POWER MANAGEMENT SYSTEM/ENERGY CONTROL CENTER DESIGN

by

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ABSTRACT

Many factors must be considered in order to design a power management system (PMS) which is effective from both a cost and benefit point of view. This paper reports on a conceptual design study and the initiation of a development project to enhance the capability of a PMS for a major electric power system. Insights are provided relative to the determination of true PMS requirements, the assessment of alternative design strategies, and the planning of a phased system development.

A brief historical background of the use of computers in power system operations is given, and the justification of a PMS concept is discussed in terms of costs incurred and performance and values returned. The relationship between growth trends, technological advances, and the functional or applications requirements of a PMS are presented. Simulation studies and investigative analyses which are essential to the evaluation and selection of alternatives are cited and positioned in an overall system development life cycle.

1. INTRODUCTION

Computer/Information systems used to aid in the real-time control of electrical power systems are interchangeably called "energy management systems (EMS)" or "power management systems (PMS)." In the Electric Utility Industry the operation of such systems is normally performed at "energy control centers," "power system coordination centers," or "power control centers."[1] These locations monitor the behavior of generation, transmission and distribution facilities, and perform analyses and control functions in order to accomplish the basic objectives of power system operations -- providing reliable, high quality service to customers at the lowest possible cost.

Early power management systems consisted of strip chart recording and indicating meters, static "mapboards" showing the status of power system apparatus components, and voice communication systems and later analog data communications and hardwired supervisory control systems. Beginning with the Southern Company system "Early Bird" installation in Birmingham, Alabama, in 1953, analog computers began to be used for load frequency control (automatic generation control). Hybrid computers began to replace analog computers around 1963, and the first complete digital system control was implemented in 1965 in Lexington, Kentucky.[2]

Today most of the major electric utilities either have installed or are planning to install modern power management systems. Installed power management systems are continuously being upgraded, converted, and enhanced as a consequence of the more stringent requirements imposed by the growth in size and complexity of the power system and the increases in capability and decreases in cost accompanying advances in information systems technology.

During the last two years, the authors have been researching cost and performance factors related to the design of a more advanced power management system for the Southern Company system. The Southern Company system is one of the largest and most complex public utility systems in the United States. It ranked third among U. S. utilities in total energy sales with 73,872 million KWH, and its maximum integrated-hour demand was 15,759,100 kilowatts in 1974.[3] The system is widely geographically dispersed over approximately 120,000 square miles, serves approximately 2.3 million customers (including residential, industrial, and commercial), and utilizes coal, oil, gas, hydro, and nuclear generating plants.[4]

2. SYSTEM DESCRIPTION

The Southern Company System put a modern digital power management system (PMS-I) into operation in September, 1973. This system (PMS-I) may be described as a centralized information processing system with decentralized control (see Fig. 1). Users are located at 18 locations and three "control levels": pool, company, and division. The pool level coordinates system generation so as to match customer demand as economically as possible consistent with high reliability. The company and division levels monitor and control the integrity of the transmission network. The central facility consists of two master computers (IBM 370/158) with two megabytes of memory each, 16 disk drives with 100 megabytes of storage each, and five communications preprocessors for data acquisition (DAQ) and video terminal communications. Additionally, tape drives, line printers, card readers, video terminals and a card punch are provided for use by the operations, maintenance and development personnel.

PMS-I CONFIGURATION

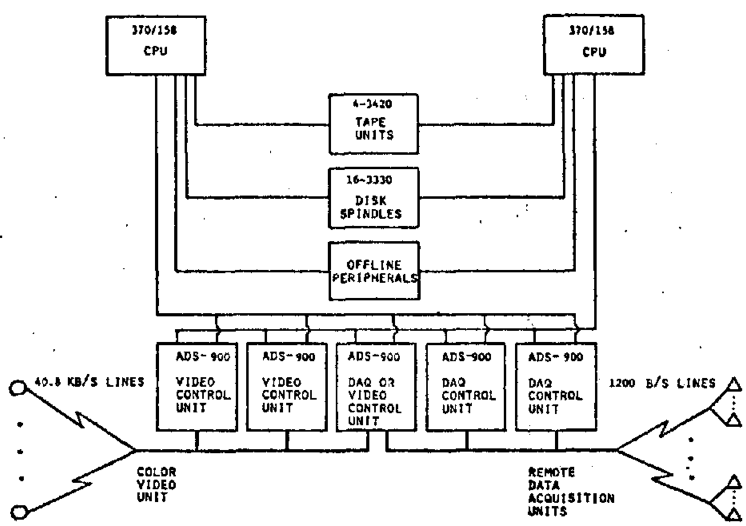

Figure 1

Analog quantities (volts, watts, etc.), status indications (breaker positions, transformer alarms, etc.), and counter values (megawatt hours, megavar hours, etc.) enter the system through remote terminals at plants and substations. The "average" remote currently monitors 25 analog points, 50 status indications, 5 counters, and has 15 control points. The remotes are polled by the DAQ communications preprocessor approximately every six seconds to obtain analog quantities and status indications. Typically, communication to a remote is at 1200 bits per second via a private microwave network to a division control center and from there by leased circuit to the remote location.

