A REAL CASE OF SELF HEALING DISTRIBUTION NETWORK

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ABSTRACT

To counter an aging grid and tightening benchmark demands from regulator, DONG Energy have developed a local automated substation (SACSe) to reenergize customers on healthy sections, within one minute after fault. This is done through automatic switching of loadbreak switches and circuit breakers based on local information only. Hereby eliminating the need for fast and reliable communication and advanced DMS

Benchmark

The Danish benchmark model is based on SAIDI and SAIFI where all outages exceeding one minute, on all voltage levels, are measured. The reason for the outage and other factors are calculated into the model.

The Grid

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

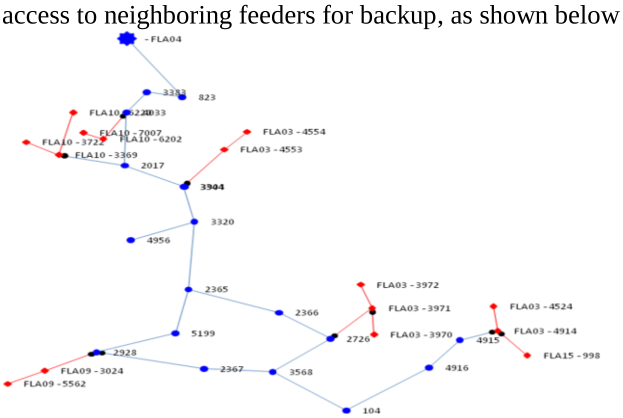


Fig. 1 Typical feeder (red is neighboring feeders)

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

Current tools to reduce SAIDI

To counter the effects of an increasingly aging grid, DONG ENERGY have used the DISCOS™ system from Powersense to remotely open loadbreak switches in specific important substations. This system is operated manually, remotely, and can only reduce the durations of outages. To reduce the frequency another tool is needed.

NEW TOOL TO REDUCE SAIDI AND SAIFI

Because of the 1 minute limit, human operation was deemed too slow and the need for automation was obvious. But whether this automation was to be a central DMS or some logic build into the local units were an open question.
The central DMS could give a more elaborate system with a higher efficiency because it would have access to more information, however for this to work, the entire process could not take longer than 1 minute including communications between the DMS and the local RTU´s. A new DMS also had to be developed to support these new functions.
So because the only possible communication platform is GPRS, and the need for a system within a very short timeframe, a local logic with the disadvantage of only having access to local information was chosen.

SACSe

“Sectionalizing And Changeover System enhanced” was developed to accommodate this need. SACSe consists of two main building blocks, a RMU[1] and a RTU[2.] Both of these are unique to the distribution grid. The RMU is equipped with two circuit breaker bays capable of tripping a short-circuit current of up to 20kA more than 40 times. The RTU includes the needed logic, as well as communications, charger, battery and over current relays for the two circuit breaker bays.

Principle

The SACSe principle works in three scenarios.
The first scenario is if the short-circuit current runs through the station. If it’s the case, the overcorrect relay trips the circuit breaker and deenergizes the faulted section of the feeder before the circuit breaker in the primary substation (H) trips, and leaves the customers, between the primary substation and the SACSe station, from experiencing an outage.

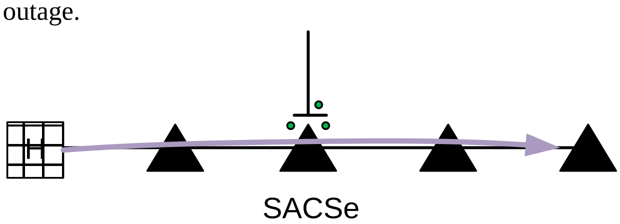


Fig. 2 Normal operation of feeder

1 Ring Main Unit
2 Remote Terminal Unit

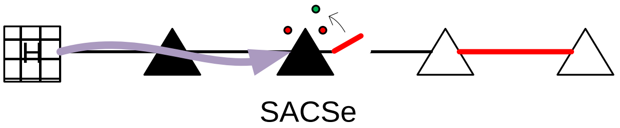


Fig. 3 Operation post fault on red cable (downstream)

If the fault however is between the substation and the primary substation, the SACSe stations does not see the fault current, and feeder is deenergized because of the tripping of the circuit breaker in the primary substation. This causes the SACSe station to open the upstream breaker and close the breaker to the backup feeder. Also known as "Auto Changeover" or ACO

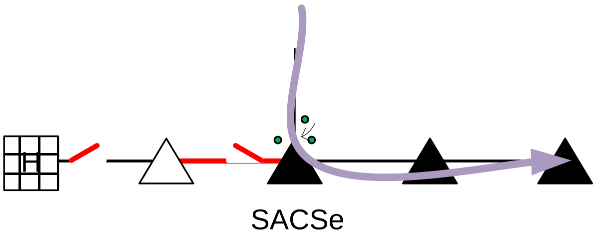


Fig. 4 post fault on red cable (Upstream)

