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REVISED

DEVELOPMENT OF ELECTRICITY GENERATION & TRANSMISSION PLAN (EGTP)

Prepared for

Ministry of Water & Electricity
Riyadh, Saudi Arabia

Prepared by

Center for Engineering Research

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SUMMARY

This proposal has been prepared in response to a request by the Ministry of Water & Electricity (MOWE), Riyadh (minutes of a meeting held on January 12, 2005 and the attached terms of reference, Appendix A). The purpose of this study is to prepare a Master Plan for the expansion of Electricity Generation & Transmission Systems in the Kingdom of Saudi Arabia.

The plan will be developed jointly by a team from King Fahd University of petroleum and Minerals (KFUPM), Dhahran and SNC-Lavalin, Canada. KFUPM team has conducted a number of studies in the field of power systems planning, including the Feasibility Study for Interconnection of Gulf Cooperation Council (GCC) Electrical Power Systems and the Feasibility Study for Interconnection of Arab Mashreq Electrical Power Systems. Recently, a team from KFUPM completed a 15 years (2008 - 2023), updated generation plan for the Kingdom under the auspices of Ministry of Water & Electricity (MOWE).

SNC-Lavalin is a well known consultant in the field of power system planning. In 1995, SNC-Lavalin developed the long term electrification plan for the Kingdom of Saudi Arabia under the auspices of the General Electricity Corporation (GEC). SNC-Lavalin is currently the owner's engineer for the GCC Grid Authority for the implementation of Phase-I of the GCC interconnection.

The master plan shall cover the electricity needs of the Kingdom of Saudi Arabia over the coming 25 years (2008-2032). The plan shall take into account the restructuring process that has been taking place in the Kingdom since 1998. Several Independent Power Producers (IPPs) have firm plans for generation projects. The study will also take into account the recent major development in the Natural Gas production and its impact on fuel supply. This study will make extensive use of the data, information, and methodology which are reported in the preceding long term plans. It will also take into consideration the impact of the GCC interconnection project, of which Phase-I is expected to be operational by 2008.

In preparing the Electricity Generation & Transmission Plan (EGTP), a team will study the Saudi Arabia demand forecast based on maximum and minimum economic growth conditions as well as most likely conditions. System load shapes, including industrial, commercial and residential load characteristics will also be analyzed and incorporated into the load forecasts. Based on the expected load growth, the project team will assess alternative supply resource options, taking into account the technical requirements of the electric systems, input from Saline Water Desalination Plan (SWDP) and additional critical factors. Alternative generation expansion scenarios will be initially formulated using the options identified in the study. The timing of generation additions will be optimized so that each option meets a pre-determined reliability criterion. Detailed simulation of the options will then be carried out using power system planning software. Based on the initial results of this analysis, further options will be studied until an optimum plan for the base case assumptions is derived.

Once the optimum production expansion plan has been developed, the transmission systems will be investigated in order to deliver the output of the production facilities to the major load centers in each area of the Kingdom. The generation and transmission expansions will then be coordinated into a phased development plan. The study will highlight the conditions to be adopted for realizing the open transmission access.

An overall method of financial analysis that will be applied consistently across the regions to all meaningful comparison to be made regarding the financial performance will be developed. The electricity sector requirements for fuel will be estimated based on the finding of the EGTP plan for the consideration of Kingdom's fuel supply policy.

KFUPM is the primary consultant and shall be responsible for the execution and the successful completion of the study. The KFUPM team will be responsible for carrying out a number of tasks. These are data collection, development of planning basis, generation planning studies, transmission planning studies and the estimation of fuel requirements. The primary responsibility of SNC Lavalin would be to conduct demand forecast and financial analysis. However, it should be noted that both the teams will work in very close cooperation for execution of the study.

The study will be completed in twenty four working months after signing the contract at a cost of SR 7,000,173 (Seven million, one hundred and seventy three Saudi Riyals).

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SECTION 1 INTRODUCTION

This proposal has been prepared in response to a request by the Ministry of Water & Electricity (MOWE), Riyadh, on January 12, 2005 and terms of reference attached (Appendix A). The purpose of this study is to prepare a Master Plan for the expansion of Electricity Generation & Transmission Systems in the Kingdom of Saudi Arabia. The master plan shall cover the electricity needs of the Kingdom of Saudi Arabia over the coming 25 years (2008-2032).

The plan will be developed jointly by a team from King Fahd University of petroleum and Minerals (KFUPM), Dhahran and SNC Lavalin, Canada. KFUPM team has conducted a number of studies in the field of power systems planning, including the Feasibility Study for Interconnection of Gulf Cooperation Council (GCC) Electrical Power Systems and the Feasibility Study for Interconnection Arab Mashreq Electrical Power Systems. Recently, a team from KFUPM completed a 15 years (2008 – 2023), updated generation plan for the Kingdom under the auspices of Ministry of Water & Electricity (MOWE).

SNC Lavalin is a well known consultant in the field of power system planning. In 1995, SCN Lavalin developed the long term electrification plan for the Kingdom of Saudi Arabia under the auspices of the General Electricity Corporation (GEC). The planning period covered was 1995-2020G. This plan was later updated by the GEC in 1998 and covered the period from 1998-2023. SNC-Lavalin is currently the owner's engineer for the GCC Grid Authority for the implementation of Phase-I of the GCC interconnection. In March 2006, a 15 years (2008 – 2023) updated generation plan was developed by KFUPM for the Kingdom under the auspices of MOWE.

