Co-Ordinated Control Of UPFC With SFCL And SMES In A Power Distribution Network With DG

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Abstract

. System stability and protection from any disturbances are significant problems in power system especially in a Distribution system with Dispersed Generation. UPFC (Unified Power Flow Controller) is the most powerful FACTS devices, it can vary the parameter values quickly so that it can control the power flow. Superconductivity is expected to be a powerful controller to stabilize and protect the power systems. Superconducting Magnetic Energy Storage (SMES) is effective to damp the power swing after the occurrence of faults. To enhance the SMES control effect and transient stability, this project proposes the coordinated control of the optimized resistive type superconducting fault current limiter (SFCL) and UPFC, SMES as the storage device. In UPFC, the DC side of the two DC-AC converters adopts capacitor as support elements. Since the stored energy of the capacitor is limited, it can only continuously inject into the system or absorb reactive power from the system, but cannot provide active power compensation for a long time to the system Super conductor magnetic storage system (SMES) was applied, to address the problems of intermittence of wind power output and instability of power supply. The system contains SFCL and SMES which can damp out most of the power oscillations. Here, UPFC is used to smooth out the power output. Since we have SMES, the overall size required for the capacitor in UPFC can be decreased (as SMES can supply most of the power output) and the system performance improves a lot which is validated by modeling the system with UPFC, SFCL and SMES in MATLAB and the simulation results are obtained from the MATLAB/SIMULINK for a power distribution network with Dispersed Generation.

1. Introduction

Protection is a pre requisite for any power system network for its proper and continuous functioning. With the increased awareness for the energy problem such as the environmental pollution and the global warming, the efforts to utilize the renewable energy such as wind power and solar cell effectively have been made. In addition, the environmental limitation of the generating plant and the efficient supply of the electric power have promoted the introduction of the Dispersed Generation (DG) using renewable energy in a power distribution system. However, introduction of numerous DGs with larger capacity has been to cause the increase of the short-circuit current. Distributed or Dispersed Generation may be from different sources such as wind, solar, fuel cell etc. Generation Presence of DG in a power distribution network will increase the fault current level even more than that without DG. So an effective protection system is essential. Superconductivity is expected to be a powerful controller to stabilize and protect the power systems.

2. Related Works

A systematic analysis of SMES is used for different tasks. SMES can be used for protection, and for damping of power swing and frequency oscillations. Application of a Superconducting Fault Current Limiter (SFCL) is to enhance the power system transient stability. The SFCL is combined with the Superconducting Magnetic Energy Storage (SMES) for power system stabilization [9]. The SMES compensates for the amount of consumed active power by the SFCL resistor to suppress the generator acceleration during a short circuit.

The resistive SFCL is a power device that uses a property called quenching to reduce the sudden fault current to a certain level. Quenching is a phenomenon in which superconductivity is lost, and the resistive SFCL uses quenching due to the over current. The transient stability of a power system can be improved by using a resistive superconductive fault current limiter (SFCL) based on the direct method. To construct the transient energy function (TEF) of the resistive SFCL with overall system, the structure-preserved model can be used as a network model with a simple resistive model for the resistive SFCL. The optimum size and location of SFCL can be calculated as in [10]. In UPFC, the stored energy of the capacitor is limited, it can only continuously inject into the system or absorb reactive power from the system, but cannot provide active power compensation for a long time[12].

The oscillation can be eliminated in case of only SMES, only SFCL, and SFCL & SMES. Nevertheless, the stabilizing effect of SFCL & SMES is much superior to that of the individual device. Additionally, the SMES bus voltage in case of only SMES and SFCL & SMES can be maintained in the constraint even the fault takes place near the generator; the SFCL & SMES can damp the oscillation while only SFCL or only SMES completely fails to stabilize the system. The MW capacity is defined by the maximum power output of SMES while the MJ capacity is defined by the difference between the maximum and minimum energy levels. The necessary MW and MJ capacities of SMES are considerably reduced when the SMES is operated with the SFCL. [9]

3. Aim

When a fault occurs in a power distribution network, it will damage the loads connected to it and the system itself. If dispersed generation is also connected to this, it become even dangerous. An effective protection system for a power distribution system with DG is the aim of this project.

