

A Smart Distribution Automation using Supervisory Control and Data Acquisition with Advanced Metering Infrastructure and GPRS Technology

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Abstract— To realize some of the power grid goals, for the distribution system of the rural area, which builds up a real-time, wireless, multi-object monitoring remote system of electrical equipment depending on GPRS network, with a feeder automation based on Advanced Metering Infrastructure (AMI) is proposed. GRID uses Supervisory Control and Data Acquisition (SCADA) to monitor and control switches and protective devices. This will improve routine asset management, quality of service, operational efficiency, reliability, and security. The three parts of the system are assimilated with the advanced communication and measurement technology. As a added advantage to the existing system, the proposed methodology can monitor the operating situation, easily detect and locate the fault of the feeders and status of breakers,. The information from the system helps in apprehending the advanced distribution operation, which includes improvement in power quality, loss detection and state estimation .

Keywords— ADVANTAGE METER INFRASTRUCTURE (AMI),SUPERVISORY CONTROL AND DATA ACQUISITION (SCADA),SMART DISTRIBUTION GRID (SDG), DISTRIBUTION AUTOMATION (DA),GEOGRAPHY INFORMATIONSYSTEM (GIS), GENERAL PACKET RADIO SERVICE(GPRS),ACCESS POINT NAME(APN),VIRTUAL PRIVATE NETWORK(VPN).

INTRODUCTION

The distribution systems face to the customers directly, as the key to guarantee the power supply quality and enhance operating efficiency [1], they are the largest and most complex part of the entire electrical system. While the productivity of the power system is rather low (about 55%, according to the statistics of USA) now days, the massive fixed asset investment were wasted [2]; More than 95% of power outage suffered by consumers is due to the electrical power distribution system (except the reason of generation insufficiency) [3]. Therefore, the advanced distribution automation should be developed to realize flexible load demand characteristics, the optimum of the assets management and utilization through the communication between utility and terminal customers.

Substation automation is an integrated system which can realize real-time remote monitoring, coordination and control, substation remote monitoring system has become one of the key parts of substation automation system because it takes advantage of the wireless communication technology which has several overwhelming advantages such as convenience, fast and low cost transmission. Furthermore, GPRS networking has already covered the whole country and become an important sustainable resource (for utilization and development).

Recently, the smart grid is the focus topic of the power industry, and the network model of it can change the future of the power system. The smart grid includes smart transmission grid and smart distribution grid (SDG). The unindustrialized smart grid system necessitates high speed sensing of data from all the sensors on the system within a few power cycles. Advanced Metering Infrastructure is a meek illustration of a structure where all the meters on a grid must able to provide the necessary information to the controlling (master) head end within a very short duration [3].With AMI, the distribution wide area measurement and control system consists the information exchange and integrated infrastructure [4]-[6].

Distribution system plays an important role in power systems. After many years of construction, the most of distribution system are equipment with SCADA, but, some distribution lines in rural areas with long distance can't be monitored and controlled at all. The optical fiber communication also suits to power systems for its insensitivity to electromagnetic interference, but it limits its usage in the whole power systems due to its high cost [2]. Therefore, for these distribution lines in rural area and lines with long distance, the solution with other kind of communication should be applied.

In this study, the wireless communication technology based on the AMI system, the measurement and control system for distribution system is proposed to monitor and control feeders with long distance in rural area, realize the management of the whole distribution system, furthermore, it will shorten the fault time, enhance the utilization rate of the power system asset, match the requirements of the smart distribution grid.

SDG AND AMI

SDG gives us a intergraded grid of all kinds of new technology emerging in distribution network, with perfect working distributive system. According to the operation of SDG, the one-way communication is replaced by the two-way, the customers can know the real-time price, to make a plan to use their own distribution generation to support themselves or supply the spare electrical

power to power system and charge at the period of high-price or they make decision to turn on electrical applications at the low price period.

The SDG requires high speed communication to the customers on the system. So, the two-way communication system is used to realize some function of SDG [3]. While SCADA infrastructure is typically limited due to cost, so that AMI is implemented.

