POWER QUALITY CUSTOMER FINANCIAL IMPACT/RISK ASSESMENT TOOL

Hadi Safari Farmad
Khorasan Razavi Electric Distribution Co. Iran
h.safari.f@gmail.com

Mohammad Reza Mozayyani
Khorasan Razavi Electric Distribution Co. Iran
manager@kedc.ir

ABSTRACT

Electric power quality problems associated with interactions between distribution and enduser systems can be prevented. While power quality is a well used (almost over-used) term, surveys of large users that buy power at transmission and distribution voltages turn up relatively few complaints about the quality of their incoming power, while surveys of small users connected at secondary voltages turn up numerous complaints about the quality of their incoming power. Three major changes in the characteristics of customer loads and power distribution systems have altered the nature of the power quality equation:
(1)greater sensitivity of devices and equipment to power quality variations, (2) the interconnection of sensitive loads in extensive networks and automated processes, and (3) an increase in loads that use power electronics in some type of power conversion process.
A review of some of the work targeted to quantify the financial losses and risks of powerquality problems indicates that a significant number of dollars are spent annually Investigated data confirms that PQ costs deviate widely among users. How much it costs depends on a variety of factors.
This paper introduces how is possible providing commercial/industrial facility managers with concepts, parameters and a checklist that spell out how to compile PQ cost data into simple formulas and calculate the total cost of power quality operating problems for a wide range of different types of businesses. Selected commercial/industrial case studies are presented to illustrate a basic spreadsheet format to assist in analyzing the total cost of a power disturbance.
First PQ areas of financial losses will be introduced and Some common symptoms of power quality problems in facilities such as unexplained equipment trips or shutdowns, occasional equipment damage or component failure, erratic control of process performance, random lockups and data errors and power system component overheating will be mentioned . then a number of factors having the greatest impact on how large PQ losses may be are detailed.
Parameters affecting cost of impacts, such as Field service costs, Productivity costs, Loss of revenue, Decreased competitiveness, Lost opportunity, Product damage, Wasted energy and Decreased equipment life will be dealed. Checklist for compiling basic PQ cost Data and Fomulas to calculate PQ costs (Identifiable and hidden PQ costs) will be introduced.
Finally three illustrative examples of the proposed framework to calculate PQ costs:
Case 1 – Commercial computer data centre
Case 2 – Industrial automotive manufacturer
Case 3 – Industrial processing plant
Will be addressed

INTRODUCTION

Electric power quality problems associated with interactions between distribution and end-user systems can be prohibited. While power quality is a well used (almost over-used) term, surveys of large users that buy power at transmission and distribution voltages turn up relatively few complaints about the quality of their incoming power, while surveys of small users connected at secondary voltages turn up numerous complaints about the quality of their incoming power. Three major changes in the characteristics of customer loads and power distribution systems have altered the nature of the power quality equation:
(1) greater sensitivity of devices and equipment to power quality variations, (2) the interconnection of sensitive loads in extensive networks and automated processes, and (3) an increase in loads that use power electronics in some type of power conversion process.
This paper was created to provide commercial/industrial facility managers with concepts, parameters and a checklist that spell out how to compile PQ cost data into simple formulas and calculate the total cost of power quality operating problems for a wide range of different types of businesses. Selected commercial/industrial case studies are presented to illustrate a basic spreadsheet format to assist in analyzing the total cost of a power disturbance.

PQ AREAS OF FINANCIAL LOSSES

Power quality problems can be complicated, involving the facility wiring, natural phenomena such as lightning, interacting facility equipment, and equipment connections to the electric power system. Most commercial and industrial production machinery is typically designed to operate with flawless electricity from the electric utility; however, many things interfere with electricity as it travels from the utility to a customer’s equipment that produces revenue- creating products and/or services.
A review of some of the work targeted to quantify the financial losses and risks of power quality problems indicates that a significant number of dollars are spent annually (see reference 3). Investigated data confirms that PQ costs deviate widely among users. How much it costs depends on a variety of factors. For example, research on the effects of interruptions in the agricultural sector in Iran showed that different types of farms, including large and small operations, had significant variations in costs due to

interruptions in service. (see reference 12).
In the industrial sector, the interruption costs of production processes can range widely, due to the potentially large number of product categories involved and the relative complexity of the production process for each category type.
Capturing the annual costs of power quality is a complicated procedure and in reality they can only be estimated. The costs of power quality problems and solutions can vary dramatically, depending on the nature of the problem, the
existing electric service system, and the type, ratings and electromechanical performance characteristics of the commercial/ industrial equipment.

