## INTEGRATION OF PROTECTION AND CONTROL FOR RAILWAY POWER SYSTEMS

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## INTRODUCTION

The technology in intelligent terminals enables communication from the process level to the SCS, substation, SCADA/EMS, and the network levels. Any function and parameter can be programmed and changed remotely. Automatic sequences can be included on bay and substation levels utilising the SCS. In addition, with serial communication, binary inputs, and user programming, it is possible to adapt for external criteria in real time. In total this allows for adaptive functions on all levels in "**The Intelligent Substation**".

The paper describes the evolution of conventional control, monitoring and protection equipment for railway power system applications into **"The intelligent substation"**, fully utilising **I**nformation Technology, **IT**. Traditionally there were separate islands with various stand-alone equipment such as protection relays, event recorders, disturbance recorders, measuring devices, alarm systems, Remote Terminal Units and control panels built up with conventional electromechanical relays and switches. The paper discusses the advantages, and the concerns, of an integrated approach for **Substation Automation**, based on modern microprocessor-, software-, and communication technology.

As one example of the new technology, the paper presents the ***"intelligent one bay terminal"*** designed for protection, monitoring, supervision and control of a complete power system bay. The designation *"terminal"* is used instead of relay or protection, since with modern equipment many additional functions as well as remote communication can be included to give a total technical and economical solution. This gives greatly improved functionality, especially with reference to information processing, information storage, and information transfer. The philosophy is "one signal - one input", which means that when one signal is measured, e.g. a current or a status indication, this signal is re-used throughout the protection, control and monitoring process for different functions.

## WHAT IS NETWORK MANAGEMENT

Operation of the railway power system includes today a large number of functions, which more or less are carried out by separate equipment and systems involving different personnel. The main functions are:

- Control of switching devices
- Protection of high voltage equipment
- Monitoring of primary and secondary equipment
- Measuring and metering
- Automatic sequential control

These functions can be designed and operated with various high voltage equipment and control equipment. Together we can today describe all these functions as **Network Management,** which can be divided into the following systems:

- SAS Substation Automation System
- SMS Substation Monitoring/Management System
- SCADA Supervisory Control and Data Acquisition System
- EMS Energy Management System
- DMS Distribution Management System

EMBEDBy co-ordinating these products and systems the design, operation and maintenance of the power system can be done more efficient and economic. This does not include only the conventional functions mentioned above but new ways of utilising the information in the complete process. Figure 1 shows an example of  the Intelligent Substation

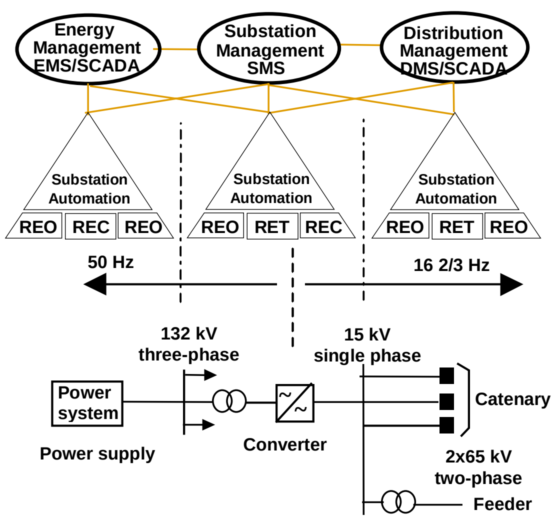


Figure 1: The Intelligent Substation

## POSSIBILITIES AND EXPERIENCE OF THE NEW TECHNOLOGY

Microprocessor technology has been used for 15 years: for designing protection and control with very good experience as was reported by Berglund et al (1), Wikström et al (2), Ohlen et al (3) and Ödmansson et al (4). The first generation products with 8 bits general purpose microprocessors increased the flexibility and gave more compact solutions. The second generation of fully numerical design was utilising high sampling technique and Digital Signal Processors. The third generation is utilising a hardware and software platform, which gives the user the possibility to design his own product or system.

With this modern technology, higher quality information as sampled wave forms allows improved accuracy and the use of more complex and adaptive algorithms. Furthermore, serial communication of data over fibre optic cables can be used to provide commands and information to/from Substation Monitoring Systems(SMS), Substation Control Systems (SCS and SCADA/ Energy Management Systems (EMS).

One of the new possibilities with this new technology is the implementation of adaptive functions, in which the information from one part of the process is used to influence e.g. another process. Adaptive control functions have been used for a long time within process automation. With this new design concept the word "adaptive" is used in a wider sense, including both adaptive protection and adaptive control.

## THE UTILITY/NETWORK LEVEL

A modern Energy management System (EMS) combines versatile power applications packages with a comprehensive SCADA functionality. In this environment, power applications can be used for real time control or for study-mode planning, using a multiple database concept. Even if all this functionality not is used in the railway application they are decribed below.

