Power Quality

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Silicon ...beyond teaching

Cu International Copper Association India
Copper Alliance

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apqi ASIA POWER QUALITY INITIATIVE

Power Quality - Distribution company Perspective

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User's understanding of Power Quality

- Power quality is "the provision of voltages and system design so that the user of electric power can utilize electric energy from the distribution system successfully, without **interference or interruption**
- Interruption is due to load shedding, faults, insulation failure, protection trips, conductor snapping etc
- Interference is due to sag, swell, transients, flicker, harmonics, radio noise.

Discom's present anxiety

- Continuity of power supply (ensuring availability with compromised quality)
- Generation of resources enough to reduce loan burden.
- Reduce T&D losses to get benefit of grants.
- Maintenance , with available inventory.
- System improvement, if funds are likely to be withdrawn.

Power quality, present perception

- Good Power Quality is considered desirable by all Discoms.
- Good Power Quality is considered necessary by many.
- Good power quality is pursued as mandatory requirement by no one yet.

  Investment on power quality is low and confined up to to Scada.

Similarity with other quality related services

- The relationship between Power Quality and the DISCOMS is similar to:-

  Quality health service and Govt. hospitals management.

  Quality Education service and Govt. primary

  schools management.

  (More a care taker ownership than pursuit of excellence).

Commonality

- Public dealing with the mass who have limited financial affordability.
- Pseudo ownership. (No freedom in policy making)
- Administrative interference from government sources.
- Lack of awareness of the customer on the issue of consumer rights.
- No benchmarking or role models
- No competition (monopolistic)

DISCOM'S PRIORITY

HIGH	LOW
• Meter reading	
• Billing and Realization	Trouble call Mgmt.
• New connection	Maintenance
• Procurement	Planning
• Load shedding	Dispute Resolution
• Disconnection	Testing and
• T&D Loss reduction	Power quality

Poor PQ, a result of negligence

- Absence of advance planning
- History of large share of investment going to generation and transmission
- Use of Power Electronics loads without studies
- Over loading of transformers and conductors.
- Un authorized connections
- No Harmonics measurement and problem mitigation in time.
- No Un balance measurement and correction
- Bad Earthing, bad workmanship
- Bad protection co-ordination

Privatization

- As a policy, privatization is good
- In reality DISCOM continues to be in the supply chain of power having no independent control on quantity of power nor the tariff.
- Expectation is high from private DISCOMS (24X7 quality power at affordable rate at 15% T&D losses)
- Discoms are the punch bags for all that goes wrong in in power delivery system, and poor performance is taken as fate accompli.

21st century expectations from 20th century assets

Dilemma with Discoms:-

- Inheritance of ageing assets and obsolete technology.
- Inheritance of non paying customers, the legacy.
- Inheritance of un trained people
- Poor rate of return on investment, large scale pilferage
- Answerability to public, threat of public anger.

Why PQ disturbances occur?

- **Daily load cycles**
- **Switching of capacitor banks**
- **Transformer energization**
- **Transmission faults**
- **Lightning strikes**
- **Downed conductors**

PQ disturbances & effects

- Voltage Swell
  - *as an increase in rms voltage/current between 1.1 and 1.8 p.u. at the power frequency for the duration 0.5 cycles to 1 min.*
- Cause
  - *system faults*
  - *switching of large loads*
- Effects
  - *insulation breakdown method or sparkover*
  - *semiconductor device damage*
  - *loss of data/stability*
  - *shorts & accelerated aging*

Power Quality and Harmonics

- Harmonic Distortion
  - AFDs, DC Drives, UPSs, DC power supplies (computers, duplicators, fax's) *will* cause current (and voltage) harmonics
    - Single phase – 3rd, 6th, etc (triplens) can cause transformer neutral conductor overheating
    - Three phase – 5th, 7th, 11th, 13th, etc can cause equipment malfunctions
    - Big questions – "How much?" and "How much is too much?"

CAUSE OF HARMONICS

- Types of equipment that generate harmonics
- Harmonic load currents are generated by all NON-LINEAR loads. These include:
- Single phase loads, e.g.
- Switched mode power supplies (SMPS)
- Electronic fluorescent lighting ballasts
- Small uninterruptible power supplies (UPS) units
- Three phase loads, e.g.
- Variable speed drives
- Large UPS units

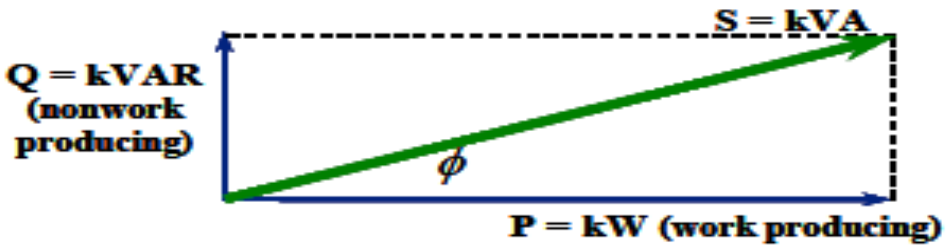
LIST OF HARMONICS PROBLEM

- Causing greater cable losses in all power distribution cable in poorer energy efficiency.
- High voltage & current by harmonic resonance.
- Non cancellation of **triple-N harmonics** causing larger neutral current than phase current.
- Further reduction of power factors and the effect that is inherent to that.
- Over stressing of power factor correction capacitor.
- Further enhancement of **skin effect** .
- Metering errors etc.

