INTERNSHIP EXPERIENCE AT
ELECTRICITY DIRECTORATE OF BAHRAIN

An Internship Report

by

NAJEEB AHMAD ALJAMEA

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Approved as to style and content by:

A. K. Ayoub
(Co-Chairman of Committee)

B. D. Russell
(Co-Chairman of Committee)

J. W. Howze
(Member)

P. S. Noe
(Member)

P. E. Pulley
(Member)

L. S. Fletcher
(Member)

J. W. Howze
(Interim Head of Department)

May 1985

ABSTRACT

Internship Experience at

Electricity Directorate of Bahrain. (May 1985)

Najeeb Ahmad Aljamea, B.S., Texas A&M University,

M.E. Texas A&M University

Co-Chairmen of Advisory Committee: Dr. A. K. Ayoub
Dr. B. D. Russell

This report describes the author's experience with the Electricity Directorate of Bahrain from September 1983 to December 1984. During this internship period. the author worked as a Senior Engineer in the System Operations and Planning Department. The intent of this report is to demonstrate that this experience fulfills the requirements for the Doctor of Engineering internship.

The author's activities during the internship period can be categorized into two major areas. The first was technically oriented, where he participated in the development of the *System Control Center* which monitors and controls the power network of the state of Bahrain. Secondly, some non-technical and business oriented areas were investigated. The tasks in these areas offered the author the opportunity to be exposed to the operation and organization of a power utility and to gain experience in a non-academic environment.

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INTERNSHIP OBJECTIVES

1. To become familiar with the structure of the organization, organizational goals and objectives, and departmental responsibilities and functions.
2. To make an identifiable contribution in the electrical engineering area within the organization.
3. To gain experience in the non-academic managerial and business activities of the organization and to be aware of the interaction between the organization and the business environment.

INTERNSHIP COMPANY

The Electricity Directorate of Bahrain is a government owned public electric utility. ED-Bahrain is one of five directorates within the Ministry of Works, Power, and Water. These directorates are: the Directorate of Electricity, the Directorate of Water Supply, the Directorate of Administration and Finance for Power and Water Affairs, the Directorate of Construction Projects and Maintenance, and the Directorate of Roads and Sewerage. The first three directorates are grouped under one Under-Secretary for Power and Water: and the other two directorates are grouped under one Under-Secretary for Works. The upper organizational chart of the Ministry of Works, Power and Water is shown in figure 1.

The Electricity Directorate of Bahrain is responsible for the generation, transmission, and distribution of electrical energy to the whole country of Bahrain. The service area includes the main island, *Manama*, and the other surrounding islands which are connected to the main island via causeways. A geographical map of Bahrain islands is shown in figure 2. Most of the population of Bahrain, which is about 400,000, is concentrated in the northern part of the Manama island and in the second largest island, *Muharraq*. In the last few years, Bahrain has witnessed a tremendous growth in the commercial and the industrial sectors. This has had an enormous effect on the social life of people and placed an enormous impact on the level of services that are provided by the government and by the public sectors in order to satisfy the commercial and industrial requirements and to cope with the increase in the general standard of living. Faced with this growth requirements, the

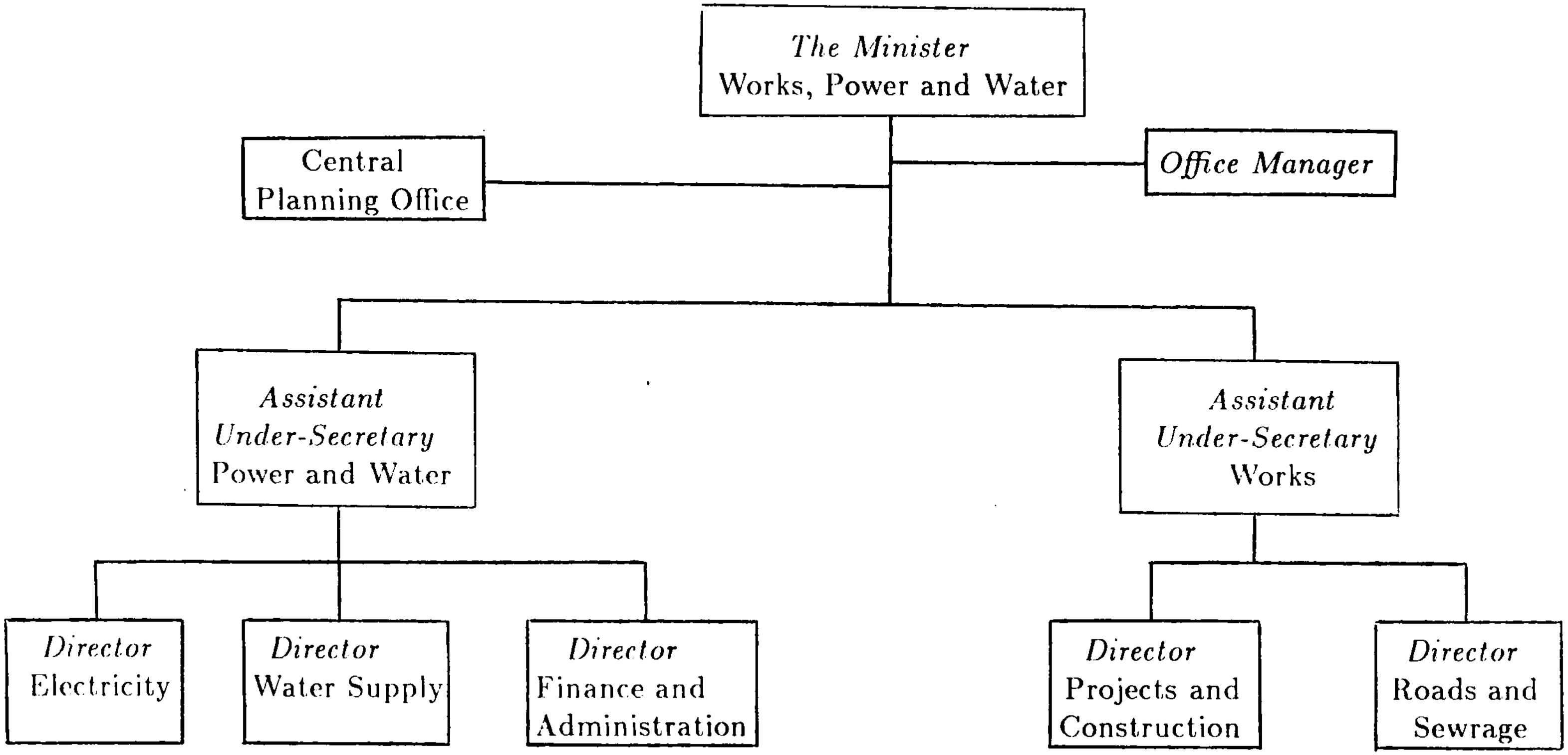
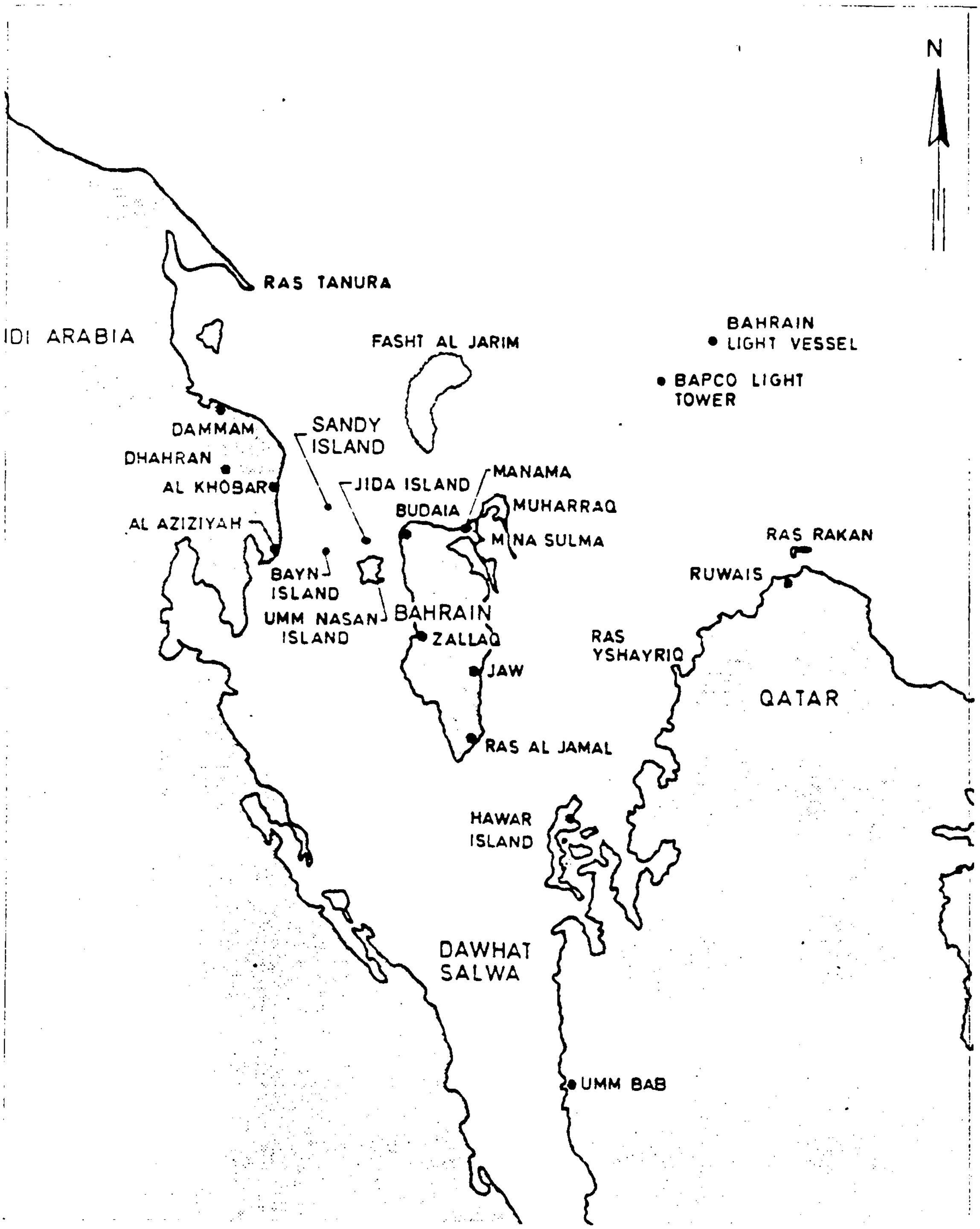


Fig. 1. Organizational Chart of
the Ministry of Works, Power and Water

Electricity Directorate of Bahrain has launched several major expansion projects in the last ten years. Among these projects are: a steam power generation and desalination plant commissioned in 1974 and expanded in 1980, a gas turbine generating station commissioned in 1978 and expanded in 1983, introduction of 220 kv voltage level in the transmission system, and commissioning the System Control Center in 1982. Future major expansions are also foreseen in the next ten years as a result of major industrial, commercial, and residential projects that are planned to be commissioned within that period. Most important of these projects are: a large petrochemical plant, a new residential city in the middle of Manama island, and a causeway that will link Bahrain to the eastern shore of the Kingdom of Saudi Arabia and which is expected to bring about a business boom into the country. Also, tie lines that will connect the electric power network of Bahrain with the rest of the Gulf Cooperation Council (GCC) countries are under study.

Fig. 2. Geographical Map of Bahrain



INTRODUCTION

This report describes my Doctor of Engineering internship experience with the Electricity Directorate of Bahrain, a government owned electric utility. The internship was performed over the period from September 2nd, 1983 to December 31st, 1984. My internship supervisor was Mr. Malcolm C. Britton, manager of the System Operations Department. During the internship, I was exposed to the technical and non-technical aspects of operating an electric utility organization.

My technical assignment was initially described in general terms: to participate in the development of computerized supervisory control and data aquisition equipment for the *System Control Center* which monitors and controls the transmission and distribution networks of Bahrain power system and allows system studies to be performed using the on-line main computer and the real-time system data.

The non-technical areas of experience during the internship varied from corporate philosophies to recruitement of new engineers. During the internship, I was given several non-technical oriented assignments which included participation in the development of a new section within the System Operations Department, participation in developing training programs for control engineers, interviewing new personnel for the department and for the organization, and representing the organization in discussions with consultants. This has exposed me directly to many areas of management like objective setting, setting up new procedures, recruitment of new staff, training, motivation and conflict resolution. Also, throughout the internship period, I was working very closely with consultants, project contractors and the

Project Department personnel within the Electricity Directorate of Bahrain.

The intent of this report is to show that my internship experience with the Electricity Directorate of Bahrain fulfilled the requirements for the Doctor of Engineering internship. The fact that these requirements have been satisfied will be demonstrated through a discussion describing how each of the three objectives of the internship were met. This report is divided into three chapters, one for each of the objectives.

CHAPTER I

OBJECTIVE

TO BECOME FAMILIAR WITH THE STRUCTURE OF THE ORGANIZATION, ORGANIZATIONAL GOALS AND OBJECTIVES, AND DEPARTMENTAL RESPONSIBILITIES AND FUNCTIONS.

Introduction

This first internship objective was met through the accomplishment of several technical and non- technical activities. Since I was with the Electricity Directorate of Bahrain before actually starting my Doctorate programme, I already had some idea about the various departments of the organization. However I found that it was necessary to increase the level of my knowledge of the organization in order to fulfill the internship requirements. I accomplished that by meeting several people in different departments of the organization and by discussing with these people the function and operation of their departments. Also, I found it very useful to spend some time in some of these departments in order to have a closer look at their activities.

The Electricity Directorate is responsible for the safe, reliable and efficient production and delivery of electricity to each home and commercial user in Bahrain. The Electricity Directorate is also a major producer of fresh water from sea water desalination plants, and has the responsibility for all street lighting throughout Bahrain. The Directorate is divided into three main engineering departments: the Production Department, the Distribution Department, and the Projects and Development Department. Each of these departments is headed by an Executive Engineer who is aided by divisional managers to provide the varying services required. The organization chart of the Electricity Directorate of Bahrain is shown in figure 3.

These engineering departments are supported by the other departments in the Administration and the Financial Affairs Directorate within the Power and

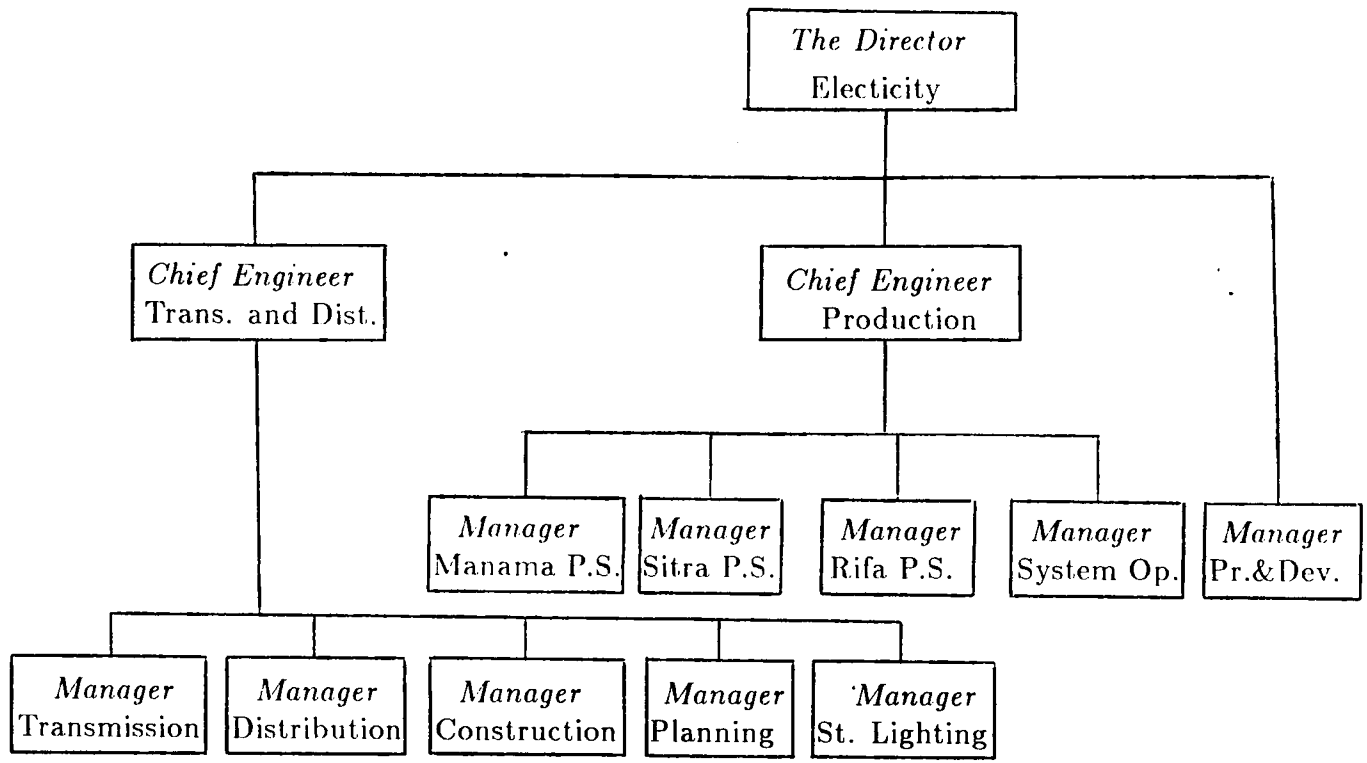


Fig. 3. Organizational Chart of the Electricity Directorate of Bahrain

Water Affairs in all functions relating to commercial matters, administration and personnel, finance and accounting, training and development, and general services.