Since 1998, major restructuring processes have taking place in the electricity and water desalination sectors. Several Independent Power Producers (IPP) and Independent Water & Power Producers (IWPP) have firm plans for generation projects. Also recently, the Kingdom has witnessed major developments in the Natural Gas production which is expected to have a great impact on fuel supply and the long term plan for the generation of electricity in the Kingdom. These factors have necessitated the development of a new master plan for the combined electricity and desalinated water for the Kingdom. This study will utilize and update the valuable data, information, and methodology which are reported in the preceding long term plan. Moreover, the study shall take into consideration the effect of the GCC interconnection project on the Saudi system. Phase-I of this project is expected to be operational by 2008.

As far as the electricity sector is concerned, the Kingdom of Saudi Arabia is divided into four geographical regions: Eastern, Central, Western, and Southern. In each of the Eastern, Central, and Western regions, there is an interconnected grid that feeds the major load centers of the region. In these three geographical regions, the isolated system represents only a small percentage of the total load. In the Southern Region, there are four autonomous systems that are not presently

interconnected with each other. There is a plan to link these four autonomous systems resulting in a grid for the Southern region major load centers.

The present installed generation capacity owned by the Saudi Electricity Company (SEC) is over 28,000 MW. In addition, there are over 5,500 MW operated by Saline Water Conversion Corporation (SWCC) and Power and Water Utilities Company for Jubail and Yanbu (Marafiq). Also, there are several independent projects being actively considered, planned or operated by many Independent Power Producers (IPPs) such as Maa'den, Water and Electricity Company (WEC), Saudi Aramco and Saudi Petrochemical Company (SADAF). The Eastern and the Central regions grid are interconnected by 230kV and 380kV overhead lines. Various studies have been performed in the past for the interconnection between the Western and the Central regions and the Western and the Southern regions so as to have one national grid. This study would draw on the findings of the previous studies to develop the plans for the study horizon.

SECTION 2 OBJECTIVES

The main objective of the study is to analyze the electricity demand with various scenarios of socioeconomic and technological development in the Kingdom of Saudi Arabia, and to develop economically optimized generation and transmission expansion plans for the study period 2008-2032.

Specifically, the objectives of this study are as follows:

1. To identify the major issues in the development of the electricity supply and identify the major assumptions for power energy resources development in the Kingdom over the planning period.

2. To develop the fuel supply guide for power generation sector.

3. To develop a viable Electricity Generation & Transmission System Expansion Plan(s) for the coming 25 years (2008-2032) based on the least cost, financial viability, and latest technologies. The plan(s) shall take into consideration a provision for co-generation of electricity and water from both the electric generation plants and the water desalination plants.

4. To evaluate the potential for regional co-operation and electric networks interconnections and energy exchange.

5. To evaluate and analyze options of providing open access electric power transmission system to competing IPPs/IWPPs in the new regulatory environment. The study shall highlight the conditions to be adopted for realizing the open access.

6. To assess the extent and timing of new generation plants required additions to meet Kingdom's needs for electricity and to encourage the competition in the power markets taking into account the ongoing electricity reforms.

7. To assess the electricity sector requirements for fuel as guidelines for the consideration of Kingdom's fuel supply policy.

SECTION 3 DISCUSSION OF THE PROBLEM

3.1 DESCRIPTION OF THE PROBLEM

The Ministry of Water and Electricity (MOWE), and the Electricity and Co-generation Regulatory Authority (ECRA) have determined the need to prepare a Master Plan for the expansion of the Electricity Generation and Transmission Systems. The master plan shall cover the electricity needs of the Kingdom of Saudi Arabia over the coming 25 years (2008 – 2032). The plan shall take into account the restructuring process that is taking place in the electricity sector in the Kingdom since 1998. It shall also take into account the recent major development in the Natural Gas production and its impact on fuel supply.

In 1995, the General Electricity Corporation (GEC) finalized an electricity generation; transmission and distribution Long Term Plan. It contains valuable information, assumptions and plans which would form the bases for the required electricity Master Plan. The long term plan was later updated by the GEC in the year 1998 and covered the period 1998 – 2023. In 2006, the Kingdom generation plan was updated under the auspices of MOWE. The study covers a 15 years period (2008 – 2023). These plans shall also form bases for preparing Master Plan for the expansion of the Electricity Generation and Transmission Plan (EGTP). The EGTP will also incorporate the findings of the Saline Water Desalination Plan (SWDP) pertaining to the associated electricity generation (Co-generation). Also, the EGTP will include studies regarding Demand Forecast, Generation Planning, Transmission Planning, and Financial Analysis for the proposed plan.

Figure 3.1 shows the necessary effort which is required in developing the EGTP. The figure indicates the role of KFUPM as well as SNC Lavalin. The KFUPM team will undertake the tasks of data collection, development of planning basis, generation planning studies, transmission planning studies, and estimation of fuel requirements. The primary responsibility of SNC Lavalin would be to develop the demand forecast and to conduct the financial analysis. However, it should be noted that both teams will work in very close cooperation for the execution of the entire study.

