Energy Management Control Strategies in The Egyptian Power System

استراتيجية التحكمات ودورها فى تشغيل الشبكة الكهربية الموحدة لجمهورية مصر العربية

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الخلاصة :
تتولى هيئة كهرباء مصر مسئولية توليد ونقل الطاقة الكهربائية لكافة المستهلكين فى جميع انحاء جمهورية مصر العربية . وقد ادى التطور الهائل فى مجال الصناعة والزراعة والتجارة والاغراض المنزلية الى زيادة الطلب على الطاقة الكهربية .

وحتى تتمكن هيئة كهرباء مصر من تامين تغذية المستهلكين فان ذلك يتطلب تشغيل الشبكة الموحدة تشغيلا سليما من الناحية الفنية والاقتصادية عن طريق التحكم الدقيق والمستمر للاستفادة القصوى بالطاقة المائية الرخيصة من محطات السد العالى وخزان اسوان مع تشغيل الوحدات الحرارية تشغيلا اقتصاديا فى حدود امان الشبكة الموحدة بهدف خفض تكلفة الانتاج .

ترجع خبرة هيئة كهرباء مصر بمراكز التحكم الى اواخر الستينات عند ربط شبكتي الوجه القبلى ومصر الشمالية بعد تشغيل محطة كهرباء السد العالى واستكمال الشبكة جهد ٥٠٠ ك.ف. حتى القاهرة .

يناقش هذا البحث النقاط التالية :

١ - نظم التشغيل الحالية للشبكة الكهربائية الموحدة لجمهورية مصر العربية .
٢ - تطور استراتيجيات التحكم بدءا بمراكز التحكم خلال الستينات ثم انشاء المركز القومى للتحكم فى الطاقة ومركز التحكم بالوجه القبلى .
٣- الخبرات المكتسبة مع مراكز التحكم عبر السنين .
٤ - تطوير مراكز التحكم من خلال نظام هرمى للتحكمات عبر شبكة اتصالات موحدة .

Abstract:

This paper presents the experience of the Egyptian Electricity Authority (EEA) in implementing many control strategies on the national and regional levels. This experience goes back to the 60's when basic telemetry was driving the Mapboard and the meters on the dispatcher's console, and extends to the implementation of computerized State-of-the-art Energy Management systems (EMS). The paper will highlight the present operating conditions, the evolution of control strategies, the role of the national and regional control centers and finally the new trends to implement a hierachical control strategy via a national data communication network (DCN).

1.0 Introduction

The Egyptian Electricity Authority (EEA) is responsible for reliable and economic generation and transmission of electrical energy to a large number of geographically dispersed customers throughout the country. The rapid industrial, commercial, and domestic developments in Egypt have resulted in a growth of demand for electricity. In Egypt

, electric power is used in increasing different ways incidental to urbanization, growing population density and changes in social conditions. Moreover, industry has shown great progress accompanied by increasing sophistication of machinery and systems. A highly reliable power supply, therefore , is essential because of the serious effects of a power failure [1] .

The challenge for EEA is to ensure a secure supply of good quality electric energy at minimum cost, utilizing all the available hydro energy within the constraints imposed by the water irrigation requirements.

2.0 Present Operating Conditions

The Egyptian Unified power system (UPS) is divided into two areas , namely: Upper Egypt and Northern Egypt. The latter is divided into five electric zones, namely: Cairo, Alexandria, mid Delta, Delta West and Canal.

The upper Egypt area has three hydro power stations at Aswan: Aswan Dam (AD1,AD2) and High Dam (HD) in addition to Assuit thermal power station. This area is interconnected through 500 KV system with the Northern area.

The Northern area is composed of 220 KV interconnected bulk transmission network. Power is supplied in this area from both the steam and peaking generating plants and the hydro generation in Upper Egypt via the 500/220 KV interconnection near Cairo.

In 1992, the installed capacity is about 11913 MW of which 25 % is hydro and the rest is Steam and Gas units, the peak demand was about 7500 MW .

The UPS present operating conditions [4] can be summarized in the following :

1. The daily peak load occurs in the evening at 18.00 hours in winter and at 21.00 hours in summer. The ratio of day maximum load and morning minimum load in percentage of the evening peak load are 79% and 63% respectively .

2. The hydro-electric power stations at Aswan cover about 25 % of the total energy consumption. The rest is covered by the running thermal power stations.

3. The operation of the UPS is carried out according to a daily plan prepared 24 hours a head, starting from an hourly load forecast, the hydrology of the Aswan hydro cascade and thermal units availability , a security constrained hydro-thermal optimization model is implemented to arrive at the set of committed units loaded economically within the transmission limitations to meet the demand with consideration of maximum utilization of hydro energy while minimizing the thermal production cost.

