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Effect of Facts Devices SSSC and STATCOM POD Controller

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Abstract: When integrating to the power system, large wind farms pose stability and control issues. A thorough study is required to identify the potential problems and to develop measures to mitigate them. Although integration of high levels of wind power into an existing transmission system does not require a major redesign, it necessitates additional control and compensating equipment to enable recovery from severe system disturbances.

This thesis investigates the use of a Static Synchronous Compensator (STATCOM) and SSSC along with wind farms for the purpose of stabilizing the grid voltage after grid-side disturbances such as a three phase short circuit fault, temporary trip of a wind turbine and sudden load changes. The DC voltage at individual wind turbine (WT) inverters is also stabilized to facilitate continuous operation of wind turbines during disturbances.

Key Words: - ***STATCOM, Wind turbine, Wind farms.***

I. Introduction

The concern about environmental pollution and energy shortage has led to amplify interest in technologies for the generation of renewable electrical energy. Among various renewable energy sources, wind influence is the mainly rapidly growing in Europe and the United States. The concept of a variable-speed wind turbine (VSWT) equipped with a doubly fed induction producer (DFIG) is getting increasing attention because of its recompense over other wind turbine generator concepts. The Variable frequency converter consists of a rotor-side converter (RSC) and a grid-side converter (GSC) linked back-to-back by a dc-link capacitor. Instability in electrical energy due to disturbances can be control using various FACTS devices.

A. Objective of Thesis:

Relively power compensating electronic devices is one aspect of power electronics revolution that is captivating place in all area of electric energy. FACTS involves conversion and switching power electronics in the range of a few tens to few hundred Mega Watt. For protection of wind farm FACTS devices will inject relively current to support grid electrical energy. When electrical energy sag occurs with rapid response time, which means they will inject current immediately after the fault is cleared.

STATCOM and SSSC are used for relively power compensation. STATCOM is now becoming a predominant new generation device for FACTS, which is used to control electrical energy through relively power reimbursement by either absorbing or generating the relively power into grid. SSSC regulate the flow of lively and immediate power by injecting a convenient capacitive or inductive impedance compensation into a row at the point of connection.

II. Overview Of Wind Power Plant

Now compare the replication results of STATCOM and SSSC using in wind farm prote Wind energy is rising day by day throughout the world. The power of wind has utilized for at least 3000 years. At the beginning of modern industrialization, the use of fluctuating wind energy resource was substituted by the fossil fuel fired engines, which provided more consistent power source.

A. Current Status of wind influence in Power system:

In mainly parts of world wind energy supplies only a small fraction of the total power demand, if there is any wind power production at all. In other region, for example in northern Germany, Denmark or in Swedish island of Gotland, wind energy supplies an ample amount of total energy demand. In German, wind energy supplied around 4200GWh of the total insist of 13353GWh in 2003. And wind power supplied 200GWh of a total system command of 900GWh on the Swedish Island of Gotland.

In future many countries are likely to experience similar penetration levels as wind power is increasingly considered not only a mean to reduce CO_2 emission. The integration of high penetration levels of wind power keen on power system that have originally designed around large scale synchronous generators may require new approaches and solution.

B. Network Integration issues for wind power:

The basic challenge about the network integration of wind power consists of following two aspects:

- How to keep an acceptable electrical energy level of the power structure for all the consumers: customers should able to continue the use of same type of appliances that they are second-hand.
- How to stability the power of the system: that is how can wind power and other generation units continuously meets the consumer's demand.

The integration issues related with wind power are very much dependent on the power system. Therefore, general methods that power method engineers have be applying for a long time can also be useful to the network integration of wind power.

C. The Wind:

The air masses move because of the different thermal conditions of these masses. The motion of these air masses can be a regional as well as local and global phenomenon. A wind turbine utilizes the wind energy which is close to the ground. The wind speed continuously varies as a function of time and height. The time scales of wind variations as a wind frequency spectrum are presented in fig1.1

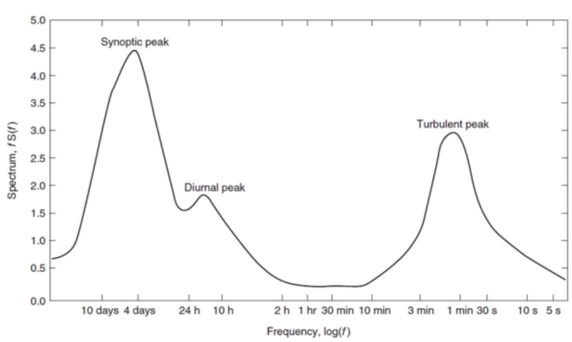

Fig.1.Wind spectrum

III. FACTS OVERVIEW

FACTS stands for supple AC communication system. FACTS controller are defined as power electronics based system provided the manage of one or extra AC transmission parameters.