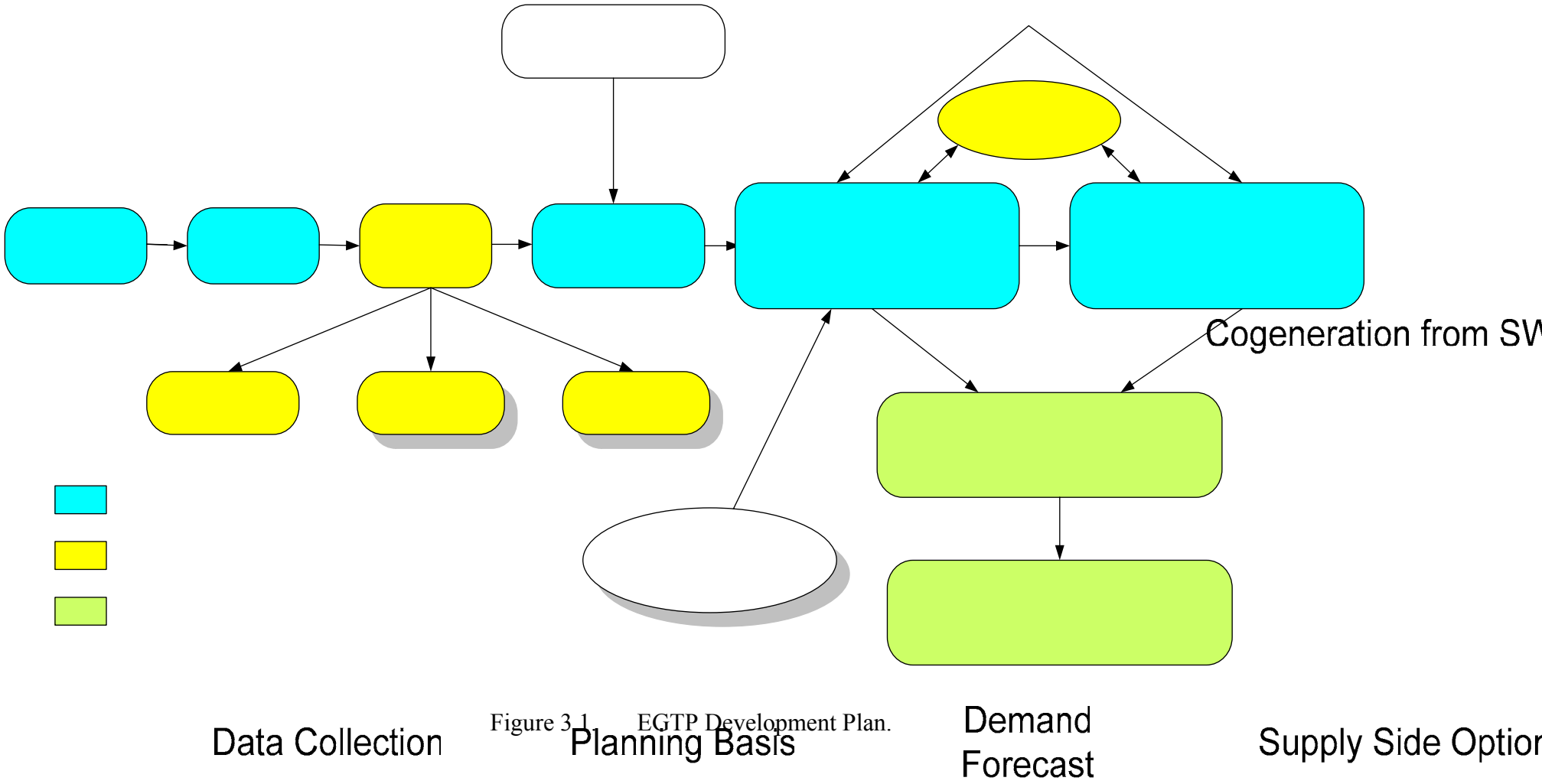


Figure 3.1 EGTP Development Plan.

3.2 APPROACH TO THE PROBLEM

This section provides an approach of the system planning process and the requirement for developing the long term electrification plan for the Kingdom of Saudi Arabia for the next 25 years (2008-2032). This study shall cover the determination of the demand on electricity and the required generation and transmission facilities to meet that demand taking into consideration the Co-generation plants as base supply. The study shall be carried out through a number of tasks.

- Data Collection and Verification
- Planning Basis Methodology
- Demand Forecast
- Generation Planning
- Transmission Planning
- Financial Analysis
- Estimation of Fuel Requirements

The tasks are detailed below:

3.2.1 Data Collection

The first step in developing the EGTP is to establish a rational data base of all elements of the existing power systems which include committed and existing transmission and generation data such as transmission lines parameters, generating unit's parameters, transformer parameters, load, reactive compensation…etc. Also, the data base will incorporate the demand and supply options available to the electric utilities in the Kingdom. The data will be collected from MOWE, Electricity and Cogeneration Regulatory Authority (ECRA), SEC, Saudi Aramco, MARAFIQ, Ministry of Planning, GCC grid authority and other related ministries and governmental agencies. A questionnaire will be prepared to collect the data; the questionnaire will be followed up by visits and discussions. Moreover, information related to new planned projects for the electrical sector will be gathered. Energy consumption patterns will also be collected. This includes historical peak load data, total energy generated as well as total energy sales. Energy sales for each region and each area will also be collected. Data for the number of electricity customers per categories for each region as well as for each operating area will be gathered. In addition to the electrical data, load forecasting will require the demographic and economic data. This includes recent census data, such as total population, income groups etc, the historical as well as the gross domestic product (GDP) and the performance of the various sectors in the Kingdom economy. It should be noted that this section provides a broad definition of the data to be collected, the details of the data requirements would be defined through questionnaire prepared during the execution of this task. In the preparation of the questionnaire, the data requirements

for the softwares such as STRATEGIST, PSS/E, TPLAN, will be taken into account. Also, the data requirement for carrying out demand forecast and financial studies will be determined in consultation with the international consultant. More details regarding the required data for the study will be given in the following sub-sections.

