Effect of an Intelligent Communications System in Enhancing the Power Infrastructure in Developing Countries

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Abstract

Since reliable electric power is key to economic development, education and medical care. Humanity finds itself confronting an enormous energy Challenge which shows that current patterns of energy use are environmentally unsustainable. Overwhelming reliance on fossil fuels, in particular, threatens to alter the Earth's climate to an extent that could have grave consequences on the integrity of vital human and natural systems. At the same time, access to energy continues to divide the 'haves' from the 'have-nots', as a greater part of the world especially Africa still lacks access to one or several types of basic energy services, including electricity, clean cooking fuels and adequate means of transportation. It is necessary to improve the operation of distribution systems and hence the quality of power supply, which can be achieved by use of the intervention of information technology (IT) utilizing the available high speed computers and communication networks. This resulted into reduced technical loss, support for commercial loss reduction, improved cash flow, low service restoration time, reduction in equipment damage, availability of system information, better operational planning, remote load control and shedding, and improved power quality and reliability.

Keywords: grid, reliable, power, costing, Alternatives, billing.

1. Introduction

In developing countries, electricity is fundamental for many essential services, including those that increase income and benefit rural areas. Major uses for electrical power are: Agricultural, Water Purification and Distribution, Health care, Education, Commercial and Industry Application, Bidirectional communication, Residential and Community Quality-of-Life to mention but a few(Alfredo Vaccaro). However, the distribution systems have generally grown in an unplanned manner resulting in high technical and commercial losses in addition to poor quality of power.

Efficient operation and maintenance of distribution system are hampered by non-availability of system topological information, current health information of the distribution components such as distribution transformers and feeders, historical data etc. Other reasons include the lack of efficient tools for operational planning and advanced methodology for quick fault detection, isolation, and service restoration, etc. All these lead to the increased system losses, poor quality and reliability of power supply in addition to the increased peak demand and poor return of revenue.

Keeping the above problems in mind, it becomes necessary to improve the operation of distribution systems and hence the quality of power supply. This can be achieved by use of better methods, proper monitoring and control of the distribution system. In view of the extensive size of the network, this task can be effectively achieved through the intervention of information technology (IT) utilizing the available high speed computers and communication networks. This system of monitoring and control of electric power distribution networks is also called as the Distribution Automation System. IEEE has defined Distribution Automation (DA) system as a system that enables an electric utility to remotely monitor, coordinate and operate distribution components, in a real-time mode from remote locations (Bassett et al., 1988). The location, from where control decisions are initiated, is generally called Distribution Control Center (DCC). Distribution Automation System encompasses data acquisition, telemetry and decision making system. It involves collecting information, transferring it to a DCC, displaying the information and carrying out analysis for control decisions and improvement in system operation (Ghoshal, 1997). The control action is then initiated either through remotely operable devices or manually. A typical DA system is composed of field instrumentation, remote terminal units, communication systems and distribution automation software. Field instrumentation includes sensors, transducers and actuators, which are directly interfaced to the equipment being monitored and controlled by the DA system. These sensors monitor certain parameters and actuators control certain equipment or feeder in the system. The actuators could be either operable remotely or manually.

Field instrumentation connected to the equipment being monitored and controlled are interfaced to a local unit called Remote Terminal Unit (RTU) that allows data manipulation and help in implementing control action in the field. Another key function of this unit is to gather data from the equipments and transfer it to the DCC. The Communication System is required to communicate data from DCC to various remote terminal units and vice

versa. Essentially, the communication system refers to the communication equipment and interface needed to transfer data between DCC and different remote terminal units. Thus, the point to multi-point communication is an inherent need of DA system. The communication media can either be wired (cable, fiber, telephone) or wireless (Wireless-in-local loop, radio etc.)(Marihart, 2001). There are two key software elements – Master DA Software and Engineering Analysis Software at the DCC.
The benefits of the distribution automation are reduced technical loss, support for commercial loss reduction, improved cash flow, low service restoration time, reduction in equipment damage, availability of system information, better operational planning, remote load control and shedding, and improved power quality and reliability (Gupta et al., 2003).
It is envisaged that the technical part of the losses can be brought down to the minimum value with the implementation of DA system. Usually reported transformer failure rate is mainly due to non-availability of transformer health parameters and its loading conditions, which can be alleviated with the AIED. Cost/benefit analysis of DA system justifies the capital investment for distribution automation system (Brown et al., 1991).
Despite the obvious benefits mentioned above, the distribution automation system has not yet gained momentum among the utilities and manufacturers in the developing countries. Utilities have realized a need of indigenous Distribution Automation (DA) system, which could be retrofitted in the existing distribution network to achieve better system operation through remote monitoring and control.
The indigenous design and development efforts have been focused on the following:

DA software to enable remote monitoring, alarm generation and remote control

Remote terminal unit (RTU) specially low cost pole top RTU

Remotely operable switches for 11kV and 415V feeders

Communication and networking technology using wired and wireless media

Data acquisition from Intelligent Electronic Devices (IEDs) such as IED meters and IED relays

Distribution network simulator (a scaled down model of a real-life distribution network) to provide a test bed for a comprehensive testing of the developed technology, components and software.

