REGULATION OF QUALITY OF SUPPLY - AN INNOVATION DRIVING FORCE? NOVEL EQUIPMENT FOR REDUCING CUSTOMERS’ INTERRUPTION COSTS BY BYPASSING SWITCHES DURING MAINTENANCE

Knut SAMDAL
SINTEF Energy Research – Norway
knut.samdal@sintef.no

Geir SOLUM
Trondheim Energi – Norway
geir.solum@trondheimenergi.no

Leif Wilhelm RAMSLIE
ABB - Norway
leif-wilhelm.ramslie@no.abb.com

ABSTRACT
Penalty schemes for customers’ interruption costs have been introduced in many countries to counteract the Distribution Network Owners (DNO) cost-cutting focus due to stricter revenue regulations. The Norwegian penalty scheme (CENS) includes all sorts of interruptions, also planned interruptions due to maintenance activities, and hence the DNOs have incentives in finding ways to prevent customers having their supply interrupted while maintenance is being carried out in the network. The paper describes an example of such an innovation, namely a novel patented method and equipment for bypassing switches while performing maintenance.

INTRODUCTION
The Norwegian quality of supply regulation also includes a penalty scheme incorporating interruptions due to maintenance. This is not the case in many other countries. The reason for many countries not to include such interruptions is believed to be due to a fear of the utilities reducing the maintenance efforts below an optimal level. However, by doing so, the motivation for innovation in this particular field might suffer. When customers’ interruption costs are not taken into account, the preferred solutions from a company economic point-of-view will be different than those where such costs are included. In here lies the essence of many of the penalty schemes being introduced around the world, but for some reasons they tend to exclude the planned interruptions due to maintenance work.

The paper gives a brief overview of regulation of quality of supply in Europe – with special emphasis on planned interruptions due to maintenance work. A more thorough description will be given of the Norwegian CENS arrangement [4] and the experience since it was put into force in 2001. Furthermore, the paper give a detailed description of a concept for non-interruptive maintenance of air insulated load switches (AIS).

QUALITY OF SUPPLY REGULATION
Regulation of quality of supply consists of a triad of regulations related to commercial quality, continuity of supply and voltage quality [2]. The first element typically relates to general supply contract conditions (billing, metering, contracts regarding network access etc) and also in some countries standards are established which require operators to meet certain minimum levels of quality of service. The Council of European Energy Regulators (CEER) has brought forward extensive benchmarking reports [1-3], showing how these regulations are developing in Europe. At present, the latest in the series is the 3rd benchmarking report (2005), and the 4th is expected to be published early 2009.

Although interruptions due to maintenance activity to a certain extent is included in guaranteed or overall standards (e.g. by setting maximum limits for restoration time or maximum number of planned interruptions per year), this is not necessarily coupled to customers interruption costs but rather penalised in terms of standardised payments for deviations from some commercial standard limits. In this regard the Norwegian incentive regulation of quality of supply [4] differs from most regulations in incorporating the planned interruptions in the performance-based regulation of continuity of supply based on surveyed customers’ interruption costs [5]. One of the worries related to considering the inclusion of planned interruptions in an incentive regulation scheme is stated in CEERs 3rd benchmarking report: “In any case is important to be aware of the fact that a scheme that allows companies to gain higher revenues by reducing planned interruptions, on the one hand, can induce companies to adopt a more efficient maintenance program or, on the other hand, may create a long term risk due to insufficient maintenance of the network.” [3: p 41]

