## Panel Discussion

# APPLICATIONS OF MICROPROCESSORS IN POWER SYSTEM CONTROL AND ANALYSIS

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## INTRODUCTION

Recent advances in microcomputer technology are having important effects in power system control and analysis. New applications or trends are emerging in control center design, substation automation and computer-aided engineering.

The panel discussions centered on applications in substation control and protection system, and interactive personal computing. About 45 persons attended the one-hour session.

## REMARKS ON SUBSTATION AUTOMATION

Dr. KEZUNOVIC presented his introductory remarks on the state of the art and future trends in microcomputer applications in electric substations and power plants.

These applications can be classified in two major categories: single device implementations and system solutions.

The single device implementations are similar in concept to the conventional devices since the major functional and performance characteristics are preserved. The advantages in using microprocessor-based design are in the areas of performance, flexibility of design and improved testing and maintenance. For example, programmability of microprocessor-based devices provides possibility of very flexible changes of settings, internal parameters and algorithm designs. Furthermore, application of microprocessor enabled implementation of elaborate test procedures including self-checking features, extensive CRT test display and elaborate historical data collection and analysis for maintenance purposes.

The major characteristics of system solution approaches are the introduction of new functions and concepts which were not feasible by using the previous technologies. Some typical system solution approaches are given below:

SCADA System. Application of microprocessors to SCADA systems is historically one of the first applications of microprocessors in Electric Power Systems. There are quite a few SCADA systems available on the market today. New designs are particularily interesting regarding design flexibility and advanced local processing functions.

Unconventional Monitoring System. Use of microprocessors enabled new approach of special purpose system designs. An example is a monitoring system designed for power transformers. Such a system enables overall monitoring of the power transformer parameters such as saturation curves, overexcitation, gas content, partial discharges, insulation damages, etc. The microprocessor application provides not only monitoring of the mentioned parameters but also extensive analysis of the operational state of the transformer.

Universal Data Acquisition and Control System. This solution consists of a universal microprocessor system architecture which can be programmed and configured for a specific function implementation. One such a solution provides the possibility of implementing any one of the following functions: voltage control, automatic switching sequences, automatic reclosing, generator sequence control, generator efficiency monitoring, revenue metering collection, alarm logging, fault level monitoring.

Integrated Substation Control system. Those systems are multiprocessor-based and provide full control and data acquisition in a High-Voltage Substation. Typical functions performed are acquisition and data-base updating, output execution, automatic execution of selected sequences, etc.

Integrated Control and Protection systems. Under this concept, both control and protective relaying functions are combined in one system. The major differences between several developments in the world are related to computer system and communication architecture as well as to functional allocation strategy.

It is expected that future trends will be a continuation of the two major trends present today: single device implementations and systems solutions.

New developments in Single Device Implementations are expected in the areas of new functional implementations (e.g. bus bar, generator and machine protective relays, switching equipment control, extensive operator capabilities in data displaying, time-tagging and analysing, etc.) and in the area of cost/performance improvements.

Future trends in System Solution approaches seem to be related to new developments in the area of multi-microprocessor system architecture and Local Area Networks for distributed processing.

New developments are expected in the integration of similar functions (protective relaying, control and data acquisition) and in the integration of diverse functions on a limited basis regarding a particular power apparatus (such as power transformer, generator) or on the level of Substation or Power Plant. Regarding the latter approach, new criteria for performance evaluation and new methodology for cost evaluation assesment are needed as Integrated Systems of this type do not have equivalent in the classical designs. Integration of either type brings new possibilities regarding local/remote automation of substations and Power Plants with benefits in the areas of maintenance and improved performance during emergency operation.

There are, however, a number of issues to be resolved in order for microprocessors to become wide acceoted technology in the area of Substation Automation and Power Plant Control. The theoretical issues involve selection and evaluation of numerical algorithms, particularily for digital relaying. Conceptual issues are centered around unconventional designs where integration of control and protection functions conflicts with the general practice of separation (even to the point of separate wiring) of these functions. Close collaboration between Utility and Manufacturers are needed in order to form a mutual understanding and acceptance of the new designs. Data sharing is another area where the new designs depart from conventional ones. Use of unconventional transducers where output is in a digital form enables design of processing algorithms which can be used for several different functions. Technical issues involve the issues of hardware and software. Different functions requires different hardware characteristics. For example, protective functions require 16-bit hardware while most control and data-acquisition functions can be accomodated with 8-bit hardware. What is needed is criteria for optimal hardware selection for various functional implementation. Issues in software relate to programming languages and system software. Future investigations are to give some answers to the question of optimal selection of language levels for various applications, optimal mix of high level and assembler language modules in one implementation and the need for a special purpose language for Power System applications. System software issues are related to the possibility of using commercially available operating systems or special purpose executives. Operational Issues are related to operator interfaces, testing and maintenance. Improvements are expected in the types and means of data displays. Maintenance practice can be significantly improved using historical data for off-line analysis and redundant architectures and repairing strategies.

Finally, economic issues relate to the development of cost evaluation procedure for new designs since they are significantly different from conventional designs. Microprocessor-based designs bring new issues of appropriate life cycle cost estimates. The direct life cycle cost includes cost of design, installation, commissioning and maintenance. These costs need to be reeaxamined in view of the new aspects that microprocessor applications bring to the problem. Indirect life cycle cost is a more important and difficult issue. This is related to the actual saving achieved in the overall Power System operation due to the use of improved microprocessor-based devices and systems designs. The cost/performance benefits that microcomputer technology brings to the area of Substation Automation and Power Plant Control must still to be answered.

## REMARKS ON CONTROL CENTER DESIGN

Dr. DY-LIACCO could not be present at the panel discussions, however his written remarks on control center design were read by the Chairman:

Microprocessors are being applied in control center design for the following elements:

A) Remote terminal units (RTU's) :
- Input/Output modules
- Sequence of events recording
- Local intelligence and Automatic control
- Multi-channel communication processors
- Local man-machine interface
- RTU-Master protocol emulators

Modularity of RTU design makes possible flexibility, expandability and ease of maintenance. Desirable design features include: data independence of firmware, downline loading capability, self diagnostics, external clock option, availability of RS-232C ports.

B) Master computer configuration
- Communication channel controllers
- Front-end processors
- Peripheral devices drivers
- Mapboard drivers
- CRT display generators

There is a trend towards the use of microsystems in the master computer configuration interfaced with supermini or mainframe computers via Local Area Networks. There are now regional control centers in service which are total microsystems with distributed, redundant processors.

## REMARKS ON APPLICATIONS IN PERSONAL COMPUTING

Dr. C.T. Nguyen presented his remarks on applications of personal computing for Power Systems Analysis and Control:

Advances in microelectronics, especially in VLSI technology, have produced new generations of microcomputers capable of handling tasks usually reserved for superminis or mainframes. These microprocessors, integrated into personal computers, or workstations, present several advantages over conventional computers: they have very fast graphics, uniform response time and a visually oriented user environment. These advantages are the result of having a very powerfull microprocessor devoted to a single user's need. In a time shared computer, it is not easy to implement an efficient interactive graphic I/O system because of limitations in the communication speed between the computer and the user's terminal, and because graphics would consume disproportionate amounts of the machine resources allocated to the user. On the contrary, the personal microcomputer is not separated from the user. The display screen is generally bit-mapped and communications between processor and screen is not performed through serial links but truly as memory access. Additional features, such as pointing devices (mouse or touch-pad) and multiple windows are also available and contribute to improving the man-machine interface, a very important issue in power system analysis and control.

The personal computer is best operated as a node in a local area network of computers, not necessarily of the same type or capabilities. A particularily compute-bound task, such as a large-scale stability calculation, can be solved on a more powerfull node, while the workstation would be used for interactive high-speed graphic I/O or for post-processing the results. Besides the benefit of sharing peripherals, data and programs, one advantage of operating the personal computer in a local area network is that system expansion is only a matter of adding new workstation according to the specific individual needs. The system grows in small increments over time, a much flexible and smoother solution than upgrading a shared computer to account for marginal increases in computing needs.

Applications for Power Systems Analysis and Planning include interactive load flow, stability calculation, distribution voltage profile calculation, harmonics analysis, electromagnetic transient simulation. Others applications include map creation, drafting and report preparation.

System operation is another area of application where the high speed high quality graphics can be put to good use. By networking personal computer to the utility data-acquisition system, engineers could acquire up-to-date data for system monitoring and simulation purposes. Data could be analysed locally without degrading the main control system response. Issues of accessing the data however must be carefully considered since many systems may be operating on the same data stream.

The key point in the success of the newer generation of workstation will be their cost. Many of the more sophisticated personal computers are available today around 30K and their prices are still dropping. Apart from the price, which makes them attractive for a large number of potential users, this new technology allows power system engineers substantial productivity improvement compared with using conventional, time-shared computers.

## DISCUSSIONS

Dr. A. MOSSE, from CEPEL (Brazil), indicated that they have developed several microprocessor-based devices for Substation and Energy Management System applications. According to Dr. MOSSE, distributed microprocessors for application in substation automation introduces communication problems. He also consider economic issues to be quite important. By using this technology, they obtained improved reliability. For example, fault location time in distribution network is reduced from an average of 5 hours to a mere 15 minutes.

In response, Dr. Kezunovic indicated that problems in communication subsystem may be solved in several ways: redundant subsystems for increased reliability, standardisation by using ISO/OSI approach (IEEE 800.3 to 800.5).

Professor O.P. MALIK, from the University of Calgary, and Dr. T. SAKAGUSHI, from the Central Research Laboratory of Mitsubishi Electric Corp., have also contributed oral and written discussions. Their comments are reproduced below.

### DISCUSSION BY PROF. O.P. MALIK

Dr. Kezunovic has given a good survey of the application of microprocessors in substation automation. However, there are many applications in the generating stations also to which he has not made any reference. Microprocessor controllers are being used to perform a number of control applications in the thermal part of a steam generating station, e.g. control of boilers, etc. In addition, a considerable amount of research is being done in the development of microprocessor-based speed governors, voltage regulators amd power system stabilizers. Microprocessors allow the development of complex controllers wherein the voltage regulation amd stabilizer functions can be integrated.

A reference was made to the integration of various functions in a substation. An integrated control and protection system for a substation may perform RCMP functions, e.g. recording, control, monitoring and protection. The basic data required for these functions is the same, and thus they can share the same data. However, the speed requirements for various functions are quite different. For example, the system needs to be sampled at the rate of a few kHz for recording function whereas the sampling rate for protection is only about 1 kHz.

I agree with Dr. Kezunovic that microcomputer-based devices will not replace the conventional devices on a function to function basis but instead on the basis of new or additional functions that can be performed by the same microcomputer-based device.

As a brief note on future developments, I feel that what is required is the development of special interfaces between computers at various levels of the power system that would transfer intelligence rather than data, just as humans do in the conduct of everyday affairs. This would be feasible with the advances in the VLSI technology which will likely produce nano-computers in the near future and pico-computers within the next 10-15 years.

### DISCUSSION BY DR. T. SAKAGUCHI

We have investigated the potential of interactive personal computing by developing a prototype system using the Appolo 420 workstation.

What we propose to do is to put the knowledge and experience of a system operator and planning engineer into the system. Task analysis has shown that it takes quite some time for utility people to come up with a good initial load flow pattern which they have to work with. Usually, from the very first load flow obtained from a rough estimate of bus injections, overload and voltage violations happen at several lines and buses. The first thing to do is to cure the violations by modifying bus injections at generation and substation nodes. In our system, many knowledge rules have been encoded to do this. Some of them are described as follows:

(Rule 1) : IF some line is overloaded, AND
a generator existing on the
infeed side is not fully loaded, AND
the generator is not a nuclear unit,
THEN decrase output of generator.

(Rule 2) : IF some bus has overvoltage,
THEN switch in shunt reactor most
near-by, OR
switch off static condensor most near-by

Our system has some 20 rules encoded as a knowledge base, and gives a guidance for curing violations. The user may follow the suggestion and initiate another load flow. Otherwise he may modify the suggestion. In this way, the computer can help the user until he obtains a good load flow pattern.

We think the interactive personal computing system from now on should be equipped with a knowledge base. This will be indispensable to improve planning quality and system operation efficiency.

Reference :
Fujiwara R. & Kohno Y. "User-Friendly Workstation for Power Systems Analysis" IEEE-PES Summer Power meeting, 84 SM 553-4, July 1984.