ES 586b Course Project Report

Distribution System Automation

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Abstract

Electric power distribution system is an important part of electrical power systems in delivery of electricity to consumers. Automation in the distribution field allows utilities to implement flexible control of distribution systems, which can be used to enhance efficiency, reliability, and quality of electric service. Presently, worldwide research and development efforts are focused in the areas of communication technologies revolution and application of IEC 61850 protocol in the distribution automation to make distribution automation more intelligent, efficient and cost effective.

This report presents brief overview about the distribution system automation. The application areas, advantages and commercially available products for the distribution system automation are also described in detail. It also discusses about the present implantation philosophies and current challenges in the distribution system automation. Further, EPRI 'IntelliGrid' project is discussed as an example of advance distribution system automation. Finally, communication aided advanced distribution system automation and its advantages are explained in detail.

1. Introduction

The word Automation means doing the particular task automatically in a sequence with faster operation rate. This requires the use of microprocessor together with communication network and some relevant software programming. Application of automation in distribution power system level can be define as automatically monitoring, protecting and controlling switching operations through intelligent electronic devices to restore power service during fault by sequential events and maintain better operating conditions back to normal operations. Now days due to advancement in the communication technology, distribution automation system (DAS) is not just a remote control and operation of substation and feeder equipment but it results into a highly reliable, self-healing power system that responds rapidly to real-time events with appropriate actions. Hence, automation does not just replace manual procedures; it permits the power system to operate in best optimal way, based on accurate information provided in a timely manner to the decision-making applications and devices. Distribution Automation Systems have been defined by the Institute of Electrical and Electronic Engineers (IEEE) as systems that enable an electric utility to monitor, coordinate, and operate distribution components in a real-time mode from remote locations [1].

There are several reasons why we need distribution automation systems. Until now, the electric power industry has made remarkable progress in both quantity and quality. But, it is expected that social demand for better services would be requested. The main function of DAS is the remote control of switches to locate, isolate the fault and restore the service, when a fault occurs in the power distribution line. Now, distribution automation has to address enhancements in efficiency as well as reliability and quality of power distribution. Today utilities are more concerned about improving reliability due to the implementation of performance based rates and improving power quality due to its impact on sensitive loads [2]. Further, Specific tools that need attention for implementation of advanced distribution automation (ADA) include tools for cost/benefit evaluation, system analysis, and reliability evaluation [3].

1.1 Literature Survey

Definition of distribution automation system, three different zones in which distribution automation is implemented and advantages of automation system is given in reference [1]. Limitation of present automation techniques used in the field, challenges of implementing new technologies are given in reference [2, 3]. Commercially available devices for distribution automation purpose are listed in references [4-6]. As the technology advances, there are possible solutions to develop advanced distribution automation system. The requirements and implementation of Advanced Distribution Automation (ADA) is explained in [7, 8]. In reference [9], new approach of using IEC 61850 at distribution automation level is discussed.

1.2 Organization of the Report

Chapter 1 gives introduction of Automation concept and definition of distribution automation system. Chapter 2 elaborates the application areas of distribution automation system and their implementation philosophies. And also list out the commercially available products for distribution automation system by different vendors. Chapter 3 list out the technical challenges of automation system implementation and discuss the possible ways of advancement in automation implementation. And also discusses the present project under taken by EPRI. Chapter 4 concludes the report by giving brief idea of present and future of distribution automation technique.

2. Implementation of Distribution Automation System

This chapter explains current philosophies for the distribution automation system implementation. Further, it highlights some commercial products available in the market from different vendors.

2.1 Benefits of Distribution Automation System Implementation

The benefits of distribution automation system implementation can be classified in three major areas are as follows:

- Operational & Maintenance benefits
  1. Improved reliability by reducing outage duration using auto restoration scheme
  2. Improved voltage control by means of automatic VAR control
  3. Reduced man hour and man power
  4. Accurate and useful planning and operational data information
  5. Better fault detection and diagnostic analysis
  6. Better management of system and component loading

- Financial benefits
  1. Increased revenue due to quick restoration
  2. Improved utilization of system capacity
  3. Customer retention for improved quality of supply

- Customer related benefits
  1. Better service reliability
  2. Reduce interruption cost for Industrial/Commercial customers
  3. Better quality of supply

2.2 Areas of Distribution Automation System Implementation

The area distribution automation system can be divided in to two areas:

A. Distribution Substation & Feeder Automation
B. Consumer Location Automation

A) Distribution Substation and Feeder Automation:
Usually the distribution automation on substation and feeder are integrated to share common monitoring and controlling equipment and devices. Distribution substation automation includes supervisory control of circuit breakers, load tap changers (LTCs), regulators, reclosers, sectionalizers, switches and substation capacitor banks. Remote data acquisition is required in order to achieve effective use of the supervisor control function.

