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Power System Transient Stability Enhancement by Coordinated Control of SMES, SFCL & UPFC

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***Abstract*—**Transient stability is the ability of the power system to remain in synchronism when subjected to a large disturbance. It is well known that the Superconducting Magnetic Energy Storage (SMES) is effective to damp the power swing after the occurrence of faults. But, if SMES is used for achieving high stabilizing effect, a large power capacity of SMES is required. Additionally, the SMES is not able to absorb enough energy during faults since the bus voltage where the SMES is installed, drops considerably. To enhance the SMES control effect and transient stability, this paper proposes the coordinated control of the optimized resistive type superconducting fault current limiter (SFCL) and SMES. When the fault occurs, the SFCL rapidly suppresses the transient power swing by limiting the fault current. When the short circuit occurs, the SFCL absorbs the generator accelerating power and supports the SMES to stabilize the power swing. By incorporating UPFC along with this arrangement, robust power system stabilization is achieved.

This paper presents the coordinated control of resistive type SFCL , SMES and UPFC for an improvement of power system transient stability. Nonlinear simulation study in a single machine infinite bus system shows that the control effect of the coordinated SFCL, SMES and UPFC is much superior to that of the individual SFCL, SMES or UPFC.

Keywords — SMES, SFCL, UPFC, Transient stability, Power quality

1. INTRODUCTION

Transient stability is concerned with the ability of power system to maintain synchronism when subjected to a severe disturbance such as a fault on transmission facilities, loss of generation, or loss of a large load. The system response to such disturbances involves large excursions of generator rotor angles, power flows, bus voltages and other system variables. Stability is influenced by the non- linear characteristics of power system. If the resulting angular separation between the machines in the system remains within certain bounds, the system maintains synchronism. Loss of synchronism because of transient stability, if it occurs, will usually evident within 2 or 3 seconds of initial disturbance.

SMES has the capability to improve transient as well as dynamic stability of power systems and to increase system damping. It can also be used to suppress any sub synchronousresonances**.** One of the assets of an SMES coil is that it can release large quantities of power within a fraction of a cycle, and fly recharge in just minutes. This quick, high-power response is very efficient and economical. So, for transient stability enhancement, an SMES unit which is able to swiftly exchange active and reactive powers with the power system can be used.

Superconducting fault current limiters can be used for resolving the voltage drop problem during fault condition by suppressing the fault current within the first half cycle of fault current. To enhance the SMES control effect and transient stability, the coordinated control of resistive SFCL and SMES is proposed. By incorporating UPFC into the coordinated SFCL-SMES device, transient stability can be further improved..

This attempt is an investigation to model a single machine infinite bus system installed with SMES,SFCL& UPFC for transient stability enhancement using MATLAB.SMES is modeled & inserted at the generator terminal. SFCL is placed

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in series with the transmission line. Then, UPFC is modeled and connected in transmission line. This paper also propose to analyse the transient stability improvement with the coordinated control of SMES, SFCL & UPFC

Chapter 2 describes about the study system and its modeling. Chapter 3 discusses about the results. Chapter 4 mention about future scope of the paper. Finally.

2. STUDY SYSTEM & MODELING

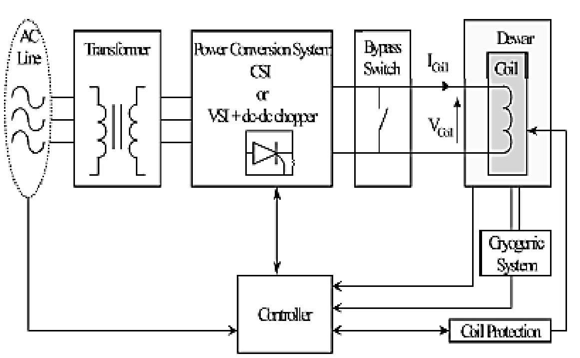

Fig. 1: Schematic Diagram of typical SMES unit

Single Machine Infinite bus system consist of a 3 phase salient pole machine of 1000 MVA, 13.8 KV,3600 rpm at 60Hz. The prime mover used is a non-linear hydraulic turbine with PID governor and a servomotor. The transformer is a 3 phase 2 winding transformer of rating 13.8/500 KV. The most severe 3 phase fault is applied at the infinite bus at time t=1s for 150 ms.

