Substation monitoring and control

Part 3.
Substation Automation

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In the preceding 2 articles the topics of measurement techniques for voltage and current has been covered. In this article we are looking at the substation automation where the analogue measures are integrated with the digital control and the communicating towards the central remote control system. The description is devided into the subjects of *Typical Substation Devices*, *Communication* and *Practical implementation*

Why Substation Control ?
To bring a cost-effective and stable delivery of power to the network, there are 2 important parameters that need focus: Actual overall network status and reaction time in case of abnormal operation.
These 2 important parameters may be fulfilled by expanding the remote supervision and remote control of medium voltage substations. During normal operation it is now possible to make sure that no individual power lines are exceeding any limits and in case of abnormal operation a very fast recovery for most of the customers is possible due to fast feedback of alarms and the option of remote control of the breakers.

Typical Substation Devices

The typical substation
The typical substation intended for automation could be a station having 3 cable sections and one transformer section. To get full advantage of automation, the switch gear must be controlled by motors.
The Substation must have a low voltage supply, making sure that a 12-24VDC is available. Often a battery backup is attached to the 24V supply, making sure that the station can be controlled in case of a breakdown of the low voltage AC supply.

Figure 1, 24V supply in substation (HEF- Denmark)

The analogue signals
For each section the following analogue signals are relevant:
- Voltage: R,S,T, R-T
- Current: R,S,T

From those analogue signals some interesting signals may be derived:
- Power: R,(S,T)
- Reactive power: R,(S,T)
- Energy direction: R,S,T
- Short Circuit Direction: R,S,T

Digital outputs
The digital relay outputs have to control the motor relays for the breakers. It might be somewhat different from one equipment to another, but it usually fits with 2 outputs per section:
- Breaker in
- Breaker out

In a 4-section switchgear the requirement is in total 8 digital outputs.

Digital inputs
To know the actual breaker situation, control situation and alarm situation in the switchgear a number of digital inputs must be available. For each section it must be possible to read the breaker position. This is implemented in different ways from the suppliers of switchgear.
In ABB SafePlus switchgear you will get:

- breaker in
- breaker out
- Earth in
- Earth out

At the Eaton/Holec's Xiria switchgear it is:

- Breaker in
- Breaker out
- Earth in
- Control ready

For both vendors it gives in total 4 digital inputs per section.

As alarm signals you can have:

- local/remote control
- 230V/24V alarm
- SF6 alarm (ABB)
- Temperature – trafo
- Door contact 1
- Door contact 2
- Extra 1
- Extra 2

For the complete switchgear this becomes 4x4 + 8 in total 24 digital inputs.

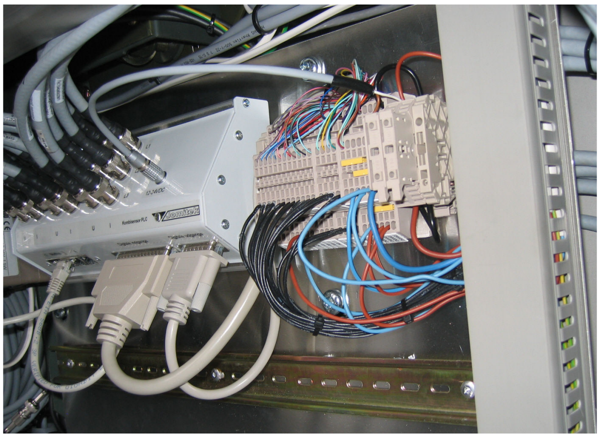


Figure 2, CombisensorPLC having 8 digital outputs and 24 digital inputs, connected to clamps.

Control signals and clamps
The digital inputs into the RTU (Remote Terminal Unit) only have to sense a voltage of 24V or 0V. Optocouplers are often used in the input stage in RTU's and they require just a few mA
The digital outputs have to signal some control-relays or contactors for the electrical motors that runs the breaker functions in the switchgear. The requirements for the wire diameters for the inputs as well as the outputs are negligeable.

Connectors and clamps have to meet a construction that withstands some harsh environmental conditions for many years. Cage clamps are the best as they will give the connection to the conductor a gas-tight connection.

Figur 3, RTU using cage clamps, Here it is from the vensor Weidmüller.

Communication

One substation – one address
Internally in a substation a number of different devices for supervision and control might need to communicate to the the remote control system. Some examples are mentioned in this text.
To make the installation process and management easy and reliable, all communication lines must be combined through just one box. This box will have just one address for the communication. The remote control will see the complete substation as one unit.
A local sensor can be the one shown in figure 4 and 5.