4. Frequency regulation is carried out automatically by the Automatic Generation Control function through calculating the area control error (ACE) and economically distributes such amount among the running units according to their participation factors and then pulses the units to raise or lower their generation

5. Automatic frequency load shedding devices and Anti-emergency automatics are extensively used in the Northern and Upper Egypt network. These measures proved to be very important for the security of operation of the system under emergency conditions and they shall continue in the future.

6. Voltage regulation is carried out at different buses which have facilities for voltage reulation. Such facilities are : generators, synchronous condensers at Cairo 500 substation, On-load tap changers available at 500/132, 500/220, 220/66 KV transformer substations and the switchable shunt reactors at the 500 KV substations.

7. Hydro and thermal units are scheduled for maintenance according to the maintenance cycles recommended by the manufactures such that the demand is met and a reasonable reserve is satisfied to guarantee a reliability level of load interruptions for one day every five years.

8. Full utilization of the natural Gas quantities assigned for EEA by the ministry of petroleum.

9. Transmission lines, transformers, and electric equipment in the system are scheduled for regular maintenance to ensure security of operation.

10. off-line studies of load flow, short circuit, transient stability, dynamic energy balance, generating units availability and productivity indices, transmission lines availability indices, and fuel budgeting are carried out for planning the operating conditions of the Egyptian UPS.

3.0 Evolution of control strategies

EEA's experience in control centers goes back to the 60's after the completion of High Dam and the 500 KV network from Aswan to Cairo. At this stage the Operation of the Egyptian Unified Power System was controlled by means of specialized dispatching centers according to a determined policy and fixed instructions and on the basis of technical hierarchy of control such that the responsibility of dispatching and controlling the UPS has been distributed, on a technical and geographical basis, among six dispatching centers.

The technology of the 60's was not able to accommodate Egypt's rapidly expanding power network, and consequently, in 1974 the decision was made to study the feasibility of implementing a national Control Center featuring latest energy management techniques. A contract was signed with Control Data Corporation (USA) in 1978 and the system began on-line operation in the early 80's.

Following the completion of the NECC, the Upper Egypt regional Control Center was modernized with a supervisory control and data acquisition system (SCADA) which was completed in 1988 by Toshiba Corporation (Japan).

The following sections cover briefly the 1960's Control Centers, the National Control Center and the Upper Egypt Regional Control Center .

3.1 The 1960's Control Centers

The six Control Centers used at this stage to monitor and supervise the operation of the power system, were organized as follows :

Central Dispatching Office (CDO)

The CDO was located in the Dispatching Inspectorate Building west of Cairo and it was responsible for the supervision and control of operation of the hydro power stations at High Dam and Aswan and the 500 KV network from Aswan to Cairo, this job has been assigned to the Central Dispatching Office due to its special importance to the UPS as a whole.

Northern Egypt Dispatching Office (NEDO)

It was located in the same building with the CDO. It was responsible for the supervision and control of operation of the thermal power station and the main 220 KV networks in Cairo, Alexandria, and Delta zones.

Upper Egypt Regional Control Center (UERCC)

It was located in Nag-Hamadi 500 KV substation. It was responsible for supervision and control of 132,66,33 KV networks in Upper Egypt zone.

Cairo Regional Control Center (CRCC)

It is located in the same building with the CDO. it is responsible for supervision and control of the 66 KV distribution network in Cairo zon.

Delta Regional Control Center (DRCC)

It is located in the headquarters builiding of the Delta zone. It is responsible for supervision and control of the 66 KV and 33 KV networks in Delta zone.

Alexandria Regional Control Center (ARCC)

It is located in the headquarters Building of Alexandria zone. It is responsible for supervision and control of the 66 KV and 33 KV networks in Alexandria zone.

Computers were not used in the six dispatching Centers but they have been provided with different visual, audible, and printed means for the purpose of exchanging instructions and information with all power stations and the major substations of the system . This gives the dispatcher a clear and instantaneous picture of the system situation and the changes that may develop. Therefore, dispatching offices were laid out to give the dispatcher all possible comfort in utilizing the telecommunication means placed at his disposal and in dealing with the information transmitted to him.

In the control room at the dispatching office where all communication channels terminate, the following equipment is available at the dispatcher's service for all the Control Centers except ARCC and UERCC who relied only on telephones.

The System Mapboard

The main electrical connections of the system are represented by conventional symbols of generating units, transformers, bus-bars, and transmission lines. Also, circuit breakers, disconnecting links, and bus couplers are represented by lighted symbols whose positions are identical to the actual positions in the stations. Whenever any status position is changed either by connection or disconnection, the dispatcher is alerted by an audible message and a flickering light of the circuit breaker or disconnecting linkindicator until its position is manually set to the new one. These indicators are connected to the equipment that transmit and receive signals from the power stations and substations to the dispatching office over high-frequency carrier channels on the power lines.

