ORIGINAL ARTICLES

Power Quality Survey for Premium Power Options In Malaysia

A. Mohamed, H. Shareef, M. A. Hannan, A. Ayob, R. A. Begum, M. F. Faisal

Department of Electrical, Electronics & Systems Engineering, Universiti Kebangsaan Malaysia
Institute of Environment and Development, Universiti Kebangsaan Malaysia
Asset Management Department, Distribution Division, Tenaga Nasional Berhad, Malaysia

ABSTRACT

For industries, where a high degree of power quality and reliability is critical, any voltage surge, sag and
momentary outage on the supply lasting more than a few cycles could cause several equipment to
malfunction. In particular for industrial customers, quality of power is as important as reliability of power.
Premium power supply can be regarded as a provision of the electricity supply beyond the required standards
with guaranteed performance levels. This paper presents a questionnaire based survey with the objective of
identifying premium power options that can be offered to industrial customers in Malaysia. The survey is also
aimed at developing a knowledge base on industrial power quality concerns such as causes and effects of power
quality disturbances and premium power options preferred by industrial customers. The results of the survey
will provide a basis for utility in planning premium power services to be offered to industrial customers.

Key words: Power quality, mitigation devices, premium power

Introduction

Power quality has now become an important issue for power utilities and its’ industrial customers. Variation
in the supply voltages, even for a very short duration, that was not a concern before is now very costly in terms
of process shut down and electrical equipment malfunctions in manufacturing plants. Modern day customers
now demand high power quality for improved production output as well as for maintaining an optimal operating
cost. Power quality problems experienced by customers are due to various causes. Some problems are a result
of the shared infrastructure. For example, a fault on the network may cause a disturbance such as voltage sag that
can affect many customers in which the higher the fault level, the greater the number of customers affected.
Another PQ problem due to harmonics arise from within the customer’s own installation may propagate into the
network and affect other customers. To understand and manage these malevolent PQ problems, many utilities in
the world have installed on-line PQ monitoring system to record all disturbances in the networks and perform
PQ surveys. Several PQ surveys have been conducted to date, in which some examples of surveys were
implemented by the Canadian Electrical Association (Hughes & Chan, 1995), Electric Power Research Institute
(Sabin et al., 1996), National Power Laboratory (Dorr, 1995; Dorr et al. 1997), CESI (Ardito et al., 2003),
European Copper Institute (Manson & Targosz, 2008) and Tasmania Power Company (Negnevitsky et al. 1997).
In 2005 to 2006, the Leonardo Power Quality Initiative team conducted a European PQ Survey by means of
face-to-face surveys carried out in eight European countries.

The aims of power quality surveys are to evaluate the quality of the power available at a specific site or
network, to define the electrical environments and to evaluate and compare PQ performance of several utilities.
The results of PQ surveys allow analysis of many associated issues such as user perceptions and causes of PQ
problems, equipment affected by poor PQ and PQ solutions that are available and adopted. From the worldwide
PQ surveys on the electric power supply, it is found that complaints due to various types of PQ disturbances are
increasing among different types of consumers. For example in Slovenia, PQ disturbances such as voltage sags
and short duration interruptions have been identified as the most common disturbances affecting industrial
systems (Kerin et al., 2007). A high proportion of the companies interviewed agreed that flicker incurs losses
which can amount to 10% of annual employment cost (Manson et al., 2008; Hannan et al. 2011). These PQ
surveys have been performed with different objectives and concerns, namely for, obtaining baseline data on PQ
events, diagnosing PQ problems, estimating economic loss to industrial customers due to PQ disturbances.

In this paper, a PQ survey has been conducted with the objective of identifying premium power options that
can be offered to industrial customers in Malaysia. Currently, many electric utilities in the world are considering
approaches to offer premium power to their customers. In the concept of premium power, a better quality of

 Corresponding Author: A. Mohamed, Department of Electrical, Electronics & Systems Engineering, Universiti Kebangsaan Malaysia
power supply at the distribution system can be offered to customers that are particularly sensitive to power disturbances and also diversified PQ levels can be offered depending on customers’ needs (Chiumeo & Gandolfi, 2010). It seems reasonable to consider this premium power option considering that different customers have different PQ requirements and it seems unreasonable to spread the costs of providing enhanced PQ to a small group of customers across the entire customer base (Madtharad et al., 2007). Before offering premium power services, it is necessary to first establish a baseline for PQ and evaluate premium power options for customers.