Parameters affecting cost of impacts

Today most engineering economic assessment studies must take into account existing conditions and the losses associated with no change, the benefit derived from system modifications and the cost to implement the modifications with financial criteria such as internal rate of return, life cycle costs, depreciation, taxes, etc. In many cases, businesses do not perform detailed economic analyses and will address a power quality problem only when it is obvious or critical. As a result, the quickest solution is often chosen, without regard for rate of return. An important part of assessing PQ-related costs is determining what, specifically, is being affected, and where, or in what aspects of business operations, do these costs show up. Some efforts have been made to identify and classify disturbances and other PQ costs. In the IEEE
following are brief examples that define some I,portant parameters:

• *Field service costs* – undetected disturbance events that result in component or circuit board failures with no verifiable cause and where either the equipment manufacturer absorbs the repair costs or the customer must bear the field service costs for parts, labor, consultants, electrical contractors, etc.

• *Manufacturing costs* – because some portion of certain manufacturing systems is affected by PQ disturbances, the whole system may not meet the performance requirements, product quality, production rates or production volume.
In these cases, the manufacturers have found it necessary to invest in backup systems of some sort to avoid disturbances, whether the disturbances are observable or not.

• *Productivity costs* – usually impacted by both hidden and direct, or identifiable, costs, e.g., idle manpower due to an interruption, cleanup operations, or corrective maintenance and the diverting of resources, which effectively decreases productivity and increases costs.

• *Loss of revenue* – any direct interruption to a manufacturing process can interrupt sales or severely impact revenue flow, resulting in delayed production schedules. The loss of revenue from any kind of process interruption
is generally an observable or direct cost.

• *Decreased competitiveness* – PQ problems in the manufacturing environment can often result in customer dissatisfaction and a poor quality product, as well as delayed production schedules. These shortcomings almost certainly decrease competitiveness and can be very costly.

• *Lost opportunity* – any PQ problems that impact any type of product and/or service processes can also mean a lost opportunity for sales, for the marketing of a new product at just the right time, or for the marketing of seasonal products at the peak of the season.

• *Product damage* – sometimes PQ problems in manufacturing processes can result in product damage. Occasionally, the damage can be directly observed and the damaged product discarded or recycled. Product damage can be costly if the damage is subtle and the effects take some time to surface.

• *Wasted energy* – any interruption to a manufacturing process will result in a waste of energy in the restart process.

• *Decreased equipment life* – many systems that experience disturbances, both detected and undetected, have resulted in decreased equipment life. High-energy, fast-rise-time transients can cause outright circuit board failure, even for systems protected by transient suppressors, or can cause degradation over time such that burnout is only delayed.

Checklist for compiling basic PQ cost data

High-speed electronic systems and equipment may be more sensitive to disturbances in the AC power system than are conventional loads. The effects of power disturbances on sensitive electronic equipment can take a wide variety of forms, including data errors, system halts, memory or program loss, and equipment damage. In many cases, it is difficult to determine whether the system hardware and software malfunctions are actually caused by disturbances in the power system supplying the equipment. These PQ realities compound the complexity of collecting basic costs for data calculations. To successfully compile basic costs, a thorough analysis of the power system and loads should
be conducted to define the areas of concern as accurately as possible before attempting to solve the problem. Coordinate with involved parties, the equipment user/owner, electronic equipment manufacturer/supplier, and discuss the objectives of compiling basic costs. This approach can enable cost-effective solutions to be implemented that not only correct the existing conditions but also minimize future problems. The key is to understand and define the problems, and to estimate cost impacts before attempting to solve them. Effective communications are essential to determine proposed solutions and their basic costs. Following is a checklist to walk through the process of gathering information.

