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Name and home country: Mr. L. TWARDY (Poland)

Field of study: Electric power

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Country (ies) of study: United Kingdom

Lucjan TWARDY

UN Fellow

FINAL REPORT

I graduated from the Electrical Engineering Department of Warsaw Technical University in 1958 with M.Sc. degree in Electrical Engineering.

During studies /1952-1958/ I have specialized in electric power station systems under supervision of Professor St.Kończykowski Ph.D.

Since April 1957 up to now I work in Electric Power Institute in Warsaw. From 1957 till 1959 I have worked as a senior engineer at first in economic problems group and then in analogue modelling group. I have been engaged in research on economic effectiveness of electric power investments and then on application of analogue models in the field of electric power system /short circuits, load flows, reactive power problems/.

From 1959 till 1963 I have worked in the Department of Electric Power Systems at the beginning as an research assistant and later as a senior research assistant.

I have worked on problems of economic distribution of load in electric power systems, on economic criteria of choice of generating units and application of digital computers in electric power systems. In 1962 I spent a year in Soviet Union on industrial practice in the field of a programming and operation of digital computers. Since 1963 I have worked as a research adiunct in the Department of

Digital Computer Applications, where I have held a position of the head of numerical computation group. My responsibility was concerned of all numerical calculations used by National Power Authority and National Control Centre. I have been mainly interested in the following problems: computer program execution, programming languages and algorithms. Personally however, I am mostly interested in mathematical modelling.

I have done some research work on determination of net available generating capacity in electric power systems.

My main work has been done in the field of statistical modelling of electric power problems with consideration of forced outages as random valuables. It was my Ph.D. thesis done under supervision of Prof. K.Kopecki Ph.D. of Gdańsk Technical University.

I received Ph.D. degree with honours from Gdańsk Technical University in May 1970. During 1970 I have prepared the Project of Data Processing System of National Control Centre for new bought computer system CDC 3175.

Since 1971 I have joined Power System Planning Department as the head of numerical computation group. My responsibility has been concerned with application computer processing system and applied mathematics to solve and optimise electric system development problems in Planning Department.

Problems of performance and development planning of modern power systems need very good staff, sophisticated method and advanced computational techniques. In last time

has been written many books and papers on applications of mathematical aids, particularly the techniques of resource planning and some of the technical-economic problems of power-system planning and operation. The decisions at issue are important and complex, involving large sums of money and often social and other factors which cannot be quantified in absolute terms or at all. Hence it would be wrong to equate practical decision - making to the determination of mathematical optima. Nevertheless, such studies can contribute valuable insight into the mechanism of solutions, for instance cost sensitivities, the effects of uncertainties and the relative importance of different variables.

The public utilities and primary fuel industries raise special problems in planning and operation. Capital requirements for expansion are very large. A high proportion of industry and household will require the products. Installation for production or distribution, usually to the consumers' premises, will be nationwide. The overall lead times for planning, obtaining statutory approvals and construction are long as a result of the big investments and impact on the community at large.

A very high standard of product availability is expected. The products are essential components in the manufacture or distribution of industrial goods in general and their costs will effect export and home price levels. Apart from cost, living standards in the home are dependent on plentiful and continuous supplies.

The planning and operation of an electricity-supply system perhaps poses these problems in a more acute form than any other of the basic industries. It is the most capital intensive industry of all. The product - electricity - cannot be stored on a scale significant with the consumption, hence the potential capacity available from the supply system must at all times exceed the simultaneous sum of consumers' demands if restrictions are to be avoided. Distribution facilities and cost cannot be shared with other industries. Apart from hydro installations, the primary energy sources must be obtained from other industries; the cost and delivery charges on these are a major part of supply system revenue charges. Electricity is not an easy product to produce and handle in large quantities. Efficiency of conversion from heat source to mechanical to electrical energy requires high temperatures and pressures and close tolerances on rotating parts. Efficient large scale distribution needs high voltages with costly insulation. Abnormalities developing in one part of the system are felt to a greater or lesser extent immediately throughout the system, calling for automatic means of controlling power production and flows and on a somewhat longer time scale manual - and automatic control systems to supervise these. It is not surprising therefore that power - system engineers have developed the application of computers into studies on the synthesis of optimum systems. Although this development has occurred in a little over 15 years, the field is now the subject of an extensive and world-wide literature.

Between many problems we are especially interested in:

1. rational usage of primary energy resources
2. improving efficiency of conversion
3. district heating
4. pollution
5. large generating units
6. very high voltage for transmission
7. nuclear power station.

To get answers on all these questions researchers must use modern methods and very big computers. We have done much work on this field in my country. The rapid progress which we have observed in this field in the developed countries make us look for adaptation of some of these projects and exchange of experiences. My country is mainly interested in advanced applications of computer systems in solving complex problems of power industry. We are interested in organisation problems of computers and software. We want to adopt modern computational methods and algorithms. We need to create computer processing systems for operating and planning of power system problems. We are interested in modern management techniques, organisation method etc.

Among the techniques used in operation of power system we are mainly interested in security assessment programs and reliability. We want to get some knowledge in the new ways which we observe now in reliability and security research in power technology.

These problems led my government to nominate me for the United Nations Fellowship.

My fellowship can be divided into three main subjects:

1. The systematical improvement of English language especially conversation. I have had such possibility during a one month course at Language Tuition Centre in London and systematical using of English Language Laboratory at University of Manchester.
2. The studies of some important technical subjects connected with my own research work at Electrical and Electronics Department of University of Manchester Institute of Science and Technology /UMIST/.
3. The visits in undertakings of Central Electricity Generating Board /CEGB/ and some of the most important factories connected with electricity industry. I mean the factories which are leading in modern world technology.

The study and research at University

The subject reliability and security assessment of Power Systems is important and a new field of applied science used in electricity production industry. The main goal of it is to guarantee safe and economical performance and proper way of development of this branch as a part of state economy. It has been realised for some years at UMIST and is lead by the people who are famous in world literature on the subject: Dr. R.N.ALLAN, Prof. R.BILLINTON, Dr. A.BRAMELLER. My scholarship

gave me a possibility to become acquaintance with the actual state of the research in this field and to get some experience.

Reliability

Intensive research has been undertaken at UMIST on reliability of power system network. Reference was made to basic proceedings which have been published at ~~IEEE~~ Transactions on PAS and devoted to this subject /De Sieco, Stinc, Gower, Montmeat, Patton, Billinton/ and research is continuing under Dr. R.N.ALLAN whose ambition is to create universal and general package of reliability and security assessment programs used in operation and planning of power system. The first work considers the important aspects associated with evaluating the reliability of power system networks. The reliability techniques used are based on the expected failure rate and average duration method, and the computational techniques on the "minimal cut set" method. The assessment includes the effect of forced outages, maintenance outages and bunching of failures in adverse weather. It has been shown in this work how reliability techniques can be used to assess complex power systems networks. The expected failure rate and average outage duration method coupled with the "minimal cut set" theory gives a computationally efficient technique for quantifying reliability in terms of indices /outage rate, outage duration and total outage time per year/ which are easily understood by engineers.

The detailed analysis illustrates the inappropriateness of the subjective approaches and shows that a relatively minor difference between two extremely similar networks can have significant variations in their reliability indices. Consequently these techniques can assist planners greatly in comparing the reliability and the consequential cost of various alternative designs.

These techniques permit the consideration of failure branching in adverse weather. The sensitivity analysis showed that this bunching effect can have a dramatic effect on the system behaviour. Consequently it is evident that careful consideration of this effect must be made in order to obtain realistic reliability characteristics. It was also shown that the duration of forced outages had a more significant effect on the system reliability than the duration of maintenance outages. This type of result is clearly indicated in a sensitivity analysis. Such analyses can lead to a sound engineering appraisal of the economics of improving component reliability, repair aspects and maintenance scheduling.

The second work take into account an efficient algorithm for evaluating the "minimal cut set" of any general network based on boolean algebra and set theory. The algorithm contains many significant improvements than those previously created and is computationally much more efficient. The most significant features are that only one set of topological input data is required to evaluate "the minimal cuts" and reliability indices of every output node, a mix of unidirectional, bidirectional

and multi-ended components can be included very simply and a new concept of overall system reliability is discussed which permits different large and complex systems to be compared.

The main and most important new features of the present algorithm include the ability to express the reliability of the overall system by appropriate indices and therefore to compare easily and efficiently different designs, the ability to deduce the minimal paths and cuts for all nodes from one set of topological input data and the ability to include simply unidirectional, bidirectional and multi-ended components.

The third work presents a novel approach to the reliability assessment of different designs of power station auxiliary electrical systems. The assessment evaluates the impact of the auxiliary system on the availability of the main unit in terms of derated states of the unit. This technique permits the reliability cost to be calculated easily for different system designs. All realistic failure rates were taken into account. An efficient computer program using these techniques has been developed and was used to obtain the practical results. To associate a cost to the reliability of a proposed design is one of the main objectives of long term reliability or availability studies. This work has proposed techniques that assist these objectives to be fulfilled with regard to the specific area of electrical auxiliary systems of power stations. The concept of system "minimal cut sets" derived from nodal minimal cut sets which leads to the evaluation of the reliability

indices of the unit derated states is very powerful and can be applied to many different problems.

The computer program that has been developed to incorporate these techniques is very efficient and require only 23.5 K words for a system having 100 elements and up to 1000 failure events. Furthermore the computing time to analyse the system considered in this work was 2.9 sec on a CDC 7600.

I myself have been engaged under taking into account overload of lines in reliability assessment of power system - coming to some general conclusions. The subject is difficult, is connected with problem of probabilistic load flow, which theoretical assumption not been developed to succesfull end.

Security assessment

The analysis of security assessment has evolved out of load flow techniques to evaluate system response for credible outage of transmission and generating plant loss of loads. The developed /under Dr A.Brameller at UMIST/ security assessment based on a decoupled load flow provides a better insight into the state of the system over the conventional D.C. reactance representation. The technique developes the use of sensitivity factors for an adjusted A.C. decoupled load flow solution which produces fast and accurate results and automatically maintains voltage and generation limits to specified values. It also includes automatic voltage regulations and governor representation for evaluation of voltage changes after a loss of generation, pick-up of spare

generation and analysis of split network conditions. The A.C. model can be used for detecting studies of critical loading conditions and is essential in planning and design. The described techniques has been implemented in the computer program on a CDC 7600 computer.

All the work mentioned so far contain an extended computer software, with which I had possibility to make acquaintance. This software is gradually extended and improved. There are exceptionally good computer facilities at Manchester University which will be described later.

University of Manchester Regional Computer Centre /UMRCC/

It is actually the most modern, efficient and economical computer system in Europe, equiped in three giant computers ICL 1906A, CDC 7600 and CDC CYBER 72.

The Regional Centre was established in 1969 and one of its first jobs was to prepare the ease for instaling computer capacity to bring up the power level to about 20 times that of "Atlas" /actual computer at UMIST in 1969/. After much discussion with the manufacturers the concept of linking /a/ the most powerful British Computer then available the ICL1906A with /b/ the most powerful American computer then available the CDC 7600 emerged . The experimental linking began at ICL's factory in Sept. 1971. By the spring of 1972 the linking software was developed to such a state that programs and data were successfully passing between the two computers. This new joint system, it was soon discovered, ran at an even greater

power than had been estimated. During the 1973 it was discovered that very substantial amounts of computing power could be dispersed efficiently using the fast telephone lines. The number of remote terminals increased from 5 to 15. The work of dispersing computer power throughout the North of England proceeds very rapidly during the whole of 1974. There are now dedicated or dial-up links to 19 Universities. The Computer Boards have recently approved the purchase and installation of the computer CDC CYBER 72, which is to provide for Manchester and UMIST, what is called an interactive service. There have been used experiments with this "continuous contact" approach, which had been performed at MIT in the 1960s. It could now be justly claimed that the plans laid for Manchester by the first Computer Board have been more successful than they could have hoped at the time.

The very important results of the joint system development, it may be claimed, may well change the face of computing on a national if not an international scale.

Firstly it was proved at UMRCC that very substantial amounts of "number crunching" computer power could be dispersed, much in the same way as electrical power, over long distances, very effectively.

Secondly it was proved that computing power could be provided at remote locations at much less cost than it could be provided by installing a smaller computer at the particular site. Current financial considerations show that the cost per

unit if UMRCC at remote stations is about one fifth of the unit of power supplied by local computer. The present experiments with the interactive machine may prove that one can disperse interactive computing in the same cost-effective way as "number crunching" power. All the present evidence is that UMRCC will be able to provide UMIST with a good an interactive service as if the interactive machine was in fact, installed at UMIST - though this still has to be shown.

This proves to be the case, than it may well also prove to be the case that the cost-effective advantages of regionalization of "number crunching" computer power may well apply also.

Visits to industry undertakings

Thanks to the numerous visits to different branches of the electrical undertakings in particular the CEGB I have learned the organisation and practical usage aspects of modern methods and computer applications. In certain research projects I could follow the path of development of the project from onset through to its first practical application and the attendant understanding which will have to exist between the University and industry. I could follow the role of the research departments of the electrical industry and its collaboration with CEGB and other utilities in different countries as well as other research institutes.

I also became acquainted with the aim of development and construction division of the CEGB i.e. at Guildford and

Gloucester, the regional headquarters and central headquarter and their connections and technical dialogue especially in the field of development and use of modern technology in the power system.

During my visit in the Planning Department of the CEEB I obtained knowledge of the collection of transmission system data which is then used by different departments in the study of existing and future networks. I became acquainted with the method of production and improvement of software used by the Planning Department with the cooperation of the Operation Department. I became acquainted with new and sophisticated computer equipment e.g. videodisplay unit, mikrofeech, calcamp plotters, multi-access terminals etc. During my visits to some substations and control centers I learned of benefits and new technical possibilities existing in application of mini computers in control schemes.

Conclusions

Having the theoretical and practical knowledge of the problems involved, which I have achieved during my training in Great Britain the possibilities of using it are almost unlimited and to enumerate them would be impossible.

Taking into account the differences of economical and political structure of both countries - Great Britain and Poland, I want to underline the next benefits of my visit covered in items as a problems or subject.

1. Possibilities created by large computer system for the assessment of reliability and security of power systems.
2. Organisation of computer services to carry out research work in power utility of U.K.
3. Characteristic features of research subjects and organisation of carrying out the task.
/Practical problems with rapid solution/.
4. Economy of research tools - the solution of subjects chosen for research must have associated economic benefits.
5. The learning of educational methods used in a known and important technical University.
6. Learning and discussion of the art of different computers techniques used in the power industry in U.K. Comparison of the theoretical studies /University/ with these used by industry /CEGB/.
7. Acquaintance with central computer installation systems and their advantages compared with small and independent systems.
8. The main assumption and philosophy of software producing for power system problem solving.

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