FACTS parameters are used for many following purposes:

- Power Flow control
- Flicker mitigation
- Power quality improvement
- Stability improvement
- Electrical energy control
- Relively Power compensation.

The use of FACTS controllers provides a smoother process and amplify the lifetime of system compared to the connection devices. FACTS devices are become fast when using semiconductor devices for obtaining maximum benefits.

The mainly interesting for the planners is that FACTS technology opens up with new opportunities for controlling power and as well as for ornamental the capability of the system. Replacement of mechanical switches by the semiconductor switches acceptable much faster response without the need for off-putting number of control actions. FACTS devices are divided into two generations is based on thyristor value while the new uses electrical energy source converters. VSC equipment does not need any bulky reactor, thus size of these procedure is significantly smaller than that of the thyristor proscribed ones. VSC technology also requires use of self-commutating semiconductor dvices which are more expensive and smaller electrical energy ratings compared to the thyristor based technology.

In general, FACTS controller be able to divided into four categories.

- Series controllers.
- Shunt controllers
- Combined series series Controllers

Series Compensation: It works as a convenient electrical energy source. Series inductance exists in all AC transmission rows. In long rows, when a large current flows, this causes a large electrical energy go down.

To compensate, series capacitors are connected, decreasing the effect of inductance. Also by connecting series capacitors in series with rows, the inductive reactance between the receiving end and the sending end will be reduced due to which power factor of system can be improved.

Shunt Compensation: It works as a convenient current source.

- *Shunt Capacitive Compensation*: This method is used to get better the power factor.
- *Shunt Inductive Compensation*: Due to very low, or no load very low current flows through the transmission row. To compensate Ferranti effect due to shunt capacitors, shunt inductors are connected crossways the transmission row.

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IV. OVERVIEW OF STATCOM

STATCOM is shunt connected FACTS controllers. it able to be based on electrical energy sourced converter or current sourced converter. Fig1.2 shows a simple one row diagram of STATCOM base on electrical energy sourced converter and a current sourced converter.

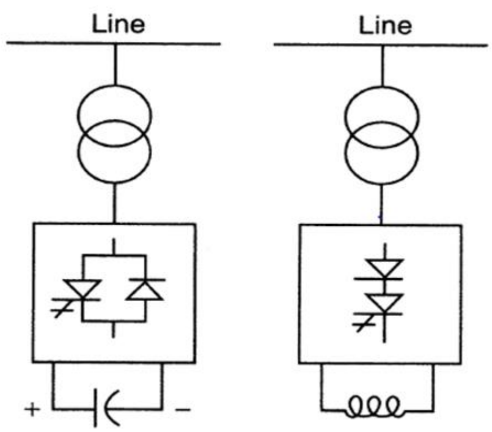

Fig.2. STATCOM Model

A. Overview of Unified Power Flow Controller(UPFC):

The concept of UPFC was future by Gyugi in 1991. UPFC stands for unified power flow controller. UPFC is a mixture of Fixed synchronous compensator (STATCOM) and an inert series compensator (SSSC) which are coupled via common Dc link. For further enhancing the effectiveness of UPFC an additional storage such as a superconducting magnet connect to the dc link via an electronic interface would provide the means of further enhancing the effectiveness of UPFC.