In the rest of this chapter I will present a description of each of the above departments and try to cover as much as possible their responsibilities and major functions. Also since these departments are supported by the Directorate of Administration and Financial Affairs, a section is included in this chapter for a brief description of this directorate.

A. The Production Department

The Production Department is charged with providing the electric power required by the country and for producing drinking water from sea water through desalination.

There are presently four generating plants which are owned by the Electricity Directorate. These are: Manama Power Station, Muharraq Power Station, Sitra Power Station, and Rifaa Power Station. Two of these generating stations, Sitra P.S. and Rifaa P.S., are undergoing large expansions. and there are plans for at least one additional generating station to be introduced before 1990. The Production Department receives natural gas, delivered via land pipework from the Bahrain National Oil Company (BANOCO), and converts it to electric power at high voltage which is then passed on to the transmission network. Utilizing the same basic gas supply, the Production Department produces fresh water by desalinating sea water and delivers it to the Water Supply Directorate distribution system. This Department also carries out the function of co-ordinating the efficient production and dispatch of electricity which is done in the System Control Center.

The Production Executive Engineer has four divisional managers reporting to him. They are the Station Managers of the generating plants and the System Operations and Planning Manager.

A.1 Manama Power Station

The Manama Power Station is the oldest generating station in the Electricity Directorate power system. It was first commissioned in May 1931 with two diesel powered generators having total output capacity of 200 kilowatts. Now the total generation capacity of the station is 125 megawatts which is delivered by 16 generating units ranging in capacity from 1 megawatt to 20 megawatts per unit. Six of these units, each rated 6.1 megawatts, are connected to the 11kv distribution network. The other units are connected to the 33kv sub-transmission network.

The organization of this power station consists of a Station Manager at the top and two senior engineers reporting to him. The Senior Operations Engineer is responsible for operating the generation equipment in the station. Several Shift Charge Engineers and Technicians work under him to ensure continuous 24-hour operation of the station in accordance with total system requirements. The Senior Maintenance Engineer's main responsibility is to ensure that all the generating and auxiliary equipment in the station are in good running order. He is assisted by a Mechanical Engineer and an Electrical Engineer. Also reporting to the Station Manager is an Administration Officer whose main function is provide assistance to the personnel in the station in all matters relating to administration and personnel.

A.2. Muharraq Power Station

This is a small power station which was commissioned in 1976 as part of a crash programme to meet load requirements and to support transmission system weakness at that time. There are two package units in this station each with a capacity of

20 megawatts. The station is controlled remotely from the Manama Power Station control room with only a skeleton staff on site.

This station is very expensive to run since the machines are arranged for burning diesel fuel which must be bought out of the operating budget at full market price. Also since the transmission system of the Electricity Directorate has improved over the last few years, this station is rarely run at present.

A.3. Sitra Power and Water Station

Sitra Power and Water Station is built on reclaimed land to meet the growing demand for electrical power and high quality water in the island. This station is designed principally for base load operation and for continuous operation at high loads for long periods. It is presently equipped with four boilers, four turbo-alternators, and two distillers. The boilers are identical and are of the natural circulation single drum type, arranged for natural gas firing with pressurized furnace, and have continuous rating of 204 t/hour of steam. The turbines are of the single cylinder, impulse reaction type, having a steam pass out belt between the high pressure (H.P.) and the low pressure (L.P.) stages. Each turbine is capable of generating 30 megawatts with reduced extraction steam. The alternators have a maximum continuous rating of 30 megawatts each; hence the total installed capacity of the station is 120 megawatts. The distillers are multistage flash (MSF) evaporators of the horizontal, cross flow type, and are rated at 2.5 million gallon per day (mgd) each. The total water producing capacity of the station is therefore 5 mgd. Future expansions in this station will take place in two phases. The first phase will comprise the commissioning of one gas turbine with a generating capacity of 25 megawatts and one distiller unit, MSF type, with water production capacity of 5 mgd. The second phase will comprise the commissioning of three more distillers each having a water production capacity of 5 mgd. These expansions will bring the installed generation capacity of the station to a total of 145 megawatts and the installed water production capacity to 25 mgd.

Responsibilities of the station include running the power and desalination plant and maintaining the plant and equipment in a good condition so as to achieve maximum availability and reliability to meet the system demand at any time. The organization which carries this responsibility consists of the Station Manager and four sections which perform the required activities. These four sections are: the Operation Section, the Maintenance Section, the Planning Section, and the Administration Section. The Operation Section is responsible for the day to day activities associated with all operational aspects of the power and water plant. This section includes a Chemical Engineering Unit which is responsible for analyzing and controlling all chemical parameters of steam raising units, steam turbines and desalination plant including control of the quality of distillate water pumped out of the station. Except for this unit, all personnel in the Operation Section perform their duties on shift to shift basis. The Maintenance Section is responsible for the proper upkeep of the plant and equipment in order to ensure the maximum reliability and availability. This section is composed of three units: the Mechanical Maintenance Unit, the Electrical Maintenance Unit, and the Instrument Maintenance Unit. Each of these units is responsible for the proper maintenance of the equipment in its area. Main activities of the Planning Section include preparation of annual overhaul schedules for the station, issueing and monitoring planned preventative maintenance (PPM) cards, monitoring job/defect cards, and monitoring the level of spares for the maintenance of plant and equipment at the required time. The Administrative Section looks after the administrative functions of the station. It is responsible for keeping the service records and time sheets for all the personnel, for issueing of the required stationary items for all the sections, etc.

A.4. Rifaa Power Station

Rifaa Power Station is the most recently built generating station in Bahrain. It was commissioned in two phases. The first phase comprised five generating units each having a capacity of 50 megawatts, commissioned in 1978. The second phase comprised six generating units each having a capacity of 75 megawatts, and were commissioned in 1983. The total generating capacity of the station is now 705 megawatts. All the generating units in the station are direct driven gas turbines. This station is used to provide the necessary power to meet the demand throughout the 24-hour day.

Organization of this station consists of the Station Manager at the top with a Senior Station Engineer repoting to him. There are three senior engineers who carry out the various activities within the station and they report to the Senior Station Engineer. These senior engineers are: the Senior Operations Engineer, who is responsible for safe and efficient operation of the power station; the Senior Mechanical Engineer, who is responsible for preparation and carrying out mechanical maintenance programmes and procedures; and the Senior Electrical and Electronics Engineer, who is responsible for preparation of maintenance programmes and procedures that relate to the electrical and electronics aspects of the plant. In addition to the above, there is an Administration Officer who provides administration back-up to the station personnel.

A.5. System Operations and Planning

System Operations and Planning has become an important division within the Electricity Directorate. Its importance is increasingly noticeable as the system becomes larger and more complex. Day to day planning, monitoring, and control of the generation and transmission systems is performed within this division through the utilization of the computerized System Control Center and a highly developed communication facilities. In order to carry out these functions, the System Operations includes three main sections. They are: the System Control Section, the Supervisory Control and Data Aquisition Section and the Power System Studies Section. The System Control Section is responsible for the monitoring and control of the power system generation and transmission and for carrying out the day to day planning of system operation. The Supervisory Control and Data Aquisition, or *SCADA*, section is responsible for the development, operation and maintenance of the communications and telecontrol equipment and all the computer systems in the System Control Center. In the Power System Studies section, power analysis programs are run on one of the System Control Center computers, usually the *Standby* computer. and the results of these studies are used to determine the security of the power system under different operational conditions and to advise the management on certain measures that may be taken to improve the performance of the system. Also in this section the protection settings are monitored and set in light of studies made on system. Since this department is where most of the internship time was spent, the organization chart of this department is shown in figure 4.

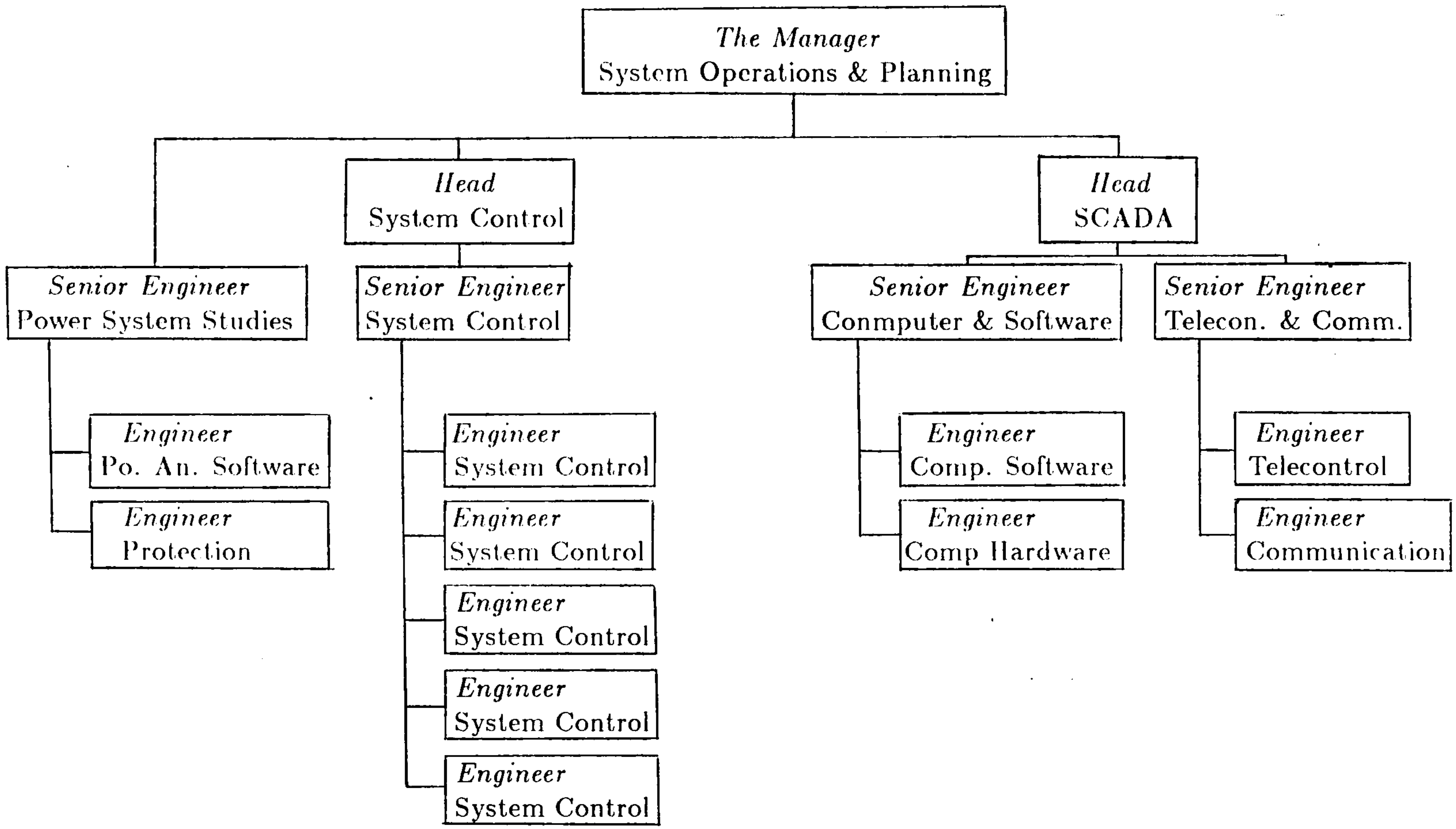


Fig. 4. Organizational Chart of
the System Operations and Planning Department

B. The Distribution Department

The Distribution Department is the largest group in the Electricity Directorate. It encompasses transmission, distribution and street lighting. In addition to delivering bulk power to each individual user this department carries out a large proportion of the new distribution installation work needed to expand and reinforce the cable network and to ensure a reliable supply to all consumers.

There are five divisions within this department. They are: the Transmission Division, the Distribution Operation and Maintenance Division, the Distribution Construction Division, the Distribution Planning Division, and the Street Lighting Division.

B.1. Transmission

The Transmission division is responsible for the delivery of electricity at high voltage from each of the individual generation stations to the primary substations from whence it is distributed to consumers via the 11kv distribution system. The transmission system of the Electricity Directorate consists of :

- Over-head lines : 33kv &66kv
- Underground cables : 33kv & 66kv & 220kv
- Substations: 33/11kv & 66/11kv & 220/66kv.

Associated with this equipment is a protection system which utilises a network of pilot cables.

The transmission system in Bahrain consists mainly of the most modern equipment in the world. In fact, at the time of writing this report 2% of the total sulfer-hexafloride (SF6) gas-insulated high-voltage switchgear installed world-wide is on the Electricity Directorate transmission system. This fact, coupled with the rapid growth of the transmission system, presents unique management problems to ensure, at all times, an organization capable of meeting the expanding demands and technological advancement.

At present, the Transmission Division consists of four sections. These are: the Substations Section, the Network Section, the Protection Section, and the Planning Section. The Substations Section has the responsibility of carrying out corrective and preventative maintenance on all the power system equipment in the primary substations. The Network Section is responsible for maintaining the transmission and subtransmission cables and overhead lines and the network of pilot cables. The Protection Section is responsible for calibrating and setting the protection relays in the system. The Planning Section coordinates the work amongst the different sections within the Transmission Division and act as a liaison with the other divisions within the Directorate in matters relating to outages on equipment for maintenance or repair.

B.2. Distribution Operation and Maintainance

This division receives electrical energy at 11kv voltage level from the bulk power substations and distributes it through to more than 2000 secondary distribution substations. At these secondary substations the voltage is further reduced to 400 volts line-to-line and the electric power is delivered to the consumers. The main responsibility of this division is to maintain, control and operate the distribution network. This division consists of two main sections: the Operation and Control Section and the Maintenance Section. The Operation and Control Section performs the functions of controlling all the 11kv distribution network and substations, commissioning of new distribution 11kv equipment, and post fault investigation and tracing of faults on the 11kv and low voltage distribution network. The Maintenance

Section plans and carries out maintenance on distribution equipment, provides fault repair service on a 24 hour basis to the public, and carries out post fault repairs on the entire 11kv and 400 volt distribution network.

