P1854 – Smart Distribution Application Guide
January 2015 Update

Shay Bahramirad, Ph.D.
ComEd
Outline

✓ Authors
✓ Sections review
✓ Gap Analysis
✓ Next steps
✓ Conference presentations/publications
  • 2014 CIGRE, Paris – Paper
  • 2014 International conference on Renewable Energies and Power Quality- Cordoba, Spain- Paper
  • 2014 GM- Panel
  • 2014 Great Lake Symposium- Panel
  • 2014 ISGT-Panel
  • 2015 ISGT-Panel
Authors

Supporting IEEE officers

✓ Larry Clark, Alabama Power Company, USA
✓ Robert Uluski, Utility Integration Solutions, USA
✓ Fredric A. Friend, American Electric Power, USA

Editor in Chief

✓ Shay Bahramirad, ComEd, USA

Section Leaders

<table>
<thead>
<tr>
<th>Section Title</th>
<th>Section Leader</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reliability</td>
<td>Sarma Nuthalapati</td>
</tr>
<tr>
<td>Power Quality</td>
<td>Shay Bahramirad</td>
</tr>
<tr>
<td>Efficiency</td>
<td>Valentina Dabic</td>
</tr>
<tr>
<td>Hosting Capacity</td>
<td>Math Bollen</td>
</tr>
<tr>
<td>Market Functioning</td>
<td>Masood Parvania</td>
</tr>
</tbody>
</table>
Contributors:

✓ Math Bollen, STRI, Sweden
✓ Jason Lombardo, S&C Electric, USA
✓ Masood Parvania, ASU, USA
✓ Vincent J. Forte, Jr., National Grid, USA
✓ Georges Simard, Simard SG. Inc, Canada
✓ Sarma Nuthalapati, ERCOT, USA
✓ Djordje Atanackovic, BC Hydro, Canada
✓ Veera Raju Vinnakota, BC Hydro, Canada
✓ Jun Yoshinaga, TEPCO, Japan
✓ Yasuhiro Hayashi, Waseda University, Japan
✓ Amin Khodaei, University of Denver, USA
✓ Valentina Dabic, BC Hydro, Canada
✓ Francisc Zavoda, Hydro Quebec, Canada
✓ Bob Uluski, Utility Integration Solutions, USA
✓ Brian Deaver, EPRI, USA
✓ William A. Chisholm, Simpatico, Canada
✓ Peg Wieser, ComEd, USA
✓ Julio Romero Aguero, Quanta, USA
✓ Aleksi Paaso, ComEd, USA
Sections

1. Reliability
2. Power Quality
3. Efficiency
4. Hosting Capacity
5. Market Functions

Gaps:
- Scope
- Terminology
Reliability – Optimal Network Configurations

- One of the important features of any distribution system is the ability to change the configuration of the network by changing the status of switches/disconnects or circuit breakers.

- Sectionalizing switches break the distribution feeder into different sections. Due to the developments in smart grid these switches have some local intelligence and can open or close based on some conditions.
Reliability – Optimal Network Configurations

✓ Optimal Network Reconfiguration (ONR) function recommends ways in which a portion of the distribution network can be reconfigured for a pre-defined or selectable objective without violating operational limits of loading or voltages on the feeder.

✓ The section in this application guide discusses various aspects of reconfiguration and practical implementation of reconfiguration in Japan, Canada, and USA.

✓ Most common objectives of ONR include:
  • Restore power to the affected customer with minimal switching
  • Balance the load between the selected group of feeders (i.e., transfer load from heavily loaded feeders to lightly loaded feeders)
  • Minimize total electrical losses on the selected group of feeders over a specified time period
  • Mitigate Operating violations of overload and over/under voltages with minimal switching
  • Minimize the largest peak demand among the selected feeders over a specified time period (only in study)
  • Combination of the above with a weighting factor for each objective

✓ Objectives are discussed in detail in the application guide draft.
Reliability – Optimal Network Configurations (Japan)

✓ Sample case: A typical implementation in Japan – 6.6 kV overhead distribution
Reliability – Optimal Network Configurations (Japan)

- The distribution system in Japan is usually in radial form around the distribution substation, because distribution lines and branch lines are extended according to the increase in electric power demand.

- For the purpose of supply reliability improvement, the distribution lines are divided into suitable sections by switches placed appropriately to minimize the area of interruption.

