Congestion Management in Distribution Networks

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Current Situation and challenges

• Old and Aging Networks

• Increase in demand

• Fossil fuel replaced by renewables

• Increasing number of DER

• Insufficient use of DER

• Safe, reliable and resilient

• Costly traditional solutions
IDE4L Solutions

- Active network instead of a passive network
  - Decentralized
  - Automated
  - Hierarchical

- Postponing the costly traditional solutions

- Using the full capacity of distribution networks
  - Monitoring the state of the network
  - Automatic decentralized solutions to solve congestions
  - Better use of distributed energy resources – e.g. through market place

Developed algorithms

- State Estimation
- Forecasting + State Forecasting
- Secondary Power Control
- Tertiary Control
  - Network Reconfiguration
  - Market Agent
  - Dynamic Tariff
DB: Data base
NRA: Network Reconfiguration
MA: Market Agent
FC: Forecaster
SF: State Forecaster
LF: Load Forecaster
PF: Production Forecaster
SSAU: Secondary Sub-station Automation unit
PSAU: Primary Sub-station Automation unit
DMS: Distributed Management System
TC: Tertiary Controller
MVSAU

DB

PF

SF

FC

PC

SE

LVSAU

Aggregator

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TC: Tertiary Controller
Technical Aggregator == Tertiary Control

NRA including PC

Market Agent

DT

Several Primary substations (MVPC)

Several Secondary substations (LVPC)

Market Operator

Other Market participants

Bidding process

TSOs

Flexibility Activation signal

Bidding process

Com. Agg. 1

Com. Agg. 2

Com. Agg. 3

Com. Agg. 4

Com. Agg. k

Com. Aggregator Assets

Control Signals

“Directly” controlled MV Flexibility activation signal

Flexibility under pre-defined contract with Com. Agg.

“Directly” controlled LV Flexibility activation signal

Flexibility under pre-defined contract with Com. Agg.

FLISR
IEC 61850 Protection Function Parameters Update

Decentralized IEC 61850 FLISR Solution

Tertiary Controller
Feeder Automation based on IEC61850

• Design of a decentralized solution based on the coordination among different IEDs distributed along MV lines and the use of IEC 61850 GOOSE communication services to accelerate the decision taken
Background

- Changes in topology for fault restoration and congestion management

- Impact of high rate of DG connection on protection systems operation: Blinding effect, unnecessary operations, Failing autoreclosing, unintended islanding...

- **28% of the malfunctions** of protection functions are already caused by **wrong configurations** according to the North America Electric Reliability Corporation last report
Inflection point

- Application of IEC 61850 standard for feeder automation
- Current trend of replacing switches by breakers along distribution feeders
- Frequent changes in network configurations to fulfil optimization functions
- Protection system reliable operations in networks with DER and DG connection
IEC 61850 Protection Function Parameters Update

Decentralized IEC 61850 FLISR Solution

Tertiary Controller
IEC 61850 Protection Function Parameters Update

• Objective
  Process to change remotely functional parameters and data subscriptions in peer to peer communications without interrupting operation

• Schema
  • Protection, monitoring and control functions modelled with standardized Logical Nodes
  • Embedded Logic at IED level for dynamic reconfiguration
  • Use of MMS messages to update:
    • LN setting values
    • GOOSE ID subscriptions
IEC 61850 Protection Function Parameters Update

Decentralized IEC 61850 FLISR Solution

Tertiary Controller
Decentralized IEC 61850 FLISR Solution

Included Use Cases
- FLISR using auto reclosers
- FLISR based on distributed control
- Islanding protection using communication command
- Configuration of IEDs

IEC 61850 parts, as of 2013
IEC 61850 future parts (already engaged)

*: use of IEC 61850 over WAN can/will take advantage of IEC 61850-80-1, IEC 61850-90-2 and IEC 61850-8-2 (web based), and IEC 61850-90-12 (WAN)
Decentralized IEC 61850 FLISR Solution

• Objective
  Decentralized FLISR Schema based on IEC61850 GOOSE messages that contemplates different interruption technologies at distribution level, islanding mode protection and new IEC 61850 guidelines

• Schema
  • Decentralized logic selectivity using GOOSE messages
    • 1st Isolation Step – Performed by IEDs controlling circuit breakers. IED closest to the fault is responsible for clearing the fault by opening a breaker.
    • 2nd Isolation Step – Performed by IEDs controlling switches. IED closest to the fault is responsible for minimizing the outage area, allowing the tripped breaker to reenergize healthy sections of the feeder
  • Loss of Mains Protection by means of IEC 61850 messages with MV IEDs
  • MMS messages to report status and interact with SAU algorithms
Decentralized IEC 61850 FLISR Solution

MG and DG Block Opening
Reclose Cycle Successfully Finished

MG and DG Block Opening
Connect Breaker Status

Breaker Status

SW Status

Breaker: 1,3,7,11,12,14
Switch: 2,4,5,6,8,9,10,13
Simulation of the decentralized solution

A tool has been developed to simulate the communication between IEDs, together with the state of the electric grid.

