Power Quality White Paper

Eliminating problems due to harmonics at the electrical reticulation design stage

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Harmonics mitigation is most cost-effective when 'designed in'. Mitigation in existing installations is possible but more than likely to cost significantly more without the performance of an 'ab initio' approach.

Good reasons for designing-in harmonics mitigation relate to economy, performance and reliability. All three of the following reasons have dollar implications.

(1) Economy: Harmonics cause energy to be wasted. Someone has to pay for this and supply authorities have reflected this in general tariffs. Expect this to end as increasing Federal and State political pressure to limit cross-subsidisation in electricity tariffs, forces supply authorities to penalise industrial and commercial consumers straining the 'poles and wires'.

(2) Performance: Harmonics degrade the performance of equipment sensitive to power quality causing productivity losses, expenditure in service, and additional capital expenditure in replacing life-span compromised equipment such as motors.

(3) Reliability: The electrical reticulation network inside a building or factory has to be 100% available. Interruption because of breakdowns including false tripping of protective gear has severe cost implications and loss of profits through production interruption.

Harmonic mitigation solutions should be tailored to the type of application. In many ways each installation is unique but broad guidelines apply.

Commercial premises

The three-phase loads are generally HVAC, moving walkways and escalators, and elevators. HVAC plant generates significant harmonics.

Single-phase loads usually provide the highest aggregate harmonic load. Primary sources are IT equipment, and lighting ballasts. Load balancing for single-phase circuits is an important design consideration when there is high harmonic content. Two-phase loads are less frequent but might be reserved for some commercial kitchens.

Changes in tenancies, and expansion of facilities (more offices, shops, etc) can overload the reticulation because of increases in harmonic content. The capacity of a sub-station transformer can easily be surpassed unless harmonic mitigation has been installed.

Industrial plants

Many loads are three-phase, three-wire. Sub-station transformers are likely for large consumers connected to medium voltage distribution and plant expansion can challenge the sub-station beyond capacity.

Single-phase loads in aggregate are likely to be less than three-phase loads. Careful consideration of circuit and load mitigation will provide high power quality (eg: mitigation of negative sequence harmonics, commutation notching from converters) and allow control gear (PLCs, micro-controllers, industrial bus systems) to operate from clean supply.

Power factor is often low or variable due to loading and unloading of motors. Consideration of power factor control in combination with harmonic mitigation is important and best done at the design phase.

This white paper provides design engineers with important points to consider when mapping out reticulation and some general rules applying to harmonics mitigation.

Voltage distortion at the point of common coupling

Harmonics mitigation adds cost to electrical installations and for that reason is often ignored. Sometimes a 'suck it and see' policy is adopted.

Harmonics are not just an internal problem. They are exported into the supply system in spite of interposing transformers—even the ubiquitous third harmonic, since installations are never phase-balanced.

If the supply authority complains about the degree of voltage distortion at the point of common coupling (pcc) harmonic filtering might be specified. Note that the relevant standard for harmonic voltage distortion in Australia is AS/NZS 61000.3.6. Supply authorities can insist on their own maximum voltage distortion levels.

Demand increased by harmonics

As energy regulators look more closely at 'gold-plating' of poles and wires, often defended on the basis of having to cater for high demand intervals, consumers can expect considerable additional charges for poor power factor and/or high apparent power demand. Flattening demand peaks is the single most important way of achieving cost-effective distribution systems.

- Demand is measured in various ways by;
- Maximum kilowatt-15/30 minute consumption
- Maximum kilovolt-amp-15/30 minute demand (apparent power)
- Maximum kilovolt-amp reactive (kVAr)-15/30 minute reactive power demand

There can also be combination of the above demand parameters and power factor, this normally being the displacement power factor. Harmonics severely lower power factor and therefore increase the apparent power.

Sub-station transformers affected by harmonics

Consumers who buy electrical energy at medium rather than low voltage will have a sub-station transformer which may or may not owned by them but the problems caused by harmonics will be owned by them. Harmonics can severely de-rate the transformer and it is not an exaggeration that in Australia not much attention has been paid to 'harmonics-hardened' transformers. Eddy current losses, proportional to the square of both the amplitude and harmonic frequency will shorten transformer life span.

Wiring losses and reliability

Proximity and skin effects in conductors due to harmonics will often increase energy losses well in excess of the I^2R losses at the fundamental frequency (50 Hz). These additional losses can wreck switchboards, overload conductors including neutrals and cause voltage distortion in the customer's installation. Reliability of protection is affected. Magnetically tripped breakers can be tripped through severe current distortion (very high peak current) and thermally tripped breakers through the heating effects of harmonic current components. Harmonics can therefore upset coordination of protective gear. Residual current devices (RCDs) can also malfunction.

Design rules

Energy waste in the reticulation system is best avoided by harmonics mitigation as close to the harmonics generating sources as possible. Economies can be achieved by aggregating some harmonics generating loads for example variable speed drives. Large rating loads are often best connected on separate circuits. Single-phase loads are generally most economically mitigated at sub-distribution board level using three-phase, 4-wire harmonic filters (active filters are recommended for high variability loads).

Neutral current compensation can be a problem in the case of unbalanced phases, and zero sequence (3rd, 9th, etc) harmonic compensation best achieved on a per phase basis. Transformer selection for sub-stations should be on the basis of having a line diagram of the installation with predicted harmonic content available. For installations with stand-by generators, mitigation filters should avoid creating leading power factors. For installations using passive capacitor-bank displacement power factor correction, detuning chokes have to be employed to avoid resonance problems.

For further details please contact Fuseco or refer to www.fuseco.com.au

The specialists at Fuseco can materially assist consultant engineers with technical and application advice to help them select effective mitigation be it active filters, passive filters, and reactors.