

Implementing Low-Cost Distribution Automation Programs

By: Jai Belagur, P.E.

Contact:

Jai Belagur

Power System Engineering, Inc.

1532 West Broadway, Suite 100, Madison, WI 53713

Phone: 608-268-3544 E-mail: belagurj@powersystem.org

www.powersystem.org

1 Abstract

This white paper presents simple Distribution Automation schemes that are geared toward small- to mid-sized utilities seeking to improve Distribution system reliability and power quality improvements. Load Control and Demand response, two widely popular Demand Side Management (DSM) applications, are briefly discussed.

2 Background

The existing distribution systems across many smaller utilities have very little or no automation. That leaves a significant gap in untapped benefits for both the utility and its end-customers.

More and more, utilities are looking to Distribution Automation programs as a means to achieving reliability improvements. Some have even gone further and implemented advanced distribution automation programs to tackle the commonly occurring power quality problems such as voltage spikes, sags, and harmonic distortions that are frequently blamed for equipment failures by consumers.

3 The Need for DA

Ageing Infrastructure: Distribution system infrastructure that is in operation at a vast majority of the utilities has been operational since the last two decades with little investment in upgrading and enhancement. This problem is more acute in urban areas.

Increased reliability requirements: Coupled with increased expectations from their customers, the performance indices (such as CAIDI, SAIFI etc.) of distribution utilities are being closely scrutinized by public and regulatory authorities.

Information era demands higher power quality: When it comes to power quality, the stakes are always high. One estimate puts the cost of “momentary interruptions” at \$52 billion annually in the US, with sustained interruptions of five minutes or more at \$26 billion. With more and more

consumers housing sensitive electronic equipment in residences, the demand for increased power quality has peaked.

Increased demand for power: The growing demand for power is once again putting pressure on utilities to increase generation. High cost of peaking units, longer gestation of base load plants combined with the carbon costs, as well as the negative publicity associated with fossil fuel technologies are becoming strong reasons for utilities to implement advanced DA applications such as Load Management and Demand Response.

4 High-value DA Applications

Distribution Automation (DA) applications can be broadly classified based on their function and the target area they impact within a utility. This section classifies the DA into three functional groups and presents an application under each functional area that is simple to implement. It may be noted that the value and the benefits that can be derived out of these implementations varies somewhat case by case as well as by the utility. The three functional areas considered in this whitepaper are:

1. Automated Switching and System Restoration
2. Power Quality Enhancement
3. Load Control and Demand Response (Demand Side Management)

4.1 Automated Switching and System Restoration

Automated switching can be used for two purposes: 1) Automatic service restoration to non-faulted sections after a permanent fault, and 2) Dynamic reconfiguration of distribution network to prevent overloading, minimize outage risks, and achieve load balancing.

Case 1

Figure 1 below illustrates system restoration through automated switching after a permanent fault in one of the feeder sections. Figure 1a below shows line section A undergoing an electrical fault. After unsuccessful reclose attempts, the feeder protection trips the feeder breaker (F11), thereby taking down line section A and the un-faulted section B. While normal restoration times could take hours, simple DA logic can facilitate automatic restoration of power to unfaulted section B by opening out switch F12 and then closing the tie switch (T1). Logic will need to consider the impact of additional load on Substation 2 before closing in the tie switch.

