Comparison of Various Auxiliary Signals for Damping Subsynchronous Oscillations Using TCR-FC

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Abstract

Because of large-capacity, long-distance and cross-region power transmission in our country's power grid, the subsynchronous oscillation (SSO) will arise from the use of series capacitor compensation and HVDC. Damping subsynchronous oscillation using static VAR compensators (SVC) is investigated in this paper. TCR-FC (Thyristor Controlled Rectifier with Fixed Capacitor) is a well known combination to improve voltage stability. Supplementary signals such as variation in reactive power, variation in frequency, variation in active power, variation in current can be used to enhance the dynamic response of the system. Their derivatives also can be used for better performance. In this paper three signals are compared and it is shown that Deviation in Reactive power gives best performance.

Keywords - FACTS; TCR-FC; Reactive power deviation; active power deviation; frequency deviation

1. Introduction

Control changing the network parameters is an effective method of improving transient stability. Flexible ac transmission system (FACTS) controllers due to their rapid response are suitable for transient stability control since they can bring about quick changes in the network parameters. Transient stability control involves changing the control variables such that the system state enters the stability region after a large disturbance [1]. Control by changing the network parameters is an effective method of improving transient stability. Flexible ac transmission system (FACTS) controllers due to their rapid response are suitable for transient stability control since they can bring about quick changes in the network parameters. Transient stability control involves changing the control variables such that the system state enters the stability region after a large disturbance.

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TCR-FC (Thyristor Controlled Rectifier with Fixed Capacitor) is a well known combination to improve voltage stability. Supplementary signals are used to improve dynamics of power system, i.e to reduce power oscillations etc. Damping of power system oscillation plays an important role not only in increasing the transmission capability but also for stabilization of power system conditions after critical faults, particularly in weakly coupled networks. Series compensation has been widely used to enhance the power transfer capability. However, series compensation gives rise to dynamic instability and subsynchronous resonance (SSR) problems. Many preventive measures to cope with this dynamic instability problem in series compensated lines have been reported in literature.

These supplementary signals may be deviation in Reactive power, deviation in frequency, deviation in bus angle voltage, deviation in active power etc. [3] [4]. Damping of power system oscillations plays an important role not only in increasing the power transmission capability but also for stabilization of power system conditions after critical faults [12]. In this paper deviation in reactive power, active power & frequency is used as Supplementary signal.

Subsynchronous resonance is addressed in three categories (i) induction generator effect (ii) torsional effect (iii) torque amplification. In all cases SSR is due to the interaction of a series capacitor with turbine generator. The first two types are caused by a steady state disturbance, while the third is excited by transient disturbance. Flexible AC transmission system (FACTS) technology provides unprecedented way for controlling transmission grids and increasing transmission capacity [7–9]. FACTS controllers have the flexibility of controlling both real and reactive power which could provide an excellent capability for improving power system dynamics. Several studies have investigated the potential of using this capability in mitigating SSR of series capacitive compensated transmission grids [10–15].

Two IEEE benchmark models have been proposed by the IEEE-SSR Working Group. These benchmark models have obtained world-wide acceptance and are extensively used for the study of different proposed damping devices SSR countermeasures [16-17].

The use of the thyristor controlled series capacitor (TCSC), static synchronous compensator and static synchronous series compensator in their balanced mode of operations has been implemented and/or studied as means for damping SSR. Generally FACTS controllers are used for power flow control and voltage stability [18-20]. Very less research has been carried out for damping of SSR using FACTS devices. In our research paper we have shown that UPFC is an effective FACTS device for damping of SSR. [21-28].

In this research paper we have developed a transmission system in MATLAB very similar to the IEEE first benchmark model.

It is helpful to look at the two SSR types within the classification which results from different sets of assumptions in our simplified model:

a) **Constant current field winding:** Only torsional interaction is present as a result of which currents and voltages at subsynchronous frequency in the stator and the shaft torque grow.

b) **Damper winding on the rotor with zero initial current:**
Only induction generator effect is present as a result of which currents and voltages at subsynchronous frequency in the stator, current in the rotor and the shaft torque grow.

c) **Constant current field winding, constant synchronous speed:** Interaction at subsynchronous frequency between the stator and rotor circuits stops. If there is no resistance in the stator, the subsynchronous currents and voltages resulting from initial conditions continue to exist without growing.

