POWER QUALITY MONITORING WITH SMART METERS

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ABSTRACT

The Tata Power Company, Mumbai has installed smart meters for high value consumers and distribution transformers. The data from these meters is captured into an Automatic Meter Reading system and further analyzed using Analytics solution. This paper explains the process of collecting and monitoring data from smart meters and its analysis to identify the power quality problems. It also describes the transformation in process of power quality data analysis from manual to system based data analysis and brings out the challenges, advantages and disadvantages of using smart meters for such a purpose. The paper highlights the need to upgrade smart meter specifications and changes needed in regulatory norms for more effective PQ monitoring and enhanced consumer satisfaction.

INTRODUCTION

Tata Power is India’s largest integrated power company with a significant international presence. The Company has an installed generation capacity of 8623 MW in India and a presence in all the segments of power sector, viz Fuel & Logistics, Generation (thermal, hydro, solar and wind), Transmission, Distribution and Trading. It has successful public-private partnerships in Generation, Transmission and Distribution in India namely “Tata Power Delhi Distribution Limited” with Delhi Vidyut Board for distribution in North Delhi, ‘Power links Transmission Ltd.’ with Power Grid Corporation of India Ltd. for evacuation of Power from Tata hydro plant in Bhutan to Delhi and ‘Maithon Power Ltd.’ with Damodar Valley Corporation for a 1050 MW Mega Power Project at Jharkhand. It is one of the largest renewable energy players in India and has developed the country’s first 4000 MW Ultra Mega Power Project at Mundra (Gujarat) based on super-critical technology.

Tata Power has a consumer base of 5.5 lakh in Mumbai City and an average of about 6,500 million units (MU’s) are sold in a year.

The consumers in Mumbai city have always enjoyed a reliable, 24X7 power supply for over a century. Availability of reliable power has greatly helped Mumbai to develop as a premier commercial center and it is today known as commercial capital of India.

Till recently, there was not much awareness regarding quality of power within the fraternity of power utilities, consumers, regulators, equipment manufacturers etc. The scenario has changed and many consumers are now aware that performance and life span of their electrical appliances / machines / gadgets etc. greatly depend on power quality. The Utilities now receive many consumer complaints related to power quality like low/high voltages, fluctuations, flickers, harmonics etc. which affects/influences performance of consumer appliances. Many State Regulators have now prescribed power quality norms in supply code which mandates utilities to maintain supply voltage within the specified range and the maximum permitted harmonic level at the point of supply.

Tata Power supplies electricity to many critical consumers in Mumbai like Oil refineries, airport, data centers, traction sub stations, research centers, call centers etc. Most of these consumers are very sensitive to power quality.

PQ MONITORING METHODOLOGY

A. PRIOR TO DEPLOYEMENT OF SMART METERS AND AMR FOR HIGH VALUE CONSUMER METERS:

Power quality monitors were installed on HV feeders emanating from Transmission receiving stations and distribution sub-stations. The transient disturbances, over/under voltages, voltage flickers and harmonic distortions were captured by the PQM meters. On receipt of a complaint from consumer regarding power quality, the PQM data of concerned feeder used to be collected and analyzed to respond to consumer complaint.

B. AFTER INSTALLATION OF AMI AND SMART METERS:

Power quality data recorded by PQM meters installed on feeders do not give true picture of power quality experienced by the consumers/end users. It is important to capture power quality data from consumer installations or points of actual consumption to get the holistic view of power quality experienced by consumers. However,
installing PQM meters at every delivery point is not only expensive but also impractical. As the smart meters are installed at many consumer supply points, it was decided to use smart meter data for monitoring Power quality actually experienced by the consumers.

Tata Power has installed smart meters at all Transmission and Distribution (T&D) interface points, Outgoing feeders from distribution substations, LT side of all distribution transformers and at points of supply of critical HT / LT consumers. All the smart meters are covered under AMR. Fig-1 depicts the smart metering infrastructure at Tata Power.

**Fig-1: Smart Metering Infrastructure**

The smart meters record instantaneous parameters like active/reactive power, energy, per phase voltage, current, PF, frequency etc on hourly basis. This power quality data is captured in the AMR server and stored in Meter Data management System which acts as a data repository. Please refer fig-2, which depicts the snapshot of AMR system showing instantaneous data of smart meters. The above data is accessed through client PC’s installed at various Tata Power installations and analyzed to detect if there are any power quality issues like voltage variations, frequency deviations exceeding regulatory norms at any consumer supply point.

