PAN EUROPEAN LPQI POWER QUALITY SURVEY

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ABSTRACT

This paper presents the results of a study conducted by a Leonardo Power Quality Initiative team. The study sample comprises 62 face-to-face surveys carried out in 8 European countries, which has allowed for an extrapolation of the overall wastage caused by poor PQ in EU-25 and for the analysis of many associated issues such as user perception of PQ problems, the causes of PQ problems, equipment mainly affected and solutions available and adopted. Additionally PQ metering and where the sources of poor PQ lie were also investigated .

INTRODUCTION

It is the contention of this paper that the EU 25 wastes a significant and avoidable amount of money annually directly as a result of industrial sectors, for which electric power is essential, not having invested adequately into their power systems.
This study has investigated industrial sectors that account for 70% of the non-residential consumption of electricity and 38% of the EU 25's turnover (€ trillion).
To arrive at such conclusions the study needed to understand what barriers faced the service providers – utilities, designers, maintenance – that stop them from persuading end users to specify installations that are fit for current purpose and future demands.
To that end, this paper covers a number of related topics addressed by this research project:

- What electrical power disturbances industry faces today.
- What solutions are available to and are adopted by those key industrial sectors.
- What levels of diagnostics and measurement are used (or not)?
- The impact and consequences of failing electrical power installations as measured by the survey

The conclusions drawn are both shaming in terms of unnecessary waste and lack of corporate social responsibility and significant in terms of avoidable reduction in productivity and thereby competitiveness.

METHODOLOGY

This study was conducted by face-to-face interviewing. There was an additional small scale web based survey where respondent self-completion was possible.

The aim was to investigate industrial sectors that accounted for the lion's share of non-residential energy use and a significant share of EU 25 turnover. This translated into representatives from 16 industrial sectors being interviewed. The respondents were technically oriented with the added definition of being senior and experienced enough to be able to answer detailed and sometimes commercially sensitive questions.
The questionnaire comprised two unequal halves. The first 5 Parts were straightforward data gathering relating to PQ problems experienced, mitigation solutions they were aware of and they had installed, perceived sources of PQ issues, measurement undertaken, relations with the supplying electrical utility. The 6th Part investigated real or hypothetical PQ Phenomena Cases to understand what consequences each would have on that particular organisation. These covered all forms of interruptions, harmonics, earthing, unbalance and EMC issues.
Interviewing was carried out by the project team initially then a network of academic centres and PQ specialists was recruited to expand the interviewing capacity. Each group was individually briefed to ensure coherence of technique and responses. The questionnaire was translated into 7 languages.
All raw data generated was scrutinised centrally and any additional information needed were secured by follow up questioning.
Based on the evidence given the project management then analysed the data in two ways – statistically cross referencing the Parts 1-5 information and calculating what the real or hypothetical economic impact was in each of the cases studied. These calculations investigated prima facie losses as well as other wastage that occurred but was surprisingly absent from any existing productivity or corporate financial analysis.
The project has been managed in equal parts from Poland and from London.

RESULTS

Survey sample

The survey interviews and web based submission were conducted over a 2-year period in 8 European countries. In all, 62 complete and 6 partial (ie excluding Part 6) interviews were carried out. Figure 1 presents the numbers of surveys across 16 specified sectors.
These sectors represent some 38% (€6.843bn) of the EU-25 total of €17. 956 bn turnover[1] and 1.862 TWh or 70% of the Region's 2.650 TWh of final electricity consumption[2].