Power system oscillations may arise due to line faults, bus bar faults or load changes. If the system has no adequate damping, these oscillations may cause the system to become unstable leading to severe damages [2]. One of the solutions to increase system damping is the use of an electrical storage unitsuch as Battery Energy Storage Systems (BESS), Compressed Air Energy Storage (CAES), Flywheel Energy Storage PES) and Superconducting Magnetic Energy Storage (SMES) . Batteries are constrained by their load cycles and rotating masses by their capacity. Some of the disadvantages of BESS include limited life cycle, voltage and current limitations, and potential environmental hazards. Again, some of the disadvantages of pumped hydroelectric are large unit sizes, topographic and environmental limitations Owing to the substantial development of high temperature superconducting materials application of superconductors has become an important issue in electrical engineering.

SMES systems have the capability of storing energy in their low resistance coils. The SMES unit can be controlled to give both the active and reactive power modulations. Active power and/or reactive power can be absorbed (charging mode) by or released (discharging mode) from the unit according the system requirements. The amount of energy to be supplied or received by the SMES unit can be controlled via controlling the firing angles of the converters of the SMES unit.

A superconducting fault current limiter (SFCL) is expected to be an ultimate automatic protection system against short circuit faults. A superconducting cable and superconducting transformer also expected to contribute to the system efficiency and stability.

The SFCL assembled with a high impedance devise such as a resistor or a reactor is expected to be a strategiccountermeasure to protect huge interconnected power system from large fault circuits. Here: a resistor based SFCL which is capable of quickly consuming the active power is applied to the enhancement of power system transient stability by absorbing the exceeding accelerating generator power. The resistor connected in series with a transmission line can effectively absorb energy during a short circuit It absolutely surpasses the conventional shunt-damping resistor, which is not able to absorb enough power during the short circuit.

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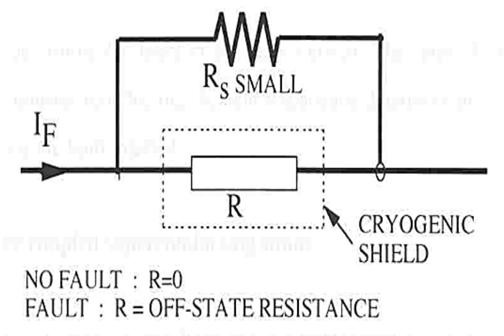

Fig. 2: Resistive Superconducting Fault current Limiter

The resistive type SFCL is expressed by a time-variant resistance depending on the quenching characteristic as [6]

$$\boldsymbol{R_{sfcl}}(\mathbf{t}) = \boldsymbol{R_m}\left(\mathbf{1} - \mathbf{exp}\left(-t/_{Tsc}\right)\right) \tag{1}$$

where, $\boldsymbol{R_m}$ is the optimized resistance of SFCL, $\boldsymbol{Tsc}$ is the time constant of SFCL during transition from the superconducting state to the quenching state, which is assumed to be 1 ms. The value of $\boldsymbol{R_m}$ is zero in the steady state. When a three-phase fault occurs, the resistance of SFCL immediately increases to with the relation in (1). After the fault is cleared, $\boldsymbol{R_m}$ exponentially decreases to zero.

In a three-phase power system, each phase of the SFCL must be modeled independently because they will operate independently, particularly during unbalanced primary system faults, which represent the predominant mode of fault in power distribution systems (particularly in overhead systems) [5].

To improve the control performance of SMES, the resistive type superconducting fault current limiter (SFCL) has been applied. When the short circuit occurs, the SFCL absorbs the generator accelerating power and supports the SMES to stabilize the power swing. SFCL assembled with a series resistor act as a powerful controller for transient stability enhancement of power system as well as current limiter. So, the application of SFCL combined with the SMES for power system stabilization is of proper significance.

3. RESULTS

A single machine infinite bus system in which the most severe 3 phase fault is applied. This will cause severe oscillations in generator rotor speed & voltage.

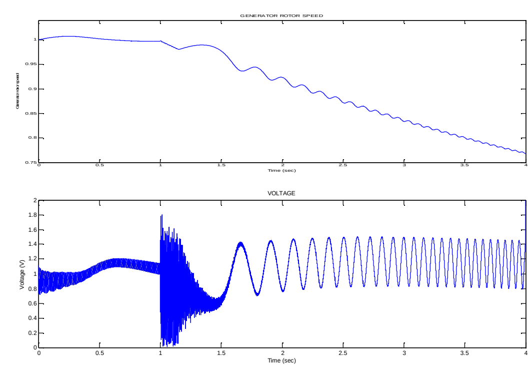

Fig. 3: Generator rotor speed & voltage of a faulted system

In order to stabilize the system, an SMES unit is installed at the generator terminal .This will absorb the generator accelerating power and try to stabilize the system.

