A SURVEY ON INFORMATION AND COMMUNICATION TECHNOLOGY (ICT) APPLICATIONS IN DISTRIBUTION SYSTEMS

Mohammad SHAHRAEINI
Mashhad Electric Energy Distribution Co. - Iran
m.shahraeini@meedc.net

Saeed ALISHAHI
Mashhad Electric Energy Distribution Co. - Iran
s.alishahi@meedc.net

ABSTRACT

Smartgrid denotes the integration of all elements connected to a power grid with a two-way communication infrastructure. The functions of smartgrid are normally performed by some computer aided tools, which are also known as ICT applications. In this paper, ICT applications of distribution systems are investigated based on their performances, data resources, and their required communication systems. In order to reach a more comprehensive result for this research, required communication systems of these applications are compared with each others. An integration method of communication systems are also suggested by this investigation.

INTRODUCTION

Smartgrid is a term which has been introduced to power system literature recently. From the view point of power system operators, this term implies the integration of all elements connected to a power grid with a two-way communication infrastructure (CI). Therefore, to establish a smartgrid, a communication infrastructure should be created in the whole power system in order to deliver data among different entities. Taking this fact into account, it can be concluded that, nowadays, communication infrastructures have been become very vital for new competitive power systems and have become fundamental part of smartgrids.
Communication infrastructure is within the framework of information and communication technology (ICT). Power system ICT was defined as [1]: “The technology involved in acquiring, storing, processing and distributing information by electronics means (including radio, television, telephone, and computers)”. This process is illustrated in Fig. 1.

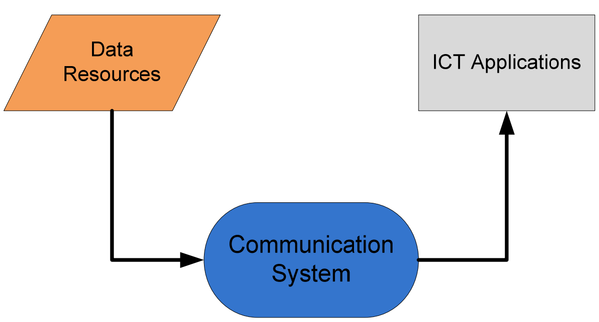

Figure 1. ICT block diagram for a power system.

Whatever happens in Fig. 1 can be explained as follow: data is acquired from data resources; which are distributed in entire system, data is transmitted to decision making location (also known as control center) through communication infrastructure, and it is processed by ICT applications and then, some decisions are made.
Considering all pre-mentioned facts into account, it is clear that smartgrid is not only communication infrastructure; also it is not only an ICT application (such as smart metering), smartgrid is a combination of both interaction and integration of all ICT applications, which utilize communication infrastructure for sharing their information and process.
Due to the fact that distribution systems are the final stage in the electricity delivery process to huge number of end users, smartgrid has become seriously important in distribution companies. Hence, the ICT applications of distribution systems, the data resources of these applications, and the way in which they share their data and information are very vital for establishing a smartgrid in a distribution company. Distribution automation (DA) and “supervisory control and data acquisition” (SCADA), Advanced Metering Infrastructure (AMI), Geographical Information System (GIS) and Customer Information System (CIS) are some examples of distribution applications.
The aim of this investigation is to present a survey of major ICT applications in distribution companies. The concepts of applications, which are examined in this article, are: the performance of each application, its data resources, and the communication system characteristics needed for this application.

DISTRIBUTION AUTOMATION

According to IEEE definition [2], Distribution Automation (DA) systems has been defined as systems that enable a distribution company to monitor, coordinate, and operate distribution components and equipments from remote locations in real-time. In general, DA consists of three main modules: substation automation, feeder automation, and consumer-side automation [2]. The overall purposes of DA include reducing costs, improving service availability, and providing better consumer service.
In three next sub-sections, these modules will be reviewed.

Substation Automation

Substation Automation (SA) is the integration of smart sensors with a communication infrastructure to control and monitor substation equipments in real-time [3]. The major functions of SA are: service restoration via bus sectionalizing, bus voltage control, substation parallel transformer circulating current control, line drop compensation, and automatic reclosing [3].
Data resources of SA are located in distribution substations

including bus phase voltages, transformer and feeder active and reactive power, feeder currents, statuses of circuit breakers, capacitors and reclosers cut-off switches, load tap changer and voltage regulator positions and status, transformer temperatures and relay settings [3].

Typically, measurement data and status data are measured by pre-mentioned data resources. Then, Remote Terminal Units (RTUs) collect data and send it to SCADA systems [3]. Finally, communication infrastructure has the responsibility of data transmitting from SCADA to control center(s).

The functions of SA are real-time or near real-time; consequently, the latency of their CI is a major concern and should be low. SA data volume varies from low to medium. Due to importance of SA functions, the reliability and security of its CI are of crucial importance [4].

Feeder Automation

Due to rapid growth in metros, Feeder Automation (FA) is one of the key elements for efficient management of the power distribution networks. The main purposes of FA are twofold. Firstly, FA aims to automate feeder switching; and second it controls voltages and active/reactive powers of feeders [3].

The main data resources and controllable devices of this function are line reclosers, load break switches, sectionalizers, capacitor banks and line regulators [3]. Typically, these data resources are much more than resources of SA and are located at distribution poles.

Most FA functions are not delay sensitive, thus, the latency of required CI can be high. On the other hand, due to characteristics of FA functions which require low amount of data, data rate of required CI is not a major concern. Medium level of CI reliability and security is accepted for FA implementation [4].

Advanced Metering Infrastructure

Advanced Metering Infrastructure (AMI) can be assumed as the central nervous system of the smartgrid architecture. AMI collects consumption data from smart meters and transmits it to control center. This function of AMI is similar to purposes of Automatic Meter Reading (AMR) systems. In Addition to reading functions, AMI also relays demand signals and pricing information to smart meters in near real-time; consequently, feedback loop is closed by AMI system [5].

Data resources of AMI /AMR systems are metering devices. But the difference between AMI and AMR is that metering devices of AMI can also be remotely controlled by system operator. Since huge numbers of metering devices are distributed in entire system, the cost of communication system, which is utilized by an AMI/AMR system, is vital. In the view of this fact, low cost communication infrastructure means more automated customers.

Since metering data and information are not required in real-time, the allowable latency of AMR and metering functions of AMI is not a major concern. As a consequence of this fact, communication technology with high latency can be used for this type of data delivery. Alternatively, the volume of metering data is low, while the reliability and security of required CI for this data should be more than low [5].

BACK-OFFICE SOFTWARES

In a distribution company, some software packages are utilized in order to manage internal and external office data and information. They are known as back-office (BO) softwares since their main contents include finance, management, human and logistics and other business operations data [6]. Enterprise Resource Planning (ERP), Engineering and Operation (E&O) applications, Geographical Information System (GIS), and Interactive Voice Response (IVR) are some back-office packages [7].

Enterprise Resource Planning

The Enterprise Resource Planning (ERP) is a computer software system which is used for managing all of the processes and information in a distribution company [8]. Typically, ERP consists of many modules which share their information among together. Work management, project management, document management, billing system, and customer information system (CIS) are some instances of ERP modules.

Generally, ERP data (including assets, financials, maintenances, costumers, meters data and etc.) are integrated in a single or multiple databases from different vendors like SAP, Oracle and JDEdward [9]. To make a smarter distribution company, ERP data are vertically integrated with SCADA and other operational data in order to perform other smartgrid modules and applications.

ERP data are transmitted among clients and servers in an office or multiple offices. Data delivery is done by Local Area Network (LAN) in an office or Wide Area Network (WAN) among different offices. Data volume of ERP may vary from low to high; consequently, ERP data should be delivered by a communication infrastructure with high data rate. Based on importance of ERP module, reliability and security of required CI vary from medium to high [4].

Geographical Information System

Geographical Information System (GIS) is a graphic software which links spatial data with geographical information about particular features on the map [10]. In other words, A GIS application tries to integrate technology that helps store and retrieve information based on its physical location [11]. GIS basic functions include collecting, managing, analyzing and exporting data [12].

A GIS system consists of three primary types of data [11]: spatial data (or layers), attribute data, and documents or images. In a distribution system, which utilizes the vector based GIS application, distribution system can be represented by its spatial component (graphs) and the thematic component (attribute tables) [10]. In such GIS application, attribute tables contain the parameters of the conductors and protective devices such as conductor type, length, construction and device type.

As mentioned earlier, data of GIS systems varies from attribute data to images. As a result, data volume of such systems is highly variable. This indicates that GIS systems should use high data rate communication infrastructures. Since some functions of GIS are not real-time and may be near real-time, the reliability of required CI is not crucial.

Interaction between GIS of electric distribution system and other metros companies make a smarter distribution network. For instance, caller ID information of customer layer in telecommunication companies GIS systems together with GIS and IVR systems of distribution system can help system operator for fault locating and other DA and BO functions.

Customer Information System

Customer Information System (CIS) handles all customer data and information of a distribution company [8]. The main applications of CIS usually include billing and accounting functions. Therefore, CIS functions can be classified as customer and billing payment functions, and customer relationship management (CRM) [7].

CRM includes methodology, software and network techniques, which aims at improving the relationship between enterprises and customers [12]. Indeed, CRM is the business function; which integrates sales, marketing, and customer service. As a consequence of this integration, customer interaction is simplified.

Data resources of CIS/CRM include all customer-related data from inner enterprises or outside, which are integrated at a same system. This integrated database can be used by other BO functions and contacting staffs [13]. Outside data is delivered to CIS/CRM systems by one of the following ways [15]: Public switch telephone network (PBX or E1 lines), Voice Over IP (VOIP), E-mail, Web, Chat, Fax, or even SMS.

