Proceedings of the Second IASTED Africa Conference
Power and Energy Systems (AfricaPES 2008)
September 8-10, 2008 Gaborone, Botswana

A SURVEY AND CLASSIFICATION OF TELECOMMUNICATION NEEDS IN POWER SYSTEMS

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ABSTRACT
In the world today, an electric power system constitutes a very large percentage of energy used by industries, commercial enterprises and domestic consumers. The need for a reliable and uninterrupted supply of electric power has gained high importance. To ensure a reliable delivery of electric power, reliable and real-time information is needed by the electric power utilities. This has created a need to enumerate and explain the needs of communication in power system industries and also to give possible telecommunication technologies that can meet these needs. This paper gives an overview of the needs of communication in power system and classifies these needs based on their sensitivity to delay, bit error and variation of delay

KEY WORDS
Energy Management System (EMS), Communication and Power systems.

1. Introduction

Most industries and private sectors depend on electric power to function properly and therefore a cut-off of the electric power due to equipment failure, accidents, lightning, human vandalisation and natural catastrophe can cause a huge loss for its consumers. The electric power industries are therefore challenged with ensuring that reliable and uninterrupted power is supplied to its consumers. The concept of electric automation, which is the creation of a reliable and self healing electric system that rapidly responds to real-time events with appropriate actions, comes into play [1].

System automation is the act of automatically controlling the power system via automated processes within computers and intelligent Instrumentation and Control devices. The processes rely on data acquisition, power system supervision, and power system control all working together in a coordinated automatic fashion [2]. Acquisition and transfer of data is important in monitoring, controlling and protecting the electric power system, these data can be used locally within the device collecting it, sent to another device in a substation or sent from the substation to the control centre. This transfer of data requires telecommunication system.

The operational and commercial demands of electric utilities require a high-performance data communication network that supports both existing functionalities and future operational requirements. This information is needed in some cases in real-time without delay and in some cases for administrative purposes which can accommodate delay in the transfer of information. Due to this reason different telecommunication technologies can be carefully employed to meet different needs.

Multidisciplinary interactions between power and telecommunication engineering needs to be maintained for the advancement of these industries. The objective of this paper is to provide avenue for recent advancements in the telecommunication to be introduced into the power system industry, and conversely the new communication challenges in the power system industry to be manifested. It is expected that through the analysis of these needs and the classification carried out, this paper will pave way for further relevant research activities to be identified and promulgated.

2. Communication Needs in Power Systems

Communication constitutes a big role in the proper operation of a power system industry. As the demand for a reliable and uninterrupted power by its consumers increases it is also important to pay good attention to communication needs in power system since it plays an important role in ensuring a reliable delivery of power.

The following are the communication needs in power system:

- Teleprotection
- Power system control
- Asset management
- Fault location and detection
- Metering and transfer of settlement information
- Security system
- Substation camera supervision
- Traditional telephony

These communication needs are fully discussed in the following sections.

3. Teleprotection

Electric power system often encounter short circuits when equipment insulation fails, due to system over-voltages caused by lightning or switching surges, to insulation contamination, or to other mechanical and natural causes. Careful design, operation and maintenance can minimize the occurrence of short circuits but cannot eliminate them. When a fault occurs current are produced, which can be several orders of magnitude larger than normal operating current and if allowed to persist may cause insulation damage, melting of the conductor, fire and explosion. Windings and bus bars may also suffer mechanical damage due to high magnetic forces during faults. For this reason a protective system needs to be put in place to clear or isolate fault within the shortest possible time.

Blackburn defines protection as “the science, skill and art of applying and setting relays and/or fuses to provide maximum sensitivity to faults and undesirable conditions, but to avoid their operation on all permissible or tolerable conditions”.[3]

A secure and uninterrupted supply of electricity is only possible with the help of comprehensive protection and control functions, which ensure the reliable operation of the power system. As the complexity and ratings of electrical power systems increase, so do the demands on the protective devices and systems which have to protect them from damage and preserve power system stability.