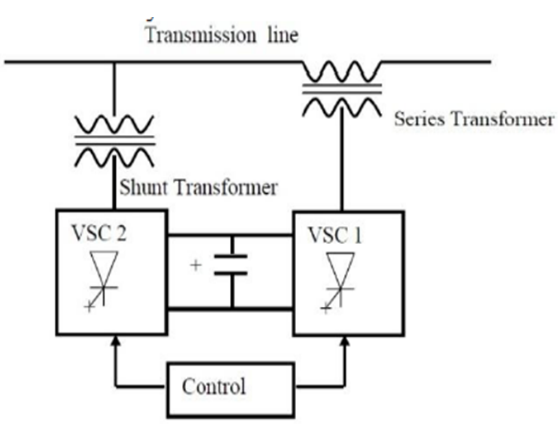

Fig.3. UPFC model

V. WIND ENERGY

Wind is a continuously varying source of energy and so is the lively power generated by the wind turbine. If a WT is connected to a weak grid (which has low short circuit power), the terminal electrical energy also fluctuates, producing flicker, harmonics and inter harmonics due to the presence of power electronics. For a set of connected wind turbines forming a wind farm, there exist certain grid codes or specific requirements with which each wind turbine must conform with in order to be allowed to be connected to the grid. Mainly wind power systems are based in remote rural locations and are therefore prone to electrical energy sags, faults, and unbalances. These unbalanced grid electrical energys can cause many problems such as torque pulsations, unbalanced currents and relively power pulsations. There are many wind turbine manufacturers who produce different wind turbine technologies.

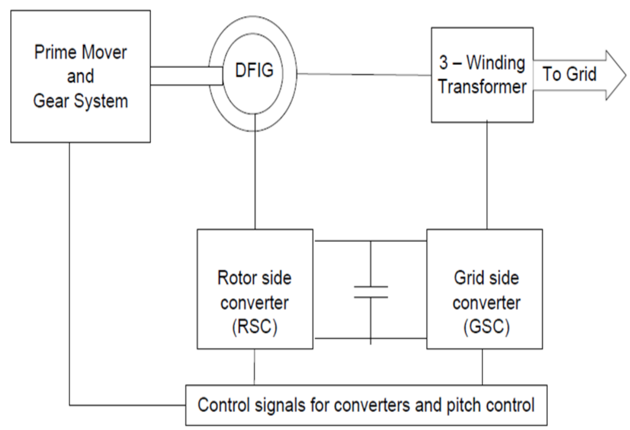

Fig.4. Block diagram of wind Power

A. The control value of wind Power

The control value of wind power considers the capability of wind power to participate in balancing production and consumption in the power system. Since electric power cannot be stored it is necessary to produce exactly as much power as is consumed, all the time. The balancing problem is handled differently depending on the time frame:

B. Primary control

Primary control considers the capability of the power system to keep a balance between production and consumption

C. Multiyear control

Multiyear control is needed in power systems with a large share of hydro power since the inflow is different during different years. This implies that water has to be stored between different years. However, the future inflow is uncertain, which means that it is not trivial to decide how much water should be stored, and having knowledge regarding this uncertainty is desirable from second to second up to about a minute.

D. An Overview of Electrical Faults in Wind Far Systems:

The economic perspective plays a major role, in which the enormous cost pressures usually coerce the wind farm designers for economic causes to remarkably reduce the utilized protection schemes. As reported by Bauscke et al. in different levels of damage were recorded resulting occasionally from the drawbacks of the associated protection system. As a result, wind farm providers still utilize simple and none-integrated protection methodologies.

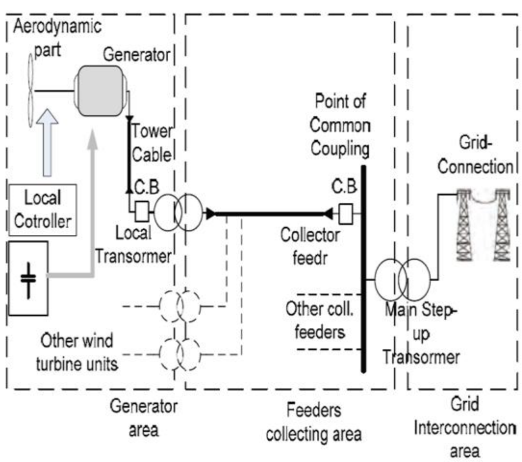

Fig.5. Typical wind farm construction with its protection zones.