User interaction with the system is via polled color video terminals that communicate with the video preprocessor through high speed (40.8 kilobits per second) lines. Through the use of a light pen and a keyboard, the user can access diagrams, tables, and summaries that inform him of the condition of the power system. Additionally, he has the capability to change the loading of certain generating units and operate certain devices (such as circuit breakers) which are two-position in nature.

The software system is composed of four major subsystems. Their functions are 1) to control the data acquisition functions and process incoming remote data and outgoing control functions; 2) to route incoming display requests and process outgoing display information; 3) to respond to display requests for data (current or historical) from monitored plants or substations; and 4) to perform power system applications calculations and respond to related display requests.

3. DESIGN INITIALIZATION

Because the growth potential of PMS-I was limited, planning was initiated for a system, PMS-II, which could meet ten-year growth requirements. There are a great many possible solutions to the problem of choosing a general concept for the design of a power management system. A large number of functional and geographical configurations were put on paper and five were chosen for further study. These appeared to represent logical distributions of the functions among geographical locations and made good use of existing facilities. The concepts chosen for further study were: 1) an expanded centralized system with remote video terminals to company and division centers, similar to the system that currently exists; 2) a two-level system with processors at the pool and company levels and remote video from the company centers to the division centers; 3) a three-level hierarchical system with processors at the pool, company and division levels and no remote video; 4) a two-level system with processors at the pool and division levels and remote video from the pool to the company levels; 5) a two-level system with processors at the pool and company levels and an independent system at the division level.

One of the first steps undertaken in the evaluation and selection process was to identify performance and resource parameters of importance. These were identified to form a basis to determine the desired features of PMS-II and to provide a general criteria for choosing between alternative concepts. The parameters identified were: 1) resource requirements for development, operation, and maintenance; 2) technical feasibility; 3) projected performance in terms of response times, availability, growth potential, and applications which could be supported. The above parameters were evaluated as objectively as possible; however, subjective evaluations based on individual preferences were also a contributing factor.

Resource requirements for each concept were divided into capital budget requirements, operating budget requirements for contracted services, and operating budget requirements for operation and maintenance. As a simplification, capital requirements for each concept were considered to be only those costs associated with expanded facilities and new hardware. Other capital requirements were included as an overhead on additional personnel. A development time was estimated as the minimum time in which a concept could be implemented independent of restraints of spending rate.

The choice of a general concept must also take into account the technologies that will be available to implement the concepts. The goal is to pick technologies that will be mature at the time of implementation and will be supported during the life of the system (preferably by multiple independent sources). There are many trends and specific disciplines that must be examined for their impact on future system design. For example, the trend in communications protocols was considered to be away from the traditional standards that assume minimum intelligence at one end of the line and toward more efficient protocols that assume communications between intelligent processors. This trend would indicate that the interchange of large amounts of data between multiple independent processors will be increasingly achievable. The aggregate effect of the trends and specific technologies generally imply an overall trend toward multiple processors configurations, each with a small number of functions, physically located as close to the functions as possible.

Performance parameters considered in the selection of a "general concept" were: 1) Growth potential--defined as a measure of relative ease with which the system may expand without excessive cost or serious disruption to operations. Growth potential was considered to be both physical in terms of remotes and control locations and also functional in terms of new applications. 2) Reliability--defined as a measure of being operationally "up" or "down" in terms of performing the functions for which the system was designed. 3) Responsiveness--defined as a measure of system performance and flexibility assuming that the system is in an open "up" status. 4) Maintainability--defined as a measure of the relative ease and time required to keep all components operational and performing to specification and to restore operation to any portion of the system which has ceased to perform its functions. 5) Acceptability--defined as a subjective measure of the concept's ability to provide the capabilities the user desires (assuming that the system is up and available). An example of an "acceptability consideration" would be the convenience of the user interface.

After carefully considering technological trends and assigning numerical ratings to the concepts in each area and, as objectively as possible, noting the major strengths and weaknesses of each, a modification of the three-level hierarchical concept was chosen (see Figure 2). A major weakness of the three-level concept was considered to be the dependence of the central facility on the availability of intermediate processors for data concerning the transmission network. Therefore, the concept was modified to include special purpose processors specifically for message routing at the company and pool locations. Consequently, data could then be exchanged between any two "working" processors without relying on any other "working" processor.

4. PRELIMINARY DESIGN STUDIES

The configuration chosen for recommendation was based on a general knowledge of the functions to be performed. However, once the configuration was recommended and general management approval of the new system concept was obtained, it became necessary to define in detail the functions PMS-II was to perform as well as develop more information on the required dimensions of PMS-II in a 10-year time frame.

