Digitization and Testing of Secondary Substations

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Abstract

Smart Grid is the talk of the town nowadays, even though hardly anyone really knows what it means. Most energy suppliers are already changing over to Smart Grid, and SÜC Energie in Coburg is no exception. SÜC Energie is digitizing its secondary substations to increase availability and keep a close eye on the power supply. This paper examines what digitization involves and the implications it has for the commissioning and maintenance testing of an intelligent secondary substation.

Keywords

- Intelligent secondary substation
- Smart Grid
- CMC
- COMPANO
- Non-conventional transformers

1 Introduction

The rapid increase in renewable energy is creating additional workloads for both the transmission and distribution networks. Whereas fewer larger power plants are being connected to the transmission network, renewable energy is behind the emergence in the distribution network of what are known as regional power plants. The transmission network is now taking on the task of distributing energy from the distribution networks to the locations across the region where demand is highest. The role of the distribution network is to deliver energy across the region and feed any surplus back into the transmission networks.

SÜC Coburg is a distribution network operator whose power supply has both an urban and a rural character. Although urban areas are generally consumers of electrical energy, rural areas can, depending on the weather conditions, produce large quantities of surplus energy.

Figure 1 Area covered by the power supply system of SÜC Energie

The power supply figures in respect of renewable energies speak for themselves. The Coburg region currently contains the following producers of renewable energy (as at 04.15.2018):

- Unit-type thermal power plants (90) 7.7 MW
- Biomass power plants (36) 12.2 MW
- Wind turbines (1) 6.8 MW
- Photovoltaic systems (2483) 69.6 MW
- Hydroelectric power plants (21) 2 MW

With annual peak load figures of 116.7 MW, it is not difficult to appreciate that the power flow in the distribution network no longer follows the traditional "top to bottom" pattern, but that it can change several times a day according to the weather conditions.

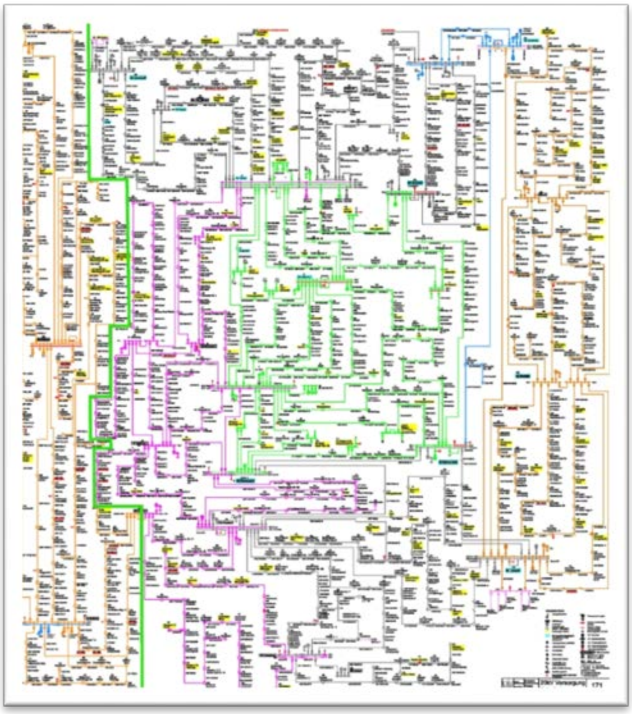

Figure 2 The 20 KV network of SÜC Energie

This unsurprisingly gives rise to a new set of challenges. Voltage drop takes on a completely new meaning, as it is not just a question of by how many percent, but also when, and under what weather and power flow conditions. SÜC Energie has already installed two in-phase regulators in the medium-voltage network to compensate for the voltage drop in rural areas.

2 New Standard for Secondary Substations

Another approach that will help overcome the aforementioned challenges it to make the secondary substation more intelligent. The idea behind this is to achieve the following objectives:

- Faster troubleshooting of faults in the medium-voltage network
- Improved fault localization in the event of a short circuit by the use of remote controlled and resettable short-circuit indicators
- Quicker resetting after clearing the fault by deploying remote-controlled load interrupters (thus reducing mean non-availability figures (SAIDI))
- More user-friendly and faster performance of scheduled switching operations (three-terminal lines and disconnectors)

2.1.1 Real-Time Power Flow

Connecting network analysis devices located in the medium-voltage network to the process control system also enables a power flow analysis to be carried out in real time (Fig. 3). These data can then be used in the network control center to optimize switching operations and detect voltage quality issues in good time.

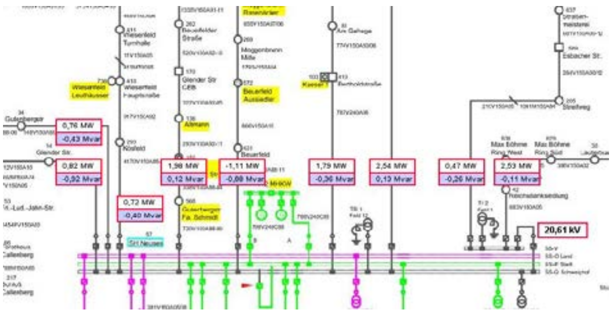

Figure 3 Power flow also in real time on secondary substations

2.1.2 Equipment in the Intelligent Secondary Substation

A FIONA manufactured by ABB (Fig. 5) has been installed for remote signaling and control purposes in the concrete cell (Fig. 4) of the secondary substation.

Figure 4 Standard SÜC secondary substation

This enables the network manager to obtain an overview of the current system status and carry out any switching operations.

Figure 5 Remote signaling and control using ABB FIONA

An ABB SafeRing AirPlus is used as medium-voltage switchgear. A SIGMA short-circuit indicator from Horstmann with a remote signaling contact is used in the cable bays. This enables the network manager to localize the source of the fault remotely and carry out the necessary switching operations.

The transformer is protected by an REF615 feeder protection relay from ABB. As the medium-voltage system is extremely compact, Rogowski current sensors are deployed for current measurements while resistive voltage dividers are used for measuring voltages.

Figure 6 ABB SafeRing AirPlus 20 kV switchgear

Voltage quality in the medium-voltage network is documented and signaled using a Janitza network analysis device.

3 Joint Workshop for Testing Secondary Substations

Staff of SÜC Energie and OMICRON met in March 2018 to discuss ways of commissioning secondary substations in an as efficient and cost-effective manner as possible in the years ahead. It was agreed that as a secondary substation is not a transformer station, a different set of conditions would apply to their testing. The question is: what are they? Where and how should testing be carried out, and in what areas can the tests be simplified?

Figure 7 Secondary substation testing workshop

First up was the ABB REF615 protection device and its non-conventional inputs. This device employs a two-stage definite-time overcurrent relay to protect the transformer.

What became immediately apparent was that the transformation ratios for current and voltage sensors in PCM 600 and Test Universe are set in different ways. Due to the non-conventional sensors, transformation factors such as 10,000/1 V for voltage and 80 A ≙ 150 mV for current were used.

All settings and parameters used in the tests refer to primary values. It makes no sense to convert them to secondary values as this is no longer necessary.

What is important is to carry out a primary and secondary wiring test ahead of the protection test itself to check that all transformation ratios have been entered correctly and that all plugs are plugged in properly.

ABB has installed a sensor test adapter in the low-voltage compartment to cater for the combination of signals from current and voltage sensors and to provide a defined “test plug” (see Fig. 8). As impedance ratios are similar to those of conventional current transformers (sensors have a high impedance, protection relays a very low one), another fact that emerged from the workshop was that no primary values are output to the protection device when a CMC test set is plugged into the ABB test adapter using the REF6XX adapter. This means that a protection test could be carried out while the equipment is in operation.

The connecting of binary contacts of the CMC test set cannot be carried out in the usual way due to the integrated coil monitoring within the REF615. The threshold value for the status assessment has to be adjusted extremely carefully to ensure that the voltage level is recorded correctly.

Figure 8 ABB sensor test adapters in the low-voltage compartment

What is striking in the case of primary injection is that the current sensor (Rogowski coil) must be positioned correctly if precise current values are to be obtained. The best approach is to feed a (medium-voltage) cable through the middle of the split-core sensor. If this is not possible because the split-core current transformer already contains a medium-voltage cable, then some deviations must be expected.

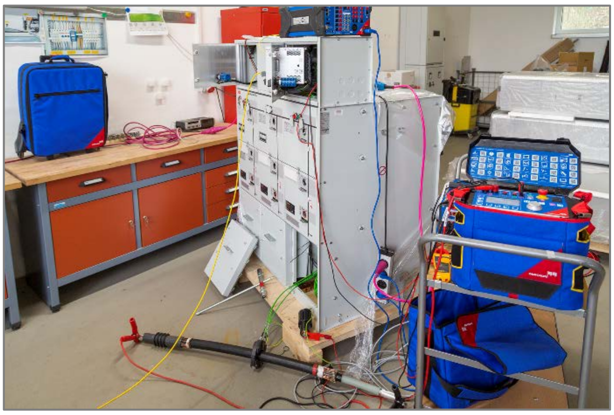

Figure 9 Primary injection into a current sensor

To optimize the measuring system, ABB has specified correction factors for the current and voltage sensors. After the primary injection and close observation of the correction factors, it became clear that these factors are negligible in the case of definite-time overcurrent protection. The correction factors make the calculation and input of the settings unnecessarily complicated, both in the PCM600 and the Test Universe. It only makes sense to use the correction factors if the protection device and corresponding sensors are being used to obtain a measurement to an accuracy of within 1%.