The Dispatcher's Console

It is designed for two or three dispatchers and provided with dispatching telephones in an easily accessible way. The console is equipped with meters for important readings: frequency, total generation, and interchanges.

There is also a panel that contains pushbuttons and keys for operating the mapboard and for communication channels failure alarms.

Electrical Measurements

The main measurements are transmitted from power stations and substations through transmitting and receiving equipment. High frequency carrier power lines is used as a means of transmitting this data to the dispatching offices. Usually, the required measurements are: Megawatt and Megavar for generators,transformers, and overhead lines, Ampere for underground cables, Kilovolt for bus bars. The measurements are displayed on measuring instruments in the control room of the dispatching office . The instruments are incorporated on the mapboard, the side panels and the console, so that they can be easily watched by the dispatcher. Special equipment on the console are used to totalize the readings of megawatts generated in different zones, power stations and the total sum in the UPS. Accurate instruments are installed in control rooms for measuring and recording the system frequency, and other instruments for recording important reading of generation and voltage.

3.2 National Energy Control Center

The National Energy Control Center [2] contains a fully-configured Energy Management System, which utilizes externsive computer modeling and analysis features in order to arrive at power network operational and econmic decisions.

The three main functions of this Center are summarized as follows:

1. To monitor the power system's real time operation

2. To apply control actions that achieve the goal of system security and economy

3. To plan the operation of the power system in the future.

Energy Management System

The Energy Management System for the UPS is made possible by a system comprised by the following subsystems:

1. Computer Subsystem

2. Communications Subsystem

3. Man-machine Interface

4. Software Subsystem

5. Facilities

Computer Subsystem

There are three levels of computers (fig.1) used in this system: Data Acquisition, Man-Machine Interface, and Main Computers.

1. Data Acquisition computers (two CYBER 18s) communicate with the Remote Terminal Units and receive the data.

2. Man-Machine Interface computers (two CYBER 18s) provide the dispatchers with access to information and control control actions and also support real time functions such as System Security Assessment and Automatic Generation Control.

3. Main computers (two CYBER 173s) process the more elaborate and complex system modeling and forecasting functions. They also provide the means to run a full suite of off-line Engineering and Planning programs .

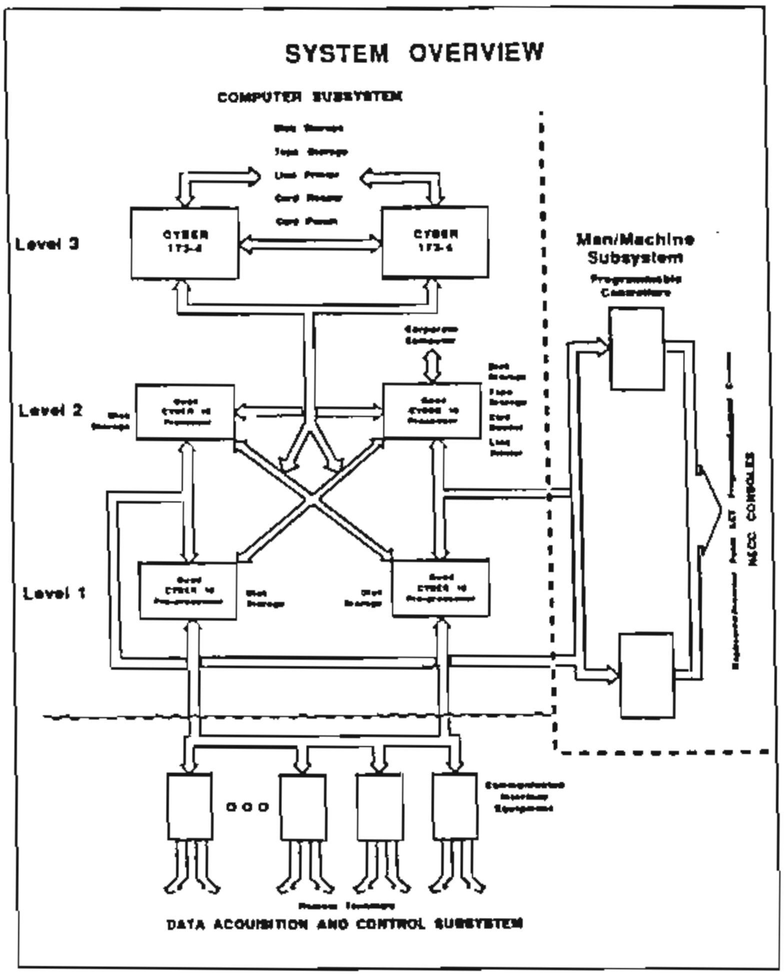


fig.1 : NECC COMPUTER SUBSYSTEM

COMMUNICATIONS SUBSYSTEM

The modern EEA communications network covering all sites of the UPS consists of a mix of microwave and power line carrier media for the transmission of voice, data, and teleprotection signals.