Identifying the most suitable technological solutions for each site is critical(Alfredo Vaccaro). This comprises gathering and analyzing local data, such as the following:
• **Weather data**: solar radiation, temperature, wind speed, etc., on a medium to long time horizon of 1 to 5 years, are necessary to identify the best generation technologies, the expected producible energy, and maintenance procedures.
• **The existing electrical infrastructure**: data about the generation, transmission and distribution facilities already in place.
• **Energy indicators:** statistical classification of economic activities, number of people in the area, number of families, energy demand, etc.
While it may be tempting to focus on power sources, it is worthwhile also to consider the power consumers. Inefficient refrigerators, incandescent lighting, and old desktop personal computers are significant energy-wasters. Improving the efficiency of such energy consumers could extend the utility of the local power-generating systems planned for installation.
We propose an electrical supply model that would
(a) immediately benefit the populace;
(b) be based on a nationally sustainable economic model;
(c) be operable and maintainable by the government cheaply; and
(d) have local backup capability to guarantee reliability and high availability?"

2. An Intelligent Electronic Unit (IED) for automatic diagnosis and remote management of distributed power resources

IEDs receive data from Transmission sensors and issue control commands, such as load shedding, if they sense voltage, current, or frequency anomalies. Or they can raise or lower voltage to maintain the desired level. An IED can assure that the Transmission function reliably; it should be equipped with an external bi-directional data-communication unit for connecting the system operator with the electricity user. With this, the system operator could receive basic information and even forecasts of the reserve levels while the electricity user would know when controls and smart-metering actions are expected at the point of use. Data exchange could be supported by mobile Short Message Service (SMS) messaging or a plug-point device, using smart-metering protocols.

a. New solutions for improving energy efficiency

Energy efficiency is one of the most effective means of meeting rising energy demands. It can limit the rate of increase of electric power consumption and so reduce the need for capital-intensive investment in generation. For example, a range of technological options is available to achieve energy savings in electric lighting. These include using more efficient lamps and ballasts, and lamps with a high light output ratio. For irrigation and potable water transportation, e.g., for moving water between cisterns, more efficient DC motors and pumps could reduce electric power requirements, freeing up power for other uses.

ii. **Training programs**: Strengthen local expertise in energy technology so as to encourage initiatives in developing reliable electrical energy systems:

Develop training courses for students and teachers in high schools, universities and technical institutes;

Favor the exchange of information among expert organizations and professionals qualified to work in the field of energy production;

Organize regional forums and workshops focused on mature technologies adapted to energy production;

Work collaboratively with industry for industry-specific but vendor-neutral certification of people qualified to install and repair smart meters and smart grids;

Offer online training courses;

Teach local talent to administer, operate, and maintain electrical power equipment.

These might be efficiently and effectively accomplished by partnering with other groups involved in supporting the local community, especially local universities.

3.0 Distribution Methodology

3.1 Distribution – distributes the energy into north, south, west and east zones.

Service Providers – The regulatory authorities

Programmers– Automatic intelligent electronic devices: As described earlier, the master DA software and the engineering analysis software are the two core software elements at DCC. The master DA software provides the system information. The engineering analysis software uses the system information to provide the appropriate control decisions, which is implemented in the field through the master DA software. The main features of the developed master DA software, an example shown in Fig. 2, are listed below.

Network Generation: Graphical representation, Editing, Validation, Bill board printing Fig. 2. User interface of DA software at DCC

Monitoring: System operating point data, Topological information, Component specification, Customization, Alarm generation (audio / video)

Control: Switch control command, Control interlock

Data Logging: Logging of system operating point, Event log report, Report generation

System Information: System quantities, % Unbalance in voltage and current, Component health, Circuit Breaker (CB) / Load Break Switch (LBS) / Isolator status, Remote / Local status, Auto trip status

Graphical User Interface and Cross Platform Portability

Security for user authentication

Watchdog diagnostic and rectification tool

The engineering analysis software for network re-configuration, load shedding, volt-var control through capacitor switching, and fault detection and isolation and integrated with the master DA software.

Transmission – 11kv, 415v, 110v.

3.2 Operations – remote terminal units, remotely operable switches/area service units:

Microprocessor based substation and pole-top RTU is a modular analog and digital I/O channels, with bi-directional data communication. The acquired data (voltage and current) are processed for rms and power factor calculations. It has a capability to exchange the information with Automatic Intelligent Electronic Devices (IEDs) such as IED meter and IED relays and can be monitored by the local area offices.