1 Eurostat, data of year 2004
2 Eurostat, data of year 2003

Figure 1. Number of surveys per sector

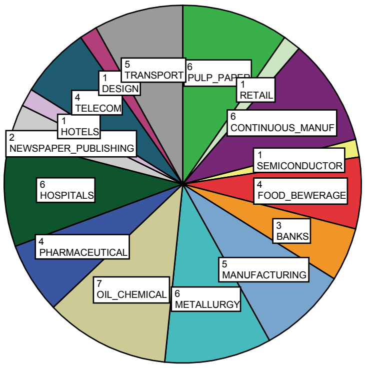
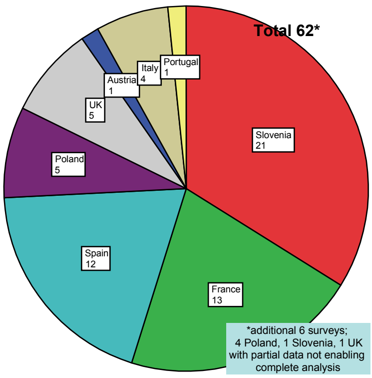


Figure 2. Number of surveys per country



Power Quality cost

The main purpose of this project was to estimate costs of wastage generated by inadequate power quality for those sectors within the EU-25. Previous, well-known international studies have only addressed some aspects of this issue. For example, CIGRE report [1] covers costs caused by interruptions in 5 of EU25 countries. PQ costs in this survey have been reported in the following categories:

- Voltage dips and swells
- Short interruptions
- Long interruptions
- Harmonics
- Surges and transients
- Flicker, unbalance, earthing and EMC problems

The following cost components have been investigated:

- Labor cost
- Work in progress (in terms of labour and materials which have been inevitably lost and labour needed to make up lost production, sales, or services such as overtime pay, extra shifts, etc.)
- Process slow down when the production process could not reach its nominal efficiency covering equipment restarts, resets, repeating operations, time needed for additional adjustments to and maintenance of equipment including losses in value of products running out of specification and / or value of insufficient quality of products as a consequence of a particular PQ disturbance
- Equipment costs including damage, shortened effective lifetime, premature component wear out, need for additional maintenance or repair and for the purchase or rental of backup equipment
- Other costs like additional fines, penalties, personnel injury related costs, including additional compensation or increased insurance rates
- Savings from unused materials, unpaid wages and mainly unconsumed energy.

All these cost were specified on an annual basis, either reported as such pro-rated where frequency was less than once pa.

Apart from specifying real PQ cost of wastage, respondents also defined those hypothetical costs that are the potential losses and risk avoided by power systems that were immunized against the PQ disturbances under review.

Based on 11 individual cases per complete interview the subsequent analysis was performed to estimate PQ cost across those sectors that offered a convergence of specific indices. These indices initially were: employment, energy consumption, contractual power, annual turnover. After refining them, the study concludes that annual turnover is a key indicator for a regression model.

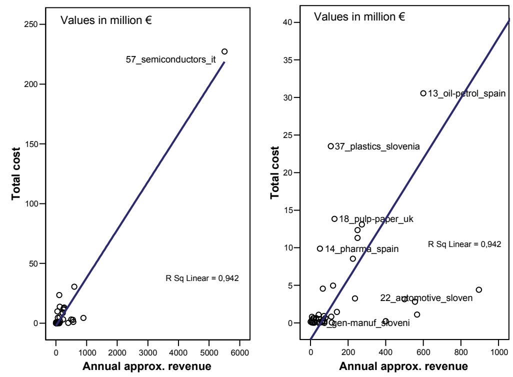
To arrive at a statistically significant and acceptable model the survey sample was divided into two sub-samples - “Industry” and “Services”. The Banking sector was excluded because of its anomalous size and structure.

Industry model

R^2 – the value of the coefficient of determination is the squared value of the multiple correlation coefficient of 0,942 and shows that almost 95% of the PQ cost variation is explained by this model.

Analysis shows that for the “Industry” sector the estimation of how much wastage is caused by poor PQ is 4% of annual turnover with standard error of 0,2%. Although constants in the regression model have a relatively high standard error their absolute levels are insignificant when considering distant extrapolation.

