NSCET
E-LEARNING PRESENTATION
LISTEN ... LEARN... LEAD...
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UNIT -3 INTRODUCTION TO HARMONICS
LECTURE 01
Understanding harmonics?
How harmonics are produced?
Mathematical analysis?
Why to worry about harmonics?
Causes of harmonics?
What is THD?
Its effect on power quality?
Mitigation steps of harmonics?
Advantages of harmonics?
Harmonics are defined as currents or voltages with frequencies that are integer multiples of the fundamental power frequency.

(i.e. if the fundamental frequency is $f$, the harmonic have frequencies $2f$, $3f$, $4f$, $\ldots$ etc)
• The harmonics have the property that they are all periodic at the fundamental frequency.
• The sum of harmonics is also periodic at that frequency.
• Harmonic frequencies are equally spaced by the width of the fundamental frequency and can be found by repeatedly adding that frequency.
• For example, if the (first harmonic) is 25 Hz, the frequencies of the next harmonics are: 50 Hz (2nd harmonic), 75 Hz (3rd harmonic), 100 Hz (4th harmonic) etc.
HOW ARE HARMONICS PRODUCED?

The distortion is mainly caused by Nonlinearity-

• In a linear circuit, the output response is directly proportional to the input.
• In an AC circuit, that means that the application of a sinusoidal voltage results in a sinusoidal current.
• As the instantaneous voltage changes over the period of the sine wave, the instantaneous current rises and falls in proportion to the voltage so that the waveform of the current is also a sine wave.
• If a circuit is composed of ideal resistors, inductors and capacitors, it is a linear circuit because those components are linear.
Harmonics in Linear and Non Linear Loads

Diagram showing the comparison between linear (inductive) load and non-linear load in terms of voltage and current waveforms.
MAIN PRODUCERS OF HARMONICS

• Most harmonics come from loads such as induction and arc furnaces, and power electronics.
• Power electronics are the biggest culprit when it comes to producing harmonics.
• Static VAR compensators, variable-frequency motor drives, and switching power supplies are the greatest concern.

The above all are non linear circuits.
LOADS PRODUCING HARMONIC CURRENTS

1. Electronic lighting ballasts/Controls
2. Adjustable speed Motor-Drives
3. Electric Arc Welding Equipment
4. Solid state Industrial Rectifiers
5. Industrial Process Control Systems
6. Uninterruptible Power Supplies(ups)systems
7. Saturated Inductors/Transformers
8. LAN/Computer Networks

These are some examples of non linear elements which produces harmonic distortion in voltage and currents.
WHY BOTHER ABOUT HARMONICS?

• 50-60% of all electrical Ac Systems in India operate with non linear type of loads.

• Power-Quality Issues & Problems

• Damage to Power Factor Correction capacitors

• Waveform Distortion can create sag/swell/notching/ringing/…

All above can cause damage effects to consumer loads.
NEGATIVE EFFECTS OF HARMONICS (CONT’ D)

• False or spurious Relay operations and trips of circuit breakers.

• Mal-Operation/un stability of voltage regulator.

• Power factor correction capacitor failure
OVERHEATING AND DAMAGE OF NEUTRAL GROUND CONDUCTERS

• In a three-phase, four-wire system, neutral conductors can be severely affected by nonlinear loads connected to the 220 V branch circuits.

• Under normal conditions for a balanced linear load, the fundamental 50 Hz portion of the phase currents will cancel in the neutral conductor.
FALSE OR SPURIOUS RELAY AND TRIP OF CIRCUIT BREAKER

• A peak-sensing, electronic trip circuit breaker responds to the peak of current waveform.

• As a result, it won’t always respond properly to harmonic currents.

• If the peak is lower than normal, the breaker may fail to trip when it should.
• Common thermal-magnetic circuit breakers use a bi-metallic trip mechanism that responds to the heating effect of the circuit current.

• They are designed to respond to the true-RMS value of the current waveform and will trip when the trip mechanism gets too hot.

• This type of breaker has a good chance of protecting against harmonic current overloads.
EFFECT OF HARMONIC ON METERS

• Harmonics can produce significant errors in meters which sense the peak of waveform, then adjust it to "RMS" by scaling by $(2)^{1/2}$.

• Errors will not occur if wave is close to sinusoidal.
PREVENTION

• “True RMS” meters can mitigate the effects of harmonics as they sample the waveform, calculate RMS value

• Display accurate results regardless of level of distortion.
MEASUREMENT AND DETECTION TECHNIQUES

DIGITAL OSCILLOSCOPE  TRUE RMS MULTIMETER
HARMONIC DISTORTION ANALYSER

DEPARTMENT OF EEE, NSCET, THENI
Digital Oscilloscope:

Wave shape, THD and Amplitude of each harmonic can be calculated with help of digital oscilloscope.

“True RMS” Multi-Meter:
Giving correct readings for distortion-free sine waves and typically reading low when the current waveform is distorted
“True RMS” Multi-Meter
DIGITAL OSCILLOSCOPE

• When harmonics are present in considerable amount, their presence can be observed with an oscilloscope.

• The waveform displayed will either have unequal positive and negative peak values or will exhibit a change in shape.

