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Department of EEE

UNIT-II

Converter and HVDC System Control

HVDC Transmission

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Topics

- Principle of DC Link Control
- Converters Control Characteristics
- Firing angle control
- Current and extinction angle control
- Effect of source inductance on the system
- Starting and stopping of DC link
- Power Control.
- Reactive Power Control in HVDC: Introduction,
- Reactive Power Requirements in steady state
- sources of reactive power-Static VAR Compensators
- Reactive power control during transients

Principle of DC Link Control

- The control of power in a DC link can be achieved through the control of current or voltage. From minimization of loss considerations, we need to maintain constant voltage in the link and adjust the current to meet the required power.

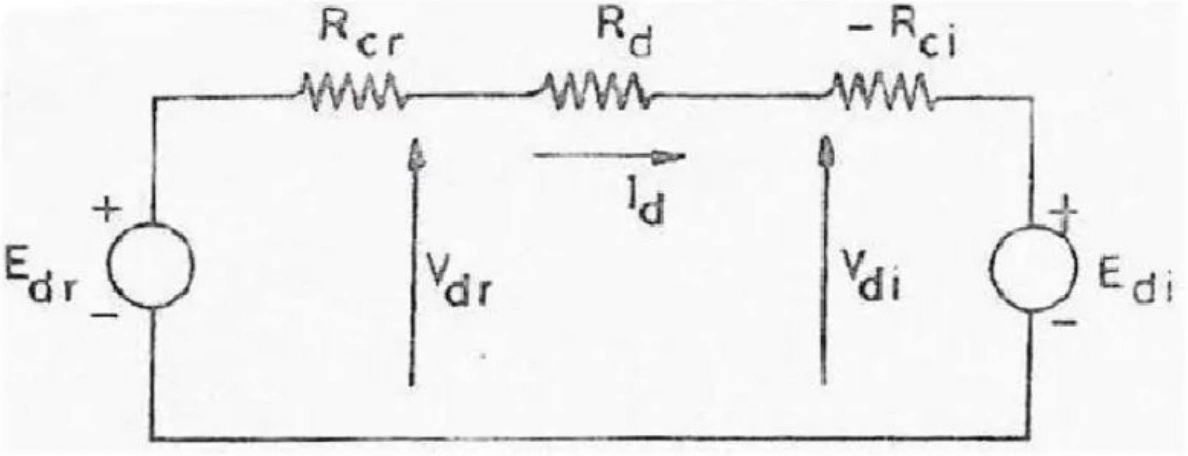
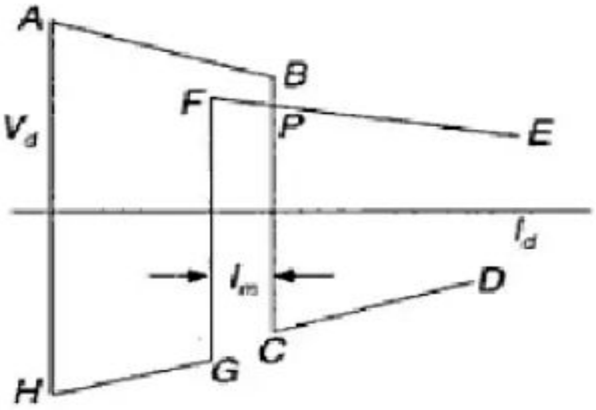


Fig 1: principle of DC link

Converters Control Characteristics

Basic characteristics:

- The intersection of the two characteristics (point A) determines the mode of operation- Station I operating as rectifier with constant current control and station II operating at constant (minimum) extinction angle.
- There can be three modes of operation of the link (for the same direction of power flow) depending on the ceiling voltage of the rectifier which determines the point of intersection of the two characteristics which are defined below
- CC at rectifier and CEA at inverter (operating point A) which is the normal mode of operation.
- With slight dip in the AC voltage, the point of intersection drifts to C which implies minimum a at rectifier and minimum y at the inverter.
- With lower AC voltage at the rectifier, the mode of operation shifts to point B which implies CC at the inverter with minimum a at the rectifier.



Controllers characteristics.

