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Improving LVRT of integration of fixed speed SCIG wind turbine to the grid

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ABSTRACT: The Fixed speed wind turbine that uses squirrel cage induction generator (SCIG) has some powerful characteristics such as it does not require slip rings with robust mechanical design. On the other hand, it suffers from the dependence on the grid to get its reactive power. This dependency may make it weak against the system faults and transients. If it is connected with FACTs devices such as static synchronous compensator (STATCOM) it will have good voltage and reactive power support during different system transients. This paper presents a method to improve the power factor and reactive power of the fixed speed SCIG wind turbine by adjusting the parallel capacitor bank of the wind turbine and the effect of this capacitance on reduction the STATCOM's converter ratings to ride through the system faults for duration of 100 milli-seconds. This will lead to the increase in wind farm generating capacity with lowering the required STACOM's converter ratings.

KEYWORDS: SCIG, wind turbine, STATCOM, LVRT.

I.INTRODUCTION

Some of the fixed speed wind turbines are equipped with a squirrel cage induction generator, which are directly connected to the grid. As it is directly connected to the grid, the changing of the wind will result in power variations, and thus it can affect the power quality of the grid. One of the disadvantages of squirrel cage induction generators is the high demand for reactive power. In view the grid connection requirements, a specific rule is applied for SCIG for their reactive power needs especially during the transients and this requires additional reactive power generation that should be provided by capacitor banks connected either to the producer's installation or to the High Voltage/Medium Voltage substation. During short circuit faults, it is critical to supply enough reactive power to reduce the magnitude of voltage sag and provide sufficient short circuit current to allow protection relays to detect and isolate the fault [1]. The ability of a power system to supply enough reactive power to reduce the magnitude of voltage sag and supply enough short circuit current to allow protection relays to operate correctly can be measured by the availability of short circuit power at the point of fault. Wind turbines in the past were designed to be disconnected in the event of major system disturbances such as faults, or downed power lines ...etc. so, this will lead to loss of generation and affect the stability of the power system and can also lead to cascaded trip and loss of revenue. Low voltage Ride through (LVRT) has a capability that enables wind turbines to stay connected to the grid during system disturbances. With this feature, wind turbines remain online by providing the required voltage and reactive power to electric grid during system disturbances [2]. The SCIG wind turbine needs the support of external devices such as Flexible AC Transmission Systems (FACTS) to remain connected during voltage dips [3]. The capacitor bank is also needed to be connected in parallel to the SCIG wind turbine to give the required reactive power to it and for power factor correction purposes. The capacitance can be selected to maximize the fixed speed SCIG wind turbine connected capacity. M. Jahangir et.al [4] presented the (LVRT) capability of wind farms with fixed-speed induction generators in their paper. The investigation of the impact of the fault ride through on the stability of fixed speed wind farm interconnected grid. The effect of fault location and its duration time are studied for different fault types. The contribution of STATCOM is to support the fixed speed wind farm interconnected 120 KV electric grid during different fault locations and different fault duration times [5] . The research that was done by Omar Noureldeen [3] to analyzes the extent to which the LVRT capability of wind farms using squirrel cage generators can be enhanced by the use of a Static Synchronous Compensator STATCOM. The wind farms have the ability to stay connected to grid during LVRT is investigated based on EONNETZ grid code. This paper will explain how to improve the LVRT of fixed speed wind turbines that is integrated to the grid by setting the value of

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the parallel capacitor of it to reduce the STATCOM converter size and to improve the transient stability of the SCIG wind turbines. All the simulations are done using MATAB simulink 2010.

II. SINGLE 3 MW WIND TURBINE CONNECTED TO THE 120 KV GRID

Figure (1) shows a single line diagram of wind turbine in MATLAB Simulink which is 3 MW, 575 Volts and 60 Hz rated frequency. The parameter of this 3 MW wind is available in [3]. A simulation model of a wind turbine consists of 3 MW wind turbine connected to a 25 kV distribution system exporting power to a 120 kV grid through a 25 kV feeder. The stator winding of SCIG is connected directly to the 60 Hz grid and the rotor is driven by a variable pitch wind turbine. Fixed capacitor banks in delta connection are connected at low voltage bus of each wind turbine 400 KVAR for 3 MW turbines which supplies the constant no load demand of reactive power. A STATCOM is connected at the main bus B_25 to provide the reactive power and voltage control capability. The bus B_25 is the same as the PCC common coupling point where another wind turbine can be connected to form a wind farm.