4. Study System

In this project the devices used for improving power system stability and protection are

- Superconducting Magnetic Energy Storage (SMES)
- Superconducting Fault Current Limiter (SFCL)
- Unified Power Flow Controllers(UPFC)

For the formation of DG, fuel cell and wind energy is used.

The SFCL is an innovative energy-technology appliance, which prevents the incidence of high fault currents in electricity grids.

Superconducting Fault Current Limiters are described as being in one of two major categories-resistive or inductive.

Suppose an SFCL (Resistive type) is connected in series with the circuit to be protected. Under normal line current it has zero resistance and when its temperature increases or fault current flows, its superconductive property will be lost and acts as a high impedance source reducing the fault current. There are both ac and dc type of SFCL. When AC type of SFCL is used, superconducting hysteresis losses may occur. This can be controlled by cryogenic study

Inductive Fault Current Limiters come in many design types. A transformer with a short circuited superconducting coil as the secondary is the simplest SFCL form. Under normal condition, there is no resistance in the secondary and so the inductance of the device is very low. But when a fault current quenches the superconductor, the secondary becomes resistive and the inductance of the whole device rises. The advantage of this design is that there is no heat that enters into the superconductor, and so the load on cryogenic system may be lower. On the other hand, the large amount of iron required for inductive SFCL shows that inductive SFCLs are much bigger and weighs more than resistive FCLs.

In this project, SFCL (Resistive type) and SMES are modelled using MATLAB/SIMULINK. SFCL working principle is as follows: Under normal condition, there is no excess current flow. So it will not provide any resistance to flow. When a short circuit fault occurs, and when SFCL's calculated current value exceeds its reference value, then it will provide a very high resistance to the flow of current and thus limits the current. When a sudden power dip occurs in a power system, SMES has the ability to supply power so as to protect the power system from a condition such as an open circuit fault. Thus SFCL has the ability to decrease the accelerating power and SMES has the ability to prevent the decelerating power.

In the basic system model, DG is formed using fuel cell and wind energy. Then this is connected to the infinite bus power grid through a transmission line. SFCL and SMES is introduced and their performance is analysed

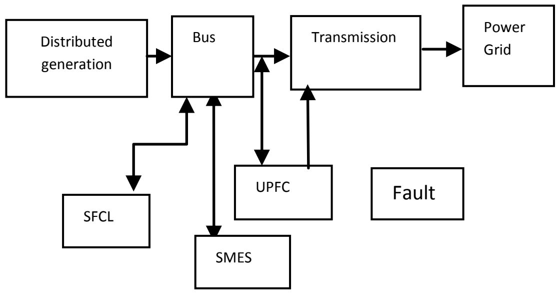

Fig 1. Block diagram representation of system model

5. SFCL model

The SFCL model is developed in Simulink/Sim-Power System. The SFCL model works as follows: Its first step is to calculate the rms value of the current passing through it and then it is compared with the reference values given in the characteristic table. Second, if the calculated value of current is larger than the triggering current level, SFCL's resistance increases to maximum impedance level in a pre-defined response time. Finally, when the current level falls below the triggering current level the system waits until the recovery time and then goes into normal state.

6. SMES model

A Superconducting Magnetic Energy Storage System (SMES) consists of a high inductance coil emulating a constant current source. Such a SMES system, when connected to a power system, is able to absorb or inject active and reactive power into or from a system. By varying the duty cycle of the power semiconducting devices in the circuit, we can control the active power injected into the system during the discharge of the coil. The output of the voltage converter can be varied to obtain necessary reactive power. Once the superconducting coil is charged, the current will not decay and the magnetic energy can be stored indefinitely. The SMES stores energy from the connected system and can be released back to the network by discharging the coil.

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Generally, the magnetic energy stored by a coil carrying a current 'I' is given by one half of the inductance of the coil multiplied with the square of the current

$$V = \frac{1}{2} L I^2$$

Where

V = energy measured in joule.

L = inductance measured in henry.

I = current measured in ampere.

Due to the high cost of superconducting wire and the energy requirements of refrigeration, SMES is currently used in applications such as energy storage for short duration. Therefore, SMES is most commonly dedicated to getting better power quality.

