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Improving The Stability of Wind Power Plants with The Constant Speed by Using STATCOM-SMES Combination Compensator

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ABSTRACT

Analyzing the stability of wind power plants and their effectiveness in to the electrical systems become more important for increasing of wind turbines. In previous study the stability of wind power plants have been improved by many parameters, such as: injection of reactive power, and variation in resistance and reactance of rotor and stator. In this paper to improve the stability of synchronous wind power a synthetic STATCOM-SMES is used. In addition the controlling strategies are analyzed. In fact the ability of reservation would be increased precisely by using STATCOM-SMES. To do this a suitable controlling plan to control the statcom and dc-dc chopper which is used to charge and discharge the SMES`s coli is presented. PSCAD/EMTDC software is used to simulate and prove the accurately of this new method.

KEYWORDS: Transient Stability; Dynamic Stability; STATCOM-SMES; Wind Power Plants.

INTRODUCTION

Any kind of FACTS equipments were used to enhance the stability in electrical systems [1]. By developing in energy storage systems, in conjunction of FACTS instrument with energy storages is used to improve and develop of FACTS applications. The mixture of FACTS instruments with storage systems seems crucial due to transient and dynamic stability, power quality and etc. on the other hand instability would be avoidable by absorbing the extra movement energy.

In [2] the compatibility of the battery energy storage system with the STATCOM was evaluated. In [3] the compound of SSSC and SMES to control of network`s frequency is used. By considering that the STATCOM is one of the FACTS family members, so it has some abilities such as: promotion the power fluctuations, improvement the transient stability, voltage supporting, and etc [4].

This paper efforts that provides those of abilities by adding a big storage system although this compensator can't inject or absorb the reactive power. Between the energy storage systems SMES is considered to mix with this Compensated because of its high speed, high efficiency, and etc [5].

What it will be considered in this paper is coordination of SMES with STATCOM, and defining an effectiveness strategy to charge and discharge of SMES in combination with STATCOM. Presentation the result of using combined compensator with the control method in a sample system is the last step in this paper.

Problem statement

Usually induction generator in wind turbines to convert kinetic energy from wind to electrical energy is used. Design, construction, repair and maintenance of induction generators, synchronous generators are much simpler than other machines. But also has some disadvantages, namely induction generators will consume a large amount of the reactive system which reduces the voltage profile and instability of wind power plants in the network. Therefore, changes must occur to control voltage and reactive power needed to supply the generators. For these purpose different types of compensator Reactive power for voltage regulation and control of wind power is used.

Another important issue in relation to a fixed speed wind turbines is their disability in short circuit conditions.

Weak and short circuit conditions when connected to allow voltage network, the fixed speed wind turbines may be caused by voltage instability. In the following the most important problems in other studies will be analyzed.

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- **Reactive power injection**
  In reference [6] of the SVC reactive power is used to provide the capacity needed for this equipment is very high and therefore will be costly. The use of other FACTS devices, which are less dependent on voltage and reactance network, is proposed.
- **Reduce network reactance**
  When the generator is connected to the network, reactance the passage can be added to the X and the result is decreased stability. Should be kept in mind that changing the network reactance is not always possible in most cases. The disadvantages of this method can increase the level of short circuit and facilitate trans-pointed cross of the harmonic.
- **Increasing the rotor resistance**
  Add generator rotor winding in the rotor resistance and the possible need for additional equipment and the error signal detector. Departure time and the amount of resistance depend on system error and system characteristics. There are also losses due to ohmic resistance, thermal limitations should also be considered.
- **Increased inertia**
  Increasing inertia, robbing the system and the mechanical oscillation frequency decreases. This approach makes the system natural frequency and damping frequency mechanical mode to another. So it increases likelyhood of mechanical resonance. This resonance can occur in the long-reaching damage to the turbine shaft. In addition, the high inertia of the mechanical parts of the system will be difficult the stopping power in emergency situations.
- **Increasing the turbine shaft stiffness**
  Methods to increase the inertia and stiffness coefficients and the parameters of the generator are not always possible and can only be applied by the manufacturer. The changes in these parameters may lead to a series ofother possible problems in the system.

Structureof statcom-smes compound compensator

STATCOM-SMES combined compensator has ability to inject or absorb active and reactive powers in compare of STATCOM compensator [7]. In fact, the addition of storage compensator to SMESSTATCOM can effective in facilitating the active form of the DC side and AC side. Fig. 1. presents the general structure of this compound compensator.

