SACSe

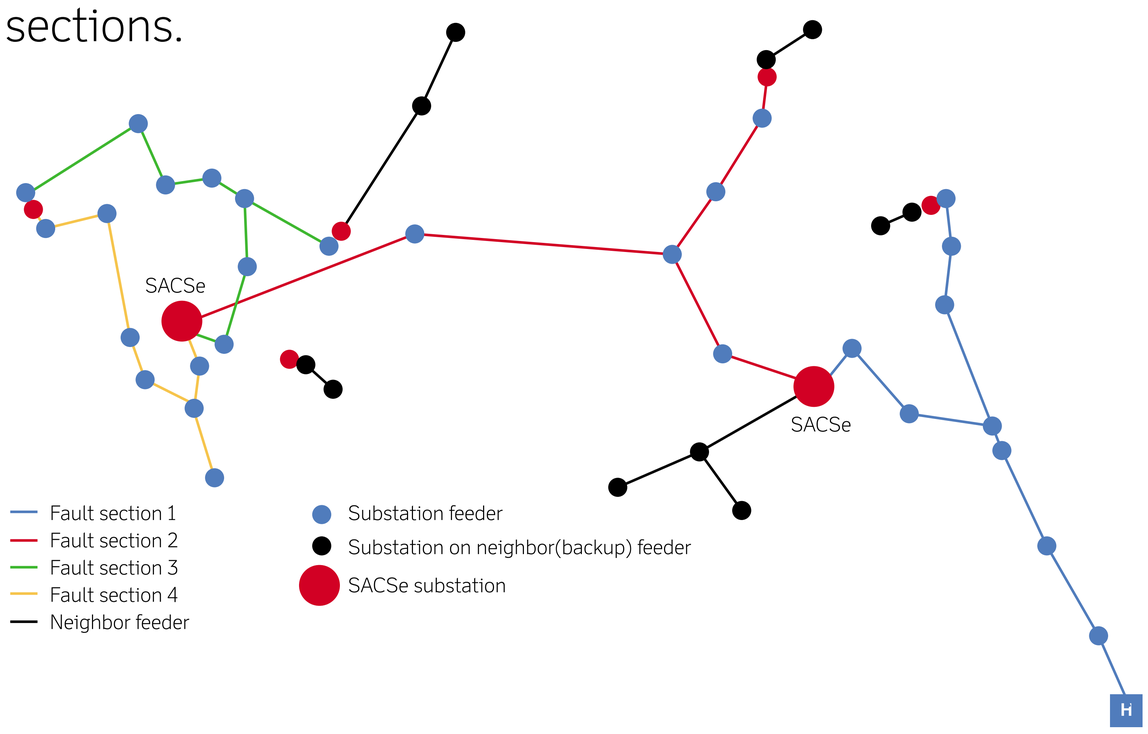
A REAL CASE OF SELF HEALING DISTRIBUTION NETWORK

Regulatory demands on SAIFI and SAIDI drives the need for automotive substation capable of re-energizing customers within 1 minute, without the need for fast communication and advanced DMS.

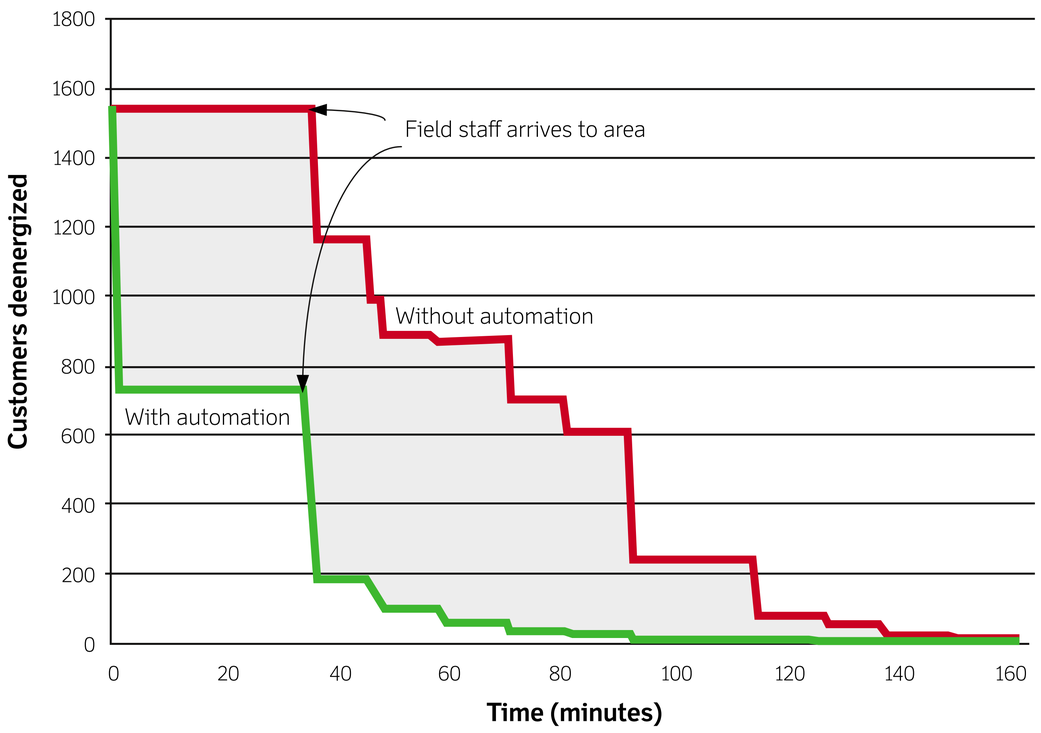
SACSe(Sectionalizing And Changeover System enhanced) uses logic, relays, circuit breakers, motor drives and only local information to deliver this functionality.