3.2.2 Planning Basis Methodology

In order to confirm that all of the generation and transmission expansion scenarios, as well as financial analyses obey certain consistent requirements in terms of performance and to enable system development scenarios to be compared on a similar technical basis, certain planning criteria which constitute planning basis methodology will be adopted. The planning basis methodology will be identified in consultation with MOWE, ECRA, SWCC, SEC engineers, and other related governmental authorities. The planning criteria, that will be adopted, will have a significant effect on the cost and the quality of service. The criteria, presently being used in the Kingdom will be reviewed and recommendations will be made on the criteria that should be retained for the development of the EGTP. Specific criteria that will be adopted for different sub-sectors of the power system as they relate to generation and transmission expansion as well as financial analyses are outlined below.

Generation Planning Criteria

- Capacity reserve criteria (percentage reserve or loss of load index) used for planning. These criteria are used to decide when new generation has to be added. The criteria have a significant effect on the amount and timing of investment in generating plant. In the case of the Kingdom, the seasonal variation in the demand (summer/winter) and the capability of the generating plant, as influenced by temperature, have also to be considered. Moreover, the occurrence of Ramadan and Hajj during the summer seasons would be addressed.

- The fuel type to be used for the power plants in the Kingdom is related to the availability and cost of local resources. General policies of fuel types and its availability, location etc. will be taken into account. However, for fuel security reasons it may be prudent to have plant with dual fuel capability.

- Alternative types of generation (gas turbine, combined cycle, steam turbine, etc.) and mix.

- The criteria to select type and size of unit additions would be defined. In considering the choice of type of and size of plant, factors to be considered include whether the plant is single purpose i.e. for electricity generation alone or whether it is dual purpose i.e. for both electricity and water.

- Maximum capacity to be installed at any station based on security considerations and the physical restrictions at existing and new sites.

- Forced outage rates of different kinds of plants will be based on experience in the Kingdom and elsewhere on reliability of plant using gas as a fuel. To

allow for partial outages the equivalent forced outages (EFOR) will be used in the reliability calculations.

- Contribution from the GCC interconnection with the other Gulf States will allow reduced reserve margins to be used in the Kingdom without loss of reliability. The effective contribution of the interconnection will be represented in the analysis to take account of this.

Transmission Planning Criteria

- It is quite likely that voltage levels presently considered for system development in the Kingdom are adequate for system development during the period 2008 to 2032.

- Criteria used for steady state operation of the system under normal and contingency conditions and security criteria.

- Contingencies such as one generator or one transmission line out of service are to be considered.

- Acceptable voltage limits at various system buses during normal and contingency operation for system peak load and light load.

- Reactive compensation to maintain a satisfactory balance of reactive power during light load conditions.

- Loading limits for transformers and transmission lines.

- Standard cable and transformer capacities currently in use and possible capacities for consideration in the future.

- Types of faults (three phase, single-line-to-ground etc.) for which system should remain stable.

- Fault clearing time, primary, and back-up protection.

- Generation spinning reserve policies and the use of under-frequency relays to cater to contingencies on the system.

Economic Criteria

- Basic discount rate for comparison of alternatives.

- Currency exchange rates.

- Fuel costs for the different fuel types used and expected real price changes.

- Cost of un-served energy.

- Amortization periods (plant life) for various types of generation, transmission lines, and substations.

Where planning criteria do not exist at present, appropriate recommendations will be made to MOWE.

3.2.3 Long Term Demand Forecast

This task will primarily be carried out by international consultant ***SNC Lavalin*** in close cooperation and consultation with the project team at KFUPM.

The next step in the study is to develop a long term demand forecast for each of the regions in the Kingdom and for the Kingdom as a whole. The demand forecast method will produce three options based on the assumptions made regarding economic growth, population growth, industrial sector development…etc; these options are:

- High demand options
- Most likely demand options
- Low demand options

The most likely demand options will be used to build the EGTP reference plan while the high demand and low demand option will be utilized in developing alternative EGTP plans which takes into account uncertainty associated with long term electric demand forecast. The load forecasts for the Kingdom and its regions to the year 2032 will be developed using techniques that are most appropriate for the type of analysis and the available primary data. The required data and the technique to be utilized for demand forecast is explained in the following sub-sections.

Demand Forecast Data

The principal required data for long term electricity demand forecast are demographic data, economic data, and energy consumption data as shown in Figure 3.2.

Demographic Data

Demographic data will be used to produce the demographic forecast. The demographic forecast is essential to establishing a realistic forecast of electricity and water demand. The evolution of population and households has a direct effect on the energy and water consumption for the residential sector and strong consequences on commercial, institutional, and industrial needs. Available population forecasts will be used in the development of the load forecast.