The main features of this subsystem are :

. Main and alternate path for data transmission.

. Main and alternate routing for telephone using microprocessor-based electronic exchanges.

. Microwave backbone of 300-channel capacity providing for future expansion.

. Hardwired and programmable Remote Terminal Units (RTUs) interrogated by the Master Station every 4 seconds .

MAN-MACHINE INTERFACE

The Man-Machine Interface (MMI) provides the means for the 24-hour load dispatching staff to access the information related to the power system. This information is available in a variety of displays at work stations and on the mapboard.

Utilizing modern techniques to provide a good working environment, the MMI consists of :

1. Three work consoles each equipped with :

   Three 19-inch colour CRTs
   One Keyboard
   Two Assignable Recorders
   One Telephone Console
   One Centronix Printer

2. Other consoles used by programmers and users.

3. Dynamic Mapboard with strip chart recorders, digital system, and standard time/frequency displays.

THE SOFTWARE SUBSYSTEM

At the heart of advanced Energy Management System lies the application software where effective utilization of computing resources works toward creating the most economical, secure, and reliable power system possible. The application software of NECC includes the following packages.

.Supervisory Control and Data Acquisition (SCADA)

The SCADA subsystem receives about 7000 digital points, 2000 analog points and 350 pulse accumulators from the existing 50 RTUs every 4 seconds, in the form of status indications, alarms, and measurements.

In addition, most circuit breakers can be remotely controlled, and Automatic Generation Control signals are transmitted every 4 seconds.

The system logs data and status changes and performs extensive economic generation calculation and reports.

.System Security Application

The System Security Application programs, executed every 3 minutes or by event trigger, provide an improved estimate of the state of the current power network.

.Scheduling Programs

Scheduling Programs enable the power systems dispatcher to plan and schedule the near term (a few hours to one week) operation of system in an economically optimum and reliable manner.

.System Engineering and operational Planning rograms

The System Engineering and Operational Planning Programs are a set of off-line programs used for operation planning of the power network.

.Training Simulator

The Training Simulator present simulated events, which cause system disturbances and require a remedy. The result is a model very close to the on-line system and an environment identical to the real-world operation.

FACILITIES

The environmental autonomy is a major and necessary feature of the National Energy Control Center. An uninterruptable power supply ensures continuous power to priority electrical loads .

The state-of-the art National Energy Control Center is thus a collection of resources to help make sound decisions about the operation and evolution of the Egyptian Unified Power System that EEA serves.

3.3 Upper Egypt Regional Control Center (UERCC)

In 1983, EEA completed National Energy Control Center (NECC) in Cairo which controls the generating station and substations connected by high voltage transmission lines.

In 1988, following the completion of the NECC, the Upper Egypt Regional Control Center (UERCC) was completed to monitor the 132 KV power systems in the Upper Egypt Zone [3].

The major functions of the UERCC system are :

1. Collect various data gathered by Remote Terminal Unit (RTU) stations located along the river Nile from Aswan to Cairo.

2. Analyze the collected data and supervise operating conditions of the power system at UERCC in Nag-Hammadi.

3. Control the power distribution system based on analyzed data and ensure the effective utilization of the electric power system.

The UERCC is composed of four major systems and details of each system are explained under the following sections.

1. SCADA system (supervisory Control and Data Acquisition)

2. TELECOM system

3. SOFTWARE system

4. FACILITIES

SCADA SYSTEM

The SCADA system (fig.2) comprises three subsystems: computer, man-machine interface (MMI) and telecontrol subsystems.

The computer subsystem form the core of the system. A powerful 32-bit architectured TOSBAC-7/70G is used as the host machine handling all major system functions. In order to ensure high system reliability, the system is duplicated with one CPU operating online and another in standby.

Major MMI devices are: mapboard, consoles and loggers. The mapboard provides the dispatchers with a means to grasp a picture of the overall status of the power system while the consoles , with 20-inch color CRTs, enable the dispatchers to monitor the status of individual equipment in detail. Alarms, events and routine logs are printed on the loggers.

The telecontrol subsystem is designated a data acquisition function. Status, analog data and pulse accumulators are collected by RTU and sent to the CPU through telecom channels, TCM and CDL.

Microprocessor-based TOSMAP (Toshiba Microprocessor-aided Power System Control) is used for telecontrol subsystem.