7. UPFC model

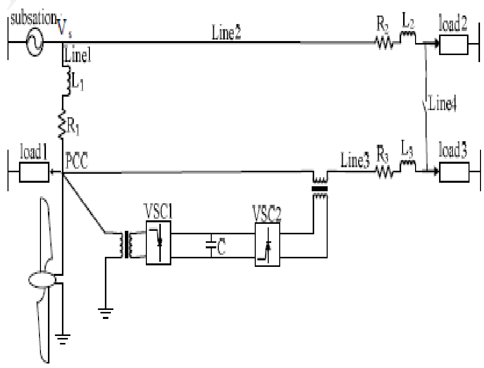

Fig 2 UPFC model

8. Wind power generation model

The SIMULINK model is shown below.Here a variable pitch wind turbine is used for the efficient power output control.Wind power generation is taken as a Dispersed Generation.

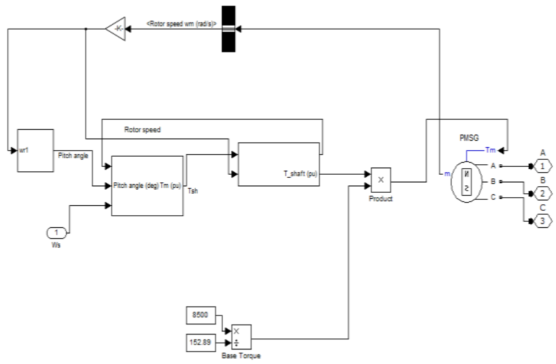

Fig 3 Wind power generation- MATLAB model

8. Simulation study

The study system model is as shown in the fig 1.The system response for both open circuit and short circuit fault is analyzed with SFCL and SMES- with and without UPFC. In a power distribution network, with Dispersed Generation, when a short circuit occurs, the fault current even increases than system without Dispersed Generation. SFCL effectively decreases the Fault current level. SMES along with UPFC can provide more smoothened output

9. Results and discussion

The Basic System output power waveform is as shown in Fig 5.The fuel cell output is first switched in and then wind power. The normal power output value is around 94Kw.

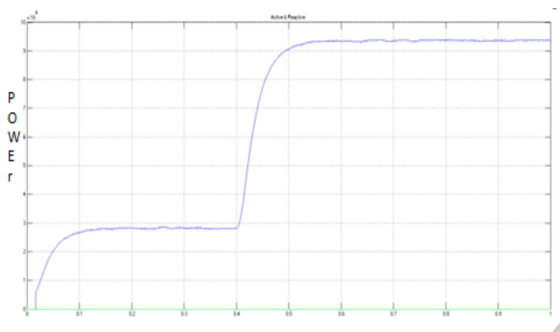

Fig 5 Output waveform of basic system

When a short circuit fault occurs, the fault current of the system will increase to a very high value. In this system, a three phase ground fault is applied for analysis. We can see that the accelerating power output is shown in fig 6.The time duration of the fault is given as 0.7ms-0.75ms.We can see that power output accelerates to a very high value due to short circuit fault(around 780kw). This can be limited using an SFCL .This is shown in fig 7. We can see that the accelerating power is decreased to an acceptable limit so that the power output is near 200Kw. ie., around 2pu which at the verge of instability. Fig8. Shows the power output when a UPFC is used along with SFCL. But when a UPFC is used along with it, the power output value reaches to around 158kw. This is an acceptable value(<2pu).

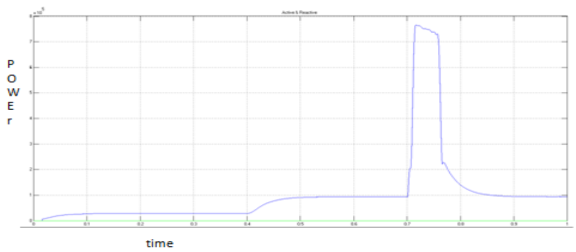

Fig 6. Power waveform when a short circuit fault occurs

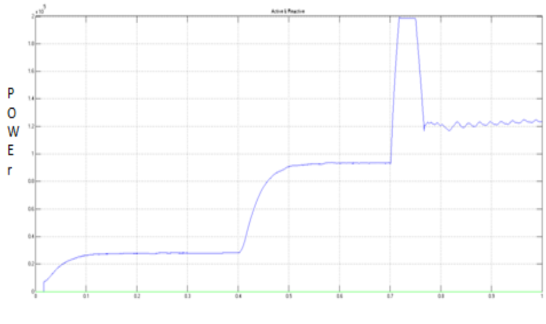

Fig 7. Power output during short circuit fault when a SFCL is connected.