AMI is the deployment of a metering solution with two-way communications to enable time stamping of meter data, outage reporting, communication into the customer premise, service connect/disconnect, on-request reads, and other functions.

The AMI systems provide a unique opportunity to gather more information on voltage, current, power, and outages across the distribution grid to enable new and exciting applications.

In the proposed system, the data gathered from AMI is used to monitor the operation status of the distribution feeder, if a fault occurred, the software will detect its location and send the command to switch off the relevant switches, furthermore, after the fault disappeared, those switches can be switched on remotely. That is a task required to realize a smart distribution grid.

PROPOSED ARCHITECTURE OF AMI SYSTEM

The measurement and control system consists of three parts, the measurement and controlling device (M&C device), communication network, and data processing center. Fig.1 shows the block-diagram of the proposed system. There are two 10kV feeders, which have 2 section switches (or recloser) each, a loop switch connects the two feeder together. The 4 section switches (S1-S4) and the loop switch (LS) are equipped with GPRS communication FTU, which is called GFTU.

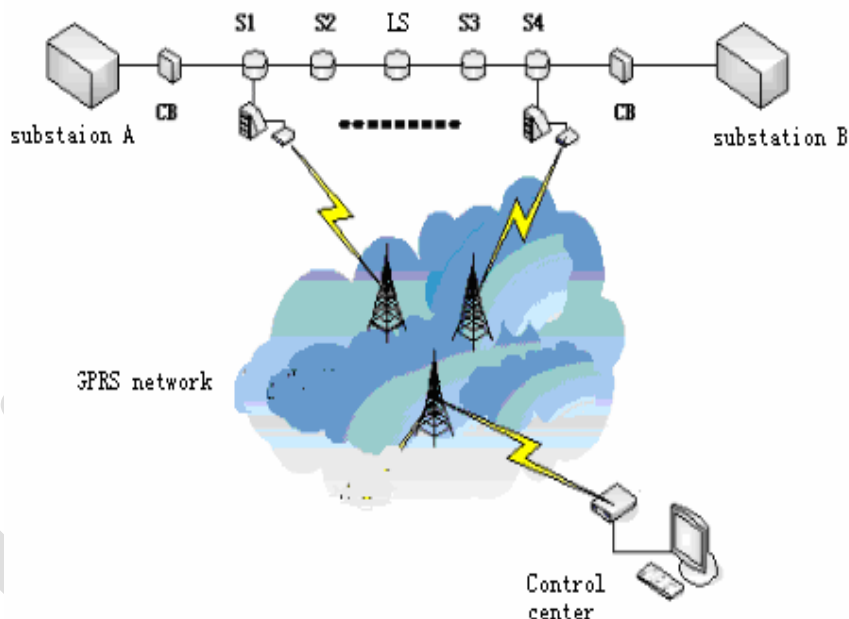


Fig.1 The architecture of the AMI system

MEASUREMENT AND CONTROL DEVICE

The measurement and controlling device consists of GPRS communication module and FTU, the GFTU is connected with switches, reclosers or breakers, gathers data from meters or switches. The configuration of the GFTU is shown in Fig.2.