- Each distribution line has interconnections which can supply electric power to healthy sections from adjacent distribution lines. This type of system is called as “Multi-dividing multi-connecting system”.

- In Tokyo Electric Power Company (TEPCO), 6-dividing 3-connecting system is normally used for its overhead distribution lines, and 4-dividing 2-connecting system is used for underground distribution line.

- The faulty section is identified and is separated automatically. Electricity is supplied to the healthy sections up using automatic re-closing of the breaker in the distribution substation.

- Reserve power is needed so that the lines do not run into over current situation of distribution lines while restoring power.
Reliability – Optimal Network Configurations (Canada)

✓ Sample case: A typical implementation in Canada

✓ As one of the Smart Grid initiatives from the Province of British Columbia, Canada, BC Hydro undertook implementation of Distribution Management System covering it’s whole Distribution network.

✓ In order to provide real time model and consistent measurements set, State Estimation (SE), Topology Analyzer (TA) and Load Flow (LF) applications are identified as core applications upon which all other applications rely on.

✓ End results from the three core applications are used by other network applications such as Network re-configuration, Volt-var Dispatch, etc. The three applications run in a coordinated manner sharing required data/results from one another.

✓ They and run in the sequence of TA, SE and LF as part of real time sequence with a typical cycle time of 15 minutes.
Reliability – Optimal Network Configurations (Canada)

- Topology Analyzer is a generalized tool that establishes the distribution model in real time on the basis of network connectivity and switchgear statuses.
- The value provided by State Estimator is supplementing the data that is missing or augmenting inadequate measurements extracted from historical data.
- Load Flow computes currents, power flows, voltages, loads, power factors, etc. It works both balanced and unbalanced situations by solving all the phases from the voltages and phase angles at each of the loads computed by State Estimator.
Reliability – Optimal Network Configurations (Canada)

Network Reconfiguration – Network is reconfigured for different purposes:

- Isolate faulty sections
- Load balancing (under load switching application)
- Loss minimization (under load switching application)
- Minimize load imbalance (under load switching application)
- Minimize largest peak demand (under load switching application)
- Unload overloads (under load switching application)
- Mitigate under voltages (under load switching application)
Distribution underground network grid monitoring and control

- The micro-processor based Network Underground relay provides opportunities to increase the functional capability of the relay and to integrate the relay into the Distribution SCADA system for remote monitoring and control.

- The relay provides communication options. These options include direct communication with the relay inside of the vault using the relay’s communication port, access to the relay’s data using a vendor supplied communication system and the integration of the relay communication with the RTU communication module.
This technology integration supports the wide-area communication deployment, provides for SCADA monitoring and control on 24x7 basis and ensures access to real-time information about the state and condition of the Underground Network system. The following goals and objectives are achieved:

- Successful integration
- Plug and Play Network Protector relay solution
- Improves SCADA technology deployment flexibility
- Facilitates presentation in Distribution Operations Center (DOC)
- Utilizes D’SCADA alarm system to improve responsiveness to system disturbances
- Facilitates 24x7 monitoring and control by system operator in DOC
- Provides for SCADA communications
Reliability Section - Gap Assessment

Smart Grid Reliability

✓ Should have an opening that ties to applications mentioned in this section under the reliability topic.

✓ Overhead loop schemes?

✓ Underground DA schemes?

Optimal Network Reconfiguration

✓ Methodologies for reconfiguration section (1.2.3) needs to be expanded.

✓ Distributed generation for CEMI improvement

Are there additional items missing?

Comments?
Two of the areas of most concern regarding power quality today are harmonics and voltage:

- Harmonics have become more of a problem for today’s distribution system as more electronic loads replace older resistive loads on the system. Electronic loads cause harmonics since they do not draw sinusoidal currents in response to sinusoidal voltage.

- Voltage issues can arise due to a variety of reasons, such as improper voltage regulation, voltage imbalance, or unplanned increased system load, all of which can result in customer complaints for “flicker”, motor start-up problems or, at worse, damage to sensitive equipment.

This chapter discusses technologies that help utilities monitor and manage power quality problems.
Power Quality – Volt-Var Optimization Systems

- Volt-Var Optimization (VVO) systems can also help utilities find and correct voltage problems, such as abnormally high and low voltage as well as voltage imbalance.
- Most VVO systems can either report power quality violations or can run autonomously and report the actions that were taken to avoid the power quality issue to the operator after they have been taken by the system.
- Model based and rule based approaches are considered.
Power Quality – Gap Assessment

✓ Is this chapter the best fit for VVO? Topic also included in next chapter, are both necessary? If this a good fit, network model based VVO systems should be included?