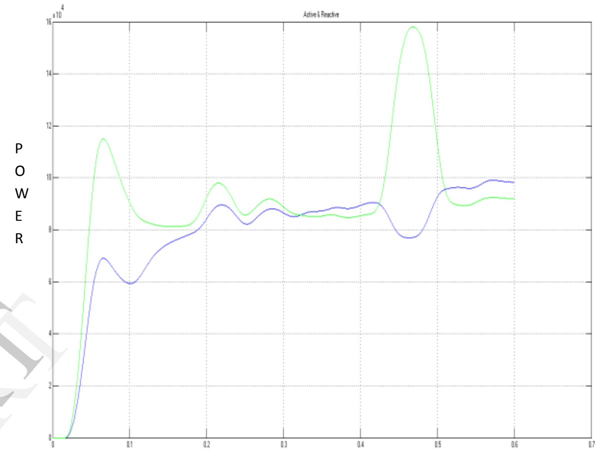

Fig.8 Power output when a UPFC is connected with SFCL

When an open circuit fault occurs; as shown in fig9, the output power suddenly approaches to nearly zero, that is, a no power condition. This sudden variation in power is very harmful based on both protection and power quality. When there is a power storage device which can supply power when there occurs a power deficiency instantaneously, then power system protection and quality can be maintained, which results in continuous operation of the system.

The best solution is to provide another source during this type of conditions occurs. SMES is an energy storage device and Fig 10 shows the simulation output in the presence of SMES when a three phase open circuit fault occurs. When SMES is used during open circuit fault, the power output is as shown in fig10.The output power value reaches to around 120kw.SMES is helpful to supply sudden need of power for a short time. In the presence of UPFC the output power during open circuit value reaches to 150kw which is above normal value, but acceptable.

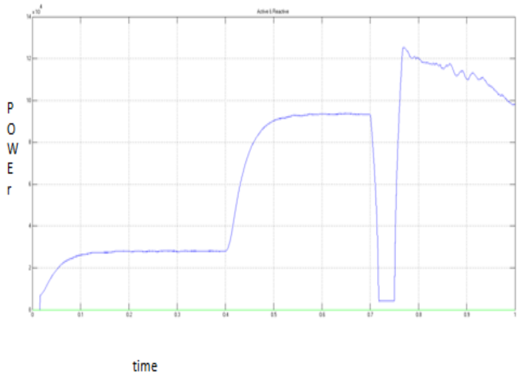

Fig 9. Power output during open circuit fault

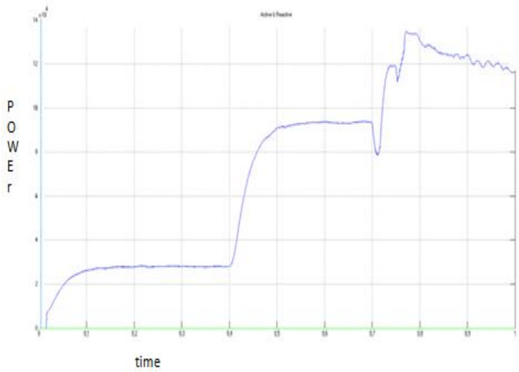

Fig. 10. Power output during open circuit fault when an SMES is connected.

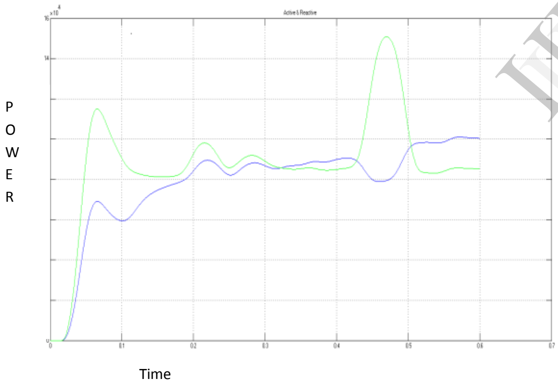

Fig. 11 Power output when a UPFC is also connected.

9. Conclusion

The optimized SFCL and SMES can be expected as the smart stabilizing devices for the future power grid. The SFCL is able to support the voltage at the SMES bus during faults so that the SMES can stabilize the system. The superior merits of the optimized SFCL and SMES such as the stabilizing effect have been confirmed. When a UPFC is also introduced, the power output can be smoothen out.

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