- ✓ Identifying what sensitive electronic equipment is experiencing problems (e.g., type, location).
- ✓ Document the types of equipment malfunctions or failures (e.g., data loss, lockups, component damage).

- ✓ Determine when the problems occur (e.g., time of day, day of week, particular system operation). Valuable information to assist in solving facility power problems and compiling basic costs is obtained by keeping an accurate log of equipment errors and malfunctions.
- ✓ Establish those coincident problems occurring at the same time (e.g., lights flicker, motors slow down). Single observations such as these provide valuable clues to identify possible problem sources and PQ impact basic costs at the site.
- ✓ Investigate possible problem sources at site (e.g., arc welders, air conditioning, copy machines, and any equipment with rectifier input power supplies).
- ✓ Make inquiries regarding existing protection for equipment (e.g., transient voltage surge suppressors, isolation transformers, internal electrical filtering circuit devices, etc.).

Formulas to calculate PQ costs

Neither power quality, nor the lack of it, is without cost. As mentioned already, an important part of assessing PQ-related costs is determining what specifically is being affected and where, or in what aspects of business operations, these costs show up. Some long-term studies reveal the effects of hidden, as well as identifiable, costs for both the utilities and their customers. Most of the literature deals with the cost of interruptions, identifiable disturbances, and naturally, identifiable costs (reference 9).

Identifiable and hidden PQ costs

Identifiable costs are generally associated with voltage sags and momentary, or longer, electric service anomalies. Identifiable costs are sometimes referred to as “direct costs,” notably including labour hours, costs of scrap, damaged products or services, costs of rework, costs to reprogram or replace lost data, costs to re-run an in-process test that was interrupted, and costs of damaged manufacturing or service equipment.

Hidden costs are sometimes referred to as “indirect costs,” or “soft costs.” These reflect costs of lost sales, costs of premature equipment failure, costs of out-of-specification products or services, costs of impacts on just-in-time delivery systems, and costs associated with poor reputation for non-delivery. Some equations have been developed (reference 3) to identify rough estimates of costs due to power disturbances on processes, from a cash flow perspective. Upfront identifiable and hidden costs that need to be quantified should include the following:

Total Cost of a Power Disturbance (TCPD)

TCPD = (A + B + C + D) ($)

where:

A = Cost of labour for employees affected ($)

B = Service or product loss due to power disturbance ($)

C = Cost of restart ($)

D = Hidden costs ($)

The values of A , B , C and D can be calculated as follows:

A = E x F x (G + H)

B = I x J

C = K x L x (G + H) + M x J

D = N x O

where:

E = number of productive employees affected

F = duration of power disturbance/interruption (in hours)

G = base hourly rate of employees affected ($)

H = overhead hourly cost per employee affected ($)

I = units of services or products lost due to power disruption

J = cost per unit of service or product lost/repaired due to power disruption

K = restart time (in hours)

L = number of employees involved in restarting

M = units of equipment damaged due to restart

N = element(s) of hidden costs

O = $/hidden cost element

Following are three illustrative examples of the proposed framework to calculate PQ costs:

Case 1 – Commercial computer data centre

Problem description – The data centre provides computer support to 10 remote locations for all business computing. Applications include payroll and time-keeping, production and cost control, inventory and general accounting. During the last year, 20 downtime episodes occurred as a result of electric voltage sags or momentary interruptions lasting from 30 cycles to a few seconds, which disrupted work production for an average of 0.6 hours. Typically, transactions in progress were lost as well as recent remote transactions. Recovery included rebuilding of payroll files and discovering what needed to be reprocessed, then retransmitting the right data from all of the remote sites. Normally, 10 new sales are recorded each business hour and are valued at approximately $250 income.