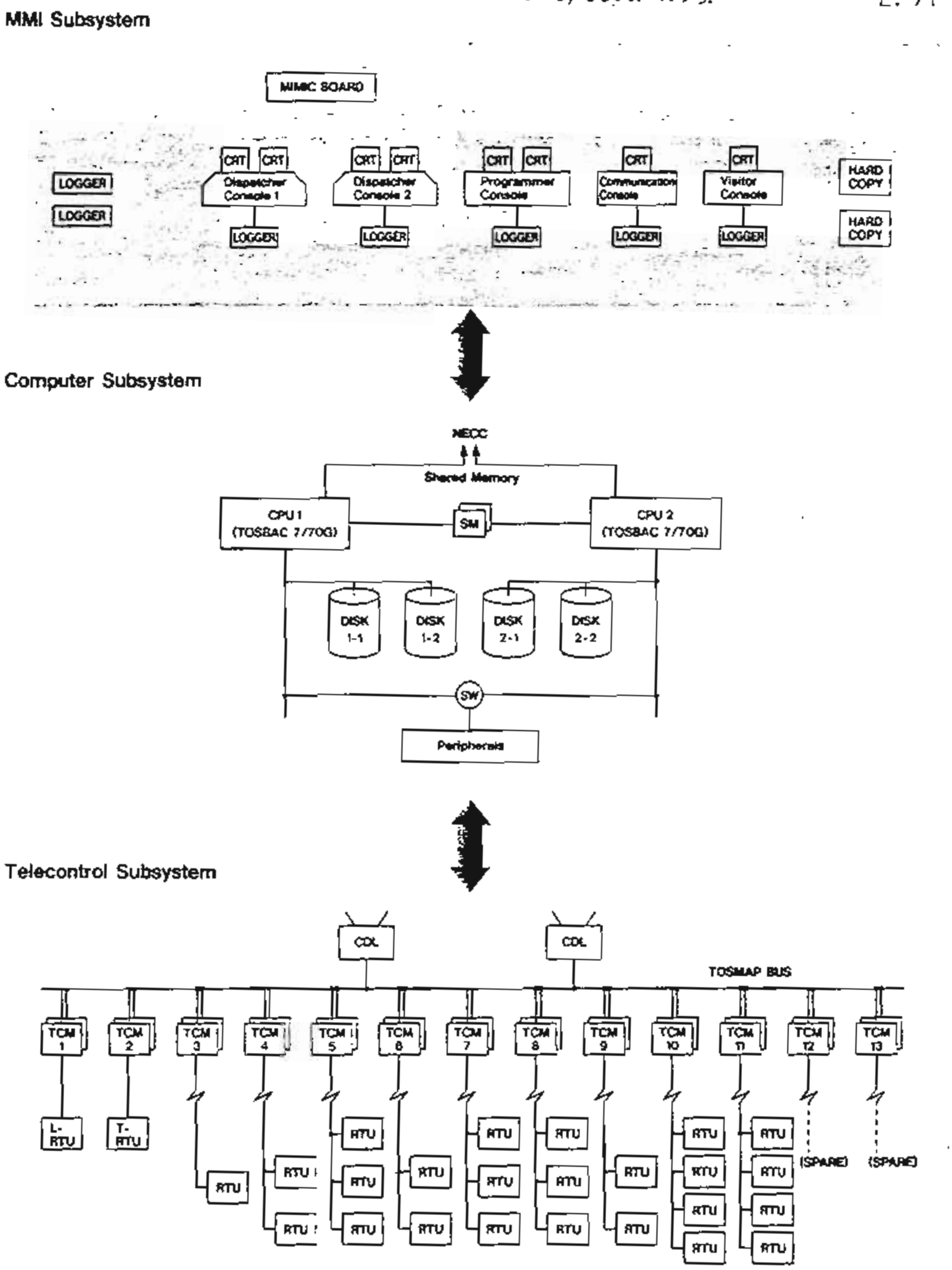
At present,28 RTUs are installed at some substations and Assuit power station to collect various field data including:

- on/off status of circuit breakers, disconnect switches,etc.

- analog data such as voltage, effective power, frequency,etc.

- pulse accumulators such as megawatt hour and megavaFr hour.

- sequence of events (1 msec resolution)



NECC: National Energy Control Center
CDL: Computer Data Link unit
TCM: Telecontrol Master unit
RTU: Remote Terminal Unit
L-RTU: Local-RTU which is located at UERCC
T-RTU: Training-RTU which is Located at UERCC
TOSMAP: Toshiba Micro-Processor Aided Power System Control
CRT: Cathode Ray Tube display

Fig.2 OVERVIEW OF SCADA SUBSYSTEM

Data communication with the master station is via a highly reliable and efficient High-level Data Link Control (HDLC) protocol.