The third scenario is when the fault is downstream, and as in the first scenario, the circuit breaker in the SACSe stations trips, but after the fault, the SACSe2 station is deenergized due to another SACSe station between the SACSe2 station and the primary substation. If it is the case, the SACSe2 station will reenergize upstream. This is a reversed ACO, and is called RACO

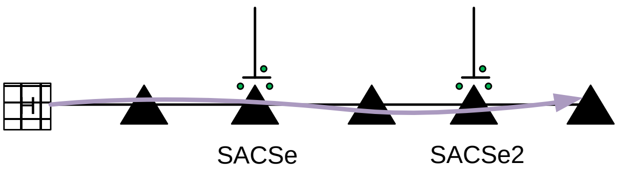


Fig. 5 Normal operation of feeder with two or more SACSe stations

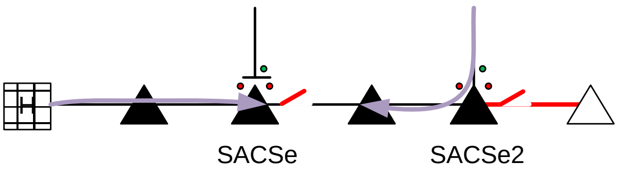


Fig. 6 Operation post fault on red cable, SACSe 2 made a RACO

As described the SACSe concept works in many different scenarios, and more SACSe units can operate on the same feeder. Because of the two circuit breakers in a SACSe station almost any combination is possible, including a simple short-circuit protection on a feeder that splits the feeder in to two branches, where the circuit breakers is placed on the outgoing branches of the SACSe station, so a fault only deenergizes one branch and not the entire feeder

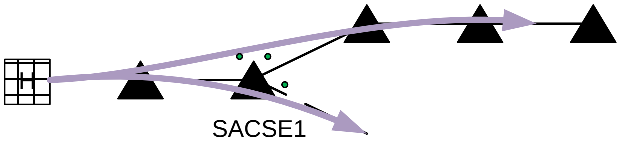


fig. 7 Normal operation of feeder

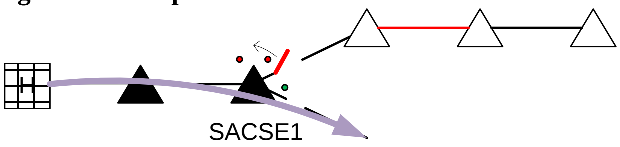
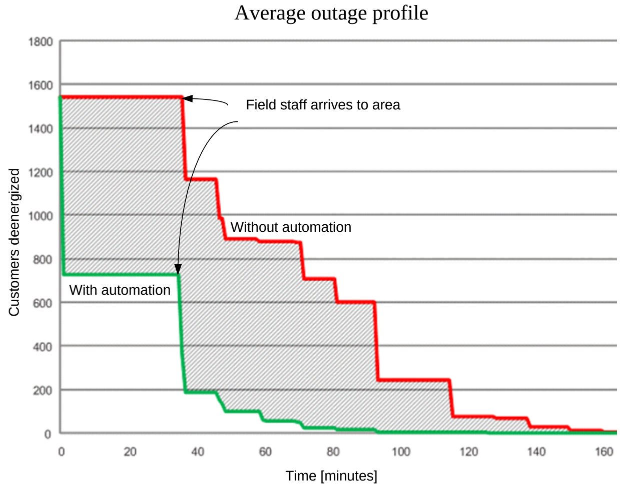


Fig. 8 Operation post fault on red cable (downstream)

The SACSe stations react semi-automatically to network reconfiguration by the switching algorithmic dynamically defines upstream, backup and downstream

Outage reduction on automated feeders

In the concept face, a case study has been made to investigate the expected results of implementing automation on a feeder. In the study the time to reenergize each substation was calculated for every possible single fault and the average outage profile for the feeder was calculated. This was done with and without automation implemented on the feeder



The large decline in the first minute is due to the SACSe concept reenergizing customers. Hereafter the remaining customers must wait for a technician to arrive and manually reenergize the rest of the feeder. With automation this process is also faster due to the information already known at this time

Hardware

From the beginning the goal has been to develop as system that only requires a minimum of installation on site. However it had to be divided into a RTU and a RMU, as the RTU was too large to be build into the RMU.

RTU

The RTU used in the 4 pilot installations is a T200 from Schneider electric. The T200 is extended to accommodate the higher hardware and logic demands of the SACSe concept. It includes installation of over current relays, directional earth fault detection, implementation of RACO and other upgrades.

RMU

The two main technical issues about the RMU are first the number of operations on opening on a short-circuit current. Only a few suppliers had the demanded numbers (beyond 40). The second issue is the physical dimensions of the RMU as some of the substations equipped, will be in substations with very limited room.
In the pilot two Xiria from Eaton Holex and two FBX from Areva have been tested, and 23 additional identical Xiria has been built into the grid, only with a simple over current protection, later to be upgraded to full scale SACSe.

Tests

The new concept of having switches opening and closing without human intervention in grid, demanded a comprehensive test to ensure intended operation. Since it is not a possibility to impose faults in the real grid, the second best solution was to set up a test feeder in a power laboratory. This test was done at low voltage, but with a short-circuit level of 6-8 kA.

