Application Guide AG 2/2000

THE BSRIA POWER QUALITY GUIDE

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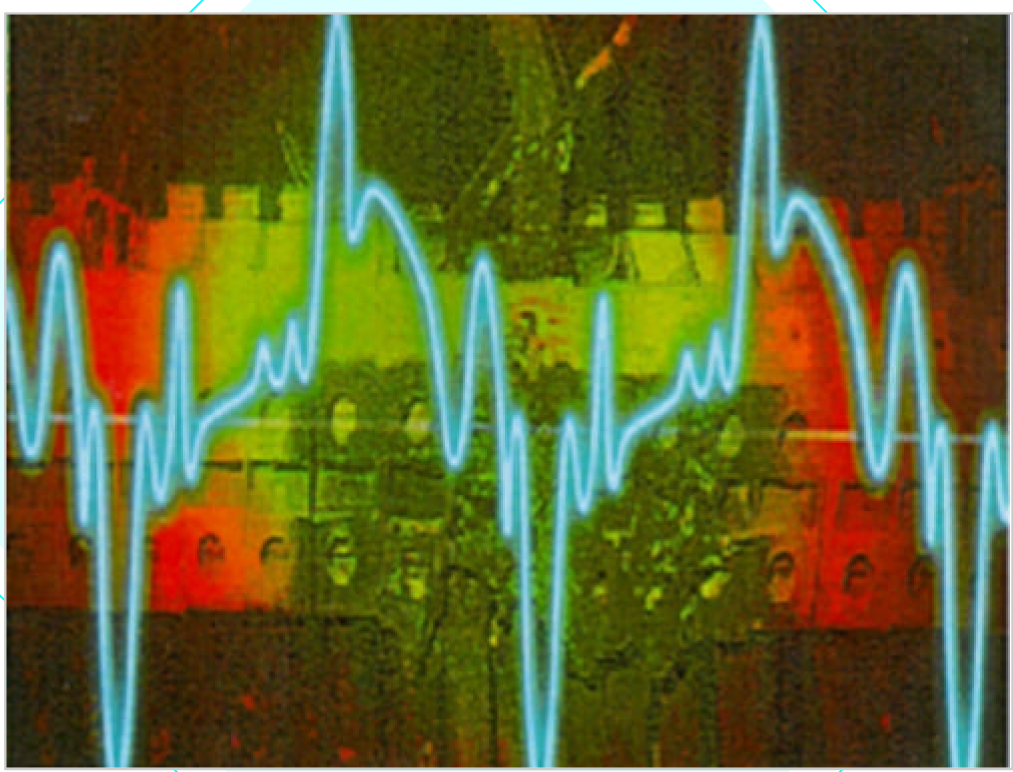

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PREFACE

A number of high profile electrical failures have highlighted the importance of ‘quality’ in the electrical power delivered to equipment in commercial and industrial buildings.

Power quality depends on at least a dozen key features of the electrical supply including frequency and voltage variations, but the critical feature that is not addressed by existing guidelines is harmonic content. This document aims to increase awareness of the problem of harmonic current and voltage in commercial buildings by gathering together information from sources in the UK and around the world.

Harmonic problems are found in most UK commercial and industrial buildings. These include severe voltage distortion, high neutral currents, high neutral - earth voltage of nearly 7 volts in one case and high earth currents. Most of these problems can be attributed to various types of electronically switched load including variable speed drives and high frequency lighting. The principal offender however is switch mode power supplies used in office equipment.

The effects of harmonic voltages lead to malfunctions in sensitive equipment, which may include the sensing circuits of circuit breakers and UPS switches. The effects of harmonic current are overheating in conductors, transformers, motor coils and capacitors. These are potentially disastrous and have led to an increasing number of building power system failures and fires.

British and European standards may not be sufficient to prevent problems. The European product standard EN 61000-3-2, that was intended to eliminate harmonic problems, has not yet been implemented and in its revised form may not sufficiently reduce the harmonic currents in commercial buildings. The existing standards and guidelines for power quality in electrical installations refer to voltage, and implicitly current, at the point of common coupling, where a consumer's supply is common with other consumers' supplies. They make no reference to the limitation of harmonic current and voltage within a building. US standards, are not directly applicable to UK installations, but they are informative, especially where comparable UK standards are not yet available.