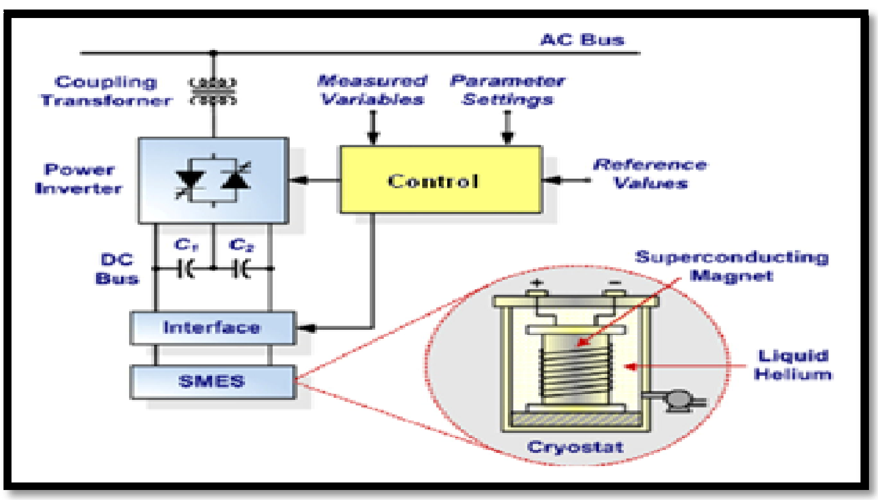

Fig. 1. Model of STATCOM-SMES compound compensator

According to the Fig.2. the benefit that is yield by adding SMES storage to the STATCOM compensator is active and reactive powers of the STATCOM-SMES combination of orthogonal so the total flow affects the flow rate when using a combination of both are used, each of which is less than when used separately. It is because the range of reactive power in STATCOM compensator is bigger than its active power, and SMES storage just effect on the active power. So amount of current is less when this two system are used impact than they use separate.

However, the actual excess capacity of SMES storage added to the STATCOM compensator can improved the performance of the converter that the total converter MVA also reduced in these conditions, so the converter losses and costs will be lower compared.

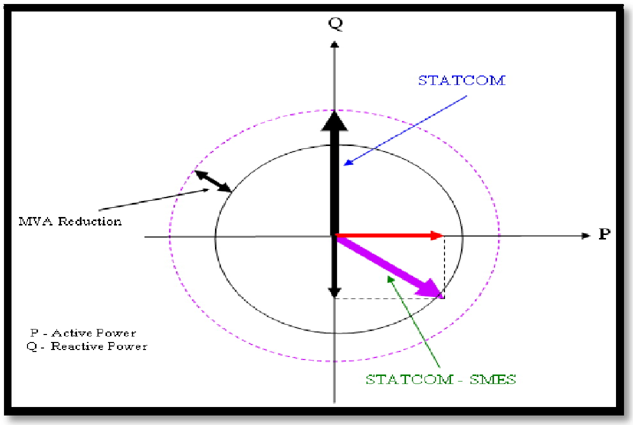

Fig. 2. Characterized by decreased expression of the STATCOM compensated by adding MVA SMES

Adjustment of voltage and current levels for both the STATCOM and SMES is an interface that requires a dihedral dc-dc chopper is used [8]. STATCOM connected to storage through the chopper outline SMES is shown in Fig. 3.

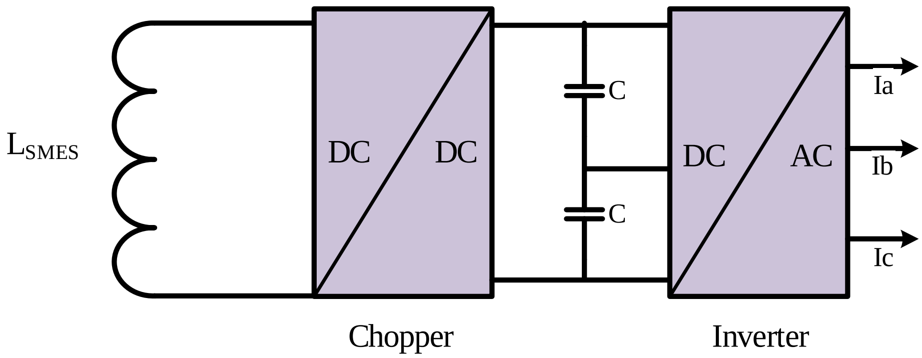

Fig. 3. Plans to connect the storage SMES compensated by STATCOM dc-dc chopper

Dc-dc chopper to charge and discharge performance of smes coil

A two-level dc-dc chopper for power exchange between the inverter and the SMES coil is used. Functional modes in three-mode dc-dc chopper charging mode and discharging mode are supported separately. It saves energy in proportion to the nominal current in SMES coil mode charge**.** In backup mode in the SMES coil is in a closed loop to circulate. In discharge mode, the energy of the SMES coil is sent to the dc link capacitor. GTO is in an on state if the duty cycle of that GTO is in one state. GTO is in an off state if the duty cycle of that GTO is in zero state. During standby mode, GTO2 is always in on mode. GTO1 can be switched in on or off mode. GTO1 should also be placed in the on state for charging coils SMES (Fig.4).

