Module 4 : Voltage and Power Flow Control

Lecture 20 : Some Real Life Examples

Objectives

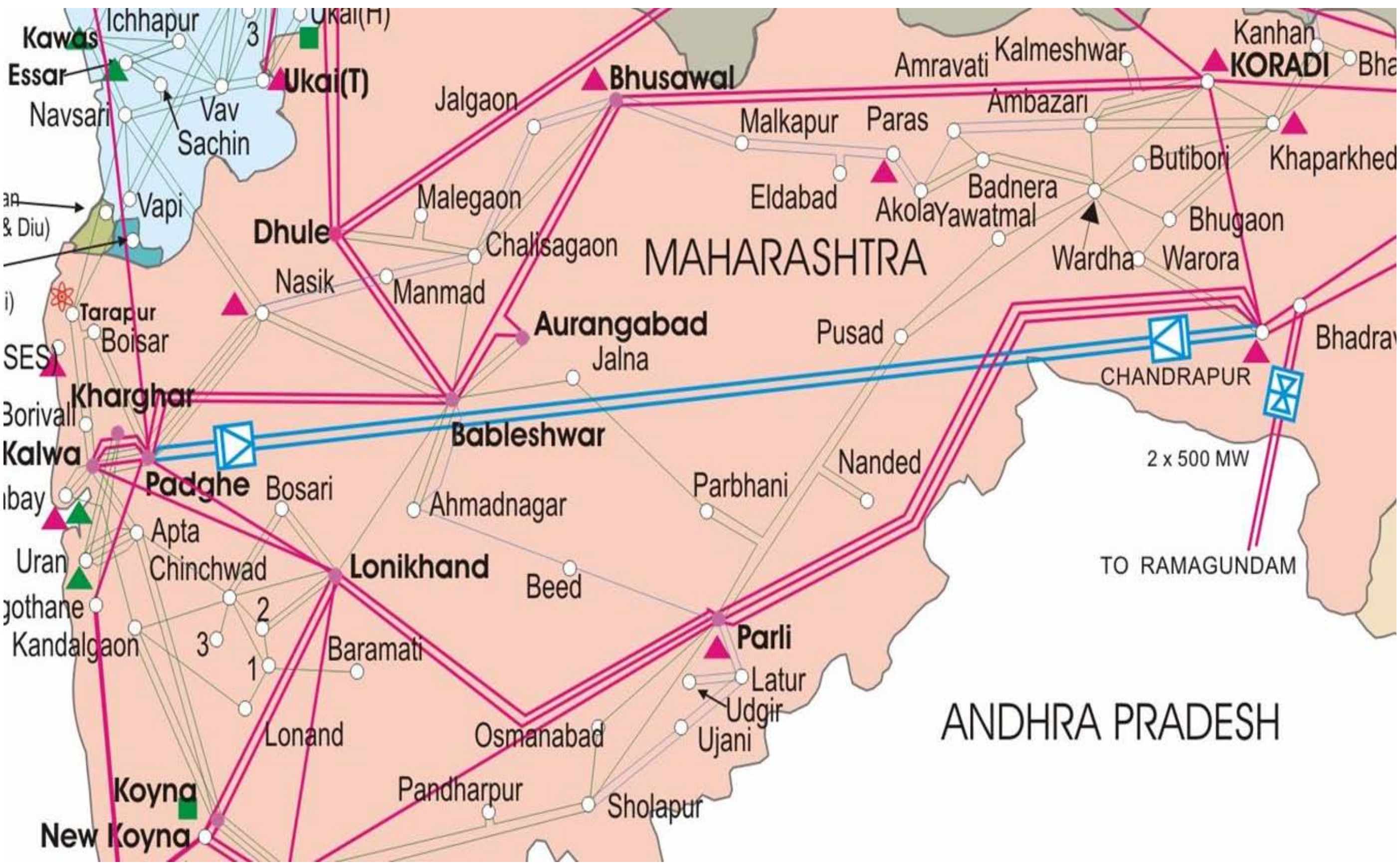
In this lecture you will learn the following

Real life examples of a few power flow and voltage control devices.