Types of Station Control Characteristics

Station-I	Station-II	Controller type
AB	*HG*	Minimum α
BC	*GF*	Constant current
CD	*EF*	CEA (minimum γ)

Fig 3: control characteristcs

Firing angle control

- The operation of CC and CEA controllers is closely linked with the method of generation of gate pulses for the valves in a converter. The requirements for the firing pulse generation of HVDC valves are
- The firing instant for all the valves are determined at ground potential and the firing signals sent to individual thyristors by light signals through fibre-optic cables. The required gate power is made available at the potential of individual thyristor.
- While a single pulse is adequate to turn-on a thyristor, the gate pulse generated must send a pulse whenever required, if the particular valve is to be kept in a conducting state.

The two basic firing schemes are

- Individual Phase Control (IPC)
- Equidistant Pulse Control (EPC)

Individual Phase Control (IPC)

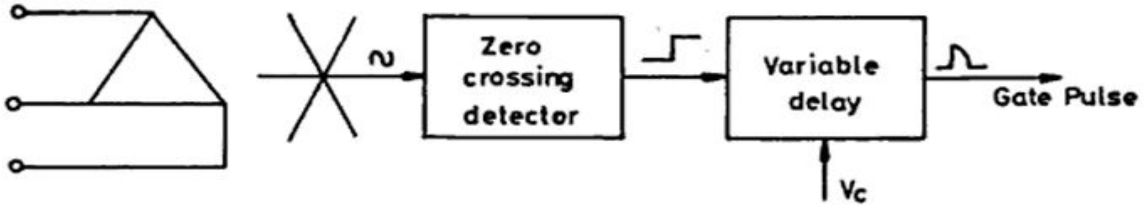
This was used in the early HVDC projects. The main feature of this scheme is that the firing pulse generation for each phase (or valve) is independent of each other and the firing pulses are rigidly synchronized with commutation voltages.

There are two ways in which this can be achieved

1. Constant α Control
2. Inverse Cosine Control

Constant α Control

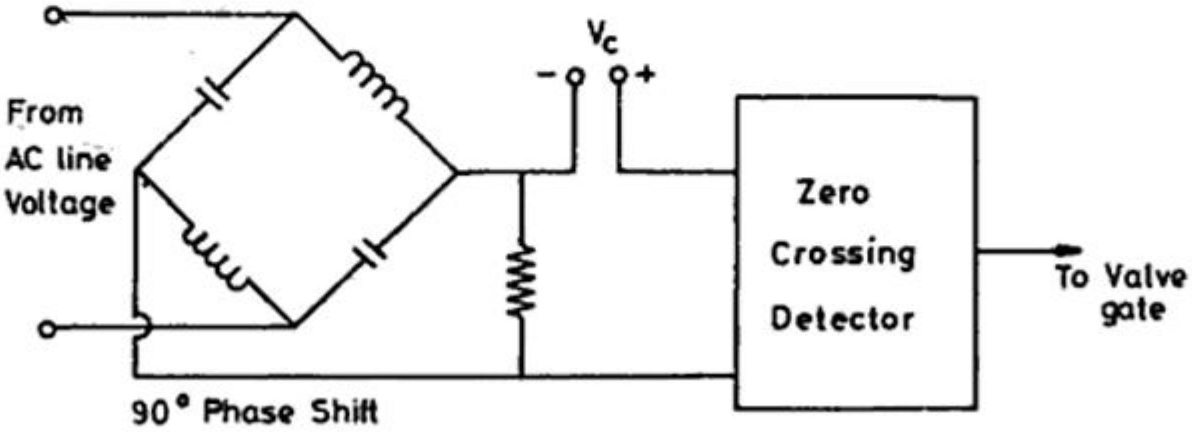
Six timing (commutation) voltages are derived from the converter AC bus via voltage transformers and the six gate pulses are generated at nominally identical delay times subsequent to the respective voltage zero crossings. The instant of zero crossing of a particular commutation voltage corresponds to $\alpha = 0^\circ$ for that valve.



The delays are produced by independent delay circuits and controlled by a common control voltage V derived from the current controllers.

Inverse Cosine Control

The six timing voltages (obtained as in constant a control) are each phase shifted by 90° and added separately to a common control voltage V.

