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INTEGRATED MICROPROCESSOR-BASED SYSTEMS FOR DATA ACQUISITION, CONTROL AND PROTECTION OF ELECTRIC POWER SUBSTATIONS

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ABSTRACT

This paper gives a survey of the state of the art research and development issues related to the concept of Integrated Data Acquisition, Control and Protection (IDCP) Systems to be applied in Electric Power Substations.

Major system aspects are considered first. Issues discussed are: Methodology for analysis, synthesis and evaluation of IDCP Systems, Application area characteristics, Cost/performance criteria.

Integrated System design considerations are also presented. Functional requirements, Numerical algorithms and Computer system architectures are the subjects of the discussion.

IDCP System implementation characteristics are outlined next. Processing hardware, Application and system software and Communication subsystem solutions are indicated with a comment regarding the future trends.

Finally, a survey of the proposed designs for IDCP Systems is given. Major developments in the area of Integrated Data Acquisition and Control as well as IDCP Systems for both High Voltage and Distribution Substations are discussed. Future trends and open R&D issues are indicated as a conclusion to the discussions given in this paper.

INTRODUCTION

This paper is concerned with Integrated Data Acquisition, Control and Protection (IDCP) Systems for Electric Power Substation Applications. Use of microprocessor technology enabled introduction of this new concept in the late 70-ties. IDCP Systems consist of a number of microprocessor-based subsystems linked among themselves by a communication medium to form a distributed processing multiprocessor system. Therefore, both "Integrated" and "Distributed" terms are appropriate to use to describe these systems.

It is important to note that these systems introduce levels of coordination among it's subsystems which were not available in the classical designs. More detailed analysis shows that the means of subsystem coordination within an IDCP System are quite complex and introduce a whole new development area which is promising regarding future cost/performance considerations (1).

s paper represents a survey of the major system and design aspects the IDCP Systems (2,3). Also, discussion of a number of developments through-out the world related to the Integrated concept is given (4). Finally, some questions related to the future developments are defined.

SYSTEM ASPECTS

Methodology for system design

The IDCP system design methodology is quite complex comparing to the design methodology needed for the classical equipment. It is essential to define a methodology which would enable identification of a very wide area of possible solutions. This methodology would be useful for designers during system design analysis and synthesis and for the users during system design evaluation.

However, design methodology issues are very little discussed in the literature. In one of the previous papers we suggested concepts of the Theory of Hierarchical, Multilevel Systems as a base for development of the design methodology (1).This theory was widely applied to the problem of Energy Management System Design for Electric Power Control Centers and it is belived that it can be applied to the IDCP system design as well.

Application area characteristics

Some major improvements were done over the years related to the data acquisition, control and protection practices and corresponding equipment, but it is also a fact that most of the practices and equipment at are used today have been developed 5-10 years ago. Therefore,any w developments have to take into account history of the previous developments in order to propose some consistent design criteria.

The IDCP Systems do represent in many respects departure from the previous design practices. The major departure is in the system design view. On the contrary,classical equipment is designed to perform single functions and substation equipment is a set of the devices performing those individual functions.

Having in mind the system aspects, special attention should be given to the following application characteristics: Substation type, Organization of the substation power and auxiliary equipment, Substation operational practices.

Cost/Performance criteria

It is widely claimed that IDCP concept provides many advantages regarding the Cost/Performance criteria. Since classical equipment was judged on the individual basis regarding cost/performance criteria, additional criteria should be established when IDCP System cost/performance requirements are defined.

Major benefits of the IDCP Systems are improved classical functions, introduction of new functions and improved lifecycle characteristics of the system. Classical functions are improved by providing better supervision and operation of the substation equipment which enables overall operation closer to the operational limits. New functions are related to the IDCP computer system and substation equipment supervision as well as to the new local and/or remote control capabilities. Finally, improvements regarding system installation, commissioning, maintenance, modification, expansion and operator training are also achieved.

IDCP SYSTEM DESIGN CONSIDERATIONS

Functional requirements

Issues still open for research are approaches to classification of the functional requirements and specification of the new functions.

It is felt that basic approach which classifies functions by the criteria of time response and operational states is quite useful (1). Another important criterion for classification is the hierarchical organization of the functions. Most common approach is to classify functions into local and centralized level. However, closer investigation shows that there are some additional hierarchical levels (1). An example is the bay coordination level.

New functions can be found in the area of protective relaying regarding the adaptive feature which can be provided. In the area of control functions, new possibilities arise in terms of distributing some of the Energy Control Center functions to the local level of a substation. Man-machine interface (MMI) functions are significantly improved.

Numerical algorithms

Major problems in the are of algorithms are mathematical methods for algorithm definition and implementation.

There are number of digital algorithms proposed to calculate required quantities (5). Critical issue is development of criteria for algorithm evaluation and selection of the best algorithm. This analysis would give answers to the questions such as: Required sampling rate, Type of sampling synchronization, Lenght of data window, Accuracy vs. time response, Analog and/or digital filtering requirements.

Computer system architectures

This issue relates to the computer system configurations, functional allocation, data flow and system interfaces (1). In should be noted that several approaches to the computer system architecture are possible (3).