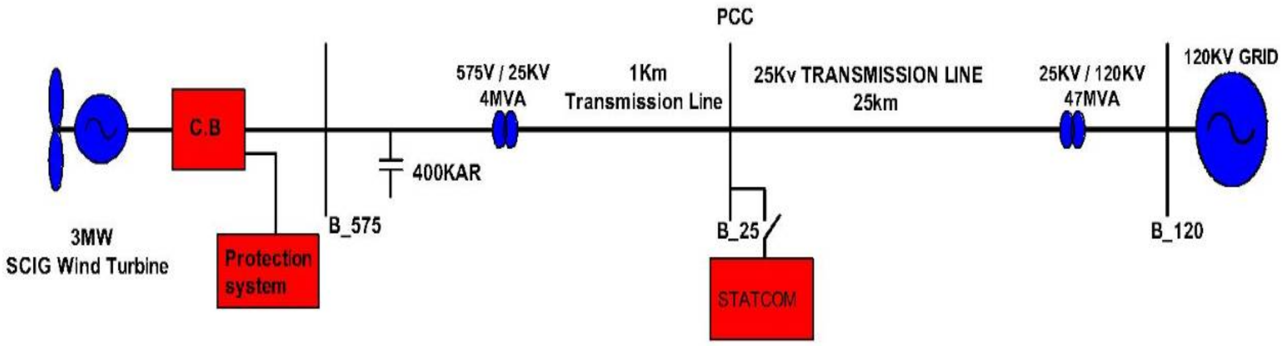

Figure (1): Single line diagram of 3MW wind turbine connected to the 120 kV grid

III. REACTIVE POWER COMPENSATION OF THE S.C.I.G. FIXED SPEED WIND TURBINE

The system of [3 & 5] is connected to a 400 KVAR capacitor. This capacitor is responsible for the power factor and reactive power of the SCIG fixed speed wind turbine. For the 3 MW wind turbine of figure (1), at the bus point B_25 the voltage, reactive power, and power factor are as shown in the figure (2).

Where at steady state the voltage, reactive power, and the power factor are 0.9896 PU, 1.11 MVAR, and 0.932 respectively at the PCC. It can be noticed that the voltage at the PCC is not unity and this is the result of a single 3MW wind turbine connected to the grid. What if several wind turbines are connected to this point? This may lead to decrease in the voltage, active power and power factor at this point, lower than the expected values. This can be solved by adjusting the value of the capacitor bank to be 925 KVAR. The new value of this capacitor will raise the voltage at the PCC point to be 1.001 PU and the reactive power and the power factor values are 0.531 MVAR and 0.98 respectively as shown in figure (3).
To measure the capacitance value at the terminals SCIG of wind turbine as [6]:

$$\boldsymbol{Q_c} = 3\, \boldsymbol{V_c I_c} = 3\, (\boldsymbol{V_s})^2 \boldsymbol{\omega_s}\, \boldsymbol{C} \quad (3.1)$$

$$\boldsymbol{C} = \frac{\boldsymbol{Q_c}}{3\, (\boldsymbol{V_s})^2 \boldsymbol{\omega_s}} \quad (3.2)$$