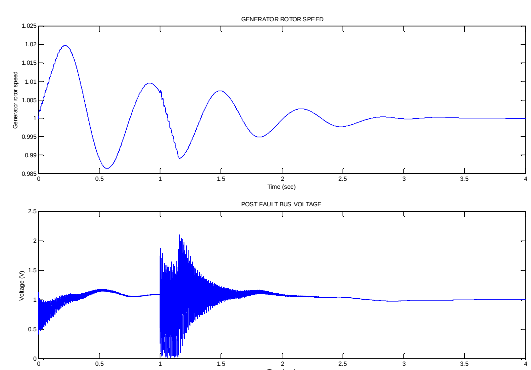

Fig. 5: Generator rotor speed & voltage of a faulted system with SMES

One of the problem in using the SMES unit is that it will require a large converter capacity. So, to enhance the stabilizing effect, an SFCL is also incorporated. It is connected in series with the transmission line.

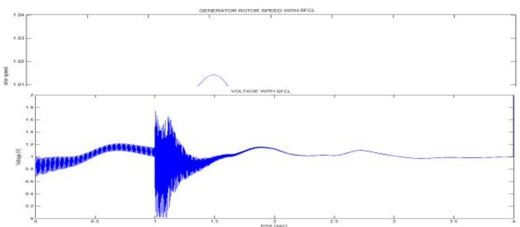

Fig. 5: Generator rotor speed & voltage of a faulted system with SFCL

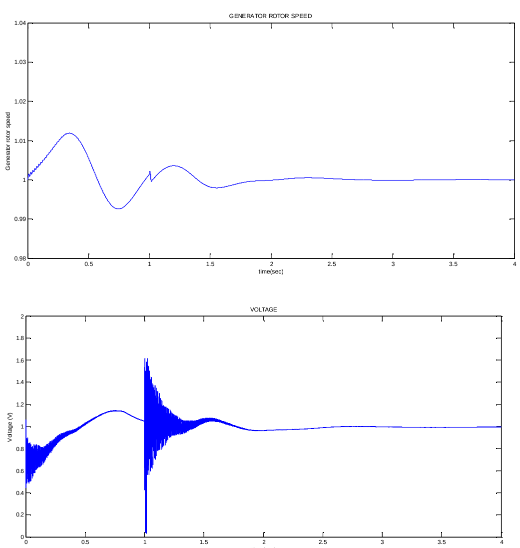

Fig. 6: Generator rotor speed & voltage of a faulted system with SMES & SFCL

Oscillations due to line faults can be minimized by the use of UPFC along with the coordinated control of SMES & SFCL.

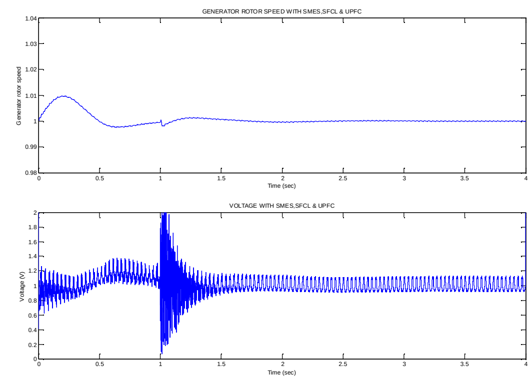

Fig. 7: Generator rotor speed & voltage of a faulted system with SMES ,SFCL& UPFC

For no SFCL & SMES, generator speed severely oscillates and the system is unstable. On the other hand, the oscillation can be eliminated in case of only SMES and SMES & SFCL. The stabilizing effect of SMES & SFCL is much superior to that of SMES or SFCL individually.

With no stabilizing devices, it fails to damp the oscillations. But in case of only SMES, the system tend to stable after 3 seconds. On the contrary, SFCL&SMES are able to suppress the oscillation quickly. The SFCL not only solves the voltage problem, but also assist the SMES to stabilize the system. Here, stability is obtained at 2.5 seconds. The SMES, SFCL & UPFC can stabilize the system robustly. Here, stability is attained at t=1.5 seconds.

4. FUTURE SCOPE

This work proposes a method to enhance the transient stability of an SMIB system during a most severe 3 phase fault. The stability enhancement can be done in a multi machine system by performing the same simulation over the test system. In this scenario, for want of better stabilizing

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effect, each device can be optimally placed and stability enhancement can be proved.

5.CONCLUSION

This paper focuses on the coordinated control of SMES, SFCL and UPFC.SFCL is able to support the voltage at SMES bus during faults and support SMES to stabilize the system. The incorporation of UPFC enables robust stabilizing effect. The superior merits of coordinated control of SMES,SFCL and UPFC such as stabilizing effect and significant reduction of converter capacity are confirmed. So, we can say that this coordinated control can be used as a smart stabilizing device for future power system.

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