AUTOMATION AND CONTROL OF
DISTRIBUTION SYSTEMS, 2ND CON
CHECHOSLOVAKIA, JUNE, 198?

# DEVELOPMENTS AND TRENDS IN APPLICATION OF MICROPROCESSORS TO CONTROL AND PROTECTION OF ELECTRIC POWER DISTRIBUTION SYSTEMS

( Invited Paper )

Dr - Ing. Mladen Kezunovic

ENERGOINVEST,
Institute for Control and
Computer Sciences,
Sarajevo, Yugoslavia

## 1. INTRODUCTION

Application of Microprocessors to Control and Protection of Electric Power Distribution Systems (EPDS) started in the early 7o-ties. During the past ten years of research and development a number of control and protection devices and systems were developed and tested in the laboratory and power system enviroments. mentioned developments proved microprocessor applications to be technically and economically attractive and a new commercial market is beeing developed for Microprocessor-based Control and Protection Equipment. Also, microprocessor technology enabled introduction of new concepts and philosophies to be applied to Control and Protection of EPDS. This, of course, made reflection on the developments of new microprocessor- based devices and systems.

This paper gives a survey and classification of the microprocessor applications in EPDS.

## 2. EPDS HIERARCHICAL LEVELS AND FUNCTIONS

One possible way to define EPDS hierarchical levels and functions is based on the type and location of the Control and Protection Equipment. Figure 1 gives simplified representation of the levels and functions. The following classification can be applied (1,2):

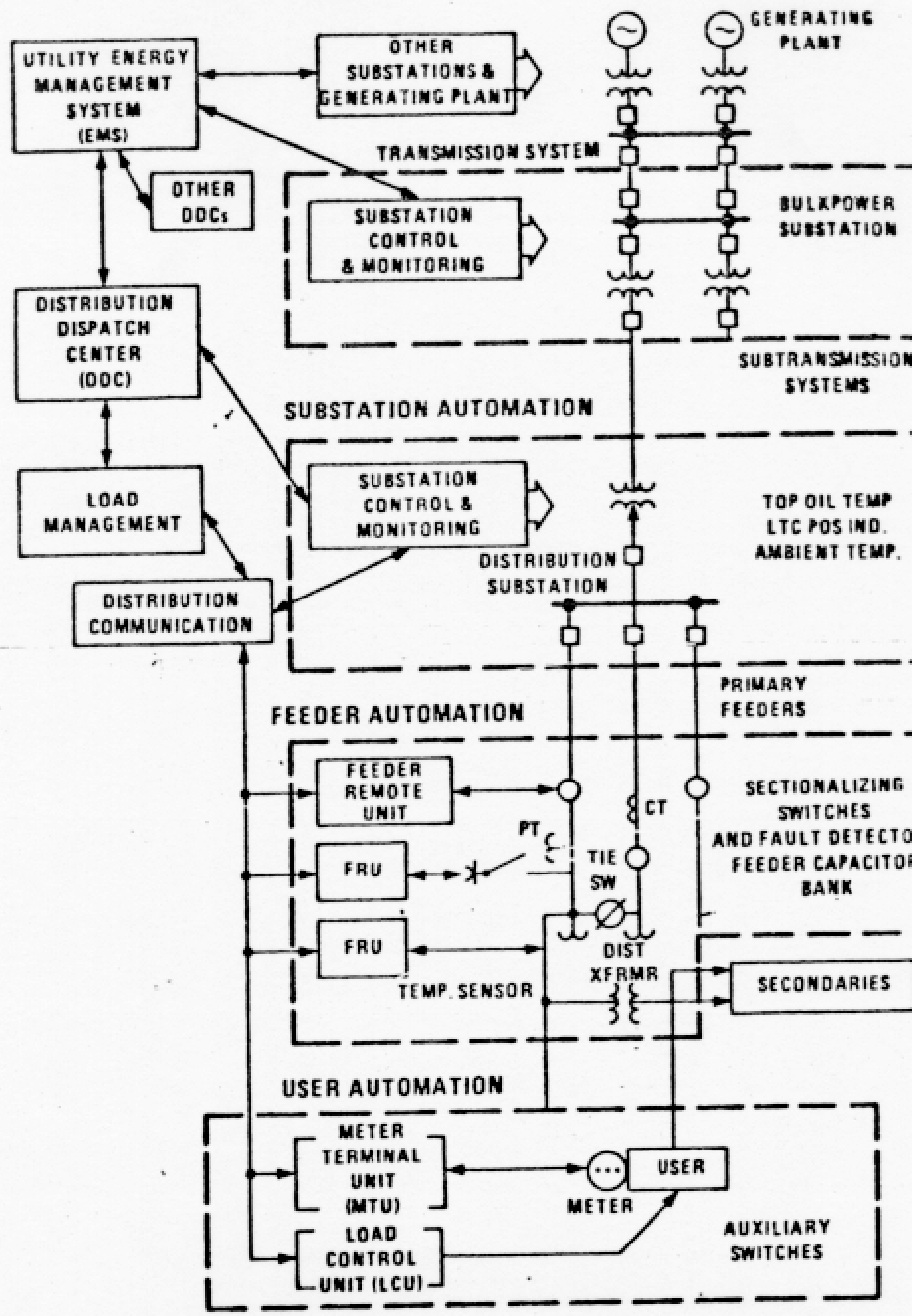
- Energy Management Systems are utilized to control overall EPDS. The most common functions implemented at this level are: Distribution Load Management, Automatic Meter Reading, SCADA Functions, Economic Dispatch, Load Shedding.