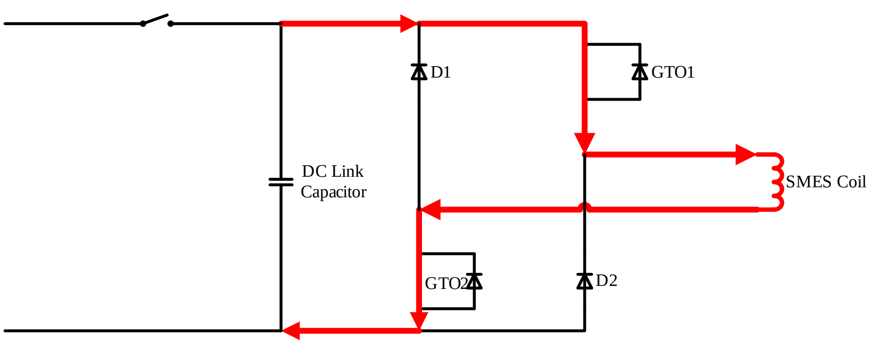

Fig. 4.Chopper circuit in the charging mode SMES coil

When the SMES coil is located in the backup mode one of the GTOs are in the off state. GTO1 is in the on state, and GTO2 is in the off state in the equivalent circuit shown in Fig.5. During this period the amount of loss is not significant, so the flow remains constant.

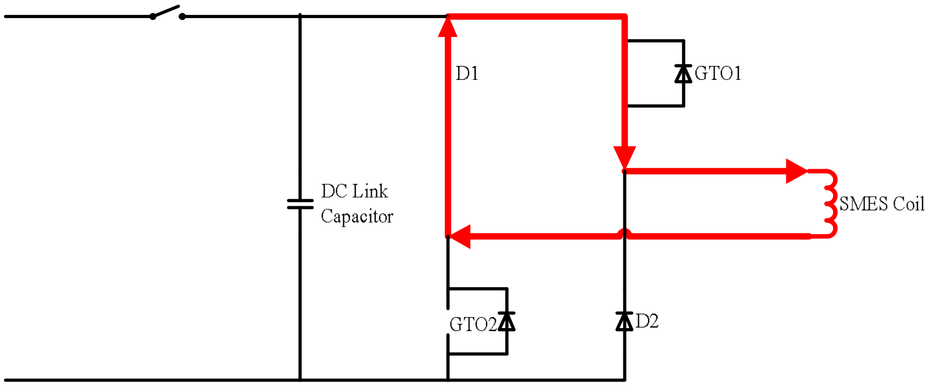

Fig. 5.SMES coil chopper circuit in backup mode

In discharge mode, GTO2 always be in off mode, and discharging cycles of the necessary work GTO1 can be changed. During the discharge cycle for a maximum discharge rates both the GTO must be in OFF mode. Discharge of SMES coil by placing the working cycle of the GTO to be controlled by a non-zero value (Fig.6).

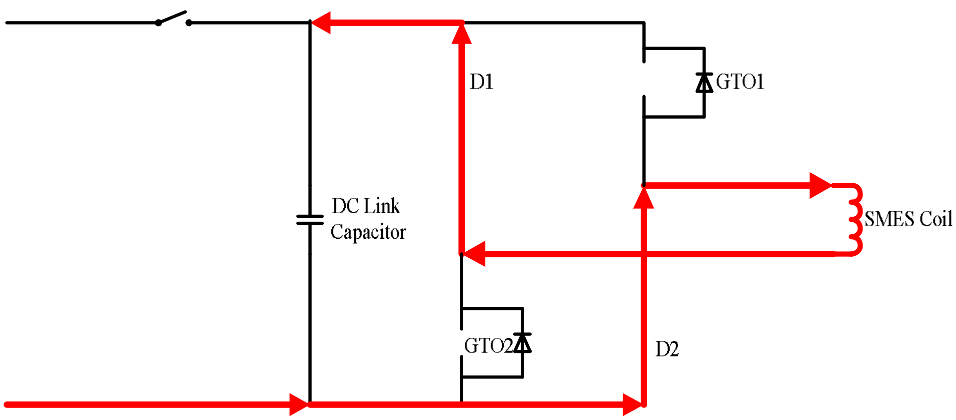

Fig. 6. SMES coil chopper circuit in discharge mode

Since the relationship between the average dc output voltage of the SMES coil voltage intermediate is expressed by (1):

$$V_{SMES} = (1-2d)V_C \tag{1}$$

So where duty cycle d is greater than 0.5 choppers is in the discharged mode and the energy stored in the coil back into the system. Where duty cycle d is smaller than 0.5 he average voltage of SMES is positive and the chopper stay in charge mode. Thus the energy would be given from the system and the current in SMES coil would be increased. If the duty cycle in the d is 0.5 chopper is in the back up mode and no energy transfer system is not performed.

Control scheme for combination compensator

STATCOM control block diagram for the compensator structure is shown in Fig. 7**.** This block diagram described by the load flows differential algebraic equations [9] which conform to STATCOM model of the injected power and involve it in load flow equations [10]. According to this structure, the control parameters (u_d ,u_q) components of the control transient (u_d'' , u_q'') and control components of the steady state (u_d' , u_q') are obtained. Steady control components with large time constant and significant impact is not remarkable [11] in improving power system dynamic behavior so transient components to improve stability and damping fluctuations can have a greater impact. For the steady state, the voltage range compared to a reference voltage STATCOM with PI controller is given to create an appropriate control signal to the output of which is associated with the STATCOM reactive power is added.

