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Computer Networking for Operation Management and Optimization in Power Utility Industry

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Abstract

The connectivity, flexibility, and real time control capability of computer systems have lead electric utility companies to consider the use of computers and telecommunication networks. The application of such an environment includes data acquisition, supervisory control, operation optimization, and data management. This paper presents the layout of a computer system network for an electric power utility.

Introduction

A computer system network consists of several computers and computer networks which share critical process information through a common data base and communicate on a high speed medium such as fiber optics. The objective of a computer system is operation at optimum level with regard to product quality, production quantity, manufacturing cost, and reliable service to customers.

Since 1970 engineers have sought ways to incorporate computers in monitoring and controlling the critical functions of various process industries, such as electric power utilities. An electric power utility consists of four major units. These units are power generating plant, power transmission lines, distribution system and substations, and the utility business segment.

The latest technology trends in computer systems that can meet the operational objectives of an electric power utility are called distributive process control, open architecture, and universal networking. Distributive process control (DPC) is configured from field sensory instruments, computers, networks, and database software. DPC allows distribution of control actions and information throughout the entire system units such as generation and transmission. An open architecture approach consists of both hardware and operating system which can be customized to meet specific power utility application requirements. Universal networking, using protocol conversions and emulation, links unit stations to dissimilar unit computers on one universal network. Networking ensures that field instruments and computerize automation link with perfect synergy.

An overview of an electric power system is reviewed in the next section of this article. Distributive process control networking is also described. Finally, a computer network structure to control the functions and processes of a power system is proposed.

An Overview of Electric Power System Structure

An electrical power system is a system of interconnected subsystems which convert non-electrical energy into electrical form, transport it over a great distance and transform it into a specific form for the user. Power systems must be reliable, safe, efficient, economical, and non-hazardous to environment. The major parts of a power system include **[1,2]**: 1)Generation - Generators represent the source of electrical energy and they are the power conversion devices which convert the non-electrical energy into electrical form. Power generated by generators ranges form 100KW to 1300MW with voltages ranging 480V to 30kV. Power for electric power system may be generated by several major methods. One method is generation with thermal power stations which utilize the energy of fuel. Another method is the hydro power stations, which utilize water power. There are also methods which utilize both thermal power and water power. 2)Transmission - Using transmission lines, power is transferred from generation sites to the areas of use. The voltages on these lines can be as large as 765KV. The device that links the generator to transmission lines is called transformer, since it transforms the lower generation voltages to the higher transmission voltages. As the voltage increases, the current is simultaneously decreased. There are two basic transmission designs: underground, and overhead. The overhead design is more common. These types of lines can cover distances up to hundreds of kilometers. Factors such as weather and transmission line loses must be considered in operation of transmission lines and distribution substations. Power generation and transmission are the focal point of power system operation. Power at transmission substations can be supplied to commercial customers such as other power utilities, large industrial users, or to low volume electric users. 3)Distribution - Transmission lines deliver the power to distribution substations, where the main transmission circuit is branched and its voltage is stepped down. Individual distribution circuits extend to industrial and residential customers from these substations. These circuits are the primary distribution points. At a secondary distribution point, voltage is stepped down to utilization level for residential and low volume commercial customers. A secondary distribution point is at the pole transformer. 4)Business Unit - The unit that coordinates the operation of the generating plant, transmission lines, and distribution system is located at the electric utility corporate office. The business unit monitors and enforces good customer relationship and marketing practices. This unit integrates data for optimum MRP (Material Requirements Planning) level business activities such as scheduling, purchasing, and sales.

Computer Networks

Computer interfacing to the process has been greatly simplified due to the development of distributed control systems. Linking these computers that need to share information and resources such as process data is the prime use of distributed control and computer networking.

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Distributive process control (DPC) is a form of instrumentation that is used to monitor and control the process of large systems **[3]**. Two major work areas considered in a DPC system are the central control station and remotely located but centrally controlled stations. There is a continuous transmission of information between these two locations. The central control station is equipped with devices to monitor process conditions and to manipulate the control functions for the processes at the remote ares. In this distributed environment upper level computers depend on lower level devices for process monitoring and data collection, and lower level systems depend on the higher level systems for sophisticated controlling functions for plant optimization. The information transmitted from the processing area is displayed on an operator interface such as a computer monitor. The DPC input module measures the analog signals of the process variable and its feedback information. The DPC output module will generate the proper signal to the devices that can manipulate the condition of the process. Analog-to-digital and digital-to-analog convertor boards and field sensory instruments are used for interfacing the process to the computer. The analog-to-digital convertors (ADC) will receive analog data from the sensory instruments and convert the information to digital form which is recognizable by the computer. Digital-to-analog convertors (DAC) are used to translate and transmit the corrective action from the computer to the process.

