ASSESSING THE ECONOMICS OF POWER QUALITY

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ABSTRACT

Power Quality is now considered as a characteristic of the electrical supply which should be more closely defined and regulated. However there is a tradeoff between the benefits from improved power quality and the costs of achieving it, with the cost benefit analysis required quite difficult to formulate.

In many cases it is the cost of the consequences of poor power quality which are set against the cost of improving the network, whereas the correct approach is to compare the costs of options to mitigate the consequences against the cost of accepting the consequence.

In the paper a complete framework for the economic analysis of Power Quality will be presented and discussed with application to current policy issues, such as the modification proposals to EN 50160.

INTRODUCTION

Power Quality (PQ) covers a range of characteristics of the electrical energy supplied to customers through the utility network. Certain aspects of PQ may have a deleterious impact on equipment or processes resulting in economic loss to the customer. These PQ features can be mitigated either by the utility or by the customer. If mitigated by the utility the extra costs are ‘socialised’ in that the extra network costs will be collected from all utility customers through increased tariffs. Conversely, if mitigated by the customer a different set of costs will be incurred but these will be borne solely by the customer concerned.

From societies point of view the optimum decision is one where the mitigation measures required produce the most economically advantageous solution for society as a whole.

In some situations economies of scale by the utility would indicate that the utility can meet the customers PQ requirements most effectively e.g. excessive voltage drop in an area might effectively be mitigated by uprating the MV voltage from 10kV to 20kV, providing improved voltage regulation to all customers as well as increased capacity and lower losses.

In other situations the PQ aspect causing problems might be particular to one part of a particular customers process, and would best be mitigated by local measures by the customer e.g. if a process control computer were sensitive to voltage dips, it would be cheaper for the customer to put in a small UPS rather than for the utility to redesign the feeding network. In this case the benefit of the customer installing the mitigation measures are that the benefits and the costs are associated with the one customer, and the mitigation costs to society are minimized.

From the above examples it is apparent that an important principle is that in comparing the two options for improving PQ – improve the network or install mitigation measures at the customer side - the costs involved in the analysis are the costs of these two options alone – not the cost of consequential loss on the customer side.

So for example if failure of a 25kVA process computer involved a direct cost for a UPS of €3,000 but had a consequential loss of €3m in lost product if failure occurred, the only costs that need to be looked at are the Utility Network costs and the costs of installing a UPS. The cost of consequential losses are not relevant as they can be avoided through the installation of the UPS.

In situations where there is a large amount of sensitive electronic equipment e.g. cash tills in a retail shopping centre, then the relevant costs would be the total costs of the multiple UPS’s required, and the alternative costs of reinforcing the network.

GENERAL APPROACH

Changes in PQ can only be implemented through changes in the network infrastructure through which the customer is connected. Such changes, of their nature, are expensive, slow to implement on a wide scale, and have a long payback period – 40 to 60 years being the typical life of a network asset.

Consequently it is essential that proposed changes are evaluated in a methodical and consistent manner, with comprehensive and well justified arguments required to ensure value for money from the associated scale of investment.

It is critical for a correct analysis to divide Power Quality into its two main components – Reliability of Supply (SAIDI/SAIFI) and Voltage Quality (Harmonics, Transients, Sags, Surges, Average RMS Voltage). Occasionally analyses appear which justify more stringent Voltage Quality based on the consequences of a lack of a Reliable Supply (outages) - justified by the need for improved “Power Quality”- where what was actually
required was a more reliable supply.

Economic Criteria:

Assessment of PQ mitigation measures is complex as it involves choices between mitigation measures which may benefit a few but which are paid by the masses, and where certain investments have a long lifetime, so that technological change may end up with them being stranded e.g. if shopping centre ran off CHP in the future with the utility network as a backup, then investments in a reinforced network would have given little return.

For clarity in decision making it is therefore important to state certain criteria against which proposals will be evaluated:

1. **Consequential loss is not relevant to the analysis**
   
   The costs of the mitigation measures on the utility side should be assessed against the alternative option of mitigation measures on the customer side. The cost of consequential losses is not relevant. e.g. the consequence of a voltage sag may be that contactors drop out, motors stop and valuable production is lost. However the cost of a ‘sag ride through’ device at the contactor board to prevent this may only be a few hundred euro.

2. **Match like against like**

   In larger geographic areas the costs of aggregate mitigation measures on the customer side should be assessed against the aggregate cost of utility reinforcement.

3. **Impact of technological change on sensitivity of customer equipment to PQ**

   - Utility investments have lifetimes of around 60 years. Customer equipment becomes obsolete due to technological change rather than due to wearing out, and indeed this is reflected in the depreciation lifetimes of computer and process control equipment which is generally less than 10 years.

   - This factor is important in any assessment as it may mean that the characteristics that make current equipment sensitive to PQ may no longer be a factor once the equipment is replaced with more modern models, in say 5-10 years, and possibly even before any major change to the network could have been completed.