EFFECT OF HARMONICS

1.ON POWER FACTOR:

With Linear Loads

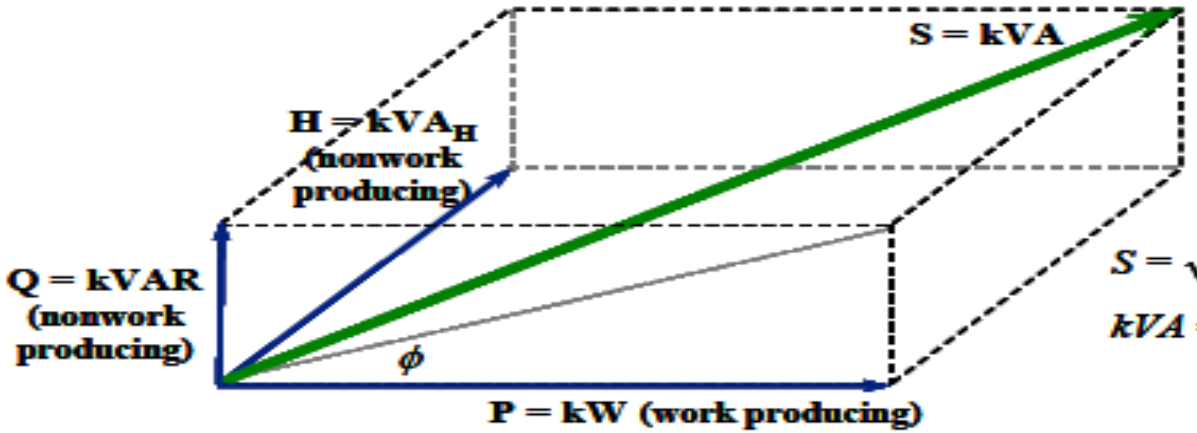


$$pf = \frac{P}{S} = \frac{kW}{kVA} = \cos\phi$$

$$S = \sqrt{P^2 + Q^2}$$

$$kVA = \sqrt{kW^2 + kVAR^2}$$

With Non-linear Loads



$$pf = \frac{P}{S} = \frac{kW}{kVA} \neq \cos\phi$$

$$S = \sqrt{P^2 + Q^2 + H^2}$$

$$kVA = \sqrt{kW^2 + kVAR^2 + kVAR_H^2}$$

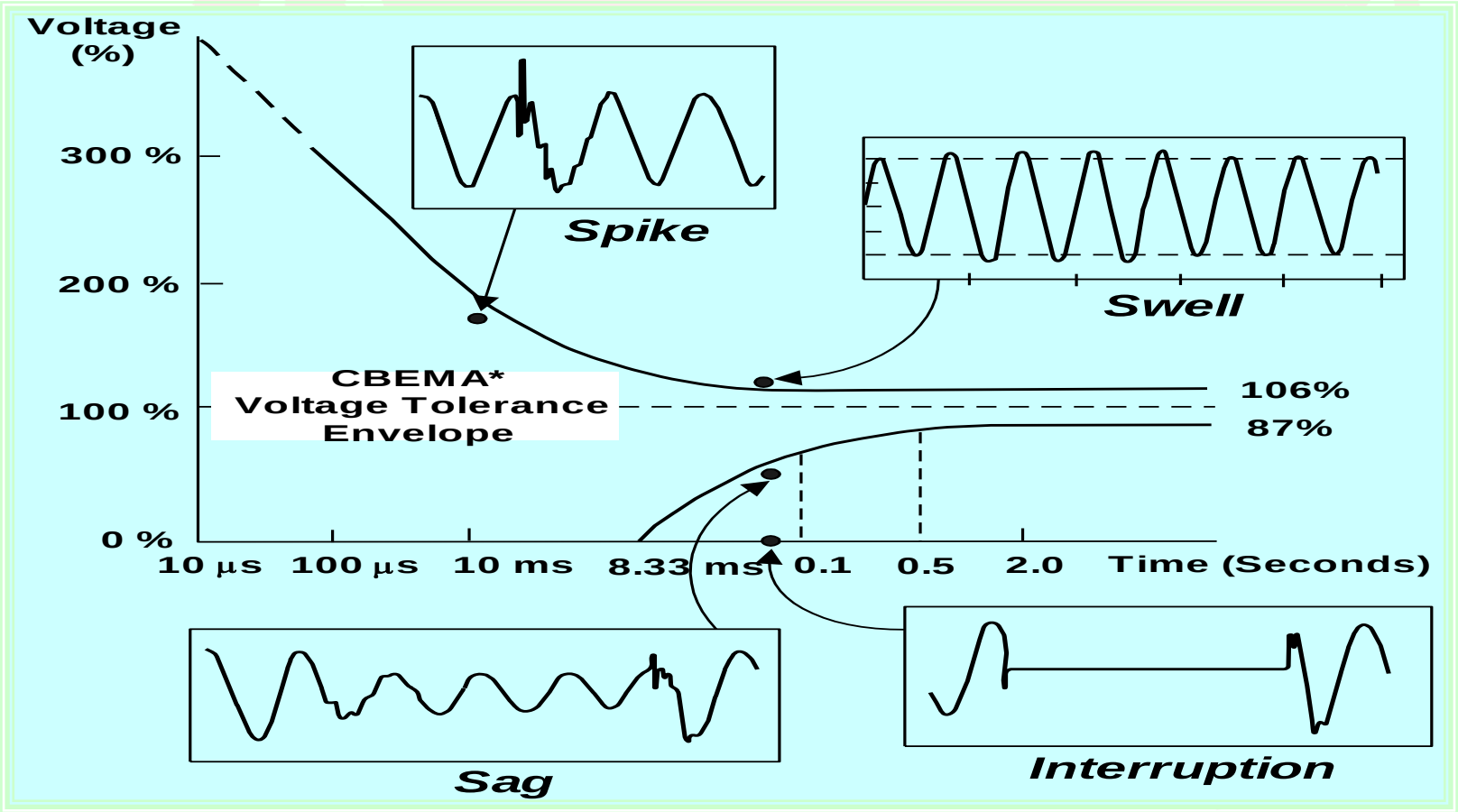
True Power Factor = (Displacement Power Factor) x (Distortion Power Factor)