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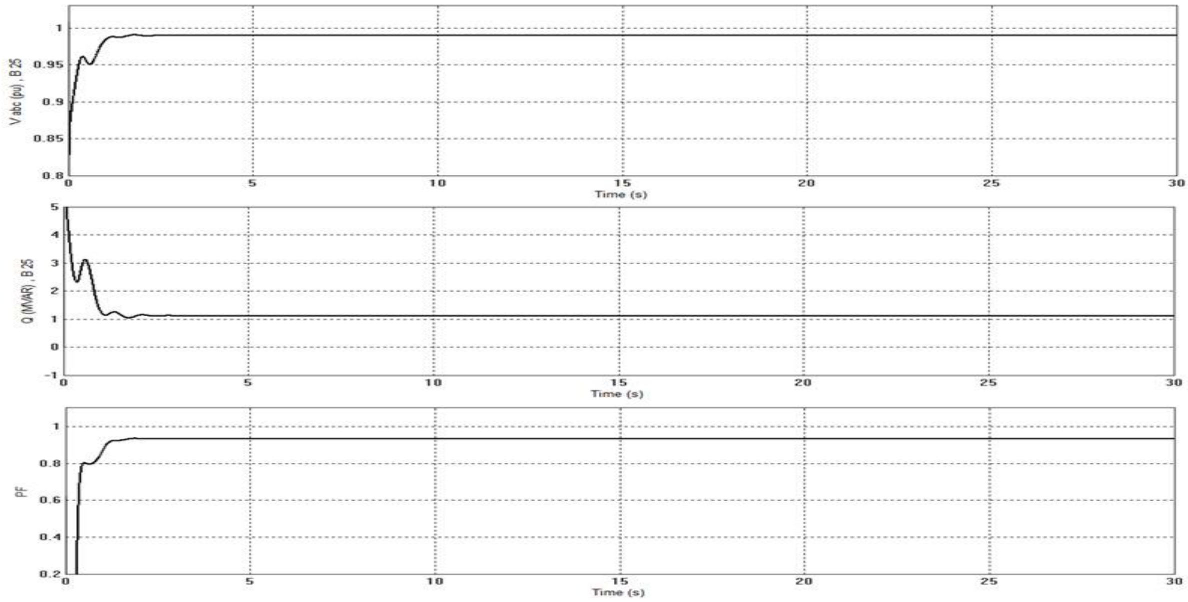

Figure (2): Voltage, Reactive power and Power factor at bus B_25 when the capacitive VAR of capacitor is (400 KVAR)

