ON THE FIELD AUTONOMOUS AUTOMATISM: A COMPLEMENTARY WAY FOR NETWORK AUTOMATION

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ABSTRACT

Under the pressure of regulation authorities, utilities are challenged to improve their SAIDI and SAIFI indicators. Usually, to reach this goal, more intelligence is put inside DMS, increasing in the same time the amount of data to be processed and the importance of the communication in the network. An alternative way, discussed in this paper, consists of using local automatisms, allowing faster reactions and therefore a drastic reduction of the number of customers affected by permanent faults, without requiring heavy communication infrastructure. In addition, this paper introduces a further enhancement allowing a faster power restoration for the remaining affected customers.

INTRODUCTION

Challenged by the Danish authorities, DONG Energy has for a long time experimented several methods to optimize the network management and particularly increase power availability.

An important step was reached when a reduction of the maximum time to reenergise a faulty location to less than a minute was decided to avoid the outage to be counted as a long one, what is degrading the SAIDI and SAIFI indexes.

DONG ENERGY'S NETWORK

DONG Energy is a major DNO in Denmark, however this experience involves only one part of its network.

The 10kV grid in DONG Energy North, is a 100% underground radial network, with high degree of access to neighboring feeders for backup, as shown in Fig. 1.

The grid is mainly urban and consists of approximately 7000 substations on 600 Feeders.

THE CONCEPT OF SACSe SUBSTATION

First of all, let’s clarify the management of phase-to-phase and phase-to-earth faults on DONG Energy network:

- phase-to-phase faults cause a tripping of a breaker and therefore an outage: the following explains how SACSe limits the number of customers affected
- phase-to-earth faults: the network is Petersen-coil grounded, allowing temporary operation with single earth fault. However SACSe provides an earth-fault localisation information because a second earth fault would cause a tripping.

SACSe means “Sectionalizing And Changeover System enhanced”.

The concept of SACSe described below is the last evolution of the network, which has already known significant improvement over the last 10 years.

A first step was taken by deploying circuit breakers in the network [1]. The goal is to put in one strategic MV/LV substation, a line circuit breaker intended to split the feeder into 2 segments in order to minimize the number of customer affected by a fault, if it happens on the downstream side. Time selectivity is used to prevent primary substation CB from tripping simultaneously. In some cases, there could be up to two line CBs on the feeder: in such a case they would use the same setting and trip simultaneously.

The second concept is a step further. In case of phase to phase fault upstream the same substation, it allows to isolate automatically the faulty segment and re supply automatically the healthy ones. This process is based on local automatism, allowing a fast reaction, and not needing any man intervention nor communication infrastructure. The solution was developed in collaboration with Schneider Electric who offers a wide range of products for network automation.

Fig. 1 Typical feeder (neighboring feeders in white)
SACSe - Main principle:
First of all, in a given feeder, one or two substations are selected to support the automatism. They are chosen because of their location: they divide the feeder in two or three segments supplying each roughly the same number of customer. They are chosen also because of the easiness to be upgraded. The principle of layout in the network of these substations is described in the ref [2]. Second, a backup line coming from the neighbour feeder is connected to these strategic MV/LV substations to allow a backup supply if required (Fig. 2).

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These particular substations are equipped with a 4 functions switchgear (fig. 3):
- 1 fuse switch or circuit breaker for the transformer protection. It can be forgotten since it has no role in the concept.
- 2 circuit breakers and 1 switch distributed among the incoming, the outgoing and the backup ways. There are two circuit breakers among the three to be sure that there will be at least one in the circuit in all network configuration cases.

If a fault occurs downstream, the breaker opens instantaneously, isolating the downstream segment(s). The status of the switchgear is then sent to the SCADA. If a fault occurs upstream, the switchgear acts as an Auto Change Over (ACO): the circuit breaker will not trip, but the lack of voltage releases the auto changeover process, ordering the incoming to open and the backup to close, which supplies the healthy downstream segment. This is the general principle. Two cases are shown fig. 4.

Since the breaker in the HV/MV substation is delayed and those in SACSe are not, the breaker in the HV/MV sub will only trip when the fault is in the first segment (fig. 4 – case 1).

In a particular case (2 SACSe on the same feeder), a fault downstream the last SACSe results in both SACSe circuit breakers tripping. In order to re-supply the segment between the two SACSe, the downstream one will act as a Reverse Auto Change Over (RACO): based on the CB tripping information, it will keep the incoming closed, and order the backup to close, therefore re-supplying the upstream segment (fig. 5).

In all cases, the time required to reconfigure is less than 20 seconds, saving automatically up to 2/3 of the customers normally affected by such a fault.

In addition, several logics are embedded in the automatism in order to avoid any improper action in case of particular cases:
- once the ACO/RACO has operated, it is blocked until human operation from the control center to prevent further action in non standard network configuration.
- a logic is in action to avoid any ACO and/or RACO action
if the network is subject to a global outage, from the transport for instance. This event is detected by monitoring the voltage presence on the back-up line. If an absence of voltage is observed on both incoming and backup line, then no action is done.

- In case of frequency drop, a recovery process exists in the HV/MV substation, it reacts by switching off some feeders. So in this case, the ACO/RACO is inhibited to allow the load shedding process to operate in a priority way.

**Infrastructure**

Basically, the system does not require any communication means to react properly and fulfilling its purpose. In fact it is even an advantage in terms of security and reliability. But of course, it is linked with the SCADA to inform about the outage on the faulty segment, in order to restore the power. In addition, it provides its status to the operating staff as Danish regulation imposes the operation to know the real status of all switches and breakers in the network all times. By these means, several other information available in the MV/LV substation can also be transmitted. In this case, and thanks to the good coverage of the area by GSM infrastructure, GPRS has been chosen to transfer data in a very economical way.

**Earth fault**

As explained above, SACSe also integrates directional fault passage indicators (FPI). These FPIs allow the staff to locate on the field the fault more accurately and faster, and therefore prevent a tripping due to a second fault.

All these features are embedded in a single box provided by Schneider Electric and described below.

**SACSE CONTROL UNIT ARCHITECTURE**

**Functional description**

The unit integrates the following functions (fig. 6):
- Phase to phase fault protection ensured by two protection relays, for the incoming/outgoing and back-up breakers
- Phase to earth fault detection ensured by two directional fault passage indicators on the same functions
- Voltage presence on incoming, outgoing and back-up cables,
- Automatism ensuring the ACO/RACO logic
- Communication with the SCADA on the status of the substation
- Power supply with batteries to supply the unit in all conditions

In addition, LV and MV measurements features have been included in the unit to provide a much better knowledge of the substation and the network load.
In terms of size, the system is made to be mounted directly on the wall of the substation. The dimensions allow to use it even in a compact substation with reduced volume available.

Interfaces are designed to make installation simple and minimize risks of mistakes by using prefabricated cables and connectors to link the unit with sensors.

The box is equipped with a transparent window on the front door, allowing to read locally all the indications on the status of the system. If needed, by opening the front door, operating people have access to local operation.

F200C : POSSIBLE FURTHER ENHANCEMENT

Thanks to the unit presented above, the SAIDI index is drastically reduced, but the ultimate quality would require some additional instrumentation of the network:

- In case of phase fault, only half (if 1 SACSe) or one third (of 2 SACSe) of the feeder customers are affected by an outage more than 1 mn long. However, the half or third of customers in the faulty segment still need to get power back as soon as possible.
- In case of earth fault, the SACSe control unit allows to indicate whether the fault is upstream or downstream the SACSe substation. But a more accurate localisation is required in order to allow faulty cable isolation without power interruption for any customer.

Of course, for obvious cost and complexity reasons, more than two SACSe substations on a feeder are not possible. Increasing the number of SACSe substations is therefore not a way to the ultimate quality.

This means a device allowing to accurately localise both phase faults and earth faults is needed in the other substations, both upstream and downstream the SACSe. Accurate localisation would ideally mean knowing the faulty cable between 2 substations.

Schneider Electric has recently launched a new communicating fault passage indicator, Flair 200C, combining in a single cost-effective product the phase-to-phase and phase-to-earth fault detection and the GPRS communication functions. This would suit particularly well the above purpose.

It is to be noted that this new Flair 200C embeds a new algorithm for detection of phase-to-earth faults on compensated networks not requiring Voltage sensing. This allows drastically simplifying the commissioning of such devices, especially for retrofit in existing substations, as well as reducing the global cost.

Additionally, this Flair 200C can optionally provide measurements, increasing again the knowledge of network load.

CONCLUSION

More and more pressure on SAIDI/SAIFI improvement usually leads to require more performance from DMS, and at the same time to manage more and more information. A complementary way consists to use local automatism able to make quickly simple actions. By this means, in case of fault, a rough but fast reconfiguration is done while the operation is simplified.

The implementation of this requires a dedicated device so that to prevent complex commissioning to spoil the solution, and therefore the Return On Investment.

REFERENCES