If harmonic problems are to be avoided in the UK then better software must be made available and used for installations that are particularly prone to harmonic problems such as financial institutions, dealing rooms and data centres.

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Every opportunity has been taken to incorporate the views of the editorial panel, but final editorial control of this document rests with BSRIA.

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1 INTRODUCTION

1.1 INTRODUCTION

The quality of electric power delivered to the equipment we use depends on a number of key features:

- Power frequency
- Magnitude of the supply voltage
- Supply voltage variations
- Rapid voltage changes
- Flicker severity
- Supply voltage dips
- Short interruptions of the supply voltage
- Long interruptions of the supply voltage
- Transient overvoltages between live conductors and earth
- Supply voltage unbalance
- Harmonic voltage
- Interharmonic voltage.

Electrical and electronic equipment can be susceptible to changes in any of these parameters. In many cases the equipment can also interact with the electrical supply to change these parameters.

Although they are all critical in certain cases, most of the parameters are adequately controlled by existing equipment, or are unlikely to go outside acceptable limits. Transient overvoltage has been the main problem in installations with computers. A 1974 report[1] stated that 9 out of 10 power problems were caused by transient overvoltage. However awareness of this problem is now quite widespread and solutions readily available. The main power quality issue that is neither properly controlled nor often monitored is harmonic voltage.

In addition there are often unrecognised problems caused by harmonic currents in electrical installations. Harmonic currents generally do no useful work in the electrical installation. They flow in the phase and neutral conductors, in addition to the required fundamental current, and develop additional power loss through heat dissipation. This represents a reduction in efficiency of the electrical installation and can lead to failures from overheating, particularly in neutral conductors, coils and capacitors.

1.2 WHY IS POWER QUALITY AN ISSUE?

Increasing use of electronic equipment has changed the load characteristic of our homes, offices and factories. Electronic loads are ‘non-linear’ in the way they draw power. They draw current from the supply for only a short part of each mains cycle. When they draw current there is a voltage drop in the supply and any other equipment connected to this supply will also experience the voltage drop for part of every cycle. The distorted current and voltage produced by this equipment can be described using harmonics (detailed explanations can be found in Section 7). Harmonics are multiples of the fundamental mains frequency of 50 cycles per second and when current or voltage of several harmonics are added they can produce a very distorted waveform.

Some of the adverse effects of concentrated non-linear loads are:

- voltage distortion leading to equipment failures and data errors
- excessive neutral currents overloading conductors
- high levels of neutral-to-earth voltage causing data errors
- overheated transformers and motors
- large magnetic fields emanating from transformers
- decreased distribution capacity
- power factor penalties
- capacitor failures.

Computers, printers, copiers, microwave ovens, stereos and televisions, all have power supplies that produce harmonics. Other types of non-linear loads include light dimmers, fluorescent lighting (mainly the high frequency electronic ballast type) battery chargers, such as UPS and variable speed drives.

In the UK the cost to customers of power quality disturbances is significant - £200 million was paid out by insurers for such losses in 1994, the latest figures available, and the cost is likely to be much higher now. However, about half this cost is likely to be due to transients and interruptions rather than harmonics. In the United States, where power quality problems struck harder and earlier, the total cost to industry is estimated as $4 billion a year.

Often more important than the physical effect on the equipment is the loss of productivity resulting from computer equipment failure, mis-calculations and downtime. It has been estimated that the total cost to US businesses of this lost productivity is a staggering $15-30 billion per year. A recent survey by E-Source indicated that, while most respondents did not calculate the cost of their annual losses due to power quality (or may even have erroneously attributed power quality problems to software or hardware), roughly a third of those that did report a loss figure said it exceeded $1 million per year.

Many facility and IT managers are becoming aware of the problem of harmonics as well as the better known problems of transients. As more and more computers and electronic equipment have been added, the power factor has dropped. In some cases, the drop in power factor has been sufficient to trigger extra charges. In at least one incident in the UK a building operator has been threatened with disconnection by the supply company if the harmonic currents were not reduced.