B) Consumer Location Automation:
Automation at the consumer's location includes the ability to remotely: read meters, program time-of-use (TOU) meters, connect/disconnect services, and control consumer loads.

2.3 Distribution Automation System Implementation Philosophies

Implementation philosophies at distribution substation and feeder; and at consumer locations are described as follows [1, 2, 3]:

2.3.1 Distribution Substation and Feeder Automation:

It is generally applied to that element of the distribution system which operates at voltages above 22 kV. Distribution substation and feeder automation also referred to as Primary Distribution automation. Different functions of Primary Automation Technique are listed below.

1) Transformer Load Balancing: Transformer load balance monitoring provides remote access to near real-time information concerning the overall operation of the distribution system. This information can be used on a daily basis to verify the effects of other down line events such as capacitor switching, residential load control, and recloser operations. It is also useful on a periodic basis to fine tune the efficiency of the Utility's power distribution configuration.

2) Voltage Regulation: This feature of DAS offers utility personnel the ability to reduce line voltage during peak demand times by remotely taking control of the Load Tap Changer. It also facilitates the remotely boosting of line voltages above the local LTC settings in case of emergency situations such as back-feeding.

3) Fault Isolation and Sectionalizing: Remote monitoring of the recloser operation to the melting of a fuse link, utilities can detect the fault very fast and can take quick action to clear that fault. Even during the outage of the power supplies distribution automation devices on that line can report the data remotely. By correlating the last voltage or current measured before an outage from several points along the distribution system, an indication of the nature of the fault as well as its approximate location can be obtained.

4) Remote Interconnect Switching: Distribution automation systems can be deployed to drive remotely interconnected switches that separate different portion of the utility distribution feeders. By the use of remote interconnect switching utilities can manipulate their distribution system to provide the most efficient configuration and also will able to remotely restore power to as many consumers as possible during the time of multiple faults.

5) Capacitor Bank Switching: It is most commonly deployed automation technique in a distribution network. The most cost effective capacitor control configuration is to install a number of one-way receivers at the capacitor locations for positive control and to monitor the aggregate effects of the capacitor switching at the substation low voltage level bus. Utilities with capacitor bank switching facilities can operate with reduced losses and as a result with higher efficiency.

6) Voltage Monitoring: By monitoring the feeder voltage remotely utility personal gets advance notification about the line voltage drop due to high usage. Also recorded data of feeder voltages will give snapshot of the actual usage patterns.

2.3.2 Consumer Location Automation:

Consumer location is the most challenging application area for the distribution automation system as large numbers of installation points are required and all the points should be economically viable.

1) Load Management: Load management is achieved by local appliance control. It consists of a utility activated relay that interrupts the power consumed by non-critical loads such as water heaters, air conditioners, electrical heaters, pool pumps, etc.

2) Automatic Meter Reading (AMR): For utilities, AMR is one of the cost effective way to read the residential kilowatt-hour meters. The AMR device can be initially programmed to report back to the utility based on a schedule or some pre-set usage level. Modern AMR devices incorporate the capability of remote reconfiguration of operating parameters and schedules.

3) Demand Side Management (DSM): An extension of automatic meter reading technology is the DSM application using Real Time Pricing. This application includes the functionality of monitoring the power usage during specific periods of the day as well as the control functionality of notifying the customer of the change of periods and the new rate for that period. For some utilities, this option is not cost effective.

4) Quality of Service (QoS) Monitoring: Quality of service is different things to different utilities. The most comprehensive definition includes monitoring power outages and its duration, the track record of power disturbances (such as voltage blinks, harmonics and voltage sags), and monitoring voltage wave-form distortions.

