SURVEY ON EDUCATION OF POWER SUPPLY SYSTEM OPERATORS

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1. INTRODUCTION

Power supply system (PSS) operator education became more important in the 70s when systems became more complex. Because of that, the IEEE Task Force was formed in 1975 to process the needs, identify the problems to be solved and identify the available sources for operator training. The Task Force became the Working Group for operator training (WG 78-4).
Since 1978, PSS simulators, made especially for operator training, became commercially available and major systems operators started using them. In most cases, it was necessary to make major software and minor hardware changes in order for the PSS simulators to be adequate for operator education [1, 2].
However, it was impossible to make a general user program that could be used by a larger number of various PSS operators. Some of the factors that affect this are:

- Topology of geographic network, reading-in centres, generation sources,
- Geographic interconnections,
- Procedures for operator groups and limitations,
- Control-management centre devices and SCADA system devices on the centralised, regional and distribution levels,
- Operators' working procedures
- PSS operating procedures

The four basic instruction areas are:

- The PSS basics and electrical, mechanical and other system components. On the general level, it is common to all systems.
- Characteristics of certain systems and characteristics of their adjacent systems because of the line structure, the load, interconnections, etc.
- Characteristics of certain control rooms and the disposition of measuring devices, communication devices, controlling mechanisms, etc. and their effect on some systems.
- The set of formally-operating action procedures and the circumstances they include, and perhaps even more importantly, the circumstances they do not include.

So, the first of these four areas can be used as a basis for training a larger number of PSSs, whereas the following three are specific-systems-oriented. The basics of these PSSs are basically the same because they abide by the Ohm's Law and Kirhof rules in the sense of electronics; they are all limited to various thermal cycles and their efficiency rate to the general hydraulic laws. PSS operating states offer natural progression from simple to the most complex situations for operators. In order to safely overcome the state of emergency, the way can be directly from the normal state or through the stand-by state. Similarly, the way from the re-established state to the normal state will probably go through the stand-by or even through the emergency state.

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2. PRESENTATION OF THE TRAINING PROBLEMATIC AREAS

The main goal of training is to teach operators how to overcome the situation they have never encountered before both in their actual work and in the process of analysis of such situations. Those very unusual situations are precisely the reason why the additional training is necessary. Out of many already existing courses, we have chosen to present fourteen problematic areas of a characteristic course for operator training.

1. Basic principles,
2. Basic device characteristics,
3. Energy flow stable state concepts,
4. Voltage control of the stable state concepts,
5. Limitations of the stable state operations,
6. Dynamic characteristics of the system,
7. Characteristics of the system device in dynamic situations,
8. Communications,
9. Technical system protection,
10. Normal hazards at work,
11. Recognising the conditions of the system state of emergency,
12. State-of-emergency measures,
13. Major damages repairing,
14. Operation of the interconnection between the systems.

The first part (1-5) contains the basic characteristics of power and devices, the concepts of energy flow and voltage status control and the survey of potential hazards to the stable system state.
The second part (6-10) represents the concepts of dynamic situations and the presentations of the system device ways of functioning for re-establishing the stable state.
The third part (11-14) gives methods for recognising emergency situations and the actions that are to be undertaken in order to limit the damages and to make system recovery more efficient.
The analysis of this course has provided the following conclusions:

- Even though the level of mathematic apparatus usage was intentionally low, it was still too high for the structure of trained groups.
- Training on how to project the system is to be avoided because there is a tendency in the materials to state more than necessary for understanding the system functioning.
- Engineers' terminology is also to be avoided, the terms such as the "vector**",** the "phasor" or the "j" operator, because it does not help to understand basic concepts of system functioning.

Since user programs differ among themselves depending on the organisation and its operating procedures, they should be supplemented with specific operator duties in his/her operating area. The basic supplements would contain: system characteristics, available controls and their effects and operating procedures. Specific supplements would contain: the survey of preconditions, specific task training, exercises and testing. [3, 4].