Figure 3- 1: Power factor relationship for Linear and Non-linear loads

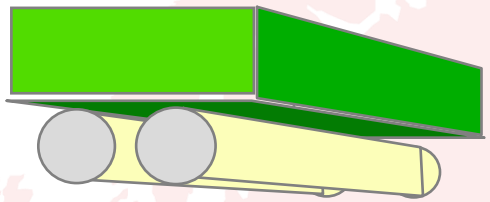
Where do they come from?

...Nonlinear devices will draw currents with distorted waveforms ,which are comprised of harmonics of the source frequency.

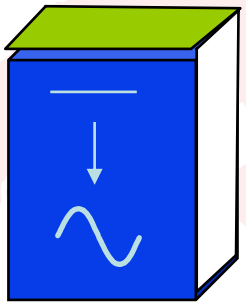
PQ Disturbances



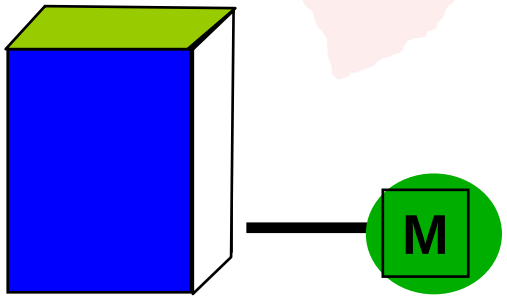
Common sources of Harmonics



Lighting ballasts

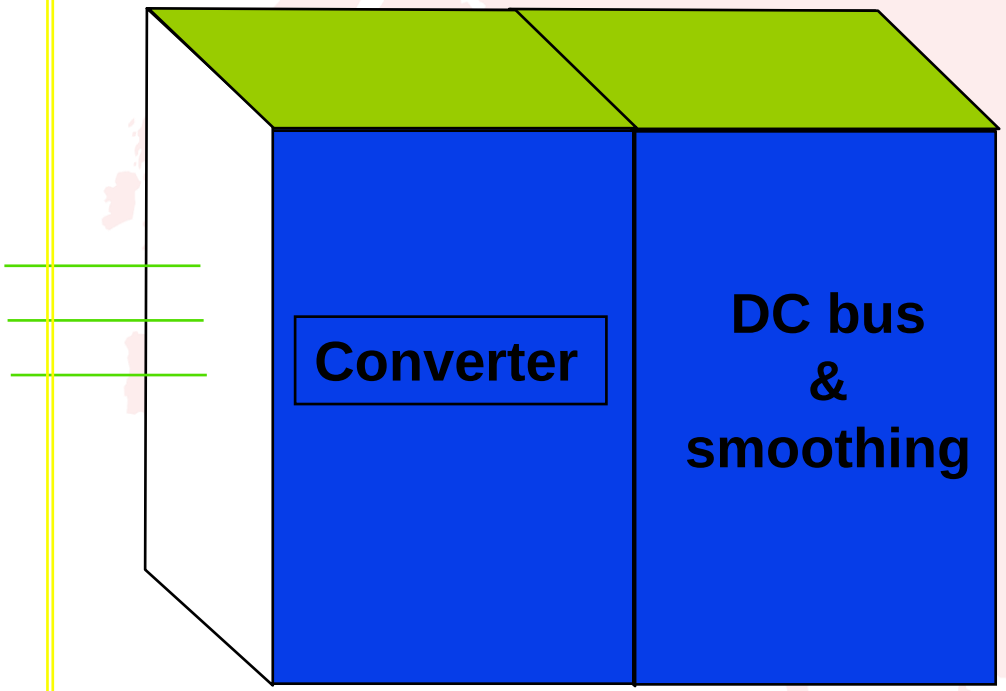


UPS systems

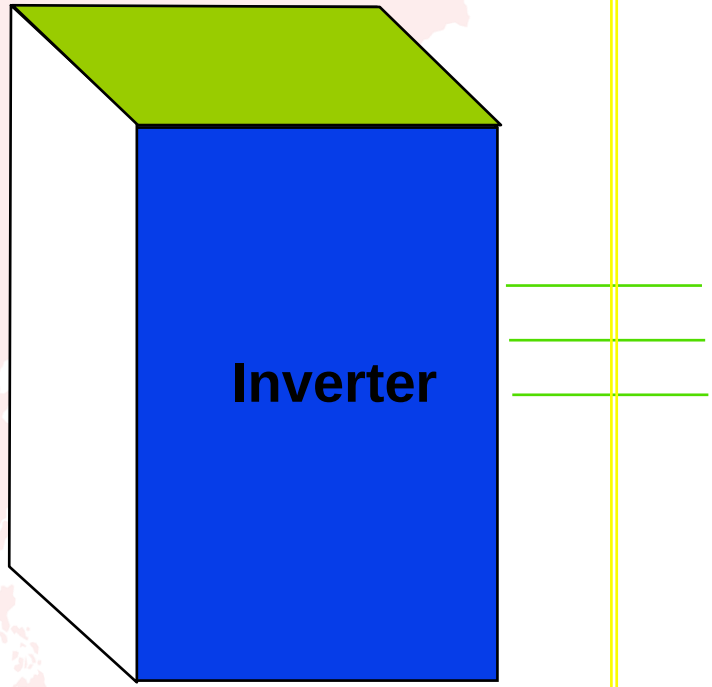


AC and DC drives

AC drives and Harmonics



Determine the line-side harmonics



Determines load-side harmonics

Attenuation of Harmonics

- **12-pulse Rectifiers**

  Method: Two separate rectifier bridges supply a single DC bus. The two bridges are fed from phase-shifted supplies.