TELECOM SYSTEM

The TELECOM system plays an important role in connecting as many as 85 node station scattered along the river Nile stretching about 900 kilometers from Aswan to Cairo. The system includes 21 stations providing both data and telephone services and 64 stations for telephone.

Due to the diversified geographical location of each node station and various service requirements, the transmission media utilized ranges from microwave radio to fiber optic transmission.

The TELECOM system also includes 13 PABXs which provide dedicated internal telephone communications to secure smooth and quick transfer of instructions necessary for the effective distribution of electricity throughout the zone.

Fiber optic transmission lines are also employed considering its outstanding feature , resistance to electromagnetic fields, particularly effective in power stations.

In order to provide a microwave communications system, a number of towers, almost 100 meters high, were constructed along the river Nile .

SOFTWARE SYSTEM

The SCADA system acquires power system data,such as status,analog data, pulse accumulators and sequence of events (SOE) and stores them in its database as current status and/or historical records of the power system.

According to the nature of the data acquired, the system presents it to the dispatchers in visible and audible (if necessary) form on the mapboard, consoles and loggers. The system is also provided with a security analysis function to assist the dispatchers in assessing security of the power system in terms of equipment overload and voltage fluctuations for selected equipment.

In addition to the power system data, alarms generated in telecom and UERCC building facilities are fed to the SCADA system and displayed on the CRTs.

Major functions of the system are :

- data acquisition and processing
- alarm reporting
- logging
- historical data recording

- scheduled outage management
- disturbance recording
- energy accounting
- alarm reminder management
- sequence of events
- data link
- security analysis

FACILITIES

The building includes all automatic control facilities consisting of central air-conditioning, halon gas fire extinguishing and fire alarm along with a sophisticated security system.

In some of the telecommunication stations where commercial power is not available, solar power equipment takes advantage of the fine weather conditions in Egypt.

4.0 Experiences gained over the years

Over more than 20 years of power system operation implementing different control strategies, two major areas can be emphasized:

. A secure supply of good quality electric energy at minimum cost is guaranteed

. The investments spent on training pay back

Regarding the first area, the distribution of responsibilities between the National and Regional control centers made it possible to achieve the goals of security and economy by following predefined operating conditions.

Moreover,the control strategies adopted has been very helpful in power system restoration during emergency conditions.

Regarding the second area, enough personnel were assigned to the NECC project from the feasibility study up to the field acceptance test. They went through the preparation of the technical specifications, the analysis of technical proposals of the vendors, Pre-contract negotiations that led to contract signing, formal classes and on-Job training in hardware, software and communications, testing the system in the factory and finally, field installations and testing.

The experiences gained led to the following:

. Complete responsibility of NECC system maintenance regarding hardware, software and communications

. Repairing electronic cards for the computer hardware, communications and RTUs.

. Enhancing the power applications software by adding new features that were not available in the original design.

. The follow up of UERCC from the feasibility study up to the completion.

. The preparation of ARCC feasibility study.

. Working jointly with the consultants to prepare feasibility studies for the remaining RCCs.

5.0 New trends in control strategies

After about ten years of NECC operation and the achievements realized in running the Egyptian UPS in the most reliable and economical manner the upgrade of the NECC is essential due to the following limitations:

. The existing NECC can handle up to 60 RTUs, this number will be reached within a year while it is anticipated to have 105 RTUs by 1995 .

. Some spare parts are beginning to become unavailable due to the shut down of the manufacture's production

The decision has been taken by EEA to upgrade the NECC, to computerize existing Cairo, Alexandria and Delta regional Control Centers and to install two more regional Control Centers serving Canal and the new Delta west zones .

To realize such decision , a contract is signed with Electricite de France jointly with EEA personnel to carry out a conceptual study to design a hierarchical control strategy [5] for the Egyptian UPS via a national data communication network.