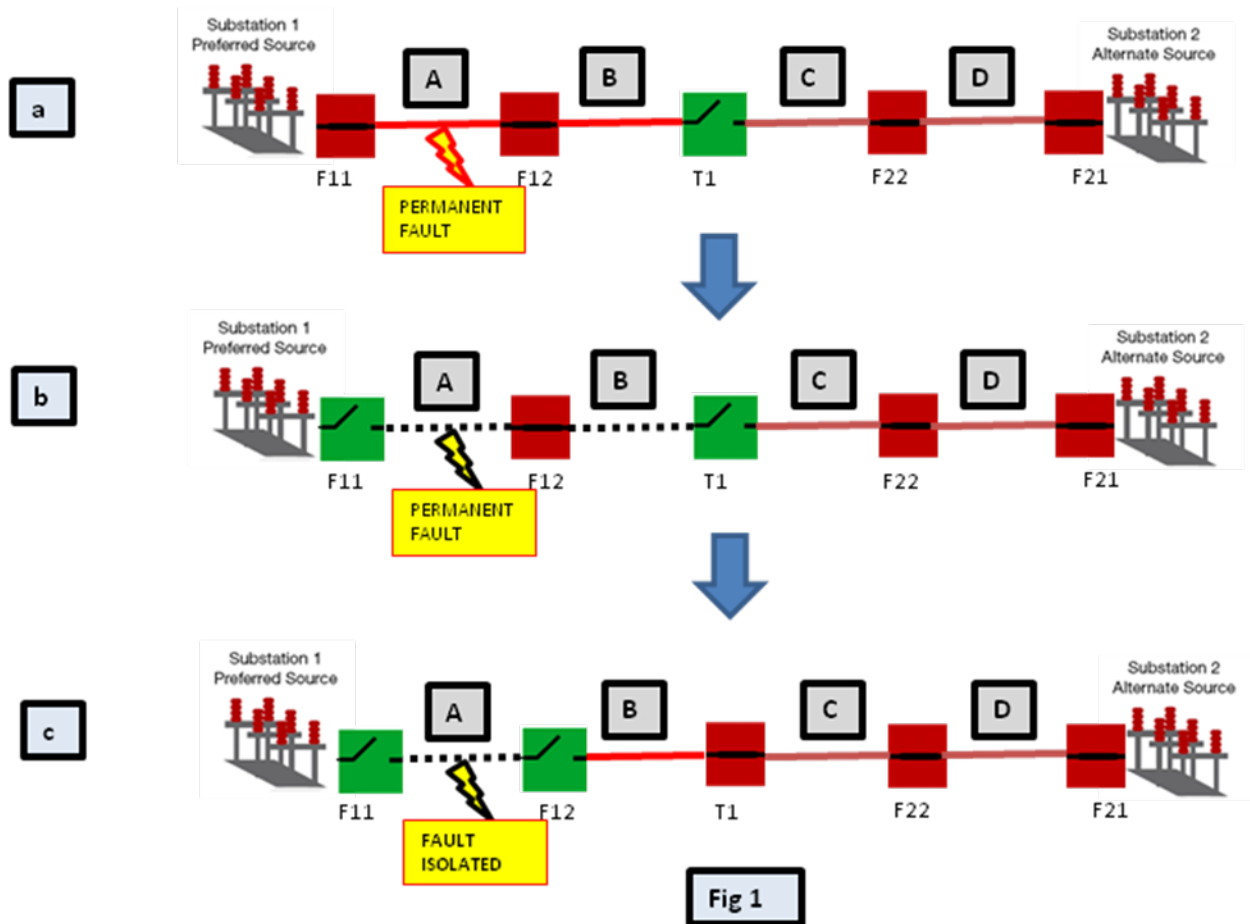


Figure 1: System Restoration through Automated Switching

DA schemes, such as these, can either be implemented locally at the switches or can be implemented in a centralized Distribution Management System [DMS]. Post-fault service restoration schemes as illustrated above are easily implemented and the benefits accrue in the form of increased revenue from decreased network downtime. Often it is very difficult, but not impossible, to quantify the societal benefits such as increased customer satisfaction, increased safety of the community served, etc.

Case 2

During peak load period, many sections of distribution systems operate in overloaded conditions. This not only increases the chances of an unwanted outage but also deteriorates the life of the equipment and results in increased energy loss. Automated switching applications provide a simple means to alleviate these problems. Figure 2 provides a simple illustration of a load balancing application through automated switching.