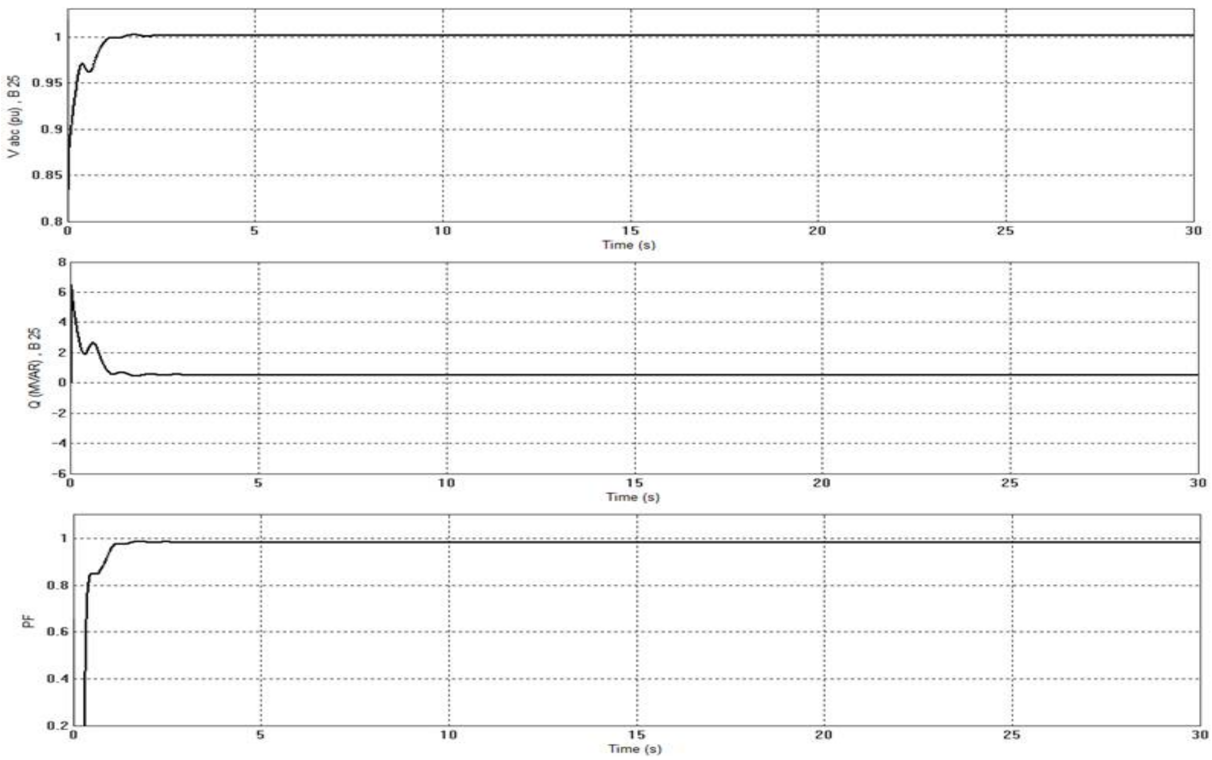

Figure (3): Voltage, Reactive power and Power factor at bus B_25 when the capacitive VAR of capacitor is (925 KVAR)

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So for capacitor of (400 KVAR)) the three phase capacitance is:

$\boldsymbol{C}$ = 1.0967× $\mathbf{10^{-3}}$ farad

And for capacitor of (925 KVAR) the three phase capacitance is:

$\boldsymbol{C}$ = 2.4737× $\mathbf{10^{-3}}$ farad

This shunt capacitor should be connected to the terminals of the fixed speed SCIG wind turbine in (Delta) connection.

IV. LOW VOLTAGE RIDE THROUGH (LVRT) OF THE 3 MW FIXED SPEED S.C.I.G. WIND TURBINE

Riding through faults means when faults occurs at some point or voltage dips from the grid side, the wind turbine has the ability to ride through this fault and not to be disconnected by its protection devices. This can be done by some time according to the grid code and only the affected area by the fault should be disconnected. The function of the STATCOM is to control the voltage amplitude and the reactive power compensation. The reference voltage of the STATCOM is kept at 1 PU to let the voltage at the PCC point 1 PU. The STATCOM is connected at the PCC as this point is the weakest point in the wind farm. At this point all the SCIG wind turbines will take its reactive power and due to this, the voltage is lower than the rated voltage which is 1 PU. To make each wind turbine connected in a wind farm and be able to ride through system faults such as single line, double lines to ground, and line to line faults without being tripped by protection system, the fixed speed SCIG wind turbine can ride through the fault that happen for 100 ms by using the STATCOM without any tripping signal from the protection system to make the wind turbine in service even during network faults as shown in figures (4 & 5). When the Qc of the wind turbine is 400 KVAR it can ride through the faults at not less than 7.2 MVA converter ratings of the STATCOM.