4. **Costs and benefits should bear fairly on the overall customer base**

   Utility tariffs are generally established by spreading the costs of the network over each customer class. Extra investments by the utility in providing greater PQ for a small group of customers will be paid for by the remaining customers in this class, who may receive no benefit. This effect is undesirable, so that solutions which better match costs and benefits to a particular customer/class are adopted, so that unfair cross subsidies are avoided.

   For clarity it is also essential to detail how the proposed improvements will be funded.

5. **NPV should be used for financial evaluations**

   Net Present Value methods which reflect the time value of money should be used in order to obtain a meaningful evaluation of the costs involved. The proposed Discount rate should be 6% which represents a typical utilities Weighted Average Cost of Capital.

6. **Application of high level judgment**

   It is important that common sense be applied in the overall evaluation. Solutions to current problems which take decades to implement are not practical and should be rejected.

   Real problems should be solved rather than potential problems e.g. TV sets are a form of sophisticated electronic equipment which are widely installed throughout Europe, yet they very rarely find PQ a problem, so that this would suggest that other electronic equipment manufactured to a similar standard should also not exhibit problems.

Application of the Economic Criteria:

It may be said that it is often easier to enumerate the economic criteria than to evaluate them due to the practical difficulties in obtaining data. However, as in most investment decisions, certain aspects of the decision will bear more heavily on the decision, so that qualitative answers in some areas and rough quantitative assessments in others will lead to a clear decision, even in the absence of detailed accurate costs.

Accordingly it is proposed that the following generic format is used, tailored to each case being considered:

**Executive Summary**

A short description of the issue covering:

(a) What change is proposed?
(b) Why it is being proposed?
(c) How much will it cost?
(d) How long will it take to implement?
(e) What % of customers will be affected by the change in terms of reduced malfunctions of their equipment?
(f) What is the economic value of this reduced level of malfunction?
(g) What other options were considered and why were they discounted?
(h) What is the risk of technological change to equipment making voltage variations unimportant?
(i) How will the proposal be funded?

Description of Problem:
A clear description of the problem, its geographic extent, frequency and severity of occurrence and actual impact is essential to any meaningful analysis.

(a) How does the current standard result in problems
(b) How many problems and in what customer groups
(c) What is economic impact of the problem
   - evidence of equipment damage
   - evidence of equipment malfunction
(d) What portion of the customers load is sensitive e.g. customer with demand of 2,000kW with 50kW of sensitive load?

Note: CBEMA curve is based on power supply design from late 1970’s, the actual sensitivity of load to disturbances should be based on modern power supply circuits, e.g. one used to feed a TV set – TV sets are omnipresent, are sophisticated electronic devices exposed to any PQ problems on the networks, yet there are few reported problems.

Solution Options:
A correct evaluation demands that any new proposal is evaluated against:
(a) the status quo (no change – do nothing),
(b) the option of solving the problem by network reinforcement and
(c) the option of the customer taking necessary measures to eliminate the problem.

(a) No Change Option

PQ Standard kept as is.

(b) PQ Standard is modified and the network consequently reinforced

How much will change cost?

This should be evaluated using Net Present Value (NPV) on the estimated costs and benefits produced over the lifespan of the project.

What is expected lifespan of the project benefits?

A critical element will be the proposed lifespan, as technological change which makes customer equipment more resilient in the future will mean that network investments will be stranded e.g. if a cable is laid to reinforce a circuit and reduce voltage drop it will last for 60 years. But if in 10 years time new customer equipment is impervious to voltage variations then all the benefits that the cable would have produced from year 10 to year 60 will be stranded. Hence only 10 years of benefits should be included in the analysis.

What specific network investments will be required to produce the improvement?

e.g. if say voltage variations are to be +/- 10% for 100% of the time then the 95th percentile of the load can not be used. It must be the 100th percentile which could be up to three times larger hence all loads will be planned using designs which use 300% of current loading, so that cable and transformer sizes will increase accordingly.

Conversely, because the percentile effect is asymptotic, a 99% standard might only increase the load by 10%.

What impact will the network reinforcement have on the rate of equipment failure or malfunction?

A change in network infrastructure will bring voltages within tighter limits, and the expected levels can be readily calculated. The impact of the extra investment may be marginal however as the equipment may not be in use when the voltage is within tighter limits etc. e.g. if high voltage occurs mainly at night but customer equipment normally disconnected or switched off at this time, then impact of improving voltage at night will not be seen. What needs to be considered in the analysis is not the change in voltage limits per se but the real impact on customer equipment. Another way of looking at this is through the use of probability factors to relate the coincidence of a PQ phenomenon with the likelihood of an impact on the equipment.

