NARSIMHA REDDY ENGINEERING COLLEGE

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Department of EEE

UNIT-IV

Converter Faults and Protection

HVDC Transmission

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Topics

- Converter faults
- protection against over current and over voltage in converter station
- surge arresters
- smoothing reactors
- DC breakers
- Audible noise
- space charge field
- corona effects on DC lines
- Radio interference.

Converter faults

A **converter fault** is an abnormal condition that affects the operation of the converter station. Faults cannot be completely avoided, but they must be detected and cleared quickly to protect equipment.

The main converter faults are:

1. Arc Back
2. Misfire
3. Commutation Failure
4. Current Extinction
5. Arc-Through
6. Short Circuit in a Bridge

1. Arc Back

Definition: Arc back occurs when a valve loses its ability to block reverse voltage and starts conducting in the reverse direction.

Causes

- Overcurrent
- High peak inverse voltage
- High rate of rise of reverse voltage

Effects

- Severe stress on converter transformer windings
- Can damage converter equipment
- Considered a serious fault

Protection

- Converter valves are blocked immediately.
- AC circuit breaker is opened.
- A **bypass valve** is used to carry current during the fault.

Arc back is a severe, non-self-clearing fault.

2. Misfire

Definition

Misfire occurs when a valve does not receive its firing pulse and fails to turn on.

Causes

- Missing gate pulse
- Failure in firing circuit

Effects

- Can lead to:
    - Commutation failure
    - Arc-through

Characteristics

- Can occur in both rectifier and inverter stations.
- More serious in inverters.
- Rare in modern HVDC systems.

Misfire is generally a self-clearing fault.

3. Commutation Failure

Definition: Commutation failure occurs when current transfer from one valve to the next is not completed before the commutating voltage reverses.

Causes

- Sudden increase in DC current
- Reduction in AC voltage
- Voltage dips and phase shifts
- AC system disturbances

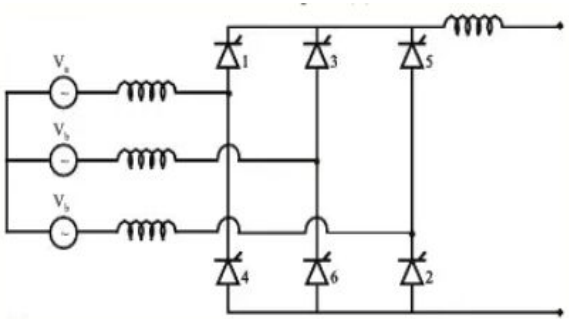

Figure (1): Circuit Diagram

Where It Occurs

Mostly in **inverters** because:

- AC voltage may become low.
- DC current may become high.

Effects

- DC voltage becomes zero temporarily.
- DC current increases.
- Power transmission is interrupted for a short time.

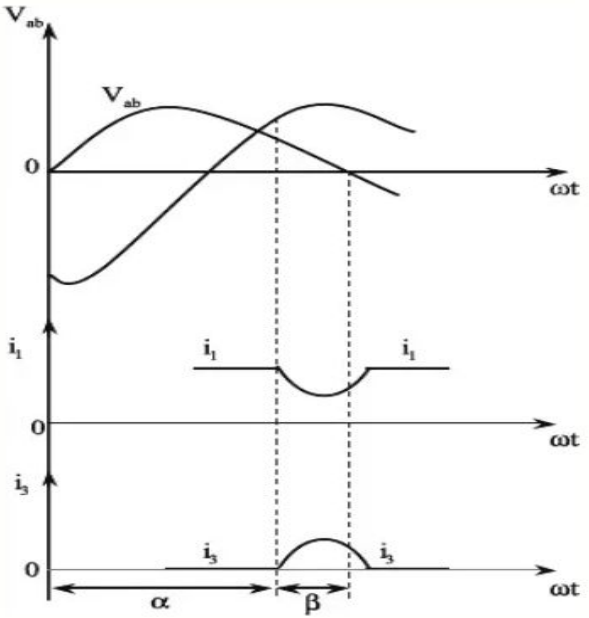

Figure (2): Commutation Failure

Types

(a) Single Commutation Failure

- One commutation fails.
- System usually returns to normal automatically.