✓ Discussion on power quality problem mitigation equipment in distribution?
  • Voltage sag mitigation
  • Harmonic mitigation – active voltage controllers?

✓ Good fit for reclosers to mitigate voltage sags (e.g. pulse closing)?

✓ Power and Energy measurements section needs to be written

✓ Voltage quality measurements section needs to be written

✓ Section on Power Electronic Devices

✓ Impact of DG in PQ

✓ Energy storage

✓ Superharmonics

Are there additional items missing?
Distribution Efficiency

- With more emphasis around reducing excess demand and energy consumption, distribution system efficiency has become a very hot topic for distribution utilities.
- Utilities are taking distribution efficiency measures to reduce peak demand charges, to meet Renewable Portfolio Standards (RPS) or other energy efficiency goals they may have.
- Voltage and VAR Optimization including, power factor correction, line loss reductions, and Conservation Voltage Reduction (CVR) are most common for utilities.
Distribution Efficiency – Volt-Var Optimization

This section of the application guide targets the functionality of CVR related to:

- Capacitor bank management – Managing distribution capacitor banks for loss reduction and power factor optimization
- Voltage optimization (aka. CVR) – Manages load tap-changers (LTC’s), line voltage regulators and capacitor banks to reduce voltage on the distribution feeders to enable demand and energy reduction.
Distribution Efficiency– Gap Assessment

- Energy Measurements section needs to be written
- Asset management functions needs to be included
- Discussion on energy storage?
- Distributed generation as a energy efficiency measure?
- Smart inverters?
- D-FACTS?

Are there additional items missing?

Comments?
Hosting Capacity

✓ The hosting capacity of the grid is the amount of new production or new consumption that can be connected without endangering the reliability or voltage quality for other network users.

✓ The hosting capacity can be calculated for individual locations but also for a larger area or even for a large interconnected system as a whole.

✓ In the application guide we only consider the hosting capacity for new production based on renewable energy (wind and solar power) and more efficient ways of production (combined heat and power), connected to the distribution network.

✓ This hosting capacity is limited by a number of phenomena:
  • Thermal overload
  • Overvoltage
  • Protection failure
  • Unaccepted voltage quality
Hosting Capacity

✓ Smart-distribution technologies to increase the hosting capacity are discussed.
✓ Distinction can be made between three types of solutions:
  • Those solutions that only involve the network
  • Solutions that involve the network user but where the control remains with the network operator
  • Market-based solutions where the network user is given an incentive to support the network when needed and where the final decision remains with the network user at all times.
Advanced Protection

✓ The protection of the distribution network is impacted by distributed generation in a number of ways:
  • The short-circuit contribution from generators connected to a distribution feeder can result in an unwanted trip of the protection.
  • The generator can also result in a reduction in short-circuit current, causing a fail-to-trip situation.
  • The protection of the generator itself can fail to detect the fault, with an uncontrolled island operation as a result.

✓ Potential impacts:
  • Increase in the number of supply interruptions for other network users
  • Safety of maintenance personnel and damage to the equipment

✓ Solutions:
  • Protection based on local measurements only
  • Adaptive protection
  • Differential protection
  • Primary/Secondary Protection zones
Advanced Voltage Control

✓ The voltage in a distribution network is maintained within acceptable limits, typically by using the following methods:
  • An automatic ("on-load") tap changer on the HV/MV transformer
  • Variable turns ratio distribution transformers
  • Limiting cable lengths of MV and LV distribution
Storage Systems

✓ Peaks in production and consumption can be flattened by temporary storing electrical energy.

✓ Storage can help in reducing peak load in general, but is especially discussed where it concerns integration of renewable energy and new consumption like electric cars

✓ The following parameters are of importance:
  • The amount of useful energy that can be stored
  • The maximum charging rate (in kW)
  • The maximum discharging rate (in kW)
  • The losses during charging and discharging (in percent or in kW)
  • The losses while the energy is stored
Dynamic Line Rating

- For cables and transformers the maximum-permissible insulator temperature sets the transport capacity.
- For an overhead line as the conductor temperature increases, it expands and the sag increases.
- With “dynamic line rating”, the maximum current is adapted to the weather circumstances. On a cold windy day, the line will be able to transport more power than on a hot wind-still day.
- Existing method of using seasonal overload settings could be extended towards daily or even hourly settings, based on weather predictions and measurements.
- Direct method would be to continuously measure the temperature and/or the conductor tension at several locations along the line and to use these either as an indicator of overload or as a basis for calculating the thermal rating of the line of the line.
Hosting Capacity – Gap Assessment

✓ Potentially a discussion on DG hosting capacity – hosting capacity heat map?
✓ Hosting capacity limiting phenomena
✓ Smart inverters may also fit here under this section for DG hosting capacity?
✓ **Curtailment** section needs to be included
✓ Applications on hosting capacity implemented?
✓ Section conclusions?