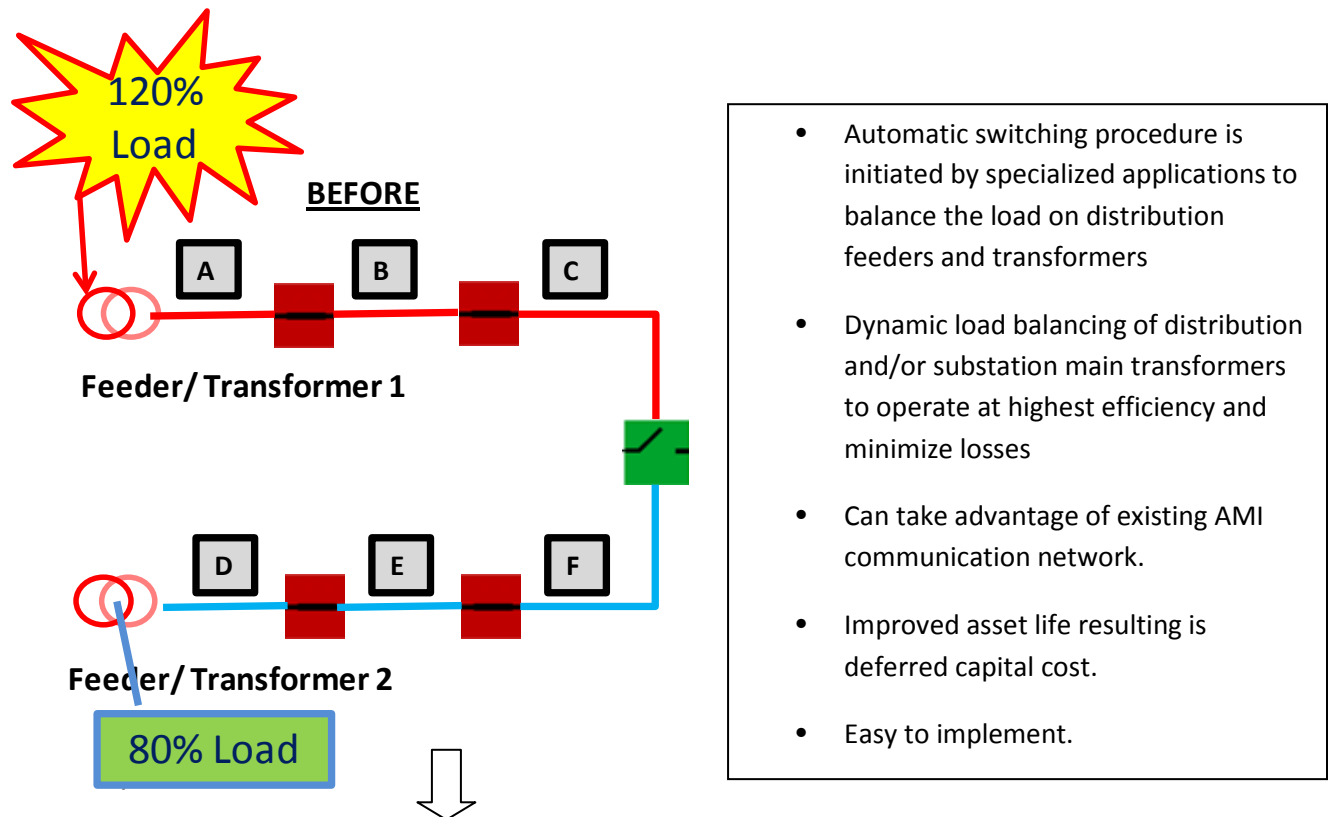


Figure 2: Load Balancing through Automated Switching

DA applications, consisting of network analysis algorithms keep track on the loading levels of substation transformers throughout the electrical network. Preconfigured logic automatically identifies loading imbalances which automatically initiates special algorithms to reconfigure the network and restore the load balance and operate the network at its optimal loading levels.

Figure 3 shows a condition where Transformer T1, upon reaching 120% load, causes the DA application to initiate a reconfiguration. Within minutes, a section of Feeder 1 load is transferred to Transformer 2 by closing the normally open tie switch and then opening the switch to isolate section B & C.