The Norwegian CENS-arrangement was put into force in 2001, and the development in planned interruptions is given in figures 1-2 below. All numbers are referred to delivery point, i.e. secondary side of distribution transformer or MV/HV point with delivery directly to customer. Please note that the public statistics published by the Norwegian regulator, The Norwegian Water Resources and Energy Directorate (NVE) uses the terms notified and non-notified interruptions. The extracts shown here are notified interruptions, thus giving indications to the extent of planned interruptions due to maintenance and other planned activity. Interruption costs due to notified interruptions in Norway accounts for approx. 20-25% of the total.
It is evident from the trend curves that a dramatic reduction in planned (notified) interruptions has been achieved. But how has this been accomplished? Is it because maintenance has been neglected, or has the penalty scheme boosted innovations? To answer the questions above is not straightforward, but investigations clearly indicate [6] that the customer now is put into focus in a completely new manner, also regarding how to perform maintenance activity with a minimum of consequences for the customers. When power cuts are needed, the utilities have incentives in making the interruption duration as short as possible. This has led to focusing on live work to a much larger extent than earlier, as well as the use of mobile generators etc. Altogether, this new focus has led to new thinking, and a novel method for performing live maintenance on switchgear which is presented in the following.

BYPASSING SWITCHES

The solution brought forward is consisting of insulating plates with integrated bypass shunt cables to be mounted on air insulated load switches (AIS) during maintenance, hence making it possible to do function testing and several necessary maintenance tasks without interrupting the supply.

The method and device is protected by Norwegian Patent 324671 and corresponding patent applications are pending in EP, US and many other countries.

The equipment

The equipment consists of 4 plates made of insulation material. 3 of them, one for each phase, are equipped with a “shunt” cable with clamps in each end, to connect to the bus bar above the breaker, and to the incoming/leaving cable connection at the bottom of the breaker. The fourth plate is placed between the steel cubicle wall and the phase (figures 4 and 5).

Installation procedure

The “shunt plates” are lifted in to the cubicle with an insulated “claw stick”, and attached to the cubicles construction, by its shape and own weight. (figures 5 and 6). The screw terminals at the end of the shunt are connected to the bottom of the breaker. (figure 7)
any maintenance action, for instance measuring of the converted current in the “Shunt”, that should be approx. 1/3 of the main current after a secure connection of the “shunts”.

Figure 6: Frontal view: All 4 plates mounted. Patent pending.

When a secure connection on all three phases have been made, it is possible to operate the breaker, and maintain it in a proper way. The maintenance, such as wet and dry cleaning, lubrication and open/close movement of the breaker can now be done, without any disturbance of the power supply to the public.

Figure 7: Side view: All 4 plates mounted. Patent pending.

NON-INTERRUPTIVE MAINTENANCE FOR AIR INSULATED SWITCHGEAR

Maintenance need
Trondheim Energi has got 900 MV/LV substations with nearly 4,000 air insulated load switches (AIS). These come to 70% of the total amount of switchgear. Maintenance of an AIS-installation is performed as part of a work-package called “MV/LV Substation overhaul”, which in addition to in/out-movement, lubrication and cleaning of all switch units, also includes maintenance of other parts of the substation.

The maintenance activities follow a risk based strategy, so that maintenance frequency is increasing with increasing age, increasing with environmental exposure and is more frequent for switches mounted in open cubicles than those in encapsulated cubicles. The maintenance frequency hence differs from 1 to 12 years due to these factors, with an average of 5 years. The total maintenance volume for AIS-installations will remain stable in the years to come, because decrease due to renewals will be balanced by increasing frequency due to increasing age. In the following we will enlighten a new method for such maintenance, and make a comparison to other alternatives.

A shift in maintenance methods
M1-“District Outage”: Before 2001, substation maintenance was performed by “district outages”. Whole HV/MV substations with their 50 – 150 supplied MV/LV substations were disconnected for a whole night, and large crews overhauled all MV/LV substations in the area during the night.

M2-“Interruptive MV/LV substation maintenance”:
When the CENS-scheme was introduced in Norway in 2001 [4], it became clear that the interruption costs incurred from using method M1 were too large. The maintenance activities were therefore redirected so that each MV/LV substation was handled individually. Some substations were maintained during planned outages at daytime, some during outages at night time and some by use of mobile generators, making the interruptions as short as possible.