E. Wind power in future power systems:

Large-scale wind power still lies in the future for many countries. There are long-term trends that can influence the impact of wind power on the system. If there are large amounts of intermittent energy sources in the system, new capacity with lower investment costs (and higher fuel costs) will be favors. The trend of increasing distributed generation from flexible gas turbines is beneficial for the integration of wind power, as is increasing load management

F. Operation of SSSC and the Control of Power Flow Description:

The schematic of a SSSC is shown in Fig. 4.1(a). The equivalent circuit of the SSSC is shown in Fig. 4.1(b). The magnitude of VC can be controlled to regulate power flow. The winding resistance and leakage reactance of the connecting transformer appear is series with the electrical energy source VC. If there is no energy source on

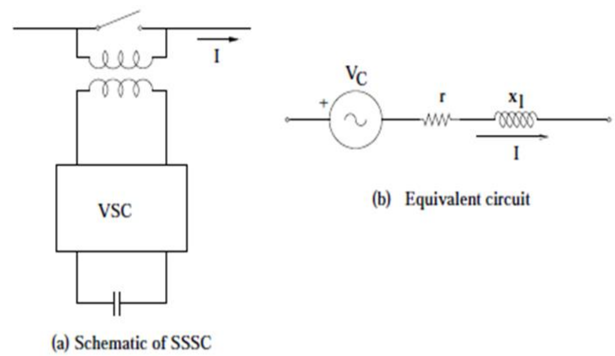

Fig.6. Schematic of SSSC

the DC side, neglecting losses in the converter and DC capacitor, the power balance in steady state leads to

$$Re[V_C I^*] = 0$$

The above equation shows that VC is in quadrature with I. If VC lags I by 90±, the operating mode is capacitive and the current (magnitude) in the row is amplified with resultant amplify in power flow. On the other hand, if VC leads I by 90±, the operating mode is inductive, and the row current is decreased. Note that we are assuming the injected electrical energy is sinusoidal (neglecting harmonics). Since the losses are always present, the phase shift between I and VC is less than 90± (in steady state). In general, we can write

$$\begin{aligned}\hat{V}_C &= V_C(\cos\gamma - j\sin\gamma)e^{j\phi} \\ &= (V_{Cp} - jV_{Cr})e^{j\phi}\end{aligned}$$

where Φ is the phase angle of the row current, γ is the angle by which $\hat{V}_C$ lags the current. VCp and VCr are the in-phase and quadrature components of the injected electrical energy (with reference to the row current). We can also term them as lively (or real) and relively components. The real component is required to meet the losses in the converter and the DC capacitor. We use the convention that the relively electrical energy lagging the current by 90± as positive (Note that for a SVC or STATCOM, we used the convention of lagging relively current as positive.) According to this convention, the positive relively electrical energy implies capacitive mode of operation while negative relively electrical energy implies

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inductive mode of operation. Since Φ is close to ±90º, we can write

$$\gamma = sgn(V_{Cr})[-90^\circ + \alpha^\circ]$$

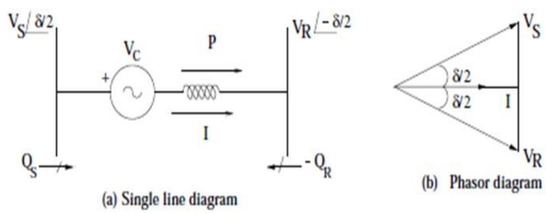

Fig.7. Representation of SSSC in a transmission row

where sgn(.) indicates the signum function whose value is +1 if the argument is positive and +1 if the argument is negative. we can write,

$$V_{Cp} = V_C \sin\alpha, \quad V_{Cr} = V_C \cos\alpha$$

Since the losses are expected to be small (typically below 1%) the magnitude of VCp is very small and may be neglected to simplify the analysis. VCp will vary during a transient to amplify or decrease the electrical energy crossways the DC capacitor (particularly in the case of type 2 converter where the ratio between the AC electrical energy and the DC capacitor electrical energy is constant, with no modulation).