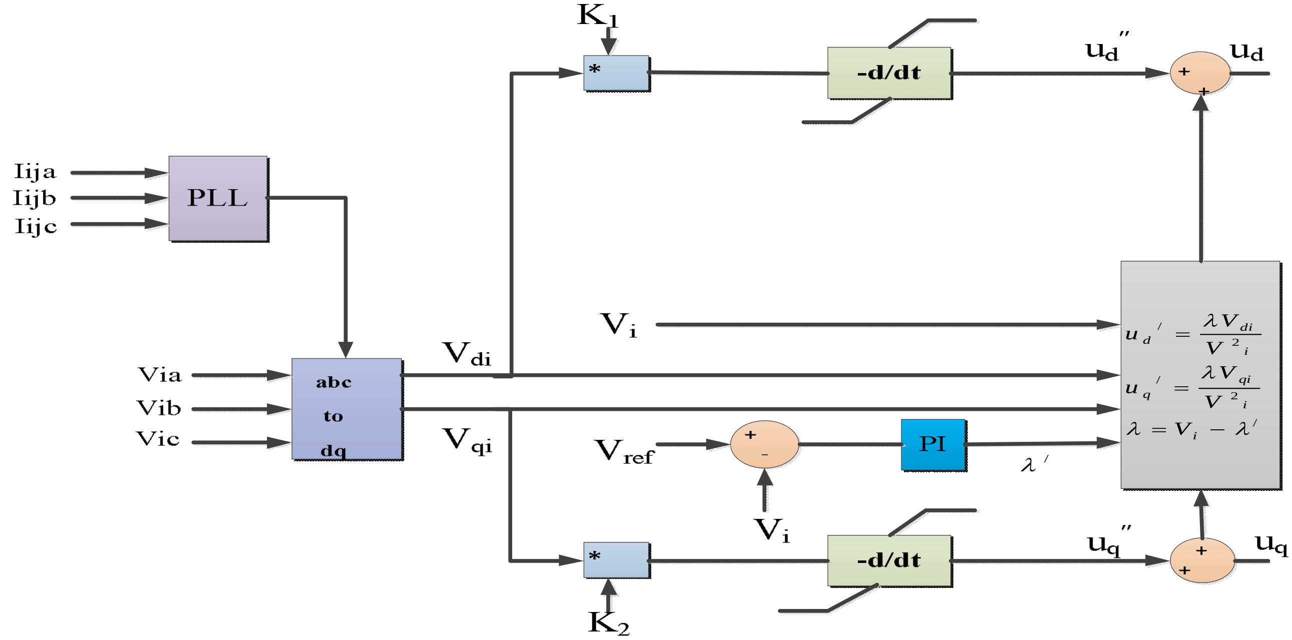

Fig. 7. STATCOM control block diagram

The control circuit of dc-dc chopper, and SMES coil in accordance with the PSCAD software is presented in Fig 8. This is similar to the control scheme described in [8] however changes in the design of the control parameters and to harmonize with the STATCOM controller have occurred. Controlled dc-dc chopper, and SMES coil current of SMES (I_{SMES}) and the dc voltage across the capacitor (dc volt) carried. The SMES coil is charged via a pathway in the control scheme then working cycle of the SMES coil to achieve the desired level of charge is put on the 0.5. Controller in the other direction is planning a new business cycle that controls the voltage across the SMES coil, so the active power is exchanged by the STATCOM. In fact, control design, the relationship between the output dc voltage, medium voltage STATCOM and the SMES coil, making the connection.

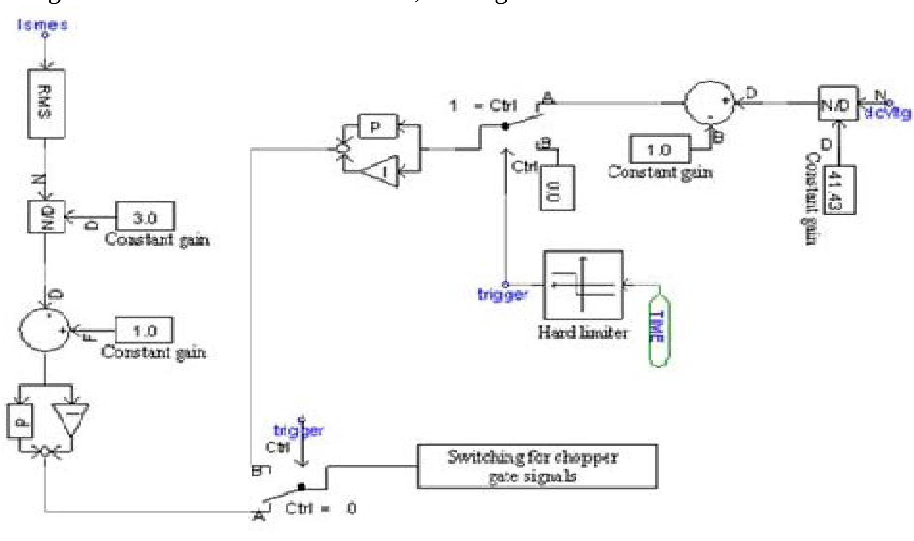

Fig. 8.Control circuit of dc-dc chopper, and SMES coil

SIMULATION

To investigate the behavior of fixed speed wind turbines equipped with induction generator in this sector a wind farm which through the two circuits is connected to a strong network will consider. This scheme is shown in Fig. 9. In this example, double-circuit lines of the circuit are used for manufacturers usually by double-circuit lines are connected to the network.