B.3. Distribution Construction

This division is responsible for the erection and construction of new works at 11kv and 400 volts levels in accordance with approved practices and specifications for the distribution of electricity in Bahrain. It is composed of three main sections: the Metering, Installation and Services Section, the Contracts Section, and the Construction Section. The Metering, Installation and Services Section performs the functions of testing, calibrations and repairs of kWh meters and other instruments belonging to distribution, inspecting of wiring installations and approval of appliances and apparatus, and construction of overhead and underground service connections. The Contracts Section is responsible for the follow up of distribution projects that are constructed by outside contractors. The Construction Section is responsible for the distribution projects that are constructed by staff employed by the Electricity Directorate. It is charged with installation of substation equipment in Distribution substations, construction of 11kv and low voltage overhead distribution mains, and construction of 11kv and low voltage underground distribution mains.

B.4. Distribution Planning

Responsibilities of this division include planning and designing all distribution network extensions, reinforcements and alterations, promoting development of engineering practices and ensuring the availability of material for all distribution network projects. There are four sections which carry out the various functions in this division. They are: the Network Planning and Design section, the Standard and Audit section, the Materials Control section, and the Development section. The Network Planning and Design is charged with forward planning for the distribution network and with providing network design related to power supply to new developments, reinforcement of existing network, and processing consumers requests for diversions and re-routing of distribution network. The Standard and Audit Section has the responsibility of establishing and maintaining standards and specifications for materials and equipment. It also has the responsibility of establishing codes of practice for planning, design, construction and maintenance of distribution network and equipment. The Material Section is charged with the prequalification and evaluation of tenders related to materials used on the distribution network, the inspection of incoming materials and monitoring performance of new materials, and the control of the usage of distribution materials. The Development Section is charged with monitoring the development in electricity technology and with investigations into new materials and techniques.

B.5. Street Lighting

This division has the responsibility of providing all public street lighting which includes new installation as well as repair, replacement and updating of equipment. This division consists of two sections. The Construction Section which is responsible for the design and construction of street lighting projects; and the Maintenance Section which is responsible for maintaining existing street lighting network and for repairing faults on the street lighting plant on a 24-hour basis.

C. The Projects and Development Department

This Department is responsible for monitoring the electricity usage on a national basis and for planning new plant and equipment to meet future needs efficiently and reliably. It is also responsible for preparing and continuously updating the development plans in order to install new power stations, desalination stations, transmission substations and cable networks so that the electric power requirements of Bahrain are always met. The bidding, erection, and commissioning of all these major contract installations are governed by this Department. At present, this department consists of five sections: the Generation Projects Section, the Desalination Projects Section, the Transmission Projects Section, the Civil Engineering Section, and the Project Planning Section. The Generation Projects Section is responsible for the management and control of all projects in the generation area. The sort of activities that this section performs are as follows. Project cost estimates and cash flow requirements are prepared for budget purposes, and methods of contract funds handling are recommended with the objective of optimizing cash outflow. The project consultants are selected and the project requirements are defined for the preparation of feasibility studies by the consultants. The design and specifications submitted by the consultants are evaluated and independent evaluation of the pre-qualifications is conducted. Tender analysis is carried out in parallel with the consultant and finally tender discussions with the consultant and the prospective contractors are held to finalize technical details and contract conditions prior to contract award. Once the contract is awarded, the section monitors the progress of the project to ensure on-time completion or to minimize delays, assesses the validity of proposed design changes, and verifies the work progress before endorsement of payments for the completed work items. When commissioning the projects, the section acts as a liaison with the consultants/contractors and the operating department on details of commissioning procedures, participates in the commissioning and reports on plant performance. After commissioning the section monitors the contractor's performance of warranty maintenance provisions if present in the contract. In much the similar way, the Desalination Projects Section and the Transmission Projects Section are responsible for the projects in the desalination area and in the transmission area respectively.

The Civil Engineering Section provides civil engineering services to other sections in the department in the areas of preliminary civil design, activity scheduling, cost estimating and budgeting, evaluation of design and specifications submitted by consultants, evaluation of bids and tenders, monitoring project progress, evaluation of civil design changes, and verification of civil works progress and endorsement of of progress payments. The section also performs project engineering duties on civil works and gas pipeline projects managed by the department. It reviews land usage, access and service requirements and co-ordinate with other project engineers and sections concerned where inter-project relationship exists. Finally, the section also initiates land allocation requests and assists in the registration and in the leasing or purchase arrangements of such sites.

The Project Planning Section monitors power cosumption patterns for the purpose of forecasting growth in power requirements and coordinates with other Ministries involved in other development projects in order to assess future supply requirements. It prepares outlines of generation and transmission schemes based on forecasted supply requirements and optimum supply security, and it prepares outlines of installation programs to support forecasted requirements. It also reviews project costing and revise the installation programs within limits of security of supply to conform with budget limitations and to optimize cash out-flows. It participates in tariff determination and fuel requirements and cost in assessing impact of large industrial consumers on power demands. It also prepares overall budget of the department and liaise with the Ministry of Finance for its approval.

D. The Directorate of Administration and Financial Affairs

This Directorate offers many essential services to the Electricity Directorate and the Water Supply Directorate. It was included in the internship programme because it in fact is an organizational extension of the two other directorates. The Directorate of Administration and Financial Affairs consists of five departments: the Training and Development Department, the Administration and Personnel Department, the Accounts and Finance Department, the Commercial Department, and the General Services Department. The organization chart of the Directorate is shown in figure 5 on the next page.

The Training and Development Department is responsible for determining the training needs of the Power and Water Affairs in the fields of management, administration, engineering, and supervisory and craft skills; and for implementing programmes to meet these needs. The Administration and Personnel Department provides a comprehensive service to Power and Water Affairs by developing, implementing and maintaining appropriate administrative procedures and interpreting and enforcing governmental administrative and personnel regulations. The department also provides advice and assistance to Managers in the areas of industrial relations, discipline, productivity and organizational matters. The Accounts and

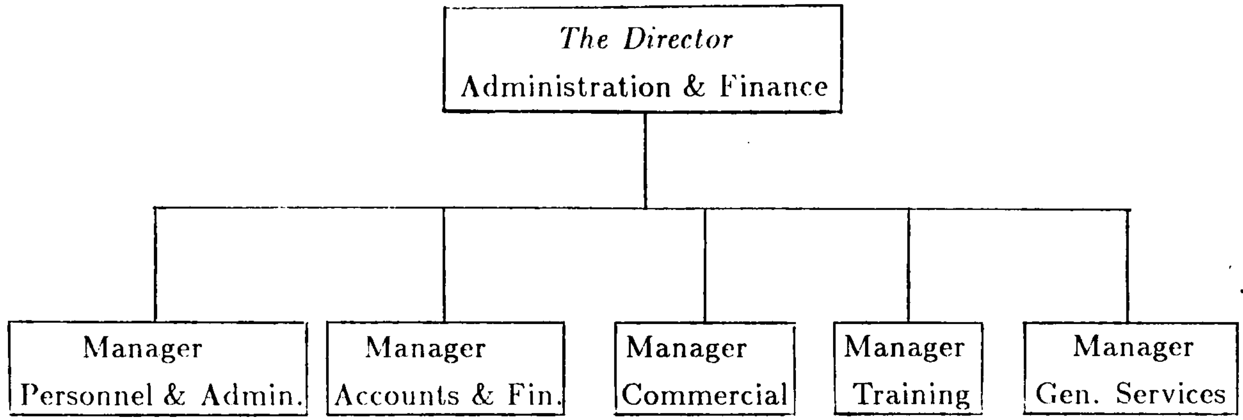


Fig. 5 Organization Chart of the
Directorate of Administration and Finance

Finance department is responsible for all the financial affairs of Power and Water Affairs including the day to day administration of the budgetry control, payroll and costing systems. Also the department provides specialist professional expertise to develop, implement and maintain modern management accounting systems for use in the areas of forecasting and appraisal, planning and control of expenditure and reduction of inefficiencies. The Commercial Department is responsible for the consumer accounting affairs of the Directorate of Electricity and the Directorate of Water Supply which involves the efficient recovery of all charges associated with the cost of supplying electricity and water. In addition to the regular billing function the department receives all applications for connection of supply, establishes and monitors the progress of new accounts. This department is also responsible for recovering any capital contribution required from the consumers in relation to the provision of supply. The General Services Department provides a central resource for Power and Water Affairs in the fields of transportation and buildings/site maintenance. It also acts as a liaison with other ministries on vehicle maintenance requirements, provision of transportation and heavy plant tools, and on general buildings maintenance and minor extensions.

CHAPTER II

OBJECTIVE

TO MAKE AN IDENTIFIABLE CONTRIBUTION IN THE ELECTRICAL ENGINEERING AREA WITHIN THE ORGANIZATION.

Introduction

This internship objective was met through the accomplishment of the primary assignment of the internship which was to supervise the installation and commissioning of computer and SCADA equipment for the expansion of the System Control Center of the Electricity Directorate. This Control Center, which is fully computerized is being used to monitor, operate and control the entire electrical power network of Bahrain. Due to major developments in the power system that took place in the last few years and which will continue in the near future, several extensions had to be made in the SCC hardware and software in order to accomodate these new developments. I was assigned the responsibility of planning and implementing these extensions. Other minor tasks were also carried out in the course of the internship.

In the rest of this chapter, I will present a detailed description of the System Control Center of the Electricity Directorate including my contribution in its development and expansion. I will also briefly present other miscellaneous tasks which were undertaken during the internship.

A. The System Control Center

The System Control Center is the nerve center of the System Operations and Planning department. From there the generation running orders and transmission operating commands are issued. This center is fully computerized and equipped with modern state-of-the-art data aquisition and man/machine equipment. Since most of my work during the internship period was related to the System Control Center development and operation, I will attempt in the following paragraphs to describe the hardware and software configurations of the System Control Center and present the functions that this center perform.

A.1. System Control Center Configuration

In order to perform its functions, the System Control Center is composed of various hardware and software equipment and modules. The hardware and software configurations of the System Control Center are presented in the following paragraphs

a. The Hardware

The hardware of the System Control Centre consists of the following three major subsystems: the Computer subsystem, the Man/Machine subsystem, and the Telemetry and Telecontrol subsystem. It also includes other supporting systems like an uninterruptable power supply, a weather station, and a private exchange telephone system. The Computer subsystem and the Man/Machine subsystem are housed in the System Control Center building which is referred to as the *Master Station*. The Telemetry and Telecontrol equipment is spread over the whole power system of Bahrain: the central components are placed in the Master Station and the rest are housed in special rooms inside the power transmission substations which are referred to as *Remote Stations*. Figure 6 shows the configuration of the System Control Center.

The Computer subsystem is composed of two main processors configured in a dual processor arrangement and a variety of peripheral devices connected to these main processors. The two main processors are of the type PDP 11/70 with 756 kilobytes of main memory in each unit. Cache memory technique is utilized in order to achieve an effective memory access time of 400 nanoseconds. The two processors are linked together with a high speed link. The peripherals attached to each processor are: two disc drives each with storage capacity of 76 megabytes,

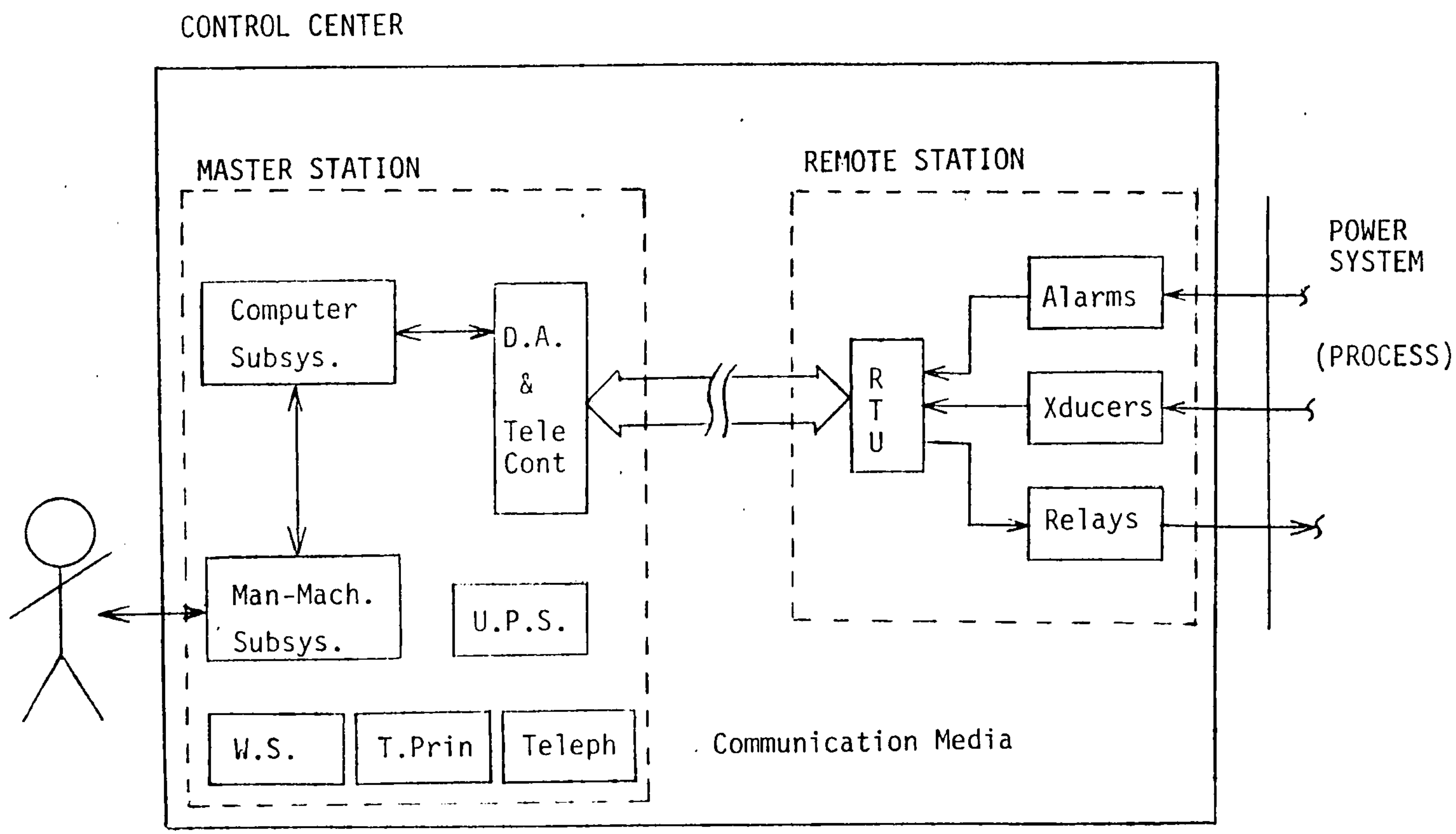
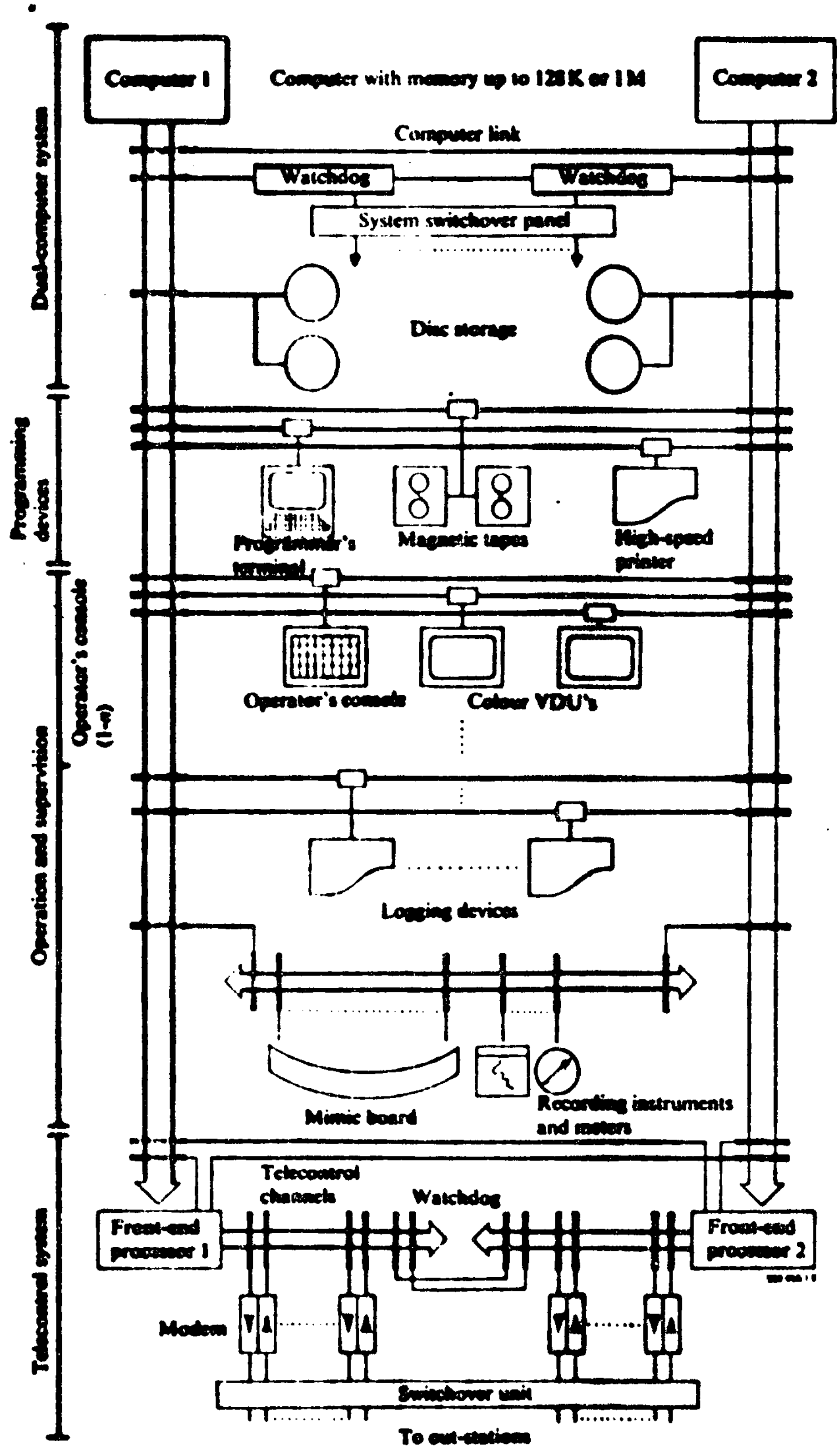