• In either case, the oscilloscope will provide a qualitative check of harmonic distortion.

• However, the distortion must be fairly severe (around 10%) to be noted by an untrained observer.
Most testing situations require a better quantitative measure of harmonic distortion.

Harmonic distortion can be quantitatively measured very accurately with a harmonic distortion analyzer.

It is generally referred to simply as a distortion analyzer.
ANALYZER
A block diagram for a fundamental-suppression harmonic analyzer is shown in figure. When the instrument is used:

- Switch S, is set to the "set level" position
- The band pass filter is adjusted to the fundamental frequency
- The attenuator network is adjusted to obtain a full-scale voltmeter reading.
ANALYZER

• Switch S, is then set to the "distortion" position

• The rejection filter(or we can say band stop filter) is turned to the fundamental frequency

• The attenuator is adjusted for a maximum reading on the voltmeter.
APPLICATIONS OF WAVE ANALYZERS

• Amplitude measurement of a single component of a complex waveform.

• Amplitude measurement in the presence of noise and interfering signals.

• Measurement of signal energy within a well-defined bandwidth.
POWER QUALITY ISSUE AND HARMONICS

What is power quality?
Why is power quality so important?
Power quality problems due to harmonic distortion.
WHY IS POWER QUALITY SO IMPORTANT?

• Power quality is an increasingly important issue for all electrical consumers.

• Problems with powering and grounding can cause data and processing errors that affect production and service quality.

• Each time production is interrupted as electrical consumer
POWER QUALITY PROBLEMS DUE TO HARMONIC DISTORTION.
POWER QUALITY PROBLEMS DUE TO HARMONIC DISTORTION.

Harmonic current are generated to small extent and at low distortion levels by
1- Generation equipment.
2- transmission equipment.
3- Distribution equipment.
4- Industrial load.
5- Domestic load.
HARMONIC EFFECTS ON POWER QUALITY

• Computer networks and computer Faulty operation of Control devices, protective relays etc.

• Extra loss in transformer, rotating machines etc.

• Noise in electrical equipment.

• Noise are generated by electronic devices.
HARMONIC EFFECTS ON POWER QUALITY

• Equipment fail prematurely.
• Decrease the efficiency of the electrical distribution and utilization network.
• Causes grounding potential rise.
• Light flickering.
• Faulty operation of Computerized data processing equipment
HARMONICS FILTER TYPES

PASSIVE FILTERS
• Uses combination of capacitors, inductor(reactors) and resistors most common
• Available for all voltage levels.

ACTIVE FILTERS
• Inserting negative phase compensating harmonics into the AC- Network, thus eliminating the undesirable harmonics on the AC Power network.
• Used only for low voltage networks.
HYBRID FILTERS

- The harmonic compensation can be obtained by Passive Filters (PF), Active Power Filters (APF) and hybrid filters (HPF).

- PF and APF have some advantage and disadvantages, but hybrid active power filters contain their advantages but not their disadvantages.
Passive filters
Passive filters

Operating principle
• An LC circuit, tuned to each harmonic order to be filtered, is installed in parallel with the non-linear load.

• This bypass circuit absorbs the harmonics, thus avoiding their flow in the distribution network.
Passive filters

• Generally speaking, the passive filter is tuned to a harmonic order close to the order to be eliminated.

• Several parallel-connected branches of filters can be used if a significant reduction in the distortion of a number of harmonic orders is required.
Typical I(THD) of 5 to 8%
PASSIVE HARMONIC FILTER
Active filters (active harmonic conditioner)
Active filters (active harmonic conditioner)

Operating principle

• The basic principle of Shunt Active Filter is that it generates a current equal and opposite to the harmonic current drawn by the load

• Injects it to the point of coupling there by forcing the source current to be pure sinusoidal.
ACTIVE FILTER CONCEPT

\[ I_{\text{source}} = I_{\text{rectifier}} + I_{\text{filter}} \]

1st 5th 7th 11th 13th

- High Filter Converter ratings: \(~ 1/3 \) of Drive kVA
- Multi-functional: reactive power factor compensation, voltage and load balancing
ACTIVE HARMONIC FILTER

Typical I(THD) of 3 to 6%

Current from Transformer

DEPARTMENT OF EEE, NSCET, THENI
ACTIVE HARMONIC FILTER
Hybrid filters
Hybrid filters

Operating principle

• Passive and active filters are combined in a single system to constitute a hybrid filter.

• This new filtering solution offers the advantages of both types of filters

• Covers a wide range of power and performance levels.
PERFORMANCE CHART OF VARIOUS MITIGATION TECHNIQUES

MITIGATION TECHNIQUES
A. 6-pulse, no link choke
B. 6-pulse, with link choke
C. Input line reactor
D. Tuned and non-tuned filters
E. 12-pulse with auto transformer
F. 12-pulse with isolation transformer
G. 18-pulse with auto transformer
H. 18-pulse with isolation transformer
I. Regenerative active front end
J. Active power filter
CONCLUSIONS

• The harmonic distortion principally comes from Nonlinear-Type of Loads.

• The greater application of power electronics is causing increased level of harmonics.

• Harmonic distortion can cause serious Failure/Damage problems.

• Harmonics are important aspect of power operation that requires Mitigation!!