How many customers are affected? and which type of customer?

e.g. if unbalance is an issue it will only affect customers with three phase motors. Most of these customers are commercial-industrial located in rural areas. So if there are 2m domestic customers and 5000 Industrial-Commercial customers of whom 1000 could be affected, this needs to be taken into account in the analysis.
What is the cost of an equipment malfunction?

In other parts of the world what is measured is the Value of Lost Load rather than the cost of customer mitigation measures, as this is an easier approach and the type of mitigation measures required would and vary between industries. Yet the economic cost is a very necessary input to the analysis.

What % of the customer’s load is sensitive to voltage quality?

Network reinforcement can only provide improvements on a “one size fits all” basis, so that if there is a load of 5MW on a feeder of which 200kW is sensitive to voltage quality, the network reinforcement must improve voltage for the 4.8MW of insensitive load in order to address the needs of the 200kW.

What percentage of the network reinforcement cost will be paid by the customers who receive the benefit?

In the example above customers paying DUoS for 4.8MW would pay the bulk of the costs but the customer with the 200kW load would receive the benefits. Such considerations of equity must be taken into account.

Use of probability factors

What use if any is to be made of the probability factors? – as greater and greater coverage of network voltage variations is sought an area of diminishing marginal returns is rapidly entered, where more and more money is spent for less and less benefit. e.g. in one load curve from Australia it can be seen that to plan for close to 100% rather than 95% means that the loads to be catered for must be increased by 50%. This may not be good value for money.

Cost of changes to PQ Standards on customer equipment costs

Tighter PQ Standards would also require correspondingly tighter controls on equipment connected to the network e.g. harmonic output from electronic equipment. This would impose extra costs on manufacturers and in turn on customers.

Similarly connection of renewables would be much more difficult, as renewables inherently cause disturbances to voltages, and with tightened standards these will be excessive. This means that renewables would only be able to be connected in lower quantities, or with more elaborate and costly connection methods.

(c) Option of Action being taken on the customer side:

What actions could be taken on the customer side to reduce the impact of voltage quality?

The main point here is that only a percentage of the customer equipment will be sensitive so that a smaller investment will be needed to cater for this load. Also, the costs and benefits are borne by the one entity - there is no cross subsidization.

What is the NPV of these customer investments?

e.g. customer installing UPS on small PC where lifetime of the UPS is the same as that of the PC means no stranding of assets

Impact of Technological Change:

This is one of the most critical areas in relation to proposed changes to PQ Standards as it goes to the heart of the issue. Modern equipment has been manufactured using more advanced technologies than those used in the past, e.g. the basis of the CBEMA -ITIC curve is a four bridge rectifier circuit which is now technologically obsolete, with most sophisticated equipment using switched mode power supplies. These supplies are very tolerant of wide voltage variations much wider in fact than this currently allowed under EN50160.

Similarly incandescent lighting was also one of the most sensitive loads in relation to voltage variations and flicker. Yet EU is now proposing that inefficient incandescent bulbs are banned and that only electronic energy efficient bulbs are sold. This changes the benefit that would be produced for lighting from tighter voltage bandwidth

This means that if costly measures whose impact is long lasting are introduced (such is extra network investment) then there is a risk that customers will only see benefits over a short period of time – the lifetime of their current voltage sensitive equipment – say 5-7 years. Once this equipment is replaced the customer finds no benefit from higher voltage quality, and the investment is now stranded.

Hence one of the most important risks to be addressed in evaluating changes to PQ Standards is the risk of investment stranding.

Comparison of Options:

What amongst the options considered provides the least NPV cost technically acceptable solution? 
- provide reasons why the other options were rejected

How long will this solution take to be implemented?
- if it takes 10 years to implement 50% is it a
reasonable solution?

What is the risk of Technological change stranding the investment?

What risks are associated with implementing this proposal and how have these risks been mitigated?

What costs are involved and how are these broken down into categories?
- are these costs accurate and well founded or are they based mainly on broad assumptions and only backed up by sparse data? – sufficient detail should be given to understand how the costs were constructed.

What is the breakdown of benefits produced in terms of money benefits amongst different groups and by benefit source?
- again sufficient detail should be provided to back up these calculations

What impact will the proposal have on manufacturers costs and also on the penetration of renewable generation?
- some estimate of the impact in money terms should be provided

Implementation Proposal:

To provide a benefit the proposal must be capable of being implemented in such a way that benefits are seen reasonably quickly.

How will the proposal be implemented?

How long will the proposal take to implement?

Can the proposal be structured in such a way as to reduce risks? i.e. stage investment stages and evaluate impact after each tranche of investment

Proposal Review:

A procedure should exist whereby changes are regularly re-evaluated in the light of new information so that inappropriate solutions no longer continue to be imposed long after the requirements have changed. One way of doing this is to have any change lapse unless it has been reviewed - this is a fail safe procedure for ensuring that bad investment does not continue as a result of inaction.

Funding:

Who is going to pay for the changes? How is it funded?

Practical Steps forward: