DESIGN AND IMPLEMENTATION OF AN INNOVATIVE TELECONTROL SYSTEM IN THE VATTENFALL MEDIUM-VOLTAGE DISTRIBUTION GRID

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ABSTRACT

*A modular technical solution for the telecontrol of medium voltage local electricity substations is described, in which a TETRA (**TE**rrestrial **T**runked **RA**dio) trunk radio network or an existing regional telecommunication cable network using DSL technology is used as the method of communication on the basis of the IEC 60870 protocol standard.*
The solution developed, consisting of UPS, telecontrol and communication module, exhibits defined interfaces, which enables the use of components from different manufacturers. For energy storage, the UPS module uses ultra-capacitors (PowerCaps), which have recently become available and which exhibit significant advantages over conventional rechargeable batteries. As an alternative to the expensive replacement of switchgear that cannot be motorised, an adaptive actuator system was developed, the advantages of which lie in the short conversion times and its non-dependence on a particular switchgear manufacturer. The widespread use of the described technical solution throughout the distribution networks in Berlin and Hamburg began in 2009. Practical experience gained in the installation, commissioning and operation of the solution is illustrated.

INTRODUCTION

The progressive development of the large cities of Berlin and Hamburg as centres of German politics and economy is leading to ever increasing customer expectations with regard to the reliability of the electricity supply, together with falling costs. Vattenfall is meeting these expectations by means of such measures as the introduction of the telecontrol of local electricity substations in order to shorten the interruption duration index (CAIDI) in the medium-voltage grid.
Since the telecontrol function is predominantly used during interruptions in the public electricity supply, the communication connections required for telecontrol must not be dependent on the public electricity supply. In addition, high standards are to be expected in terms of availability, as well as the prevention of manipulation and data security. Public communications networks cannot currently fulfil these requirements economically, if at all. The solution developed therefore concentrates on the existing TETRA trunk radio networks, as well as the company's own telecommunication cable network existing in parts of the supply region.
The TETRA networks were established in 2006/07 by Vattenfall Distribution Berlin and Hamburg to replace the outdated analogue private mobile radio networks and were originally only intended for the purpose of guaranteeing emergency communication. Since TETRA networks enable packet-orientated, IP-based data communication as standard, this also fulfilled an important prerequisite for establishing a communication link between the substations to be controlled and the central control centre systems for network management.
The comprehensive establishment of the ability to control local electricity substations remotely is a project that can only be implemented in the long term and which requires substantial investment. In order to be able to achieve high investment security and long-term non-dependence on a particular manufacturer from the outset, the specification of a modular system based on open standards was unavoidable. This also made an open tendering procedure according to EU regulations possible.
The medium-voltage switchgear used in the past normally has no motorised actuators for telecontrol. A further challenge to the economic implementation of the project was therefore the creation of a universally applicable retrofit solution for existing installations, since the complete replacement of all the switchgear concerned is ruled out for reasons of cost.

PRIMARY TECHNICAL COMPONENTS

The medium-voltage section of local electricity substations in the Berlin and Hamburg distribution network is usually structured according to the principle illustrated in fig. 1.

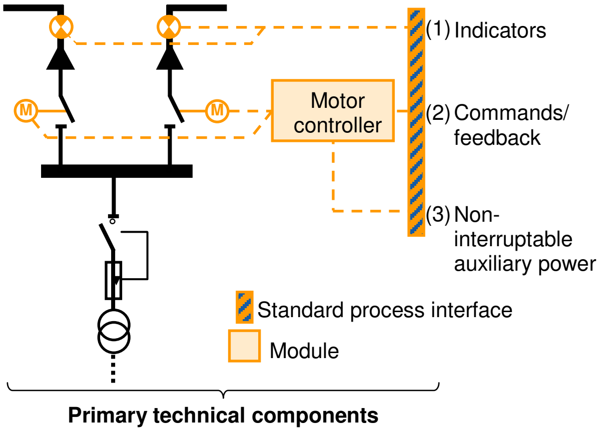

Fig. 1: System configuration – primary equipment section

The establishment of telecontrol capability according to the principle foreseen by Vattenfall requires the retrofit of the additional components shown in colour in figure 1.

Existing and new local electricity substations

Interior and compact local electricity substations with air-insulated or SF6-insulated switchgear are mainly in use in Berlin and Hamburg; these are to be retrofitted with motorised actuators and remotely readable short circuit indicators in order to enable telecontrol.
When new substations are built today, the switchgear is equipped with motorised actuators as standard. Appropriate switchgear is available in the form of standard products from many manufacturers. The extra costs in comparison with non-telecontrollable systems are relatively small.
In the case of existing local electricity substations, a choice is made between replacement with a new system or the retrofit of motorised actuators, depending on the age, type and condition of the switchgear. Retrofit kits are available from the manufacturers for systems installed since the mid 1990s.
In the case of around half of the local electricity sub-stations that are planned to be equipped for telecontrol, a system replacement is out of the question for economic reasons and retrofit kits are not offered by the switchgear manufacturer. Therefore, in cooperation with the LINAK company, a new technical solution was developed in which the manual operating elements of the switchgear are used for the purpose of motorised control.