**Power Quality Survey Methodology:**

For the PQ survey, a questionnaire has been constructed to seek the experiences and opinions of industrial customers on PQ problems encountered. The objectives of the questionnaire survey are i) to identify PQ disturbances that cause industrial equipment to malfunction, ii) to identify availability of industrial solutions to mitigate PQ problems and iii) to seek customer preference of premium power options.

The questionnaire has been structured in several sections, each aimed at inquiring information regarding the following aspects:

a) General information on the industry, such as, the contact information and category of industry  
b) Classification of the industrial PQ problems  
c) Frequency of PQ disturbances that cause industrial equipment to malfunction  
d) Consequences of PQ disturbances  
e) Classification of affected equipment due to PQ disturbances  
f) Availability of industrial solution to eliminate the effects of PQ problems  
g) Classification of sources of poor PQ problems  
h) Frequency of conducting PQ monitoring  
i) Choices of mitigation devices that can be considered for providing premium power  
j) Premium power options that can be offered to the customers.

The PQ survey questionnaire has been delivered to industrial customers across the country through an online web-based system. Individual contacts have been provided by first using a phone contact and then followed by sending questionnaire by email. Some face-to-face contacts have been made through an interview based upon the questionnaire form given to customers. The questionnaire was distributed to 130 industrial customers selected from a database obtained from the power utility and 70 industrial customers responded. The data obtained from the respondents were analyzed by converting the qualitative data into quantitative data and statistical values using the Statistical Package for the Social Sciences (SPSS) software.

The respondents to the survey are industrial customers from the semiconductor industry, process industry, heavy industry, light industry, utility, and office. Figure 1 shows the percentage of respondents in terms of type of industries. The highest response is obtained from the semiconductor industries (28.24%) which includes the companies that manufacture the chip resistors, silicon wafers and fine copper wire, followed by process industries (23.53%) that are composed of pharmaceutical, oil and petrochemical, food, plastic and paper industries, heavy industries (20%) that includes automotive and glass industries, light industry and utility (11.76%) and others (4.71%) which include commercial offices.

![Fig. 1: Percentages of the participating industries in the survey](image-url)
Results And Discussion

The survey results are presented and discussed in terms of the classification of industrial PQ problems, frequency and consequences of PQ disturbances, types of affected equipment due to PQ disturbances, availability of industrial solution to PQ problems, causes of PQ disturbances, frequency of conducting PQ monitoring, customer choice of mitigation devices for premium power and customer solution for premium power.

Classification of industrial PQ problems:

To identify the respondent understanding on the effects of PQ disturbances, they were asked to indicate the various types of PQ disturbances that affect industrial operation and equipment. Many respondents have identified PQ disturbances as short interruption, long interruption, voltage sag and swell, transient, harmonics, earthing and unbalance as PQ problems as shown in Figure 2. About 15.65% respondents classified that the short interruption is the most significant PQ problems that occur in their industrial premises while about 14.84% indicate that long interruption is significant. The percentages of industrial problems related to voltage sag/swell and transient are both 14.52% while for harmonics, earthing and unbalance the percentages are 14.03%, 13.87%, 12.57%, respectively.

![Fig. 2: Classification of disturbances that cause industrial PQ problems](image)

Frequency of PQ disturbances that Cause Equipment Malfunction:

Table 1 reports response relevant to the inquired frequency of PQ disturbances that cause equipment malfunction in industries in terms of most frequent, frequent, sometimes, infrequent and no disturbance effect. The survey response indicate that the disturbances such as long interruption, voltage sag/swell, transient, harmonic distortion, flicker, undervoltage/overvoltage, voltage unbalance and earthing/electromagnetic compatibility (EMC) problems are the most frequent disturbances that cause equipment malfunction. The short interruption disturbance has been categorized as a frequent disturbance that cause equipment malfunction.