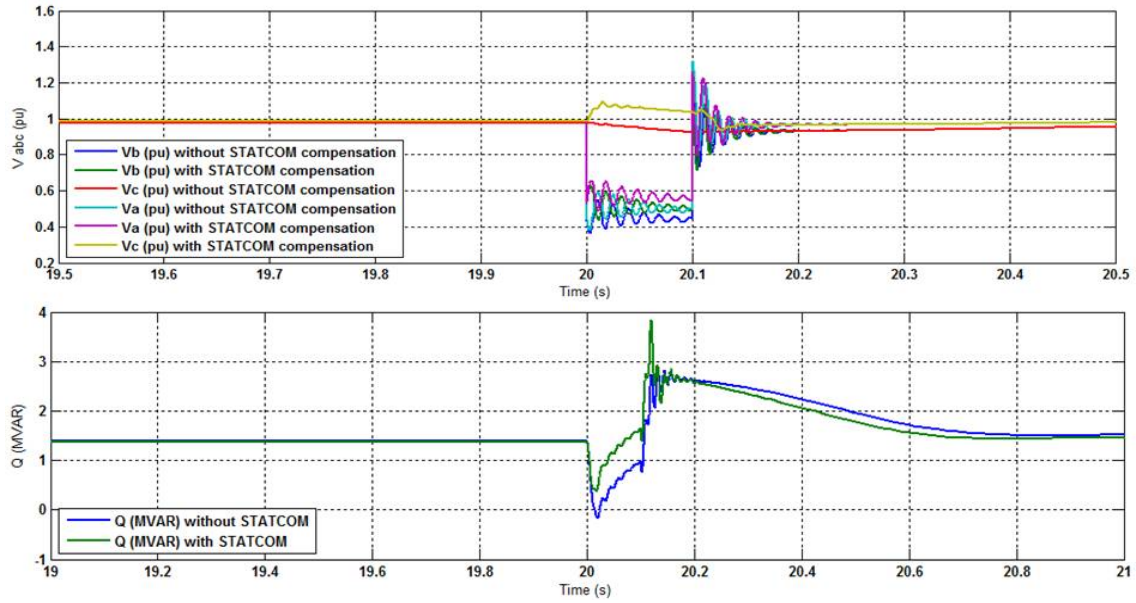

Figure (4): Simulation of wind turbine voltage and reactive power with 7.2 MVA STATCOM and without it at (line to line fault) with 400 KVAR of capacitor

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V. REDUCTION OF THE STATCOM CONVERTER RATINGS FOR LVRT OF A SINGLE 3MW WIND TURBINE

To let the system of figure (1) has the ability to ride through faults at lower STATCOM converter ratings and at the same time increasing the wind turbine generating capacity, a modification can be made by adjusting the value of the Qc value to change its value from 400 KVAR to be 925 KVAR . As the 925 KVAR of the Qc has made good improvement of the voltage and power factor at the PCC point, this value of Qc also can reduce the required voltage source converter (VSC) rating of the STATCOM to be 4.7 MVA instead of 7.2 MVA. The reduction of the STATCOM VSC is good factor because this reduction will increase the generating capacity of the connected wind turbines with the LVRT capability as shown in figures (6 & 7).

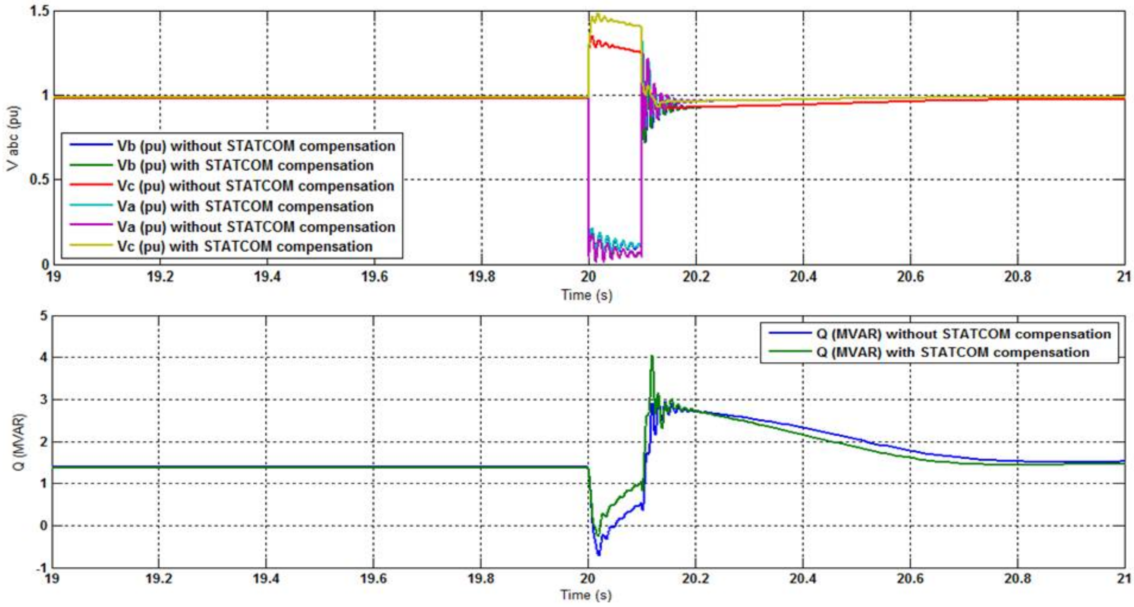

Figure (5): simulation of wind turbine voltage and reactive power with 7.2 MVA STATCOM and without it at (double lines to ground fault) with 400 KVAR of the capacitor