2 SACSe substations applied to a feeder yield a dramatic decrease in SAIDI and SAIFI for the feeder.

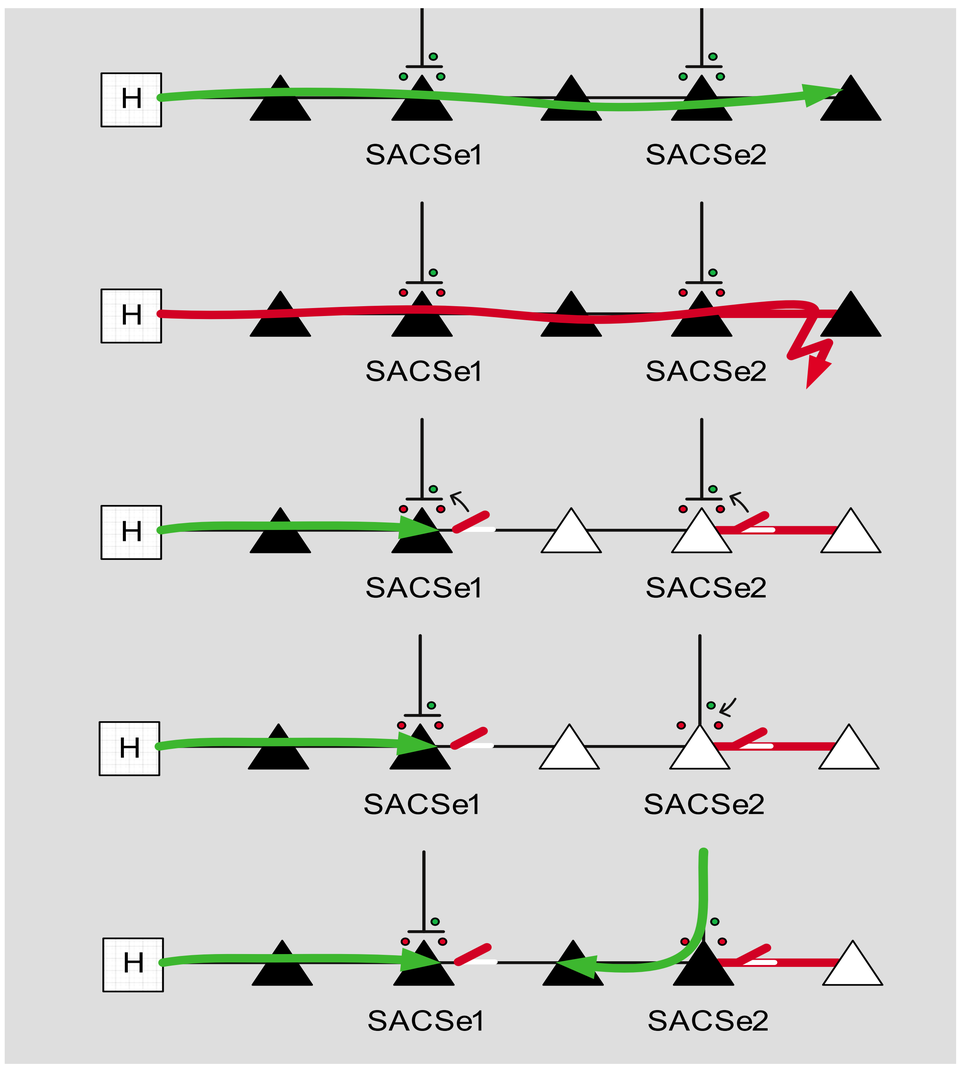
2 SACSe substations divides the feeder into 4 fault sections.



Average outage profile



SACSe switching with 2 substations on a feeder with a the fault downstream.



Current SACSe consists of a Xiria RMU from Eaton Holec and a T200P RTU from Schneider.