1.3 WHAT CAN BE DONE ABOUT IT?

It is possible to design and build power electronics that do not introduce harmonics. In the long term these will be widely available and used but the extra cost of equipment that generates little voltage or current harmonic is still a barrier. Product standards, such as BS EN 61000-3-2 (see Section 11) are intended to limit harmonics but there have been delays in implementing them. When such standards do become mandatory they may be made less stringent, thus problems are likely to remain until ‘cleaner’ equipment becomes widespread. Section 11 describes standards, e.g. EN 50160 and guidelines, e.g. G5/4 which can be utilized to prevent one consumer’s harmonics affecting neighbouring consumers.

There are a number of partial solutions that, individually or combined, can significantly reduce the risk of failures. Specialist consultants and research associations, including BSRIA, are now offering a power quality diagnostic service.

Technologies used to solve power quality problems include:

for transients
- surge suppressers

for interruptions
- uninterruptible power supplies (UPS)

for harmonics
- passive filters (low frequency as opposed to radio frequency filters often found in electronic equipment)
- active filters
- isolating transformers
- k-rated transformers
- phase shift transformers
- increased conductor size
- active filters.

Other solutions are continually being developed and the choice can be baffling. An expert power quality survey can diagnose problems and indicate the most appropriate solution.

Key points for system design include:

- specify equipment with linear current draw if possible
- ensure full size neutral conductors are used for each single-phase circuit
- do not combine neutral conductors supplying multiple single-phase loads
- ensure neutral conductors from single-phase non-linear loads are double sized where they combine at the main distribution board, but not necessarily for the distribution board feeder, where diversity and combination of loads will reduce the percentage contribution of harmonic currents
- estimate the likely harmonic content at each distribution board and circuit
- consider using harmonic cancelling transformers
- monitor all installations regularly, at least following the addition of new equipment.

1.4 COST OF PROBLEMS

The presence of harmonic distortion on the utility system results in incremental costs in the operation of the system. These losses include:

- costs of harmonic mitigation measures (filtering)
- increased losses in conductors, transformers, motors, etc.
- engineering effort to diagnose problems
- accelerated ageing of equipment due to heating and other harmonic effects
- derating and oversizing of equipment to withstand harmonic duties.

Results of preliminary efforts to characterise these costs on the distribution network have been published by the IEEE[2]. This study showed that the most important cost component is likely to be the costs associated with applying mitigation measures, such as harmonic filtering, to reduce harmonic levels. The costs include the total active power loss and the capital invested in design and construction of filtering stations needed to maintain THDV below 5%. The study focuses on the forecast load (75% residential 8% commercial and 17% industrial) totalling 10 MVA on three different 13.8 kV feeders. The results are given in the form of a ratio ($ per year per kVA harmonic). Based on these incremental costs, substantial investment in mitigating harmonic generation in the end use equipment could be justified. Another study [3] evaluates different types of filters used to reduce harmonic currents in commercial office buildings. Two single-phase and three three-phase active and passive harmonic filters were added to the electrical system of a typical commercial building and evaluated by computer simulation. The resulting current/voltage distortion and estimated cost of the filters are compared to the predicted loss in an uncompensated system.

Tariffs may offer an opportunity to encourage and economically justify the application of harmonic control measures, such as filters or higher pulse number converters. Many of the industrial and commercial tariffs include demand charges and power factor penalties. It would be possible to construct a tariff that also includes a charge for harmonic current components injected onto the power system. This would allow customers to make economic decisions regarding the harmonic control. If the customer does not control the harmonic injection, the utility would have the funds to control the harmonics on the utility system in a similar manner to the application of power factor correction capacitors. However, no such tariff has been offered or devised for customers in the UK.

The benefits of controlling the harmonic levels on the customer side would include the following:

- The application of harmonic filters (passive) should improve the power factor and reduce the MVA demand for the facility. If the demand charge is based on peak MVA (as opposed to MW), it would be economically attractive for a customer to install harmonic filters to reduce the demand charge. The economic benefits derived from the filter installation can be determined by comparing the reduction in the annual bill to the cost of the filters. The impact of a filter installation on power factor penalties can be evaluated in a similar manner.
- The filtering will reduce the harmonic voltage distortion within the plant and the harmonic currents injected into the power system.
- The customer should be less susceptible to transient voltages during switching of larger capacitor banks on the utility system. The filters provide damping for these types of transients.