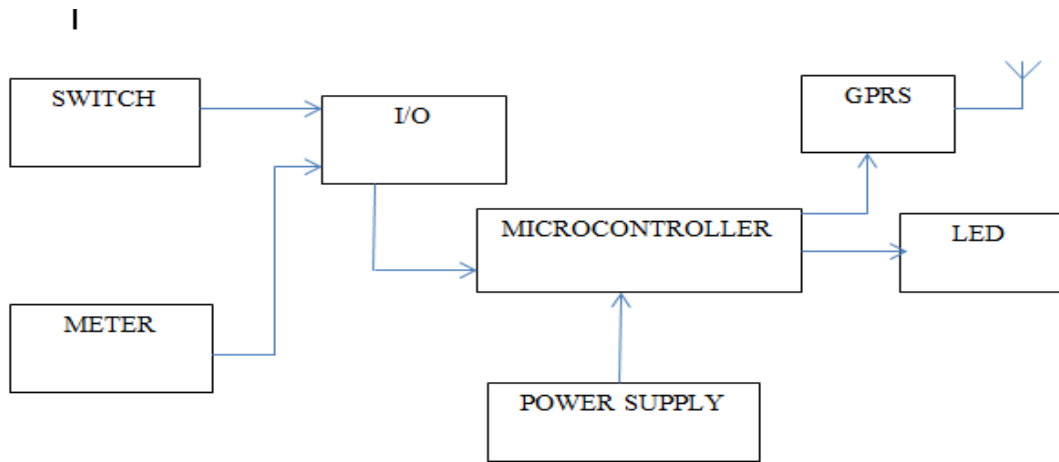


Fig.2 The diagram of the GFTU

The microcontroller collects and packages the data of the switch, and then sends them to the control center by GPRS network. The data collected includes voltage, current, power factor and so on. On the other hand, the GFTU receives the command from the control center and controls switches on or off.

COMMUNICATION NETWORK

In the proposed system with AMI, there are two levels of communication, the first level is from switches or meters to GFTUs by RS-232 or RS-485. The second level is the communication between GFTUs and the center. The GPRS communication network includes GPRS modules, which is embedded in the GFTUs, GPRS network and the server.

In this system, APN (Access Point Name) private tunnel and VPN (virtual private network) encryption and authentication technology were adopted in the control center. Each GFTU has a static IP address, they register and send data to APN (given by mobile department), and then the data are sent to the server. For the adoption of the technology of exchanging tunnel, the user can be identified. The user's data would be transmitted through the public network with high security and speed. The scheme of the GPRS network is shown in Fig.3.

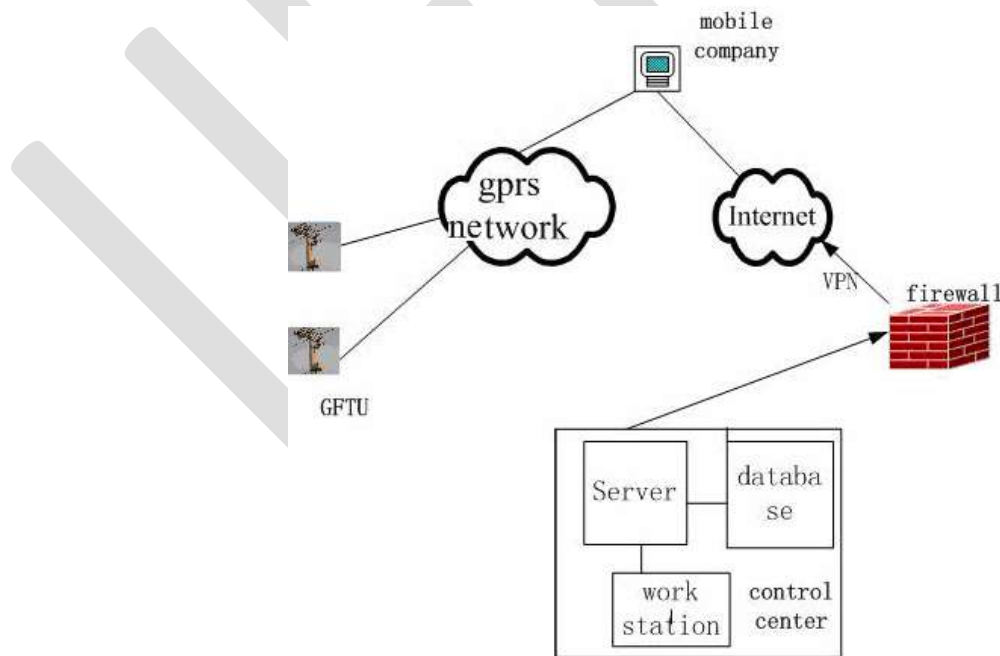


Fig.3 Schemes of the GPRS network in the AMI system

PROCESSING SOFTWARE

The processing software includes database and GIS (Geography Information System) the software gathers, process and transmit data to realize such functions:

- Display the current operating situation of the feeder onScreen;
- The fault detecting, locating, insulating and restoration in distribution systems.