Effects

- AC current stops briefly.
- Bridge voltage becomes zero.
- DC current rises.

(b) Double Commutation Failure

- Two successive commutations fail.
- More severe but very rare.
- Usually self-clearing.

Protection

- Advance the next firing pulse.
- Maintain proper extinction angle.
- Use smoothing reactors to limit current rise.

Commutation failure is the most common inverter-side fault.

4. Current Extinction

Definition

Current extinction occurs when valve current falls below the minimum holding current.

Causes

- Very low current through the valve
- Improper firing pulses

Effects

- Valve stops conducting unexpectedly.
- Overvoltages may appear across the valve.

Prevention

- Modern HVDC systems provide repeated firing pulses to ensure conduction.

Current extinction can cause dangerous overvoltages.

5. Arc-Through

Definition

Arc-through occurs when a valve conducts during a period when it should be blocked.

Causes

- Failure of negative grid pulse
- Early positive firing pulse
- Malfunction of gate pulse generator

Effects

1. Frequent short circuits
2. AC current may cease temporarily
3. Delay angle decreases

Characteristics

- More common in inverter stations.
- Usually self-clearing if the disturbance is temporary.

Arc-through is caused by unwanted firing of a valve.

6. Short Circuit in a Bridge

Definition: A short circuit occurs inside the converter bridge due to insulation failure or flashover.

Causes

- Flashover of bushings
- Internal insulation failure

Effects

- Heavy fault current
- Damage to converter equipment

Worst Case Occurs when firing angle: $\alpha = 0^\circ$

Protection

- Block all firing pulses.
- Clear the fault when current becomes zero.

Short circuits are rare because converter valves are installed in controlled valve halls.

Quick Summary of converter faults

Fault	Cause	Effect	Nature
Arc Back	Reverse conduction of valve	Transformer stress	Non-self-clearing
Misfire	Missing firing pulse	Valve fails to conduct	Self-clearing
Commutation Failure	Incomplete current transfer	DC voltage collapse	Usually self-clearing
Current Extinction	Current below holding value	Overvoltage	Self-clearing
Arc-Through	Unwanted valve firing	Short circuit risk	Self-clearing
Short Circuit in Bridge	Flashover/insulation failure	Heavy fault current	Requires protection

Protection Against Overcurrents in HVDC Converters

Overcurrent is a condition in which the current flowing through a conductor or electrical equipment exceeds its rated value. Excess current produces heat, which can damage equipment and insulation.

Types of Overcurrent

1. Overload
2. Short Circuit
3. Earth Fault

1. Overload: An **overload** occurs when the current flowing through a conductor is slightly higher than its rated current.

Characteristics

- Does not cause immediate damage.
- Can be tolerated for a short duration.
- Long-term overload causes overheating and insulation failure.

Example: A transformer rated for 100 A carrying 120 A for a long period experiences overload.

2. Short Circuit

A **short circuit** occurs when two conductors accidentally come into contact, creating a very low-resistance path.

Characteristics

- Current rises to a very high value.
- Produces excessive heat and mechanical stress.
- Must be cleared immediately to prevent equipment damage.

Example

When phase conductors touch each other due to insulation failure.

Protection Against Overcurrents

Since overcurrents can seriously damage HVDC equipment, special protection systems are provided in converter stations.

The main protection systems are:

1. **Group Differential Protection**
2. **Overcurrent Protection**
3. **Pole Differential Protection**