Chandrapur Padghe HVDC link

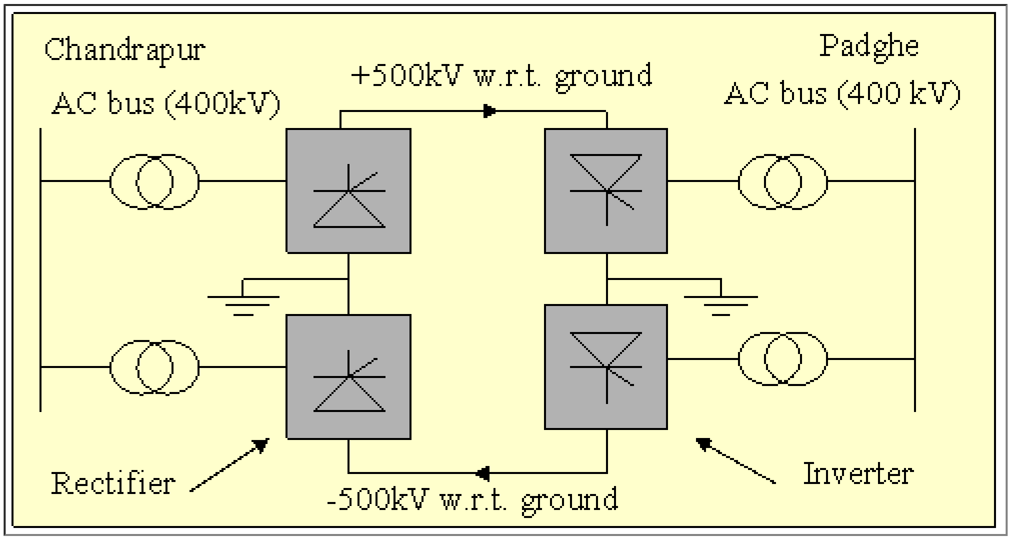
Maharashtra state, which is a part of the western regional grid of India, has most of its large generators in the eastern part of the state. The thermal power station at Chandrapur generates more than 2200 MW of power. However, most of the major loads lie in the western part of the state, i.e., in and around Mumbai, Nashik and Pune, which are at a distance of more than 600 km. Although 400 kV AC lines, are present they pose stability and voltage constraints due to the long distances involved. Therefore an HVDC link between Chandrapur and Padghe was planned and executed.

We have seen the power map of the western region of India. The figure below highlights the Maharashtra state grid. The 400 kV lines are in pink while the HVDC link is shown in blue. An asynchronous DC link between the Western and Southern region is also present (between Bhadrawati and Ramagundam).



The Chandrapur -Padghe DC link is primarily meant for point to point bulk power transfer. The overall capacity of the link is 1500 MW and consists of two sets of converters at Chandrapur (rectifier end) and Padghe (inverter end). The voltage between the two lines which form the link is maintained at about 1000 kV. The voltage of each line with respect to the ground is about +/-500 kV. The link also allows for power flow in the ground for a short while if one conductor which forms the return path is unavailable.

The power flows are set as per the schedule decided by a system operator, and implemented by closed loop control of the firing angles of both the rectifier(Chandrapur) and inverter (Padge).



Ratings of Link	Power Transmission Capability (MW)
Minimum Continuous Rating	1500
Nominal Rating	1500
2 hours overload rating	1650
5 second overload rating	2000
Rating under reduced DC voltage	1000

Fast control possible with power electronics also allows for the additional capabilities:

a) In case degraded insulation conditions exist, power can be transmitted at slightly lower voltages (losses will increase though).

b) The link can reverse power flow in case the system conditions so demand.

c) The HVDC link can act like an asynchronous link in case the eastern and western part of the state are not in synchronism and power flow can be controlled to keep frequency at one end constant.