In a network system, computers can share information through communication with each other. Computer networks can have multiple configurations. These configurations can be point-to-point, point-to-multiple points (star), multi-point distributed (bus), and multi-point fault tolerant (ring) **[4]**. Many networks combine two or more configurations in the same communication system. Standardizing communication between systems from different manufacturers is a necessity. Standards that address network protocol and address the interface with the computer programs are proposed by Open System International (OSI) and the Institute of Electrical and Electronic Engineers (IEEE) **[5]**.

Fiber optic cables are the most recent medium for computer networking. Due to their design features, fiber optic cables can eliminate a variety of network problems. Fiber optic cables transmits information using pulses of light and due to this feature they offer complete protection of data transmission from external electromagnetic interferences. The interferences can cause bit errors and garbled messages. Fiber optic is constructed from pure glass with high melting point and outstanding insulation. These properties enable fiber optic cables to provide isolation of critical communication paths from harsh or hazardous environment. These cables can carry a high volume of information over long distances. The cost of fiber optic cables in local area and wide area networking is lower than installing copper cables carrying the same amount of information. Coaxial cables, shielded twisted pairs and electrical conduits are not required when fiber optic lines are used **[6]**.

Computer networking within an organization is no longer a single vendor environment. The integration of distributed computer control in this multi-vendor environment necessitates applications of open architecture software and protocol convertors. The integration would result connectivity among each of the network data bases and these distributed databases can be the source of the entire system data.

Computer Network Structure for a Power Utility

The computer network structure for a power utility is illustrated in Figure 1. Using this structure, computers in different levels can combine the production, scheduling and management functions with process control data. This structure has four levels:

<u>Cell level</u>:

Control of each operating unit which uses material and energy. These operating units are controlled by supervisory functions from upper levels, to perform at maximum efficiency. The control within the level reacts to alarms and emergencies within the area of its control. The functional tasks of the first level are fixed and will not require human interaction. The list of processes in a power utility that can be controlled at the cell level are listed in Tables 1a, 1b, and 1c.

<u>Center Level</u>:

This level performs supervisory control. It coordinates cell level activities and optimize the operation at both cell and center levels. The supervisory task assures the limit on the material and energy used. It also responds to alarms and any other emergencies of the units under its control by shutting down the process or other interlocking safety actions. The computers at this level are capable of communicating to upper level computers for more information. The operator is responsible for monitoring the process and updating the required controlling algorithms. The functions of a power utility that are in this level are listed in Tables 2a, 2b, and 2c.

<u>Factory Level</u>:

The overall production control and system optimization of each center is done at this level. This level decides the unit operation based on optimum combination of time, energy, material, and customer needs.

The factory computer performs forecasting tasks to coordinate the processes at the power plant and transmission and distribution centers. Daily, weekly, and monthly reports for each of these units are developed in this level. The factory computer also monitors and performs business-related functions such as data processing, document management, maintenance, and material control. Figure 2 illustrates the function modules within this level.

The role of the operator at this level can be one of the following. In the first method, information on the controlled system is directly feed to the computer from the lower level. The data analysis, and calculation of deciding factors is done by computer. It will recommend the action and the proper controlling device to the human operator. The recommended action would be performed by the operator. In the second method, the computer will receive data directly from the lower level, and will recommend corrective actions to the operator, and also sends controlling commands to the lower level. The operator at the lower level updates the controlling algorithm required by this action.

<u>Corporate Level</u>:

The corporate computer coordinates the operation of all factory computers, collects data and summarizes the operations and performance of the entire firm. The functions performed by the corporate computer are: customer information, customer billing, trouble call management, buy/sell management, report generation, strategic planning, human resource management, electronic mail service, and finance. At this level, the computer recommends the path of actions based on the information given to the computer, gathered and developed by operators. The final decision is made by the management group.

Reliability assurance and availability of systems are the functions of all levels. These tasks are based on fault detection redundancy and other built in methods which are included within the levels during the design and implementation.

Conclusion

Computer networks can contribute to development of further application possibilities in the power utility industry. The productivity analysis and transmission of information by power utility operators would be improved by office automation and its link to other units.

Following critical activities should be considered in integration of a computer control system:

1. Assessment of user needs.
2. Establishment of system architecture using computer industry standards.
3. Development of unit control strategies and distributed data base.
4. Selection of Communication medium and protocols.
5. Identification of data base users and security levels.

