Solutions to harmonic problems
Solutions to harmonic problems

- Structural modifications
  - Isolate harmonic sensitive loads from harmonic producing
  - Use high pulse number drive configurations
  - Use special transformer couplings

- Often only possible in design phase of the installation
- Not always possible for all non-linear loads
- May turn out to be very expensive with high space requirement (life cycle assessment)
Solutions to harmonic problems

- Passive filters: reactor and capacitor in series
  - Offers ‘low’ impedance path for harmonic component(s)
  - Filtering efficiency depends on network parameters, hence filtering performance cannot be guaranteed
  - Danger for overloading
  - Difficult to extend
  - Danger for resonance
  - Multiple branches required for filtering more than one harmonic
  - Large space requirement
  - Provides always capacitive power
    - AC drives do not require capacitive power
    - Generators may not cope with leading power factor
Variable speed motors: DPF and PF

Example: Acceleration of a motor controlled by an AC drive
Solution to harmonic problems

Series passive and active devices
Attempt to prevent the harmonics from flowing by imposing high series impedance at the harmonic frequencies

- Device is in series with the load: high quality bypass required
- Affects the supply voltage value of the load
- Needs to be sized for the load rating (fundamental + harmonics)
- Difficult to extend to higher powers
- May lead to very high voltage distortion (‘current has to flow’)

\[ \text{Supply} \rightarrow \text{Series device} \rightarrow \text{Load} \]
Solution to harmonic problems

- ‘Low pollution’ AC drives:

Supply

Diode bridge rectifier

DC link

Inverter

Supply

Input filter

IGBT bridge

Inverter
Low pollution drive application area

- Low pollution drives can be used to control AC motors.

- Low pollution drives are not used for applications that do not require the control of AC motors, e.g.
  - In 4-wire office applications (‘PQFK’-application area)
  - Control of DC motors (very high installed base)
  - ...

![Motor diagram]

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Good low pollution drives (ABB):

‘THDI(%) < 5% of nominal drive rating’

- At lower than nominal rating THDI may be (is) higher
- Beware of ‘bad’ clean drives
  E.g.: High frequency ripple destroys components of the installation
Low pollution drives: conclusions

- Good low pollution drives do a good job in having a low harmonic signature at nominal load

- However:
  - They do not solve the problems of the complete installation
  - They are expensive when applied to all the loads

- Therefore:
  - Use them possibly for single large loads
  - Filter the rest of the installation with an active filter
Proposed solutions to overcome poor PQ in LV

Active filters:

Supply ——— Harmonics injection ——— Load
Active filter principles

- Parallel topology: basic concept

Put a switching inverter in parallel with the load that is injecting compensation currents at the harmonic frequencies.
The ultimate solution to poor Power Quality

- ABB premium class Active Filters: ★★★★★★★★

PQFS  PQFK  PQFM  PQFI

Leading by excellence!
The ultimate solution to poor Power Quality

Modern Active Filter technology: Flexible answer to all problems

- Harmonic filtration up to high order
- Reactive power compensation
- Load imbalance compensation
- Self-limiting
- Upgradeable
- Network monitor
- ...

Feeder

PQF

FUNDAMENTAL ONLY

ONLY HARMONICS
The ultimate solution to poor Power Quality

- ABB Active harmonic filters
  - Filtering principle: cancellation of harmonics by equal and opposite harmonic generation by an active filter device
How does an active filter work (1)

Output filter

Line reactor

PWM reactor

PWM Inverter (IGBT-based)

Control system
How does an active filter work (2)?

- High filtering efficiency and reliability
- Modern digital technology using multi-DSP systems and MicroController
### Different modes of operation

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### Reactive compensation:
- none
- dynamic (cosφ target)
- static (constant Q)
- Load balancing combined with reactive compensation
Active filter control approaches

- Best results up to high frequencies are obtained by using closed loop control systems.
- Directly measure and control harmonic current flowing to network.
- Correction for system inaccuracies.
- Can verify harmonics according to regulation directly.
- Can be used for power factor targeting.
- Simple CT connection.
- Easy for future harmonic load extensions.
- Appropriate for local & global compensation.
Active filter control approaches

Open loop systems:

In open loop control, the sequence of commands in the program is carried out irrespective of the consequences. For example, a teacher may set a class some work to do (the instructions) then leave the room.

Closed loop systems:

In closed loop control, the teacher would set a class work to do, then monitor their progress to make sure that it is done. If pupils stop working or misbehave then she would take action. The teacher observes the class, obtains feedback and takes appropriate action if the target is not being met.
Open & Closed loop control: examples

Open Loop systems

§ Switch microwave on to defrost for 2 minutes. The turntable will turn and the food be microwaved for 2 minutes irrespective of whether it is thoroughly defrosted or not.

§ Program a toy robot to walk in a certain direction. It will follow all instructions even if there is an obstacle in the way.

§ Switch a sprinkler system on to water the garden at set times. The garden will continue to be watered at these times even if it is pouring with rain.

Closed Loop systems

§ Central heating systems

§ Ovens

A closed loop system is one that involves feedback to ensure that set conditions are met.
Open and Closed loop response example

- Open loop step response
  - Transient response
  - Steady state error
  - Process may not run

- Closed loop step response
  - Transient response
  - No steady state error
  - Process runs smoothly

Picture source: ‘Automatic Control Systems – B.C. Kuo’
Active filter control approaches

- Best results up to high frequencies are obtained by using *frequency domain control approach*

- Dedicated optimizing controllers for each harmonic up to high order
- Individual harmonic selection capability for optimal use of resources
- In combination with closed loop control, allows to set up user requirements for each harmonic (e.g. standard targeting etc.)
DVD Demonstration
ABB

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