HYBRID OPERATION OF FAULT CURRENT LIMITER AND THYRISTOR CONTROLLED BRAKING RESISTOR

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ABSTRACT

This paper discusses hybrid operation using Fault Current Limiter (FCL) and Thyristor Controlled Braking Resistor (TCBR) for transient stability enhancement. When a power system is subjected to a large disturbance, control actions need to be taken to limit the extent of the disturbance. In this proposed scheme Fault current limiter (FCL) and Thyristor controlled braking resistor (TCBR) are used. In the case of a severe fault occurrence in a power system, FCL is used for fault current limiting, transient stability enhancement and reduction of torsional oscillations and TCBR is used for fast control of generator disturbances. The effect of these two instruments discussed together in a single machine power system connected to the infinite bus with applying a three phase symmetrical fault. The simulation results show the improvement of transient stability of the power system by using both devices.

Keywords: Equal Area Criterion, Fault Current Limiter, Power System Transient Stability, Thyristor Controlled Braking Resistor.

I INTRODUCTION

When a power system is subjected to a large disturbance, control actions need to be taken to limit the extent of the disturbance. Various methods have been taken to improve the transient stability of power systems, such as high-speed exiting, steam turbine fast-valving and dynamic braking. Also, the wide usage of FACTS controllers is another method that helps to enhance power system transient stability. Using fault current limiter (FCL) reviewed as a necessary device for limiting fault current and improvement of power system transient stability in the past. When a fault occurs, the FCL generates impedance, which can limit the fault current. In addition to generating the impedance, FCL can increase output amounts of synchronous generator that decreases when the fault occurs. However, as FCLs installed in series with transmission lines that can be just operated during the period from the fault occurrence to the fault clearing, they cannot control the generator disturbances after the clearing of fault. Dynamic Braking uses the concept of applying an artificial electrical load during a disturbance to absorb the excess transient energy and increase the electrical outputs of generator and therefore reduces rotor acceleration. With improvement in power electronic technologies, conventional circuit breaker controlled braking resistor is being replaced by thyristor controlled braking resistor (TCBR). In the past decade, thyristor-controlled braking resistor switching strategies have been extensively studied by many researchers [1]-[8], and several approaches have been developed, e.g., the time optimal switching method [1],[2], the decoupled variable structure control scheme [3], the hierarchical structure approach [4], and others. TCBR has some other application in power system:

- Prevent transient instability during the first power system swing cycle, by immediately taking away the power that would otherwise be used in accelerating the generator.
- Enhance damping to prevent dynamic instability involving low frequency oscillations between interconnected ac systems.
- Damp subsynchronous resonance (SSR) resulting from series capacitor compensation.
- Reduce and rapidly damp subsynchronous shaft torques. Thereby enabling safe high-speed reclosing of lines near a power plant. This is of significance with or without series capacitor compensation, although this problem is further aggravated by series capacitor compensation of lines leaving a power plant.
- Facilitate synchronizing a turbine-generator. Out of-phase synchronizing of a turbine-generator can produce shaft torques more severe than a bolted three-phase fault at the generator.

By given appropriate control it can be reached some of these functions concordantly. In general, a TCBR can often be the lowest cost, and a simple, highly reliable FACTS Controller.

In this paper, a thyristor controlled braking resistor has been approached by using Equal Area Criterion (EAC) that employs conventional control strategy to improve power system transient stability. Section II reviews the concept of EAC; Section III introduces the power system model; Section IV provides modeling of FCL; Section V presents modeling and describes conventional control strategy of TCBR; Section VI discusses simulation results of single machine test system simulated by power system toolbox of MATLAB/simulink. Through the simulation results, the effectiveness of the use of both devices on transient stability enhancement is demonstrated.