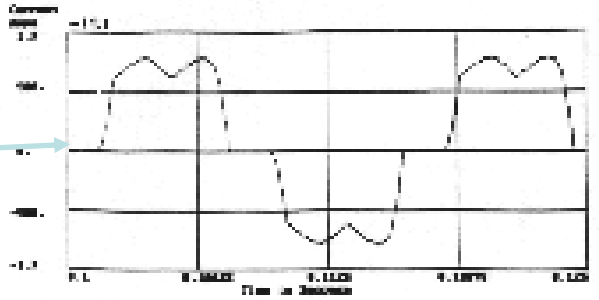
  Benefits: Very effective in the elimination of 5^{th} and 7^{th} harmonics.
  Stops harmonics at the source.
  Insensitive to future system changes.

  Concerns: May not meet the IEEE standards in every case.
  Does little to attenuate the 11^{th} and 13^{th} harmonics.

Comparison of waveforms

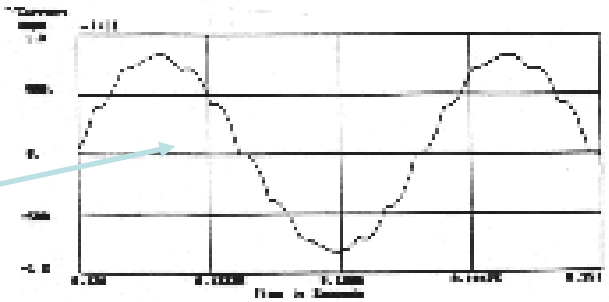
6-pulse converter

note the level of distortion and steep current rise.



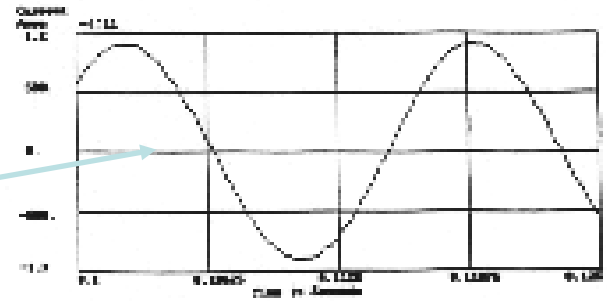
12-pulse converter

the waveform appears more sinusoidal, but still not very smooth.



18-pulse converter

virtually indistinguishable from the source current waveform.



Active Filters

Currently they are based on PWM converters and connect to low and medium voltage distribution system in shunt or in series. Series active power filters must operate in conjunction with shunt passive filters in order to compensate load current harmonics. Shunt active power filters operate as a controllable current source and series active power filters operates as a controllable voltage source. Both schemes are implemented preferable with voltage source PWM inverters.