**PROCESS FOR ANALYSING POWER QUALITY DATA.**

Initially, the instantaneous data captured in AMR server was processed manually to detect the PQ abnormalities. This task was very tedious and highly time consuming as the data size is very large. It was decided to develop a tool to automate the process of data analysis so that the task can be completed in reasonable time. Thus, a tool was developed in house in MS-Excel for analyzing power quality data. Hourly instantaneous data from AMR server was exported to MS-Excel once every week. Various logics were applied to the available data to check if the power quality meets regulatory norms and consumer expectations. This tool is capable of processing large volume of smart meter data captured in AMR data base in few minutes and provide a list of consumer sites showing PQ abnormalities. With this tool, daily monitoring was made possible and initiated.

The type of power quality abnormalities detected through the in-house tool are missing/high/low/unbalance voltage, current unbalance, low PF, frequency deviations, power outage etc. Further, the list of consumer sites obtained as above is sent to Operations department for further investigation and corrective actions. This tool gave fast and accurate results. Many consumer supply points having voltage related abnormalities could be identified and quick corrective actions taken to resolve the same. Fig-3 shows sample snapshot of output obtained from analysis tool in excel.

**Fig-2: Snapshot of AMR system showing instantaneous data of Smart Meters:**

<table>
<thead>
<tr>
<th>Meter Make</th>
<th>Meter Type</th>
<th>Meter Date</th>
<th>Meter Time</th>
<th>V-RPh</th>
<th>V-YPh</th>
<th>V-BPh</th>
<th>I-RPh</th>
<th>I-YPh</th>
<th>I-BPh</th>
<th>RPh PF</th>
<th>YPh PF</th>
<th>BPh PF</th>
<th>Avg PF</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>SC002598</td>
<td>DT</td>
<td>29-12-2014</td>
<td>12:51:19</td>
<td>0238.950</td>
<td>0237.706</td>
<td>0238.750</td>
<td>000.180</td>
<td>000.168</td>
<td>000.170</td>
<td>0.63</td>
<td>0.64</td>
<td>0.70</td>
<td>0.66</td>
<td>50.082</td>
</tr>
<tr>
<td>SH000008</td>
<td>HT</td>
<td>29-12-2014</td>
<td>12:44:09</td>
<td>065.752</td>
<td>65.584</td>
<td>65.042</td>
<td>000.240</td>
<td>000.227</td>
<td>000.250</td>
<td>0.982</td>
<td>0.987</td>
<td>0.977</td>
<td>0.983</td>
<td>49.907</td>
</tr>
<tr>
<td>05005631</td>
<td>LTCT</td>
<td>29-12-2014</td>
<td>12:49:16</td>
<td>0239.852</td>
<td>0238.645</td>
<td>0240.633</td>
<td>000.030</td>
<td>000.020</td>
<td>000.010</td>
<td>00.895</td>
<td>00.901</td>
<td>00.974</td>
<td>0.947</td>
<td>49.895</td>
</tr>
</tbody>
</table>

**To Date:** 29-12-2014

[Export To Excel]
Fig-3: Sample Output Sheet of Analysis Tool in Excel Showing Sites Having PQ Issues

<table>
<thead>
<tr>
<th>Meter No.</th>
<th>Ref. Voltage</th>
<th>Volt Hi</th>
<th>Volt Low</th>
<th>Volt &quot;0&quot;</th>
<th>Volt unbalance</th>
<th>Meter Date</th>
<th>Meter Time</th>
<th>Voltage R Phase</th>
<th>Voltage Y Phase</th>
<th>Voltage B Phase</th>
</tr>
</thead>
<tbody>
<tr>
<td>SH000323</td>
<td>63.5</td>
<td>PASS</td>
<td>FAIL</td>
<td>PASS</td>
<td>PASS</td>
<td>28/10/2014</td>
<td>1:18:45</td>
<td>58.32</td>
<td>58.216</td>
<td>57.996</td>
</tr>
<tr>
<td>SH000324</td>
<td>63.5</td>
<td>FAIL</td>
<td>PASS</td>
<td>PASS</td>
<td>PASS</td>
<td>28/10/2014</td>
<td>1:20:31</td>
<td>71.231</td>
<td>71.79</td>
<td>71.938</td>
</tr>
<tr>
<td>LCD000127</td>
<td>240</td>
<td>PASS</td>
<td>FAIL</td>
<td>PASS</td>
<td>FAIL</td>
<td>28/10/2014</td>
<td>0:51:31</td>
<td>240.256</td>
<td>0.029</td>
<td>240.463</td>
</tr>
<tr>
<td>5053477</td>
<td>240</td>
<td>PASS</td>
<td>PASS</td>
<td>FAIL</td>
<td>PASS</td>
<td>28/10/2014</td>
<td>0:52:17</td>
<td>245.32</td>
<td>245.14</td>
<td>0.00</td>
</tr>
</tbody>
</table>