The components of an electric power system protection are;

1. Instrument transformers
2. Relays
3. Circuit brakers
4. Communication channel

The first three components are basic and general to protection within power system equipment like generators, transformers, buses, and motors and protection between two devices which are situated at one geographical location where current transformers and relays can be directly interconnected. The fourth component is needed in a situation whereby protection is needed between two devices which are situated in two different geographical locations and also transmission lines. For the purpose of this paper we will focus on protection between devices which are in different geographical locations and this type of protection is called Teleprotection.

Depending on the protection scheme in use, the command signals trip the remote circuit breaker either directly (direct tripping) or are first enabled by the local protection device (permissive tripping). Other protection schemes involve tripping prevention by the local protection device (blocking). A fundamental requirement in all these applications is that command signals are communicated reliably at the highest possible speed. In the event of a fault on the protected unit, the command signals must be received at the remote end in the shortest possible time even if the channel is disturbed by the fault (dependability).

On the other hand, interference on the communications channel must never cause unwanted operation of the protection by simulating a tripping signal when there is no fault on the power system (security). The most important features of teleprotection equipment are therefore transmission time, dependability and security. From the communications engineering point of view, the bandwidth teleprotection equipment occupies must also be taken into account. [4]. It is seen that teleprotection is important to ensure a reliable power delivery and the backbone of teleprotection is a good telecommunication technology.

4. Power System Control

Power system control mainly includes supervisory control of the power process on secondary or higher levels. These systems are of the kind: SCADA/energy management system (EMS). SCADA is the acronym for supervisory control and data acquisition. SCADA systems are typically used to perform data collection and control at the supervisory level. Some SCADA systems only monitor without doing control, these systems are still referred to as SCADA systems. The supervisory control system is a system that is placed on top of a real-time control system to control a process that is external to the SCADA system (i.e. a computer, by itself, is not a SCADA system even though it controls its own power consumption and cooling). This implies that the system is not critical to control the process in real-time, as there is a separate or integrated real-time automated control system that can respond quickly enough to compensate for process changes within the time-constants of the process.

For the purpose of this paper we will focus on the uses of SCADA in electric power system industry. A SCADA system includes input/output signal hardware, controllers, HMI, communication infrastructure, database and software. A reliable telecommunication technology is an essential component of a SCADA system.

5. Asset Management

Modern electric power systems comprising of power transmission and distribution grids consist of a large number of distributed, autonomously managed, capital-intensive assets.

Such assets include power plants, transmission lines, transformers, and protection equipment. Avoiding catastrophic failures and ensuring reliable operation of such a complex network of assets presents several challenges in data-driven decision making related to the operation, maintenance and planning of assets. Specifically, decision-makers must anticipate potential failures before they occur, identify alternative responses or preventive measures, along with their associated costs, benefits and risks.

Effective decision-making in such a setting is critically dependent on gathering and use of information characterizing the conditional, operational and maintenance histories of the assets, e.g., equipment age and time since the last inspection and maintenance. Recent advances in sensing, communications, and database technologies have made it possible, at least in principle, for decision-makers to access operating/maintenance histories and asset-specific real-time monitoring data, which can be used to ensure reliable and cost-effective operation of modern power systems so as to reduce (if not eliminate) the frequency and severity of catastrophic failures such as blackouts.[5].

Asset management decision problem can be divided into five layers [6] namely;

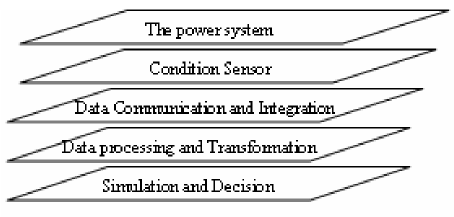


Figure 1. Asset management layers

This process involves gathering and transfer of information from one location to another; this is realized with the help of a good telecommunication technology.

6. Fault Detection and Location

Fault detection scheme that detects and locates feeder fault under fault condition accurately will facilitate a safe, prompt and yet reliable reconfiguration of the distribution network. Achieving this objective will result in an improvement in the Reliability of Supply which is a key factor to the power system operation. Remote monitoring of the distribution network will further facilitate the operational enhancement of the network by providing feeder analogue data that is invaluable for optimizing network operation. [7] To locate a fault in a conventional power system, one relies on data collected by recording devices such as digital fault recorders or digital relays at the substations. The data can usually be acquired through the control centre of a power company.