CONPARISON OF COMMUNICATION SYSTEMS

In this section, the pre-mentioned applications are compared with each other in table 1 [4]. The comparison criterions are data volume, data rate, allowable latency, reliability of required CI, and security of CI.

Inspection of table 1 shows that in DA functions, reliability and security of communication infrastructure are major concerns. It can be also concluded that if a DA function is performed in real-time or near real-time, the communication latency is essential. Pre-discussed characteristics of BO applications indicate that such applications are usually bandwidth hungry, while the allowable latencies of these applications are in medium level.

Table 1. Comparison between communication systems of ICT applications.

Application	Data Volume	Data Rate	Allowable Latency	Reliability	Security
SA	Low	Low	Med.	High	High
FA	Low	Low	High	High	High
AMR/AMI	Low	Med.	High	Low	Med.
Back Office	High	High	Med.	Med.	Med.

COMMUNICATION INTEGRATION

An efficient and money saving method for designing communication systems is the integration of them. As a result, in this section we try to suggest an integration method for communication systems of a distribution company.

An examination of pre-mentioned ICT applications indicates that the communication systems of discussed applications can be classified as follows. First one is in-office communications, which mainly deliver back-office information in an office or among multiple offices of a distribution company. The second type is automation communication, which is responsible for transmitting automation information in entire distribution network.

Typically, in a distribution system, customers' tasks and equipments are divided into multiple geographical areas, and each area has its own local office with engineering/maintenance group located in this office. This classification can be also generalized into communication system in the following way:

Local offices are connected together with strong communication links. The BO and DA infrastructures among local offices can be physically isolated. For example, if local offices are connected by fiber cables, different fiber cores can be used for DA and BO communications, separately. This separation strongly improves the reliability and security.

DA communications can be limited in a local office zone. As explained before, the numbers of data resources increase from SA to FA and from FA to AMI. In contrast, the importances of these resources reduce from SA to AMI. As a consequence of these facts, distribution substation of a local zone can be connected to its local office securely and reliably by a guided media such as twisted pair or fiber optic cables. Alternatively, FA communications can be established by unguided media between distribution poles and a zonal distribution substation. Similarly, AMI metering can also communicate in the same way. Due to the fact that three types of DA functions are merged and communicated in a single communication system, Quality of Service (QoS) methods or virtualization methods (such as virtual LAN) can be used in order to enabling data priority.

A representation of three areas distribution system (without central office) is illustrated in Fig. 2.

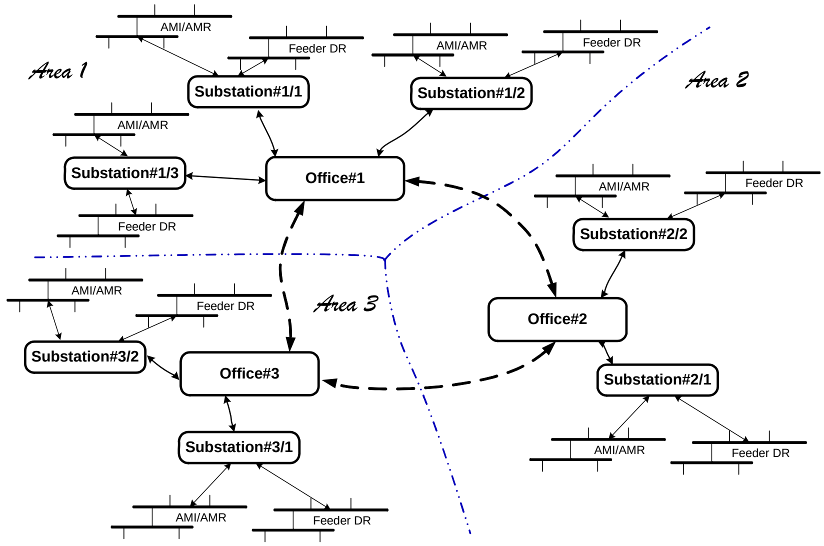

Figure 2. Integrated communication system for distribution systems.

CONCLUSION

Smartgrid implies the integration of all elements connected to a power grid with a two-way communication infrastructure. Therefore, communication infrastructures have been become very vital for new competitive power systems and have become fundamental part of smartgrids. For establishing a smartgrid, communication infrastructure is used by some computer aided tools called ICT applications.

In this paper, main ICT applications of distribution systems have been reviewed and examined. Consequently, a general view of all data resources and their CIs are obtained. Additionally, the specifications of communication systems are also compared with each other.

As a consequence of pre-mentioned examination and comparison, this investigation suggests an integrated communication system for all ICT applications in order to minimize the total cost and maximize the manageability.

Future works may involve integrating the databases of DA and BO applications, both vertically and horizontally.

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