It can be noted that among the most frequent PQ disturbances, the highest percentage of most frequent PQ disturbance that cause equipment malfunction is due to voltage unbalance (52.9%), and then followed by earthing/electromagnetic compatibility (EMC) problems (50%), harmonic distortion (48.6%), flicker (40%), both undervoltage/overvoltage and long interruption (38.6%), voltage sag/swell (34.3%) and transient (31.4%).
Table 1: Survey response on the frequency of PQ disturbances that cause equipment malfunction

<table>
<thead>
<tr>
<th>PQ PROBLEMS THAT CAUSES THE EQUIPMENT MALFUNCTION</th>
<th>NEVER</th>
<th>INFREQUENTLY</th>
<th>SOMETIMES</th>
<th>FREQUENTLY</th>
<th>MOST FREQUENT</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>SHORT INTERRUPT &lt; 1 min</td>
<td>1</td>
<td>1.4</td>
<td>7</td>
<td>10.0</td>
<td>19</td>
<td>27.1</td>
</tr>
<tr>
<td>LONG INTERRUPT &gt; 1 min</td>
<td>1</td>
<td>1.4</td>
<td>3</td>
<td>4.3</td>
<td>17</td>
<td>24.3</td>
</tr>
<tr>
<td>VOLTAGE SAG/SWELL</td>
<td>0</td>
<td>0.0</td>
<td>6</td>
<td>8.6</td>
<td>17</td>
<td>24.3</td>
</tr>
<tr>
<td>TRANSIENT/SURGES</td>
<td>1</td>
<td>1.4</td>
<td>6</td>
<td>8.6</td>
<td>21</td>
<td>30.0</td>
</tr>
<tr>
<td>HARMONIC DISTORTION</td>
<td>2</td>
<td>2.9</td>
<td>4</td>
<td>5.7</td>
<td>12</td>
<td>17.1</td>
</tr>
<tr>
<td>FLICKER</td>
<td>2</td>
<td>2.9</td>
<td>5</td>
<td>7.1</td>
<td>18</td>
<td>25.7</td>
</tr>
<tr>
<td>UNBALANCE</td>
<td>1</td>
<td>1.4</td>
<td>4</td>
<td>5.7</td>
<td>14</td>
<td>20.0</td>
</tr>
<tr>
<td>EARTHING AND EMC</td>
<td>7</td>
<td>10.0</td>
<td>5</td>
<td>7.1</td>
<td>10</td>
<td>14.3</td>
</tr>
<tr>
<td>UV/OV</td>
<td>7</td>
<td>10.0</td>
<td>6</td>
<td>8.6</td>
<td>14</td>
<td>20.0</td>
</tr>
</tbody>
</table>

Consequences of PQ disturbances:

A questionnaire has been posed to identify the consequences or effects of PQ disturbances experienced by industries. Responses have been obtained in which this survey identified 13 typical consequences of PQ disturbances which are capacitor bank failure, circuit breaker and RCD’s nuisance tripping, computers lock up, damage of computers or other electronic devices, data loss, employees receive electric shocks, lights flicker, blink or dim, loss of synchronization of processing equipment, motors or process equipment are damaged, noise interference to telecommunication lines, relays and contactors nuisance tripping and transformers and cables overheating. Figure 3 shows the results of consequences of PQ disturbances in terms of percentage of consequences. The highest percentage of PQ disturbance effect is circuit breaker tripping (12.36%) and then followed by data loss (10.55%), both computer damage and dimming of lights (10.18%), noise interference to telecommunication lines (8.73%), transformers and cables overheating (8.36%), nuisance tripping of relays and contactors (8.00%), computers lock-up (5.45%), electric shocks (4.36%) and capacitor bank failure (4.18%).

Classification of affected equipment due to PQ disturbances:

A question has been posed to identify equipment that is affected by PQ disturbances in industries. Responses have been obtained and the results are summarized as depicted in Figure 4. The highest percentage of equipment affected by PQ disturbances are the electronic equipment such as computer and programmable logic controller (19.44%) and then followed by other affected equipment such as electric motors (16.67%), switching devices comprising of relays and contactors (14.35%), network communication equipment (12.50%), lightning equipment (9.26%), uninterruptible power supplies (UPS, 8.33%), capacitors (7.41%), cables (6.94%) and variable speed drives (5.09%).
Availability of existing industrial solution to mitigate the effects of PQ disturbances:

To reduce the effects of PQ disturbances and to prevent the potential production stoppage, usually industries will install and apply some form of mitigation devices in their installations. A questionnaire has been posed to identify the mitigation devices used by industrial customers to overcome the PQ problems. The survey results as shown in Figure 5 indicate that the most effective and commonly used solution in industries is by using back-up and standby generators which constitutes 15.49% of respondents. The second solution preferred by the respondents is by using voltage stabilizers (12.68%). In addition, the responses on other solutions to eliminate the effects of PQ disturbances are by using UPS (11.62%), shielding and grounding devices (11.625), surge protectors (8.10%), isolation transformer (7.39%), dynamic voltage restorers (6.34%), harmonic filters (5.63%), line conditioners or active filters (4.93%), over sizing equipment and cables (4.58%), static Var compensator (4.23%), multiple independent feeder (3.87%) and static transfer switches (3.52%).