PMS-II CONFIGURATION

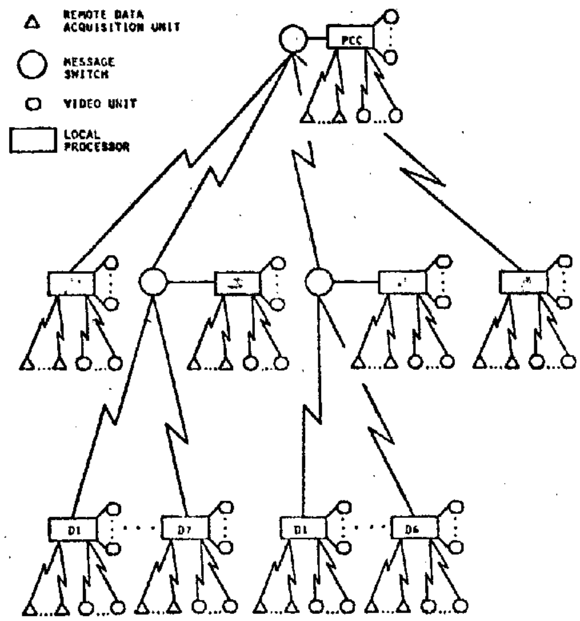

Figure 2

It was felt it was key to document and obtain concurrence on a functional requirements document prior to design. An attempt was made to identify individual requirements so that they could be categorized based on their importance and urgency. The categories chosen are: 1) those requirements which must be satisfied in the initial implementation to allow normal operations; 2) those requirements which must be satisfied at a later date to allow operators to cope with the expected growth in the power system; and 3) those requirements which are desirable enhancements to the basic functions. Additionally, attempts were made to avoid making design decisions in the functional requirements. It is a key to successful development to avoid limiting the design in the early stages by making premature conclusions about the method of satisfying the requirements regardless of how obvious the conclusions. It was also recommended that an update procedure be established for the functional requirements to allow corrections and additions to be made to the requirements but not without adequate assessment of their impact on the development.

A PMS should monitor and control not only the power system but also itself. Part of the function of any PMS is to monitor, diagnose, and take corrective action on data acquisition hardware, communications lines, display systems, etc. These additional functions and any algorithms used require documentation by support personnel in the same manner as those requirements placed on the system by power system users.

A major effort was undertaken to determine what the true PMS requirements were in terms of physical parameters; i.e., remotes and video terminals to be handled, communications loadings, data requirements. Remotes were projected by each company based on the current power system configuration and planned growth with an eye toward which lines and substations were important from a monitoring and supervisory control standpoint. The video terminal estimate was a judgment based on company control locations, number of personnel to be used in that capacity, and some assumptions of the capabilities of the displays associated with each application. Communications loading has been the subject of an extensive GPSS simulation to determine the speed and number of lines necessary for interprocessor communication. Actual data (real and reactive power flows, current, voltage, etc.) has been sampled on the current system, statistical analysis performed and projections have been made based on these results. An important question is, "What is each particular application going to do with the data?" This places requirements on the frequency of data collection and the simultaneity (time window) with which each scan of the data must be completed. A partial list of affected power system applications would include automatic generation control, economic dispatch of generation, study mode and real-time load flows, contingency evaluation, state estimation, generation scheduling, and various logging requirements for records such as energy accounting and billing.

During the planning and design, a good relationship with the users is of vital importance. Thus, it was deemed advantageous to keep the users well informed about the development effort by means of periodic briefings. The users have developed a better understanding of the impact of their requirements on the design and those involved in the development effort have learned valuable information about the needs on which the specific requirements are based.

All personnel involved in such a project should keep it clearly in mind that the system is being designed to serve a specific purpose. The system discussed here exists to aid in the management of a power system. There is a tendency on the part of specialists to concentrate on their own particular area of specialty. This may lead to many efforts which are non-productive during the early portions of the development life cycle and to conflicts between people who put heavy emphasis on a particular application, function, or piece of hardware. In the design of a system of this size and scope, it is essential to keep a total system's approach in view. This should be continually emphasized to all personnel concerned, even though they may only be involved in a small portion of the design.

5. CONCLUSIONS

In a short paper such as this, it is not possible to present all of the considerations that should go into the design of a power management system. The authors have attempted to simply summarize a few of the key ideas which must be kept in mind to achieve cost-and-benefit effectiveness.

The fundamental importance of power systems objectives is emphasized throughout this paper. The authors feel that an orderly, well phased system development must begin with a clear definition of true functional requirements and that these requirements must serve as a basis for all design decisions. Analysis of the power system itself should receive attention early in the design process to determine data requirements and evaluate growth requirements.

The existing state-of-the-art in information systems technology provides a basis for designing lower cost, more capable power management systems than ever before. The realization of power systems applications objectives presents a challenge and an opportunity for those who design future systems.

6. ACKNOWLEDGEMENT

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direction of Mr. Robert O. Usry, Manager, Operating Services. Subsequent to the investigations reported here, Mr. James F. Tillery was named Project Manager for the PMS-II project and, in that capacity, will coordinate future efforts of the five companies of the Southern Company system.

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