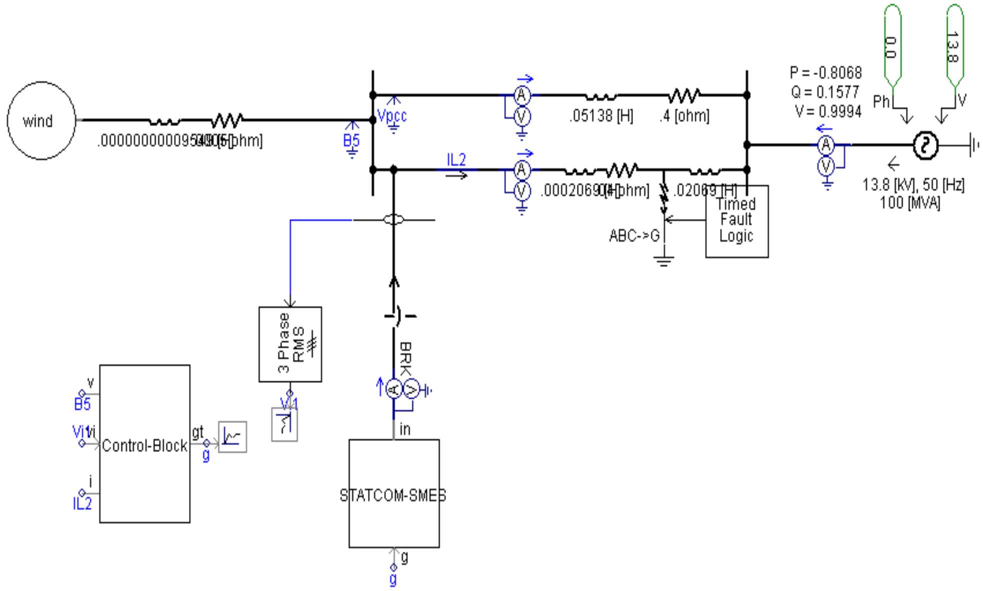

Fig. 9. Simulation of wind power compared with fixed speed STATCOM-SMES

Induction generator with a nominal voltage, 750 KVA and 690 V in the simulation has been used. Stability of induction generator at the plant have been investigated by applying a three phase to ground fault at the time of10 seconds to 0.35 sec in the line of wind power to the infinite bus.

SIMULATION RESULTS

The results of the simulation are presented in following figures. These figures are Terminal voltage generator according Pu, angular speed of generator in terms of Pu, torque generator according Pu, active and reactive powers for wind power plant depending on the MW and MVAR respectively, the current of SMES according to kA and active and reactive powers of energy storage element respectively.