TCPD Case 1 = A + B + C + D

A = (100 employees) x (0.6 hours) x [($15/hour) + ($7.5/hour)] = $1,350/episode

B = (200 lost transactions) x ($22.5/transaction) = $4,500/episode

C = (0.5 hours/restart) x (100 employees) x ($22.5/hour) + (2 bad disks/power supplies) x ($1500/repair) = $4,125/episode D = (6 lost sales) x ($250/lost sale) = $1,500/episode

TCPDCase 1 = $1,350 + $4,500 + $4,125 + $1,500 = $11,475/episode

If there were 20 power quality disturbance episodes per year as characterized above, the yearly power quality cost impact on this customer would be 20 x $11,475/episode = $229,500/year.

Case 2 – Industrial automotive manufacturer

Problem description – This automobile manufacturer experiences tripping of adjustable speed drives (ASDs) and robotics for no apparent reason. Some electronic damage occurs, but the real problem is downtime. The downtime associated with each of these problems averages 30 minutes, and that has a growing financial value in lost time, production and raw materials. A special problem is the paint shop, where robots painting cars are interrupted. While 50 unpainted cars result due to each disruption, there are significant hidden costs associated with resending an additional 50 cars ($35 per car), lost paint ($25 per car), and the need to repaint cars ($75 per car) that have out-of-specification paint coats. In addition, since this auto plant runs at full capacity, 50 lost car sales ($500 per car) increases the total hidden costs per car to $635. The problem seems random, and the cause is the transient associated with utility capacitor switching. The utility has turned off automatic control and is now coordinating the manual operation of the capacitors with the manufacturer. This is unacceptable as a permanent solution, as the capacitors are not available to control utility voltage as needed.

TCPDCase 2 = A + B + C + D

A = (1,000 employees) x (0.5 hours) x [($17/hour) + ($9/hour)] = $13,000/episode

B = (50 unpainted cars) x ($75/car) = $3,750/episode

C = (0.5 hours/restart) x (50 employees) x ($26/hour) + (4 damaged ASDs/controllers) x ($500/repair) = $2,650/episode

D = (50 resanded & repainted cars) x ($135/repaint) + (50 lost car sales) x ($500/lost sale) = $6,750 + $25,000 = $31,750/episode

TCPDCase 2 = $13,000 + $3,750 + $2,650 + $31,750 = $51,150/episode

Case 3 – Industrial processing plant

Problem description – This industrial plant (plastics, chemicals, textiles, etc.) experiences tripping of motor-contactors because of utility distribution system faults over a wide area. They are exposed to about 10 to 20 events per year ranging from a few cycles to 10 seconds. Each event costs about one hour of lost production by idling 350 employees, creating scrap materials, and the subsequent restarting costs. There are 175 motor-contactors ranging from 1 horsepower to 250 horsepower. Up to 30 of the contactors malfunction anytime their electric service voltage drops to 88% of normal. All the motor-driven systems need to operate together to produce products from this plant. Process equipment "drop-outs" affect many plastic material temperature controller systems during each disruption. This situation results in 20 reels of out-of-specification plastic product and the need for extensive clean-up with chemical agents. Hidden costs of each disruption are estimated at $725 per reel.

TCPDCase 3 = A + B + C + D

A = (350 employees) x (1 hour) x [($12/hour) + ($4/hour)] = $5,600/episode

B = (125 reels plastic sheet) x ($175/reel) = $21,875/episode

C = (1 hour/restart) x (10 employees) x ($16/hour) + (2 damaged contactors & 1 damaged motor) x ($750/repair) = $3,850/episode

D = (20 out-of-spec reels) x ($725/reel) = $14,500/episode

TCPDCase 3 = $5,600 + $21,875 + $3,850 + $14,500 = $45,825/episode

At times a simple PQ cost analysis might only include TCPD elements A, B, and C, but a more complete PQ cost analysis should include D, hidden costs. Hidden PQ costs may not be associated with interruption of service or observable disturbances, but can result in increased costs by one or more of the following:

• increased equipment losses
• reduced product quality
• increased maintenance costs

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