II EQUAL AREA CRITERION AND TRANSIENT STABILITY

Power system transient stability means, “Reaching to a normal operating point after occurrence of a disturbance”. This disturbance may happened by applying an instantaneous large load, losing a power plant unit, disconnecting an instantaneous large load, or occurring a large disturbance by short circuit. Equal area criterion (EAC) as a well-known method can be used for power system stability analysis. This method can be used just for single machine systems connected to infinite bus and also it can be used for two machine systems. EAC method presents a good physical view for dynamic behavior of synchronous machines. EAC method is on the basis of acceleration torque of synchronous generators that is difference from mechanical and electrical torque. This method explains a single machine system by considering a power-angle curve as demonstrated in Fig. 1 Suppose that input power P_m is constant and machine applies power to the system with the angle $\delta_\circ$ in steady state. As the fault occurs, electrical power reduces rapidly and moves from point a to point b. In this point mechanical power is greater than electrical power, therefore the rotor accelerates and causes to increase angle δ . This operation of machine is indicated by moving from point b to point c on the during fault curve. In point c the line is isolated by circuit breakers, therefore electrical power increases greater than mechanical power. In this point the net power causes negative acceleration of rotor and because of reserved kinetic energy, operating point moves on post fault curve toward point f. In this point, kinetic energy equals zero. As P_e is greater than P_m, yet, rotor keeps on its negative acceleration and operating point goes through the power-angle curve by the mean of point e.

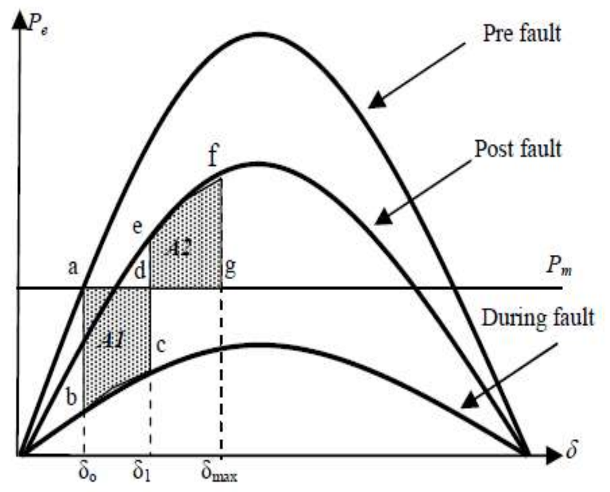

Fig. 1. Equal area criterion for a three phase fault

The rotor angle oscillates around point e by its natural frequency and finally the damping characteristic of the machine causes these oscillation damped and new steady state operating point produced at the conjunction of P_m and post fault curve. Additional reserved energy of the rotor at the time of accelerating is equivalent of area A1 and missing energy of the rotor at the time of negative acceleration is equivalent of area A2.In point f area A1 and A2 are equal and then the machine will be stable.

III MODELLING OF FCL

Fault current limiters (FCLs) usually consist of a detector, a controller and a limiter resistor. The use of FCLs is being evaluated as one necessary element to limit the fault current and enhance the power system transient stability. However, as FCLs installed in series with transmission lines, it can be just operated during the period from the fault occurrence to the fault clearing; they cannot control the generator disturbances after the clearing of fault. Fig. 2 shows the changes over time for the limiting resistance created in an FCL. It is assumed that the limiting resistance value is 1.0 pu (based on generator rating), and the fault detection time and starting time of limiting resistance are 2 m sec and 1 m sec respectively [12]. Namely, FCL starts to operate at 0.502 sec, and then the limiting resistance increases linearly from 0.0 pu to 1.0 pu within 1 msec. Although the effect of enhancement of transient stability is changed depend on the limiting resistance value, 1.0 pu is the most effective value on the transient stability enhancement which is determined based on the results of simulation using various limiting resistance values

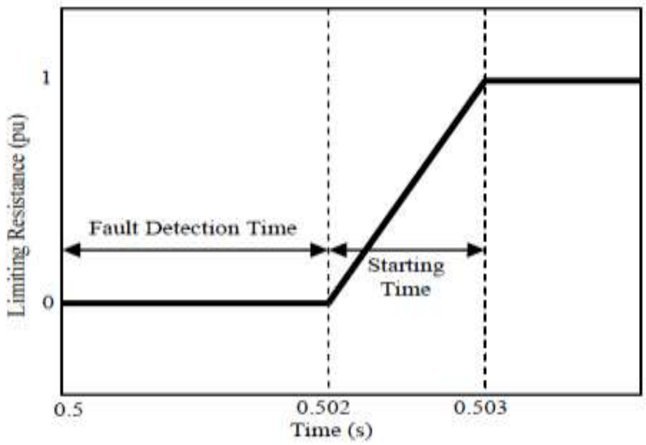

Fig. 2. FCL characteristic

IV POWER SYSTEM MODEL

Single line diagram of the single machine power system illustrated in Fig. 3. In this model a synchronous generator with its turbine-governor and excitation system is connected to infinite bus by a transformer and a double line. As it is shown, the FCL is in series with the transmission line. The TCBR also is connected to Y-side of the transformer and is paralleled with the line by the thyristors. The connections of TCBR are in delta form. In the simulation study, it is assumed that a three phase symmetrical fault occurs at the TCBR bus at 0.5 sec. The breakers on the faulted line open at 0.8 sec.

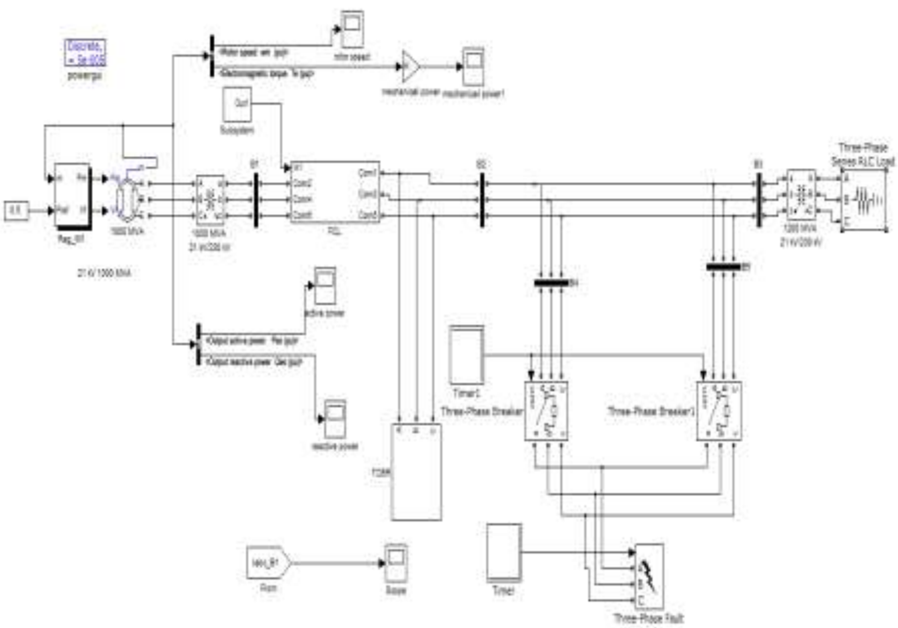

Fig.3. Power System Simulink Model with FCL And TCBR

V SIMULATION RESULTS

Fig. 4 shows the rotor speed responses of the generator. It can be seen that in case of 'without TCBR and FCL' rotor speed has severe oscillations that may cause power system instability.

As it is shown, in case of ‘with FCL and TCBR’ a noticeable improvement in rotor speed stability happens. It can be seen that the first swing of rotor speed in this case is restrained effectively. This is because of the difference between mechanical input power Pm and electrical output power Pe of the generator. Also, as it is clear, the rotor speed after second swing becomes almost constant. As FCL can be just operated during the period from the fault occurrence to the fault clearing it cannot limit the rotor speed swing after the fault cleared

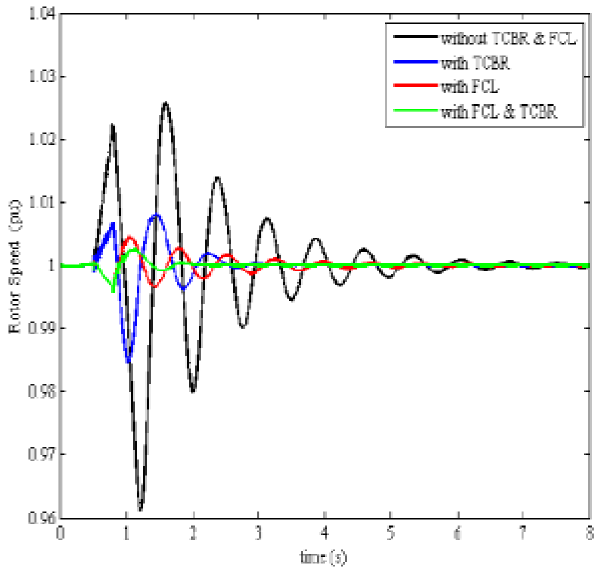

Fig. 4. Rotor speed responses

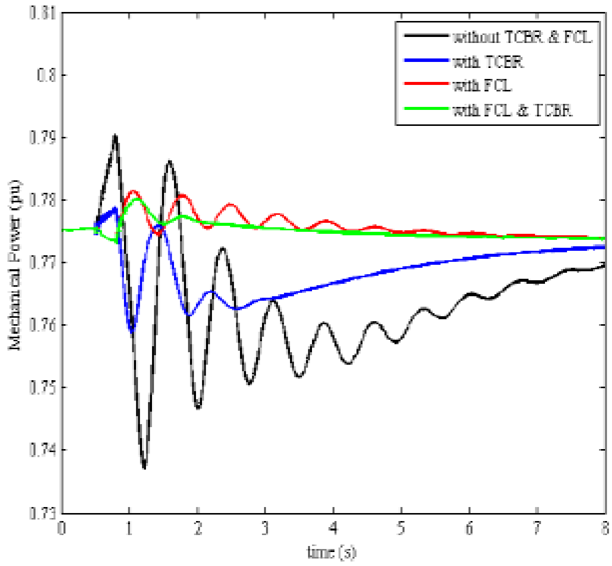

Fig. 5. Mechanical power of the generator

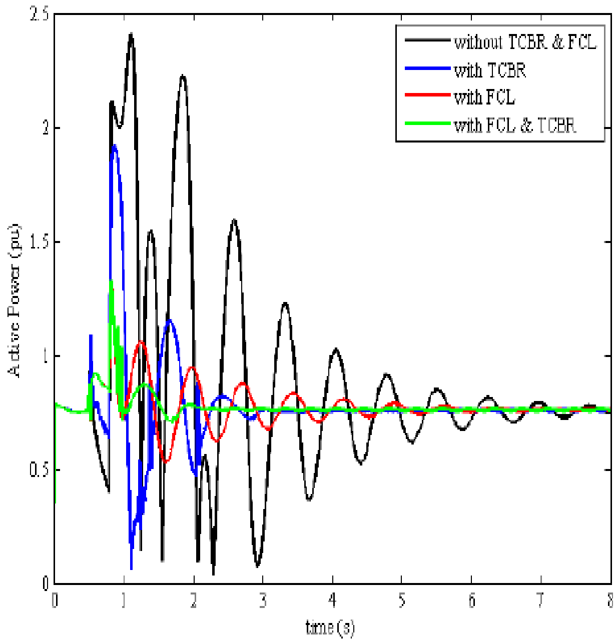

Fig. 6. Active power of the generator

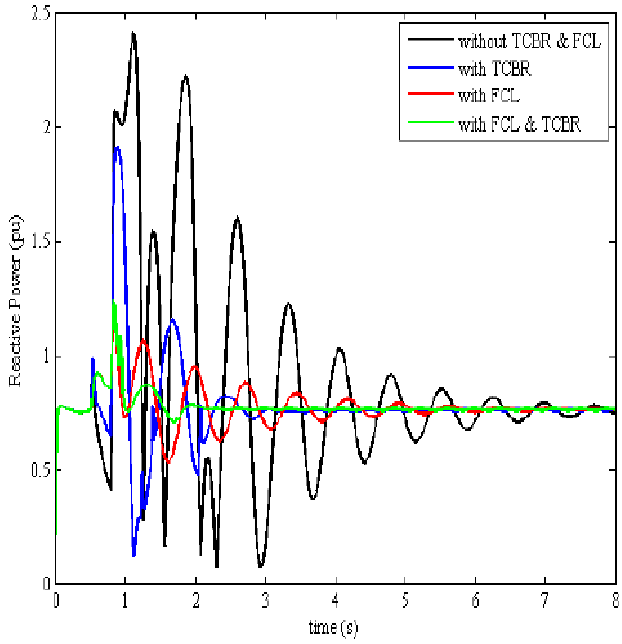

Fig. 7. Reactive power of the generator

Fig. 5 shows the mechanical input power Pm of the generator. It can be seen that in case of ‘without TCBR and FCL’ the mechanical power gets away from its reference value and also it shows that by use of both of the devices, TCBR and FCL, after two swings it becomes almost constant. Fig. 6 and Fig. 7 show active and reactive power of the generator, respectively. As it is clear, in these Figs by using the two devices, severe oscillations that produce in case of without TCBR and FCL' are damped properly. It is clear that the generator has a proper operation by using TCBR and FCL together.

VI CONCLUSION

In order to improve power system transient stability the use of hybrid operation of both devices, fault current limiter and thyristor controlled braking resistor is proposed in this paper. Simulation results on the single machine power system clearly indicate that by using both of devices transient stability will be improved properly. On the other hand, the simulation results show that by using the conventional control strategy of the TCBR it can be reached to proper results. However, using other control methods like fuzzy control will have better results.

VII ACKNOWLEDGMENT

The authors are grateful to their respective institutes and their colleagues for their support

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