- Substation Control and Protection Equipment is located at the transformer and switching substations. The following functions are executed at this level: Data Acquisition and Logging, Status and Alarm Logging and Monitoring, Automatic Bus Sectionalizing, Transformer Monitoring and Control, Automatic Breaker Reclosing, Time and Instantenious Overcurrent Protection, Frequency Protection, Distance Protection, Synchro-Check and Automatic Synchronizing, breaker Failure Protection, Bus and Transformer Fault Protection.

- Feeder Equipment is located along the feeders next to the switching equipment and the transformers. Functions implemented at this level are: Fault Protection, Control of Capacitor Banks, Voltage Regulation, Load Management, Sectionalizing.

- Customer Site Equipment is located at homes, public and bussines bildings and at industrial sites. Functions performed at this level are: Automatic Meter Reading and Automatic Billing, Local Energy Management Functions.

Above classification associates functions to the levels at which the operator interface for the function is provided. However, it should be noted that the equipment to implement those functions can be located at some other hierarchical levels as well.


UTILITY ENERGY MANAGEMENT SYSTEM (EMS)
OTHER SUBSTATIONS & GENERATING PLANT
GENERATING PLANT
TRANSMISSION SYSTEM
OTHER DDCs
SUBSTATION CONTROL & MONITORING
BULKPOWER SUBSTATION
DISTRIBUTION DISPATCH CENTER (DDC)
SUBTRANSMISSION SYSTEMS
SUBSTATION AUTOMATION
LOAD MANAGEMENT
SUBSTATION CONTROL & MONITORING
TOP OIL TEMP
LTC POS IND.
AMBIENT TEMP.
DISTRIBUTION SUBSTATION
DISTRIBUTION COMMUNICATION
PRIMARY FEEDERS
FEEDER AUTOMATION
FEEDER REMOTE UNIT
CT
SECTIONALIZING SWITCHES
AND FAULT DETECTOR
FEEDER CAPACITOR BANK
PT
FRU
TIE SW
FRU
DIST XFRMR
TEMP. SENSOR
SECONDARIES
USER AUTOMATION
METER TERMINAL UNIT (MTU)
USER
METER
LOAD CONTROL UNIT (LCU)
AUXILIARY SWITCHES

## 3. MICROPROCESSOR DEVELOPMENTS

This section is devoted to a survey of present microprocessor applications. It should be noted that most of the mentioned devices and systems are result of the research and development projects and are still in the laboratory or field testing stages. However, some of the microprocessor-based equipment is already commercially available on the world market.

The following survey is given making classification of the microprocessor-based equipment into two broad categories:

- Single function devices
- System solutions.

Single function devices are microprocessor-based equivalents of the classical control, protection and data acquisition equipment. Table 1 gives a list of the single devices developed so far using various microprocessors (3-11):

| Protective Relaying | Control | Data Acquisition |
|---|---|---|
| - Overcurrent<br>- Directional<br>- Distance<br>- Frequency<br>- Transformer<br>- Breaker Failure | - Voltage Regul.<br>- Synchro-check<br>- Load Shedding<br>- Automatic Switching<br>- Automatic Reclosing | - SOE Recording<br>- Allarm Logging<br>- Revenue Metering<br>- Operator Metering<br>- Fault Location |

Table 1. Single Function Device Developments

It should be noted that application of microprocessors to single-function devices has brought improvements in the areas of flexibility, compact packaging and performance characteristics.

Flexibility is achieved by means of programability. All of the microprocessor-based devices are programable and there is a a number of equipment characteristics which can be set according to the user needs. Good example is an overcurrent relay (3) which is possible to program to execute any of the 4 inverse time and 3 definite time characteristics. Another example are distance relays (8) which can be programed to execute any zone and time characteristics.

