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Distribution Automation – a Modern Perspective

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Abstract— Advanced Distribution Automation (ADA) is a term coined by the IntelliGrid project in North America to describe the extension of intelligent control over electrical power grid functions to the distribution level and beyond. It is related to distribution automation that can be enabled via the smart grid. The electrical power grid is typically separated logically into transmission systems and distribution systems. Electric power transmission systems typically operate above 110kV, whereas Electricity distribution systems operate at lower voltages. Normally, electric utilities with SCADA systems have extensive control over transmission-level equipment, and increasing control over distribution-level equipment via distribution automation. However, they often are unable to control smaller entities such as Distributed energy resources (DERs), buildings, and homes.

Index Terms— CAN (Control Area Network), GUI (Graphical User Interface), DAS (Distribution Automation System), MATLAB, Vehicular Network Toolbox (VNT)

I. INTRODUCTION

Distributed generation is increasingly important in power grids around the world. This generation can help to support local power grids in the presence of blackouts, and ease the load on long-distance transmission lines, but it can also destabilize the grid if not managed correctly. Usually, utility control centers are unable to manage distributed generators directly, and this may be a valuable capability in the future. Industrial and residential loads are increasingly controlled through demand response. For example, during periods of peak electrical demand in the summer, the utility control centers may be able to raise the thermostats of houses enrolled in a load reduction program, to temporarily decrease electrical demand from a large number of customers without significantly affecting their comfort. Customers are usually compensated for their participation in such programs. To enable demand side management, where homes, businesses, and even electric vehicles may be able to receive real-time pricing (RTP) signals from their distribution companies and dynamically adjust their own energy consumption profiles to minimize costs. This would also preserve customer autonomy and mitigate privacy issues. • To further the penetration and quality of self-healing, which reduces or eliminates outage time through the use of sensor and control systems embedded in the distribution system. The concept of distribution automation first came into existence in 1970's[1] and since then its evolution has been dictated by the level of sophistication of existing monitoring, control, and communication technologies, and performance and economic factors associated with the available equipment. Evolution of Supervisory Control and Data Acquisition (SCADA) systems, which have been in use for monitoring the generation and transmission systems, has also helped progress in the field of distribution automation.

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Although distribution systems are a significant part of power systems and progress in computer and communication technology has made distribution automation possible, advances in distribution control technology have lagged considerably behind advances in generation [2] and transmission control. Progress of distribution automation has been relatively slow due to reluctance of utilities in spending money on automation since many utilities have found it difficult to justify automation based purely on cost-benefit numbers. Apart from SCADA there are several systems which are in place today in different places to implement the concept of distribution automation. Let us discuss all of them one by one:-

A. Power Line Communication

The first DAS using PLC was installed in Kyong–Gi District Head Office in 1983. This system uses two-way data transmission over the 22.9 kV distribution network. At the substation, signals are injected onto the 22.9 kV distribution network and 42 automatic switches in two substations have been remotely controlled. However, the signal transmission speed was too slow compared with other communication media. In the case of frequent changes of distribution lines like underground construction and load transfer, the change of communication path often causes transmission failure, which is called "open circuit problem." In other words, communication is lost with devices [3] on the far side of an open circuit. This severely restricts the usefulness of PLC systems for applications involving reclosers, switches, sectionalizes, and outage detection. PLC systems also require that a signal transmitter/receiver be installed in all distribution substations that have a downstream PLC device. These are expensive and can have significant negative impact on the cost effectiveness of PLC solutions. Recently, a new technology using high frequencies is being developed and under field test, with the advantage that utilities do not need to invest for additional communication network.