The control centre is also equipped with the SCADA system and EMS that provide computer, communication and software facilities for system operators to monitor and control the system. [8] Traditional power system fault location techniques involve the use of different protection or recording devices, such as Digital Fault Recorders, Digital Relays, Sequence of Events Recorders, and Phasor Measurement Units.

When a fault occurs the event data is stored and transported to the master station via a communications system which is constantly communicating with the traveling wave equipment sites, whether there is a fault or not. Event data can be transported to the master station in seconds, depending upon communication system configuration, communication channel speed, and scan rates. The master station receives data from the faulted line as well as other lines in the area. The faulted line generally will have the earliest time tags.

Other information systems, such as relays and fault recorders, will confirm the fault. Once the faulted line is identified, the fault location calculation occurs. The use of conductor length instead of line length during the calculation can improve the accuracy. Further conductor length accuracy can be obtained by considering conductor sag due to loading and temperature and wind conditions at the time of the fault.

With sufficient line information, the system operator will be able to locate the transmission tower or towers to investigate and their location and number can be given to the field crews. The system operator may also be able to isolate the fault via supervisory-controlled switches or circuit breakers to quickly restore service to customers [9], communication is of paramount importance in the area of Distribution Feeder Automation in general. In particular, demanding system performance characteristics required by the protection side of automation result in specific communications solutions for specific applications.

7. Metering and Transfer of Settlement Information

The manual meter reading has been replaced in many countries with an automated meter reading, which makes use of a communication system to transfer data collected from the meter. Telemetering is referred to as the facilities that measure, transmit and record real time operational data (e.g. instantaneous voltage, current, energy, and status and alarm information) to the system control entity.

7.1 Metering System Components

Metering systems consist of the following basic components:

- Meters
- Data-collection system
- Data storage
- Data analysis and presentation.

These components are found in even the simplest monthly manual-reading system, where the meter has a visual display and is read and manually recorded by a human meter reader. This information is then manually entered into the billing system and presented in a monthly bill. For this discussion, the manual activities need to be replaced by automated processes, and the data analysis and presentation need to provide much more detailed information about the nature of energy consumption. Depending on the needs, real-time or near-real-time data presentation may be necessary. The replacement of this manual reading brings about the concept of telemetering. The amount of energy consumed by the consumer is monitored automatically with the help of a good telecommunication technology.

8. Security System

Big organizations like the power system industry put security systems in place to provide a safe working environment for their staffs and also to prevent intruders from gaining access into their premises. There are different types of these security systems used for example access into buildings, equipments, and even computers. It can be in the form of passwords, fingerprint, magnetic tapes or materials, voice recognition, iris detector and so on. Without a proper communication system, none of these is possible.

9. Substation Camera Supervision

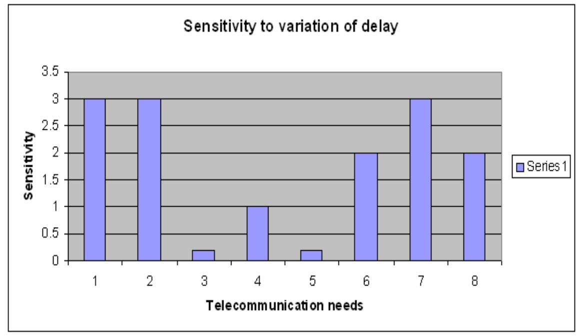
Cameras are placed in substations to monitor any event in the substation. This can be mainly for security reasons. Closed Circuit TVs (CCTV) are strategically distributed within the substations to monitor the equipment in the substation. These cameras are monitored in a control room and this involves communication between the cameras and their monitors.