VI. EFFECT OF THE ADJUSTED QC VALUE ON INCREASING WIND FARM GENERATING CAPACITY

The value of the Qc is adjusted to be 925 KVAR. This value is suitable to keep the voltage at rated voltage at the PCC. In comparism with [3] , a STATCOM with 36MW wind farm has the ability to let the wind turbines of this wind farm ride through fault without being disconncted by their protection system. The fault occurance is at the PCC for 100 ms. The simulation was done for faults (single line to ground , double lines to ground, and line to line) and also in case of voltage sag at grid side up to 0.2 PU for duration of 100 ms where the converter rating of the STATCOM converter rating is 35MVA as shown in figure (8).

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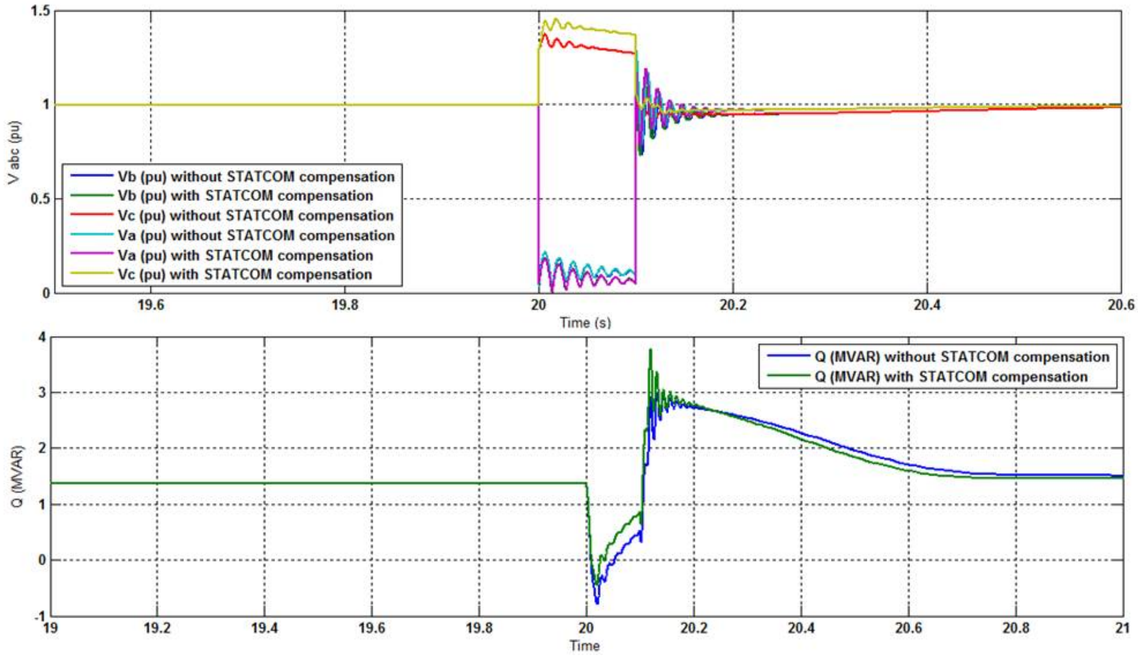

Figure (6): simulation of wind turbine voltage and reactive power with 4.7 MVA STATCOM and without it at (double lines to ground fault) with 925 KVAR of the capacitor

