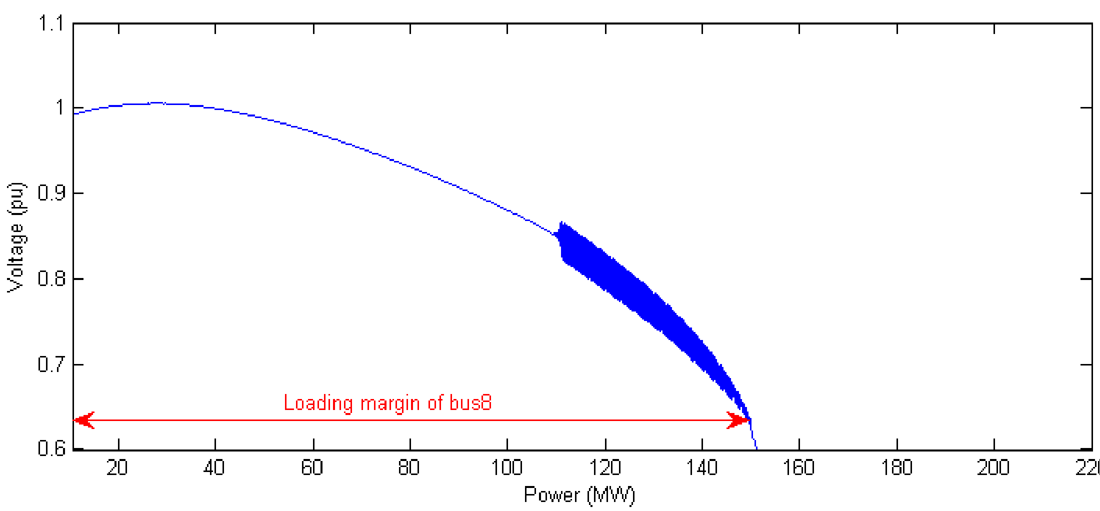

Figure 27: P-V curve in Bus 8 with reactive power injection of STATCOM

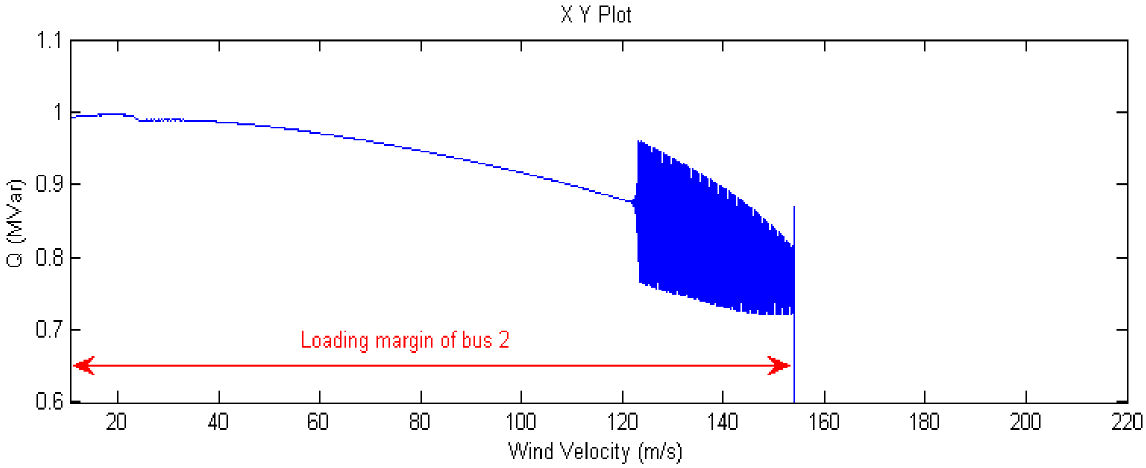

Figure 28: P-V curve in Bus 2 with reactive power injection of SVC

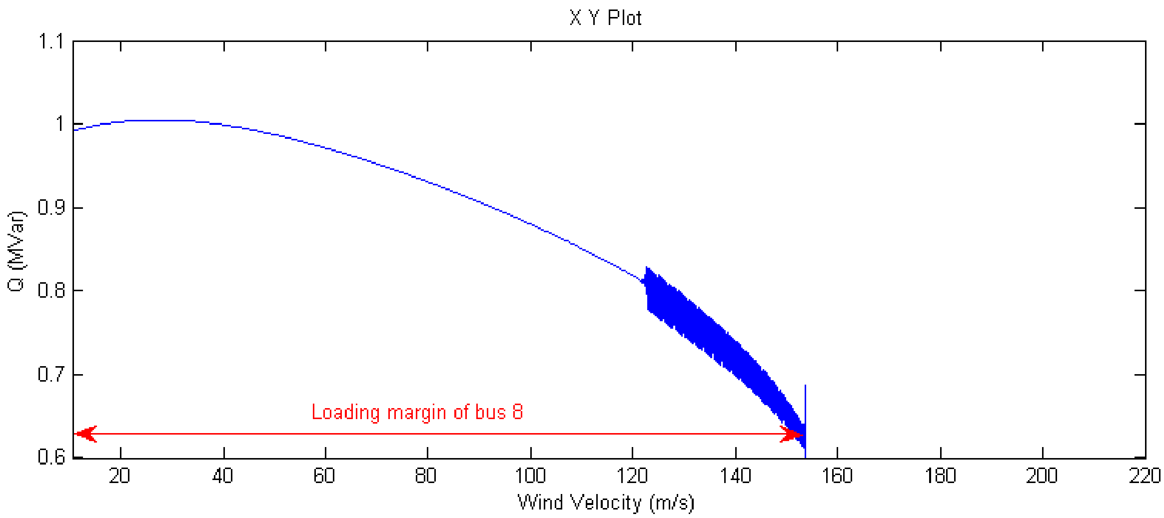

Figure 29: P-V curve in Bus 8 with reactive power injection of SVC

As shown, all the tested buses, a slight decrease in voltage level when the load is connected. In particular bus which connects the wind farm, with small deviation. When a load is connected, STATCOM and turbines, so the reactive power injection voltage is reduced to a small size. This voltage level is much higher than the case where there is no reactive power compensation. It is noteworthy to know that the STATCOM corrects voltage at the connection point of the wind farm and it helps to stabilize the system buses voltage. This can be seen in the P-V curves.

P-V cures are generated by increasing the active power of one load or of a certain number of loads by keeping the power factor constant. The loads are increased until the load flow doesn't converge any more. In this case, variation in the load A Bus 8 are applied. Initially a 10MW load with 0.85 power factor considered. As the system approaches the maximum loading point or voltage collapse point, both real and reactive power losses increase rapidly. This phenomena can be seen from the figures, commonly referred to as P-V curve.

CONCLUSION

In this paper presented three strategies for reactive power control in wind farm with STATCOM. A 9-bus network with synchronous generators, various loads and a wind farm which has a FACTS devices (STATCOM or SVC) has been modeled. A new purely reactive load has been connected on the system to cause a voltage fluctuation at all system buses. Three strategies for STATCOM and wind turbines reactive power control have been considered to compensate this sudden voltage drop. The first strategy consists wind turbines are working with a unity power factor and STATCOM is the only element that injects reactive power. In the second strategy a proportional dispatch of reactive power between wind turbines and STATCOM. In finally strategy wind turbines delivers reactive power when the STATCOM system reaches its maximum capacity. If wind turbines inject reactive power, they suffer a lower voltage drop at their connection point, but their stator currents are higher due to the injection of reactive current. P-V curves have been plotted to study the effect on voltage stability of the reactive power added to the network by STATCOM or SVC. Then we used SVC in system. As seen from waveforms, STATCOM has optimal performance is better than SVC.

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