

## Module 4 : Voltage and Power Flow Control

### Lecture 18 : Reactive Power Characteristics of Special Devices

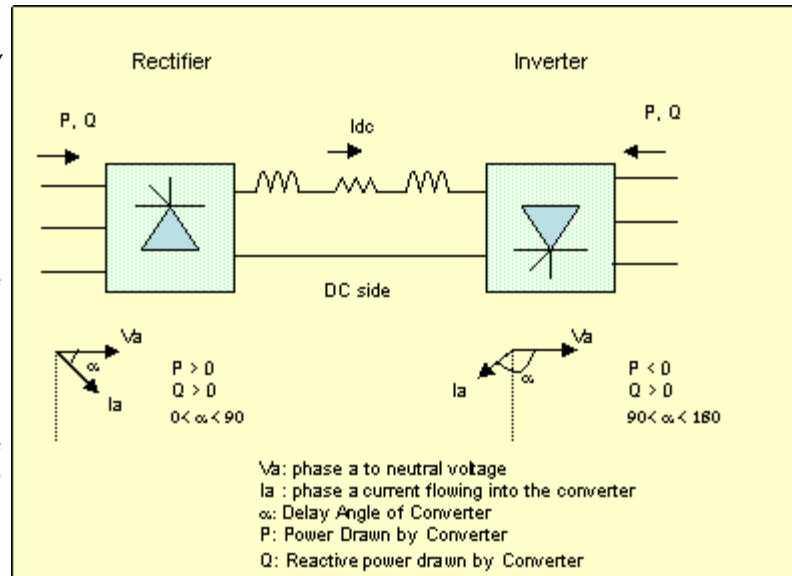
#### HVDC Terminals

You must have learnt about various kinds of AC/DC converters in a Power Electronics Course. Line Commutated Converters (Thyristor Rectifier / Inverter Bridges) always absorb reactive power. The reactive power absorbed is substantial and can be as much as 30-40% of the power transmitted by the HVDC link. Usually shunt capacitors are connected to provide reactive power on the ac side of the converters.

If the thyristors are fired *as soon as they get forward biased*, then we say that the "delay angle" is zero. In such a case a thyristor bridge is identical to a three phase diode bridge. However, by delaying the firing, we can control the average voltage which appears on the DC side.

The delay angle associated with these controlled rectifiers results in lag of the fundamental of AC side current by approximately the same angle as the delay angle.

This is also true for inverter stations where the firing angle is greater than 90 degrees but less than 180 degrees. This is illustrated by the figure given on the right.



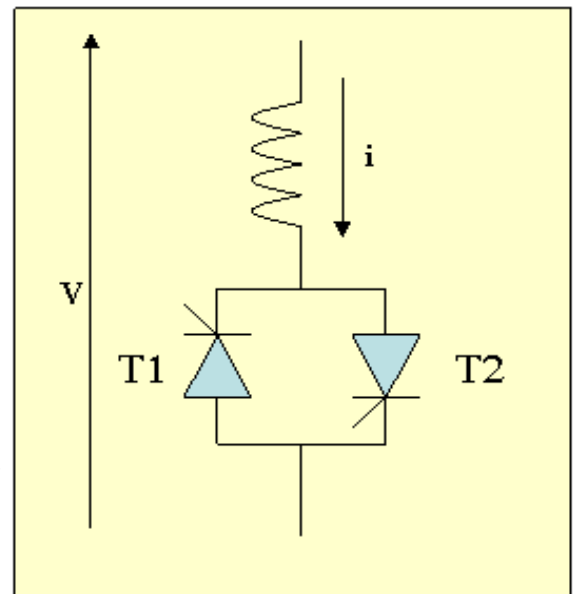
You may simulate HVDC link behavior using the MATLAB/SIMULINK file ([HVDC.mdl](#)).

HVDC systems of lower ratings may also be implemented using **Voltage Source Converters**. These converters use devices like Gate Turn off Thyristors which can be *turned off* by a gate signal. Unlike in a line commutated converter, the voltage on the DC side is unidirectional while current can flow in either direction on the DC side. **These converters can absorb or supply reactive power independent of the real power flow in the line.** As an exercise, read about AC/DC converters in a book on Power Electronics (e.g. Power Electronics by M.H.Rashid, Prentice Hall, 2002).

#### Static Var Compensators (contd..)

While the major means of control of reactive power and voltage is via the excitation systems of synchronous generators, devices may be deployed in a transmission network to maintain a good voltage profile in the system.

Shunt connected devices like shunt capacitors or inductors or synchronous condensers can be used for reactive power control. Shunt Capacitors/Inductors may be fixed or switched (using circuit breakers). *Vernier* or smooth control of reactive power is also possible by varying effective susceptance characteristics, by use of power electronic devices. As an example let us consider a "Static Var Compensator (SVC)" which



employs thyristors. An SVC is a parallel combination of switched or switched capacitors and a **Thyristor Controlled Reactor (TCR)**.

The basic principle of operation of a TCR (see figure on the right) is as follows:

A reactor is connected in series with a back-to-back connected pair of thyristors. The thyristor does not conduct if gate pulses are not provided. In such a case, the effective susceptance is zero.