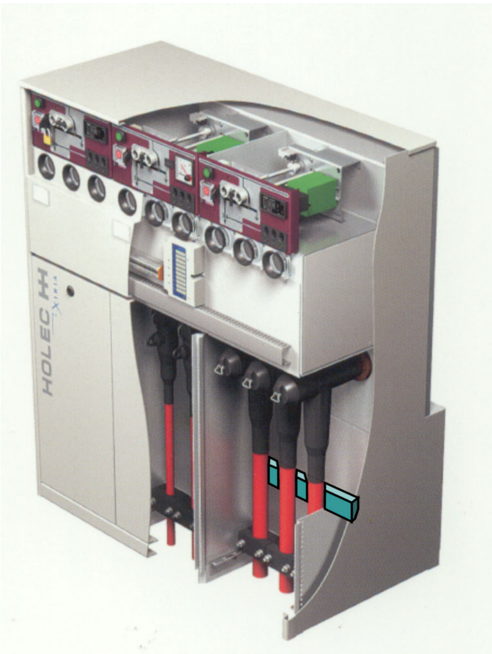


Figure 4, Xiria switchgear with motor control and with sensor position illustrated

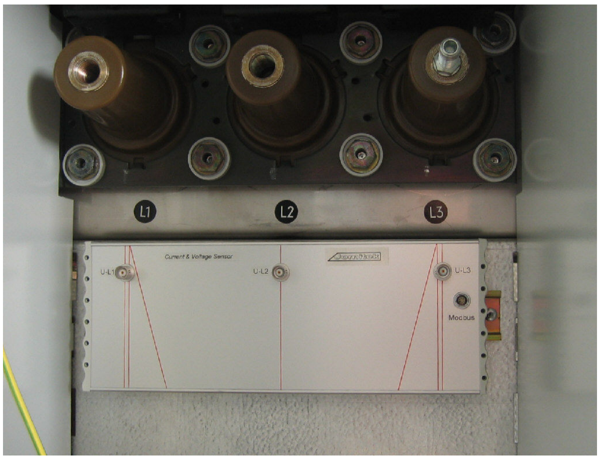


Figure 5, Compact Sensor in ABB SafePlus section

Communication
A number of communication options are available:
- Direct cable connection
- Radio Modem
- GPRS
- Optical fibre

Whenever information has to be interchanged, an electrical interface and a protocol is needed. The protocol is the language or set of commands that is understood in each end.

As electrical interface we see these options:
- RS232 (Serial – like in stationary PC's)
- RS422/RS485 (Serial - longer cables)
- Ethernet (local network or internet)

As protocols we see the options:
- Modbus
- IEC 60870-104
- IEC 60870-101

The first 2 protocols works by serial communication either using RS232 or RS422/485 as interface. The last of these protocols is intended for Ethernet (IP) communication.

Choise of protocol
As a requirement the central supervision system must be able to support the chosen protocol. As an example the ABB Becos32

system is useful for communication via the Modbus protocol. Siemens may support both the Modbus and the IEC protocols. All new supervision systems prefer the IEC protocols.

Local control

During installation and maintenance of automation equipment, it is important to have the option for a local control in the station. This tool must be able to give full control and give 'live' readouts as if it was communication to the SCADA system or even better.

An example of a local control is the Windows program shown in figure 6. This program contains all the functions needed for a local control. The program consist of just a single .exe-file that might be used on a laptop PC brought into the substation by the technician.