G. Modeling of SSSC

Neglecting harmonics, we can express the system equations (including SSSC) in D {Q variables (referred to a synchronously rotating axis). The advantage of using these variables is that in steady state, the D {Q components are constants and can be expressed as rectangular coordinates of phasors. For stability studies involving phenomena of frequency below 5 Hz, it is adequate to express the network equations using phasors by neglecting network transients. However, for phenomena involving higher frequencies, one cannot ignore network transients (even for studies involving sub synchronous frequency oscillations). We can illustrate the derivation of the network equations by considering the single row containing a SSSC shown in

Fig. 7.2. Neglecting, zero sequence components, we can express the network equations (using two phase variables, α and β) in the complex form given below

$$L\frac{d\hat{i}}{dt} + R\hat{i} = \hat{v}_S - \hat{v}_C - \hat{v}_R$$

where

$$\hat{i} = (i_\beta + j i_\alpha), \quad \hat{v}_S = v_{S\beta} + j v_{S\alpha},$$
$$\hat{v}_C = v_{C\beta} + j v_{C\alpha}, \quad \hat{v}_R = v_{R\beta} + j v_{R\alpha},$$

Transforming from α, β to $D-Q$ components which are related as,

$$\begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} = \begin{bmatrix} \cos\theta & \sin\theta \\ -\sin\theta & \cos\theta \end{bmatrix} \begin{bmatrix} i_D \\ i_Q \end{bmatrix}$$

where μ = !0t+μ0. There is no loss of generality in assuming μ0 = 0. Similar transformation as given above applies to the variables VSα; VSβ and VSD; VSQ and so on.

We can also express as a complex equation given below.

$$(i_\beta + j i_\alpha) = (i_Q + j i_D)e^{j\omega_0 t} = \hat{I}e^{j\omega_0 t}$$

latter can be expressed as

$$L\frac{d(\hat{I}e^{j\omega_0 t})}{dt} + R(\hat{I}e^{j\omega_0 t}) = (\hat{V}_S - \hat{V}_C - \hat{V}_R)e^{j\omega_0 t}$$

Simplifying, we get,

$$L\frac{d\hat{I}}{dt} + j\omega_0 L\hat{I} + R\hat{I} = \hat{V}_S - \hat{V}_C - \hat{V}_R$$

where

$$\hat{I} = I_Q + jI_D, \quad \hat{V}_S = V_{SQ} + jV_{SD}, \quad \hat{V}_C = V_{CQ} + jV_{CD},$$
$$\hat{V}_R = V_{RQ} + jV_{RD}$$

In steady state, $\hat{I}$ is a constant and $\frac{d\hat{I}}{dt} = 0$. Hence, we get (in steady state),

$$(R + j\omega_0 L)\hat{I} = \hat{V}_S - \hat{V}_C - \hat{V}_R$$

H. Impact of STATCOM on Relay Protection System

In this thesis, MATLAB/Simulink based wind farm protection under three phase fault will be analysed. Fig.3. shows STATCOM based simulink and network modeling of the integration of wind farm with grid system. The faults is initialed at t =15s. To analyses the effect of of STATCOM on system, STATCOM must be disabled manually. Fig.4. shows results of electrical energy profile from wind farm to grid and power system during disabled STATCOM. From Fig. 4 it is observed in absence of support for relively power, electrical energy at grid will go down ped below 0.9 p. u. due to which relay trips at t=13.43s by the AC over current protection. For the comparison, when STATCOM enabled Fig.5. shows results. From Fig.5, we can observe during electrical energy sag, relively power compensation, the system electrical energy near to 1.0 p. u., which controls stability in the system during disturbances. The relay will trip at t=15.11s by the under electrical energy protection from turbine unit. From the above two cases, we can say that using STATCOM, electrical energy level could be maintained, and the relay can function well.