M3-“Non-interruptive MV/LV substation maintenance”
The main driving forces for the development of the new method for non-interruptive maintenance was two-fold:
1. Increasing need for maintenance activity due to component ageing in the network.
2. Increasing focus on quality of supply from customers and the society as a whole, put into force through the CENS-arrangement.

During the years 2007 and 2008 Trondheim Energi performed maintenance on more that 1,000 switch units using the new method described in this paper.

Effects on interruption costs
The most important output effect from using the new method compared to the other two, is that maintenance can be performed without interruption of supply and thus no interruption costs.
“District outages” (M1), where all MV/LV substations in an
area were disconnected for a whole night (even though the maintenance job itself would last only 1.5 hours) used to result in interruption costs of more than 30,000 NOK (9 NOK \approx 1\text{ euro}) per MV/LV substation job. Compared to the other methods this is obviously the most costly one because of the large customer interruption costs'.

Interruptive individual maintenance (M2) normally causes a planned interruption of supply for about 1.5 hours per MV/LV substation job. Average interruption costs for such an interruption is 13,000 NOK if the interruption occurs at daytime and 6,000 NOK at night-time for a typical MV/LV substation in Trondheim.

When there is no interruption of supply, there is also no need for notifying customers. Notifying activities include analysis of which customers are affected, writing letters to these customers and/or announcements in the local newspaper. The cost for notifying customers connected to a specific MV/LV substation is on average 3,000 NOK.

**Effects on labour cost**

Non-interruptive maintenance using the new method (M3), also causes a reduction in labour cost by on average 4,000 NOK per MV/LV substation job. This largely due to two factors;

1: Reduced sectioning and earthing work, and
2: No night time work.

The maintenance work itself takes only marginally longer time per switch unit using the new method than before. Another advantage with the new method that is not quantified is that maintenance work can be performed in the winter instead of summer. In Norway there is more working capacity in wintertime than in summertime, and performing maintenance in heavy load periods also gives a better opportunity for condition monitoring (a.o. thermography).

**Utility value**

Table 1 sums up the utility value per job for non-interruptive maintenance (M3) compared to interruptive maintenance (M2).

<table>
<thead>
<tr>
<th></th>
<th>Labour costs</th>
<th>Notific. costs</th>
<th>Interr. costs</th>
<th>SUM</th>
</tr>
</thead>
<tbody>
<tr>
<td>M2 daytime</td>
<td>5</td>
<td>3</td>
<td>13</td>
<td>21</td>
</tr>
<tr>
<td>M2 night-time</td>
<td>11</td>
<td>3</td>
<td>6</td>
<td>20</td>
</tr>
<tr>
<td>M2 average*</td>
<td>8</td>
<td>3</td>
<td>9.5</td>
<td>20.5</td>
</tr>
<tr>
<td>M3</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>Gross cost savings (M2 average vs M3)</td>
<td>4</td>
<td>3</td>
<td>9.5</td>
<td>16.5</td>
</tr>
</tbody>
</table>

*M2 average is calculated assuming 50% of the maintenance executed in daytime and 50% during night-time.

Based on the above, an approximate total benefit for Trondheim Energi will be in the magnitude of 3 MNOK per year (assuming an average of approx 180 MV/LV substations undertaken per year). Please note that the figure represents the gross cost savings, costs of applying the new method not considered.

**CONCLUSIONS**

The innovation described in the paper is to a large extent triggered by the utility facing economic consequences (the customers’ interruption costs) of planned interruptions. This is the case due to the specific public regulation of quality of supply in Norway. It is therefore relevant to ask if regulations where planned interruptions are not regulated are hampering such innovations, thus holding the technological developments in this field at status quo? However, as the example figures from Trondheim Energi illustrates, the method developed has significant advantages even without taken into account the saved customers’ interruption costs. Hence it is appropriate to conclude that although the concept was conceived under the economic pressure from the specific quality of supply regulation in Norway, it is believed to be of interest for any utility, irrespective of the governing regulatory principles it is subjected to.

**REFERENCES**