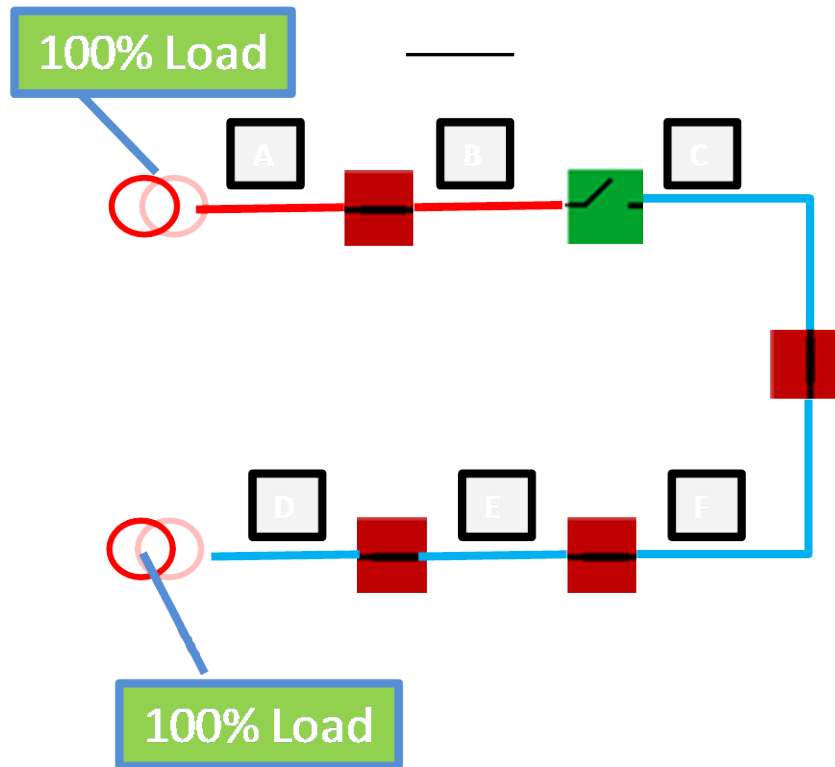


Figure 3: Load Balancing through Automated Switching

4.2 Power Quality Improvement

Harmonics, voltage sags, spikes, and phase Imbalances constitute the bulk of present day power quality problems. Together, they are believed to be the root cause for equipment damage worth billions of dollars annually. Voltage sags can occur when transitory events such as a startup of large load, a power system fault, or momentary overloads occur in the system. Modern computers and electronic loads that utilize thyristor-type power electronic modules, light dimmers, variable frequency drives, UPS systems, electronic motor and fan controls, and fluorescent lighting contribute significantly to harmonic problems on the distribution system. Even to this day, voltage spikes caused by lightning and other power system disturbances continue to be the leading cause of damage to sensitive and often expensive electronic equipment owned by consumers.

There is, however, no single solution that can adequately address all these concerns. Tackling disturbances often requires the combination of various techniques. Proper grounding, improved shielding, and addition of surge arrestors provide the first line of defense to contain the harmful effects of these disturbances. If this fails to mitigate the problems, other, more sophisticated power electronic solutions may be required which can drive the costs up considerably. At this point, the economics and ROI factors take control in justifying such investments.

Dealing with harmonics requires a two-pronged strategy. First, the utility is responsible for maintaining the waveform within acceptable norms. Since the customer-owned equipment is also a significant source of the harmonics, the utility has to define a guideline for acceptable harmonic levels from the customers' end and also suggest measures that customers must undertake to minimize interference on the distribution grid to avoid penalties. Case 3, below, considers one such power quality problem and presents a low-cost remedy.

Case 3

Phase imbalance is a condition in which load is unevenly distributed on a three-phase distribution circuit (compared to ideal conditions in which the load is distributed evenly on all three phases). This imbalance causes unwanted zero-sequence currents to flow through neutral and ground paths, which in turn causes costly power quality problems as follows:

- increased line losses
- increased voltage drop on heavier loaded phase(s)
- interference with telephone and communication circuits
- heavier loaded phase conductors experiencing higher thermal stresses leading to early failures.

A simple solution to phase imbalance requires rebalancing the loads evenly on all three phases by transferring loads from the higher loaded phases to lightly loaded phases. A variety of inexpensive distribution optimization tools are available to assist distribution planning engineers to alleviate the phase imbalance.

Benefits are instantaneous and quite often significant with notable improvements in voltage drop and line losses. Reduction of phase imbalance also results in improved distribution line asset management leading to longer equipment life and reduced failures.

4.3 Load Control and Demand Response (Demand Side Management)

Demand Side Management broadly refers to any measures adapted by a utility to alter either the amount of electricity used by consumers or the times at which that electricity is consumed. Several DA technologies are commercially available, allowing utilities to deploy them cost-effectively and permitting the utilities to share some of the benefits with their customers. Load control and demand response programs have received wide attention in the recent past and have been successfully implemented across many utilities. A notable feature is that several small distribution utilities have realized a strong business case and quick return on investment.