A USED CASE

During daily monitoring of smart meter data captured in AMR system, data of one of the 11 KV HT consumers showed voltage abnormality. Although voltage variation was within regulatory limits, it was observed that phase to neutral voltage was varying from a low of 6.19 KV to a high of 6.51 KV during the day. Discussions with the concerned consumer revealed that the consumer had experienced premature failure of few A.C. motors in the recent past.

In view of these initial observations captured from analysis of smart meter data, we decided to install a PQM analyzer at the consumer premises for further study. The power quality data captured by PQM analyzer is depicted in Fig-4 and Fig-5.

Fig-4: Voltage profile

As depicted in Fig-4, voltage was found to be lowest between 6 AM to 9 AM and was reaching its maximum at 8 PM in the evening.

Fig-5: Harmonic content profile

Fig-5 clearly showed that the 11th and 13th Harmonic were the most prominent in the system ranging from 1.5 – 6 % of the fundamental component (Regulatory limit is 2%).

It could be concluded that the premature failure of AC motors could be due to presence of 11th harmonic at consumer premise.
As illustrated in the used case, the initial list of consumer sites generated through analysis of smart meter data helped us to proactively identify consumers experiencing power quality issues. After the successful use of in-house Excel tool, ‘Meter Data Analytics System’ was installed for carrying out methodical, accurate, system based analysis of power quality data captured from Smart Meters.

The smart meter data is now analyzed using Analytics solution periodically. Voltage, current and frequency trends are plotted at various levels like T<->D interface points, distribution substations and consumer premises. Please refer fig-6 showing voltage trend at a consumer supply point.

**Fig-6: Voltage trend over a period**

This has helped us to co-relate PQ issues experienced by the consumer at his premise up to the feeder emanating point in Distribution sub-station. This analytics system is capable of identifying sites that do not meet the regulatory requirements. The System output format is very simple and actionable as it provides the list of affected consumer sites on a single page with type of abnormalities. Please refer fig-7 which shows the report from Analytics system.

**Fig-7: Report showing sites with PQ abnormalities**

PQ Sites not meeting the regulatory standards are listed in the order of severity/sensitivity. Also, the sites which have common connectivity to same feeder/circuit are grouped together. This helps in faster implementation of the identified solution.

**CHALLENGES AND FUTURE COURSE**

Present smart meters capture parameters like voltage, current, PF on hourly basis. It also records power outage events. Thus, PQ monitoring using smart meters today is limited mainly to tracking voltage characteristics only. A power quality monitor is required to be installed at suspected sites for further analysis as discussed in the used case. If the smart meter capable of recording full PQ parameters is available, PQ analyzer would not be needed at all.

To extend the smart meter capability to fully capture power quality data on a real time basis, it needs to record voltage spikes/swells, intermittent dips/sags, harmonic distortions, transients, voltage flickers, positive and negative sequence voltages etc. In addition, the sampling rate of recording the mentioned PQ parameters needs to be improved. A push from regulatory bodies and active interest from manufacturers would be required to develop such a smart meter.

As the cost of such a smart meter is expected to be much higher than present smart meters, regulatory push is needed to make installation of such smart meters mandatory at least at the sensitive locations. Power quality data can be transmitted on weekly basis to the central database in order to avoid transmission and storage of large data from the smart meter.

Smart meter with enhanced power quality recording features along with analytics system at the back end will help utilities to monitor power quality at consumer premises on nearly real time basis. It would help utility and concerned consumers to take corrective measures. This smart application would justify the large investments utilities have already made in developing advanced metering infrastructure.