Fig. 6. Configuration of the System Control Center

one console printer, and one magnentic tape drive. The peripherals and system components which are common to both processors and which can be connected to either one via a *switch-over* panel are: two operators' desks, one training desk, the mimic board controller, six *front-end* processors, six programming consoles (VT100s), two dot-matrix printers, one line-printer, one hard-copy unit, a plotter, and a weather station. Figure 7 shows the hardware configuration of the Master Station.

The Man/Machine system components are located in the Control Room of the System Control Center and they consist of the mimic board, the two operators' desks, the two dot-matrix printers as loggers, and a variety of indicators, meters and chart recorders. The mimic board presents to the control engineer an overview of the whole electrical network of the Electricity Directorate including the generating stations, the primary substations and the transmission lines. The information presented on the mimic board consists of a static part and a dynamic part. Static information convey the general layout of the transmission network with some detail of the layout of the transmission stations and the generating plants. The dynamic information includes the status of generator switches in the power stations, the status of transmission feeders switches in the transmission substations, and the direction of power flow in the transmission lines. The total generation output from a power station is shown adjacent to the power station and the presence of any alarm in a substation is indicated by an ALARM light near the substation. The dynamic information is constantly updated by the on-line processor through the mimic board controller. The operators' desks are equipped each with a functional keyboard, a typewriter keyboard and three visual display units (VDUs). Other Man/Machine facilities in the control room include two frequency meters, four chart recorders,

Fig. 7. Hardware Configuration of the Master Station



a hard-copy unit, and two dot-matrix printers as loggers. One frequency meter is an analogue meter driven directly by the line voltage and the other is a digital meter driven by the on-line processor. Two of the chart recorders are dedicated for recording total system load and frequency; the other two can be set to record any variable on the system that the control engineer selects using the functional Keyboard and a VDU. The hardcopy unit is used to produce a hard copy of any VDU picture. One of the two loggers prints all the events on the system with date and time stamping; the other logger is used to print reports that are produced by the control engineer.

The Telecontrol and Telemetry subsystem is composed of the data transmission equipment, the remote terminal units (RTUs), and the power interface equipment. The data transmission equipment include the communication media, which in our case is a network of pilot cables, and the modems at the Master Station and at the Remote Stations. The remote terminal units are microprocessor based devices located in a *Communication Room* in the transmission substation. They collect various data from the substation and formulate them into massages ready for transmission to the Master Station. Also these devices decode the incoming massages from the Master Station and supervise carrying out the instructions conveyed in these massages.

The power interface equipment consist of the current transformers and voltage transformers on the power components side and the transducers and analog-to-digital convertors on the RTU side. They also include pick up relays, activating relays and motor mechanisms in order to pick up indications and to carry out remote switching operations.

The supporting systems in the System Control Center are relevant to the requirements of the Electricity Directorate of Bahrain and can widely vary from utility to utility. The uninterruptable power supply was included to isolate the major SCC components from faults on the power system and to keep them running in case of a failure in the power system, i.e. when the System Control Center facilities are needed most. Equipment in the Remote Stations are also supplied with battery backups so that all the functions of the System Control Center can still be available for few hours after a total power system collapse; e.g. a blackout. The weather station is used to collect weather data which are fed into the computer, sampled and archived for presentation to the control engineer and for future studies. The private exchange telephone system enhances the communication within the system and provides an operational back-up to fall back to in case the System Control Center fails.

b. The Software

The software of the System Control Center may be classified into three main types representing three software levels: the *Operating System* level, which controls the operation of the computer system and regulates the input/output activities; the *Engineering Application* level, which includes the various programs for handling data aquisition, data processing and data presentation; and the *Power Application* level which includes several power system studies programs.

At the heart of the Operating System software there is what is called the *Executive*, which directs and coordinates the execution of all the programs in the system in such a way that efficient use of system resources is achieved. In a real-time environment, such as the System Control Center, this Executive has to meet the additional requirement of rapid response to real-time events. Another part of the Operating System consists of routines that control the input and output activities between the main processor and the peripheral devices; usually called *I/O drivers*. The Operating System also includes development programs which are used to build new programs and integrate them into the system. Such programs are the editors, the compilers, the linkers and the task builders. Important components of the operating system also include debugging aids and error logging and diagnostic programs. The Operating System software is highly machine dependent in general and is usually delivered by the computer vendor as a package along with the computer system hardware.

The Engineering Application software is usually developed by a third party using the program development facilities and the various utilities offered by the Operaing System software. This software is composed of two main parts. The first part is the Data-base Management System (DBMS) which contains the programmed facilities to define, generate and modify the data-base. The Data-base Management System is designed so that it allows system modification and extension while the system is running, it allows simple but secure access to the process control data from high level languages, and it allows coordination of big systems where many programmers are at work at the same time. The achievement of these requirements in the DBMS of the SCC is made possible by defining two distinct data structures; the *logical* data structure and the *physical* data structure. These two structures are completely seperated so that re-structuring the data-base physically does not necessitate altering the existing user programs; and the system programmers need only concern themselves with the logical structure of the data-base. Data is represented in the logical structure by simple two dimensional tables which are called *arrays*. Each array has a unique name attached to it and each row in the array is used to describe one object in the data-base. The columns of the array are the *atributes* of that object and they can be referred to by an *atribute name*. Therefore, in the logical structure, any data-base item can be identified by specifying an array name, an attribute name and a row identifier which can be an object name or any key attribute of the object. For example, active power flow in a feeder can have the following attributes: object ID, real-time value, low limit, high limit, substation ID, feeder ID, alarm status, manual-marking status, etc. These attributes occupy one row of an array, say ARRAY1. Therefore, to access the real-time value of this measurand-object, one needs to specify the array name, ARRAY1; a key attribute, like the object ID; and the attribute desired, in this case the real-time value. The physical structure of the data-base on the other hand is made up of *files*, *ports*, and *streams*. The files are contiguous areas on the mass storage devices which are identified by ordinary file specifiers, e.g. SY4:[220,205]DATBAS.DR1;1. The ports are contiguous areas in the computer main memory which are dynamically controlled by the memory management function of the computer system. They can be considered to act as data buffers in the main memory which at any one time hold parts of the data which exist in files on the mass storage medium. The streams define the sets of data that reside on specific files and use specific ports, i.e. a stream defines on which file a set of data resides and which port is to be used to buffer that data. The link between the logical structure and the physical structure manifests itself in the way data sets are defined in a stream. The columns of an array are grouped in one or more sub-arrays and each sub-array is stored row-wise in a stream. Once a logical data-base description of a certain data item is specified, i.e. array name, attribute name and an object specifier, a reference number is obtained. This reference number in turn points to a port, a file, a file reference which is a byte position within the file, a sub-row size, and an offset. The data item physical position can then be calculated according to the formula :

Data item position = file reference + (index) × sub-row size + offset

The other part of the Engineering Application software includes the various program modules or tasks that handle the data aquisition, data processing and data presentation functions and are refered to as the *handlers*. These modules or handlers include : the measurand handler, the indication handler, the command handler, the object handler. the alarm handler. the key handler, the visual display handler, the event-log handler. and the mimic handler. The measurand handler receive and processes the measurand telegrams coming from the front-end processors. It calculates the absolute addresses of the measurands and updates their values. The indication detector converts the hardware addresses of the indications received from the front-ends into data base references. The output of the indication detector is passed to the object handler and/or to the visual display handler. The object handler updates the status of the objects according to requests received from other functional modules. It can also invoke other modules like the visual display handler, the alarm handler. the key handler. and the command handler. The alarm handler updates and maintains the alarm lists in the system in accordance with alarm records received from the object handler. The alarm lists of the system hold information describing the objects which are in an alarm state, the time and date of the alarms, and the types of the alarms. The alarm handler sends its output records to the visual display handler to be displayed on the VDU screens. The command handler dispatches to the right target driver the control commands issued in the system. It receives the commands from the key handler through a priority queue, formulates a command telegram and issues it to the appropriate front-end processor. The key handler analyses and interprets commands from the keyboard and forwards them to other functional modules. Many other handlers are included in the system like the time handler, the central error handler and the link handler.

The third level of software in the System Control Center is the Power Application level. Within this level the programs that are used to carry out power system studies for operational and planning purposes are included. The software modules that are available in this level are the following : topology determination and network definition. state estimation, limit checking, economic load dispatching, voltage/reactive power control, short circuit analysis, load flow and contingency analysis, interactive long term and short term load forecasting, and interactive unit commitment. A detailed description of the Power Application software and its functions is presented in Appendix A of this report.

c. Computer System Operation

The Computer system can be in one of several *states* depending on the *mode* of each main processor. A main processor is in *Online* mode if the front-end processors and the man/machine equipment are connected to it and both the Operating System software and the Engineering Application software are running on it. In this mode the processor can communicate with the power system and with the control engineer and is capable of updating its real-time data-base. A processor is in the *Standby* mode if it is not connected to the front-ends processor nor to the man/machine equipment but the Operating System software and the Engineering Application software are running on it. In this mode the processor cannot communicate with the outside world but it can still update its real-time data-base by receiving the real-time information from the other Online processor over the high speed link. The processor is in the *Offline* mode when the Engineering Application software is not running on it but the Operating System software is running. The processor in this case cannot update its real-time data-base but it can run standard operating system tasks.

The Computer system is in the nomal operational state when one main processor is in the Online mode while the other main processor is in the Standby mode; this state is referred to as the *HOT ONLINE* state. In this state, if the Online processor fails the Standby processor takes over immediately and since the data-bases of the two processors are identical, the switch-over takes place smoothly. When one processor is in the Online mode and the other processor is in Offline mode the Computer system becomes in a *COLD ONLINE* state, i.e. a failure of the Online processor will cause the system to be down untill one of the processors is brought to Online again.

A.2. Functions of the System Control Center

The System Control Center of the Electricity Directorate performs the following five major functions: monitoring of the power system variables, remote control of the power system devices, economic dispatch of load among the generating units, carrying out power system studies, and finally data archiving and report generating. Each of these functions is described in more detail below.

a. Monitoring the Power System

The monitoring function is accomplished by collecting real-time values of the power system variables from the Remote Stations and by presenting them in a convenient manner to the control engineer in the Master Station. A VDU picture of a substation is shown in figure 8. These system variables can be classified into two main types: the analog type or the *measurand* variables, e.g. voltages and power flows; and the digital type or the *indication* variables, e.g. circuit breaker states and alarms.

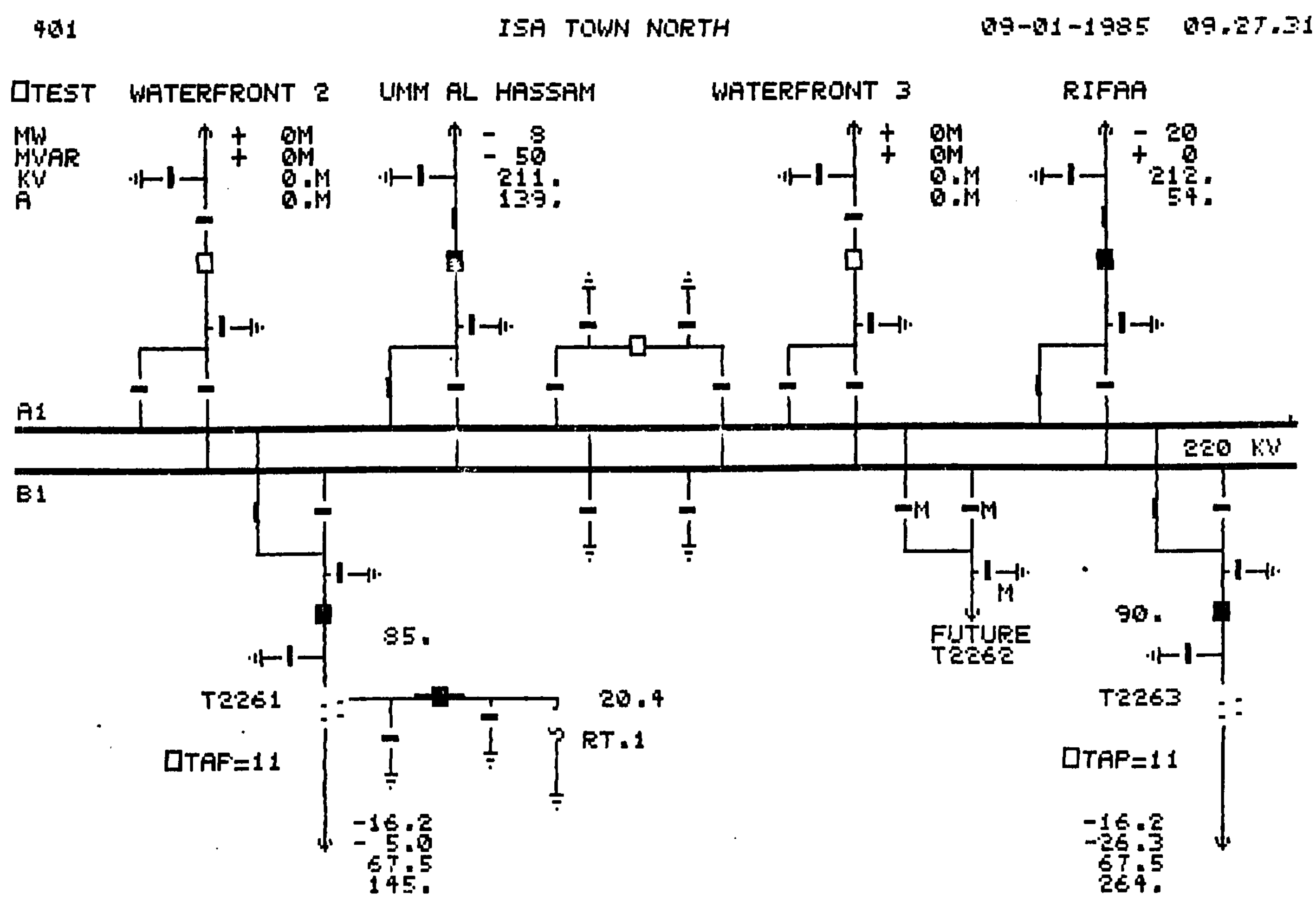


Fig. 8. A VDU Picture of a Substation

The measurand variables for which real-time values are collected are the following:

- the voltage levels, V, the real power flows, P, and the reactive power flows, Q, at each end of the 220kv feeders and the 66kv feeders and on the secondary side of the 220kv/66kv transformers and 66kv/11kv transformers;
- the current flows, A, in the 11kv feeders and on the primary side of the 220kv/66kv and 66kv/11kv transformers; and
- weather data which include: temperature, humidity, wind speed, wind direction, and solar radiation.