Fig. 9 Test Setup at laboratory

The second test is a field test, this test is not as comprehensive of nature and intends more to test communication, installation and operation.

Communication and SCADA

The function of SACSe stations does not depend on communication when a fault occurs, but it's necessary to be able to communicate with the unit to have remote control possibility and to retrieve any changes in breaker position etc. Measurements of U, I, P and Q are also retrieved to be used in an online state estimator SmartPIT (Cired 2009-0435). As stated earlier the only possibility was to use GRPS as medium and it was chosen to use the IEC 60870-5-104 communication protocol because this already is implemented in SCADA (SPC) and will be used in all other equipment in the future. The current DMS does not support IEC 60870-5-104, but this is to be changed within 2 years, where a new active DMS is implanted. So for now the stations interfaces with SCADA.

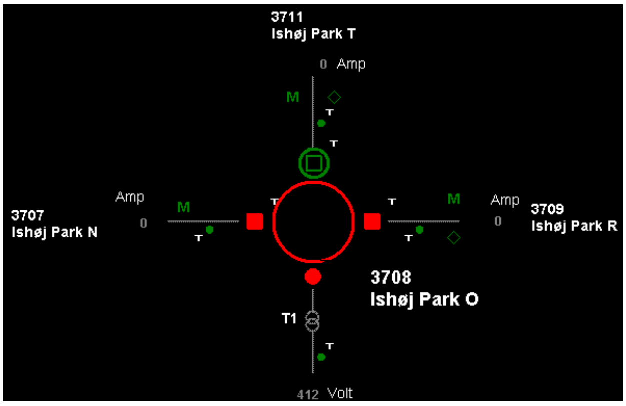


Fig. 10 SACSe UI in SPC

CHOOSING SUBSTATIONS FOR AUTOMATION

Technically SACSe can be placed with a number of stations on every feeder, and would affect SAIDI and SAIFI the most if it is done. But SACSe are more expensive than normal substations, so only a number of stations can be build into the grid. Therefore it's important to choose the correct substations on the correct feeders to affect SAIDI and SAIFI the most.
The first step is to locate the feeders that will affect the key figures the most in the future. Only to look at the worst feeders in the past will not be the correct way as the faults here may origin in a little section of bad cable or a lot of building activities. Therefore both the history of the grid and the theoretically worst feeders has been evaluated and the feeders that is bad in both history and theory is the best guess to be the ones affecting the SAIDI and SAIFI most in the future.
In the way SAIDI and SAIFI are calculated, it's not only the frequency and duration of interruptions are important, the customers affected are equal important, so it might be more efficient to choose a feeder with a lower fault ratio but with many customers

When the Feeders are chosen, the next step is to find the optimal substation on these feeders, not only in terms of most reduction in SAIDI and SAIFI but also in terms of most value for money. It's more efficient to replace and old substation than a relative new one.

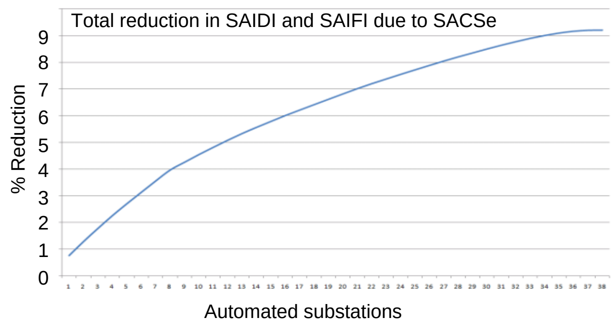
To evaluate the benefit of a substation on a feeder, 2 methods have been tested. The first is the one mentioned earlier in this paper, where every fault is calculated by hand, with and without automation.

The second method is developed in cooperation with NEPLAN® from BCP. This tool has been extended to accommodate automated substations in the reliability algorithm.

Several iterations of the process was necessary, as a feeder might be bad in SAIDI and SAIFI, but the automation was expensive or might yield little benefit because of the topology, so it might be better to choose another feeder.

Expected results

Simulations have shown that there is not a linear function between the number of automated substations and the total reduction in SAIDI and SAIFI achieved. This is because the worst feeders with the most customers and best topology are equipped first. Every substation equipped here after will decline in total efficiency as one or more of the parameters are going down. For the first 38 stations in DONG Energy´s Northern grid (600 feeders) the total drop in SAIDI and SAIFI are expected the graph stipulates:



Current state

As for now the first 4 pilot installations are installed and tested in the grid, and are working online.

Fig. 11 First online SACSe station

FUTURE

The plan is to install up to 200 SACSe stations total in the grid (3% of substations). However the specifications of the 4 pilot installations are to be extended in the next generation to support a more dynamic grid. And over the next years, the benefit in terms of SAIDI and SAIFI will be monitored and the number of automated stations adjusted accordingly.

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 in using local automatism, able to make simple actions quickly. By this mean, in case of fault, a rough but fast reconfiguration is done while the operation is simplified.

ACKNOWLEDGMENTS

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