Compact packaging is reflected in reduction of the overall electronic components density and ammount which is used per a device. Also, power supply requirements are reduced as well as the a.c. equipment burden.

Performance improvements are quite evident in almost all applications. Typical example is a frequency relay (5) where setting resolution of 0.01 Hz and accuracy of + 0.005 Hz can be easely achieved. Transformer protection function (6) is yet another example where accurate determination of the harmonic content of the differential current can be determined so that there could be performed any scheme of harmonic percentage restrained protection algorithm. Variety of automatic switching sequences can be also programed (12) and those sequences can be executed with the speed and safety not available by the classical equipment manipulated by the operator.

Finally, it should be noted that microprocessor application introduced some improvements in the area of testing, diagnostic and maintenance procedures. It is achieved by using self-checking procedures which can be implemented at the various levels of complexty. Using the mentioned features system availability performance is also improved.

System solutions include microprocessor-based systems which perform complex functions generaly not available by the classical equipement. Typical system solutions which introduce some new functions are: SCADA Systems, Universal Substation Control Systems, Integrated Substation Control and Protection Systems, Local Energy Management Systems.

SCADA Systems (13) are widely used today. Using intelligent RTUs those systems can perform number of local control and acquisition functions usually not available by the classical SCADA Systems.

Universal Substation Control System (12) is quite a new concept in equipment design which was not possible by using the classical technologies. This system is microprocessor-based and can be programmed to perform, one at the time, any of the following functions: Event Logging, Auto-switching, Sequence Control, Voltage Control, Telecontrol and Indication, variety of Metering applications. It is easy to recognize great flexibility provided by this type of systems which could be considered, in some application situations, as cost effective advantage.

Integrated Control and Protection Systems (14,15,16) are also a new concept which was made possible by introduction of microprocessors. This concept assumes that all of the control and protection functions available in a substation can be executed by a single, multimicroprocessor system. Typical functions of such a system (15) are shown in Table 2. Those systems open new possibilities for implementation of complex control and protection functions and benefits are expected in the area of system cost reduction and performance improvements. It should be noted that there are only several Integrated Substation Systems beeing developed and tested today. Those solutions vary from totally distributed multimicrocomputer systems (16) to compact packed multimicroprocessor systems (14,15).

| | |
|---|---|
| - Data Acquisition<br>- Data Monitoring<br>- Data Logging<br>- Status<br>- Alarm<br>- SCADA Interface<br>- System Interface<br>- Substation User Interface<br>- Feeder Remote<br>- Feeder Deployment Switching and Automatic Sectionalizing | - Automatic Bus Sectionalizing<br>- Integrated Voltage/Var Control<br>- Time Overcurrent Protection<br>- Instantenious Overcurrent Protection<br>- Synchronism Check<br>- Underfrequency Protection |

Table 2. Integrated System Functions

Local Energy Management Systems (17) are beeing lately used in large public, bussines and military buildings and storage facilities. The basic aim of these systems is to provide Energy Management within a local consumer sites by scheduling and controlling the use of energy by small but numerious loads such as building lightning, heating/cooling, ventilation, etc.Application of microprocessors enables great variety of Energy Management strategies which can yield substantional energy cost savings.

Finally, it could be concluded that major advantage obtained by using microprocessors is the possibility to improve performance of the classical functions and to introduce some new functions.

## 4. FUTURE TRENDS

One visible future trend is in the area of single function devices. It can be noted that research and development activity in this area is still very productive and it can be expected that most of the classical equipment will be challanged by microprocessor-based devices in the near future.

However, much more attractive are new system developments (18) in the area of Integrated Substation Control and Protection Systems, Customer Energy Management Systems, Load Management Systems and Distribution Automation Systems.

It is expected that new Integrated System developments will emerge in the near future and that more field service experiances will be obtained. This will enable more precise cost/performance evaluation of this approach which is the basic condition for a wide use of these systems.

Customer Energy Management Systems (19) for home use are expected to be explored in the future which will enable local control of energy consumption and the cost by the customers. Industrial Energy Management is also expected to be much more utilized in the future.

Load Management Concept has been developing for the past fifteen years (2o) but some new develcpments are also expected in the future. The trends are to include Local Customer Energy Management Systems into overall Distribution Load Management System.

Distribution Automation (1) is a concept which needs much more investigation in the future before it becomes a reality. However, great advantages of these systems are visible and development of individual subsystems are under way. This makes Distribution Automation to be a realistic development goal in the future.

## 5. PROBLEMS TO BE RESOLVED

Future microprocessor developments for the EPDS application area depend on solution of the variety of problems which can be classified as: Technical, Economic, Application.