Figure 3. Regression – industry, full and zoom left corner

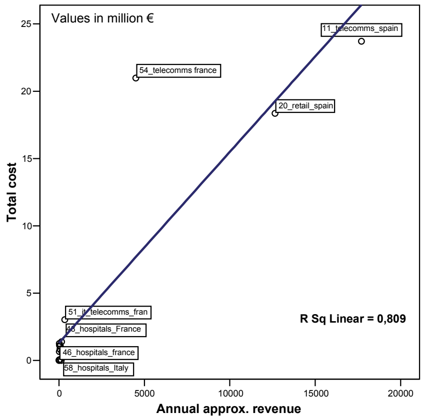


Services model

R^2 – the equivalent for the “Services” sector is 0,809 and the model estimation of wastage is caused by poor PQ is 0,1419% of annual turnover with standard error of

0,01784%. For the Banking sector, the overall estimates have been based on classical descriptives; mean, standard deviation and variance. The sector value estimate would be 0,0083% of annual cost with standard error being equal to the mean. For this reason Banks have been excluded from summary conclusions.

Figure 4. Regression model - services



Whilst regression analysis is more a tool to estimate values within a range of variables, it is also suitable for extrapolation - the simplest way being graphically to draw the trend line.

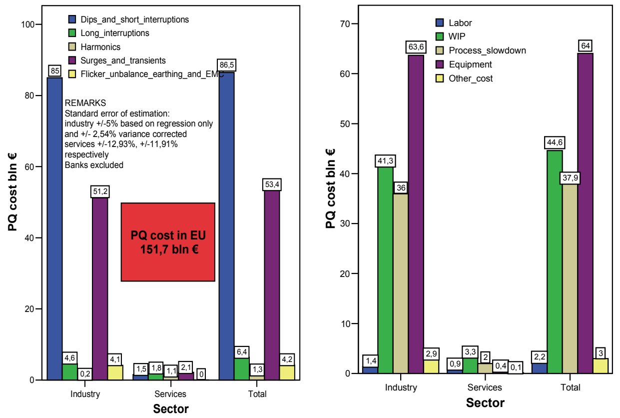
To use regression analysis as a general tool, despite the fact that the linear regression model assumes that there is a linear, or "straight line" relationship between the dependent variable and each predictor, the sample selection must be random. The interviewees have not been selected randomly. The interview demanded a lot of goodwill and respondents had to be prepared to identify potentially sensitive PQ issues. This might suggest an above average PQ economic impact for the cases they discussed, as knowledge about these issues in these sectors is not that deep nor that widely spread.

Statistical bias is inevitable in research like this, especially in terms of how representative the study is of the target universe. This was only resolved once the random and statistically based samples were checked. The regression analysis in our project proved that the samples and models are large and good enough to conclude that the variation explained by the model is not due to chance and that the relationship between the model and the dependent variable, which is annual PQ cost, is very strong.

The extrapolation error in our study was based on the regression model, which proved to be very accurate. It was further refined from the sectoral point of view by the so-called variance factor, which is a ratio of standard deviation to the mean.

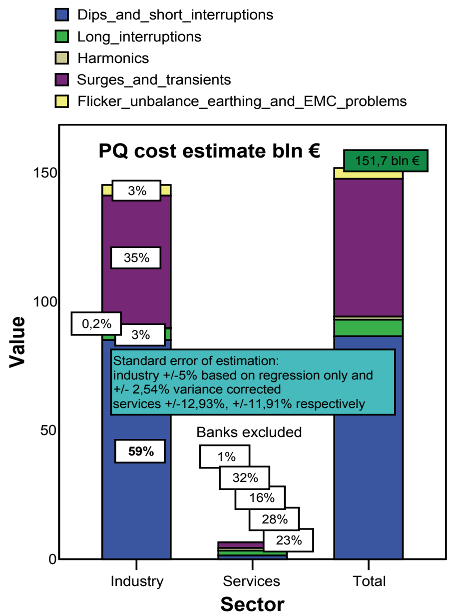
The following chart presents the cost estimates of wastage caused by the range of PQ phenomena throughout the sectors investigated in EU-25:

Figure 5. Cost of PQ wastage EU-25 by PQ Phenomenon and cost category



The cost of wastage caused by poor PQ for EU-25 according to this analysis exceeds €150bn. "Industry" accounts for over 90% of this wastage. The think that so small contribution of "Services" to total PQ cost may result from certain cost underestimation as services often experience problems in office environment where distinguishing between PQ cause and other root cause may be difficult. Furthermore some services sectors like data centers which probably experience higher PQ cost have no representation in the survey. Hospitals, although well fit into the "Services" model demonstrate slightly higher PQ cost than other services sectors. Dips and short interruptions account for almost 60% of overall cost to industry and 57% for the total sample.