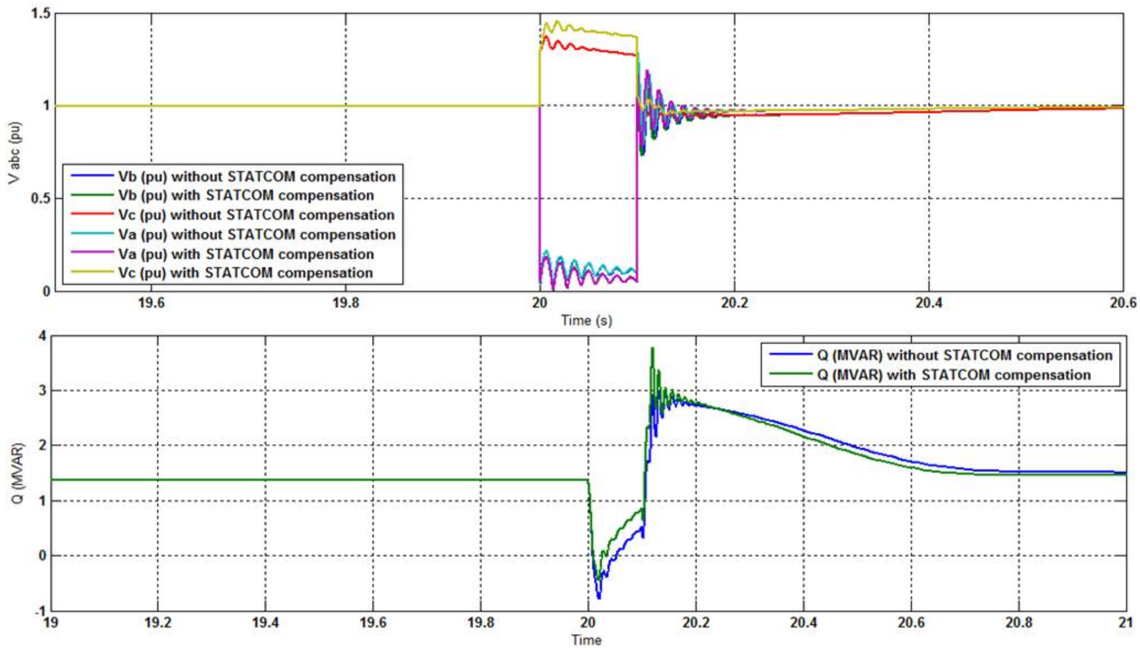

Figure (7): simulation of wind turbine voltage and reactive power with 4.7 MVA STATCOM and without it at (line to line fault) with 925 KVAR of the capacitor

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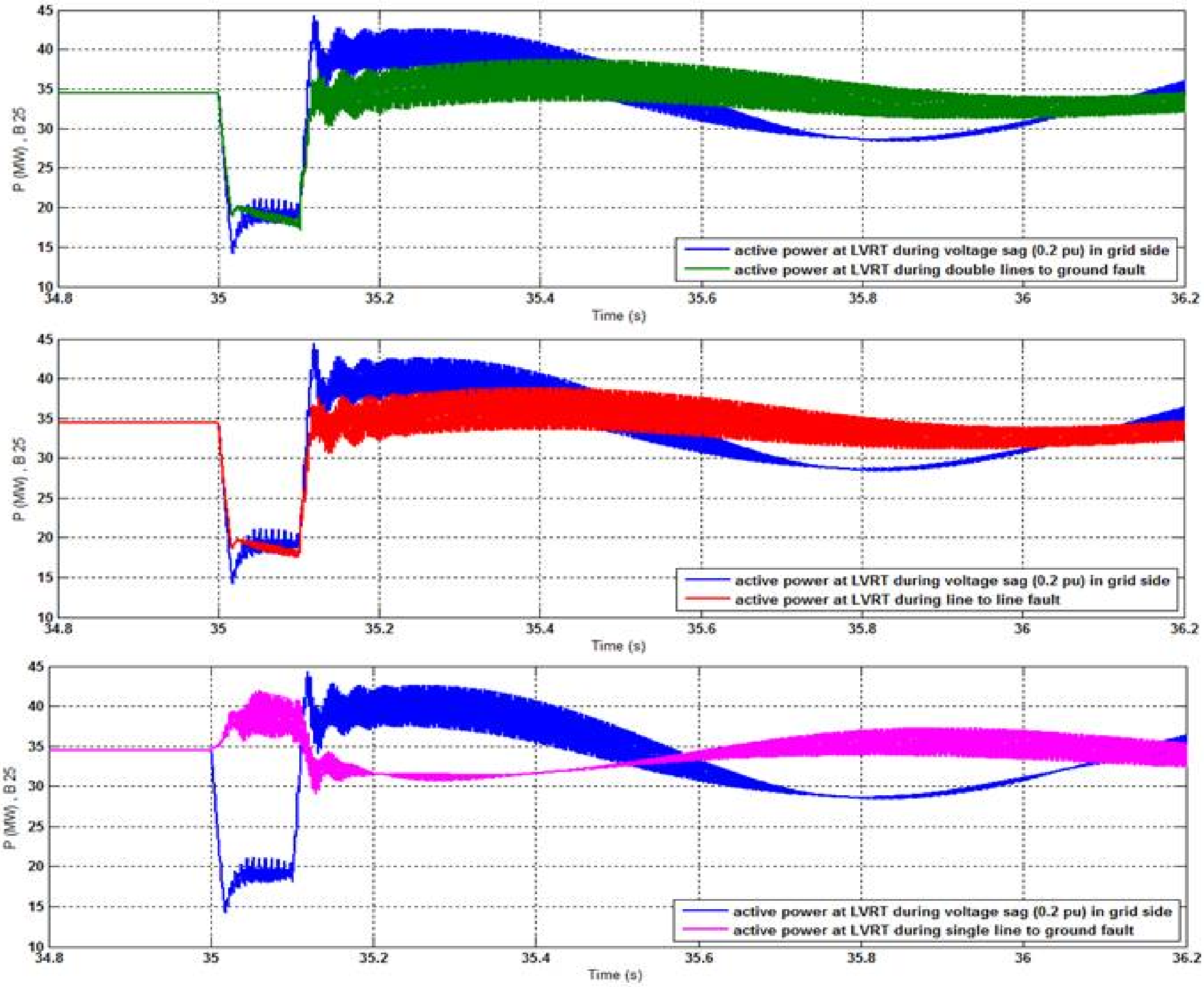