Shunt Active Filters

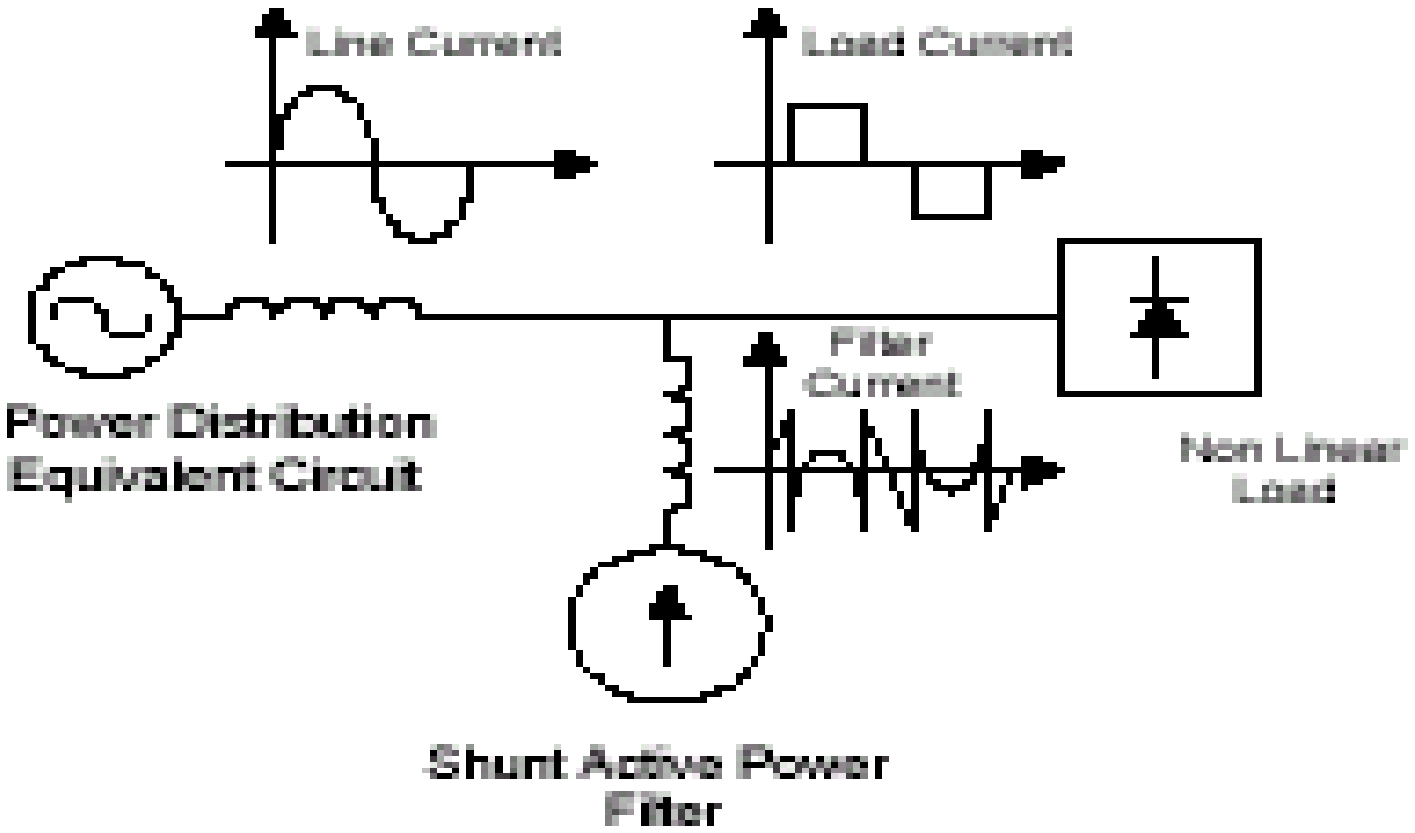


Fig. 1.- Compensation characteristics of a shunt active power filter

Current Waveforms

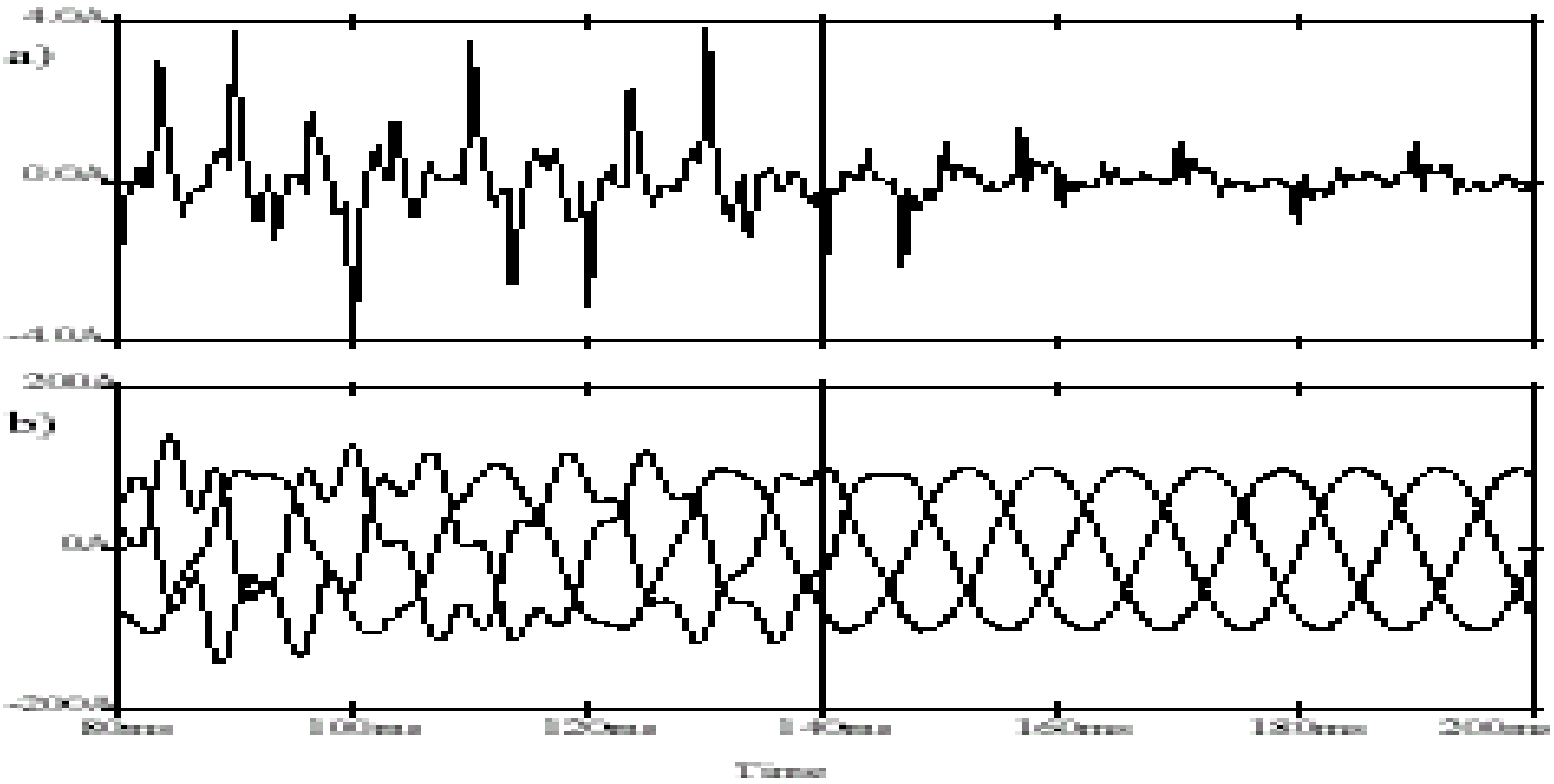


Fig. 9. Simulated waveforms for current harmonic compensation. a) Neutral current flowing to the ac mains before and after compensation. b) Line currents flowing to the ac mains before and after compensation. (Voltage unbalance compensator not operating).