2.4 Commercially Available Distribution Automation Systems

Current distribution automation products offered by different vendors are listed as follows:

2.4.1 ABB Distribution Automation Products [4]

1) PCD2000 Recloser Control
Features:

- Under/Over voltage, frequency control and alarming (1phase or 3 phase); Directional specific over current protection, power flow control; Records kW, kVAR & volts per phase, Operation/Fault Records, Power quality recorders per ANSI/IEEE 1159 Standard, and also have Oscillographic capture facility.
- Open protocols, DNP3.0, Modbus, RS232, RS485, programmable I/O and optical port are all standard.

2) SCD2000 Switch Control
Features:

- Fault indication that utilizes currents or currents and voltages; Phase imbalance; Switch failure alarm; Number of operations; Sectionalizing function; Automatic source transfer

3) DCD2000 Communications Gateway
Features:

- Provides multiple master/slave operation in one integrated box; Provides interface to multiple applications; Provides interface to substation and field devices
- Support standard protocols (MODBUS and DNP 3.0)

2.4.2 SEL Distribution Automation Products [5]

1) SEL-351A Distribution Protection System
Features:

- Dependable Over current Protection; Innovative Directional Elements; Under/Over frequency Protection; Reclosing Control; Metering and data recording

2) SEL-2411 Programmable Automation Controller
Features:

- Flexible I/O for automatic control; Sequential events reporting; Station integration; Remote monitoring; Plant control systems

3) SEL-2030 Communications Processor
Features:

- Two Plug-In Protocol-Processor Card; Automatic Database; Modbus® Slave, DNP 3 Level 2 Slave, and ASCII Serial Protocols; Programmable Logic Controller (PLC) Functions

2.4.3 GE Distribution Automation Products [6]

1) Digital Multifunction System (DMS)
Features:

- Under/Over voltage, frequency control and alarming (1phase or 3 phase); Directional specific over current protection, power flow control; Event and Oscillography Recorder, Separate local MMIs for P & C
- RS232 port, faceplate accessible for local communication

2) SMOR-B Feeder Management System
Features:

- Hiset/loset phase, ground, instantaneous O/C and negative sequence TOC; Directional under and over frequency, phase and ground unit TOC; Cold load pickup, breaker failure logic; Records kW, kVAR & volts per phase, Operation/Fault Records and Oscillography
- Front and rear RS232 ports ,Optional rear fiber optic port ,M-LINK & Modbus protocol

3. Advanced Developments of Distribution Automation System

Advanced Distribution Automation (ADA) is far more than just the addition of remote control of substation and feeder equipment [7]. Technical challenges to future distribution automation and need for Advanced Distribution Automation system is explained in following subsections.

3.1 Technical Challenges for Conventional Distribution Automation System

In the future, the advances in distribution operations technology will add a new set of challenges as follows.

3.1.1 Technical Challenges for Conventional DAS

a. Customer demand for better power quality and less outages

b. Utility business pressures to minimize capital and operational expenses

c. Market opportunities that are beginning to reach into the distribution arena, such as "demand response" and "real-time pricing"

d. Regulatory pressures for system reliability and performance

e. Increased interconnection of Distributed Energy Resources (DER) to the distribution system, either at substations or within customer premises. All these DER systems will interact among themselves and with all other controllable devices and systems connected to the same distribution area.

3.1.2 New Technological Capabilities for Advanced Distribution Automation

a. More widespread communications interface among DAS devices. Further, world wide accepted standardized communication protocol such as IEC 61850 is available.

b. Advanced integrated and coordinated protection using intelligent electronic devices (IEDs): It includes the functions like intelligent fault location and isolation, auto-restoration systems, contingency analysis, relay protection integration and coordination, restoration of normal connectivity, etc. This requires remotely controlled switching devices and reliable and fast communication systems. This results into improvement of the service reliability.

c. Equipment monitoring and diagnostics: this result in to extension of equipment life-time, reduction of capital and maintenance expenses.

d. Load management schemes: It includes the functions like distribution load forecast for short-term distribution operation studies, planned outage scheduling etc. Advantage of this is improved reliability and quality of service, better utilization of distribution facilities and better utilization of workforce.

