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Power system protection and automation reference

Fast substation busbar protection with IEC 61850 and GOOSE



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Falu Elnät AB applies new power system protection and automation technology

Falu Elnät AB, a subsidiary of Falu Energi & Vatten AB, is a municipality-owned power transmission and distribution company located in the municipality of Falun, approximately 230 km northwest of Stockholm, the capital of Sweden. In July 2009 ABB and Falu Elnät signed a three-year frame agreement including native IEC 61850 IEDs of the Relion® product family for substation retrofit and greenfield projects. Having committed itself to the IEC 61850 standard Falu Elnät takes a strategic step forward when implementing the latest technology in the field of power system protection and control for fast and selective protection and future proof solutions.

Falu Elnät distributes electricity to approximately 30 000 customers in the municipality of Falun. The parent company, Falu Energi & Vatten, is apart from being the owner of Falu Kraft AB the largest

shareholder of Dala Kraft AB, a collaboration of nine energy companies in the region. Due to the deregulation of the electricity market in the mid 90's the power generation and distribution were separated into two different companies within Falu Energi & Vatten. The transmission and distribution network of Falu Elnät comprises 23 substations, over 1000 km of overhead power lines and more than 2000 km of underground cables for the supply of approximately 550 GWh of electricity to its customers. The company has strategically invested in underground cables in order to create a weather-proof network and to increase the reliability of the power supply. Furthermore, by investing in new protection and control equipment and utilizing the thorough knowledge of the personnel, Falu Elnät aims at serving the customers better even in network disturbance situations.

The Linghed substation, operated by Falu Elnät AB, supplies power from the grid and a wind power park to the local community.



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 Christer Johansson
 and Jan Östlund of
 Falu Elnät AB.



Renewed substation in Linghed to increase the reliability of the power distribution

The 55/22/11 kV substation in Linghed, situated some 30 km NNE of the city centre of Falun, was built in 1986 and equipped with ASEA (now part of ABB) Safesix switchgear. The substation is connected to Fortum's grid and it is fed from two power transformers. The three-winding (T2) 55/22/11 kV transformer rated 16/10/6 MVA was delivered by ABB in 2009 and the older two-winding transformer (T1) 55/11.5 kV rated 6 MVA is currently used for backup purposes. The three-winding transformer feeds the local 11 kV distribution network and connects the 22 kV line of the wind power park at Tavelberget about 12 km NNE of Linghed to the public network. For protection of the new power transformer the delivery included a RET670 Transformer Protection IED. Falu Elnät aims at increasing the reliability of the power supply by usually providing substations with two power transformers, a main transformer and a backup transformer. Two power transformers allow undeniable maintenance flexibility and security of supply. The transformer maintenance planning can thereby be based on the actual need instead of on waiting for a suitable time from a network load perspective. "Having two power transformers is a strong benefit seen from the maintenance point of view. We don't have two transformers throughout the network but nevertheless in many substations. We have a number of substations with a single power transformer and the problem then is that the tap-changer revisions must be done during a low-load summer period. Now we can do the maintenance work at any time because now the work only affects the wind power production," says Mr **Christer Johansson** Operations Manager of Falu Elnät.

As a next substation retrofit step Falu Elnät decided to replace the current protection relays of the 11 kV outgoing feeders with ABB's Feeder

Protection and Control REF615 IEDs (Intelligent Electronic Device) thus utilizing the scope of the Relion® product family. "One of the main reasons why we chose ABB as our supplier of the protection and control equipment was that ABB offers a complete range of protection and control IEDs. That is, voltage regulation IEDs, transformer differential protection IEDs for three-winding transformers and protection and control IEDs for the distribution network, all products of the same unified product family. In addition, ABB offers one configuration tool for all of the IEDs," Mr Christer Johansson, Operations Manager and Mr **Jan Östlund**, Operations Engineer of Falu Elnät explain.

Life cycle and asset management

The renewal of the Linghed substation included the decision to keep the existing ASEA Safesix switchgear system including CBs but to exchange the existing protection relays. Thanks to the built-in CB condition monitoring of the REF615 devices the life-cycle of the current CBs of a substation can be prolonged for increased cost-efficiency. This will extend the life-cycle of the substation through the utilization of the whole technical life-cycle of the switchgear and its CBs.

The decision meant that the investment costs were optimized. The protection system was modernized to ensure a fast and selective operation in fault situations while minimizing incorrect and unwanted tripping of circuit breakers. "At the moment we have a number of switchgear panels of around 20 years, so it is about time to exchange the protection system," says Christer Johansson.

During the renewal of the substation a new communication network (LAN) was installed for the IEC 61850 communication including GOOSE messaging for fast protection schemes. Further, during the retrofit of the substation the remote communication system was renewed.