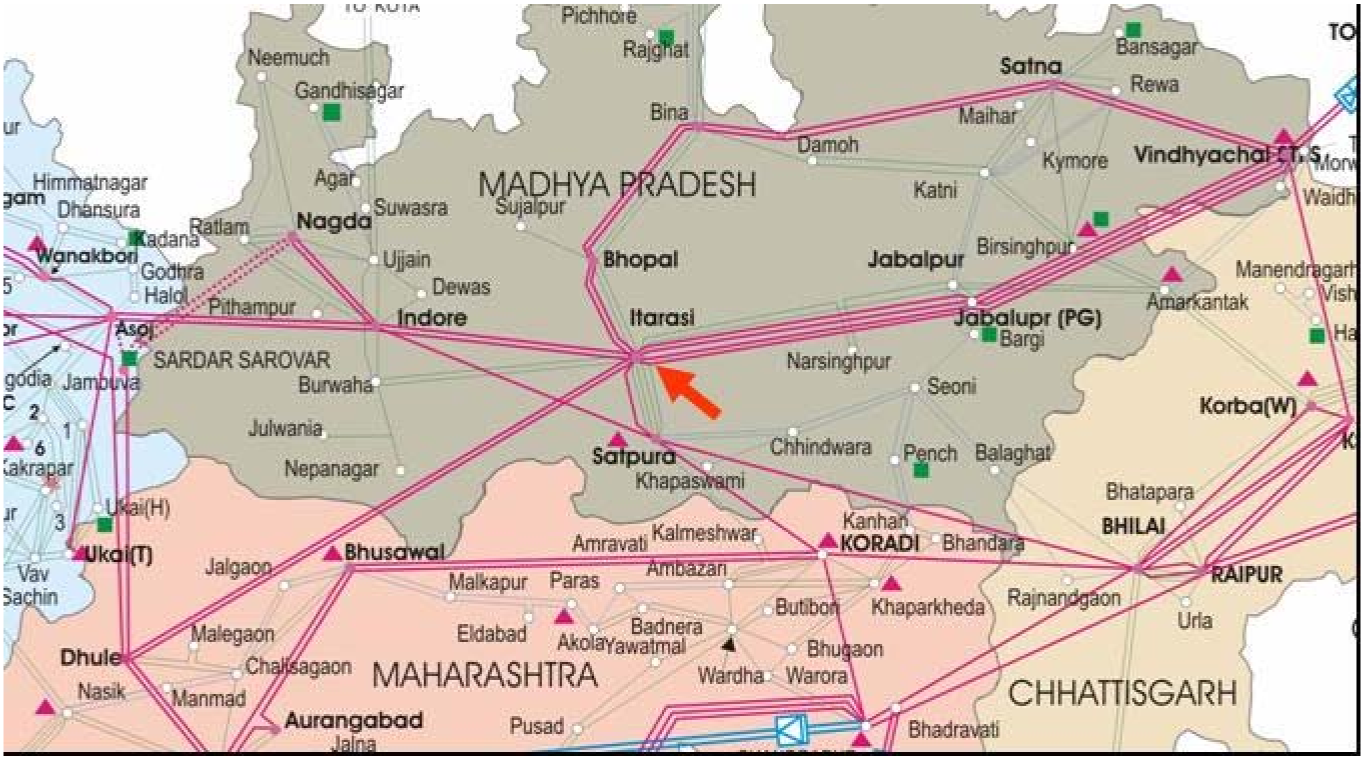
d) The reactive power absorbed at both rectifier and inverter can be increased if overvoltage conditions exist.

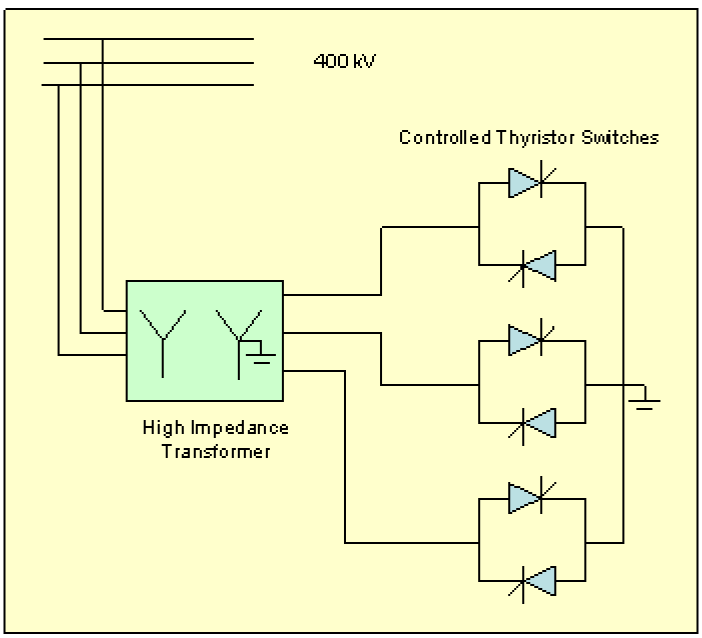
e) In case a parallel AC line (e.g., Chandrapur -Parli 400 kV line in the above figure) is tripped, it is possible to increase the power flow in the DC link to prevent instability or overload of other AC lines.