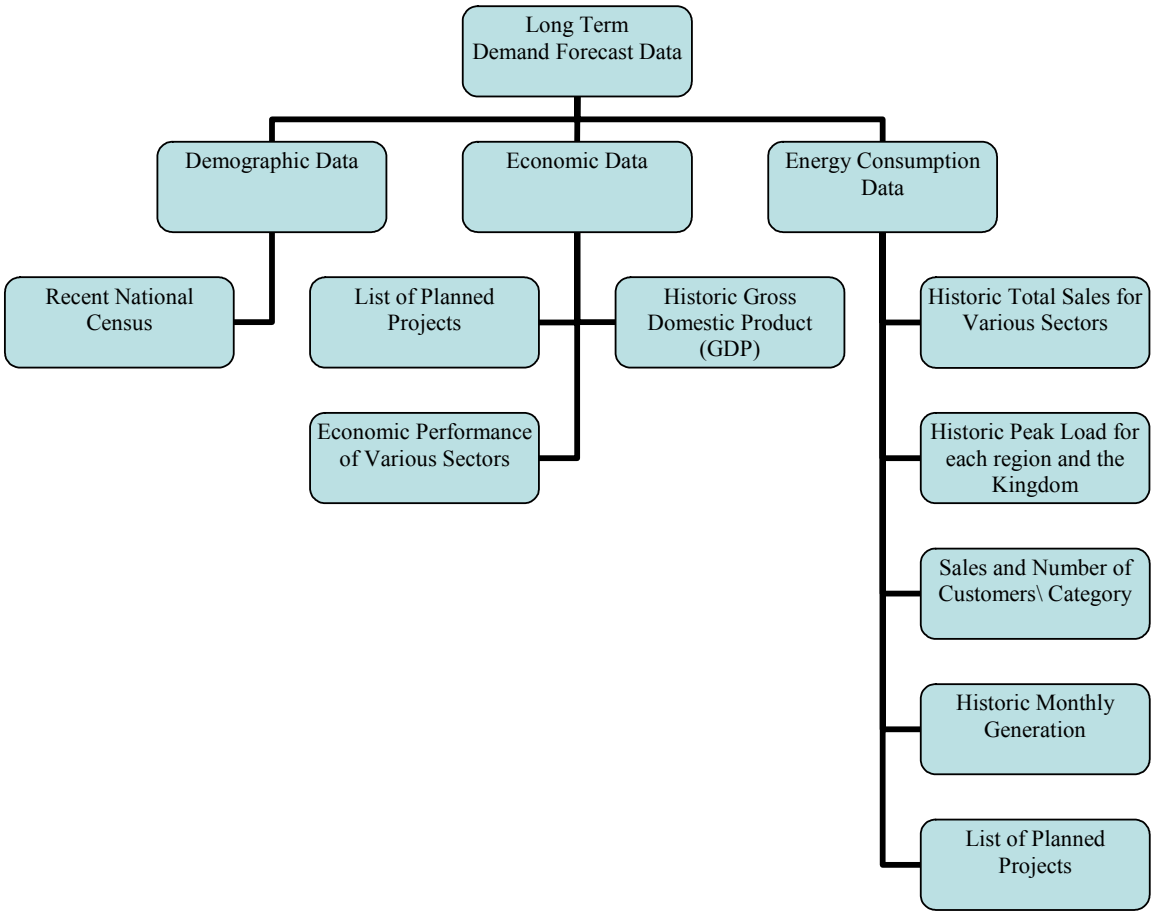


Figure 3.2. Long term load forecast data.

The first stage in developing the population forecast will be to examine the results and the methodology used in the demographic models developed by the concerned agencies in the Kingdom. The methods and the global result for the country will be compared to the latest population forecast made for the country by international agencies like the United Nations, the World Bank, and the US Bureau of Census.

Economic Data

The electricity consumption based on the economic sectors or the consumption sectors (residential, commercial, government, industrial, agricultural, etc.) can be explained using socio-economic variables and indices associated with those sectors.

As described above, the base demographic data will be collected from the National Census, the Government, and from international agencies. The economic data are usually available from numerous sources. The most useful economic data is the historical Gross Domestic Product (GDP) and its breakdown into economic sectors. Factors like employment, personal income, government programs, and others, will also be considered as available. These economic data are the key to the development of the commercial, institutional, large industry, small industry, and agricultural sector forecasts. A long-term economic forecast from governmental agencies would also be very useful in applying the forecasting model.

Energy Consumption Data

Energy consumption data will be the key to understanding the consumption profiles of the different regions and the various sectors of activity. The important element in proper data validation is to transform the data into useful information that will feed the basic models used in developing the forecast. The first goal will be to identify weak data areas needing supplementation and strengthening. For example, the reliability of the historical billing data and the relationship with power generation data will be reviewed.

The data provided should include:

- Billing data (with number of customers and energy sold) for several historical years, for each category of customers and for each area of the Kingdom
- Tariffs and average price of electricity
- The peak load (coincident and non-coincident) for each area and the Kingdom for the historical years
- The monthly historical generation data
- Historical hourly load profiles for a few selected years
- Information on planned new projects for the industrial, commercial, and institutional sectors (modernization and expansion programmes)

- Industrial demand by major customer and expansion programmes of the key national industries
- Plans for governmental and commercial developments
- Plans for new housing developments (new towns)
- Patterns of electricity consumption including diurnal and seasonal variations
- Consumption and prices for other forms of energy
- Loss reduction programmes and objectives

Demand Forecast Methodology

Analytical (disaggregated) methods which consider the end-use of electricity will be used to develop the demand forecast. These models will be applied on a regional and customer category basis. This group of models uses analytical techniques which utilize a multi-regional end-use approach for forecasting. For each customer, the supply needs are broken down into utilization types which are defined according to specific explanatory variables (such as the number of customers and the corresponding per unit consumption). The extent of this disaggregating depends on the data available. Projections of these explanatory variables are made using utility data for the number of new customers and/or network extensions, and external data for demographic and economic forecasts.