Optimized protection functions and in-depth fault analysis

By introducing the 615 series IEDs Falu Elnät acquired a range of new functionality that was previously not offered by the old relays. There was no need to change the power system protection philosophy, but the new IEDs brought about higher operating speeds and better protection coverage and new functionality, e.g. intermittent earth-fault protection, including disturbance recorder functionality. "At the moment we apply the intermittent and transient earth-fault protection, but just for signaling purposes, not yet for tripping CBs. We collect field experience of this novel protection principle, because it is not quite easy to test in the field. But it is a function much longed for," says Jan Östlund.

The disturbance recorder functionality of the 615 series IEDs allows recording of both binary and analog signals. The function has actively been taken into use by Falu Elnät and the disturbance files are routinely downloaded to the network control centre for further analysis. In addition, the disturbance recorder allows protection functions to be optimized and parameter settings to be fine-tuned to improve the reliability of the devices during network disturbance situations. "We really like the disturbance recorder function of the 615 series IEDs. If there has been a fault you can go back and find out what happened, how high the fault currents were and how the fault started and developed. The disturbance and event recorder functionality is new to us, but in the Linghed substation it has now been taken into use to our satisfaction," explains Jan Östlund.

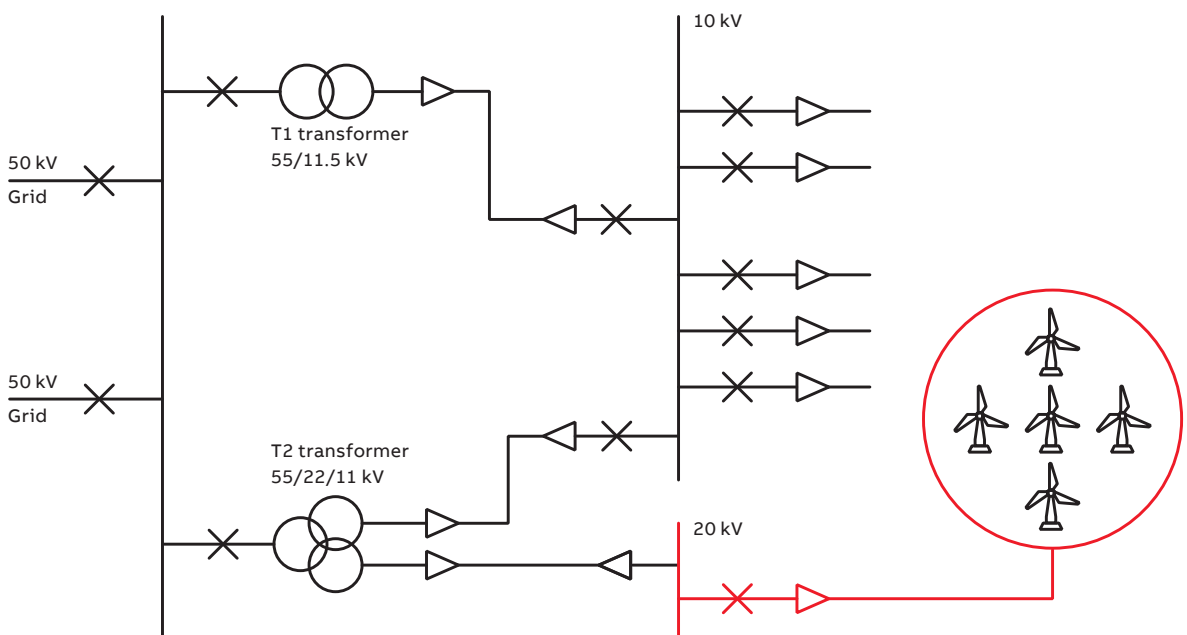
"Without the disturbance record you have no information of what has happened, just that a CB has tripped due to overcurrent or earth fault, if you have made that distinction. But by analyzing the available disturbance record you can find out what caused the fault and read the magnitude of the fault currents," Christer Johansson resumes.

The high competence of the personnel is of utmost importance to Falu Elnät as, e.g. all of the IEC 61850 engineering and disturbance record analysis is done in-house. This philosophy ensures that Falu Elnät can act fast in case of network disturbance and thereby secure the power distribution to the end customers and shorten the potential delays, for example, because of busy subcontractors. "We feel it is important that we have in-house experience and knowledge of our power system. It is a natural preference for us to go on working with new technology when we encounter it. In this way we learn ourselves and we are able to rapidly intervene when needed. We regard ourselves as such a big power utility that we need to have this knowledge in-house," Christer Johansson and Jan Östlund explain.