3. THE OVERVIEW OF THE MOST USED COURSES

We will here present the eleven most used courses for training operators on devices developed by various producers from the USA.

a) Control Data Corporation – dispatcher training simulator which consists of a digital computer and CRT human machine interface, along with the simulation software and a user-oriented database for simulation training.

b) Power Technologies – "the basics of power systems for system operators" course which gives hardware system concepts with minimum of mathematics with the aim to help operators understand the "what" and the "why" of the occurrences within the system.

c) Harris Controls – dispatcher training course based on the back-up device used by CRT human machine interface, alarm processing and SCADA devices. The course student is provided with a real interface used for on-line control.

d) General Electric Company – often organises weekly courses for operator training. Intensive theoretical training is combined with a practical part that contains demonstrations, experiments, films, slide pictures and direct problem solving by PSS interactive simulation. The course consists of the following parts: Electrical Engineering Basics, EES Elements, Integrated EES and Its Control, System Dynamic Behaviour and Sub-system Control.

e) Stagg Systems – specialised courses adjusted for dispatchers and operating engineers with the installation of producer's computer programs.

f) Babcock and Wiblox – lesson-based courses for work on nuclear plants for the controlling and engineering staff and specialised courses for operators in nuclear plants. The training is conducted in producer's training centres with the help of plant simulators.

g) Honeywell – lesson-based courses in producer-owned centres include: programming, work on the software and producer computer system hardware maintenance.

h) Bailey Meter Company - lesson-based courses which include measuring, measuring devices, analogue and digital components analysis, computer programming and computer hardware.

i) Power Technologies - 20-hour material for operators' training on video cassettes, designed as a self-study package with questions and answers.

j) ESCA Corporation – dispatcher training simulator which operates on the VAX family of digital computers. Human machine interface is very flexible and can be adjusted to the human machine interface of the existing PSS control system.

k) Westinghouse Electric Corporation – dispatcher training simulator TNR-500 which represents PSS and can be used both as an independent training system and as a system with the installed energy-management package.

4. PROGRAM PACKAGES

With a rapid development of information science, the amount of data related to PSS has significantly increased in all phases of work - from projecting to simulation and training. Therefore, it is often impossible to conduct phenomenon analysis in real conditions, so it is necessary to use the appropriate modelling on computers. However, computers cannot be adequately applied without permanent training and advanced training of the staff [5, 6].
Program packages used in PSS can be divided into *general purpose programs* (text processors, technical design programs, Internet programs, program languages, databases) and *specialised user programs* mostly developed by final users. Here, we will list most used program packages:

1. For PSS analysis
   - DIgSILENT Power Factory
   - ETAP Power Station
   - EDSA Power System Analysis Software
   - PTW Power Tools for Windows
   - CDEGS, Current Distribution, Electromagnetic Fields, Grounding and Soil Structure Analysis
   - CYME Software for Electrical network Analysis
   - NEPLAN - Network Planning and Information System
   - SynerGEE Simulation and Analysis of Power Distribution System
   - Power World Simulator
   - EUROSTAG
   - CAPE Softvere for Protection Engineering
   - ERACS Power System Analysis Software
   - ERLAN 21 Electro - CAE
2. For planning and electric device analysis:
   - FEMLAB Electromagnetics
   - MAGSOFT Electromagnetic Software Solutions
   - OPERA Software for Electromagnetic Design
   - QuickField FEA Software
   - RMxprt i EMpulse
   - ANSYS Multiphysics
   - Mathematic program languages such as: Mat LAB, Mathematic, MathCAD etc.

The most complete program package from this group is SynerGEE based on objectively-oriented design, where each system element is modelled in detail by an algorithm that represents the exact actual characteristics of the element in question.
The characteristic representative of the second group is the FEMLAB program package, characterised by user interface and powerful mathematics tools. It is also worth mentioning that the main directions of further development of PSS operator education lie in bringing software tools closer to the needs of the final user, because of solving the more and more complex problems and situations within power systems.

4. CONCLUSION

It is obvious from the presented paper that it was impossible to standardise specific operator duties for a large number of users; i.e. each user program had to train operators using its own system and to solve its own operating problems, using its own operating controls according to its own operating procedures.
The common area, viewed from the point of PSS operator training, is the basic characteristics of electrical and mechanical equipment and EE process. The course formation should start with defining "what the operator is supposed to do", i.e. with defining operator's duties depending on the specific task.
The next question is "which information is necessary for operator training in order to be able to adequately fulfil their tasks".
The main goal of these issues would be to teach operators not only how system operates, but also why it operates the way it does, which is important for the formation of a competent PSS operator, because most of the problems that arise during unexpected interruptions are the ones that the operator has never experienced before neither during actual work nor during the training on simulators (training devices). After the basic characteristics have been adopted, it is much easier to understand characteristics of certain areas.

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