B. Pair Cable

The prototype of Korean DAS (KODAS) was developed jointly by KEPCO Research Institute (KEPRI), Korea Electro technology Research Institute and six industrial partners from 1991 to 1993, as a national research project to enhance the competitiveness of domestic manufacturing industry. To evaluate in the real field, the prototype was installed in Kang–Dong Branch Office (B/O)[4] in Seoul and in operation since 1994. Asa communication media, 70 km-long pair cables were constructed and 125 automatic switches were installed to verify theremote control functions. The other SCADA system using pair-cable has been in operation to study its performance and applicability to distribution line. The 122 automatic switches in 22 kV- underground distribution lines have been remotely controlled in Choong–Boo B/O in downtown Seoul.

Due to the low efficiency and poor reliability, pair cable has not been extended any more.

C. Telephone Line

The demonstration system using telephone line was installed in UI-ReungB/Oin 1997.Upon evaluation of the model system, it has been expanded to eight B/Os in rural area since 1998and recently, and about 19% of automatic switches have been controlled by telephone line. The advantage of telephone line is its wide service area all over the country. However, different ownership of the line and equipment's often cause the delay of service restoration. Some intermittent communication errors still need to be improved continuously. These days, telephone lines are used less because of the costs associated with installation of telephone lines and dielectric isolation equipment, and also due to the monthly cost. The cost for installation of telephone lines is increasing with the remoteness of the location.

D. Wireless Data Communication

Wireless solutions have shown the greatest potential for automating distribution networks because they communicate virtually anywhere at a very low cost. A demonstration system using a private wireless network was developed and installed in Gyong–GiB/O[5] to test the feasibility of data communication. Upon evaluation of the model system, DA using wireless data service has been expanded in their possible service areas. However, the service area of wireless data communication network is restricted to some big cities for their commercial use, and data communication response had been delayed during peak time intervals like an opening time of the stock exchange market.

E. Fiber Optic Solution

Fiber-optic cable is a very technically attractive solution, offering relatively unlimited bandwidth. Its dielectric and EMI/RFI noise immunity characteristics make it an ideal fit in the high-voltage operating environment. While fiber optic solutions are expensive, they offer two large benefits: first it allows utilities to bring back large amount of data on a frequent basis. Second, it can provide true, real-time communications. These benefits make fiber optic communications an attractive alternative if getting large amounts of data on a real time basis is critical and the location is not extremely remote. KEPCO itself possesses a huge backbone network covering the GW (composite ground wire with optical fiber). Large-scale D whole country with OPAS in urban area needs high reliability and high-speed because it needs to process a large amount of data in a short time compared with small-scale DAS in rural area with more dispersed facilities. About 57% of automatic switches in large cities have been remotely controlled, showing the best reliability and communication speed among all other communication media.

II. CAN OVERVIEW

Controller Area Network or so-called CAN is a serial bus that utilizes broadcast method to transmit messages across all CAN nodes. It uses a serial control protocol which provides reliable, efficient and economic link between devices to support the distributed real time applications by using a bitwise deterministic collision-resolution mechanism. It was originally developed in the 1980s by Robert Boush as an alternative data communications for interconnecting the control components in automotive vehicles. Prior to CAN technology [6],[7],[8],[9], all manufacturers used to connect devices within vehicles using point to point wiring systems. Wiring started to become more complex, bulky, heavy and expensive as more electronics and controllers are deployed in a vehicle. This problem can be seen in Figure 1(a), where the abundance of wiring is required which makes the whole circuit even more complicated. CAN system can solve this problem by utilizing a twisted pair cable to communicate with each other as shown in Figure 1(b).Initially, it was designed to allow the microcontrollers and devices to communicate with each other within a vehicle without a host computer. It has been fast gaining wide appreciation with further applied in various automation industrial including military, aviation, electronics, factories and many others due to its high immunity towards electrical interference, and the ability to self-diagnose and repair the data errors. Additionally, the low cost, performance and upgradeability to provide tremendous flexibility in the system design add to its many advantages.