Alternative adaptive actuator system

The result of the cooperation between Vattenfall and LINAK is the so-called iMotor-Compact, a switchgear-neutral, adaptive actuator system that can be installed in both interior and compact local electricity substations with cramped spatial conditions (fig. 2).
An installation kit developed for the respective type of system fastens the actuator system to the outside of the switchgear, without affecting the type approval of the system or station.

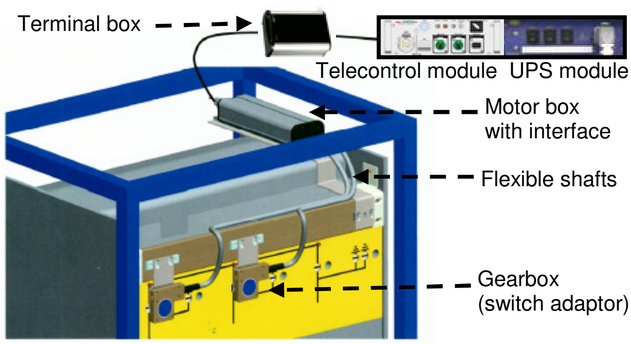

Fig. 2: Adaptive actuator system – iMotor Compact

The actuator system consists of four components.

The **motor box** is equipped with two motors. It also contains all the electronics for controlling the motors. The box can switch two loadbreakers and requires little space for installation.

The **gearboxes** adapt the standardised motor box to the system-specific mechanism of the manual control elements of the switchgear. The gearboxes can be removed for local switching, should this be necessary in exceptional cases. The installed size on the front of the switchgear (gearbox with mount) can be minimised to 35mm. Thanks to an absolute position indicator in the gearbox, all the usual switches with various switching angles can be accommodated. The maximum torque is 120 Nm. Figs. 3 and 4 show practical solutions in the Vattenfall distribution network.

The motor box is connected to the gearboxes via **flexible shafts**. The advantage of separating the motor box from the gearboxes is the more flexible integration of the drive unit in the cramped spatial conditions in compact local electricity substations. The flexible shafts can be made up to two metres long.

The **terminal box** contains the standard process interface between the motor box and the telecontrol equipment.

Fig. 3: Adaptive actuator system on switchgear GA F&G (Ormazabal)

Fig. 4: Adaptive actuator system on switchgear FBA AEG (Areva)

SECONDARY TECHNICAL COMPONENTS

A standard process interface couples the primary technical section to the secondary technical section of the telecontrollable local electricity substations (figs. 1 and 5).

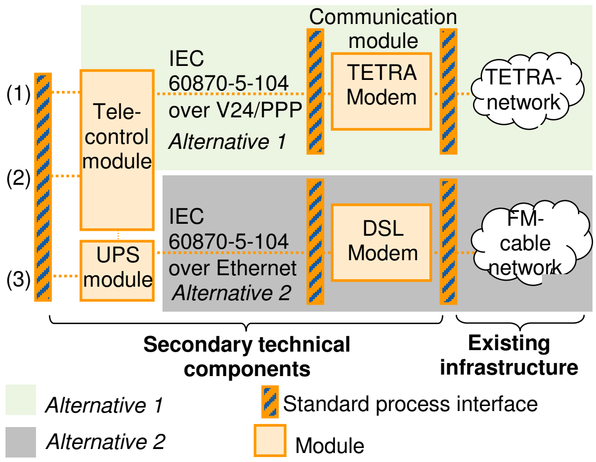

Fig. 5: System configuration of the secondary technical section and existing network infrastructure

Substation equipment

The housings of the secondary technical components were designed such that they can be mounted in the only existing accessible free space in compact local electricity substations, a narrow gap between the switchgear and the roof of the station (fig. 4).

The technical solution developed, with UPS, telecontrol and communication module, is designed by means of its modularity and defined interfaces to allow the combination of components from different manufacturers. It is designed for a technical service life of more than 15 years for each module.

Due to the requirements for temperature stability, life span and maintenance costs, the **UPS module** that supplies the power to the motorised actuators, the telecontrol module and the communication module was designed on the basis of PowerCaps, with the result that it was possible to dispense with the conventional battery technology. The capacity of the capacitors is designed for an independent operating time of approx. 90 minutes with two possible switching operations.

The **telecontrol module** processes the range of commands and messages for medium-voltage switchgear and short-circuit indicators standardised by Vattenfall and communicates with the central grid control level using the packet-orientated IEC 60870-5-104 protocol version. In principle, therefore, any method of communication that can transmit TCP/IP can be used. The telecontrol module was specified such that a fixed, defined space is reserved for the communication module required in each case. Attachment is by means of a standard DIN mounting rail.