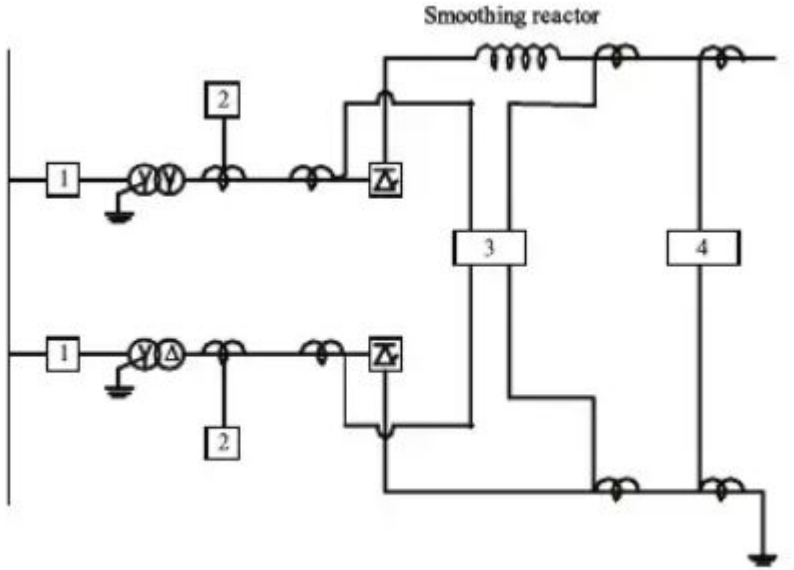

Figure: Overcurrent Protection of a Converter

Types of Faults Producing Overcurrent

1. Line Faults

- Most common faults.
- Occur on transmission lines.
- Usually controlled by current control systems.

2. Internal Faults

- Occur inside converter equipment.
- Produce very high overcurrents.
- Less frequent but more severe.

3. Commutation Failures

- Common in inverter stations.
- Cause temporary overcurrents.
- Occur relatively frequently in HVDC systems.

Protection Against Overvoltages in HVDC Systems

Overvoltage is a condition in which the voltage across an electrical equipment exceeds its rated or maximum permissible value.

Overvoltages can damage insulation, transformers, converters, and other power system equipment.

Types of Overvoltages

Overvoltages are classified into three types:

1. Temporary Overvoltages
2. Switching Overvoltages (Switching Surges)
3. Lightning Overvoltages

Smoothing Reactor in HVDC Systems

What is a Smoothing Reactor?

A **smoothing reactor** is a high-inductance coil connected in series with the DC side of an HVDC converter station. Its main purpose is to reduce ripple (harmonic currents) in the DC current and make it smoother

Necessity of a Smoothing Reactor

The DC output from a rectifier is not perfectly smooth. It contains harmonic components called **ripples**.

Since the smoothing reactor has high inductance:

- It offers high impedance to harmonic currents.
- It allows DC current to flow easily.
- It stores energy in its magnetic field.
- It prevents sudden changes in current.

As a result, ripple currents and fluctuations are reduced, producing a smoother DC current.

DC Circuit Breakers

A **DC circuit breaker (DCCB)** is a protective device used to interrupt fault currents in HVDC systems and protect equipment from damage.

Classification of DC Circuit Breakers

DC circuit breakers are classified based on:

1. Voltage Capability
2. Current Capability
3. Energy Capability
4. Switching Time

Importance of Corona Loss in DC Transmission

What is Corona?

Corona is the phenomenon of hissing sound, violet glow, and ozone gas production around a transmission line conductor due to the ionization of air when the electric field exceeds a critical value.

In HVDC transmission systems, corona is mainly related to the electric field distribution around the conductor. When corona occurs, discharge currents are produced, resulting in power loss, radio interference, television interference, and audible noise.

Effects of Corona

- Causes power loss in the transmission line.
- Produces radio interference.
- Produces television interference.
- Creates audible noise (hissing sound).
- Generates ozone gas.
- Reduces transmission efficiency.

Radio interference.

Radio Interference (RI) is the disturbance caused to radio communication signals due to the electromagnetic noise generated by corona discharge around high-voltage transmission line conductors.

When the electric field around an HVDC conductor exceeds the critical value, the surrounding air gets ionized and corona occurs. This corona produces high-frequency current pulses that radiate electromagnetic waves, which interfere with radio reception.

Causes of Radio Interference

- Corona discharge on transmission line conductors.
- Rough or damaged conductor surfaces.
- High operating voltages.
- Rain, fog, snow, and other adverse weather conditions.
- Water droplets on conductor surfaces.

Methods to Reduce Radio Interference

- ➢ Use bundled conductors.
- ➢ Increase conductor diameter.
- ➢ Maintain smooth conductor surfaces.
- ➢ Avoid sharp points on conductors and fittings.
- ➢ Increase conductor spacing.
- ➢ Operate below excessive corona levels.

THANK YOU