Load control and management essentially refers to a voluntary program for which customers can sign up that allows the utility to remotely shut off their water heaters and air conditioning units (major loads) during the peak load period. Assuming sufficient customers sign up and

participate in such a program, the utility can then avoid paying demand tariff and avoid peak penalties in some cases. Participating customers can expect to see a reduction in their monthly electricity bills (usually between 5-15%) depending on their consumption patterns. Typically, a utility installs a load control switch at the customer premises which is controlled by the load management system at the utility headquarters. Older load management systems were programmed to send open commands to a predetermined set of load switches stored in a lookup table in the load management system. (For example, if the utility desired to shed 10 MW's of peak load, it would send an open command to one or more groups of switches that are expected to yield a 10 MW reduction instantly. However, not knowing the status of these switches in real time was, and still is, a major drawback in legacy load management systems, resulting in partial hit rates most of the time). The trend toward deploying AMI systems with two-way communication systems is slowly changing this picture. Modern load management systems can now take advantage of the AMI two-way communication systems to learn real-time status of loads and select the appropriate loads to send control commands.

Demand Response programs seek to modify the energy consumption pattern of participating customers through “in-home display” (IHD) units. These IHD units provide pricing information to customers in real time, enabling them to shift their usage profile to times when the electricity is cheaper. Efforts are on to build home appliances that can directly communicate with utility to learn the pricing and operate the devices at the lowest possible cost.

5 DA Implementation

Some types of DA applications, such as automated switching and feeder automation, can be implemented based on either a centralized approach or a distributed approach.

A distributed approach is usually simple and flexible. A small section of the distribution network devices consisting of a few pole top reclosers and/or circuit breakers are grouped into a team that can communicate between each other locally. Preconfigured logic constantly monitors the condition of the power system locally within the group and initiates a network reconfiguration in the event that an abnormal condition is detected. Local schemes can be implemented on a small scale, but can only provide limited DA functions.

A centralized approach requires bringing all the information from remote switches to one central computer, which is usually the central office of the utility, where the intelligence and the logic resides. The centralized approach provides more complete DA functions but requires large-scale implementation.

6 Conclusions

Recently enacted legislations such as the EISA 2007 and the subsequent Smart Grid initiatives have all emphasized the urgent need to further evolve the nation's electric grid by adapting

modern distribution automation technologies toward building a self-healing resilient electric grid system. The federal and state governments have introduced and funded several Smart Grid grant programs, providing a golden opportunity for utilities to adapt smart grid technologies such as distribution automations systems and demand-side management technologies.

Nevertheless, it could still prove to be a daunting task for smaller utilities to make huge capital expenditures without a clear understanding of the cost/benefits associated with such investments. The cases presented in this paper are primarily aimed at providing a soft start for utilities to consider low-cost programs that can deliver quantifiable benefits with manageable risks. It is expected that these low-cost programs, once successfully implemented, will provide necessary confidence, knowledge, and insight for the utility to consider other high-value distribution automation programs which may require a greater investments.

About Power System Engineering

Power System Engineering, Inc. (PSE) is a full-service, independent consulting firm for electric utilities. Our clients include distribution cooperatives, generation and transmission cooperatives, investor-owned utilities, municipal utilities, public utility districts, and industry associations. The professionals at PSE include engineers, IT and communication experts, economists, and financial analysts. The PSE team has extensive experience in all facets of the utility industry. PSE is employee-owned and 100% vendor independent, with offices in Minneapolis, MN; Madison, WI; Indianapolis, IN; and Marietta, OH.

About the Author:

Jai S. Belagur (*Utility Automation Consultant*)

Jai holds a Bachelor of Science and Master of Technology Degree in Electrical Engineering and has over 15 years of experience in electric utility systems integration, design & planning Wide Area Networks for mission critical communications networks, Distribution System Automation, Distribution SCADA project implementation, Advanced Metering Infrastructure and Demand Side Management. His current interests include communications and sensor technologies for Smart Grid Applications, Enterprise wide Smart Grid Architecture development, Advanced Distribution Automation and decision support systems based on business intelligence platforms.