Power Grid Corporation of India Ltd (PGCIL) has purchased two Thyristor Controlled Series Capacitors (TCSC) from ABB. The banks were installed on the Rourkela-Raipur double circuit 400 kV power transmission interconnector between the Eastern and Western regions of the grid. The length of the interconnector amounts to 412 km.

The main purpose of this major AC interconnector is to enable export of surplus energy from the Eastern to the Western regions of India during normal operating conditions, and also during contingencies. The TCSC are located at the Raipur end of the lines. The TCSC enable damping of interarea power oscillations between the regions, which would otherwise have constituted a limitation on power transfer over the interconnector. Dynamic simulations performed during the design stage, and subsequently confirmed at the commissioning and testing stage, have proved the effectiveness of the Raipur TCSC as power oscillation dampers. Furthermore, system studies performed showed no risk for Sub-Synchronous Resonance (SSR) in the Indian network.

**Power oscillation damping**

Low frequency interarea oscillations are a well-known phenomenon arising between distinct groups of rotating machines, interconnected by a weak or heavily loaded AC tie. The interarea oscillation frequency is typically in the range below 1 Hz. Previous studies carried out by PGCIL had identified poorly damped behaviour of the power grid manifesting itself in low frequency interarea oscillations between the Eastern and Western regions. As a solution to these interarea low frequency power swings, the studies proposed two fixed Series Capacitors, each with 40% degree of compensation of the Rourkela-Raipur line, and two TCSCs, each with 5% degree of compensation of the Rourkela-Raipur line. For power oscillation damping (POD), by control of the boost factor, the TCSCs introduce a component of modulation of the effective reactance of the power lines. During power swings the inserted TCSC reactance can be changed between –20.5 Ω capacitive, corresponding to a boost factor of 3.0, and 1.3 Ω, corresponding to TCSC bypass. By suitable system control, this modulation of reactance counteracts the oscillation of active power, thereby quickly damping it out. The Rourkela-Raipur TCSCs have proven effective as power oscillation dampers.
The graphs show a 1500 MW power transfer situation from Eastern to Western regions, with a single-phase to ground fault at Raipur s/s, cleared after 100 ms. A severe 0.35 Hz power oscillation is triggered over the interconnector and actively damped out by means of the TCSC. The damping effect of the TCSC is very distinct as shown in the “Power oscillation damping” graph to the right in this page.

Control and protection
The control system is based on the ABB MACH 2 concept, which is a hardware and software system specifically developed for power applications. The MACH 2 system is built around an industrial PC with add-in boards and I/O racks connected through standard type field busses like CAN and TDM. This has facilitated very high performance together with small dimensions of the hardware. The TCSC can be controlled from two different locations. In the local control room there is an Operator Work Station (OWS), based on a personal computer. The TCSC can also be remotely controlled via a Remote Work Station (RWS) from the substation control room.

Current measurements for the control and protection functions are attained by use of Optical Current Transformers (OCT). The OCT consists of a current transducer in the high voltage busbar and an optical interface module in the control room. Signal transmission between transducer and interface is carried out by means of an optical fibre system including platform links, high voltage signal columns and fibre optical cables. When power oscillations are detected, the POD control function changes the reactance reference in such a way that the power oscillations are damped out.

Thyristor valve
For controlled series capacitors, a thyristor valve is used for controlling the apparent reactance of the capacitor. This is done by adding charge to the capacitor through the thyristor valve, i.e. boosting the capacitor voltage. The valve, located on platform level, is water-cooled and equipped with two vertically mounted, antiparallel stacks of thyristors. Each valve string consists of 14 thyristors in series connection, each with a wafer diameter of four inches. All communication between valve and the ground mounted control system is done via fibre optics. The thyristor valve is rated for a continuous current of 1850 A and a voltage of 12.7 kVrms. It is furthermore rated to withstand short-circuit currents up to 55 kApeak, safely above any plausible fault situation that the valve may have to endure in operation.

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