All the above values are converted from analogue values to digital values in the Remote Station and sent cyclically to the Master Station where they are received by the front-end processors. The front-end processors perform three types of checks on these measurand values before passing them on to the main processor. First the validity of these values is checked to see whether they are within the corresponding transducer limits. If a value exeeds that limit, then a transmission error is assumed and another attempt is made to collect that value. If the value is still in error after the third attempt, the value is flagged as non-valid and stored in the data-base as such. The second check is made against their operational limits which are set by the control engineer. If a value is found to be outside its operational limits, then an alarm is generated and sent along with that value to the main processor. The third check is done against the previous values of the measurands. If it is found that a received measurand value is not different than the previous value, within a certian *dead-band*, that measurand is considered unchanged and the received value is not passed to the main processor. This saves a lot of main processor time, as well as provides a *fine tuning* mechanism by adjusting the dead-band value to suit system requirements.

The indication variables for which real-time values are collected include the status of the switches and circuit breakers in the substations and the various alarms that either originate in the Remote Station or are generated in the Master Station itself. These values are handled on an *interrupt* bases; i.e. once a change of state of an object occures or an alarm is detected in the Remote Station, the cyclic collection of measurand variables is interrupted and the change of state or the alarm is immediately transmitted to the Master Station. In the case of change of state of an object, the main processor checks whether that object has just been controlled or not. If it has been controlled then this change of state is considered a *back indication* confirming that the control action has actually been successfully executed, and the status of the object in the data-base is changed to the new state. If however the object has not been controlled then the change of state is interpreted by the Master Station as a *trip* and the appropriate alarm is generated and sent along with the new status to the data-base. Whether an alarm is received from a Remote Station or it was generated in the Master Station, it will always initiate the following activities:

- an audible signal, *horn*, will sound in the Control Room,
- an ALARM light will flash on the mimic board next to the substation where the alarm has originated, and
- an alarm message will be formulated, shown in red on all the visual display units, stored in an alarm list in the data-base, and printed on the alarm logger in the Control Room.

See figure 9 on the next page.

Some of the above *collected* variables are used to produce *calculated* variables.

```
61  PAGE 1 OF 4  LDC POWER SYSTEM ALARMS   000/005     09-01-1985  09.30.01





31-12  **.**.**.**   UMMALH   SPARE.4.ALM LOW.OIL.PRES           ALM. CHK
31-12  12.07.29.54   SITRA.   GEN.STN.ALM   BOIL.TR.ALM1         ALM. ON
02-01  12.16.03.94   ISA.TN   GEN.STN.ALM   AIR.CON.FAIL         ALM. ON
02-01  12.53.10.56   RIFAAP   220KV  AIR.CON.FAIL                ALM. ON
07-01  08.07.01.14   UMMALH   BUSAITIN.1  PROTECTION ALM         ALM. ON
```

Fig. 9. A VDU Picture of the Alarm List

These calculated variables include: the currents, A, on each end of the transmission feeders, the total generating stations outputs, the total 11kv demands on the transmission substations and the daily maxima and minima of the system load and weather station data. These values are cyclically updated and stored as part of the system data-base. Figure 10 shows some of these calculated values displayed on a VDU picture.

All the variables in the data-base, whether collected or calculated, can have their values *manually-marked* by the control engineer. This is done by selecting the variable object on a VDU picture, pressing a MANUAL-MARK key on the functional keyboard, entering the desired value, then pressing an ENTER-VALUE key. The entered value will be stored in the data-base and will not be changed by an incoming value until the manual-marking is taken off. This function has an important practical use especially during commissioning or in cases of a malfunction in any of the Remote Stations or in the data transmission system.

b. Supervisory Remote Control

This is an important facility in the System Control Center since it allows the control engineer to remotely open or close circuit breakers and isolators anywhere in the system from the Control Room in the System Control Center. Objects that can be controlled are circuit breakers, isolators, switches, and transformer tap positions. Control of any of the above objects is performed by carrying out the following steps. First, the object is identified by selecting a picture on the VDU where the object is shown and then moving the cursor to the object position. Second, the control sequence is initiated by pressing the CONTROL button on the functional keyboard, the system will respond by displaying the object identifier on the response line of the VDU. The third step is to specify the type of control action desired by pressing

21 PAGE 1 OF 1 DAILY MAXIMUM - MINIMUM VALUE 09-01-1985 09.27.54

SYSTEM TOTAL :	HIGHEST VALUE	206.2M	ON	9.01	AT	7.13
	LOWEST VALUE	127.1M	ON	9.01	AT	2.50
WET BULB TEMP:	HIGHEST VALUE	12.1				
	LOWEST VALUE	10.8				
TEMP:	HIGHEST VALUE	14.8				
	LOWEST VALUE	13.4				
HUMIDITY :	HIGHEST VALUE	76.0				
	LOWEST VALUE	68.0				
WIND SPEED :	HIGHEST VALUE	7.6				
	LOWEST VALUE	3.6				
SOLAR RADIATION:	HIGHEST VALUE	391.0				
	LOWEST VALUE	0.0				

Fig. 10. A VDU Picture of
Daily Maximum and Minimum Values

either the ON button or the OFF button, the system will again echo the entered function. The final step is to press the EXECUTE button which causes a command message to be formulated and transmitted to the Remote Station involved. In the Remoter Station the message is decoded and the desired control action is excuted. The control sequence, once started, is fully supervised so that validity of each step is checked by the system and an error message appears on the visual display unit in case of an erroneous entry. Also, upon transmitting the command message, the master station expects the receiving substation to acknowledge the receipt of the message and to send back a *back-indication* message which indicates that the object has actually changed its status. Failure to receive that signal within preset time will result in a *time-out* alarm to be generated in the Master Station.

c. Economic Dispatching

Economic operation of the system includes the operation of the plant in the generating stations, but in the context of the *System Operation* it is assumed that the generation plant is operated to meet the control engineer's requirements in the most economical manner. The economic objective of the control engineer is to select the optimum combination of generators and then to adjust their output in such a way that the total cost of generated power is minimised. In doing so he must take into account the daily load curve, system reserve, security requirements and individual generator operating constraints. This is solved by using the System Control Center computers in two stages. The first stage is what is known as the *Unit Commitment*. In this stage coarse optimization is carried out where the day is divided into operating periods, say one hour, and for each operating period the optimum combination of available plant is selected. The efficiency of units is taken into account together with startup/shutdown costs, unit failure rate and any system constraints. The next stage is the *Economic Dispatch*. In this stage, the machines which are on line within an operating period are loaded according to their incremental fuel cost. The Economic Dispatch program which performs this function is run cyclically every 15 minutes and on operator's request. Therefore, the operating points, or set points, of all the generators are updated every 15 minutes, at most. These set points are presented to the control engineer as a recommended set of operating points - see figure 11. It is then left to his discretion to decide , based on his experience and his knowledge of the system, whether he will follow these program suggestions or not. A provision for the inclusion of an *Automatic Generation Control* facility is available and is considered for implementation in the future.

d. Running Power Application Software

This facility allows the control engineer as well as the system planning engineer to run useful power analysis programs in order to assess the level of system security under different system conditions. The programmes which are available in the System Control Center now are: operator load flow program, short circuit analysed program, contingency analysis program, and voltage/reactive power control program.

To enable these programs to run, a separate data-base is utilized where the real-time data of the power system is filtered through a *State Estimation* program and made consistent with each other. This is necessary for two reasons. First, the real-time data is continuously changing and if too many things are happening in the system at the same time, updating the data-base may take some time and therefore the data-base may not reflect the true picture of the system at one instant of time. The second reason is that errors may creep up during data transmission which are

8001 PAGE 1 OF 1 EDC SUMMARY 09-01-1985 09.26.40

☐EDC REQUEST (PRESS 'LOG') RESELECT PIC FOR UPDATED PFACT. - NOT CYCLIC

MANAMA & MUHARRAQ P/S						
GEN	MOD	MIN	POW	MAX	BPT	PFACT
B5	1	5.	+ 0.0	6.	+ 0.	0.000
B6	1	5.	+ 0.0	6.	+ 0.	0.000
B7	1	2.	+ 0.0	6.	+ 0.	0.000
B8	1	4.	+ 0.0	6.	+ 0.	0.000
B9	1	2.	+ 0.0	6.	+ 0.	0.000
B10	1	2.	+ 0.0	6.	+ 0.	0.000
C1	D1	3.	+ 0.0	12.	+ 0.	0.000
C2	1	3.	+ 0.0	11.	+ 0.	0.000
C3	1	3.	+ 0.0	11.	+ 0.	0.000
C4	1	3.	+ 0.0	11.	+ 0.	0.000
JB1	1	6.	+16.2	17.	+ 16.	0.042
JB2	1	6.	+15.5	17.	+ 16.	0.042
AEG1	D1	5.	+ 0.0	20.	+ 0.	0.000
AEG2	B1	0.	+ 0.0	1.	+ 0.	0.016

LAST EDC RUN 9:25 FREQ. 49.99 HZ
INCREMENTAL COST 10.9 BD/MWH
TOTAL POWER DESPATCHED 189. MW

SITRA P/S						
GEN	MOD	MIN	POW	MAX	BPT	PFACT
GT5	1	5.	+ 6.0	7.	+ 6.	0.061
TA1	D1	0.	+ 0.0	1.	+ 0.	0.000
TA2	1	15.	+17.6	30.	+ 17.	0.010
TA3	P1	23.	+23.4	30.	+ 23.	0.010
TA4	1	22.	+21.6	30.	+ 22.	0.010
RIFFA P/S						
G1D	1	10.	+ 0.0	35.	+ 0.	0.000
G2	1	10.	+25.2	41.	+ 27.	0.303
G3	1	10.	+ 0.0	41.	+ 0.	0.000
G4	1	10.	+26.0	41.	+ 27.	0.303
G5	1	10.	+ 0.0	41.	+ 0.	0.000
G6	1	10.	+ 0.0	31.	+ 0.	0.000
G7	1	10.	+ 0.0	31.	+ 0.	0.000
G8	1	10.	+36.0	36.	+ 35.	0.193
G9	1	10.	+ 0.0	31.	+ 0.	0.000
G10	1	10.	+ 0.0	36.	+ 0.	0.000
G11	1	10.	+ 0.0	36.	+ 0.	0.000

Fig. 11. A VDU Picture Showing the Economic Dispatch Program Output

not detected by the system. Therefore if the Power Application programs were accessing the real-time data-base directly they might pick up unconsistent input data. The state estimator takes a snapshot of the real-time data every 30 minutes or every time the *topology* of the system changes, then it performs consistency checks by utilizing a minimizing of sum of the least squared weighted average technique and stores the resultant consistant data in another data-base which the Power Application programs can access. More detailed information on the state estimator and other power application software is included in Appendix A.

e. Data Archiving and Report Generation

Values of certain variables, collected and calculated, are sampled from the data-base at 3 minutes intervals then averaged on half hourly boundaries and stored in an area of memory called the *Historical Data Base*. These values are retained for a period of forty days after which they are dumped onto magnetic tapes and new values are stored on the Historical Data Base. The daily maximum and minimum values for system total generation and for weather data are also collected daily and retained for 400 days. The values in the Historical Data Base are used to construct *trends* on the VDU's for any variable which is selected by the control engineer. An example of a trend picture is shown in figure 12. Also there is a facility to generate various reports from the Historical Data Base values which can be viewed on any of the VDU's or printed on any of the printers.

A.3 System Control Center Development

As was mentioned earlier in this report, the power system in Bahrain is undergoing major expansions in most of its areas. This expansion is largely due to the increase in demand on electricity during the last few years and also due to the forecast of electricity demand in future years. The forecasted future system peak demands are

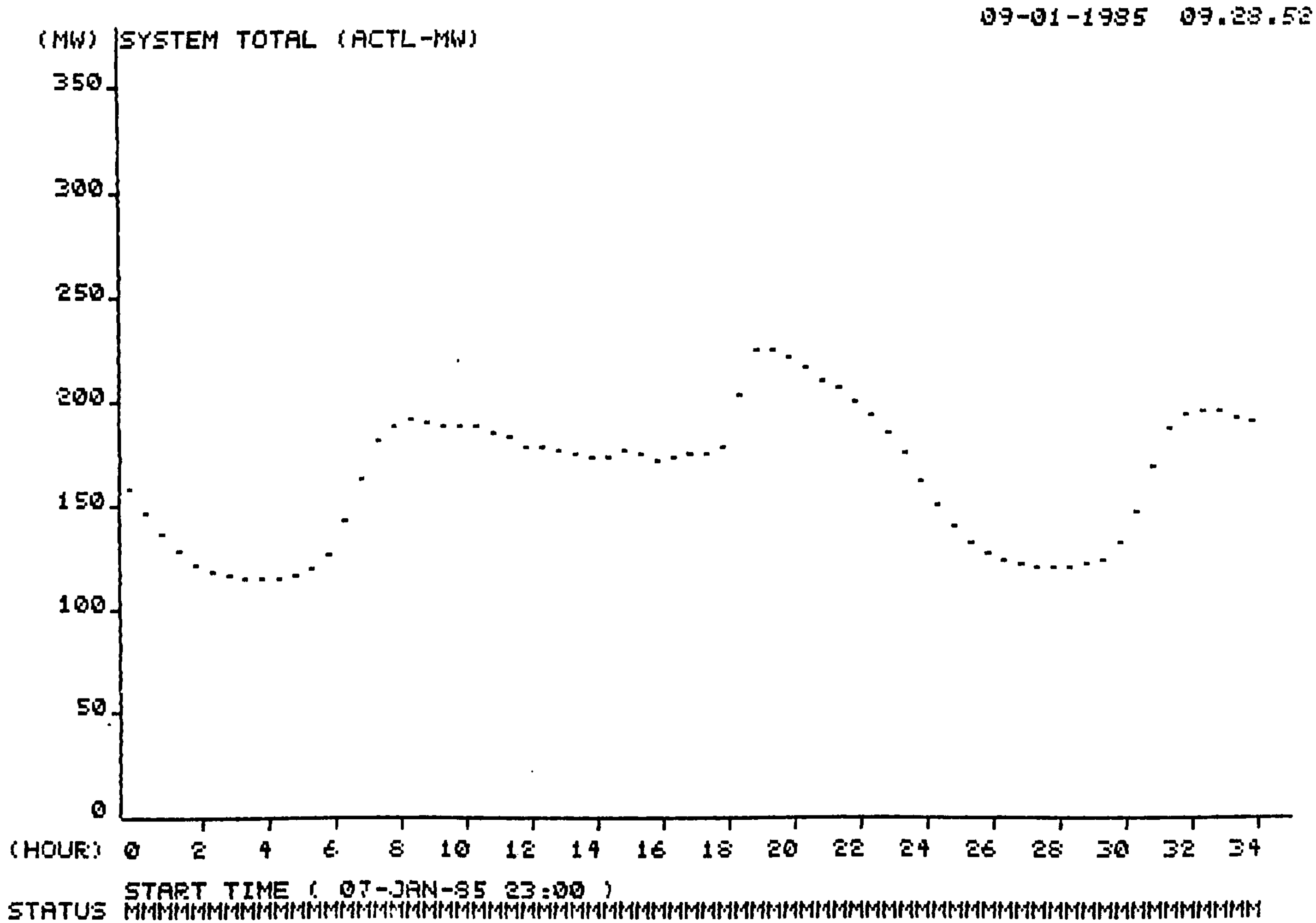


Fig. 12. A Trend Picture for System Total Load

TABLE I.
Bahrain Load Forecast

Year	Max. Demand (MW)	Units Gen. (GWH)	Load Factor (%)	Min. Demand (MW)
1984	545	2235	46.8	98
1985	658	2260	46.1	123
1986	763	2954	44.2	137
1987	845	3284	44.4	153
1988	901	3652	46.3	171
1989	996	4064	46.6	202
1990	1071	4525	48.2	220
1991	1150	5040	49.0	239
1992	1280	5616	50.0	261
1993	1395	6205	50.8	285
1994	1520	6858	51.5	310
1995	1660	7581	52.1	338

shown in table I.