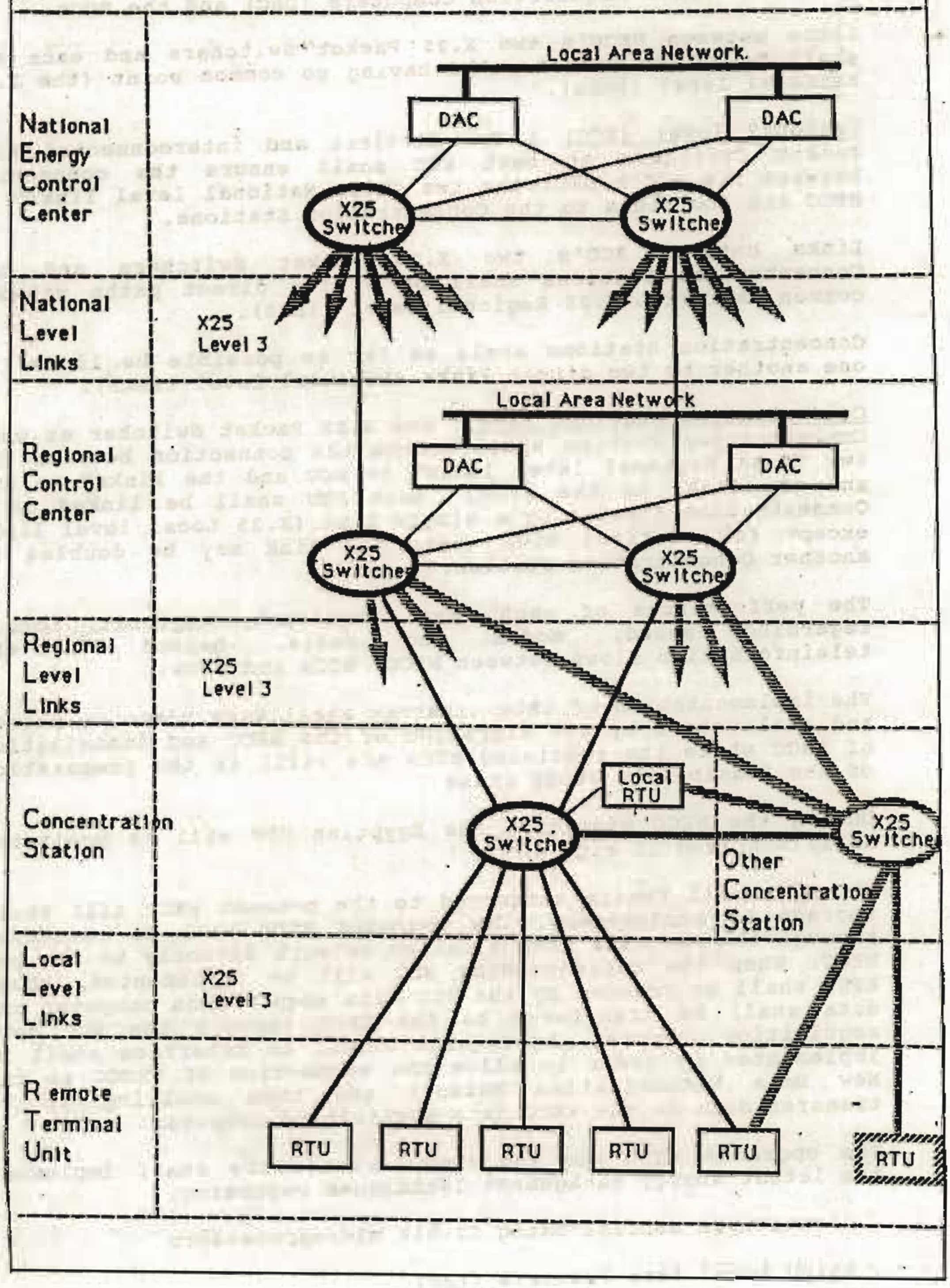
The study proposed a hierarchical control strategy that distributed the responsibilities between the NECC and the RCCs as follows :

. The NECC shall be responsible for the management and operation of the generating plants, supervision and control of the 500 KV network and just monitoring of the 220 KV network for the purpose of the overall security assessment of the entire network.

. The computerized RCCs shall be responsible about the supervision and control of the 220 KV network in their zones in addition to original responsibilities outlined in section 3.1

This strategy can be made possible by implementing a hierarchical data communication network (fig. 3) which is based on a 3 level architecture as follows :

National level (NECC): Two distinct and interconnected X.25 Packet Switchers at NECC shall ensure the connection between fig. 3 :DATA COMMUNICATION NETWORK



NECC's two Data Acquisition Computers (DAC) and the RCCs.

Links between NECC's two X.25 Packet Switchers and each RCC shall be by two direct paths having no common point (the X.25 National level links).

Regional level (RCC) : Two distinct and interconnected X.25 Packet Switchers at each RCC shall ensure the connection between the RCC's DAC, the two "X.25 National level links" to NECC and the links to the Concentration Stations.

Links between RCC's two X.25 Packet Switchers and the Concentration Stations shall be by two direct paths without common part (the X.25 Regional level links).

Concentration Stations shall as far as possible be linked to one another by two direct links (Regional level links).

Concentration Stations level: One X.25 Packet Switcher at each Concentration Station shall ensure the connection between the two "X.25 Regional level links" to RCC and the links" to RCC and the links to the RTUs. Each RTU shall be linked to a Concentration Station by a single link (X.25 Local level link) except for critical RTUs where the link may be doubled to another Concentration Station.

The performances of each level (National, Regional, Local) regarding speed, modem and media, depend on the teleinformation flows between NECC, RCCs and RTUs.