Before and after compensation

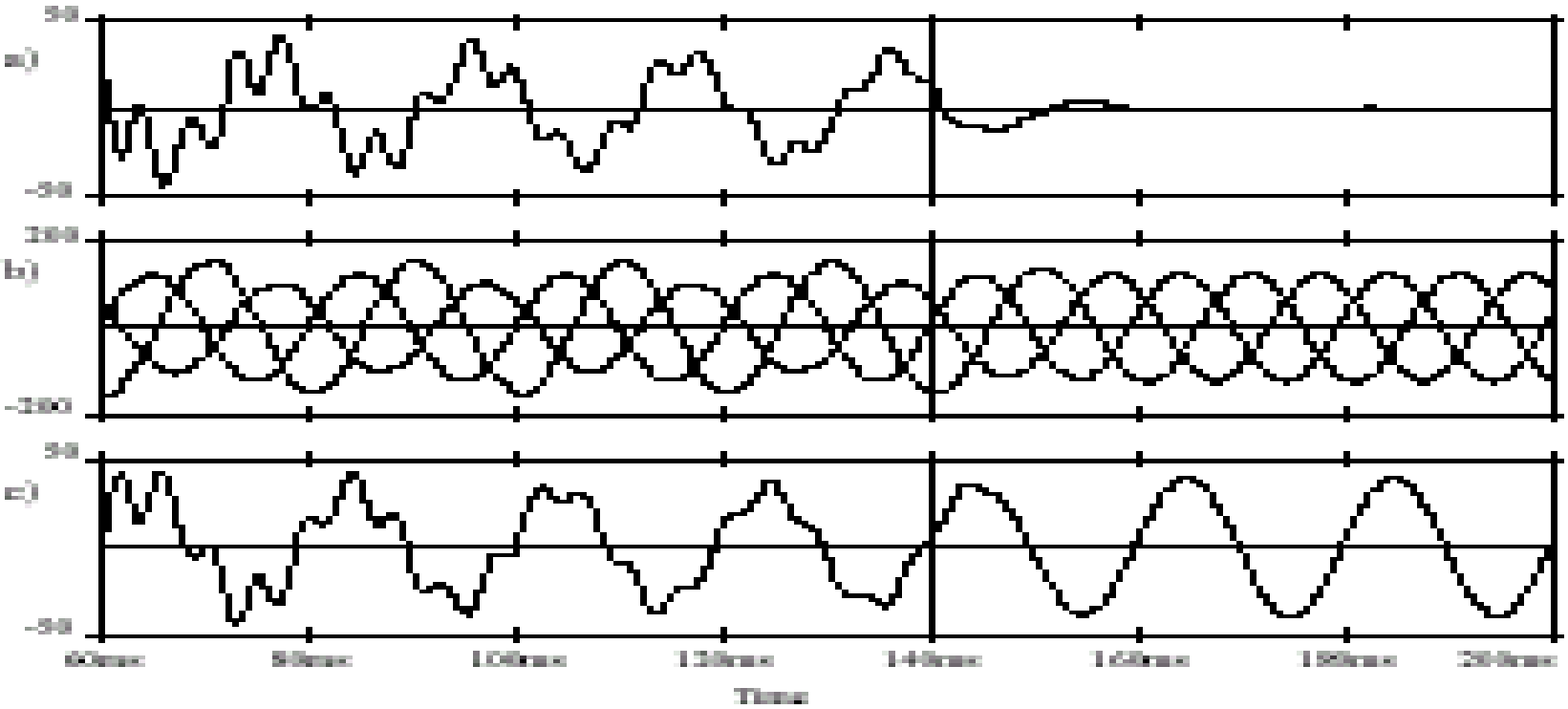


Fig. 10. Simulated results for voltage unbalance and current harmonic compensation, before and after compensation. a) Ac mains neutral current. b) Phase to neutral load voltages. c) Ac source line current.