(Data obtained from "Operation, Maintainance and Protection Aspects of 1500 MW, +/- 500 kV Chandrapur-Padghe Bipole project", by R.S. Khandagale et al, Annual Workshop for Load Despatch Personnel and System Operators, Sept 2002, Mumbai)

The Controlled Shunt Reactor at Itarsi

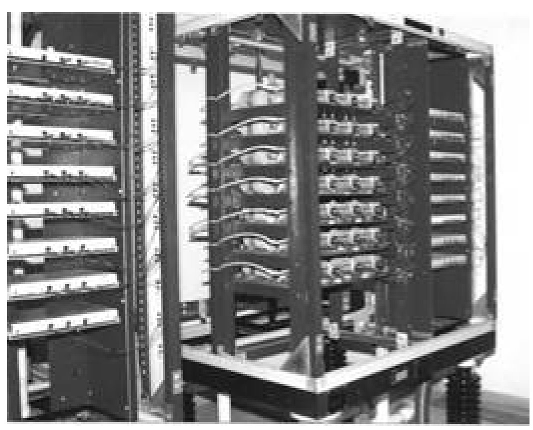
The Itarsi bus in the Western Regional grid of India has several 400 kV long lines (shown in pink in the Figure below) incident on it. These lines carry a large amount of power from the east to the west. However, to prevent over-voltages during *light* load conditions, reactive power has to absorbed at various buses. During heavy load conditions there is a sag of voltages at buses like Indore. Thus controlled reactive power is desirable rather than having *fixed* shunt reactors.





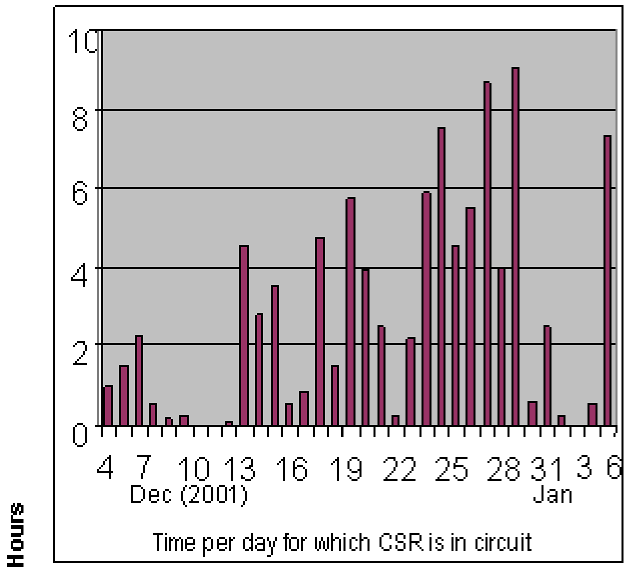
Schematic of the CSR

We have learnt about shunt reactive control using a thyristor controlled reactor (TCR). Usually, a TCR is connected to a high voltage bus using a transformer. However instead of having a separate reactor, the leakage reactance of a transformer, (which is designed to be high) itself may be utilized thereby achieving some economy. Such a device, denoted as a Controlled Shunt Reactor - CSR- has been designed and implemented by BHEL at Itarsi 400 kV bus in the Western Regional grid of India. The rating of the CSR is 50 MVAr.