On the other hand if thyristors are always on, the effective susceptance is equal to that of the inductor. Now if the each thyristor is fired at a delay angle (as measured from the point where it gets forward biased) between 90 and 180 degrees, the resulting current waveform is as shown on the right. The figure shows the current waveform for various values of delay angle. Note that this waveform is obtained by integrating the voltage from the point at which the thyristor switches on using the rule:

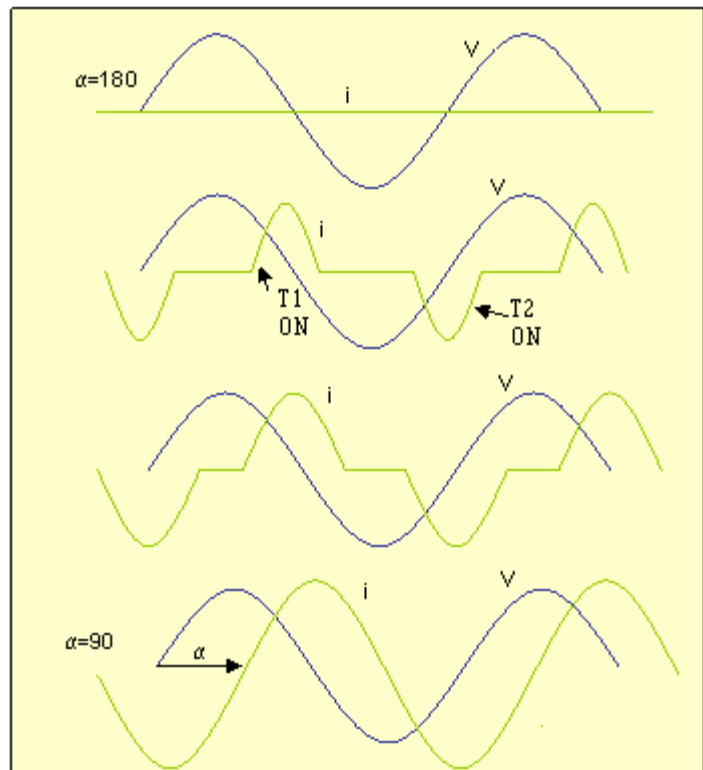
$$L \cdot i = \int v \, dt$$

The thyristor switches off when the current through it falls to zero. The reverse connected thyristor behaves similarly for the other half cycle. The instantaneous current  $i$  over half a cycle is given by

$$i = \frac{\sqrt{2}V}{X_L} (\cos \alpha - \cos \omega t), \quad \alpha < \omega t < \alpha + \sigma$$

$$= 0, \quad \alpha + \sigma < \omega t < \alpha + \pi$$

where  $V$  is the rms voltage applied,  $X_L$  is the fundamental frequency reactance of the reactor.  $\omega$  is the radian frequency of the voltage and  $s$  is the angle for which a thyristor conducts. Show that  $s = 2(\pi - \alpha)$ .



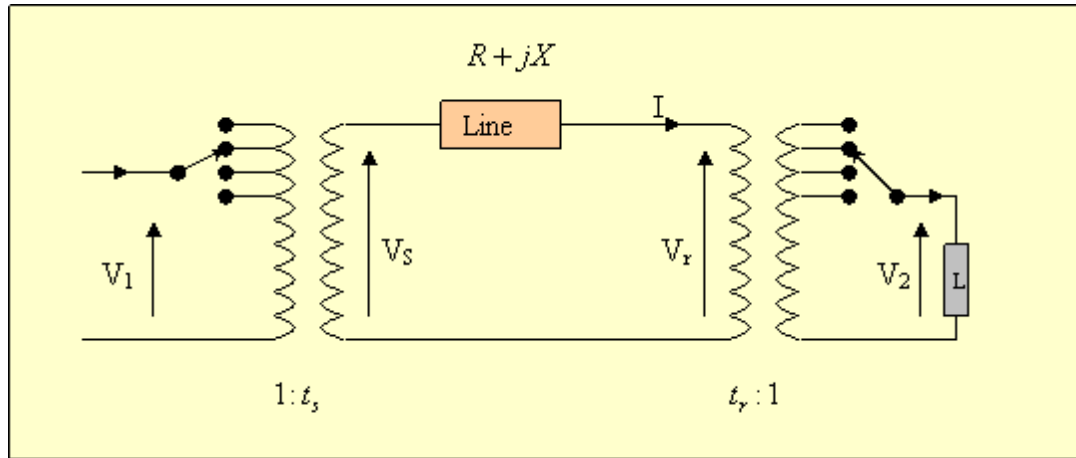
## Other Devices

Series Connected Devices like fixed, switched or controllable series reactance compensators can also be used for reactive power control. While the basic aim of connecting series capacitors is for power flow control and enhancement (to be discussed later), they also affect the voltage profile in a system.

Tap Changing Transformers provide a means of controlling voltage and reactive power flows in a system.

Typically, all generator step-up transformers and auto-transformers (which inter-connect EHV lines which are at different voltage levels) are provided with a facility for on-load tap changing. The change of tap is effected by motors and follows a manual command or the output of an automatic voltage regulator (as in a generator). Tap changing is a slow process and there are several inherent and deliberate delays and dead-bands in the control system to avoid frequent changes in tap. Tap changing can also be effected by power electronic switches.

A schematic of a tap changing transformer scheme is shown in the figure below.



Voltages at all buses should be within acceptable bounds.

Reactive Power flow should be reduced (generate or absorb reactive power locally) otherwise voltage profile is poor and losses increase. Unlike frequency control wherein the cumulative load and generation determines the system frequency, the voltages are usually amenable to control by local injection/absorption of reactive power.

Reactive Power control done at 2 levels:

1. Transmission System Compensation or Voltage Control
2. Load Compensation or Power Factor Correction / Distribution System Voltage Control

We now consider an [example](#), of voltage control in an power system.

## Recap

In this lecture you have learnt the following

- Special devices like Static VAR Compensators and tap changing transformers can be deployed in the network to improve voltage profile of a system
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- Line -commutated rectifiers or inverters, employed in HVDC links, always absorb reactive power.
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- Voltage control of a bus can be done by local reactive power injection.

Congratulations, you have finished Lecture 18. To view the next lecture select it from the left hand side menu of the page.

