RESTRUCTURING OF THE SWEDISH NATIONAL GRID CONTROL CENTRES

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1. ABSTRACT
The Swedish Transmission System Operator, Svenska Kraftnät, has since its creation in 1992 completely renovated its control structure for the national 400 and 220 kV grid. In the previous structure the grid control was based on contracted services from 15 control centres operated by other companies. Today the restructuring process is completed and the entire Swedish national grid and substations are supervised and controlled from two own control centres fully integrated with other system operation objectives.

Strong motives for the changes have been to achieve an integrated management of the operational activities including the staff competence. Fewer but more efficient control centres will have better possibilities to prioritise workforces to urgent matters. The knowledge level of the operators is also now on a higher level since it is easier to provide more qualified and realistic training and education in a familiar operational environment supported by an in-house developed real-time simulator.

By this restructuring process in several steps, Svenska Kraftnät has obtained a more efficient grid operation with several advantages to a much lower cost. A cost reduction of 60% has been reached.

2. INTRODUCTION
The introduction of control centres started early in Sweden. In the 60’s the first remote control centres were established and furnished with systems for data collection, supervision and control of power stations throughout the country. In the beginning it was relatively simple functions that were used, but the systems improved gradually. At the end of the 70’s almost no substations or hydropower stations where manned. During the 80’s several control centres where divided into smaller units with the concern not to overload the operators during critical situations. Thus the number of control centres increased.
In the beginning of the 90’s the Swedish national grid was controlled from 15 control centres. Since Svenska Kraftnät initially did not have any own control center resources, these services were contracted from companies operating power stations or regional grids to continue their supervision and control of the national grid assets.

The first step of the restructuring process was taken in 1994. One grid control centre together with the operators was transferred to Svenska Kraftnät and moved to the central office in Stockholm. At the same time a project started to establish a new national control centre in Stockholm entirely within the responsibility of Svenska Kraftnät. The objective was to accommodate the new functionalities that followed from the appointment as Transmission System Operator (TSO) and the opening of the Swedish and Nordic power market. This was accomplished in the beginning of 1996.

Among other functions the national control centre includes a grid control centre with responsibility to supervise and control national grid stations initially in the central east part of Sweden. Since then this grid control centre has increased its number of stations and geographical area. Today it has taken over all the stations and grid at the national grid level in the whole central and southern Sweden from the formerly contracted control centres. It also operates the interconnections to Denmark, Poland, southern Norway and southern Finland.

The process for the northern part of Sweden started in November 2000 by establishment of a new grid control centre in the northern city of Sollefteå and a gradual overtaking of stations. Since December 2002, that control centre operates all the stations and grid at the national grid level in the northern part of Sweden, including the interconnections to northern Norway and northern Finland (see figure 1).

A corresponding concentration has also been implemented in the remote control structure for the numerous hydro power stations in northern Sweden.

![Figure 1: Comparison of control centres 1990's and 2002, and number of stations to control](image)
3. MOTIVES FOR THE RESTRUCTURING PROCESS

Ever since the beginning, Svenska Kraftnät has had a goal to get all the operational supervision and control for the national grid concentrated into own control centres. The motive has been to get a better and direct overview and control of the power system. Also the communications between the operators are shorter and easier with today’s structure.

The control centre restructuring process has been facilitated by the simultaneous development of a new telecommunication structure. A meshed network of optical fibers has been established, mainly carried by the power lines, substituting older telecom devices and offering far more powerful communication between control centers and grid stations.

Another important motive has been the economical benefits. The costs have been reduced by 60%, around 3.5 Million Euros per year (2001). Most of the cost reductions are related to benefits for operating own control centres instead of the earlier contracted ones such as fewer support systems to maintain, fewer locations to rent and less operators and other staff.

4. OPERATIONAL STRUCTURE OF THE SYSTEM CONTROL

In the national control centre there are four different functions. Firstly the grid security supervisor has the overall responsibility to set system limits, hold enough reserves and coordinate activities for the grid control. It also includes coordination with the System Operators (TSO:s) in the neighbour countries. Secondly there is a balance service operator, responsible for the load-frequency control in collaboration with corresponding functions within the other Nordic TSO:s. The third function is responsible for supervising the support systems including telecommunication and remote control systems to the stations. The fourth function is the grid control, operating all substations, power lines, transformers, shunt reactors etc. That function is divided in 5 different positions located in two physically separated control centres (see figure 2).

![Figure 2: Organization of system control for the Swedish National Grid](image)

The structure of the two grid control centres is made to facilitate the supervision and control of the entire national grid virtually as one control centre with five different operator positions.
although the positions are in two different geographical places. The function is manned 24 hours a day. At nighttime only one operator is awake and in charge of all 5 positions. The operators are rotating on the different positions, working in traditional 2-shifts, 2-shifts with call on-duty or only daytime hours. The different shifts are depending on which position they are working at. In that way there is always five people ready to get to work in short notice in case of for example a large disturbance.

All control centre positions are manned with a continuing 9 weeks schedule. The schedule also include that they are rotating on all the positions in order to be a full back up for each other and to keep a high competence among all the operators. Daytime there is 3-4 additional people to handle other operational activities.

