IEC 61850:n hyödyntäminen pientuotannon hallinnassa

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Protect-DG

19.9.2017
**Tuloksia**

- IEC 61850 pohjaisten loogisten solmujen (LN) määrittely kevyeen IED laitteeseen (BeagleBone)

- Adaptiivinen mikrosähköverkon suojaus
  - Aushiq Ali Memon, ”AC Microgrid protection utilizing IEC 61850 based communication - Case study of adaptive protection of radial AC Microgrid in PSCAD”, Presentation at The Nordic Workshop in Power System Protection and Control, Trondheim, 23.5.2017
  => draft paper

- Mikrosähköverkon tehon hallinta
Microgrids

In recent years, the structure of the electrical power system has changed, and all aspects of power generation have shifted towards bidirectional and smart methodology. The Microgrid (MG) as a popular concept for the modern grid and advanced communication techniques play major role in future smart grids.

Microgrids consist of a number of Distributed Generation (DG) systems organized together in a way that increases the system capacity and improves power quality. The smart grid dictionary defines an MG as a small power system formed of various self-contained generators (such as wind turbines and photovoltaic cells), storage systems (such as batteries and super capacitors), transmission elements, and distribution and energy management devices, which are capable of operating in either island or grid-connection modes.

The integration of Information and Communication Technologies (ICT) into existing power system is one of the major differences between smart MGs and traditional electrical system.
Radial AC Microgrid System under study (20/0.4 kV, 2.4 MW):
- Load and generation assumed balanced with additional energy storage

Grid-connected:
Fault F1:
Method-A:
1) Non-adaptive IED1 detects fault and trips CB1 in 20 ms.
2) After tripping CB1, IED1 sends GOOSE message to IED2 and all IEDs within AC Microgrid (20-40 ms two-way transfer time)
3) CB2 will transfer trip to isolate fault F1 completely (20 ms)
Method-B:
1) IED1 detects fault and send GOOSE message to IED2. CB1 tripping and message transmission occurs at the same time (20 ms)
2) IED2 trips CB2 after receiving GOOSE (20 ms)

-After receiving CB1 status signal, DGs set-points change to islanded mode and all adaptive IEDs change to islanded mode settings.)

Method-C: Communication failure/data loss
IED2 trips with adaptive settings with AC Microgrid already islanded.
-Islanding detected by DG undervoltage.
Adaptive Protection IEDs

- Instantaneous Overcurrent Protection
- Overload Protection
- Time Overcurrent Protection

Grid 0
Island 1

Adaptive OC protection IED (Line/Load/DG)

- Adaptive OC protection has been studied
- Focus only on 3-Ph faults in distribution lines and LV load
- Generic DG models have been used
- DG models provide LVRT up to any fault duration by default, any value of \(I_{g_{max}}\) can be selected (1.2 pu selected)
- Decision of adaptivity made by IEDs based on CB status transfer

Adaptive OC protection with backup voltage protection for AC Microgrid loads

Multifunctional adaptive protection IED for DGs
Conclusions:

- Adaptive protection can be realized in AC Microgrid using IEC 61850 Communication Standard.
- Undefined and unpredicted communication delays between IEDs create challenges for adaptive protection settings/coordination, since fault current by DGs can be supplied for limited time (150 ms or less).
- Monitoring of communication channel continuity at each IED is a must.
- Passive anti-islanding protection of DGs should be activated when communication link fails.
- DGs with well defined LVRT are needed for adaptive OC protection to work even if communication links are faulted.
- High speed transfer trips (CB status signals) via GOOSE messages are useful for seamless operation of AC Microgrids.
- Fault current magnitude before and after fault at fault location shared with other IEDs will help finding fault location quickly.
- OV/UV voltage protection may be required for back-up of adaptive OC protection.
- For complex systems adaptive directional OC will be required.
Microgrid control – Previous research

MG systems consist of two main parts: the power system and the communications system. From power system point of view, an MG is composed of three different units: the Generation part, the Energy storage system (ESS) and the Load; the critical point in such a system is to control the generation and ESS by managing the power between them.

To achieve optimum operating performance, hierarchical control needs to be implemented. The hierarchical control can be described as having four levels for MGs. The control levels are responsible for processing (inner control loop), sensing and adjusting (primary level), monitoring and supervising (secondary level), and maintaining and optimizing (tertiary level).
Implementation of IEC 61850

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Hierarchical information structure

The hierarchical information structure for monitoring and managing MGs based on IEC 61850 can be defined in three different levels:

- **Station level** (*Human–Machine Interface (HMI) and SCADA systems*): on this level the MG is generally managed and operates in both automatic and manned management modes.

- **Bay level** (*protection relays and control devices*): Supervising, monitoring, and controlling the MG are all performed in this level. The metering and monitoring data from lower levels is received and sent to the station and process bus after meeting management targets.

- **Process level** (*Current or Potential Transformers (CTs, PTs), Circuit Breakers (CBs), and DG and ESS output/input*): This level has a direct interface with the power system and their power electronic devices (such as inverters and converters). The output power of the sources and the power management in ESS is based on a signal received from the bay level. Generally, each device on this level has its own data manager, measurement, and conversion modules.
Control principles

- MGs can operate in either island or grid-connection mode, and power converters in this system operate on voltage and frequency bases in island mode and on active and reactive power in grid-connection mode. In both operation modes, sensing, transferring, and exchanging data is done through communication interface.

- The first step in MG control is the control of the source operating point using power electronic devices; this is responsible for determining the frequency and voltage inside the sources. The voltage reference value for the inner control loop is determined through the primary control level and depends on the state of the MG, these two levels (inner control loop and primary control) can be implemented in the power system section without any communication link (e.g: by droop control). However, two other control levels (secondary and tertiary) are based on communication links and are implemented in the bay and station levels; the reference value for primary and secondary control levels are then available in the process and station buses, respectively.
Microgrid control basing on IEC 61850

- The bay level receives the measuring value, such as power generation of sources, the available capacity of the ESSs, and the load demand, through the process bus.

- The reference value of the voltage and frequency, as well as the operation mode of MG (e.g., centralized, decentralized, and island or grid connected mode) is received from the station bus.

- The data collected from the process (measuring value) and station buses (reference value) are compared with each other, and the measurement error is sent to the primary control to restore the voltage and frequency.
Conclusion

- The role of the communication is significant in the hierarchical control—and especially for secondary and tertiary control—so a high speed of data transfer between the different DG units and the main grid connection point is required.

- IEC 61850 has good potential in these applications due to available definitions in the latest versions of the standard.

- Practical implementation is possibly only after each element in microgrid supports the standard.