- It is based on OMNeT++
- It can show an animation of the FLISR process
- It can register the interchange of messages for later examination
Simulation of the decentralized solution

Multiple simulations and statistical analysis are used to evaluate the robustness of the solution, depending on

- the reliability of the communication channels
IEC 61850 Protection Function Parameters Update

Decentralized IEC 61850 FLISR Solution

Tertiary Controller
Network reconfiguration algorithm

- Schema
Tertiary controller for network congestion management

- Specifications
  - Automatic control of the whole network (PC + NR)
  - Connection to the market place
  - Automatic utilization of flexibility services to DSOs
  - Economically optimizing network operation
  - Functioning as a slow restoration solution for network faults
  - No direct control of DER. DER activated through the market place
  - Day ahead + on-demand operation
  - Located at control center
Real-Time Operation in the A2A Network: FLISR signal + high demand

Tertiary Control: Network Reconfiguration Algorithm (NRA)

- After a fault at F9 (high demand) NRA restores the isolated load appearing an overloading in some branches of the new topology.
- After a fault at the rest of sections (F1…F14) NRA restores the isolated without congestion.
Real-Time Operation in the A2A Network: high demand + fault at F9

Tertiary Control: Market Agent Algorithm

- After Faults at F9 (high demand) NRA restores the isolated load, but line E23L01-SS545 remains congested in a 108% (new topology).
- The market agent makes use of the available CRPs already contracted (shown in the table).

Solution found:

- Flexible loads at nodes 297 and 1006 should decrease in 150 kW.
- Aggregated LV load at node 1056 should decrease in 106 kW.
- Cost of the activated flexibility: 28.95 €/h (per activation).

<table>
<thead>
<tr>
<th>Node</th>
<th>Quantity (↓ demand) [kW]</th>
<th>Activation Price [€/MWh]</th>
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<tr>
<td>297</td>
<td>150</td>
<td>70</td>
</tr>
<tr>
<td>1006</td>
<td>150</td>
<td>70</td>
</tr>
<tr>
<td>1056</td>
<td>110</td>
<td>75</td>
</tr>
<tr>
<td>1512</td>
<td>150</td>
<td>70</td>
</tr>
</tbody>
</table>
Real-Time Operation in the A2A Network: FLISR signal + high demand

Tertiary Control Output

**Scenario 2**

- **Pisolate (after Fault)**
- **Prestored (after NRA)**

**Imax Branch (%)**

- **After NRA**
- **After MA**
- **TC output**
Secondary controller for network congestion management

• Specifications
  • Automatic control of a local network
  • No connection to the market place. Only direct control (through an aggregator – predefined contracts)
  • Coordinated operation with upper level controllers
  • Voltage control
  • Real time operation + congestion forecasting
  • Located at secondary and primary sub-stations
The Low Voltage Power Power Controller is effective in curtailing active from PV units...

Active Power in Congested Network

- 1a. BAU – Net Load
- 2b. Congestion – Net Load
- 2b. Congestion – Curtained DG

Feeder capacity limit
The LVPC is also effective at minimizing reactive power flows:

Reactive Power Flow at Grid Connection

- 1a.BAU
- 1b.50%-DER
- 1c.100%-DER
Dynamic Tariff (DT)

- Dynamic tariff is changeable at different time and different node, implemented by the following procedure:
  - Step 1: DSO collects information for day-ahead energy planning
  - Step 2: DSO calculate and publish DT before closure of spot market
  - Step 3: DR at the commercial aggregator side - Aggregator make energy plan based on DT and energy price
  - Step 4: Commercial aggregator submit energy bids to spot market

Time frame of the DT method
Concept of DT Method for Congestion Management

Main features:
- Decentralized control framework
- The DSO has the chance to maximize the social welfare
- It can be easily integrated into the existing market
How breakthroughs will be achieved

- Development of algorithms
- Test of algorithms as individuals as well as one whole system
- Analysis of functionality and performance
- Promoting economical values for DSO
- Integration to the other pieces of the developed concept
- Promoting an IDE4L concept
Thanks for your attention

• Questions?