e. Coordinated Volt/VAR control schemes: Application of this function requires facilities like remotely controlled voltage controllers of transformers, voltage regulators, distributed generators, power electronic devices and remotely controlled capacitor banks. Benefits of these implementations are improvement of power quality, better utilization of operational tolerances, non-intrusive load management in near-real-time and better utilization of generation capacity based on Watt-Var relationships.

f. Automated meter reading and analysis: It also includes the functions like power quality monitoring, analysis, and reporting, reliability monitoring, analysis, and reporting. To implement these thing it requires planning of AMR system including automated kWh and multifunctional meters, communication system between the AMR master and the customers, customer information database and AMR analysis computing applications. It also includes real time pricing, to obtain demand side management.

g. Distribution automation in case of DER should also include islanding (micro-grid) scheme as a part of distribution operations and control. The dynamic regulators, universal transformers, more sophisticated voltage and VAR control schemes and algorithms based IED can be used at distribution level too.

3.2 EPRI's IntelliGrid Project: Advanced Distribution Automation (ADA)

Project Objective: The objective of Advanced Distribution Automation Function is to enhance the reliability of power system service, power quality, and power system efficiency, by automating the following three processes of distribution operation control: data preparation in near-real-time; optimal decision-making; and the control of distribution operations in coordination with transmission and generation systems operations [8].

Scope of the Project: The ADA Function performs following functions:

a) Data gathering, along with data consistency checking and correcting
b) Integrity checking of the distribution power system model
c) Periodic and event-driven system modeling and analysis
d) Contingency analysis
e) Coordinated Volt/VAR optimization
f) Fault location, isolation, and service restoration
g) Multi-level feeder reconfiguration
h) Logging and reporting

These processes are performed through direct interfaces with different databases and systems, comprehensive near real-time simulations of operating conditions, near real-time predictive optimization, and actual real-time control of distribution operations.

Status of the Project: The methodology and specification of the Function for current power system conditions have been developed, and prototype (pilot) and system-wide project in several North-American utilities have been implemented by Utility Consulting International and its client utilities prior to IntelliGrid Architecture project [8].

3.3 Communication aided Distribution Automation using IEC 61850

Communication aided distribution automation is the effective mix of local automation, remote monitoring and control capabilities on strategic field devices. This combination of technologies empowers a highly reliable, self-healing (auto-restoration) power system that responds rapidly to real-time events with appropriate actions. Automation does not just replace manual procedures; it permits the power system to operate in a most efficient and optimal way, based on accurate information provided in a timely manner to the decision-making applications and devices.

Many DA functions have been implemented by utilities throughout the world. These DA functions vary greatly in nature and so does their communication requirement. Different DA functions have so far almost always been implemented by using proprietary protocols. Thus, there has long been a great need for an open and integrated communication system capable of supporting all DA functions transparently [2]. Communication standards have now been developed that make use of these technologies. In particular, IEC61850 (with some extensions for distribution equipment) can provide solutions to automation issues using state-of-the-art object modeling technologies.

IEC 61850 based interoperable IEDs can be installed to act as controllers and monitors of the power system equipment. The IED is a generic term for intelligence and communication that can be designed into any field device and can serve multiple functions. These IEDs have the compute capacity to execute software applications that can analyze local conditions and make pre-programmed responses to these local conditions. These IEDs can also interact with each other (using IEC 61850), either within a substation (e.g. protection signals to circuit breakers) or on feeders (e.g. automated reclosers and switches along a feeder responding to isolate a fault). These actions can greatly enhance response times, improve local conditions, and minimize outages [9].

Further, communication in distribution automation can provide following special features:

1. Fast Transfer Trip to upstream relay for instantaneous operation
2. Breaker failure scheme: IED communicates with upstream breaker IED to trip.
3. Selectivity between feeder and bus faults
4. Zone sequencing to reduce momentary outages
5. High speed substation bus reconfiguration
6. Automatic load shedding
7. Auto-restoration schemes

4. Conclusions

This report identifies the advantages of automation application at distribution level. Distribution automation enhances the efficiency and productivity of a utility, and also provides quality and reliable supply to the consumers. Commercially available products for distribution automation application are also discussed. Later part of the report discusses the challenges faced by current distribution automation system and need for advanced distribution automation. Further, developments in communication technology and standardized protocol 61850 for the implementation of advance distribution automation are illustrated with details.

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