A ‘MAINTENANCE FREE’ MONITORING SOLUTION FOR MEDIUM VOLTAGE OVERHEAD NETWORKS, TO ADDRESS NEW DEMANDS FROM THE REGULATOR ON POWER QUALITY PERFORMANCE

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INTRODUCTION

The deregulation of the Electricity Market has placed an enhanced emphasis on customer service and quality. The Swedish network regulator, Swedish Energy Agency, will introduce a new regulation based on a network performance assessment model, that values quality of supply. It is difficult however, for Electricity distributors to provide the quality and continuity of supply that is demanded, particularly in networks where the medium voltage system uses overhead designs. The installation of sensors throughout a medium voltage network, that will monitor the current and voltage levels and locate faults, can provide a number of advantages in the performance of the network. This paper reviews the value of a new monitoring sensor solution, with reference to the Swedish Regulator’s Performance Assessment Model, and the valuation of power cuts from Swedish association of distributors, Svensk Energi.

THE PERFORMANCE ASSESSMENT MODEL

The Swedish Regulator will, from the 1st of January 2004, introduce a new regulation based on a performance assessment model [1]. Since 1998, the regulator has been working on the creation of a model to assess tariffs charged by the electricity distribution companies to customers in their concession areas. In November 1999 the deregulated market was opened to include domestic customers. Following on from that, customers and media have paid much more attention to both network tariffs, and quality of supply. This also focused more attention on the regulation of tariffs for domestic customers (mass market). The Swedish Electricity Act requires network tariffs to be ‘reasonable’. The operational conditions however differ greatly from one distribution company to another, and what is considered a ‘reasonable’ tariff can also vary accordingly. The model is designed to be a method of assessing the tariffs that allows for the differing conditions, as well as for the quality of performance provided by each company. The Regulator intends to use the model for objective measurements of the electricity distribution companies’ performances as seen by their customers.

The concept of performance will be defined by constructing a fictitious network for each utility, and will use it to calculate the resources needed in order to distribute the electricity. The necessary resources will be simulated in the model from a number of items of input data. The resulting performance - i.e. the value of the distribution network - will then be related to revenue, in order to assess the reasonableness of the network tariffs.

The Network Performance Assessment Model (NPAM) also values the quality of supply as described in figure 1. The quality of supply is related to the fictitious network as a factor, and the value is dependant on the fault statistics from the network company. The performance of quality of supply valued in this way is then added to the value of the network performance. This together gives the resulting total performance for the distributor. It is possible to increase the resulting performance value by improvement of quality of supply. A new network monitoring solution described in this paper is a method to improve the quality of supply in medium voltage networks with overhead design.

A NEW NETWORK MONITORING SOLUTION

A new design has been produced for a line mounted network current monitoring device that utilises the magnetic field provided by the current flowing in the overhead conductor (The Crystal System™). This use of the magnetic field as a primary power source, means that batteries are not required to power the sensor, and therefore minimal maintenance is required. The sensor is mounted directly onto the line and communicates via a built-in radio transceiver. In the first instance a set of three sensors communicate with each other to firstly calculate the current characteristics, primarily the amplitude and phase. The timing of the measurement is achieved by synchronous communications and this gives the system a high level of accuracy. Importantly this allows the sensors to distinguish between reactive faults, and provides a
highly reliable fault detector, that once bolted into place requires little or no maintenance. The built in transceivers relay the information from one to another and back to the substation, where a small data acquisition and communications device is fitted, (DAC unit). This DAC unit then has a number of onward communication options, LAN, TCP/IP, RS232, RS485, SCADA, or Satellite. The fault information can then be used for notification, monitoring, or automated network control via the use of automated sectionalisers.

Other properties may be measured using the sensors, ie line temperature, ambient temperature and voltage fluctuations as defined by the purchasing Utility.

FUTURE BENEFITS

There are further benefits to discuss and explore. Some of these benefits are:
- Using the resources more effectively at interruptions.
- Using the monitoring system to break the “right” line in the network by remote control and reduce the outage time for affected customers.

A COST BENEFIT CALCULATION

A cost benefit calculation is based on all the costs and benefits generated by an investment through a calculation period or a lifetime. The calculation method used here is Net Present Value (NPV) complemented with Life Cycle Costing (LCC). This means that not only costs are calculated but even incomes generated by investing in the network monitoring system.

The monitoring system has some investment and maintenance costs over its lifetime. Investment costs are paid the first year. Maintenance costs are a prediction of needs for the corrective maintenance for the system.

The financial impact of improving the Network performance

By installing the network monitoring system the customer satisfaction will increase because of following factors:

1. By reducing frequency for temporary failures lasting less than 3 minutes
2. By reducing the outage time for affected customers (SAIDI, CAIDI)

The first factor in the chapter above is not included in our calculation but the second factor is.

Used methods are:
- Network regulation method from Swedish Energy Agency (Described above).