The areas to be considered in the regional analysis will be selected, in conjunction with the MOWE, on the basis of the historic breakdown of historic data into areas. Figure 3.3 shows a schematic diagram for analytical load forecast methodology which will be adopted during the study.

3.2.4 Generation Planning

The input to the generation planning process is the comprehensive data defining the output from demand forecast study, generation planning criteria, the existing and committed generation system, and the generation options to be considered to meet the future demand. These data will be utilized to assess the generation capacity requirements for each major region up to year 2032. The plan shall identify possible scenario of regional surpluses and deficits taking into account the regional plans of generation additions and growth in demand. The developed optimal generation capacity plans will be based on the following:

a. Power Generation Options

Power generation options as depicted in Figure 3.4 will include steam units, gas units, combined cycle units, diesel units, and co-generation based on future Saline Water Desalination Plans (SWDP). The input for future SWDP should be provided to the team no later than month no. 8 from the commencement of the

study. In addition, the study shall consider the committed IPP/IWPP and co-generation plans by major industrial customers.

b. Transmission Requirements

Optimal grid interconnection shall be considered in deciding the optimal generation plan. Major transmission upgrade requirements in each region shall also be taken into consideration.

c. Inter-Regional Power Exchange

Power exchanges between regions shall be taken into consideration.

d. Fuel Supply

The optimal generation plans shall be developed taking into account the existing and future planned fuel supply proposed by the Ministry of Petroleum and Minerals.

e. Foreign Power Import

The generation plan shall take into consideration the import from the Gulf Cooperation Council (GCC) countries and the firm power exchange agreements with any neighboring countries provided the data related to this is made available before month no. 8 from the start of the project.

Figure 3.4 depicts the data required to carry out the generation planning study.

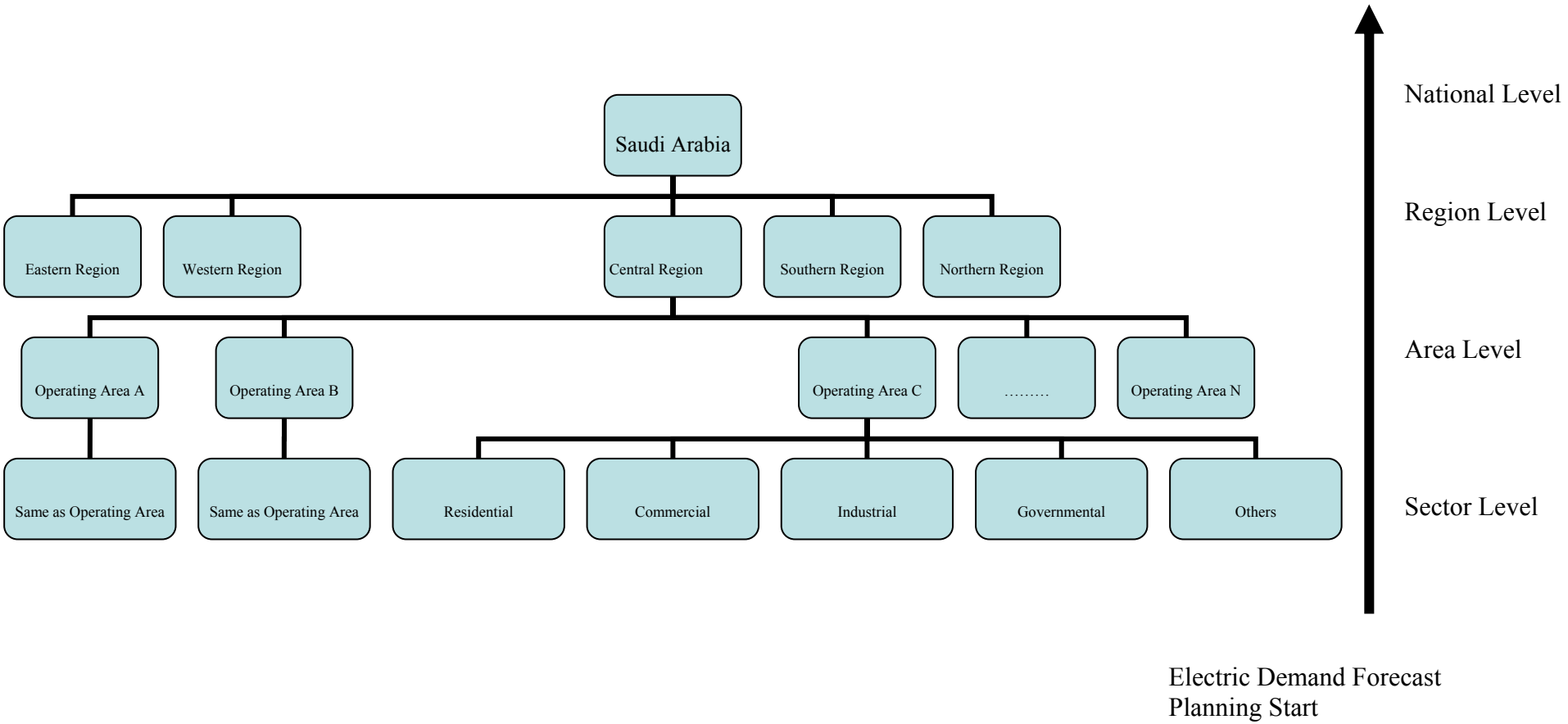


Figure 3.3. Desegregation demand forecast as applied to the Kingdom of Saudi Arabia.