One of the major technical problems is the communication system problem (21). Reliable communication system is the main condition for development of control systems for load management and distribution automation. Other problems, which are not less important, are the digital equipment testing and maintenance facilities and metodologies which need to be developed in order to make microprocessor-based equipment competitive and attractive for every day use.

Economic problems are related to the definition of economic evaluation procedures (23) which can be applied to the microprocessor-based systems. It is crucial that those procedures be developed since the complexity of economic evaluation of the new systems can be the major obstacle for the wide acceptance of the new developments.

Finally, the application problem should be recognized and carefully analysed. It should be noted that microprocessor-based developments may require change of the traditional reasoning of the utility personal in the are of designing the control and protection systems for EPDS applications. Further more, it may be required even to change practices of the primary equipment design (23). Therefore, the strategies for introduction of the microprocessor-based devices should be carefuly outlined and applied in order for this equipment to come into the every day use.

As a conclusion of this paper it can be stated that microprocessor applications in the EPDS have become a reality and future trends show that development of interests for the wide spread application is under way.

6. REFERENCES

1. A.C.M. Chen " Automated Power Distribution " IEEE Spectrum, April 1982.

2. R.A. Fernandes "Evaluation of a Conceptual Distribution Automation System " IEEE TPAS, Vol. 1o1, No. 7, July, 1982.

3. GEC Measurements "The Application of Microprocessors to Power System Protection Relays" Publication R-5543A, October, 1983.

4. E.O. Schweitzer et. al. " Experimental Microprocessor-based Protective System for Electrical Utility Distribution Circuits" Western Protective Relay Conference, October, 198o, U.S.A.

5. Westinghouse Electric Co. " Type MDF Microprocessor Frequency Relay " Publication I.L. 41-5o5, December, 198o.

6. M.A. Rahman et. al. " Fast Algorithm for Digital Protection of Power Transformers" IEE Proc., Vol. 129, Pt. C, No. 2, March 1982.

7. E.D. Spooner" Microprocessor Implementation of Breaker-Fail Protection" IFAC Symp. on Automatic Control in Power Generation, Distribution and Protection , South Africa, September, 198o.

8. M. Kezunovic et. al. " Microprocessor - Based Distance Relay Solutions " Conf. on Automation and Control of Distribution Systems, Czechoslovakia, June, 1984.

9. R. Grondin " Computer-Dedicated Voltage Regulation Method for Distribution Substations ", IEEE TPAS, Vol. 1oo, No. 5, May 1981.

1o. A.K. Ghai et. al. " Microprocessor Assisted Check Synchronizing" Proc. of IEEE IECI Conf., U.S.A., March, 1979.

11. A.K. Ghai et. al. " Microprocessor Controlled Automatic Load Shedding and Restoration " IEEE PES Summer Meeting, Paper No. SM 51o-8, U.S.A., July, 198[illegible]

12. GEC Measurements " PERM 2oo for Control and Data Colection " Publication R-5398.

13. K.P. Lau et. al. " SCADA'S State of the Art and Future U.S. Trends in Substation Control" 1982 CIGRE Conference, Paris, September, 1982.

14. T. Sugiyama et. al. " Development and Field Experience of Digital Protection and Control Equipment in Power Systems " IEEE PES Winter Meeting, Paper No. WM 173-3, U.S.A., January, 1983.

15. J.L. Mc Coy " An Automated Control and Protection System For Distribution Substations and Systems " Conf. for Protective Relaying Engrs, Texas A&M University, U.S.A., April, 1982.

16. J.D. McDonald " Management of Distribution Systems with Dispersed Microprocessor-based Controls" American Power Conf., April, 1982.

17. R.I. Staab, et.al. " Microprocessor Energy Controllers for Navy Buildings " IEEE IECI Conf., U.S.A., March, 1979.

18. IEEE Report " The Distribution System of the Year 2ooo " IEEE TPAS, Vol 1o1, No. 8, August, 1982.

19. F.C. Schweppe et. al. " Homeostatic Control for Electric Power Usage " IEEE Spectrum, July, 1982.

2o. M. Granger Morgan et. al. "Electric Power Load Management: Some Technical, Economic, Regulatory and Social Issues" IEEE Proc., Vol. 67, No. 2, February, 1979.

21. IEEE Report "Communication Alternatives for Distribution Metering and Load Management" IEEE TPAS, Vol.99, No.4, July/Aug., 198o.

22. D.W. Ross "New Methods for Evaluating Distribution Automation and Control (DAC) System Benefits" IEEE TPAS, Vol. 1oo, No. 6, 1981.

23. J.R. Redmon "Affect of Distribution Automation and Control ...