A component of the TETRA standard is an IP-based packet data service, which is in principle adequate to meet the requirements of IEC60870-5-104. At the time of making the system decision, however, this was not yet in use in a comparable application anywhere in the world. In the course of the project, a solution has been developed that implements the transmission of the IEC60870-5-104 protocol version with the low data rate of the TETRA network (3-5 kbit/s) with full standard conformity. To this end, parameters of the TCP/IP stack that are not normally accessible had to be made configurable in the software of the telecontrol module.

The **communication module** for the TETRA version fully complies with the TETRA standard for packet data communication. The user interface specified therein (PEI - **P**eripheral **E**quipment **I**nterface) is based on the ITU recommendations V.24 and behaves to a large extent like a modem with an AT command set. IP communication takes place via the point-to-point protocol using compression methods and is fully controlled by the TETRA network infrastructure. TETRA-specific cryptographic authentication methods are used to protect against manipulation on the transmission path. In principle, any commercially available TETRA terminal with PEI could be used as a communication module. Vattenfall specified a design adapted to the environmental conditions for use in the telecontrol module. The devices employed today use the TOM 100 TETRA modem from Motorola.
A commercially available SHDSL modem with Ethernet interface, which is designed for use in process control systems and with which both line and redundant ring topologies can be constructed, is used as the communication module for the DSL version.

Existing infrastructure

Vattenfall's own DIMETRA IP systems from Motorola are used as the TETRA network infrastructure. Each radio base station covers a radius of approx. 3 - 5 km. 20 base stations are currently in use in Berlin and 16 in Hamburg. This level of development enables the online connection of approx. 2.000 and 1.600 local electricity substations respectively to the central control centres. The theoretical maximum capacity is around 20.000 stations.

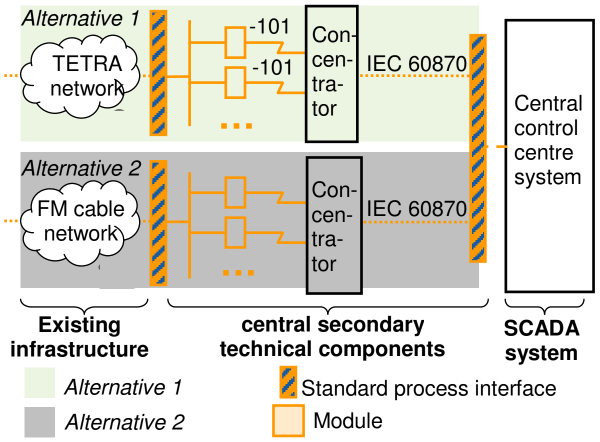

Fig. 6: System configuration – connection to the SCADA system

Central concentrators

The central concentrators (fig. 6) serve as links between the high number of local electricity substations and the existing central control centre system. They consolidate the process data model, schedule the TCP/IP connections adapted to the specific characteristics of the TETRA network and contain firewall functions for the protection of the system against external manipulation. The concentrators are scalable in steps of 200 local electricity substations and can thus be adapted according to the number of telecontrollable stations.

INNOVATIVE ANTENNA SOLUTIONS

The large supply radius of a radio base station and the locations of the local electricity substations, which are not always ideal from the point of view of HF, make reliable radio linking over the TETRA network a challenge. For that reason innovative antenna solutions with good HF characteristics were developed together with antenna manufacturers. A further development requirement was that the design should be as inconspicuous as possible, in order to prevent the danger of destruction by vandalism and manipulation.

Door sign antenna for walk-in stations

Many walk-in local electricity substations are accessible via the station's own door. This lends itself to the attachment of an antenna and functions as an HF balance weight for the antenna (fig. 7). Thanks to a printed laminate, the antenna is taken to be a sign.

Roof antenna for compact local substations

In the case of compact local electricity substations, the antenna can be set into the concrete roof of the station and provided with a sturdy GRP cover (fig. 8). The cover is coated in a concrete colour, so that it and the antenna are barely noticeable.

Fig. 7: Door sign antenna

Fig. 8: Roof antenna without GRP cover

CONCLUSIONS

The gradual widespread and comprehensive introduction of telecontrol in Berlin and Hamburg began in 2009. On the basis of experience so far in the retrofitting of telecontrol to medium voltage substations, the modular design with standardised interfaces has proven to be outstanding in installation and commissioning. Specially developed test devices and methods were used for testing the individual modules. The installation of the telecontrol and UPS modules in the local electricity substations, with subsequent testing of the individual functions and indicators, takes place without intervention in the ongoing operation of the switchgear. The integration of the telecontrollable switchgear into the central control centre system, including commissioning test, completes the installation. Thanks to the modular design, the time taken and the coordination required for the installation and the commissioning test are reduced by 30 % in comparison to previous solutions.

Initial experiences of the systems in operation have been positive. The predicted shortening of the interruption duration index (CAIDI) in the medium-voltage grid of 50 % is fully achieved.