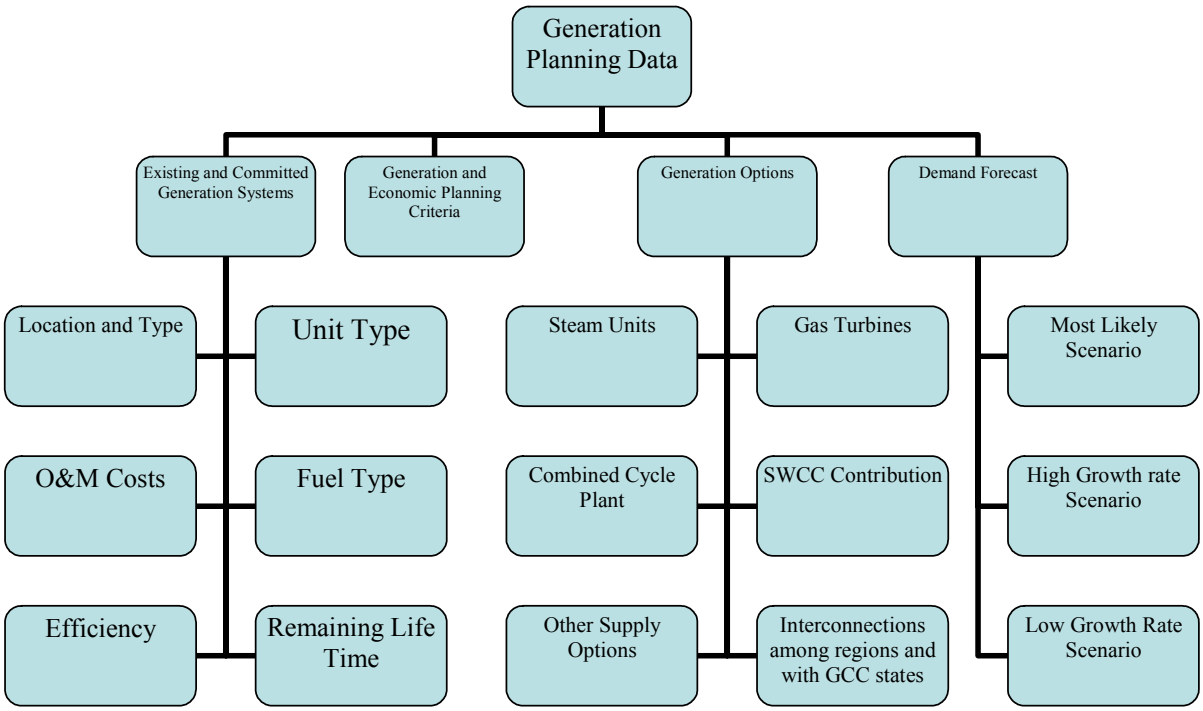


Figure 3.4. Data required for electricity generation planning.

Generation Planning Methodology

Alternative generation expansion scenarios will be initially formulated using the options identified in the study. The timing of generation additions will be optimized so that each sequence meets a pre-determined reliability criterion. Detailed simulation of the sequences will then be carried out using ***STRATEGIST*** software. Appendix C gives a brief description of the software capabilities and features. Depending on the results of the analysis, further sequences will be tested until an appropriate plan for the base case assumptions is derived.

The result of the generation planning studies will be a definition of the schedule, type, and size of the generation additions for each year of the plan period. Once these additions are determined, the selection of suitable locations can be made by considering the relative economics and feasibility of extending existing sites and/or developing new sites. This will allow the site requirements to be quantified in terms of the number of units, unit size and type, substation capacities, fuel handling/storage facilities, infrastructure, etc. which will enable the costs associated with each site to be included in the comparison of alternative development scenarios.

The main economic criteria used to compare alternative sequences are the discounted value, at an agreed discount rate of all system costs. An analysis of the load forecast, the reliability/reserve criteria, and the performance characteristics of the existing and committed generation will define the timing and magnitude of the additional generation required.

The present worth of all costs, both operation and investment costs will be determined for a series of discount rates. A comparison of the present worth of the different system development plans will be used to determine the least cost development sequence. The least-cost development plan will be based on the most-probable demand forecast scenario.

The following studies will be considered in developing generation planning:

- Reliability analysis studies;
- Generation resource and capacity expansion studies;
- Production simulation studies;
- Sensitivity Analysis studies;

Reliability Analysis Studies

The project team will take into consideration the definition of an acceptable reliability target for the system. Reliability analysis studies will take into account demand forecast, load shapes, sizes and outage characteristics of generation units in the region to evaluate the probability of the system not being able to serve a certain amount of load, for an acceptable duration. The loss-of-load probability (LOLP) method has been the most commonly used.

Generation Resource and Capacity Expansion Studies

The generation capacity expansion study seeks to develop a plan for resource additions that will adequately serve the expected demand. In other words, the study will yield a capacity expansion program for the system by comparing the demand forecast and system reserve margin requirement with the total installed capacity of all existing generation units. Probabilistic simulation models with forward-looking capability or iterative algorithm are commonly used to determine the timing, quantity, and characteristics of the capacity expansion program.

Parameters, such as the efficiency of the generation option as well as the fuel cost projection, are crucial to the analysis. Uncertainties of load growth and fuel availability, as well as generation potentials from hydroelectric units, also require additional attention.