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TABLE-1a CELL COMPUTERS FOR GENERATION
1. Material Handling Control
2. Cooling Towers Control
3. Feed Water Treatment
4. Evaporator Control
5. Heat Exchange Control
6. Turbine Safety & Interlocks
7. Generator Speed Control
8. Frequency Control
9. Miscellaneous Temperature Control
10. Miscellaneous Flow Control
11. Miscellaneous Pressure Control
12. Miscellaneous Mass Control
13. Shut Down Interlocks

TABLE-1b CELL COMPUTERS FOR TRANSMISSION
1. Pre/Post Fault Recording
2. Operator-Event Recording
3. Operator-Event Time Tagging
4. Feeder Load Monitoring
5. Feeder Harmonic-Noise Recording
6. Remote Transfer of Fault Recording
7. Protective Relay Monitoring
8. High Voltage Switch Gear Monitoring
9. Transformer Monitoring
10. Voltage on The Bus
11. Current Draw
12. Power Flow and Power Available
13. Weather Information

TABLE-1c CELL COMPUTERS FOR DISTRIBUTION
1. Pre-Post Fault Recording
2. Operator-Event Recording and Time Tagging
3. Feeder Load Monitoring
4. Feeder Harmonic-Noise Recording
5. Remote Transfer of Fault Recording
6. Protective Relay Monitoring Voltage
7. Current Draw
8. Real Power Flow
9. Reactive Power Flow Power Factor
10. Weather Information
11. Medium Voltage Switch Gear Monitoring & Control
12. Transformer Status Monitoring and Control

TABLE-2a CENTER COMPUTERS FOR GENERATION
1. Plant Wide Data Acquisition Display
2. Plant Wide Monitoring
3. Plant Wide Alarm Annunciation
4. Continues Data Logging
5. Historical Data Archival
6. Automatic Testing
7. Automatic Turbine Start-Up
8. Automatic System Shut-Down
9. Program Down-Load Capability
10. Generation Process Optimization.

TABLE-2b

CENTER COMPUTERS FOR TRANSMISSION

1. Alarm Management
2. Automatic Generation Control(AGC)
3. State Estimation
4. Unit Commitment
5. Load Flow
6. Load Forecasting
7. Capacity Calculation
8. Power Flow Optimization
9. Program Down-Load Capability
10. Switch Gear and Transformer Control
11. Protective Relay Remote Setting

TABLE-2c

CENTER COMPUTERS FOR DISTRIBUTION

1. Distribution Load Management
2. Alarm Management
3. Time Data Gathering
4. Power System Event Logging
5. Geographical Mapping
6. Time-Event Logging
7. Program Down-Load Capability
8. State Estimation and Optimization
9. Security Analysis
10. Power Flow
11. Power Quality Monitoring
12. Feeder Analysis

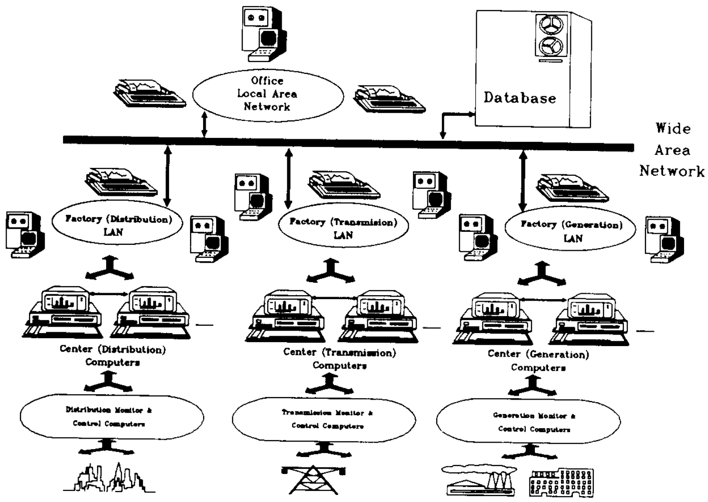

Figure 1. DPC Structure for Electric Utility

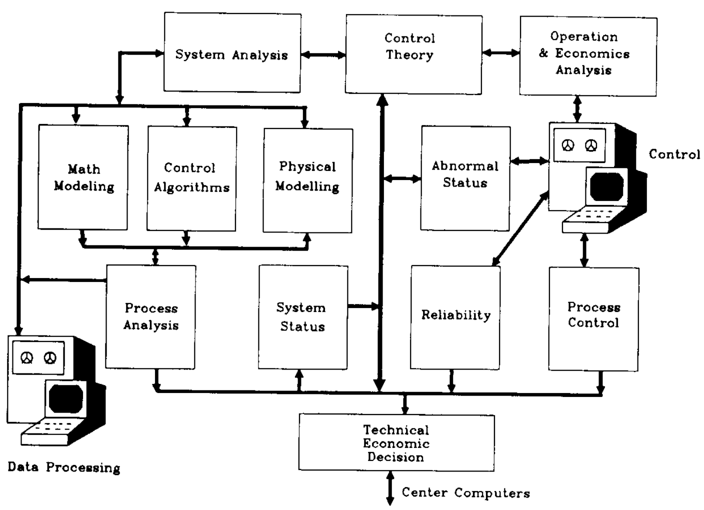

Figure 2. Factory Level Computers