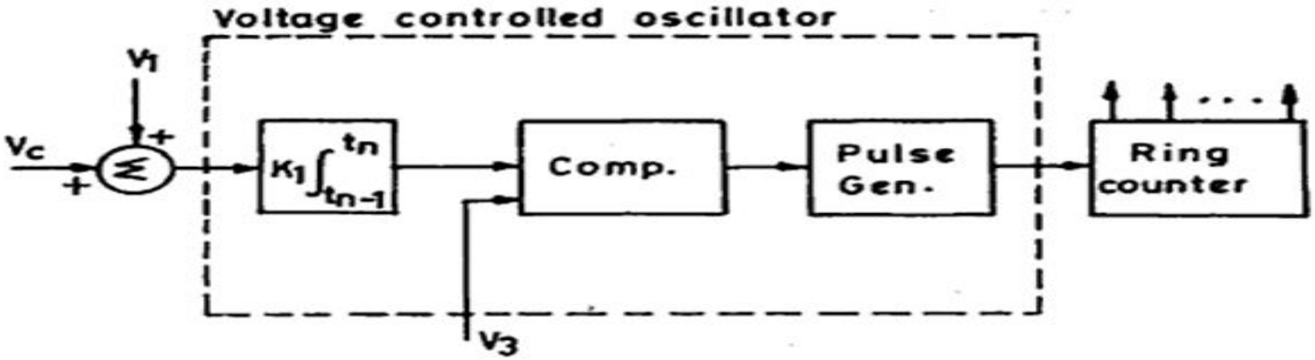


Equidistant Pulse Control (EPC)

The firing pulses are generated in steady-state at equal intervals of 1/pf , through a ring counter. This control scheme uses a phase locked oscillator to generate the firing pulses. Thre are three variations of the EPC scheme

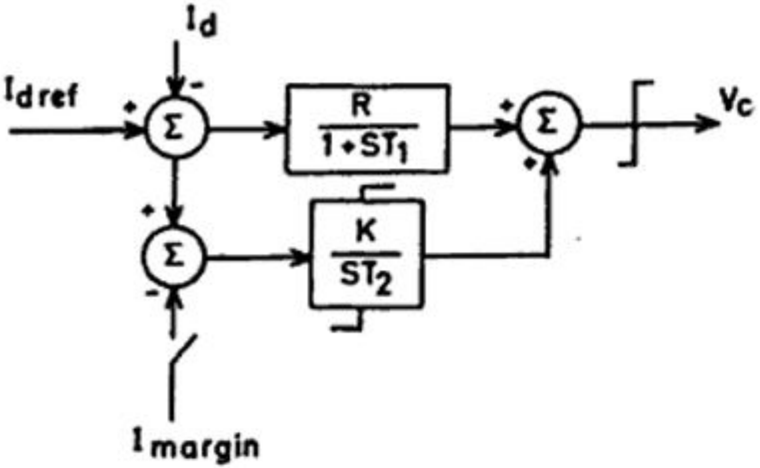
1. Pulse Frequency Control (PFC)
2. Pulse Period Control
3. Pulse Phase Control (PPC)

Pulse Frequency Control (PFC)



Current and Extinction Angle Control

The current controller is invariably of feedback type which is of PI type.



The extinction angle controller can be of predictive type or feedback type with IPC control. The predictive controller is considered to be less prone to commutation failure and was used in early schemes. The feedback control with PFC type of Equidistant Pulse Control overcomes the problems associated with IPC.

Starting and stopping of DC link:

The **starting and stopping of a DC link** are important operations in an HVDC transmission system. Since HVDC converters use thyristors or power electronic valves, special control procedures are required to safely energize and de-energize the DC transmission line.

1. Starting (Energization) of a DC Link

Starting a DC link means bringing the HVDC system from a de-energized condition to normal power transmission.

Objectives of Starting

- Establish DC voltage across the line.
- Build up DC current gradually.
- Avoid excessive overcurrents and overvoltages.
- Ensure stable converter operation.

Sequence of Starting

Step 1: AC System Energization

Step 2: Converter Valve Preparation

Step 3: De-blocking of Converters

Step 4: Voltage Build-Up

Step 5: Current Ramp-Up

Step 6: Normal Power Transmission

2. Stopping (De-Energization) of a DC Link

Stopping means safely removing power transfer and shutting down the HVDC system.

Objectives of Stopping

- Reduce DC current safely.
- Prevent overvoltages.
- Avoid converter damage.
- Disconnect equipment safely.