**Power System Control** functions keep system frequency and tie-line interchanges constant, irrespective of the actual loading conditions. They control production units according to schedules and operational constraints.

**Network Monitoring** functions provide the operator with the best possible picture of the system. The security level of the actual power system, or a planned configuration, is analysed by the **Security Assessment** functions.

**Operation Enhancement** provides the operator with recommendations on how to improve reliability and economy of power system operation.

**Energy Planning** uses forecasts for scheduling power plant operation in an optimal way. A vertical integration allows rapid collection of all data from the power system as well as a possibility to remotely control all devices.

**Distribution Automation** includes distribution network monitoring functions combined with geographical mapping, for enhanced presentation. It integrates network operation with field work management, outage management, analysis and restoration. Fault location and remote control of disconnectors in the distribution network improves the availability. It also integrates **Load Management** and can through intelligent meters in the future be integrated with **Home Automation.**

## THE SUBSTATION LEVEL

The full benefits of the new technology will be further obtained in the fully automated substation. In order to simplify the description the designation REL, REB, RET and REC are used to designate line, bus and breaker, transformer and control terminals. The combined control and protection terminal for railway systems is designated REO. These terminals are built on a standard multiprocessor platform with parallel DSPs and a 32 bit Micro Controller.

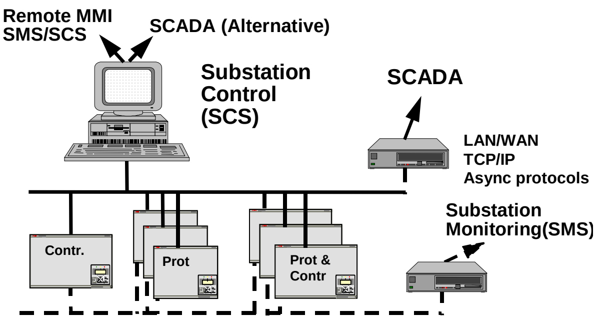


Figure 2: Substation Automation

From a large software library of control, protection, monitoring and measurement functions, it is possible to configure the terminals to suit a specific application. To gain the full benefit of Substation Automation, as in Figure 2, it is necessary with a Local Area Network (LAN), which can handle both protection, control and monitoring (Disturbance recording). Such protocols are available as open and published protocols. With Substation Automation including SCS and SMS it is possible to supervise the complete primary and secondary processes on line

## OPEN DESIGN CONCEPT

One important concern in the integration of many devices and systems is the inter- operability. Manufacturers of utility protection, control and communication equipment should attempt to design with so called "open concept design". This includes all levels in the ”Intelligent” Power Network. Open system requirement has three aspects:

- Open to interface with other manufacturers of similar technology
- Open to interface with older generation equipment
- Open to accept a customer specific design

The advanced EMS/SCADA constitutes the kernel for **horizontal integration**, when connecting centralised computing resources. It also facilitates the **vertical integration,** by connecting plant computing resources in power stations and substations to a central position. The concept of open systems architecture inherently offers an increased control system **availability** and improved **upgrade ability**.

## INTELLIGENT POWER SYSTEM MANAGEMENT.

With the described technology in the new intelligent terminals it is possible to communicate in both directions from the lowest level close to the process up to the SCS and substation level and further to the SCADA/EMS and the network level.

Any function and parameter can be programmed and changed remotely. Automatic sequences can be included on bay and substation levels utilising the SCS. With serial communication or binary inputs in addition to possibility to user programming it is therefore possible to adapt for external criteria in real time. In total this allows for adaptive functions on all levels in "The Intelligent Substation".

The above described terminals are examples of a compact, safe and "adaptive" way to utilise the advantages of micro-processor technology and remote communication. Basically, with the exception of some visual and injection testing functions, everything which can be done in the station, can be done remotely.

With self-monitoring and post-fault analysis, the reliability and availability can be significantly improved. The terminal can be used stand alone as conventional protection, but also be part of a SCS or a SMS System.

## AN EXAMPLE OF AN INTELLIGENT SUBSTATION AUTOMATION INSTALLATION

In Sweden (as well as in Germany, Norway, Austria and Switzerland) the railways are powered at $16^2/_3$ Hz. This means that they can not be directly powered from the normal power network of the countries that uses 50 Hz. Instead converters are used for converting the 50 Hz three-phase system into $16^2/_3$ Hz single-phase system. Earlier rotating converters were used but today static converters are mostly used. In Sweden an additional two-phase 130 kV feeder system is also used to reinforce the power supply along long, heavy loaded railways.
When a new converter station was to be built it was decided to use an integrated protection and control system based on REO-terminals to get a cheaper and more reliable solution. A schematic diagram over the installation is found in Figure 3.

The installation consists of a connection to a 132 kV, 50 Hz public power network. The power is fed to the primary side of two converters via two converter transformers. The secondary side of the converters is connected to one section each of a two-section 15 kV, $16^2/_3$ Hz single-phase busbar. To the busbars are connected five outgoing lines for the catenary system of the railway together with the low voltage side of two 15/(2X65) kV transformers. The high voltage side of the transformers is connected to 130kV feeder networks.