Also the electromagnetic torque component on the generator rotor is present, but since with our constant speed assumption we have actually placed an independent torque source on the generator rotor which completely compensates this torque, the mechanical oscillations do not grow.

d) **Damper winding with zero initial current, constant synchronous speed:** Interaction at synchronous frequency between the stator and rotor circuits stops. The electrical induction effect on the stator side results in currents and voltages at subsynchronous frequency to grow.
2. Study System

The study system consists of a steam turbine driven synchronous generator supplying bulk power to an infinite bus over a long transmission line. The study system, shown in Fig.1 consists of one synchronous generator, two transformers T1 & T2, one series capacitor and a TCR-FC in the middle of line. Modelling of above system & initial conditions are given in [1]. Block diagram of TCR-FC is shown in Fig.2. This block diagram includes firing control system and represented as a first order model having gain K and time constants T1 and T2.

![Block diagram of TCR-FC](image)

The controller sends firing control signals to the thyristor switching unit to modify the equivalent susceptance of the TCR. In Fig. 2 V\text{meas} is bus voltage at TCR –FC bus. V\text{supp} is change in voltage due to auxiliary signal deviation (reactive power, active power or frequency deviation) at TCR –FC bus.

3. Fault Simulation

In synchronous machine initial power is 2 pu. Suddenly it increased to 2.5 pu.
TCR bus voltage Without Supplementary signal

Generator rotor angle Without Supplementary signal

TCR bus voltage With Supplementary signal-reactive power

Generator rotor angle With Supplementary signal-reactive power

TCR bus voltage With Supplementary signal-active power

Generator rotor angle With Supplementary signal-active power
4. Results

(a) Without any supplementary controller - Voltage stability - Fig.4 Rotor stability - Fig.5
(b) With supplementary controller (auxiliary signal-reactive power) Voltage stability-Fig.6,Rotor stability Fig.7
(c) With supplementary controller (auxiliary signal-active power) Voltage stability -Fig. 8, Rotor stability Fig.9
(d) With supplementary controller (auxiliary signal-frequency deviation) Voltage stability -Fig. 10, Rotor stability Fig.11

5. Conclusion

In this paper the effectiveness of combined voltage and reactive power with TCR-FC auxiliary controllers have been evaluated for damping the subsynchronous oscillations in a given series compensated power system. Supplementary signal deviation in reactive power (Fig.6 & 7) gives best result, then frequency deviation gives little better results and out of three signals deviation in active power gives least result. No doubt that without Supplementary signal (Fig. 4 & 5) results are poorest. The response curves of terminal voltage, TCR-FC bus voltage, generator torque angle show a remarkable improvement and their oscillations die down effectively. The further work is going on with combining two signals in one controller.

Acknowledgements

The work presented in this paper has been performed under the AICTE R&D Project, “Enhancing the power system performance using FACTS devices” in the Flexible AC Transmission Research Laboratory at Delhi Technological University formerly Delhi College of Engineering, Delhi (India).
References


Appendix A.

Generator data: 1110MVA, 22kV, Rg = 0.0036, Xl = 0.21
Tdo = 6.66, Tgo = 0.44, Tdo’ = 0.032, Tgo’ = 0.057 s
Xd = 1.933, Xq = 1.743, Xd’ = 0.467, Xq’ = 1.144, Xd” = 0.312, Xq” = 0.312 p.u.
IEEE type 1 excitation system:
TR = 0, TA = 0.02, TE = 1.0, TF = 1.0 s, KA = 400, KE = 1.0; KF = 0.06 p.u.
Vfmax = 3.9, Vfmin = 0, Vrmax = 7.3, Vrmin = -7.3
Transformer data:
Rt = 0, Xt = 0.15 p.u. (generator base)

Transmission line data:
Voltage 400kV, Length 600km, Resistance R = 0.034 Ω / km, Reactance X = 0.325 Ω / km
Susceptance Bc = 3.7 μmho / km

SVS data:
Six-pulse operation:
Tm = 2.4, Ts = 5, TD = 1.667 ms, Kt = 1200, Kp = 0.5, KD = 0.01

Torsional spring-mass system data

<table>
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<tr>
<th>Mass shaft Inertia H (s) Spring constant K (p.u. torque/rad)</th>
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| HP-IP | 25.772 |
| IP-LPA | 46.635 |
| LPA-LPB | 69.478 |
| LPB-GEN | 94.605 |
| GEN-EXC | 3.768 |

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