Based upon these forecasts a generation development plan was drawn and subsequently a transmission development plan was also made. The important aspects of the plans which are of interest to us now are summarized and presented in table II. From these results the it can be seen that there is a need for upgrading the System Control Center facilities at some stage in the future in order to ensure satisfactory performance of these facilities. As can be seen in table II, the development of the generation and the transmission system takes place in phases, hence the development of the System Control Center facilities could also be divided into two main phases: the short term phase, in which the built-in provisions for expansion in the existing facilities are utilized in such a way that other performance parameters of the system, such as response time, do not fall below an acceptable level; and the long term phase, when it becomes necessary to upgrade the system with new facilities that should be able to accomodate the power system development over a span of, say, 10 more years.

TABLE II.
Summary of
Power System Future Development

Period	Related to	Existing	New
1986-88	Transmission	11	7 (subs)
1989-90	Transmission	10	6 (subs)
1991-93	Transmission	17	4 (subs)
1994-95	Transmission	9	2 (subs)
1986-95	Generation	—	11 (sets)

a. Short-Term Developments

The power system developments which were to take place in the years 1983 and 1984 were considered short term development as far as the System Control Center is concerned, because they could be accomodated by the existing facilities without affecting the system performance. These developments included the commissioning of seven new primary substations and modifications in some existing substations.

The corresponding extensions in the System Control Center involved the following areas: extension of the dynamic mimic wall diagram to show the new stations and updating the mimic controller to include in it the additional objects on the mimic; extension of the data-base to include the new internal and external objects and their attributes in the data-base arrays and the generation of new static and dynamic pictures of the new stations for VDU presentation; installation of the new Remote Terminal Units in the new substations and making the necessary wiring and terminal connections; and, finally, testing and commissioning of all these extensions and new equipment. In the few paragraphs that follow, the various steps that were taken to implement these extensions are described.

The starting point in introducing a new substation is the preparation of *Signal Lists* for that substation. An example of a Signal List is shown in figure 13. Different Signal List forms for the various types of signals, i.e. measurands, indications, commands, etc., that are brought from and sent to the substation are filled out. Each signal on the Signal List is assigned an identification name *Object ID*, a descriptive name *Litra*, and a hardware address. These Signal Lists are used by the software personnel to enter the signals information into the appropriate arrays in the data-base. This can be done while the system is running on-line by using the Direct Memory Access facility. However since the number of signals to be entered is too large then it becomes more convenient to enter them in two steps: first the data base arrays involved are dumped onto ordinary files in memory, these files are then edited using ordinary line or text editors, then the edited arrays are *binded* to the data-base in off-line mode using special binding programmes. These binding programmes actually re-adjust the cross references in the data-base to incorporate the newly editted arrays.

SCHEMANAME : CARBAH	ANALOGUE INPUT	REMOTE STATION
CHANNEL REF : 8	MODULE ED: 1310c	CHANNEL NR : 8
STATION NAME : RSBUJR	CABINET NR: 01 STATUS-ADR. :	STATION NR : 83
PRINT REF. : RAJ001	TIER PLACE: 01 DATA-ADR. : 26000	BLOCK NR : 10
BECOS TYPE : B 30	PCB PLACE: 05 VECT-ADR. : 20	GROUP NR : 00

SIGNAL SPECIFICATIONS			INDACTIC CABINET			MARSHALLING FRAME				TRANSDUCER CABINET	MARSHALLING FRAME		
SIGNAL IDENT.	SIGNAL DESCRIPTION	TYPE	PCB BIT POS	PCB FUNCTION	PCB CON		STRIPS	CROSS CONNEC 0,75mm²	TERMIN BLOCK TB		TERMIN. BLOCK TB	CROSS CONNEC 2,5 mm²	TERMIN. BLOCK TB
RAJF2P6A	Rifaa 1 MW +/-10 -90 90	MW	0		2/3 5		1 2						
RAJF2Q6A	Rifaa 1 MVAR +/-10 -65 65	MVR	1		7 9		3 4						
RAJF2V6A	Rifaa 1 kV 0-10 0 75	kV	2		11 13		5 6						
RAJF3P6A	Rifaa 2 MW +/-10 -90 90	MW	3		15 17		7 8						
RAJF3Q6A	Rifaa 2 MVAR +/-10 -65 65	MVR	4		19 21		9 10						
RAJF3V6A	Rifaa 2 kV 0-10 0 75	kV	5		23 25		11 12						
RAJT1C6A	T611 AMP 0-10 0 - 400	A	6		27 29		13 14						
RAJT1P1A	T611 MW +/-10 -45 45	MW	7		31 33		15 16						
					35 37		17 18						
					39 41		19 20						
RAJT1Q1A	T611 MVAR +/-10 -35 35	MVR	0		53 55		21 22						
RAJT1V1A	T611 kV 0-10 0 15	kV	1		57 59		23 24						
RAJT2C6A	T612 Amps 0-10 0 400	A	2		61 63		25 26						
RAJT2P1A	T612 MW +/-10 -45 45	MW	3		65 67		27 28						
RAJT2Q1A	T612 MVAR +/-10 -35 35	MVR	4		69 71		29 30						
RAJT2V1A	T612 kV 0-10 0 15	kV	5		73 75		31 32						
RAJF6C6A	R.0.1 Amp 0-10 0 400	A	6		77 79		33 34						
RAJF7P1A	AL-DUR 1 MW +/-10 -45 45	MW	7		81 83		35 36						
					85 87		37 38						
					45/89 2/91		39 40						

Fig. 13. Signal List Examples (a)

SCHEMANAME. CARBAH
CHANNEL REF: 8
STATION NAME: RSBUJR
PRINT REF : RAJ015
BECOS TYPE : B 30

DIGITAL INPUT
MODULE ED: 1121a
CABINET NR . 02 STATUS-ADR :
TIER PLACE : 01 DATA-ADR : 23042
PCB PLACE : 05 VECT-ADR : 20

REMOTE STATION
CHANNEL NR : 8
STATION NR : 83
BLOCK NR : 4
GROUP NR : 42

SIGNAL SPECIFICATIONS			INDACTIC CABINET				MARSHALLING FRAME			PROCESS
SIGNAL IDENT	SIGNAL DESCRIPTION	TYPE	PCB: BIT POS	PCB: FUNCTION	PCB: PCB CON		STRIPS	CROSS CONNEC 075mm²	TERMIN. BLOCK TB	
RAJF3B6C	RIFAA 2 66kV CCT. BKR.	ION	0		2/3		1			
"	" " " "	IOF	1		5		2			
RAJF3M6N	" MAINT. ETH. DV.	ION	2		7		3			
"	" " " "	IOF	3	BYTE 0	9		4			
RAJF3I6C	" BUS. ISO.	IOF	4		11		5			
"	" " "	IOF	5		13		6			
RAJS1I6M	66kV BUSBAR A1 ETH. SW	ION	6		15		7			
"	" " " " "	IOF	7		17		8			
RAJS1I6C	" BUS.SEC. A1/A2 A1 ISO	ION	0		19		9			
"	" " " " "	IOF	1		21		10			
RAJS1M6N	" BUS.SEC. A1/A2 MNT.ETH	ION	2		23		11			
"	" " " " " "	IOF	3	BYTE 1	25		12			
RAJS1I6D	" BUS.SEC.-A1/A2 A2 ISO	ION	4		27		13			
"	" " " " " "	IOF	5		29		14			
RAJS1I6M	" BUSBAR A2 ETH. SW.	ION	6		31		15			
"	" " " " "	IOF	7		33		16			
				CM 1	35		17			
				CM 2	37		18			
				CM +	39		19			
				E -	2/41		20			

Fig. 13. Signal List Examples (b)

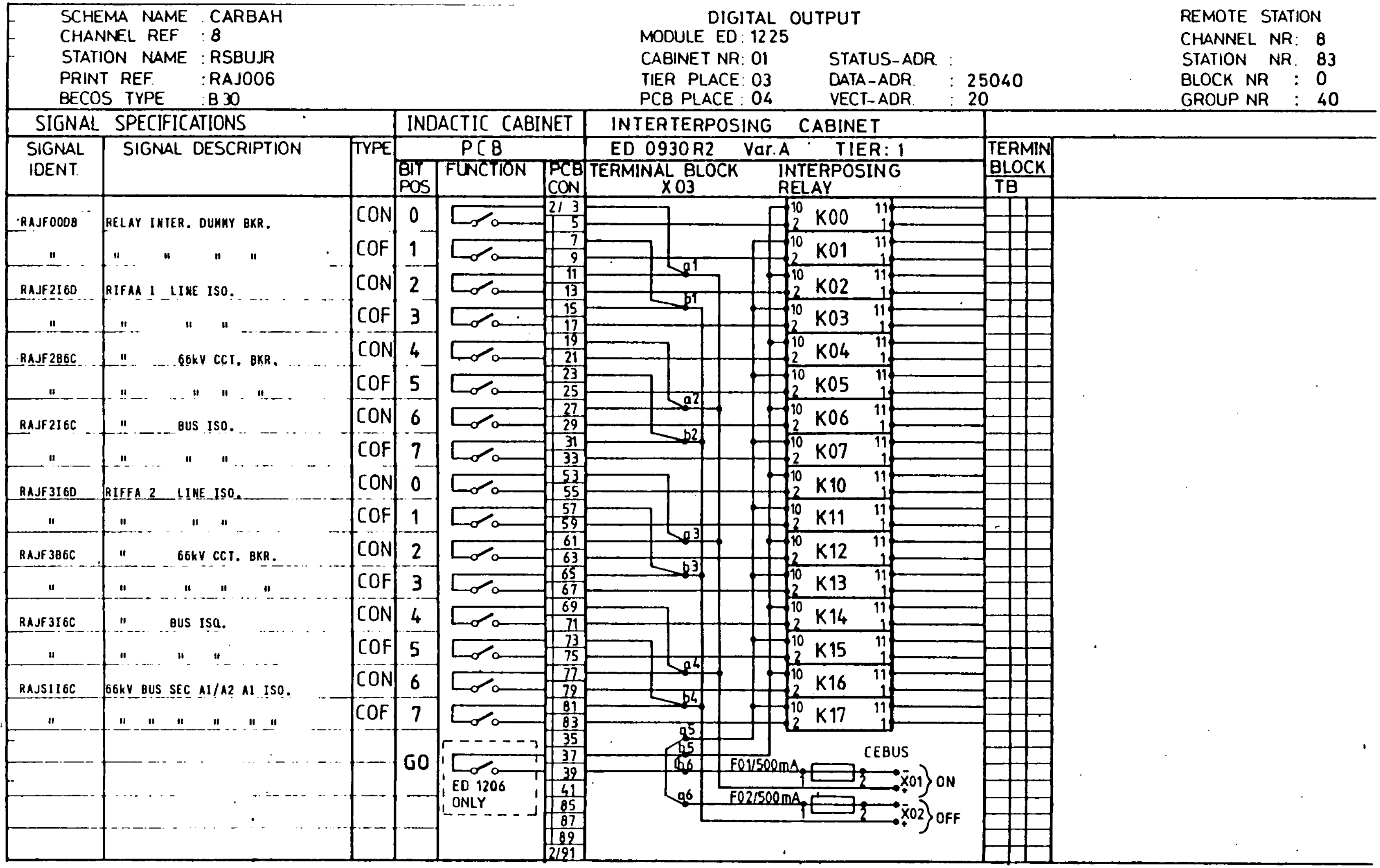


Fig. 13. Signal List Examples (c)

Once this is done, other changes in the data-base are made that involve the mimic diagram arrays in order to incorporate the added controllable lights on the mimic board. Changes are also made in the configuration arrays of the front-end processors to which the new substations are connected.

At the same time, new VDU pictures for the added substation are designed and constructed using a *Picture Generation* function that is part of the Engineering Application software. A static part of the picture is constructed first showing the fixed lines and the literature, then a dynamic part is added for the variable objects on the picture. The picture is then registered in the data-base and binded in much the same way as binding the data-base arrays.

The Signal Lists are also used by the hardware personnel installing the Remote Station equipment in order to connect the right transducers on the power system side to the right terminal points of the digital cards in the RTUs.

The final step in implementing the extensions is the testing and commissioning of the new equipment and software in the Master Station and the Remote Stations.

b. Long-Term Developments

As far as the performance and the design limitations of the System Control Center is concerned, there are three main levels of limitations that can be identified. The first level is the absolute maximum number of remote stations that can be connected to the master station. This is set by the maximum number of *part-systems* that can be connected to the Master Station, which is 15 part-systems, and the maximum number of Remote Stations that can be included in a part-system, which is 16. Therefore the absolute maximum number of Remote Stations is 240 Remote Stations which actually sets the addressing space of the Master Station. The next limitation level is the amount of on-line storage ,i.e. disc space, available for storing all the data-base arrays. At present the disc drive that is used has a capacity of 67 megabytes of on-line storage. A total of 37 megabytes is used up by the system, and out of that approximately 13.5 megabytes is reserved for data-base arrays and substation related information. The rest of the disc space, 30 megabytes, is free for program development and for future expansions. With the existing data-base arrays configuration, i.e. without changing the amount of reserved space on the disc, up to five substations can be added to the system. To add more than five stations, the sizes of data-base arrays have to be increased and some of the free disc space need to be used at the rate of approxmately one magabytes for every four new stations. The third limitation level is the acceptable response time of the system which is the most subtle and complicated type of limitations. To this type of limitation the following factors attribute : the amount of main memory in the system and the type and speed of that memory; the instructions execution times of the CPU especially those instructions which handle data transfer: the size of the data-bus and the data registers inside the CPU; the way the operating system software handles interrupts and real-time events.

Referring back to the power system development plans, it can be easily seen that the first two limitation levels are not really critical; for in the first case the maximum number of addressable remote stations will not be reached or even approached in the foreseen future and in the second case the amount of on-line storage can be increased by replacing the existing disc drives with another disc drives having more capacites. The most serious limitation as far as system performance is concerned is the third one and more specifically the three last factors which contribute to this limitation. It is serious because it can be easily approached long before any of the other two and because the factors contributing to it cannot be easily quantified. Even if they were it may be impossible to improve on them without undergoing major changes encompassing the whole system, i.e. replacing the Computer system, the application softwares, or both.

In order to determine the effect of including the new developments of the power system on the System Control Center performance it will be necessary to make a rigorous study in order to identify the exact contribution of each of the above factors to the system response time and then determine at which point it will be necessary to consider upgrading and/or changing the existing facilities. The results of this study may also be used as guidelines when drawing the specifications for the new facilities.

B. Miscellaneous Tasks

During the course of the internship, several tasks were undertaken in addition to the major task. These tasks include drawing up and following through a maintenance contract for the System Control Center equipment, and participating in writing application programs that were incorporated into the Engineering Application software.

