NARSIMHA REDDY ENGINEERING COLLEGE

An Autonomous Institution| Affiliated to JNTUH | Approved by AICTE
Accredited by NBA & NAAC with 'A' Grade

Department of EEE

UNIT-V
Harmonics

HVDC Transmission

Prepared by
Mounika M, Assistant professor, EEE

Topics

- Generation of Harmonics
- Characteristics harmonics
- calculation of AC Harmonics
- Non- Characteristics harmonics
- adverse effects of harmonics
- Calculation of voltage and Current harmonics
- Effect of Pulse number on harmonics
- Filters: Types of AC filters
- Design of Single tuned filters
- Design of High pass filters

Generation of Harmonics:

The harmonics which are generated are of two types.

(i) Characteristic harmonics.

(ii) Non- characteristic harmonics.

Characteristic Harmonics:

The characteristic harmonics are harmonics which are always present even under ideal operation. In the converter analysis, the DC current is assumed to be constant. But in AC current the harmonics exist which are of the order of

$$h = np \pm 1$$

and in DC current it is of the order of

$$h = np$$

where n is any integer and p is pulse number

Neglecting overlap, primary currents of Y-Y and Y-Δ connection of the transformer are considered taking the origin symmetrical where

$$\left.\begin{aligned} i &= I_d \text{ for } -\pi/3 \le \omega t \le \pi/3 \\ &= 0 \text{ for } \pi/3 \le \omega t \le 2\pi/3 \text{ and} \\ &\qquad -\pi/3 \le \omega t \le -2\pi/3 \end{aligned}\right\} \text{for Y-Y}$$

connection

converter

transformer

$$\begin{aligned} &= -I_d \text{ for } -2\pi/3 \le \omega t \le -\pi \\ &\text{and} \\ &\qquad 2\pi/3 \le \omega t \le \pi \end{aligned}$$

Characteristic Harmonics

Characteristic harmonics are those naturally produced by a converter under ideal operating conditions.

For a converter with pulse number p, the characteristic AC harmonics are given by:

$$h = np \pm 1$$

Where:

- h = Harmonic order
- p = Pulse number of converter
- $n = 1, 2, 3, \ldots$

For a 6-pulse converter:

$$h = 6n \pm 1$$

Calculation of Harmonic Frequency

The frequency of a harmonic is:

$$f_h = h \times f$$

Where:

- f_h = Harmonic frequency
- h = Harmonic order
- f = Fundamental frequency

Example

For a 12-pulse converter connected to a 50 Hz system:

11th harmonic:

$$f_{11} = 11 \times 50 = 550\ Hz$$

13th harmonic:

$$f_{13} = 13 \times 50 = 650\ Hz$$

Non-Characteristic Harmonics

Introduction

Non-characteristic harmonics are harmonics that do not follow the relationship:

$$h = np \pm 1$$

They are not produced under ideal converter operating conditions but arise because of system imperfections and disturbances.

Causes of Non-Characteristic Harmonics

AC System Unbalance

Unequal phase voltages produce asymmetrical converter operation, generating additional harmonic components.

Transformer Asymmetry

Differences in transformer impedances and winding parameters can create unexpected harmonics.

Firing Pulse Errors

Inaccurate firing of thyristor valves causes unequal conduction periods and harmonic generation.

Commutation Failures

Temporary failure of current transfer between valves leads to waveform distortion and non-characteristic harmonics.

Control System Disturbances

Improper controller operation and transient switching conditions may generate additional harmonics.

Common Non-Characteristic Harmonics

In a 12-pulse converter, harmonics such as:

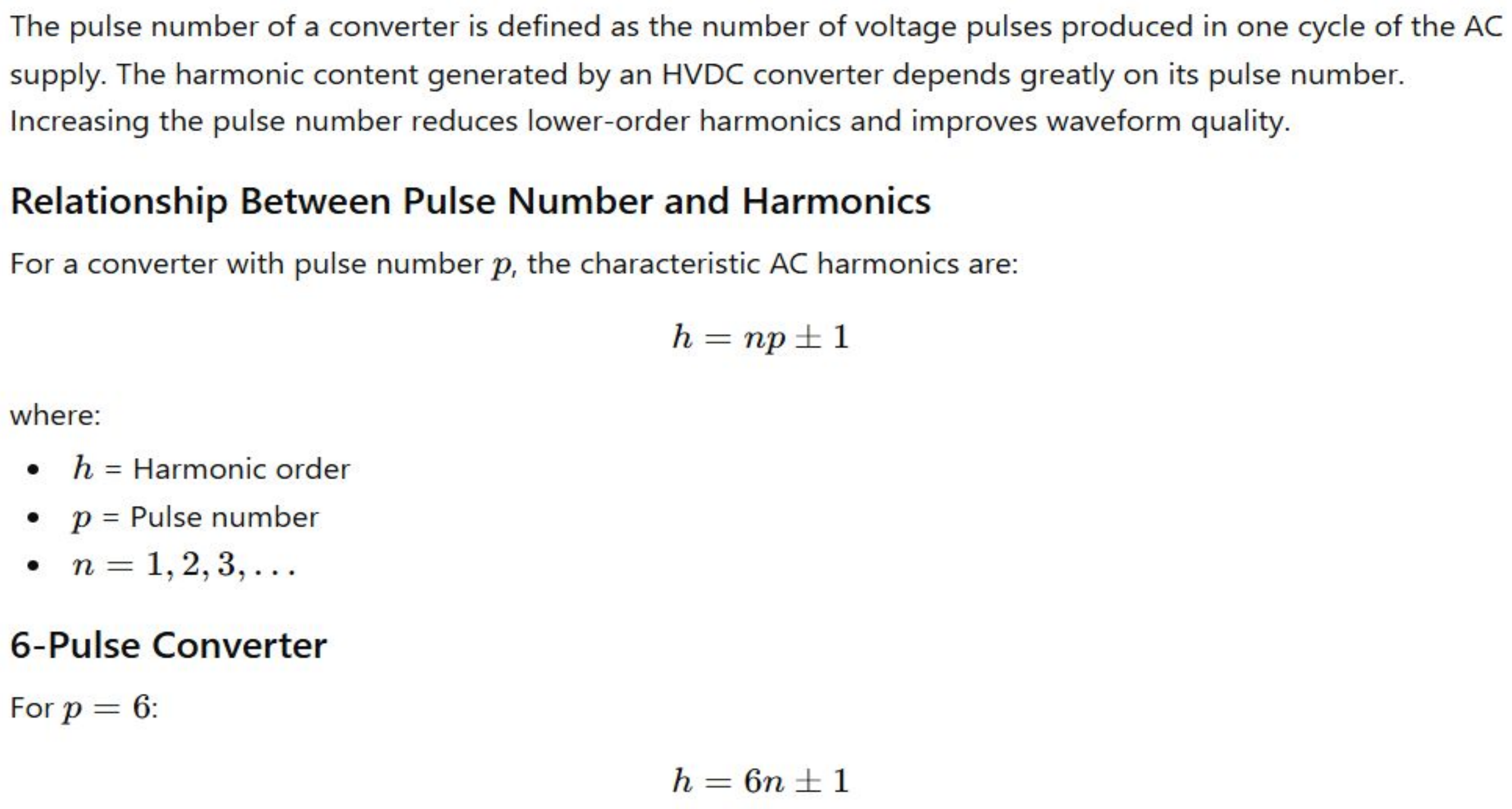
- 2nd
- 3rd
- 4th
- 5th
- 7th
- 9th

may appear under abnormal operating conditions even though they are theoretically absent.

Effects of Non-Characteristic Harmonics

- Increased voltage distortion
- Additional heating of equipment
- Communication interference
- Misoperation of protection systems
- Increased converter losses
- Reduced power quality

Effect of Pulse Number on Harmonics



The pulse number of a converter is defined as the number of voltage pulses produced in one cycle of the AC supply. The harmonic content generated by an HVDC converter depends greatly on its pulse number. Increasing the pulse number reduces lower-order harmonics and improves waveform quality.

Relationship Between Pulse Number and Harmonics

For a converter with pulse number p, the characteristic AC harmonics are:

$$h = np \pm 1$$

where:

- h = Harmonic order
- p = Pulse number
- $n = 1, 2, 3, \ldots$

6-Pulse Converter

For $p = 6$:

$$h = 6n \pm 1$$

Advantages of Higher Pulse Number

- Lower harmonic distortion
- Reduced filter size
- Improved power quality
- Better converter efficiency
- Reduced communication interference

Thus, modern HVDC systems commonly use 12-pulse converters.

Filters in HVDC Systems

Introduction

Converters generate harmonics that can adversely affect power system operation. Filters are installed to absorb harmonic currents and improve waveform quality.

The functions of filters are:

- Harmonic suppression
- Reactive power support
- Voltage waveform improvement
- Reduction of communication interference

Types of AC Filters

Single Tuned Filters

A single tuned filter is designed to eliminate one specific harmonic frequency.

Characteristics:

- Simple construction
- Low cost
- High filtering efficiency at tuned frequency

Applications:

- 5th harmonic filter
- 7th harmonic filter
- 11th harmonic filter
- 13th harmonic filter

Double Tuned Filters

These filters are designed to suppress two harmonic frequencies simultaneously.

Advantages:

- Reduced equipment cost
- Less space requirement

Applications:

- Combined 11th and 13th harmonic filtering

High Pass Filters

High pass filters provide low impedance to a wide range of higher-frequency harmonics.

Characteristics:

- Effective for high-order harmonics
- Wide frequency coverage
- Good damping properties

C-Type Filters

These are improved high-pass filters that reduce losses at the fundamental frequency while maintaining effective harmonic filtering.

Advantages:

- Lower losses
- Better efficiency
- Suitable for HVDC applications

Design of Single Tuned Filters

Basic Circuit

A single tuned filter consists of:

- Capacitor (C)
- Reactor (L)
- Damping resistance (R)

connected in series and placed in shunt with the AC system.

Design of High Pass Filters

Introduction

High pass filters are used to suppress a broad range of high-order harmonics that cannot be economically filtered using multiple single tuned filters.

Basic Circuit

A high pass filter consists of:

- Capacitor (C)
- Reactor (L)
- Damping resistor (R)

The resistor provides damping and broad-band filtering characteristics.

Cut-off Frequency

The cut-off frequency is determined by:

$$f_c = \frac{1}{2\pi\sqrt{LC}}$$

THANK YOU