Basic decision is to be made regarding data asquisition subsystem which is interfaced to the substation switchyard equipment. A decision is to be made regarding the data sharing concept. It is possible to route input data from the switchyard in a conventional way providing separate links between each signal source and destination. On the other hand,it is possible to collect switchyard data only at distinct locations and to multiplex data on a data link. The data is demultiplexed at some level within the architecture and distributed to the required processing units.

The next decision is related to the location of the processing units. One approach is to locate processing units in the switchyard and yet another approach is the control house. Further more it is important to define what level of date exchange is needed among processing units and between processing units and the overall coordination unit.

IMPLEMENTATION CHARACTERISTICS

Processing hardware

The most stringent hardware requirements come from the protective relaying functions where minimum processing power required are 16-bit microprocessors having the clock frequency above 5 MHz with MOS technology implementations (2). It is belived that the design choice for Integrated system should be universal use of 16-bit processors through-out the system. Exceptions should be allowed for in data acquisition and operator interface units.

Finally, future trends are toward 32-bit processing requrements and clock rates above 10 MHz with CMOS technology implementations.

Application and system software

Programming languages used so far are assembly language for the time critical functions and high level languages for less critical functions. Further trends in this are should be the use of high level languages for overall software implementatation (2). Particularly interesting is development of a specially designed control language for the substation applications.

System software used so far was mostly custom designed (2). Future trends are toward use of the commercially available system software,primarily the operating systems. Developments are expected in the future regarding the data base management software suitable for the substation system applications as well as the testing and diagnostic software.

Communication subsystem

This issue includes discussion of the first two communication protocol levels defined by the ISO OSI Reference Model. The links used in the Integrated system are point-to-point serial links, parallel multiprocessor links and serial multidrop links (2).

Regarding point-to point serial links, critical choices are speed of transmission, encoding, modulation, data link control protocols and communication medium. Parallel multiprocessor links are Multibus-type. Access arbitration techniques are the problem which needs further investigation. Local Area Network protocols such as the CSMA/CD and Token pass are satisfactory for serial multidrop links. Coaxial cable or fiber-optic communication medium are desirable. Problem of line access protocol for data exchange on a multidrop line requires further study.

SURVEY OF THE PROPOSED DESIGNS

Integrated Control Systems

Large number of the Integrated system proposals are related to implementation of the data acquisition and control functions while protective relaying functions are left for some future implementation phases. Examples of such developments in Europe are given in Table 1. It should be noted that proposed solutions may seem quite similar, but more detalied analysis reveals significant differences regarding computer system architecture and function allocation strategy (6).

IDCP Systems for H.V. Substations

A development undertaken in France is quite similar in concept to the classical equipment (6). Single devices performing functions such as distance relaying, transient recording, substation control and breaker monitoring are already developed and they will be interconnected in the future to form an Integrated System.

Another development performed in the U.S.A. is also similar in concept to the classical equipment but new provisions are made for use of the data sharing concept for purpose of back-up redundancu (6). New approaches are undertaken regarding the way application functions are grouped and allocated to the processing units. Finally, yet another development in the U.S.A. represents significant departure from conventional design practices including number of aspects such as computer system configuration, functional allocation, data flow and interfaces (7).

IDCP System for Distribution Substations

One of the first developments, which was implemented in two phases providing two different systems, was introduced in Japan in 1977 and 1981 respectively. Basic architecture is quite similar to the conventional system except that measurement and control functions are grouped and allocated to separate dedicated units (4).

Another development undertaken in the U.S.A. is also quite simmilar in concept to the conventional equipment. Extensive number of functions are implemented and functions are grouped an allocated to the specific processors for execution (8).

CONCLUSIONS

The IDCP Systems are beeing developed today using quite different approaches in almost all of the proposed cases. It is expected that these trends will continue with most of the approaches starting with Integrated Control Systems and exploring later to the full scale IDCP System. It is also evident that the system concept proposed by the IDCP Systems requires new considerations regarding classical equipment operational characteristics and performance requirements.

There are number of R&D issues which need future investigations. Almost all of the issues related to the system design considerations should be topics of the future research. Partircular attention should be given to the new developments regarding unconventional instrument transformers and fiber optic technology. Relation between IDCP System and Energy Control Systems should be also investigated. Finally, classical design approaches related to the substation power equipment should be reexamined.

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Table 1. Integrated Control Systems

Country	Hierarchy	Location	MMI	Commun.	Year
Belgium	two-level	Control House	CRT Op.panel	Parallel	1981
Sweden	two-level	Control House	CRT,Print., F.Keybrd.	Parallel and serial	1982
Italy	two-level	Data acq.: Switchyard Data Process.: Cont.House	CRT Printer	Parallel and serial	1985
Spain	two-level	Data acq.: Switchyard Data Process.: Cont.House	CRT,Print., Keyboard, Mimic Brd.	Local Network	1985
Austria	two-level	Data acq., preprocess.: Switchyard Main Process.: Cont.House	Op.panel Printer Mimic Brd.	Parallel and serial	1984