3.3 Customers/Markets

Communication System

Communication system enables distributed data acquisition, monitoring and control system functions. Unlike traditional communication solutions, the approach adopted here is to have a core communication controller at the Service Provider that can support diverse choices of communication media (dialup, Ethernet, WLL, GSM) as shown in Fig. 1. This open approach facilitates cost effective implementation. The communication controller has cross-platform portability, supports functions for communications network management, and permits LAN, Internet, and Intranet connectivity through Ethernet.

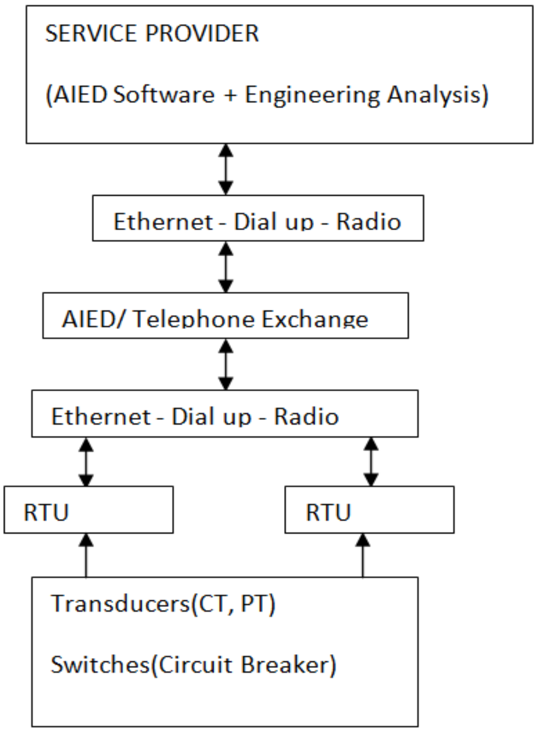

Fig. 1: Communication system for the Automatic Intelligent Electronic Devices (IED)

3.3.1 Substation AIEDs

A pole top RTU is required at each distribution transformer and a panel mounted RTU is required at each distribution substation for the purpose of their computer aided monitoring and control. These RTUs need to communicate the data with the Automatic Intelligent Electronic Devices (IEDs) available at the site Fig. 2. Examples of AIEDs are electronic meters and relays with data communication interface. The existing AIED meters and relays shall be utilized to retrieve the analog and digital information by the RTUs to reduce the instrumentation activities. The other analog quantities and digital information, which are not retrieved directly from the IEDs, are taken through the Input/Output interfaces of the RTU. This requires installing additional instrumentation between RTU and power distribution components such as transformer and feeders. Also, the RTU has provision to send the control command to the actuator of a switching element through the IED relay if available at the site. The IED meters and relays installed at the substation shall be used to retrieve the analog and digital information at the substation level (McDonald, 2003). A Personal Computer (PC) with AIED software is installed and connected in the substation to perform the task of monitoring and remote control. Few analog and digital signals, which are not handled by any of the IEDs, are directly connected with the RTU that communicates with AIED.

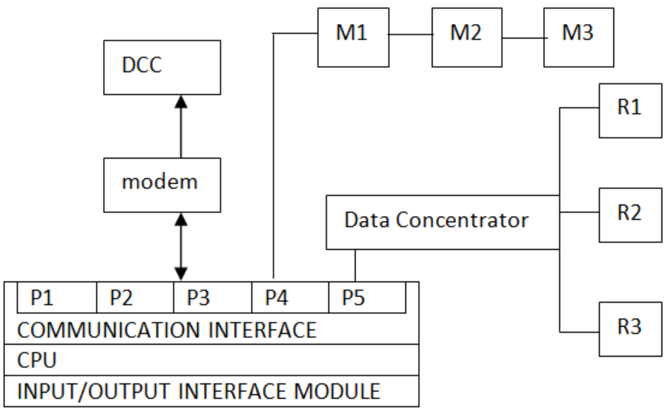

Fig. 2: Substation RTU and IED

3.3.2 Distribution Network Simulator

As a part of DA system development, a simulator has been developed which is a scaled-down model of the actual distribution network. This consists of suitably scaled-down versions of transformers, 11kV feeders, circuit breakers represented by four-pole controllable relays (with selection for remote/local operation), LT loads which can be varied from 0-150% in steps of 25%, communication linkage (for Ethernet, dial-up), single generic RTU (digital I/O and analog channels) covering all transformers. This is shown in Fig. 3. The simulator applications include testing of various communication systems and protocols, testing of DA software, fine tuning of RTU and LBS control prior to their field installation, and integration and testing of engineering analysis software. As the simulator provides a feel of actual physical system, it can serve as a training tool for operators of the DA system.