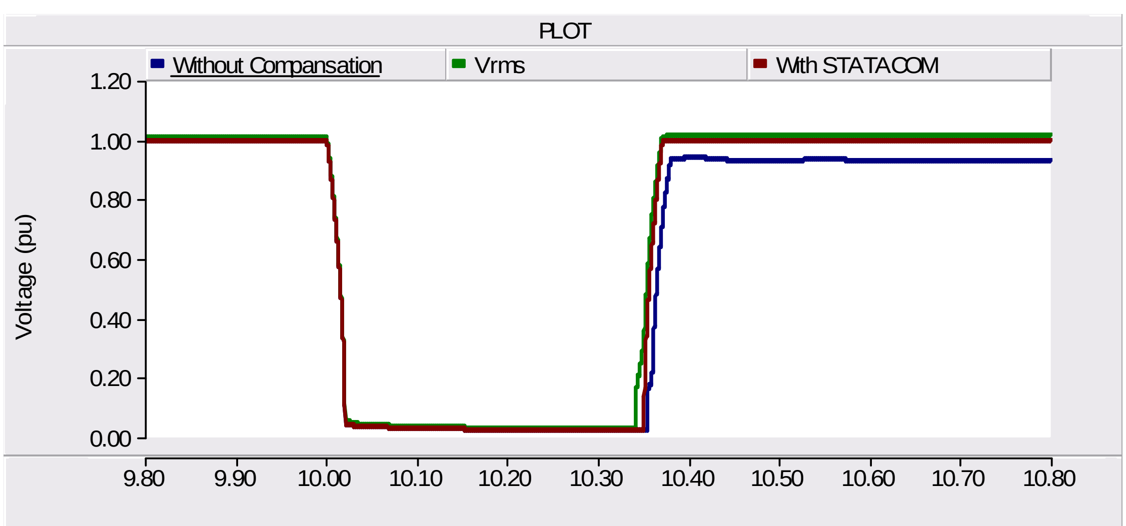

Fig. 10. The voltage of generator terminal

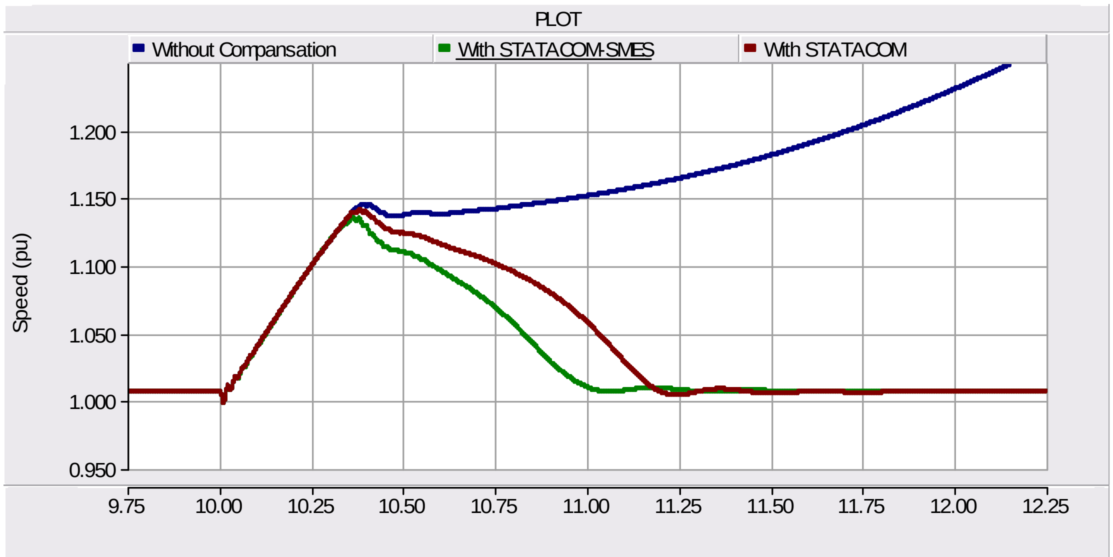

Fig. 11. Angular speed of generator

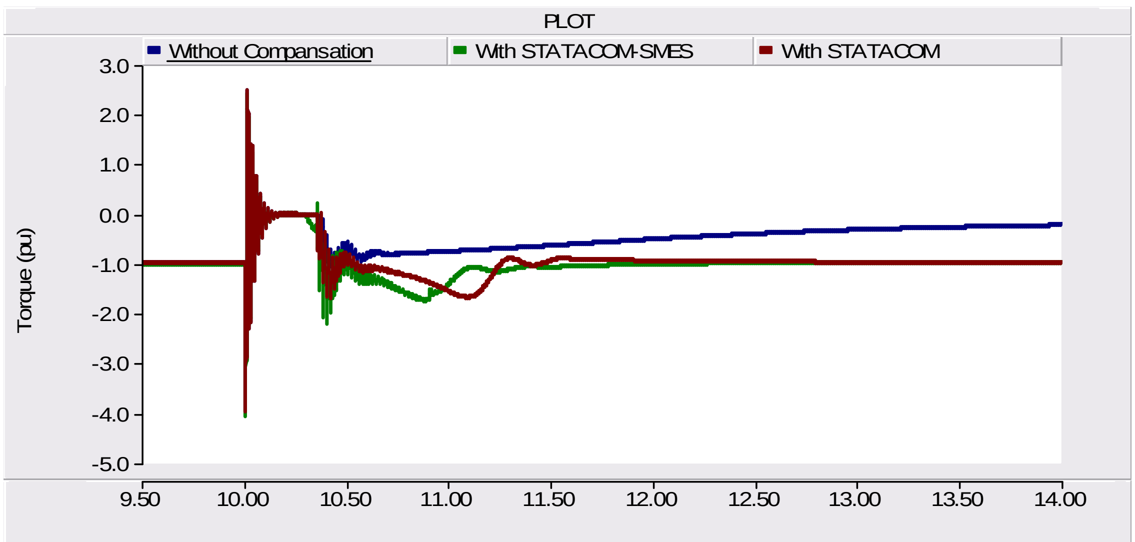

Fig. 12. Torque of generator

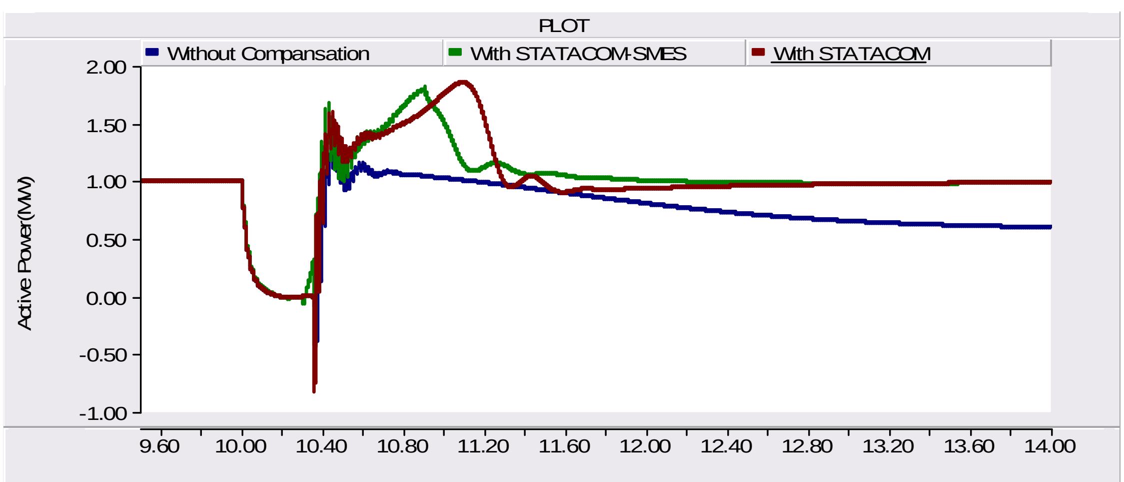

Fig. 13. Active power of the wind power plant

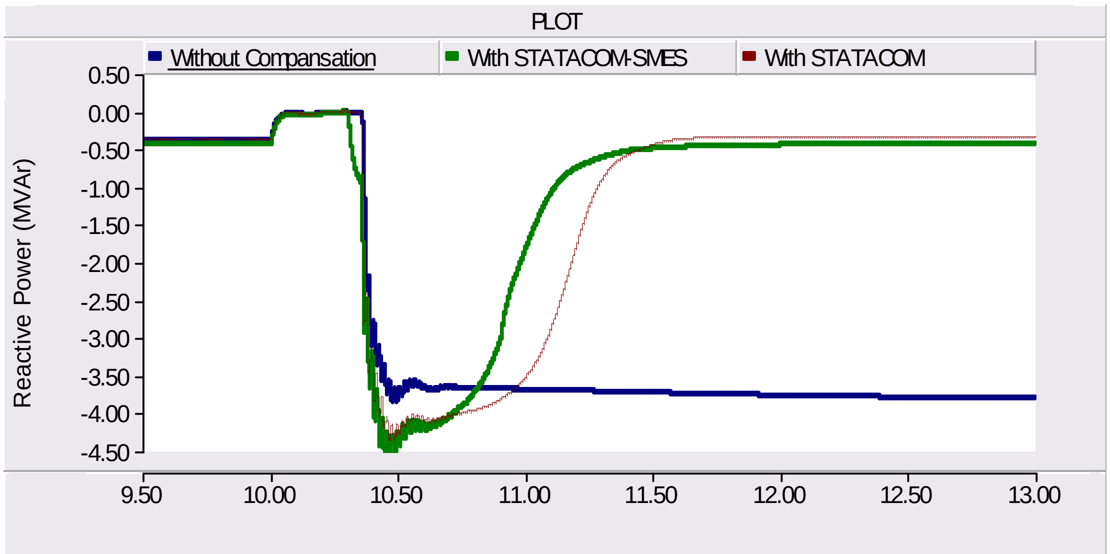

Fig. 14. Reactive power of the wind power plant

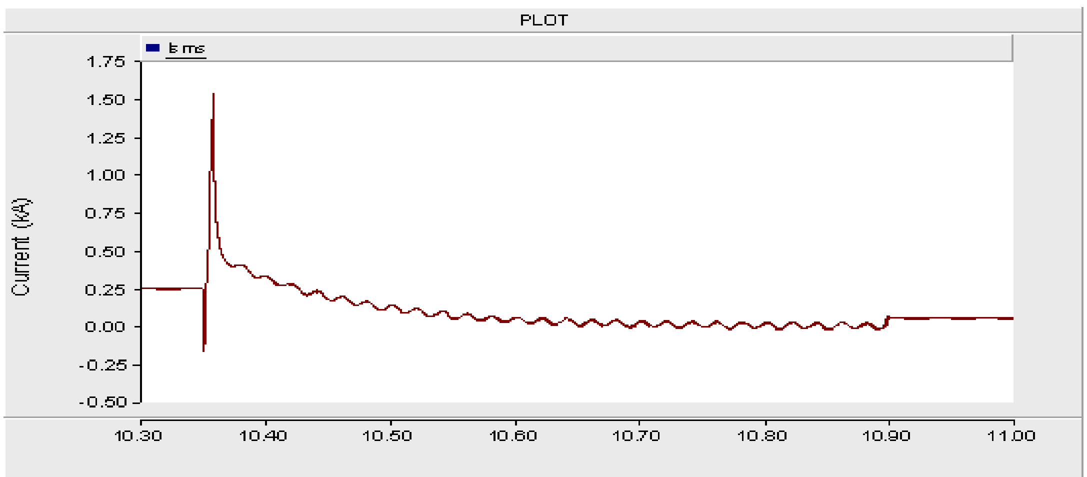

Fig. 15. Current of SMES

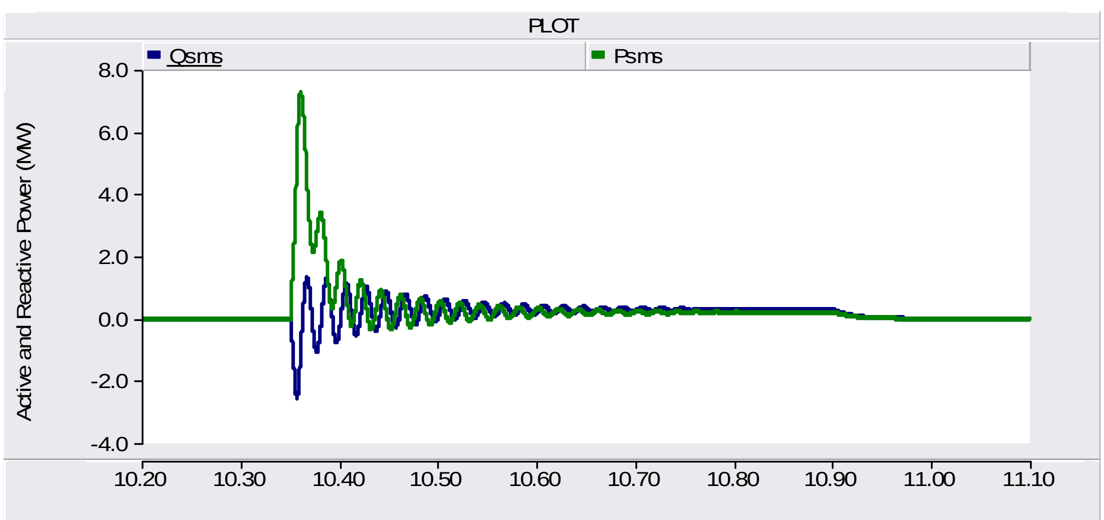

Fig. 16. Active and reactive power of the wind power plant

Results in non-compensated

As it is shown in figures 10, 11 and 13, if an error occurs in the infinite network of lines connecting the wind turbine, generator speed will rise. It is because in this type of generators output is strongly dependent on terminal voltage, so the voltage drop, and power generator manufacturing slump has caused an imbalance between the mechanical and electrical power. This also increases the speed of the generator. At the time the error occurred due to the reduced voltage, active power output and speed of the rotor will start to increase, but reactive power does not change much (Fig.14). After error disappears, due to the extreme stretch ability and high magnetic slip, Reactive power consumption dramatically increases. This process continues until the high speed generator units out of orbit is unstable.