By reducing the outage time for customers, the customer satisfaction will increase due to this.

TABLE 1. Provisional specification*

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current Range</td>
<td>5 to 300 amps</td>
</tr>
<tr>
<td>Accuracy</td>
<td>+/- 1%</td>
</tr>
<tr>
<td>Temperature range</td>
<td>-50°C to +80°C</td>
</tr>
<tr>
<td>Fault current sensitivity</td>
<td>Down to 1 Amp</td>
</tr>
<tr>
<td>MTBF</td>
<td>15 years</td>
</tr>
<tr>
<td>Weight</td>
<td>2 kgs</td>
</tr>
<tr>
<td>IP Rating</td>
<td>IP 65</td>
</tr>
<tr>
<td>Radio Range</td>
<td>1.5 Km (LOS)</td>
</tr>
</tbody>
</table>

* as lab tested by FMC Tech Ltd
satisfaction, which is a great factor in the network regulation model, will increase. By simulating the model we can find out the possibility for increasing the income for a district (or get acceptance for present revenue).

- Valuation of power cuts from Svensk Energi (Swedish Association of distributors).

Svensk Energi has a method for calculating the customer satisfaction. The method is based on the category of the customer: Services, Household, Agriculture or large industry. Every category has a cost for outage of power depending on frequency and duration of power outage. The formula for calculating the outage cost will be:

\[
K_j = f \times (K_1 + K_2 \times t_a \times P_m)
\]

Where
- \(K_j\) is the outage cost in SEK
- \(f\) is the outage frequency in times/year
- \(K_1\) is the fixed part of the outage cost in SEK/kW
- \(K_2\) is the flexible part of the outage cost in SEK/kWh
- \(t_a\) is the estimated duration of power outage in hour
- \(P_m\) is the Energy used in kW

Cost benefit in network operation with the monitoring system

The network monitoring system will reduce some actual cost elements in the network. Some of these cost elements follow here:

1. Costs for corrective maintenance of the network by:
   - Reducing the frequency for temporary failures lasting less than 3 minutes.
   - Reducing the time to find the fault on the network.
2. Reduced warranty payments for power cuts more than 24 hours.
3. Reduced lost of income, network distribution fee.

The case study

A district called Nord-Upland with 22,000 customers and 1333 km line has been the subject for our study. The calculations have been carried out with data of consumed energy and consuming categories for 2001 from all customers in that district. One part of the district, customers connected to a 10 kV network feed from one of the primary substations, Tierps-Väsby, has especially been studied in order to verify the necessary number of sensors in a practical case. Figure 3 shows the planned position of sensors in that network.

The assumption made here for the NPV calculation is:

- A Calculation period/lifetime by 15 years
- Weighted Average Cost of Capital (WACC) is 7.5% Nominal after taxes
- The inflation will be constant at 2.5%
- The tax in Sweden is 28%
- A Euro is equal to 9 SEK (Swedish Crowns)

The assumption made for costs of the network monitoring system are:

- The investment costs for the monitoring system are estimated to 200 Euro per km line.
- The MTBF (Mean time between failure) for the sensors in the monitoring system is predicted to 15 years
- MTTR (Mean time to repair) for the sensors in the monitoring system is predicted to 8 man-hours including the time to travel.
- SAIFI (System Average Interruption Frequency Index) for this area has been 2.5 faults/customer

The assumption made for benefits of the network monitoring system are:
- The Mean time to find a fault in the network will be reduced by 1½ ± ½ hour/fault.
- A simulation of network regulating model shows that the customer satisfaction generated by decreased power cuts is worth 90000 Euro/year (+47%; -39%).
The assumption above gives a Net Present Value of 600000 Euro (+52%; -64%) after 15 years of usage of the network monitoring system.

The above graph shows the net present value by the Network Performance Assessment Model (NPAM) when the reduction time is estimated to 1, 1.5 and 2 hours. This result gives a pay back time on investment between 3 and 6 years depending on the reduction time.

Valuation of power cut from svensk Energi gives an increased customer satisfaction by 800000 Euro/year (±30%) which gives a net present value of 5 million Euro (±35%) after 15 years of usage of the network monitoring system.

A simulation of NPV regarding customer satisfaction valued by Svensk Energi using Montecarlo method gives us the result shown in the figure 5.

The numbers in parentheses show the relative power usage of each category in the studied area.

CONCLUSIONS AND COMMENTS

By using the monitoring system the power outage for customers will decrease because the time to locate a fault will be shorter. The cost benefits calculated with the Swedish Network Regulator Model gives a pay back time between 3 and 6 years, on our investment for the studied network in region Nord-Uppland. With the valuation of customer satisfaction by the method of Svensk Energi, we would have a pay back on investment only after one year.

It is of importance to note that all calculations are based on the premise that the installed system functions to specification.

REFERENCES