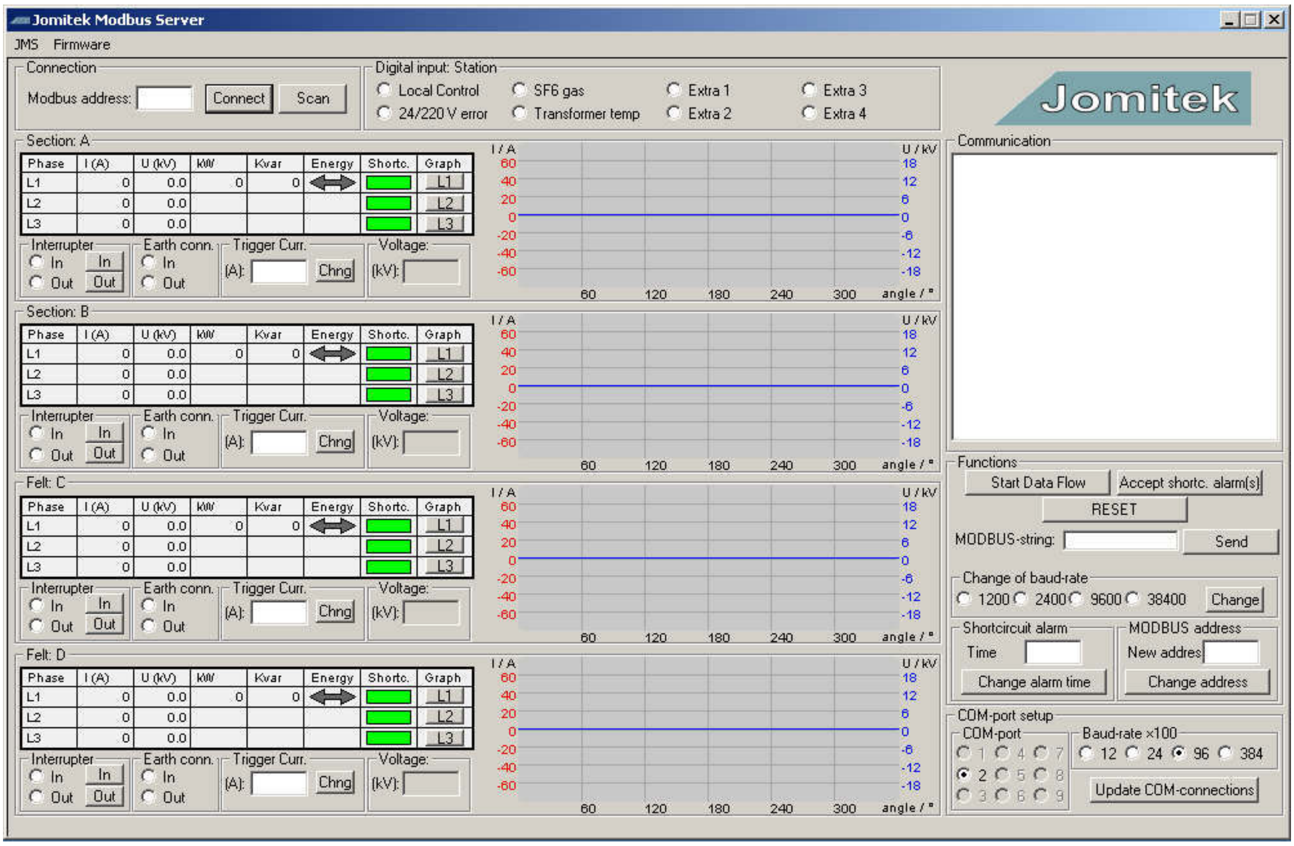


Figure 6, Software for local installation and control of substation.

Practical implementation

Sensors
For new switchgears it is possible to use the ABB c*ombisensor*, where the Jomitek C*ompaktsensor* may be used in both new and old switchgears and only require a very simple installation.

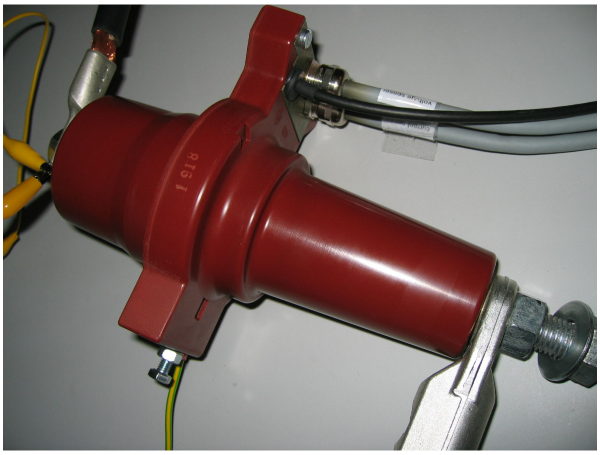
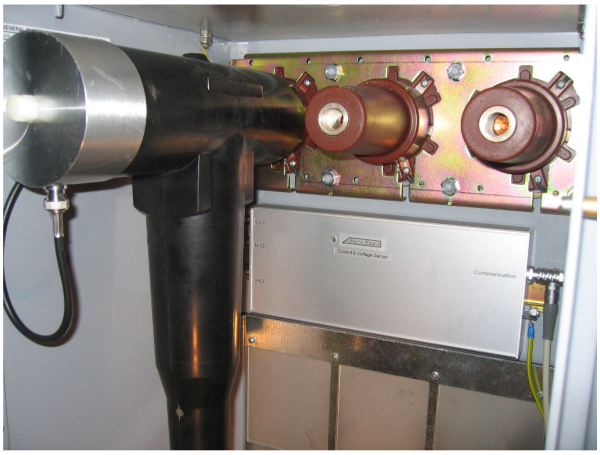


Figure 7, ABB combisensor, Lab. photo.

The *Combisensor* is placed inside the bushing and therefore this requires to be mounted in the factory. ABB delivers RTU equipment giving up to 9 analogue channels for this sensor. For this type of sensor Jomitek delivers a *CombisensorPLC*, having in total 18 analogue inputs. The Jomitek box can interface in total 3 sections having each 3 current sensors and 3 voltage sensors, giving 18 analogue inputs.
The *CompactSensor* from Jomitek is an integrated sensor and PLC unit, having a simple interface. It includes a small measurement box which through a thin cable communicates directly to either the communication modem or into the box having the digital I/Os. The *CompactSensor* is available for a number of switchgear types.