3.3.4 Field Implementation

As a pilot level installation for field reliability evaluation, the developed components and technologies of the DA system shall be installed in the real life distribution network for system monitoring and control. The distribution network considered for implementation of DA system is a part of the power distribution system at IIT Kanpur. The single line diagram of this distribution system is shown in Fig. 3. This distribution system is having various distribution components such as substation transformers, distribution transformers, feeders / lines, circuit breakers, buses, bus couplers, isolators, load break switches, loads etc.

The IITK distribution system consists of one 33/11 kV substation and 5 numbers of 11/0.415 kV substations. Further, the 33/11 kV substation includes one incoming 33 kV feeder from the KESCO utility, two units of 33/11 kV, 5 MVA transformers, four outgoing 11 kV feeders and necessary switch-gears, control and relay panels. Each 11/0.415 kV substation includes one or more 11/0.415 kV distribution transformers of different ratings ranging from 250 kVA to 2 MVA and single or multiple incoming 11 kV feeders. The 415 V feeders coming out from these distribution transformers run to different locations including residences, academic buildings, laboratories, workshops, hostels, commercial establishments, air conditioning plant etc.

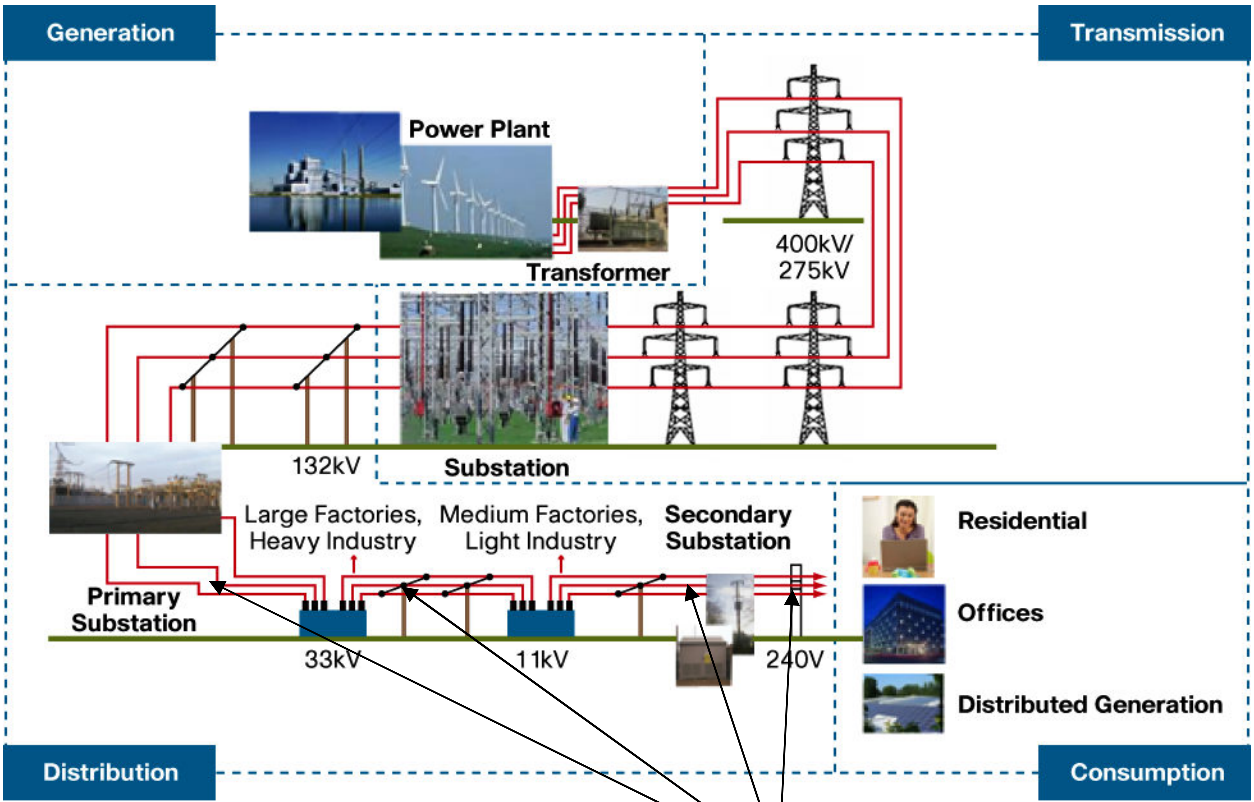

Fig. 3: Physical View of Power Infrastructure (Source: Cisco)

RTU

4.0 Conclusion

Different components of Distribution Automation System have been indigenously designed, developed and successfully implemented in the past but major developments under the project are comprehensive DA software for monitoring and controlling, microprocessor based RTU, remotely operable load break switches, data communication interfaces, distribution network simulator and necessary field instrumentation. The substation IEDs can be used to retrieve the substation data. Use of IEDs simplifies the DA installation at the substation level.

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