B.1. Equipment Maintenance Contract

The maintenance period which was contracted with the System Control Center main contractor was approaching its end in December 31, 1983. It was decided that maintenance for the following years would be opened for tenders from local computer maintenance firms. It was requisted that the tender be in two parts. The first part consists of the Computer system equipment which were mainly manufactured by DEC. The second part includes all other equipment of the SCC which were manufactured by several other manufacturers including the main contractor. Quoting for the second part was made optional.

I participated in drawing up the technical part of the maintenance contract specifications, then revised the offers received from several local computer maintenance companies and finally selected the most appropriate one. Funds had to be provided for this project, and since the amounts involved were around U.S. $ 200,000 per year, expenditure of such amount should be approved by the Ministry of Finance. Therefore we had to deal with that ministry in going through the necessary procedures for getting the approval and finally having the the maintainance contract started on its designated date, January 1st, 1984.

B.2. Computer Programes

Occasionally, the control engineers or the management require that some nonexisting function to be added to the the System Control Center. As a senior engineer for Computer and Software section, I had working with me some engineers and programmers and I had to find out if our resources are sufficient to provide this function. If so, I would define the problem, assign one or two engineers to work on it and supervise them until it is completed and implemented. Sometimes I would participate in the programing if I find that would speed things up, since I was eventually responsible for it before the management. Some of the functions for which in-house programs were developed are: a substation demand output program. a load-shedding program. and an underfrequency coverage program. A brief description of each program follows.

a. Substation Demand Output

This program was developed to enable management to have a printed output of the half hourly readings of the substations total demands at the end of every week. The program extracts the data from the Historical Data-base and directs it after some formatting to the line printer output stream. This program was written using CORAL, or the *COmputer Real-time Application Language.*

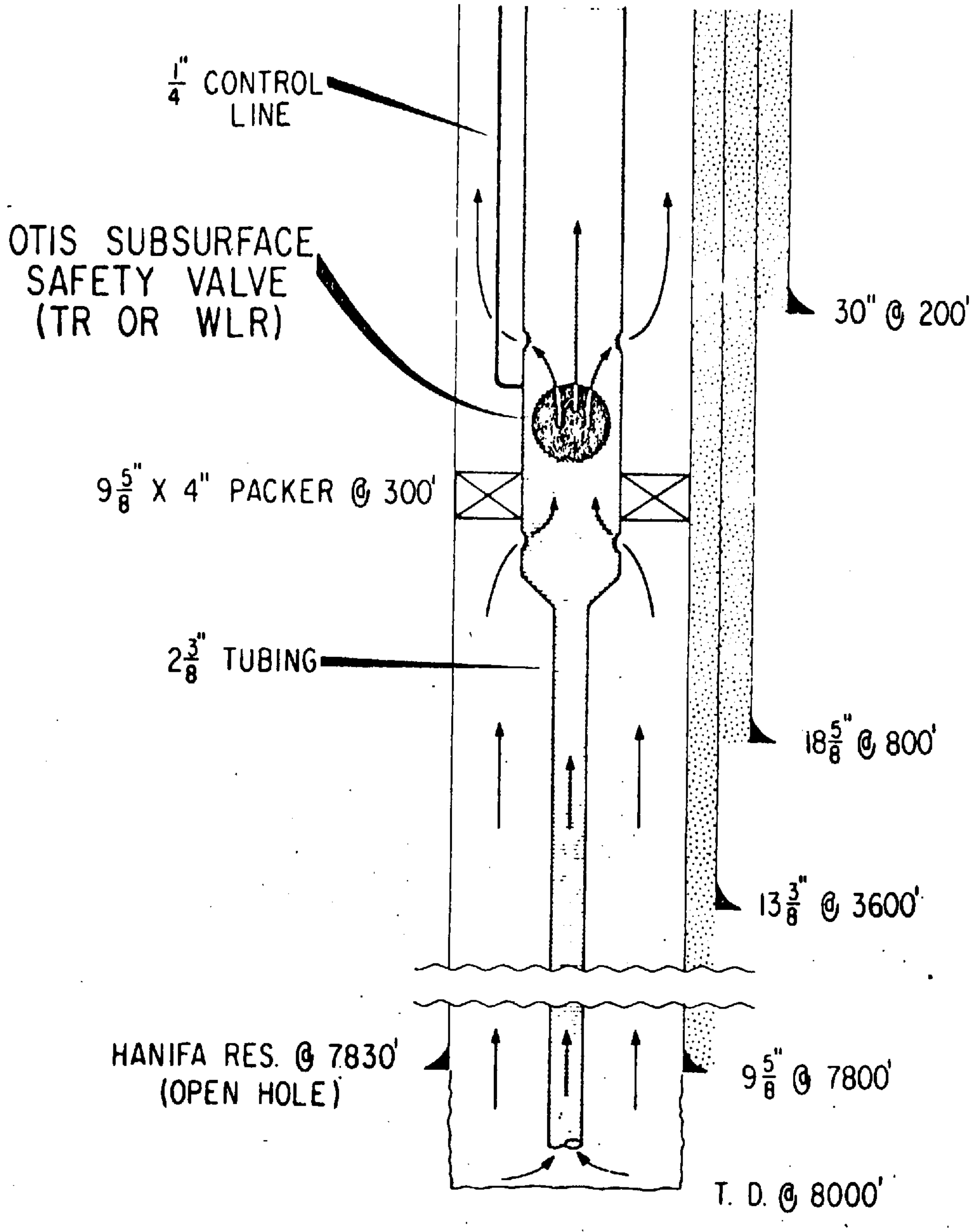
b. Load-shedding Program

This function enables the Distribution Control engineers to assign different 11kv feeders to the load-shedding groups. There are five groups and each group can be activated by pressing a dedicated button on the functional keyboard. Activating a group will cause the circuit breakers on all the feeders in that group to open, therefore eliminating a certain amount of load. The amount of load each group carries at any one time is calculated by this program and can be presented to the control engineer on a VDU picture any time he wants that information; or alternatively can be printed on the logger. This program was written in FORTRAN language and incorporated into the Engineering Application software.

c. Underfrequency Coverage

This program is similar to the previous one except that it calculates the amount of load that would be eliminated if the relays in any of the various underfrequency stages were operated. There are three main underfrequency stages and the underfrequency relays in the transmission system are set such they will be activated once their corresponding stage is reached. This was also written in FORTRAN and incorporated into the Engineering Application software.

ORIGINAL BERRI OFFSHORE SINGLE WELL COMPLETION



ACTIVITIES – SAFETY VALVE
1971 – EXHIBIT 2

OBJECTIVE

TO GAIN EXPERIENCE IN THE NON-ACADEMIC MANAGERIAL AND BUSINESS ACTIVITIES OF THE ORGANIZATION AND TO BE AWARE OF THE INTERACTION BETWEEN THE ORGANIZATION AND THE BUSINESS ENVIRONMENT.

Introduction

The third objective of the internship was satisfied by undertaking tasks that required interaction with other government agencies, with private institutions, and with the public. Some of the technical oriented tasks were already presented in chapter II. The System Control Center development for example required interaction with the main contractor and with the consultants in order to organize the work. On the equipment maintenance contract, contacts were made with the local firms who were involved in maintenance of computer equipment, and discussions were held with the Ministry of Finance to provide the necessary funds. In this chapte, tasks that are of non-technical nature will be presented. Such tasks included: participation in the expansion process of the department, participation in drawing up training programmes for personnel in the department, interviewing new engineers and technicians for the department and for the organization as a whole, and representing the organization in discussions with consultants.

A. Department Expansion

As the System Operations and Planning Department gained more importance within the Electricity Directorate, and as its functions and services became more diversified, the need was felt to expand it to perform its added functions. It was necessary to establish a number of new positions, and some of the existing positions needed modification. A new organizational chart incorporating all the necessary changes and additions was devised for the department and presented as a proposal to the upper management. Since the Electricity Directorate is part of the

Ministry of Works, Power and Water which itself is part of the overall governmental structure, changes like these have to go through several bodies and organizations in the government. These organizations set the rules and regulations governing these changes. However if the changes are major, some across the table discussions have to take place. The Civil Service Bureau (CSB) was the central body in the government with which we dealt most regarding these changes.

The first step in a series of procedures in implementing the new chart was to submit it along with the job descriptions of all the positions and the justifications for the newly created positions and the modified positions to the CSB through the Directorate of Administration and Finance in our ministry. A line of communication was then commenced between a CSB representative and the Department in the form of several discussions and meetings in order to cosolidate the Departments needs with the general CSB policy and negotiate out any differences. The CSB then came with a counter proposal which we accepted on certain conditions. The CSB accepted our conditions and the new chart was put to effect starting December 1st, 1984.

My responsibility lied in ensuring that all the job descriptions were available for presentation to the CSB, and for that I had to write the job descriptions and the justifications for the new positions in the Computer and Software section. I also had participated in discussions with the representative of the CSB to convey to him the necessity of the positions in my section and I did some of the follow-up on the chart until it was finally approved. Part of the new chart was shown in figure 4.

B. Training Programmes

The type of work in the System Operations Department is highly technical, therefore a high degree of technical competence is required from personnel working in the department. In areas like System Control, experience is of paramount importance, because in this area not only may expensive power system components be damaged but the personnel safety is also involved. Therefore it is very important that engineers filling such positions pass through proper training programs. Usually training programs for personnel in a department of the Directorate are made by training specialists in the Training Department in coordination with the senior members of the department involved. Since I was in charge of the Computer Section, it was my responsibility to make sure that proper training programs are made and approved for the engineers in the section.

I also participated in the attempts that were made in trying to devise a training program for System Control Engineers in the System Control Section of the Department. This was not a straight forward task because different people had different views and feelings about it. This training program was important because all the System Control Engineers in that Section are expatriates and the attempts to attract Bahraini engineers to fill these positions has so far failed because of the absence of a proper training program. Therefore I thought it would be useful, as a step in the right direction, to collect these different views and analyse them. I did that and the result of my work is included in Appendix B.

C. Interviewing New Engineers

I was appointed on an Interview Board to interview Bahraini engineers who were applying for positions in the Electricity Directorate. The board consisted of representatives from the various departments of the Directorate and I was representing the System Operations Department. Our assignment was to study the applications, conduct the interviews and come up with recommendations to allocate the applicants among the various departments taking into consideration the suitability of each applicant and the requirements of the departments. We also suggested broad outlines for the training of each applicant depending on his or her past experience.

SUMMARY AND CONCLUSION

This report serves the purpose of describing the various aspects of my internship with the Electricity Directorate of Bahrain.

I feel that the internship experience has been beneficial to me in two respects. First, it helped me attain the three internship objectives which in turn fulfilled the requirement of the Doctor of Engineering Internship Programme. Second, I had a good experience in both engineering and management areas.

From a personal point of view, this internship experience was one of the best experiences I have had. The willingness to cooperate at all levels within the organization was a significant factor in the successfull completion of this internship.

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VITA

Najeeb Aljamea

P. O. Box 7591

College Station, TX 77844

Birthplace:	Muarraq, Bahrain
Birthdate:	May 11, 1953
Family:	Married with two Children
Education:	Five years at American University of Beirut, Lebanon, 1970-1975.
	B.Sc. in E.E., Texas A&M University, 1976.
	M.E. (Electrical), Texas A&M University, 1977.
Expereince:	Senior Engineer, Electricity Directorate of Bahrain (Doctor of Engineering Internship) September 1983 - December 1984.
	Engineer, Electricity Directorate of Bahrain, January 1981 - August 1983.
	Graduate/Trainee Engineer, Electricity Directorate of Bahrain, January 1978 - December 1980.

APPENDIX A

POWER APPLICATION SOFTWARE

General

The power application software of the System Control Center comprises the following functions:

A. Topology Determination and Network Definition

B. State Estimation

C. Limit Check

D. Economic Load Dispatch

E. Voltage/Reactive Power Control

F. Short Circuit Calculation

G. Operator's Load Flow and Contingency Analysis

H. Interactive Unit Commitment

I. Interactive Long Term Load Forecasting

J. Interactive Hourly Load Forecasting

Each of the above functions is realized by one or more software modules. A description of each function is given below.

A. Topology Determination and Network Definition

The topology determination function is started either from the data communication system, i.e. when a circuit breaker or isolator status changes, or from the man machine system, i.e. by operator request. On the basis of the network structure that is stored in the data base, plus the telemetered circuit breaker and isolator status, the electrical connectivity of the network is calculated. The calculation proceeds in the following steps:

1. For all telemetered isolator status, the connectivity down to substation level is determined for each substation and stored in the data base.
2. For all telemetered circuit breaker, the connectivity of each substation as derived in step (1) is subsequently refined to incorporate the circuit breakers. This final connectivity for each substation is stored in the data base.
3. The final connectivity for each substation from step (2) is then combined to the sending and receiving ends of all lines and transformers to determine the total configuration within the network. If it is found that the network as a whole is not electrically connected, then connected subgroups are identified. In the event of more than one network group being defined, a *split system* alarm is produced.
4. For the whole network, network groups and nodes are numbered sequentially (from 1 upwards).
5. For generators and loads connected to the same node, the total injected quantities are calculated.

The results of these calculations, i.e. network group numbers, node numbers, and electrical loading of nodes, are written in the data base. When a circuit breaker status change is transmitted from a substation, the connectivity of that substation is redetermined as per step (2) using the still valid isolator configuration of step (1). The network connectivity is subsequently derived by repeating step (3). When an isolator status change is transmitted, the connectivity of that substation is re-determined as per steps (1) and (2). The network connectivity is then derived by applying step (3).

B. State Estimation

This function is started either cyclically or from the man machine interface. On the basis of the network structure as given by the Topology function and the telemetered information, a determination is made of the complex node voltages which minimize the sum of the squared measurement errors. The state estimation determination proceeds in the following steps:

1. The measurement quantities and the weighting factors for the most recently telemetered condition are initialized.
2. The structure of the *gain matrices* for the decoupled active and reactive power equations is determined and stored in a compact form in the data base.
3. The mismatch between measured and estimated quantities for the active and reactive powers is calculated.
4. The influence of the *bad data* is suppressed by deweighing those measurements suspected of being in error.
5. The values of the elements in the gain matrices as defined in (2) are calculated and the modified mismatches as defined in (3) are evaluated to define all quantities A and B in the equation set :

   $$A \cdot X = B$$

   where :

   A is the calculated gain matrices for active and reactive power equations after deweighing suspected measurands,

   B is the vector of active and reactive powers which are derived from the new modifies mismatches, and

   X is the vector of complex node voltages.

   The active and reactive power quantities are determined separately.
6. The equation set as defined in step (5) is solved to obtain phases and magnitudes of the complex node voltages. The steps (3) through (5) are repeated

iteratively untill convergence is achieved within certain tolerence.

C. Limit Check

The limit check function is started either cyclically or upon operator request through the man machine interface. On the basis of the values determined in the state estimation function, a check is performed for all the network elements to determine possible overloads. The check proceeds in the following two steps:

1. The transmission elements, lines and transformers, are checked to determine whether the calculated currents exceed the limits entered in the data base.
2. The network nodes are checked to determine whether the calculated injections of active and reactive power exceed the limits entered in the data base, and whether the calculated voltage magnitudes exceed the data base limits. If the program detects any *overload*, it produces an alarm.

D. Economic Dispatch Calculation

This function calculates the system generation required to supply a given load. The required generation is assigned to the available generators with the objective of minimizing the overall production cost. The results of the Economic Dispatch program are base points and participation factors for each generator. The base points represent the optimal power outputs of the generators needed for the given load. The participation factors determine in which way the deviation between the given load and the actual load has to be allocated to the single generators, i.e. has to be added to the base points. The Economic Dispatch program takes into account the generators maximum and minimum power limits and, on operator request, the transmission losses by using the B-coefficients which are stored in the data base by a separate program. The program can either be started cyclically or upon operator request through the man machine interface.