In the system, data transmission between the switches and the GFTU, the GFTU and the center are bidirectional. The operator in the center monitors the operating situation of the feeder and also controls the switches in the feeder when a fault occurs.

FAULT DETECTION AND LOCATION

The distribution feeder enhances the outage management systems, to enable the “fault diagnose” capabilities of the software, which will not only lead to improved outage restoration times and also provides support for moreeffective restoration procedures.

The GFTUs collects the operating information of the switches such as voltage, current and its status. If a fault occurs, the CB willswitch off immediately receiving the current operating information from all GFTUs. In the center,the fault can be located with the help of the data from every GFTU on feeders, according to the fault current.

If it is a transient fault, the CB would reclose successfully after several seconds. If not, it would open again. The action of switches will be recorded, to make the decision to switch off the relevant switches to insulate the fault, and to reconstruct the distribution feeder to make the loss low.

For example, as shown in Fig.4, the hand to hand circle between the substation A and B, the loop switch is in off state. When a permanent fault occurs between S2 and S3, the CB at line A trips and at the same time GFTUs at the line A sends the voltage and current parameter to the control center, the fault current will be found in data from S1 and S2, otherwise from S3 and S4.

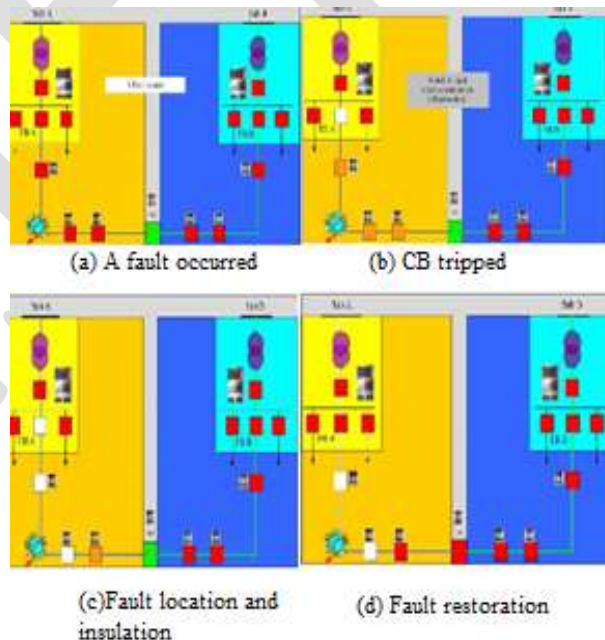
According to the topological structure, the fault was located between S2 and S3 should be switched off and the CB should be switched on remotely to restore the power supply of the feeder circuit.

AID TO ADO

To work with other systems, the monitor and control system helps in running the advanced distribution operation (ADO) of the whole distribution system, the connection of the proposed system with other software is shown as Fig 6.

MAKETHEINVISIBLEVISIBLE

The geography information system (GIS) receives the data and display on the map, so the operating situation of feeders can monitor clearly. When the fault occurs, it is displayed on the map along with its location. This helps workers to find easily.



Red: ON Green: OFF

Fig.5 Fault location and restoration.

IMPROVE POWER QUALITY

The GFTUs collect the voltage value at the different point of the feeder, the power parameters like harmonic value and reactive power can be analysed quickly helping the utility to adopt relant technology and improving the power quality of the device and also avoids the unnecessary investment.