Classification of sources of PQ disturbances:

The sources of PQ disturbances may originate from utility, customer installation sites, customers, neighboring sites and also due to natural causes like lightning. Figure 6 shows the response related to the sources of PQ disturbances in which 29.15% of respondents indicated that the main source of PQ disturbances is that originate from utility due to switching operations which include capacitor and load switching. The second highest source of PQ disturbances (27.94%) is from the natural phenomena such as lightning that cause voltage transients. Two other sources of PQ disturbances are due to faults at the customer own installations (21.86%) and from the neighboring customers who are connected to the same or adjacent feeder of the network (21.05%).
Power quality monitoring is an essential service many utilities perform for their industrial and other key commercial customers to provide information about the quality of the power. Industrial customers also sometimes need to perform PQ monitoring to diagnose PQ problems which may cause equipment malfunction and failure. A questionnaire is posed to identify the frequency of conducting PQ monitoring by industrial customers in Malaysia. Figure 7 shows the response results in which 50% industries perform PQ monitoring only when needed, 20% industries perform PQ monitoring continuously, 15.71% industries perform monitoring regularly and 5.71% industries perform yearly monitoring. However, 8.57% industries never conduct any PQ monitoring.

In order to have an idea on the choice of PQ mitigating devices, customers have been asked for indicating their preference on equipment such as UPS, dynamic voltage restorer, active power conditioner and renewable energy based on-site generation. The results obtained are reported in Figure 8 in which the highest choice of
mitigating devices for providing premium power is UPS (30.83%) and then followed by dynamic voltage restorer (DVR) (17.29%). Other choices are by installing on-site generation (13.53%) such as fuel cells, micro turbines or renewable energy based generators, active power conditioner devices (AVC) (12.78%), integrated power-storage systems (12.43%) using batteries, flywheels or superconductors, dual redundant distribution system (4.77%) and combined heat and power (CHP) (4.77%).

![Diagram of mitigation devices for premium power](image1)

**Fig. 8:** Percentage on the choice of mitigation devices for providing premium power

**Solution of premium power by customers:**

Respondents are also asked on their preference of solutions for premium power. Figure 9 shows the response results in which a large number of respondents (22.75%) suggested continuous monitoring of power quality performance as one of the best options for premium power. 19.58% of respondents prefer to have guaranteed performance level by the utility companies and 17.46% respondents prefer to receive maintenance requirement of the premium power schemes as an option that can be offered to industrial customers. In addition, 15.87% of the respondents require special installation requirements and 15.34% prefers to be given solution options by utility. A small percentage of respondents (8.99%) prefers a specialized costs or tariff for premium power service. By providing premium power solution to the customers, customer retention can be improved, premium power rate in a regulator friendly environment can be achieved and possible maintenance agreement for PQ devices can be placed in service.

![Diagram of premium power options](image2)

**Fig. 9:** Percentage of premium power options preferred by customers
Conclusion:

A questionnaire based survey has been conducted on industrial customers in Malaysia to assess the present PQ problems, identify availability of industrial solutions to mitigate PQ problems and to seek customer preference of premium power options. From the survey results, it can be concluded that i) short interruption is the most significant PQ disturbance, ii) the most frequent PQ event that cause equipment malfunction is voltage unbalance, iii) circuit breaker tripping is the most significant effect of PQ disturbance, iv) electronic equipment such as computer and programmable logic controller are the equipment most affected by PQ disturbances are the v) back-up and standby generators are the most commonly used PQ solution in industries, vi) utility switching operations is the main source of PQ disturbances, vii) industries perform PQ monitoring only when needed, viii) UPS is the most preferred mitigating device for providing premium power and ix) continuous PQ monitoring is considered as the best option for premium power. The results obtained from the survey would be useful for power utilities to plan for providing future premium power services for customers in Malaysia.

References