A primary injection into the sensors is a way of checking how the currents and voltages have been allocated. In the case of a 20 kV installation, the voltage indicators on the REF615 when used together with a resistive voltage divider react above approx. 200 V. This corresponds to 20 mV “secondary”.

The functional check of the Horstmann SIGMA 2.0 short-circuit indicator can also be carried out using a primary injection. The Test button can be used to lower the settings to 10 A primary to check operation and phase allocation as far as the process control system.

4 Findings from the Workshop

Carrying out the “secondary” protection testing of the protection devices in a secondary substation makes a lot of sense. Some irregularities occurred that would not otherwise have been detected, even when testing this decidedly simple definite-time overcurrent relay.

To simplify the parameterization of protection devices for the secondary substations in the future, a single protection relay configuration has been created for all transformer types. The parameters are organized using parameter groups to allow the settings to be adjusted to cater for the respective outputs of the transformers. As the same sensors can be used for all transformers and the REF615 supports six parameter groups, parameterization becomes much simpler. This is a real plus point, as the team frequently does not know which transformer the respective secondary substation is using until it arrives on site.

5 Factory Acceptance of a Secondary Substation

SÜC Energie will in future carry out a protection test with a CMC 430 during factory acceptance (commissioning in the factory yard) in order to verify that all the settings in the protection device have been configured. A comprehensive wiring test, which will also include components in the process control system, will also be carried out. This will enable control of the installation to be tested before it is installed in the factory. The final stage of commissioning is a system test using a primary injection.

6 Commissioning of a Secondary Substation

Once the secondary substation has been trucked to the site, all that then remains to be done in terms of on-site commissioning is to carry out a brief check using a primary injection. This allows the operation of the already configured components to be checked one more time. As the primary tripping currents can be generated by the battery-powered COMPANO 100, this new OMICRON test set is the ideal on-site partner. As no laptop is required, the engineer can carry out the test very easily. The device is also able to carry out other on-site tests such as microohm measurements, grounding and step and touch voltage testing.

Figure 10 Step and touch voltage testing using COMPANO and HGT1

7 Maintenance Testing of a Secondary Substation

Maintenance testing can be carried out in much the same way as commissioning. A short primary test will suffice to check the operation of the entire troubleshooting process. This complete system test covers the whole troubleshooting process: Sensors, secondary wiring, protection relay and the circuit breaker. The best method of assessment is to measure the auxiliary contact of the circuit breaker.

8 Summary

New technology brings secondary substations up to speed to meet the challenges of the energy revolution. However, testing is strongly recommended to ensure that the technology is working properly. Care should be taken to ensure that the effort involved is expended wisely; after all, a secondary substation is not a transformer station. It is good practice to draw up a strategy for factory testing, on-site commissioning and repeat testing so that the operation of installation components can be ensured at all times. The same applies when differentiating between the test sets used in each case, as these will have been optimized for the various applications.

About the Authors

Electrical engineer **Rico Reißmann,** born in Erlabrunn in 1977. After an apprenticeship as a power electronics installer at Energieversorgung Südsachsen, he worked as a service technician on the medium-voltage network. Rico Reißmann has been working for SÜC Energie und H^2O GmbH since 2000 – he began as a service technician for power supply systems and studied at the same time to become an electrical engineer, a qualification he obtained in 2004. He was deputy technical supervisor from 2004 until 2007, when he moved to the line protection/cable test vehicle department. In 2017, Rico also took on responsibility for the SÜC network control center.

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Florian Fink was born in 1983 in Bergisch Gladbach. He studied Electrical Engineering at the University of Applied Sciences in Cologne, where he completed his undergraduate engineering degree (Dipl.-Ing. FH) in 2009. From 2009 until 2012, he worked for Cegelec Deutschland as a project engineer, and from 2012 to 2013 was employed by InfraServ Knapsack as a planning engineer. He has been working as a product manager in the field of industrial and distribution networks for OMICRON since 2013.

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