Figure (8): LVRT of (36 MW) wind farm with (35 MVA) rating of STATCOM

VII. CONCLUSIONS

In the study of the performance of the fixed speed SCIG wind turbine, a modification is done to get better performance of it. The improvements are in the power factor and the voltage at the PCC. The Qc (reactive power) of the capacitor that was connected to the wind turbine terminals to get the voltage at the PCC point equals 1 PU (rated value) and the power factor equals 0.98. This value of Qc helped to reduce the VA ratings of the STATCOM's converter which is used for dynamic compensation of reactive power and voltage control at the common coupling point. This Qc also made an improvement in the LVRT and the way of increasing the wind farm generating capacity with lowering VA ratings that is required for the STATCOM for LVRT operation.

REFERENCES

[1] “Vertical and horizontal wind turbines: weighing the difference”, http://windturbinesllc.blogspot.in/2011/02/weighing-difference-horizontal-vs.html, February 24, 2011.

[2] Mukund R. Patel, “Wind and Solar Power Systems Design, Analysis, and Operation”, 2^{ND}, New York: CRC Press Taylor & Francis Group, 2006.

[3] Omar Noureldeen, "Low Voltage Ride through Strategies for SCIG Wind Turbines Interconnected Grid", *International Journal of Electrical & Computer Sciences IJECS*, Vol. 11 No. 02, April, 2011.

[4] M. Jahangir Hossain, Hemanshu R. Pota, Valeri A. Ugrinovskii, and Rodrigo A., " Simultaneous STATCOM and Pitch Angle Control for Improved LVRT Capability of Fixed-Speed Wind Turbines", *IEEE Transactions, Sustainable Energy* , Vol. 1, No. 3, PP. 142 – 151, Oct. 2010.

[5] Omar Noureldeen, Mahmoud Rihan, and Barkat Hasanin, "Stability improvement of fixed speed induction generator wind farm using STATCOM during different fault locations and durations", *Ain Shams Engineering Journal*, pp. 1-10, 2011.

[6] Bin Wu, Yongqiang Lang, Navid Zargari and Samir Kouro, "Power conversion and control of wind energy systems", 1st., Canada: A. John wiley & sons, Inc., 2011.