The implementation of this strategy shall take place in phases and shall start by the migration of the NECC and installation of ARCC while the remaining RCCs are still in the preparation of the feasibility study phase .

During the NECC migration the Egyptian UPS will be monitored as illustrated in Fig. 4 .

CDC RTUs will remain connected to the present NECC till their upgrade or replacement. The upgraded RTUs will be connected through the New data Communication Network directly to the new NECC. When the corresponding RCC will be implemented, these RTUs shall be scanned by the RCC data acquisition computer and data shall be transfered to the NECC through the RCC data acquisition computer. As regards UERCC, an interface shall be implemented in order to allow the connection of URECC to the New Data Communication Network and thus enabling it to transfer data to the NECC data acquisition computer.

The upgraded NECC and the computerized RCCs shall implement the latest Energy Management Techniques regarding:

. Distributed control using 32-bit microprocessors

. Using Local Area Networks (LAN)

. MMI enhancements via full graphics

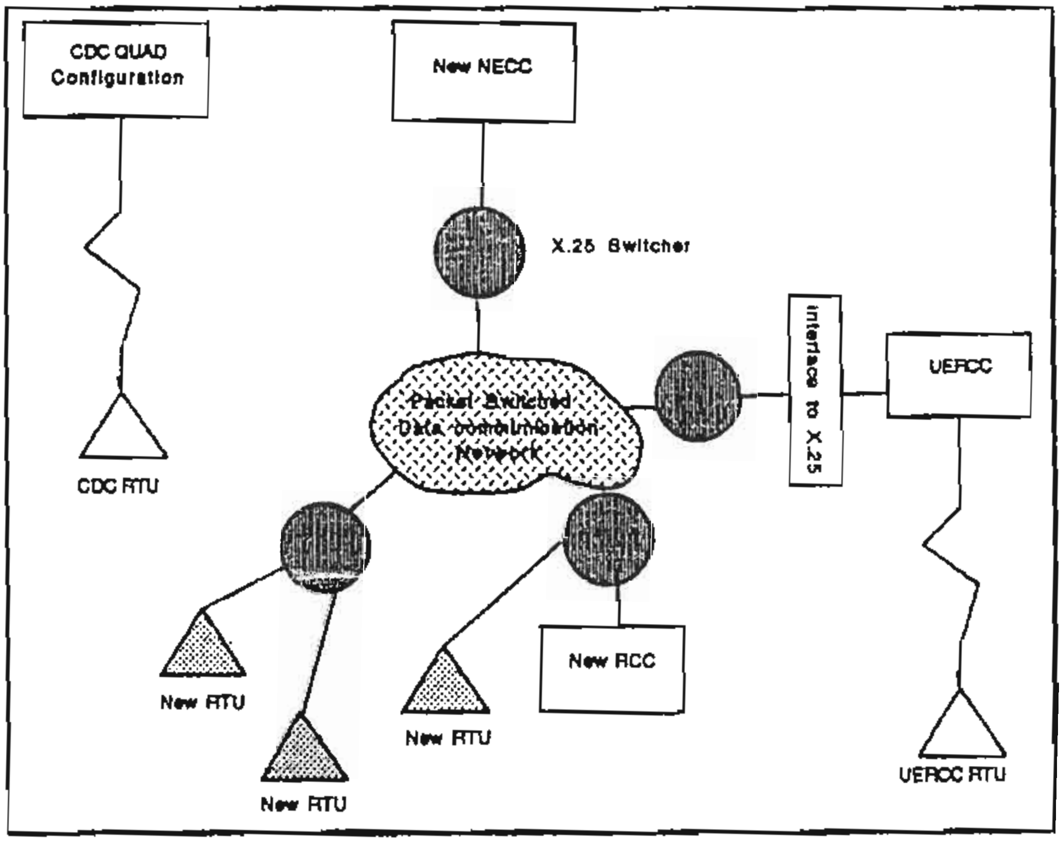


fig. 4 : NECC MIGRATION PHASE

The upgraded NECC and the computerized RCCs shall implement the latest Energy Management Techniques regarding:

. Distributed control using 32-bit microprocessors

. Using Local Area Networks (LAN)

. MMI enhancements via full graphics

. Introducing Artificial Intillegence (AI) in Alarm processing, Remedial actions and fault analysis .

6.0 Conclusion

The implementation of modern Energy Management systems in the supervision and control of the Egyptian UPS led to great economical savings. The introduction of large size thermal units and combined cycle units with the aid of economical operation of such generating resources using NECC software facilities, have resulted in decreasing the fuel consumption from 342 gm/KWH in 1982 to 252 gm/KWH in 1992.

Moreover, it turned out that training is one of the major issues utilities have to consider to benefit from such high technology EMS systems.

7.0 References

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