The input to Economic Dispatch program can be classified into three basic categories: the system depending parameters, the data aquired by the telemetry system, and the data entered by the dispatcher. The system depending parameters are more or less fixed values which include names of generating units, B-coefficients matrices, and cost curves matrices. The telemetered data are the actual real time information obtained from the power network and they include generators net megawatt outputs, generators breaker status, and availability of generators. The data entered by the operator can be program global parameters like repetition rate of the program, the iteration limit, and inclusion or exclusion of B-coefficient matrices; or they can be generator specific parameters like unit control mode to indicate wether the generator is included in the economic alogarithm or not, and the unit maximum and minimum limits.

The outputs from the Economic Dispatch program are the base point for each generator, the participation factor for each generator, the total power dispatched, and the system incremental cost of delivered power.

E. Voltage/Reactive Power Control

This function is started from the man machine interface upon operator request. On the basis of the results of the last state estimation calculation, and the stored *desired* voltage profile for the nodes in the network, the function determines tap ratio settings, and possible line, transformer and shunt reactor switchings that will achieve the desired voltage profile. Limits on reactive generation, transmission, and tap ratios are taken into consideration. Switching is only considered for those elements of the network that are specifically identified as *switchable* elements in the data base.

The function proceeds in the following steps:

1. The load-flow equation set for the present operating condition is solved to determine the sensitivity of busbar voltages to reactive power injections and transformer tap ratios.
2. The resulting sensitivity coefficients are incorporated into a least square minimization algorithm to determine the *optimum* reactive injections and tap ratios.
3. For the solution aquired from steps (1) and (2), the sensitivity coefficients are used to determine whether or not any switching should be implemented on lines, transformers, or shunt reactors. The optimization process is then repeated for the new configuration.

The output of the Voltage/Reactive Power Control function is a list of the suggested operating conditions for generating plant and transformers. Possible line, transformer, and shunt switchings are included. The subsequent implementation of this operating strategy is left to the discretion of the operator.

F. Short Circuit Analysis

This function allows the control engineer to check whether the short circuit ratings of the power system equipment are being exceeded or approached. The check is done for the actual network situation as derived by the Topology Determination function and stored in the data base. This function proceeds in the following steps :

1. The nodal admittance matrix for the positive sequence system for the actual network state as taken from the data base is set up.
2. The nodal admittance matrix is factorized.
3. For each fault location which is predefined by the operator, the equivalent

network characteristic with respect to this location is calculated.

4. The total fault current is calculated.

5. The fault current through the network is calculated around the fault location and the results are checked against the predefined limits.

The results of the program are stored in an output file in the data base ready to be presented to the operator.

G. Operator Load Flow and Contingency Analysis

The operators load flow is started by the man machine interface, i.e. by operator request. The system to be studied or the *Base Case* can either be an image of the actual system or a projected system. In the first case, a study version of the relevant parts of the on-line data base must be initiated and stored in a file along with alterations provided by the operator if any. In the second case, the power system to be studied has to be available in the form of a load flow input data set, and can either exist on the mass storage media or can be read from an input device.

Once the input system is identified, the load flow calculations proceed in the same manner. The load flow algorithm uses a decoupled Newton-Raphson method to solve the set of non-linear system equations. Limits on transformer tap ratios and generator reactive power levels are considered and node types are changed appropriately. A number of edit functions are available to the operator which enable him to make modifications to: P and Q busbar injections, limits of injections, transformer tap ratios and their limits, type of load flow algorithm desired e.g. decoupled or full Newton-Raphson, convergence criterion and accuracy, area load increase/decrease in percent, and voltage levels at busbars. In addition it is possible for the operator to identify elements as being in or out of service which enables contingency checks to be performed. A list of the elements to be checked in the contingency analysis is made available to the operator, which he can modify via the system editor. For each element on the list, a check is made on its outage to determine wether it causes a *split* in the system, if so a warning is given and the load flow is not performed. If no split is produced by the outage a new solution is derived with the appropriate network element out of the network. The output of the program is list of results similar to that provided by the state estimation program.

J. Interactive Unit Commitment

The Unit Commitment program is used to preschedule the operation of the power plants for a twenty-four hour period according to a given load curve. The spinning reserve requirements. the minimum and maximum loading. the operating as well as the start-up and shut-down costs of each unit type are taken into consideration. The program works interactively with the following modes made available to the user: the load demand mode. to revise the load demand curve and spinning reserve requirements: the on-line generator data mode. to revise the on-line generator data e.g. fix-on and fix-off generation and initial state; the off-line generator data mode. to revise the off-line generator data, e.g. number of units and minimum and maximum loading: the generating costs mode, to revise the generating costs, the fixed and variable operating costs. and the start-up and shut-down costs; the unit commitment mode, to determine the optimal unit commitment under consideration of the last updated values: and the exit mode, to close the session and save the new data if required.

The output of the Unit Commitment program is a listing of the optimal number of running units and the average loading for each unit type. This listing is displayed on the screen and printed on the line printer.

I. Interactive Long Term Load Forecasting

The main purpose of this function is to produce a weakly peak load for the rest of the current year and up to two years in advance based on historical load data. The user works with the program in an interactive way and the following activity modes are available: the display mode, to display and revise stored data; the forecast mode, to build the forecasts; the update mode, to enter new actual data; the parameter mode, to estimate new model parameters and replace the old parameters if necessary; and the exit mode, to close the session and save the new data if required.

J. Interactive Hourly Load Forecasting

The purpose of this function is to produce an hourly load forecast up to one week in advance based on historical load and weather data. The user works with this program in an interactive way with the following activity modes: the display mode; the forecast mode; the update mode; the parameter mode; and the exit mode. These modes work in exactly the same way as in the Long Term Load Forecasting program discussed above.

APPENDIX B

SYSTEM CONTROL ENGINEER TRAINING

General

The ultimate aim of an electrical power utility, the Electricity Directorate is no exception, is to provide the maximum achievable level of service to the consumers. To do that, the utility strives to maintain a high level of expertise in the critical areas. The Electricity Directorate, however, is also faced with the other requirement of Bahrainization which is directed upon it by an overall government policy.

In many areas Bahrainization is not a problem because there are enough competent and experienced Bahraini's to occupy the positions, or because the positions are not so critical, therefore experience can be *picked up* along the way. Unfortunately, in the area of System Control, neither of the above situations apply. Furthermore, previous attempts to produce and implement a training programme for System Control Engineer has failed, and although virtually all technical positions within the Directorate have a training programme, as yet there is no training programme for the position of System Control Engineer.

As a first step in attempting to tackle this problem, and in order to identify the points of difficulties, some of the views of the people most directly concerned were collected and analysed.

A. System Control Section

The System Control view can be summarized by one statement: *A person can NOT be trained to be a System Control Engineer.* In other words, a Control Engineer should come from a background where he had been in a line position and where he had experienced the sense of responsibility first hand for some period of time in an area closely related to the operation of a power system. One likely area is Generation, another area is Transmission. This view is based on the undisputable fact that not only the overall system security, but also people safety and lives are at stake. Holders of this view claim that the usual practice in other utilities in the more advanced parts of world is that the System Control Engineer is someone who has been working in a power station or transmission for a long time.

B. Power Stations and Transmission

The management in the power stations looks at the problem from an entirely different angle. Their view is that as they are now, the power stations are severly under-manned. Therefore an attempt to take away any engineer from the power plants will not be favored.

The engineers in the power stations seem to have their own view too. As it stands now, the System Control Engineer grade on the Directorate professional scale is grade four, or P-4, which is not attractive for a Shift Charge Engineer whose grade is also P-4. The move from a power station to System Control is not a promotion, and therefore is not worth the trouble of re-adjusting, etc.

C. The Graduate Engineer

For the Graduate Engineer, a System Control Engineer position is interesting and attractive. However, having to undergo a training programme which lasts for more than three years is not acceptable. The standard training period to get into a P4 engineering position in the Directorate is three years.

D. Conclusion

In the light of the above, there seem to be three alternative lines of action which the Directorate can follow in order to fulfill the two overall objectives as mentioned in the begining of this section, namely good service and Bahrainization. These lines of action are:

A. The Directorate can choose to do nothing. The slow process of experience build-up takes place over a number of years within the Directorate and at a suitable time in the future when the System Control Center becomes more integrated into the system and more leverage is put on its operation, the status of the System Control Engineer grade is incremented to provide an incentive for experienced engineers to move to it form other positions. By that time there will be enough engineers in the Directorate to ensure that such movements will not negatively affect the other departments.

B. The Directorate chooses not to make a training programme for the System Control Engineer specifically. However the training programmes for the Shift Charge Engineers in the power stations and in transmission are slightly amended such that they are reduced to two years instead of three years and are targetted to the line position of an Assistant Engineer P-3, one grade less than an engineer. At the point when the Assistant Engineer is moved up to an Engineer position P-4, and upon an assessment of his abilities, he is offered the position of System Control Engineer as an alternative.

C. The Directorate goes through the exercise of designing a new training programme specifically for the position of System Control Engineer. This programme will have to include the following in a period of not more than three years:

- Initial general training in the Directorate.
- Overseas training in utilities.

- A period in power stations operations and maintenance.
- A period in transmission operation and maintenance.
- Specific courses in related subjects: e.g. power system studies, operational safety procedures, first line management, etc.

APPENDIX C

PROGRESS REPORTS

Dr. A. K. Ayoub
Department of Electrical Engineering
Texas A&M University
College Station, Texas 77843
U. S. A.

Dear Dr. Ayoub,

Enclosed please find my first progress report covering the period from September 1st, 1983 to December 31st, 1983 as per the requirements of the Doctor of Engineering Internship Program. Other reports covering the rest of the internship period will follow shortly.

Truely yours,

Najib A. Aljamea

c.c.: Mr. M. C. Britton

Introduction

This report covers the period from September 1st, 1983 to December 31st, 1983. In general, the activities in this period included re-familiarization with the organization and the system and engaging in several tasks within the System Operations Department.

Refamiliarization with the Organization

To accomplish this task, I met some of the key personnel in different departments and discussed with them their departments main functions and responsibilities. Also, to refresh myself on the System Control Center I went over some of the documentation and manuals in the department; and to bring myself up-to-date with the state of equipment in the Computer and Software Section I read some of the previous incident reports and the monthly reports.

1983/1984 Power System Extensions

Due to the expansion inthe power system, some extensions had to be made in the System control Center. These extensions range from up-dating the minic diagram to expanding the data-bases of the Computer systems. The first phase of these extensions involves the addition of three transmission substations and making major modification to one substation. As a senior engineer in the Computer section I had the responsibility of having this phase of the extensions completed and implemented before the substations were actually commissioned.

System Control Center Equipment Maintenance

The maintenance period which was contracted with Brown Boveri & Co., the main original contractor, was to end in December 31, 1983, and it was planned that maintenance for the following two years of that date should be made open for maintenance firms in Bahrain. The tender was to be in two parts. The first part covers the Digital Equipment Corporation, DEC, equipment which include the computers and their peripherals. The second part includes all BBC and other manufacturers equipment in the System Control Center. Quoting for the second part was made optional. As a senior engineer, I was involved in writing and revising the contract specifications and following it through the administrative departments to make sure that the contract starts on its designated date , January 1st, 1984.

Expansion of the Department

As a result of the newly added responsibilities to the System Operations Department, the need was felt for new positions to be created. Hence, a new organizational chart for the department was prepared to be presented to upper management for approval and for carrying out the necessary steps for its implementation. Part of the preparation of the chart was writing up the job descriptions for all the positions on the new chart, a task which I undertook since most of the new positions were related to the Computer section.

Day-to-day Operation of the System Control Center

As a senior engineer in charge of the equipment in the System Control Center, I also had the responsibility of ensuring the proper operation of all the equipment in the System Control Center and of managing and directing the personnel in that section. The equipment in the System Control Center include :

- the computers and their peripherals,
- the Man/Machine subsystem
- the Operating System software and the Engineering Application software.

The personnel working in the section were:

- a seconded engineer from our consultant.
- two graduate/trainee engineers
- one senior technician
- two technicians
- one programmer.

Dr. A. K. Ayoub
Department of Electrical Engineering
Texas A&M University
College Station, Texas 77843
U. S. A.

Dear Dr. Ayoub,

Following my previous letter dated September 10, 1984, I hereby submit to you the second progress report as per the requirements of the Doctor of Engineering Internship program. This report covers the period from January 1st, 1984 to April 30th, 1984.

During the course of the covered period with the Electricity Directorate of Bahrain, the following were accomplished:

1. Phase I of the 1983/1984 Extensions was completed and commissioning the Remote Terminal Units in the substations was started.
2. Work on Phase II of the 1983/1984 Extensions was started which included the addition of four substations to the power network. These substations were scheduled to be commissioned in the period between October 1984 and February 1985.
3. The System Control Center Equipment Maintenance contract was completed and I started following it up with the Administration and the Accounts departments.
4. I participated in a Seminar for assessing training needs within the Electricity Directorate.

5. I reviewed the existing equipment in the SCC in order to determine the levels of spares required.

6. I reviewed the storage and workshop facilities in the section in order to put a plan for improvement in these areas.

I feel that by performing the above tasks and by other interactions with people within and outside the Directorate, I was getting the experience and the exposure intended by the internship program.

Truely yours,

Najib A. Aljamea

c.c.: Mr. M. C. Britton

Dr. A. K. Ayoub
Department of Electrical Engineering
Texas A&M University
College Station, Texas 77843
U. S. A.

Dear Dr. Ayoub,

I hereby submit to you the third progress report as per the requirements of the Doctor of Engineering Internship program. This report covers the period from May 1st, 1984 to August 31st, 1984.

During the covered period with the E.D.-Bahrain, the following were accomplished:

1. Continuation of the work on Phase II of the 1983/1984 Extensions of the power system. This work included:

   a. preparation of the extensions on the mimic board,

   b. implementation of extensions on the mimic board,

   c. generating static and dynamic pictures in the computers data-bases,

   d. preparation of *Signal Lists* which contained information about all objects of the substations to be added. These lists are used by the software staff to update the computer data-base in the *Master Station* and by hardware personnel to make the necessary connections in the *Remote Stations*.

2. Participation in the development of an *Underfrequency Report* computer program. This program enables the control engineer to estab-

lish at any time the amount of load which would be disconnected if underfrequency operation takes place at that time.

3. Participation in planning and supervising the maintenance of the Engineering Application and the Power Application software which was carried out by two software specialists from the main contractor in conjunction with staff from our section.
4. Following up on the new organizational chart of the department.
5. Going on an assignment for five days to Dublin, Ireland, to discuss future consultancy arrangements with the *Electricity Supply Board of Ireland* for the SCADA and communications systems of the Electricity Directorate.

I feel that I have aquired a lot of the experience and the exposure intended by the internship program and I shall continue to work hard in order to gain more experience and attain the goals of my internship.

Truely yours,

Najib A. Aljamea

c.c.: Mr. M. C. Britton

Dr. A. K. Ayoub
Department of Electrical Engineering
Texas A&M University
College Station, Texas 77843
U. S. A.

Dear Dr. Ayoub,

I hereby submit to you the fourth progress report as per the requirement of the Doctor of Engineering Internship program. This report covers the period from September 1st, 1984 to December 31st, 1984.

During the covered period with the Electricity Directorate of Bahrain the following were accomplished:

1. I continued the work on Phase II of the 1983/1984 Extensions on the System Control Center.
2. In the period from October 13th, to November 14th, I attended a seminar/course sponsored by the World Bank and held in Bahrain. The seminar was titled *The Second EMENA Regional Energy/Power Projects Course*. It was an extremely useful seminar and it covered several areas related to utilities management and operation. Among these areas were: management, finance, cost/benefit analysis, economics, demand forecasting, projet management, and energy pricing. A copy of the seminar program is attached.
3. I was appointed to represent the System Operations Department on an Interview Board to interview new graduate engineers for the Electricity Directorate.

I feel that I have gained a lot of the exposure and experience intended by the internship program and I have benefitted immensely from the World Bank seminar.

Truely yours,

Najib A. Aljamea

c.c.: Mr. M. C. Britton