Figur 8, The CompaktSensor in a Xiria switchgear. The capacitive voltage is measured at phase R.

A simple Short Circuit Indicator
In many small substations a simple indication of short circuits is sufficient. For ABB switchgears having the ABB *Combisensor*, Jomitek offers such a simple indicator, see figure 9.

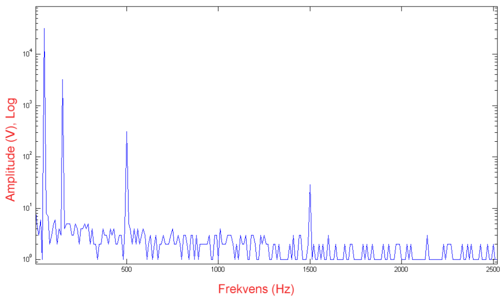
Figure 9, Short Circuit Indicator for ABB Combisensor

Substation Control in the future

By using Smarttransformers, having built in automatic voltage control, and the Wind turbines having automatic reactive power control, we are facing more switching noise from these sources.

It is of high interest to get a local observation of the harmonic noise, especially the 3rd, 5th, 7th etc harmonic of the 50 HZ frequency. The requirement is often measurement of up until the 50^{th} harmonic ie. 2.500Hz.

Using the capacitive measurement of the voltage, these measurements are easily done. The first equipment having build in frequency measurement directly into the sensors are the CompactSensors.

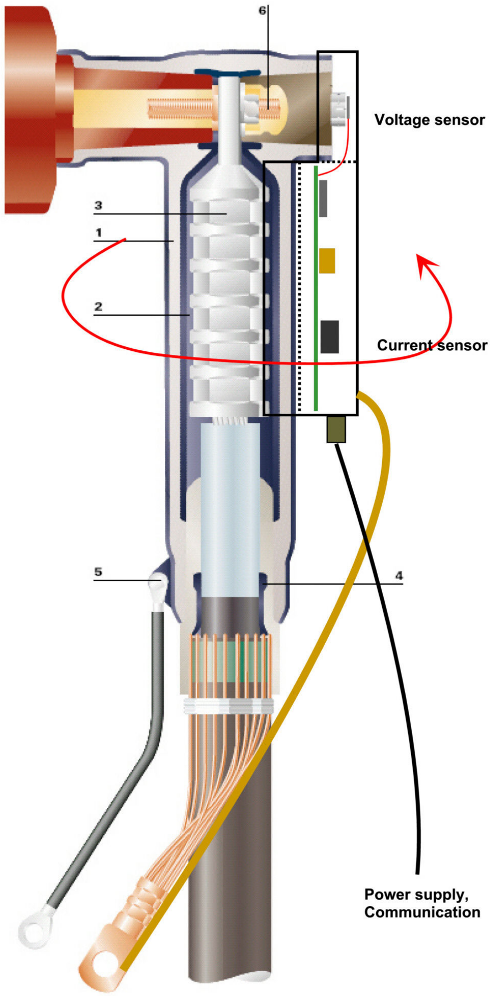


Figur 10, Frequency analysis from the CompactSensor

Using the capacitive method for the measurement of voltage, it is possible to measure even very high frequent signals. This opens for measurement of Partial Discharges (PD) in the substation where the sensor is placed.

The ultimate sensor

The ultimate sensor is a sensor which is integrated into the elbow connector. Tyco/Raychem is the first vendor that will be able to offer such a connector. It will be based on the new shielded and silicone isolated elbow connector RSTI-58. This connector is specified up to 800A and up to 24kV and the sensor part will meet this range as well. The output signal from this connector-sensor will be the same as the output signal from the other sensors mentioned in this article. It will be a serial communication giving data for current, voltage, energy direction, short circuit direction, power and reactive power. If required it will also have the option for frequency analysis.



Figur 11, The new intelligint connector from Tyco-Raychems.

Summary

This series of articles was focusing first on the options for measuring currents and voltages by use of techniques that makes installation work easy and at the same time reliable and affordable.

In the first part focus was on the capacitive measurement of the medium voltage directly, and including a number of practical implementations.

In the second part the use of semiconductor based sensors for current measurement was introduced. It was shown how these sensors are easily placed in compact switchgears without interruption of any medium voltage components.

Finally this article covers the technical implementation of practical substation automation, where the interface to the SCADA system is very simple. Examples of relevant sensor measurements and digital inputs and outputs, are shown. Additionally a number of commercially available systems are mentioned.

About the author:
Peter Johansen is the founder of the 10 year old company Jomitek in Denmark. Jomitek specializes in measuring electrical and magnetic fields. More information is available at www.jomitek.dk

Reference: “Practical Implementation of distribution automation” by *Jesper Bak-Jensen, HEF Net A/S og Hans Jørgen Jørgensen,DEFU.*

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