Thyristor Valve for CSR circuit

A CSR provides for controlled reactive compensation only when it is required (i.e. during light load conditions). Unlike fixed reactive compensation which results in voltage sags during heavy load conditions and reduction in power transfer capability, a CSR can be controlled or switched off during



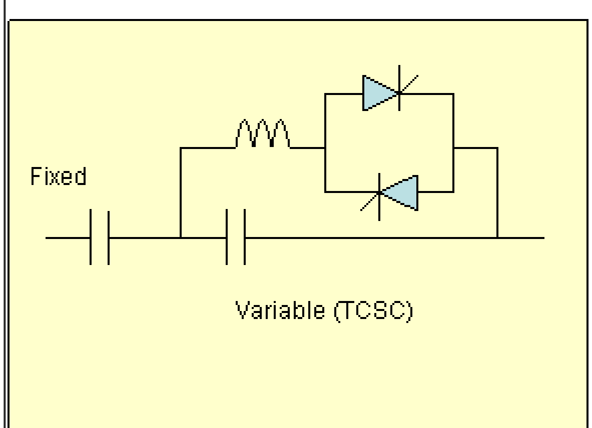
heavy load conditions. For example, if the voltage goes above 1.05 pu, then CSR is switched in. The typical response time is of the order of 10 ms.

(Details obtained from "Controlled Shunt Reactor : A member of FACTS family", S.V.N. Jithin Sundar et al, 11th NPSC, Bangalore, Dec. 2000, pp 63-68 and "Controlled Shunt Reactor", by Dipak Dutta, International Seminar and Tutorial on Power Transmission Research and Challenges, CPRI, Bangalore, 21-22nd Dec, 2005)

The Kanpur-Ballabhgarh 400 kV Thyristor Controlled Series Compensator

Based on system studies, a TCSC was planned on the 400 kV, 400 km line between Kanpur and Ballabhgarh, in the Northern Regional grid of India. This line is a part of one of the transmission corridors which evacuate power from the generation rich south-eastern part of the grid to the northern part. It was envisaged that the power carrying capability of the line could be securely increased from 400 MW to 600 MW. This would improve the grid capability in case of outages of parallel lines.

The power flow can be controlled by scheduling a certain value of the TCSC reactance. Also, the TCSC reactance may be controlled so as to improve angular stability. TCSC (a capacitor in parallel with a Thyristor Controlled Reactor -TCR) is used in conjunction with a fixed series capacitor bank as shown below. The parameters of the TCSC are given below:



System Parameters	Fixed capacitor	TCSC capacitor
Rated Voltage (line-line)	420 kV	420 kV
Nominal Reactive Power	151.6 MVAr	79.87 MVAr
Continuous Effective Impedance	31.5 W	10.4 W
Maximum effective dynamic impedance (because of the TCR)	31.5 W	26 W
Rated Current	1200 A	1600 A
Rated Continuous Voltage (across capacitor)	42.2 kV	16.6 kV
TCR inductance per phase	-	4.4 mH

(Data obtained from, "Application of FACTS in Indian Power System", by S. Mukhopadhyay et al, Transmission and Distribution Conference and Exhibition 2002: Asia Pacific, 6-10 Oct. 2002 Volume: 1, On page(s): 237- 242 vol.1)

Exercise:

1) Survey all the DC links existing in India

2) Study the following power flow controllers which have been installed in the world:

   a) TVA's Sullivan Static Synchronous Compensator (STATCOM)

   b) AEP's Inez Unified Power Flow Controller (UPFC)

   c) The Variable Frequency Transformer (VFT) at Langlois (Hydro-Quebec)

Note that (a) and (b) are based on voltage source power electronic controllers while (c) is a rotary device.

An interesting new concept in power flow control and series compensation is "Distributed Static Series Compensator". Can you find out more about this ?

Recap

In this course you have learnt the following

- Three real life examples of real/reactive power flow control devices: An HVDC link, a Controlled Series Reactor, and a Thyistor Controlled Series Compensator

Congratulations, you have finished Lecture 20. Please view the next slide for concluding remarks for this module.

We now summarize what we have learnt in this module :

a) Devices like generators can be made to absorb or supply reactive power by controlling their field voltages. Reactive power may be controlled so as to maintain terminal voltage of a generator constant.

b) Transmission Lines absorb or supply reactive power depending on loading. Cables invariably generate reactive power.

c) Tap Changing Transformers, Static VAR generators etc are devices which may be used to control voltages at key points in the system.

d) Power Flow Control and increased utilization of transmission lines is possible by series compensators. Power flow between two regions or across long distances can be achieved using DC links.

e) Power Electronics based variable shunt or series devices allow fast voltage and power flow control.

Congratulations, you have finished Module IV.

To view the next lecture select it from the left hand side menu of the page.