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USING CONTINUOUS STATE ESTIMATION IN GRID PLANNING

In 2008 DONG Energy implemented the IT solution 'SmartPIT' that determines all line flows, transformer loads and bus voltages in the entire MV network every 10 minutes – allowing for analysis, planning and operation on actual hour-by-hour values rather than peak estimates.

DATA AQUISITION FROM PRIMARY SUBSTATIONS

Primary substations are monitored with a traditional SCADA system.

Data imported into SmartPIT every 10 minutes are:
- Bus configuration and voltage at primary substations
- Load currents at feeder head
- Switching state (topology) in MV network

VALIDATION OF MEASUREMENTS

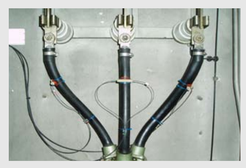
Incoming measurements are validated with the ILog rules tool. The purpose is to:

- Protect state estimation calculations against implausible measurements
- Notify the operator so 'bad' measurements can be found and rectified
- Scale measurands to correct units
- Other logical rules

DATA AQUISITION FROM SECONDARY SUBSTATIONS

Secondary substations are monitored using the distribution automation system Discos from PowerSense.

Data imported into SmartPIT every 10 minutes via GPRS are:
- Phase currents
- Active and reactive power on MV lines and transformers
- LV voltages



NETWORK DATA

In order to build an exact network model for the continuous calculations, network data are imported once every 24 hours from two sources, SAP PM and GIS:

- MV lines
- HV/MV and MV/LV transformers
- Generators
- Network structure and line lengths

LOAD DATA, 'SMALL' CUSTOMERS

For customers consuming less than 100,000 kWh/year, the only information known is expected energy sales for the next year.

From SAP IS-U, the following information on more than 900,000 customers is retrieved once every 24 hours:
- Expected annual consumption
- Load Category
- Topological connection to network

Energy sales are then converted into synthetic load curves.

SOLUTION OVERVIEW

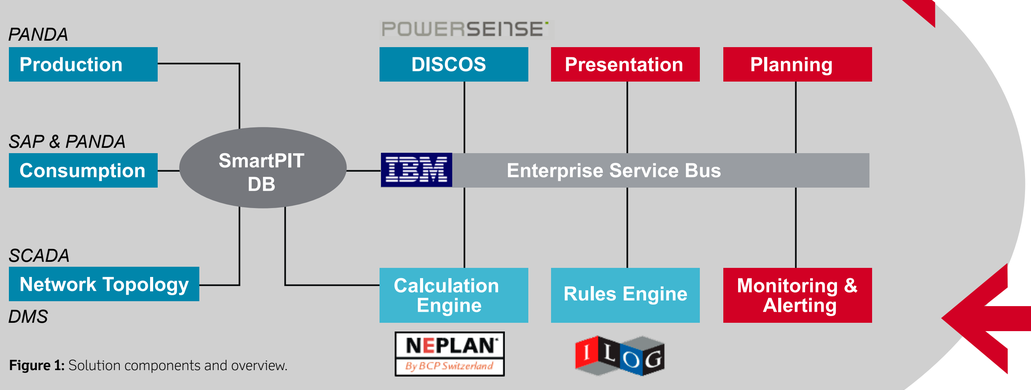


Figure 1: Solution components and overview.

LOAD DATA, CUSTOMERS WITH AMR

In Denmark, automatic meter reading (AMR) is mandatory for customers with an annual consumption above 100,000 kWh:
- Readings are retrieved once a day via SMS or dial-up lines
- Measurements are checked for validity and sent to SmartPIT after 72 hours
- Data contain hourly sales; i.e. kWh/h and is used as an estimate for the mean load in that specific hour.

LOAD DATA, EMBEDDED GENERATION

Embedded generation is quite common in Danish MV grids.

The most usual types are:
- CHP (Cogeneration Heat & Power) plants; typically in the 100 - 5,000 kW range
- Wind turbines; typically in the 100 - 2,000 kW range
- Wind farms; typically in the range of several MW

Data is handled like AMR data.

FROM PEAK LOADS TO SYNTHETIC LOAD CURVES P(t)

In DONG Energy's case, 22 different seasons are used instead of weeks and months; some several weeks long, other just a few days, e.g. Christmas, to give the best possible representation. This gives actual load of:

$$P(t) = P_{max} \cdot Profile_{day}(t) \cdot Profile_{season}(t) \cdot Profile_{year}(t)$$

By analyzing a large number of actual load curves, synthetic curves are defined for workdays, Saturdays and Sundays in all seasons; see example below:

'High' curves represent workdays; 'low' curves are Saturdays and Sundays.

Profiles show a clear variation over hours, weekdays and seasons.