Experimental Current Waveforms

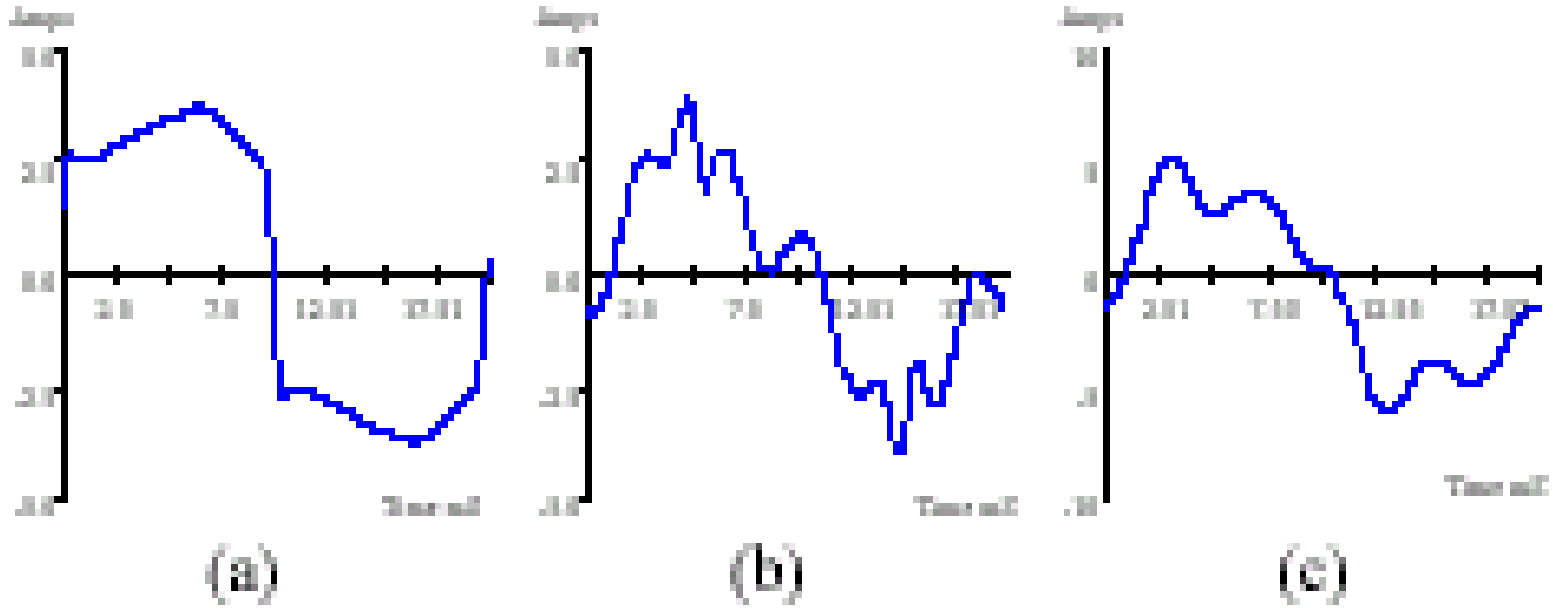


Fig. 11. Experimental current waveforms of the system without the operation of the series active power filter. (a) Load current. (b) Shunt passive filter current. (c) System current.

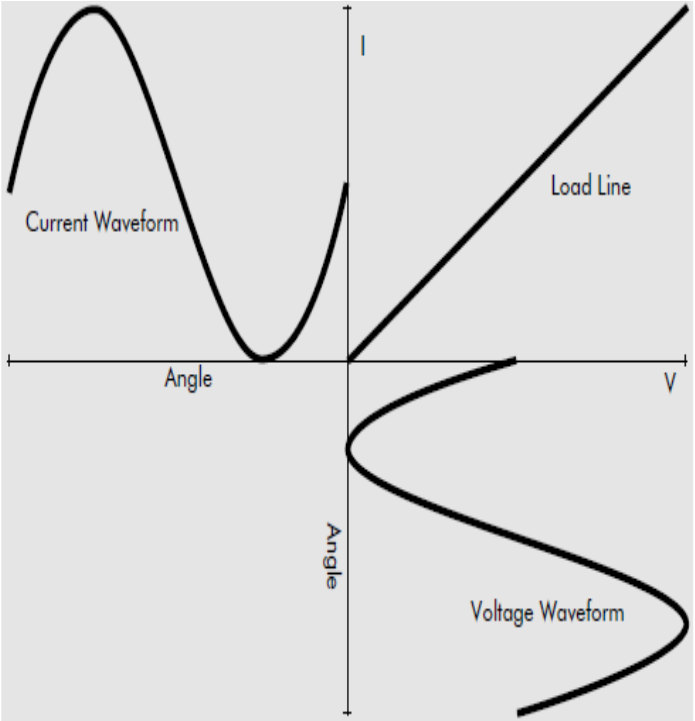
Electrical Loads

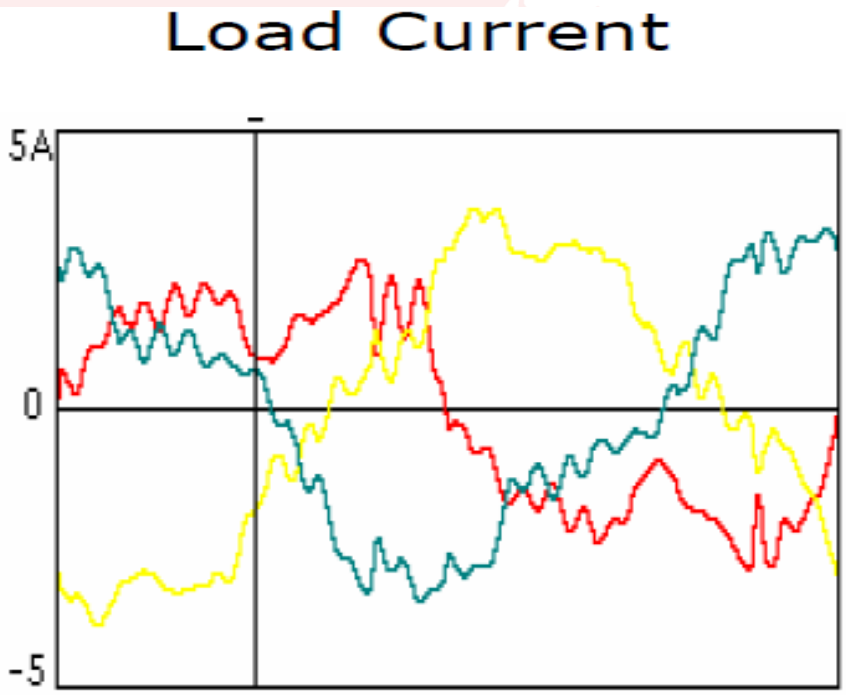
Linear Loads

- Supply voltage is sinusoidal
- Current drawn by load is sinusoidal

Non-linear Loads

- Supply voltage is sinusoidal
- Current drawn is NOT sinusoidal





New Power Quality Indices Based on Time-Frequency Analysis

- **Time dependent power quality indices:**

✓**Instantaneous THD**

=disturbance energy / fundamental energy

✓**Instantaneous Distortion Index**

=disturbance energy / total energy

✓**Instantaneous Frequency**

=1st order frequency moment / total energy

✓**K-factor**

=normalized 2nd order frequency moment / total energy

Effect on Equipments

2.