A. CAN Protocol

The CAN system uses carrier sense multiple access with collision detection (CSMA/CD) and arbitration on message priority as its communication protocol [10]. This communication protocol allows every node in CAN to monitor the network bus in advance before attempting to transmit a message. When no activity occurs in the network, each node has the same opportunity to transmit a message. Additionally, this communication protocol allows collision to be solved by using bit-wise arbitration. It is based on a pre-programmed [11] priority of each message in the identifier field of a message. This configuration allows the messages to remain intact after the arbitration is completed even if collisions are detected. In order for the arbitration process to be successful [12], the logic states need to be defined as dominant or recessive. An example of CAN arbitration can be seen when three nodes are assumed to be transmitting simultaneously. When three nodes start transmitting their start of frame (SOF) bits simultaneously, the Nodes 1 and 2 stop transmitting as soon as they transmit bit '1' (recessive level) while Node 3 is transmitting bit '0' (dominant level). At this instance, Node 3 will continue its transmission when the identifier of bit '0' has been transmitted while Nodes 1 and 2 are entering into the receiver mode which indicated in grey color. The CAN protocol [13] is defined with the ISO *standard* of 11-bit identifier that provides for the signaling rates from 125 kbps to 1 Mbps. This standard is later improved to allow for larger number of bit with the "extended" version of 29-bit identifier. The 11-bit identifier [14] standard provides 2^{11} or 2048 different message identifiers while the extended 29-bit identifier standard provides 2^{29} or 537 million identifiers [15].

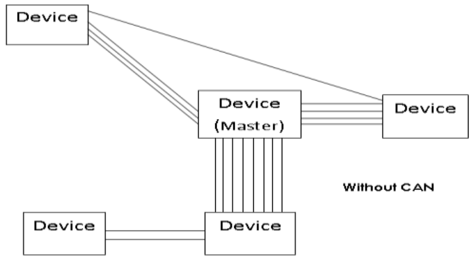

Fig. 1 (a) Traditional Wiring

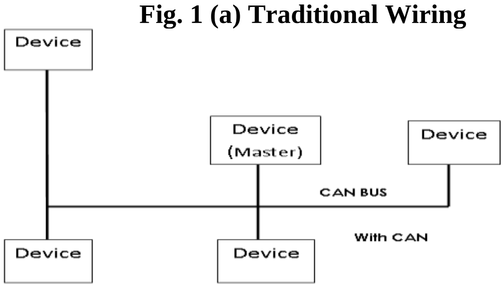

Fig. 1 (b) CAN Wiring

B. CAN in Matlab

Vehicle Network Toolbox™ provides connectivity to CAN devices from MATLAB® and Simulink ® using industry-standard CAN database files. The toolbox provides MATLAB functions and Simulink blocks to send, receive, encode, and decode CAN and XCP messages, enabling you to exchange messages between a CAN bus and your programs and models. It also can connect to an ECU via XCP on CAN using A2L description files. From MATLAB or Simulink, we can monitor, filter, and analyze live CAN bus data or log and record messages for later analysis and replay. Also simulate message traffic on a virtual CAN bus or connect Simulink models to a live network or ECU. Vehicle Network Toolbox supports CAN interface devices from Vector, Kvaser, and National Instruments.

III. PROPOSED WORK

Getting the details from the above discussion a new, innovative and modern perspective approach on distribution automation is suggested. In our proposed work we have decided to design a GUI (Graphical User Interface) system built on Matlab that will provide the link up with CAN bus. For the said purpose it has been decided to use the Vehicular network Toolbox in Matlab. The Matlab GUI will send and receive data from the CAN environment and repository mechanism to effectively utilize the information will be deployed.

IV. CONCLUSION

In this research article, a comprehensive approach toward distribution automation has been taken. Several methods were evaluated on the basis of cost and performance. In addition to that a new system based on Control Area Network has also been discussed. The proposed system is under development and GUI (graphical user interface) for the same has to be developed. Also all the technological solutions have been discussed keeping in view Indian scenario and development state in our country.

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