LOSS DETECTION

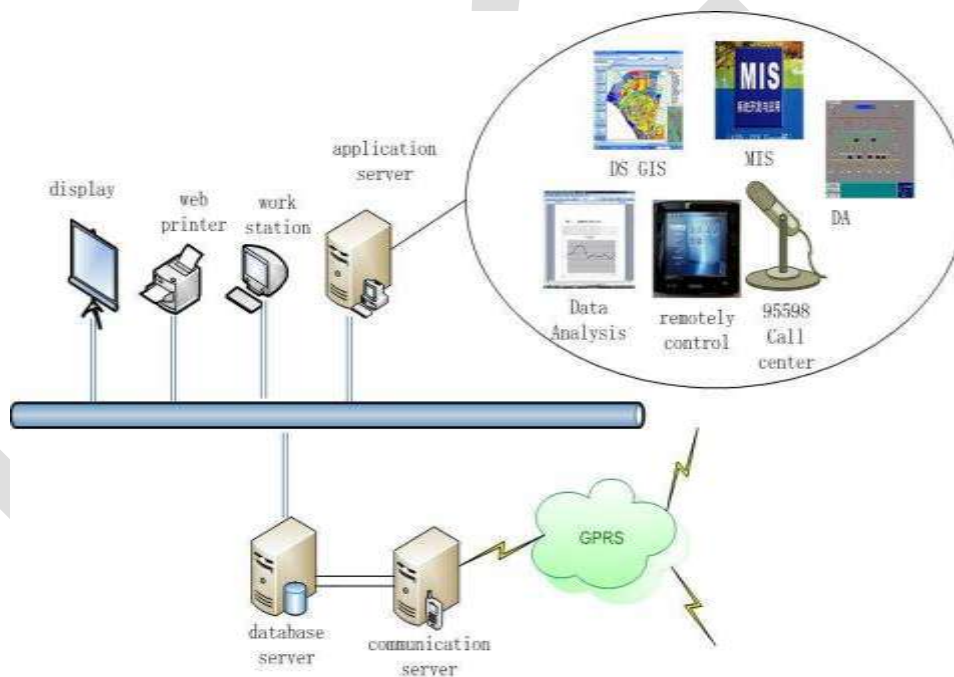
It is very difficult to know the actual losses on the distribution network. Generally, rules of thumb are used to estimate the power losses. It is probable to calculate the system losses by relating information nodes at the distribution feeder and distribution transformers. This empowers better tracking and efficacy on the distribution network.

STATE ESTIMATION

The measurements are only available at the distribution substations. The power flowing on the distribution grid are unclear, they are typically allocated using the generic models or transformer kVA rating.

By utilizing the information from the beginning and end of the distribution feeders, accurate load models can be computed allowing accurate load estimation on the distribution grid.

This data is perilous to understand the impact and benefits of connecting renewable energy sources to the distribution grid.



APPLICATION CASES

The proposed monitor and control system has run for more than one year with success in Qingdao utilities Shandong Province, China. The distribution feeder lines, line Y and line Q, are located in the north urban area of the Qingdao city, far away from the central office, about 30km. Before the installation, the lines were patrolled manually every day or week and those switches were on or off manually, it was difficult to find the fault location. 7 GFTUs were equipped in the two feeders.

The application of the proposed system helped in gathering the data almost immediately and shortened the time used to location the fault. When the measurement and controlling system based AMI was coming into use, a comprehensive test carried, as shown in the Table 1.

Table 1. The Test Item and the Result of the system

Item	Result
Switch on/off the loop switch 3 times	Correct Success rate: 100% Response time:1.2seconds
Remote reading every 5 minutes	GPRS code loss rate: less than 1%

The proposed system is cost-effective. To the information from the company, the power supply of the two lines are 12.3026MkWH and 6.70MkWH, if two fault occurs in each line, the benefit of the measurement and control system for distribution feeder is listed in Table 2.

Table 2.The benefit of the system

Item	Benefit
Saved time to seek the fault	More than 10 hours
Saved Transportation fee	500,000Yuan RMB
Avoided Electricity Loss	44,000KWH
Saved Device Loss	2530,000Yuan RMB
Total Benefit	3610,000Yuan RMB

CONCLUSION

Smart grid is a throng of perceptions that includes newpower delivery components, control and monitoring throughout the power grid and more informed customer options about the next generation power system. Smart distribution grid is an important part in it. To realize the smart distribution grid, an AMI based measurement and control system for the distribution system is proposed in this paper.

It enables utilities to run the advanced distribution operation in a cost-effective manner. The adoption of advanced multi-communication media, such as GPRS or 3G, enables the AMI system to collect the meter data quickly with accuracy automatically. The proposed system can work on existed feeder automation system with other communication types, and integrate distribution automation system to reduce the labour cost, accurate loss detection and load forecasting. It will be a very important installation to the realization of the smart distribution grid.

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