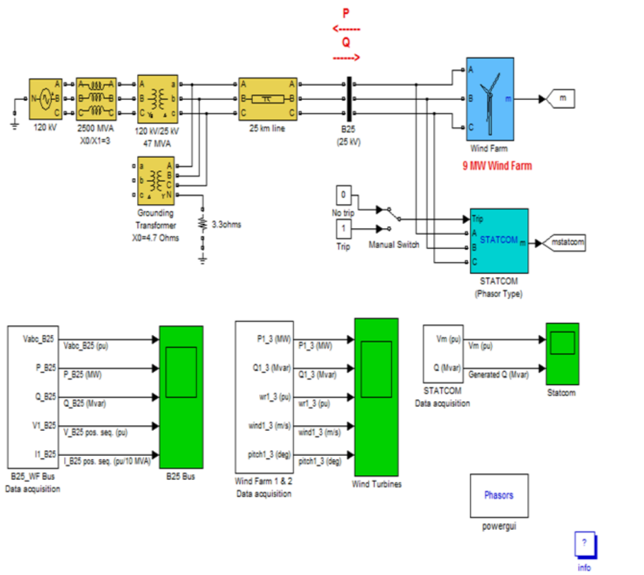

Fig. 8. Network modeling of case study for STATCOM with wind farm

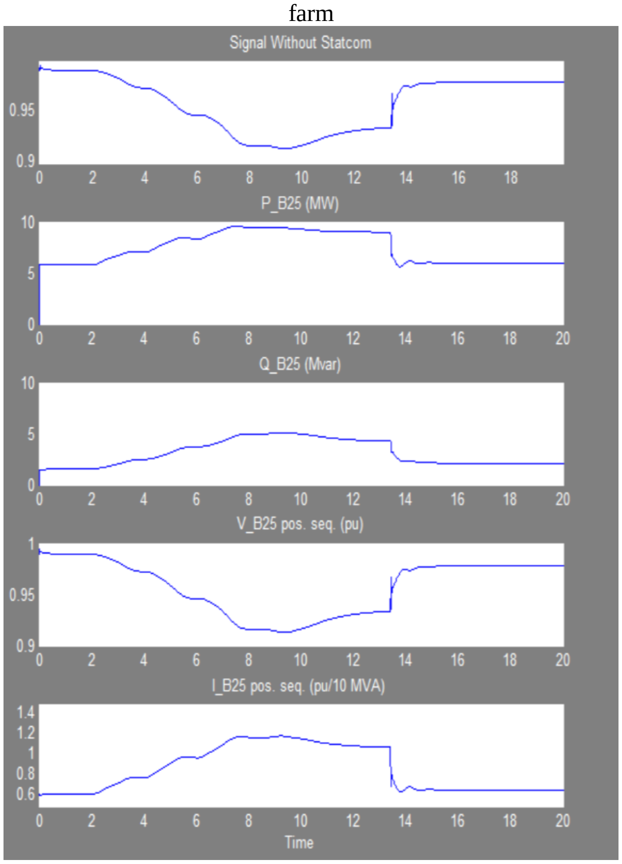

Fig.9. Case study result for system without STATCOM

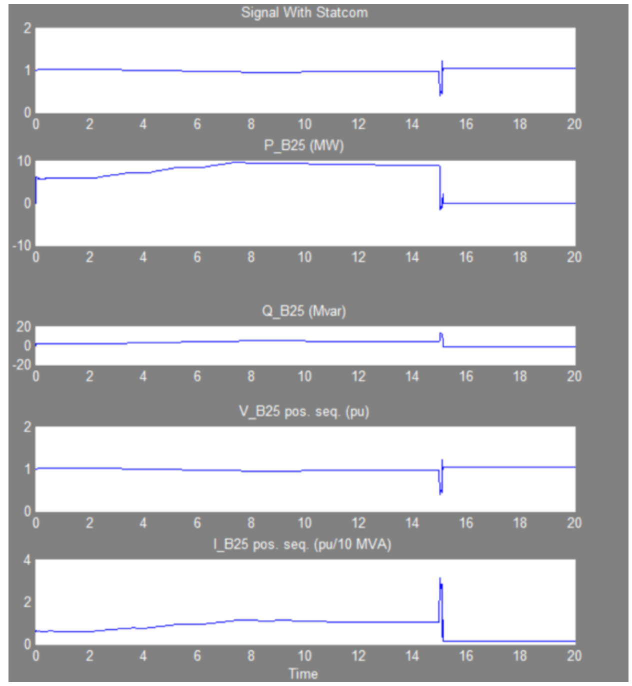

Fig. 5.3. Case study with STATCOM

VI. Conclusion And Future Scope

Power system with wind farms performance can be improved using FACTS devices such as STATCOM and SSSC. The dynamic model of the studied power system is simulated using Simulink Matlab package software. To validate the effect of the STATCOM and SSSC controller of power system operation, the system is subjected to different disturbances such as faults and power operating conditions. The digital results prove the powerful of the proposed STATCOM and SSSC controller in terms of Stability improvement, power swings damping, electrical energy regulation, and an amplify of power transmission and chiefly as a supplier of convenient relively power to accelerate electrical energy recovery after fault occurrence.

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