ON TRANSFORMER:

There are 2 types of losses in transformer

a.Load loss (eddy current loss) b . Noload loss

Eddy current loss:these are induced current in transformer caused by magnetic flux. This current f flow in the winding causes additional heating.

$P_{ec}=k_{ec} * I^2$

Core loss: the increase in the core losses in the presence of harmonic will dependent upon effect of harmonic on applied voltage & design of transformer core.

Effect on capacitor

6.On capacitor:

effect of harmonics on capacitor includes

a. increased in voltage stress

b. addtional heating due to over loading

$I = C\,dV/dt$ in case of harmonics due to increse in frequency

dV/dt get increased and this is the case of voltage stress.

in case of harmonic resonance

$X_L = X_c$ so effective value of impendence get decreased lead to increase in current.

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Harmonics on metering

5. On metering:

Electric utility company usually measure the consumption of 2 quantities. They are total cumulative **energy demand** & maximum **peak demand.**

But in case of domestic users the energy meters are generally calibrated on the basis of fundamental current.

So here due to harmonic current the error increases due to increase in harmonic frequency & no of harmonic component.

In case of non linear current

$$P_{measured} = P_1 - a_3P_3 - a_5P_5 - \ldots\ldots\ldots\ldots$$

SO measured power < actual consumed power

Harmonics on cables

3. ON CABLES:

IN cables it is found that there is enhancement of skin effect due to due to the cumulative effect of frequency & inductance.

Here the ac resistance is not only effected by inductance but also by harmonic frequency which was not in case of eddy current loss in transformer.

In this case the joule loss I^2R loss is further increased by additional effect of increase in resistance (R_h) and harmonic current (I_H).

SO net loss is $I_H^2 R_h$.

Harmonics,effect on telicommunication

4.On Telecommunication:

Harmonic current flowing on the utility distribution can create interference in communication circuits.

mainly the **triple-n** harmonics create trouble in 4 wire because they are in phase in all the conductors and directly in neutral circuits which has a greater exposure with telecommunication system.

so due to high current in neutral the telecommunication cable comes under the flux linkage created by neutral wire

Hence Interference comes into consideration.

Noise on communication circuits degrades the transmission quality and can interfere with signalling.

The purpose of the power system is to transmit energy at high efficiency but with relatively low waveform purity.

Power Electronics and Power Quality

- Power Electronics focus is shifting to the distribution system for the improvement of quality of power,
- These devices have a new name and being known as custom power devices.
- The main custom power devices which are used in distribution system for power quality improvement are distribution static synchronous compensator (DSTATCOM), dynamic voltage restorer (DVR), active filter (AF), unified power quality conditioner (UPQC) etc.

Discoms are having plenty of options

- Sag and swell monitoring by UPQC, DSTATCOM and DVR
- Harmonics monitoring by active and passive filters
- Continuous power supply and reliability through UPS, SMPS, sectionalizers, auto reclosures, Ring main units
- Gas insulated and container based substation to reduce faults

Smart grid Opportunities

- We are talking of smart distribution grids with attractive options:-

1. HVDS to reduce theft of power
2. RTUs to reduce cabling in substations
3. Communication facility to remote centres (using Optical fibre, VHF, microwave, VSAT etc)
4. Smart meters, AMR and AMI systems.

Power Quality from DISCOM's perspective

- Discoms know that rapid modernization of their system with poor infrastructure will take time and same for quality power. However in an effort to improve infra structure through various efforts like smart metering, system strengthening, asset management and using various grants available , they can go closer.
- The speed of reform has to be accelerated keeping in mind the sensitivity of the sector

Some FACTS

- 1. Discom's financial viability is threatened because of high losses and poor administration.
- In present scheme of things IT implementation is going slow and modernization going in in piece meal.
- Franchisee approach has created new problems. Even the logic of private companies managing distribution sector is being questioned.
- The present level of reliability and availability does not encourge large scale maufacturing as wished under 'Make in India'

Recommendations

- 1. More considerate tariff calculation to fish out the DISCOMs from financial crisis.
- A 1% cess recommended at national level for accelerated reform in distribution sector, preferably to be given to a SPV
- Wire company may be created and separated from Discom to become custodian of the distribution grid and encourage competition

Recommendation -II

- Utility must be coerced to abide by some power quality norms on maintaining availability and reliability which could be progressively made to match international standards.
- Every customer must be a paying customer. For subsidized sectors Govt. should be the customer.
- Stricter rules for theft control must be implemented with zero tolerance and pre paid metering encouraged

Discoms must change

1. Essential that DISCOMS change their mind set and come out of their comfort zone.
2. Must adopt ‘ IT’ in a big way and operate from the field.
3. Must handle planning and system improvement themselves without out- sourcing .
4. Must go for trained engineers and dynamic MBAs to manage their affairs.
5. Must think of a Power Quality laboratory to prepare to adopt advanced technology .
6. Discom business is one of risk management. The employees must learn to take risk .

conclusion

- POWER quality issues are well worth serious consideration. DISCOMS must be modernized
- Quality improvement improves customer satisfaction and trust on DISCOMs.
- Discoms must be helped to turn around .
- Even if the availability & quality of power is quite critical but Correct identification of the root cause of problem is essential to choosing & implementing the best solution.
- Investing over power quality will improve both operation & Profit.

Questions?

- 1. More industries, more power electronics control, higher harmonics resulting into more losses and amplification, equipment failure, control mal operation.
- 2. Is there an urgent need for penalizing loads generating harmonics in excess?
- 3. Should harmonic audit be mandatory?
- 4.Should privatization policy be relooked?