Sequence of Stopping

Step 1: Reduce Current Order

Step 2: Current Extinction

Step 3: Blocking of Converters

Step 4: Isolation of DC System

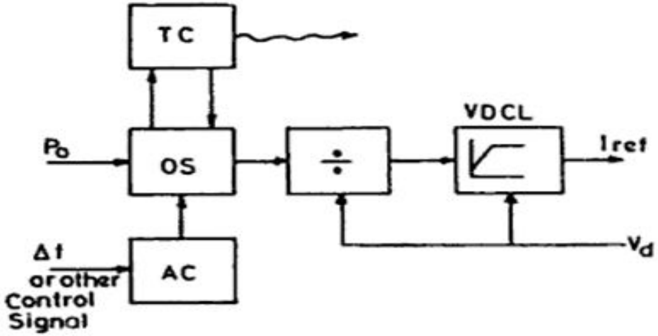
Step 5: AC Side Shutdown

Power Control

The current order is obtained as the quantity derived from the power order by dividing it by the direct voltage. The limits on the current order are modified by the voltage dependent current order limiter (VDCOL). The objective of VDCOL is to prevent individual thyristors from carrying full current for long periods during commutation failures.

By providing both converter stations with dividing circuits and transmitting the power order from the leading station in which the power order is set to the trailing station, the fastest response to the DC line voltage changes is obtained without undue communication requirement.

The figure below shows the basic power controller used.



TC-Telecommunication equipment
OS-Order Setting unit

VDCL-Voltage dependent current limiter

Reactive Power Control in HVDC Systems

Introduction

Reactive power control is one of the most important aspects of High Voltage Direct Current (HVDC) transmission systems. Although power is transmitted in DC form through the transmission line, the converter stations operate with AC systems and consume a significant amount of reactive power. If adequate reactive power support is not provided, AC bus voltages may decrease, leading to poor system performance and instability.

Typically, HVDC converter stations require reactive power equal to about **50–60% of the active power transmitted**. Therefore, proper reactive power compensation is essential for efficient and reliable operation of HVDC systems.

Reactive Power Requirements in Steady State

Why Reactive Power is Required

Converter stations use thyristor valves for AC/DC conversion. During the conversion process, the current waveform lags behind the voltage waveform, resulting in reactive power consumption.

The reactive power requirement depends upon:

- Converter firing angle (α)
- Extinction angle (γ)
- DC power transmitted
- AC system voltage
- Converter transformer reactance

Reactive Power Consumption

The reactive power consumed by a converter is approximately given by:

$$Q = P \tan \phi$$

Sources of Reactive Power

The reactive power required by HVDC converters can be supplied by:

AC Filters

AC filters are installed to eliminate harmonics generated by converters. These filters also provide capacitive reactive power to the AC system.

Advantages:

- Harmonic reduction
- Reactive power support
- Improved power factor

Shunt Capacitor Banks

Capacitor banks are connected to AC buses to generate reactive power.

Advantages:

- Simple construction
- Low cost
- Easy operation

Static VAR Compensators (SVC)

A Static VAR Compensator (SVC) is a fast-acting reactive power compensation device widely used in HVDC converter stations.

Construction

An SVC consists of:

- Thyristor Controlled Reactors (TCR)
- Thyristor Switched Capacitors (TSC)
- Harmonic Filters
- Control System

Working Principle

- When system voltage decreases, the SVC supplies capacitive reactive power.
- When system voltage increases, the SVC absorbs excess reactive power.
- The thyristor control system continuously adjusts reactive power output.

Reactive Power Control During Transients

Introduction

A transient condition occurs whenever there is a sudden disturbance in the power system, such as:

- Faults on AC lines
- Sudden load changes
- Converter blocking
- Switching operations
- Generator outages

During such disturbances, converter reactive power demand changes rapidly, causing voltage fluctuations.

Problems During Transients

- Sudden voltage drop
- Voltage oscillations
- Increased converter commutation failures
- Power transfer reduction
- System instability

Methods of Reactive Power Control During Transients

Static VAR Compensators (SVC)

SVCs provide rapid reactive power support within a few cycles after a disturbance.

Functions:

- Maintain AC voltage
- Reduce voltage oscillations
- Improve transient stability

Synchronous Condensers

A synchronous condenser is an unloaded synchronous machine operating solely to generate or absorb reactive power.

THANK YOU