New implementation of traditional protection

At the Linghed substation Falu Elnät has taken advantage of the potential of the IEC 61850 standard and its GOOSE service. The GOOSE service of IEC 61850 can be used for implementing fast blocking-based busbar protection schemes. In this approach the conventional hard-wired blocking signal paths between the switchgear cubicles are replaced with a substation-wide Ethernet LAN.

The Linghed substation integrates renewable energy resources into the power system.



Protection schemes based on blockings are well-known and widely accepted throughout the business. When a fault arises on an outgoing feeder of a substation the protection relays of both the incoming feeder and the faulty outgoing feeder start. On starting, the IED of the outgoing feeder, however, blocks the fast-acting stage of the IED of the incoming feeder. On the other hand, should a fault arise on the busbar system, the IEDs of the outgoing feeders will not start and the IED of the incoming feeder is allowed to operate after a short coordination time and trip the CB of the incoming feeder. "We have implemented new technology without changing our proven protection philosophy to obtain added value through better coordination and operating times. In all our substations where we renew the protection system we will use GOOSE messaging for blocking of the incoming IEDs on faults on outgoing feeders, that is for substation busbar protection," says Jan Östlund.

Fast and reliable busbar protection with GOOSE

By transferring GOOSE messages between IEDs interconnected with a local area network (LAN) the blocking signals can be sent directly from IED-to-IED without additional delay from auxiliary relays or input filters. In complex busbar systems the blocking signals have to be routed to several objects. For hardwired schemes this means insertion of auxiliary relays, which add delay to the blocking circuit. This additional delay must be taken into account when the total operating time of the protection is determined.

By means of the new technology the traditional interlocking scheme can be speeded up considerably. At the same time the new technology offers an increased reliability of operation and flexibility of the protection. "The requirement has been an operating time of 150 ms. This setting has been used in the past. I have now done some testing showing that when using GOOSE even 40 ms is enough to allow the IEDs of the outgoing feeders to block the IED of the incoming feeder. Now the setting of the incoming IED is set at 60 ms, in practice half the time that the setting used to have," says Jan Östlund. This also means that the total operating time of the busbar protection will be speeded up correspondingly.

The operational reliability of a blocking-based busbar protection scheme with GOOSE messaging is significantly enhanced by the inherent supervision of the GOOSE service. Further, the blocking principle itself incorporates features, which secure operation in fault situations: should the blocking circuit be broken, no blockings will be issued. The broken blocking circuit will not render the protection system inoperative, but may allow unwanted tripping.

The supervision function of the GOOSE service generates an alert, should the message not get through, allowing appropriate repair measures to be taken immediately. "This is a great advantage. If a wire of a hardwired busbar protection system based on blockings has been broken nobody knows about it, until a protection system fails to operate. But if we get a GOOSE error message we know that the communication is down. This allows us to take immediate corrective measures," says Jan Östlund.

Integrating renewable energy sources into the power system

The substation in Linghed is located just 12 km SSW of the new wind power park at Tavelberget. The park includes five 2 MW wind turbines, which are connected to the Linghed substation with a 22 kV feeder. Two of the wind turbines are owned by Falu Energi & Vatten and are strategically in line with the company's aim to develop "climate smart" power generation. Apart from wind power the company has invested in hydro-power and biofuel power plants, thus aiming at a reduction of the CO₂ emissions by 145 000 tons a year.

The five wind turbines at Tavelberget were connected to the grid in July 2010 and are expected to generate approximately 32.5 GWh a year. The incoming cable feeder from the wind power park is protected by a REF615 IED in the Linghed substation. By combining renewable energy resources with the IEC 61850 standard Falu Elnät takes a determined step towards both climate smart power generation and a future proof power system protection and automation solution.

Towards the future with IEC 61850

Over the coming years Falu Elnät will continue renewing the protection and control devices of other substations in the transmission and distribution network. All substations will be equipped with IEC 61850 compliant devices thus putting the company strategy into action. During 2011 four or five substations will be renewed, and the project will continue including about 15 substations altogether.

The renewal of the Linghed substation will be continued during 2011 with the replacement of the protection and automation devices of the two-winding power transformer with an ABB Transformer Protection and Control device RET630. "It is a big step going from an old, familiar technology to a completely new one. It is a matter of being able to take the leap and really put the plans into practice. As we now have these new protection IEDs up and running, we would wish to incorporate the same equipment in all our substations," Christer Johansson concludes.



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For more information, please contact

ABB Distribution Solutions

P.O. Box 699

FI-65101 VAASA, Finland

Phone: +358 10 22 11

abb.com/mediumvoltage

abb.com/substationautomation