ANALYSIS IN ORDER TO COMPENSATE

As in (Fig. 15) is observed**,** SMES in the power system is increased and get the energy from system thus preventing the accelerant's of generator. After the short circuit Disappear because generator rotates at high speed, reactive power is consumed more and the recovery voltage shall be slowly.

It is obvious in Fig. 14 that reactive power consumption of these types of turbines has gone up drastically after short circuit disappeared, and the network should be able to enrich produce this power. This may lead to instability of low voltage networks. Thus the need for reactive power consumption compared to this type of turbine is clear, especially in short circuit conditions. In this simulation compensated dynamic reactive power by STATCOM static compensator is used. The above forms can clearly see the positive effect of these devices. It is evident from these features that when STATCOM-SMES combination compensator is used in the place that wind power plant connected to the common bus network the errors are caused by fluctuations faster eliminated and thus will increase the overall system damping. In addition it is clear that STATCOM-SMES combination is more flexible than is STATCOM because of its faster response to fluctuations in the damping.

Conclusion

Because there isn't something tangible in power systems to improve the performance of induction generators by energy storage devices, so this paper used STATCOM-SMES combination compared with fixed-speed wind power plants which use the induction generators and analyze the stability of these power factories. In fact, satisfactory performance of STATCOM was compensated using additional energy storage SMES. Thus, by presenting the control scheme for STATCOM control and Controlled dc-dc chopper to charge and discharge SMES coil**,** compensated combined effect in a sample system was studied.

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APPENDIX

TABLEI
Parameters used in simulation

Ht= 1.5 s	**Generator**
Hg= 0.5 s	**P=660 kW**
Capacitor Bank	**Sb=750 kVA**
C=3×1672μF	**V=690 V**
	Rs=0.0518 pu
Transformer	**Xs=0.02 pu**
X=.04 pu	**Rr=0.0156 pu**
Grid	**Xr=0.186 pu**
V=20 kV	**Xm=8 pu**
Ssc=100 MVA	**Turbines Axis**
R=1.24 pu	**K=200 pu**
X=6.16 pu	**Dm=1 pu**
	D1=0.005 pu
	D2=0.005 pu