Are there additional items missing?
Comments?
Market Structure in Presence of Smart Distribution Systems

- Utilities have to plan, implement and evaluate relevant plans to encourage customers to adjust their electricity consumption behavior with respect to the time and the level of demand.
- DR implementation faces two obstacles including lack of effective management systems and lack of customer knowledge on energy scheduling strategies.
- Proper scheduling and data acquisition tools would have to be introduced to advice consumers and perform load scheduling automatically with a minimum consumer intervention.
- The financial incentives offered to consumers, who would consider load scheduling strategies according to real-time electricity prices, is the most momentous driver for adjusting consumption habits.
- By implementing this architecture, the communities will be able to participate in the wholesale electricity markets.
Demand Response Programs

- Based on the type of incentives for participation in DR programs, two types of DR can be identified:
  - Incentive-based DR programs
  - Time-based rates

- Incentive-based DR programs offer payments for customers to reduce their electricity usage during periods of system need or stress.

- By adjusting production, shifting load to off-peak periods, or running DG, customers can reduce the level of demand that they place on distribution networks.

- Customers who participate in incentive-based DR programs either receive discounted retail rates or separate incentive payments.

- A range of **time-based rates** are currently offered directly to retail customers.

- These are different from flat rates, which are unvarying and offer no price signals. Flat rates are often assigned to residential customers, and are the only option in the absence of meters that can record time-differentiated usage.

- Customer DR, incentivized by time-varying price signals, is one way for electricity customers to move away from flat pricing.
Demand Response Programs

Demand response programs discussed in the application guide include:

**Incentive Based DR Programs**
- Direct Load Control
- Interruptible/curtailable (I/C) service
- Demand Bidding/Buyback Programs
- Emergency Demand Response Programs
- Capacity Market Programs
- Ancillary Services Market Programs

**Time-based rates**
- Time-of-use (TOU)
- Real-time pricing (RTP)
- Critical Peak Pricing (CPP)
Demand Response Costs

The costs of realizing DR can be distinguished as customers and system costs:

- **Initial customers’ costs**: Initial customers’ costs are incurred before a particular DR behavior or action can be undertaken.

- **Ongoing customers’ costs**: Ongoing customers’ costs are incurred by customers when they respond to high prices or DR program events.

- **Initial system costs**: Initial system costs can be organized into several functional categories:
  - Metering/communication system upgrade costs
  - Utility billing system upgrade costs
  - Customer education costs

- **Ongoing system costs**:
  - Program administration and operation
  - Payments to participating customers
  - Equipment operation or leasing
Demand Response Benefits

✓ The benefits of DR can be classified into three functional categories: direct, collateral and other benefits:
  • Direct financial benefits (direct)
  • Direct reliability benefits (direct)
  • Short-term market impacts (collateral)
  • Long-term market impacts (collateral)
  • Collateral reliability benefits (collateral)
  • More robust retail markets (other)
  • Improved choice (other)
  • Market performance benefits (other)
  • Possible environmental benefits (other)
Demand Response Assessment

- Objectives include process evaluation, impact evaluation, as well as Retrospective and Prospective Impact Evaluation.

- Measurement and evaluation of DR programs is challenging, some of the techniques include:
  - Matching day
  - Regression modeling
  - Aggregate analysis
  - Evaluation of short-term/high-frequency DR events
Market Structure – Gap Assessment

- Examples of different types of programs/practical implementations
- Section for Advancement in Smart Technologies for Demand Response needs to be included
- Section on technology to implement DR programs?
- More on the evaluation for Techniques for Pricing Programs?
- Conclusions of the section
- Discussion on DSO models?

Are there additional items missing?

Comments?
Next Steps/Deliverables

✓ Volunteers for open sections
✓ 2015 GM Panel
Open Discussion