Figure 6. Cost of wastage caused by poor PQ in EU-25: Summary

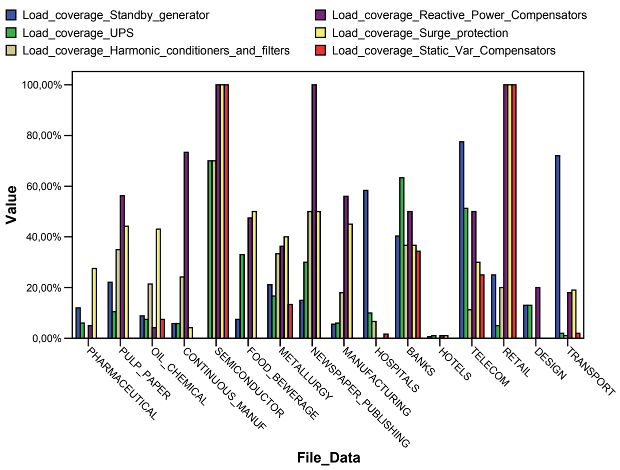


This extrapolation corresponds well with those levels indicated by EPRI CEIDS [2] PQ survey in US in 2000 which reports between $119-188bn as the cost of poor PQ generated wastage in the US with 4% of companies reporting annual costs of 10% or more of annual revenue and 9% reporting costs between 1 and 9,99%.

Power Quality solutions

The companies covered by the study invest yearly €297,5 million in different power quality solutions. Figure 7 charts the proportion of load per sector covered by different types of redundant or mitigatory solutions.

Figure 7. Load coverage - solutions



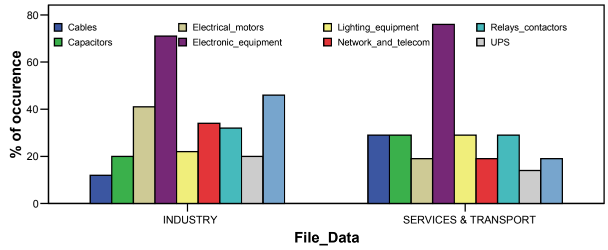
The analysis of solutions produced some interesting conclusions:

- Most of the correlations between solutions (both investment and load coverage) and PQ cost, frequency of events or sensitivity to PQ problems are statistically insignificant
- One side effect of UPS' use is the increased cost of harmonics. This can be explained by suboptimal use of UPS systems that are based on diffused small units without active power wave modulation, which in turn generates significant input current distortion.
- Although there is no significant correlation between solutions and real cost, a strong correlation exists between investment in PQ solutions and hypothetical to real cost ratio. This results in an indirect but clear link between solutions and (real) consequences.
- There is small but noticeable (positive) correlation between number of power lines and cost of short while such correlation is insignificant in case of dips.

SUMMARY AND CONCLUSION

The study provided numerous additional conclusions about occurrence of PQ problems, their sources and equipment affected. The example is the occurrence of different equipment being affected by PQ, presented in figure 8. While in "industry" and "services" electronic equipment is affected most of all, the next for industry are static converters while in services other are more equal.

Figure 8. PQ affected equipment



In addition to those technical conclusions, it is astounding that industrial sectors, for which electrical power is critical, are not fully aware of these issues. The main conclusion however remains that PQ costs in Europe are responsible for serious reduction in industrial performance with an economic impact exceeding €150bn.

ACKNOWLEDGEMENTS

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- Laborelec (Belgium)
- MGE UPS Systems (EU)
- Schneider Electric (EU and Spain)

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[2] D. Lineweber, S. R. McNulty, 2000, "The cost of Power Disturbances to Industrial & Digital Economy Companies". *Report of Primen for EPRI's (CEIDS)*