5. NEW SUPPORT SYSTEM

In parallel with the control centre restructuring, a new support system was taken into operation between 1999 and 2001. The new system replaces several old systems and gives better flexibility for the users and has many more functions. The main reasons for changing the old support systems was:
- The control centre restructuring
- Reduce the number of support systems
- Old system expensive to maintain and develop
- Change to new technology and platform
- Implement new SCADA and EMS functionality

The support system named HANSA consists of 5 different systems, main and reserve systems plus systems for development and training. All of them are available from the national control centres and the office environment. They also have connections and data exchange with other IT systems and naturally communication to all our stations. Beside normal SCADA functionality there are EMS functions such as state estimation, forecast functions for transmission, load and losses and contingency analysis. There is also an in-house developed security assessment tool integrated. With exceptional numerical stability this tool continuously calculates the transfer capacity in different bottlenecks with respect to voltage collapse. The support system also includes a function for outage planning and some support for the balance service function.

The biggest advantages with the new support system are:
- Supports the reduced number of control centres
- Easier and more realistic operator training
- Better performance and more information
- Better tools for analysis of the power system
- Classified access to the support system from outside of the control centres
- Lower costs
- Improved information to Market players and Power Exchange (NordPool)

The development of the open market environment has created a demand for an extensive exchange of data between the operators and external actors. To a certain extent these needs have been integrated in the SCADA system. Still there are numerous other support systems needed to manage all data transaction and back-up requirements. Svenska Kraftnät has around 20 surrounding systems to support the control centres beside the main system.
6. OPERATIONAL BENEFITS AND RISKS

One of the benefits with a concentrated control centre function is a better overview of the national grid system. This structure makes it possible to get a faster and more precise voltage control, reactive power optimisation, switching rearrangements and restoration. This new concept together with the new support system (see chapter 5), gives a better environment for the operators. For example they can use available manpower resources appropriately and help each other during different working peaks on each position. Work is also in progress to make a better alarm presentation and a much better and IT supported phone system.

The support system also allows implementation of fast simultaneous or sequential control of large number of objects. For example the activation or deactivation of several restoration automatics in the substations throughout the grid can be made in one manoeuvre. In a disturbance situation that feature can be very helpful. Wall displays and overview information also gives the operators a fast understanding of the status of the whole system. This combined with the operational responsibility structure makes it easier to issue orders and take actions among the different functions in the control centre. Also, due to more complex and advanced work and better technical support, the operators get more motivated, especially taking into account the advanced training and educational activities.

One risk with a centralized structure is vulnerability in case of for example a sabotage or fire in the control centre, on the support system or to the communication. To eliminate that risk, Svenska Kraftnät has full redundancy for the support system. It is possible to run the system from at least three different places, including secured reserve locations. This actually results in a more reliable operation than before with many control centres covering smaller areas. The new structure is also depending much more on the telecommunication system, which is a risk. That risk is managed by the redundancy of the highly meshed system.

During the blackout in Southern Sweden and Denmark September 23, the new organisation and support systems was put to the test. Some experiences were:

+ Flexible communication between the different functions
+ Easy to support heavy work loaded functions with extra personnel
+ Possibilities for a flexible restoration strategy
+ The support systems were able to handle the massive number of alarms and events
  - Difficulties to understand and make priorities out of the long alarm and event lists
  - Some alarms from relay protection systems and automatics were not established and shall be added in the future for easier and faster analysis

A risk with many stations under each control centre in such an event can be high workload for each operator. However, this event actually showed that all the available operators and staff could easily be moved around and placed where the workload was highest.

An analysis report from the blackout is available at www.svk.se

7. BENEFITS IN OPERATIONAL TRAINING AND EDUCATION

One benefit that was obvious from the beginning was the development of the staff competence. By centralizing and limiting the number of grid control centres, it is easier to
assess and manage the training needs. Dedicated efforts have therefore been done where a part of the cost reductions has been used to build a good training and educational environment.

Besides normal power system related education, the operators are trained in crisis scenarios and different types of simulator supported training. The training is divided in the following parts:

- Roles and responsibilities of the operators
- Tools for operational supervision and power system analysis
- Power system understanding
- Relay and control equipment
- Components in the power system
- Electrical safety regulations
- Interaction with hydro and thermal power stations
- Market issues

The operator training covers activities from all the operational states such as normal, alert, disturbed and blackout with following restoration.

An in-house developed real-time power system simulator, ARISTO, supports a major part of the training. Recently the simulator was integrated into the new support system. That together with a specially adapted training room forms a replica environment where all the operator roles and most of the SCADA/EMS functions are represented. The simulator consists of a power system model that is able to model arbitrary switching configurations in the grid. It also includes detailed modelling of for example all primary components, dynamical data for machines, relay protection system and automatics etc. The simulator works in real-time with an incremental time step of 20 ms. That together with the same user interface as the ordinary control centre support system makes it possible for very realistic training (see figure 3).

![Figure 3: Training environment using ARISTO and HANSA](image)

This environment has created new possibilities for training and education. The operators can be trained separately or in role-plays in different types of situations, from normal operation to
a blackout situation and a restoration process. It is also a good way of training all the control centre functions together during different kind of disturbance situations.

8. CONCLUSIONS
By a well-structured rationalization, Svenska Kraftnät has attained a more efficient system control with lots of advantages to a much lower cost. Some of the benefits are:

- Cost benefits such as
  - Lower costs for premises
  - Less personnel
  - Less computer systems to maintain and develop
- Coordination benefits such as
  - Joint training and education
  - Higher competence among the operators
  - Better system overview
  - Easier and faster communication between the operators
  - More interesting and varied work

The new structure has led to some risks and problems. Svenska Kraftnät has handled them for example by:

- Rebuild the national control centre
- Establish two new grid control centres
- Replace the whole SCADA/EMS support system
- Establish a completely new structure and strategy for backup systems, reserve control centres and communication systems
- Allocating more resources and focus on operator training and education

“Less people have better tools and more knowledge to do their job, at a lower cost”.

9. REFERENCES
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