All bays (15kV outgoing lines, converters, transformers and 130kV feeders) are equipped with integrated protection and control terminals that not only protect but are also used for control of apparatuses and monitoring of voltage, current and power to the bays. For some functions, e.g. transformer differential protection and backup overcurrent protection for outgoing lines and 130kV-feeders, conventional protective relays are used.

All terminals are connected to a LON bus for communication with a local SCADA system and over a gateway to a remotely located Regional Control Centre for power system operational purpose. The LON bus is also handling interlocking between the different apparatus. The terminals are also connected over a SPA bus and via a modem to a remote Substation Monitoring System for supervision of the protection and control terminals and also for disturbance evaluation.

## CONCLUSION

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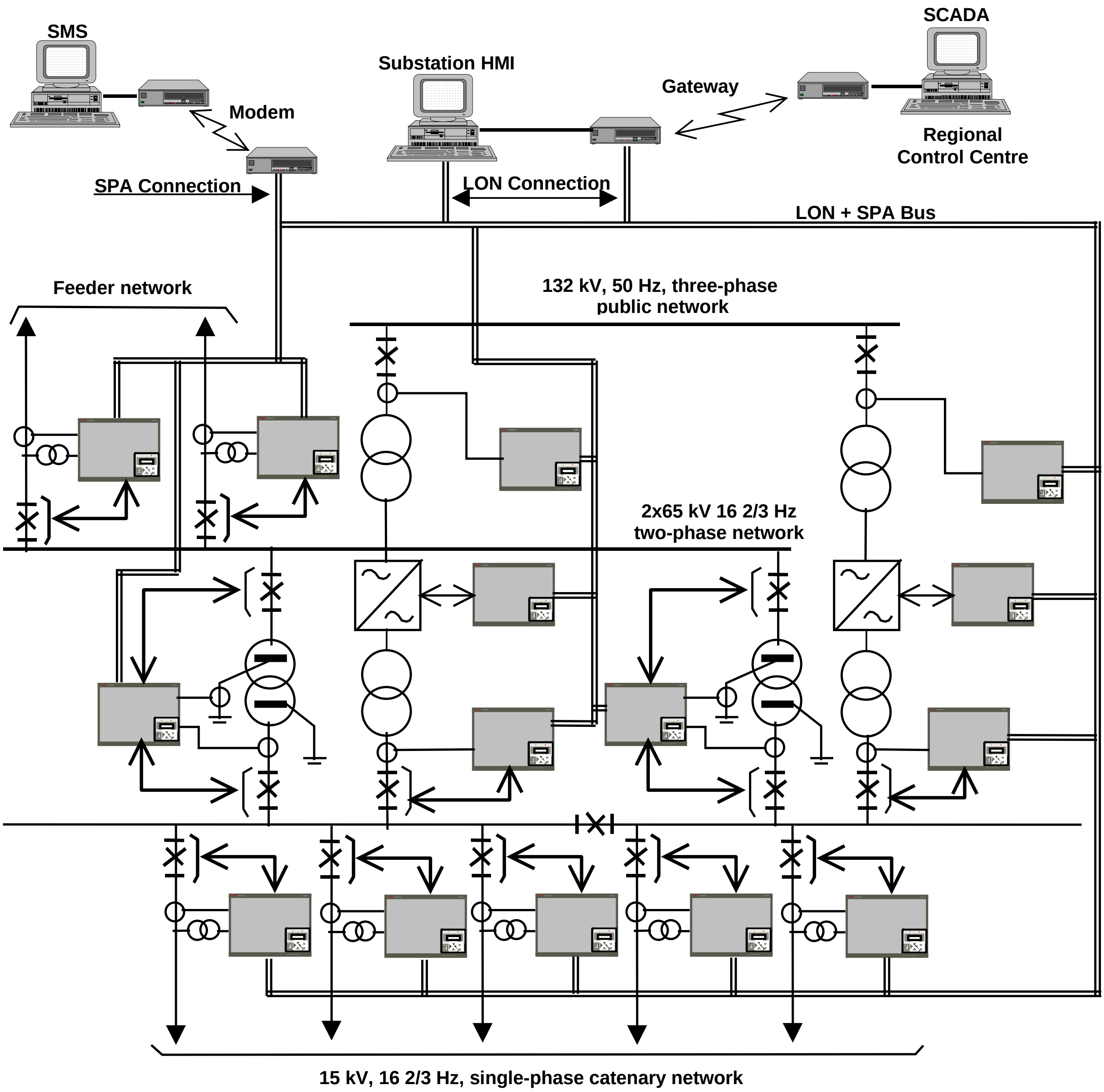


Figure 3: Example of an Intelligent Substation Automation for railway application

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