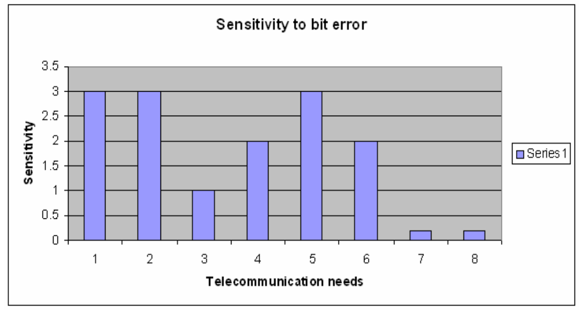
10. Traditional Telephony

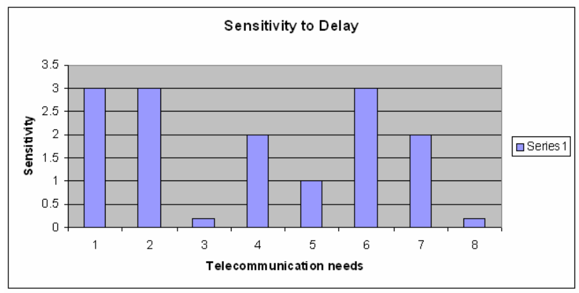
Voice communication is important in proper functioning of a power system industry. According to Ericsson, [10] traditional telephony can be classified under real-time operational voice communication, where voice communication has an operational purpose, e.g. troubleshooting in a disturbed power operational case or power system island operations. It can also be classified under administrative communication where voice communication and facsimile is needed within the company and also between the offices at different geographical locations for administrative purpose.

11. Classification of Communication Needs

Telecommunication needs in the power system industry can be seen in terms of voice, data and video. The speed at which these services (voice, data, and video) are transferred depends on the medium of communication and also the data quantity to be transferred.







S/N	Telecommunication Needs In Power System
1	Teleprotection
2	Power system control
3	Asset management
4	Fault location and detection
5	Metering and transfer of settlement information
6	Security system
7	Substation Camera supervision
8	Traditional telephony

11.1 Voice Communication

This class includes mainly the traditional telephony which can be provided for both administrative purposes and administrative operational purposes.

11.2 Data Communication

This class includes teleprotection, power system control, asset management, fault location, metering and transfer of settlement information and security system.

11.3 Video Communication

This includes mainly the substation camera supervision.

The graphs below show the sensitivity of the various needs to delay, bit error and variation of delay.

12. Discussion of the Classification

The graphs give the summary of the sensitivity of the communication needs, which helps in classifying these needs into three different categories namely;

- Highly sensitive telecommunication needs
- Sensitive telecommunication needs
- Less sensitive telecommunication needs

The sensitivity scale is from 3-1, 3–shows the highly sensitive telecommunication needs and decreases to 1 which shows the least sensitive. These according to Ericsson [10], was classified as;

- Real-time operational communication
- Administrative operational communication
- Administrative communication

12.1 Real-Time Operational Communication Requirements

Real-Time operational communication constitutes communication in real time that is required to maintain operation of the power system. This category of communication needs requires that information being transferred is delivered in the shortest possible time without delay and this interaction must take place in real time. Communication in this class requires a communication technology which can transmit information in the shortest possible time.

This class is in turn divided into real-time operational data communication and real time operational speech communication.

Real-time operational data communication constitutes;

- Teleprotection
- Power system control

Real-time operational voice communication constitutes;

- Traditional telephony; where voice communication has an operational purpose, e.g. voice communication between a control centre staff and a field engineer for the purpose of trouble shooting a disturbed power system.

12.2 Administrative Operational Communication Requirements

This class of communication requirement includes information which supports the description of what has happened in minor and major power system disturbances. Examples are interactions with local event recorders, disturbance recorders, and power swing recorders. This class of communication is characterized in that interaction does not need to take place in real time. Time requirements are moderate. The following functions are included in this class:

- Asset management;
- Fault location;
- Metering and transfer of settlement information;
- Security system;
- Substation camera supervision.

12.3 Administrative Communication requirements

Administrative communication includes voice communication and facsimile within the company (also between the offices that are at different geographical locations) as well as to and from the company where the communication has an administrative purpose. Examples include the following:

- Telephony, facsimile (over PSTN and/or cellular network);
- e-mail which serves as substitute and/or supplement to internal and external regular postal services.

These supports can also be used for administrative operational communication purposes. [10].

This class is also important for the smooth running of power system industries. It involves coordination of all the man power that constitutes the industry.

13. Conclusion

This paper has given an overview of communication needs in power system and it has classified these needs according to their sensitivity to delay, bit error and variation of delay. This classification also shows the importance of the various telecommunication needs in power system.

This paper can help power system industries to accurately decide on which telecommunication technology that best suits these needs.

With the improvement in telecommunication technologies the next stage of this work will deal with the corresponding communication technologies that best suit these needs.

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