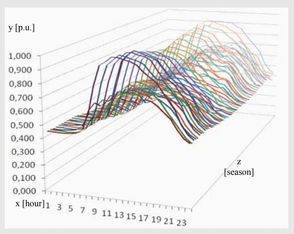


Figure 2: Synthetic load profiles for 'Bank & Insurance'

FROM ANNUAL ENERGY TO PEAK LOADS Pmax

All non-telemetered customers are divided into 27 unique categories, giving a fine discrimination between different load patterns. For each category, annual energy sales Q are converted into to peak load Pmax, using Velander's formula:

$$Pmax\ [kW] = A * Q\ [MWh] + B * \sqrt{Q}$$

Parameters A and B have been determined for all 27 categories, using up-to-date load measurements.

CONTINUOUS NETWORK STATE ESTIMATION

From the information imported into SmartPIT, a full network model including loads and generators is built.

- Approx. 7,000 secondary substations are modelled in this phase
- Calculation 'engine' is the planning tool NEPLAN from BCP
- State estimation uses load balancing
- The simultaneity factors of the synthetic load curves are adjusted to meet power or current measurements

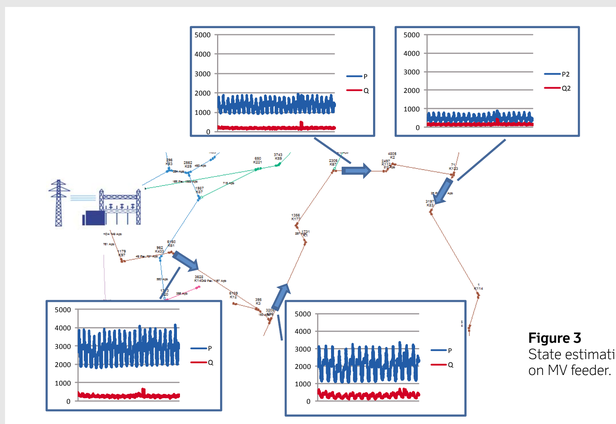


Figure 3 State estimation on MV feeder.

Calculated flows and voltages are returned to SmartPIT and stored as 'virtual' measurements. Now, the network can be analyzed, planned and operated on basis of the actual 10 minute loading of individual components.

TEST RESULTS

Good estimates of loads and voltages
The synthetic load curves and the calculation methodology has been validated by comparing estimated and real loads on two feeders, densely equipped with Discos units.

The figure below shows estimated and actual current [A] on MV feeder GHOA3 from 7th December 2007 to 14th January 2008:

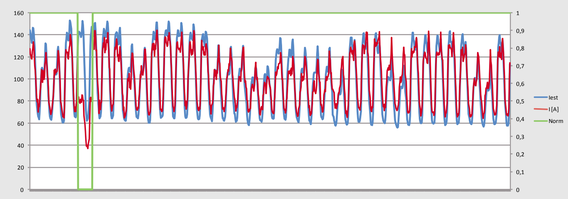
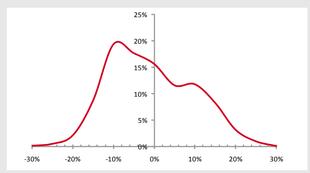


Figure 4: Calculated and measured MV feeder current.

Blue and red curve is estimated and actual current; green curve shows an abnormal switching state on 11th December. In general, estimates proved quite fair with a MAPE value (Mean Absolute Percentage Error) at approx. 9 % before supportive Discos measurements.

The absolute deviations over the period are:



Next step is to include Discos power flow measurements on feeder branches to improve these figures.

Figure 5: Error distribution curve, feeder GHO A3.

BUSINESS PERSPECTIVES

Dimensioning MV feeders where the only information available is energy sales and peak load at feeder head is a well-known challenge.

The traditional approach based on energy sales has several shortcomings:
- Empirical corellations are rarely updated and do not reflect changes in e.g. load utilization time over the years
- Solution will satisfy feeder peak load, but not true line and substation peak load
- In networks with embedded generation, line loads may be severely under- and overestimated
- Load variation over time is not available, meaning that assets must be dimensioned to carry peak load 'for ever'

Historically, utility companies have had either to build in enough network capacity to handle the uncertainties above leading to higher investment costs or to accept the risk of compromising network safety and power quality.

With the help of the SmartPIT solution from IBM:
- Real peak load data for individual components have become available
- Voltage levels may be monitored continuously
- Synthetic load curves permits a reliable MV network state estimation even with a low number of live measurements
- Capital expenditures can now be optimized and directed to the real bottlenecks of the network.

By taking this step towards the Intelligent Utility Network, DONG Energy becomes able to make more efficient use of existing electrical infrastructure and avoid unnecessary grid reinforcements plan more intelligently for the future.

The expected reductions in grid investments provides a good business case in it-self for the SmartPIT system, but the SmartPIT system is at the same time a necessary first step and an integral part of DONG Energys SmartGrid vision for a grid with an increased amount of embedded generation and flexible demand including a high penetration of electric vehicles

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