Production Simulation Studies

One of the selection criteria for a viable EGTP is to determine if the plan yields the least total system cost. The capital cost required for building new plants, the labor and materials cost of plant maintenance, the cost of fuel depending on the type of units, the interest rate, and the financing costs are all part of this cost equation. Resources with low fuel costs will be dispatched to a greater degree during operation, thus running as base-load resources. The evaluation and tradeoffs among different generation types can be very complex. Production simulation models are therefore developed to aid in these types of complex analyses. The project team will use these models to simulate the operation of future systems, computing fuel, operational and maintenance costs.

Sensitivity Analysis

Sensitivity studies will be carried out to determine the impact of alternative planning and economic assumptions on the proposed development plan. The key parameters which will be analyzed include the following:

- Demand forecast
- Unit types
- Fuel types, costs, and escalation rates
- Capital costs and escalation rates
- Discount rates
- System interconnections

The sensitivity analysis will assess the effect of variations in the key parameters on the results and thus decisions could be made on the development strategy to be adopted after assessing risks associated with the variations of the pre-mentioned key parameters. The result of this assessment will lead to a definition of the long term

strategy based on the least-cost expansion sequence as well as the determination of the short and medium term expansion strategies.

The above studies will be primarily carried out using the ***STRATEGIST*** software. A brief description of the program capabilities is presented in Appendix C.

3.2.5 Transmission Planning

As an integral part of the EGTP, consideration must be given to the primary transmission network required to integrate the new generating facilities into the existing network, to cater for shifting load patterns and the general increase in load levels through the planning period and the integration of the GCC interconnection. These studies will be principally directed at determining the transmission needs in the Kingdom. The transmission study would evaluate and analyze options of providing open access electric power transmission system to competing IPPs/IWPPs in the new regulatory environment.

The demand forecast will be used in conjunction with the proposed generation development plan, transmission and economic planning criteria, and the existing and committed transmission plans to determine the transmission necessary to integrate the generation into the system and for system reinforcement to deliver the generation to the load with an acceptable level of reliability and within the planning criteria adopted. Figure 3.5 shows the necessary data to be collected for carrying out the transmission planning.

The existing substation load forecast for the period will be reviewed in the context of the area-wise load forecast, prepared as part of the master plan, and any additional information which may become available during the course of the study.

The substation forecast will be adjusted if necessary and projected forward to the year 2032.

The output of the generation planning study in terms of units' size, location, and time of installation will be fed into the transmission planning study. Transmission planning is concerned with providing suitable optimum way to integrate this newly installed capacity into the system to feed the expected load growth.

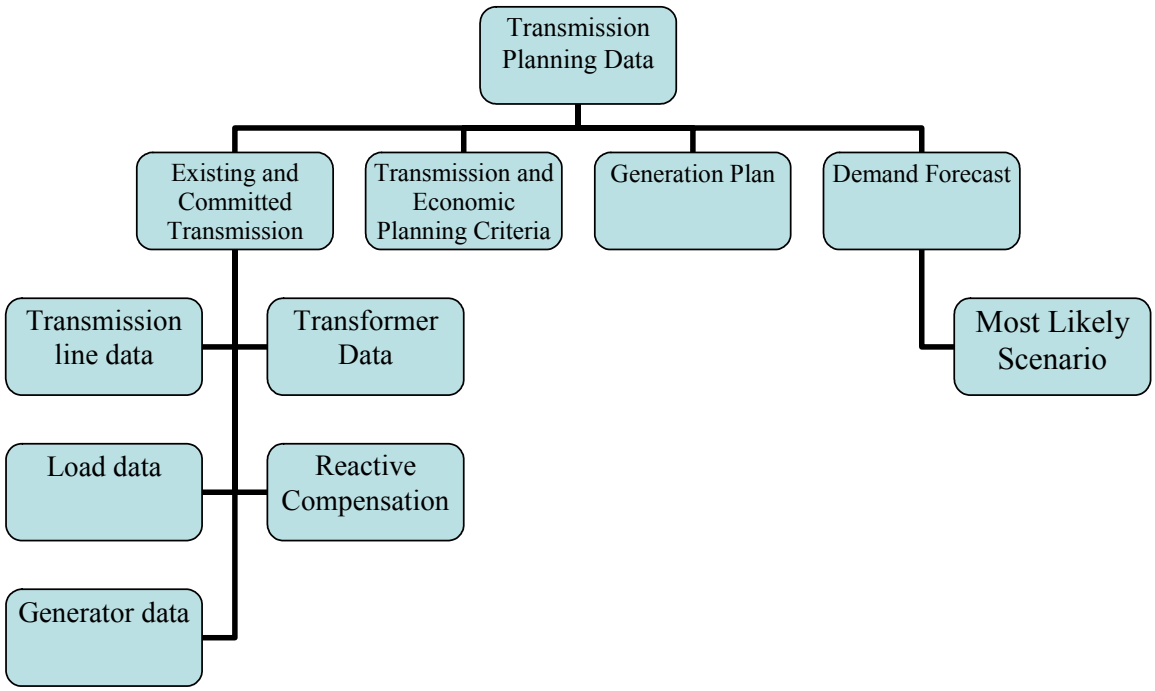


Figure 3.5. Transmission planning data.

Transmission Planning Methodology

Conceptual transmission planning studies will be carried out to investigate various transmission alternatives to integrate the generation additions into the network and to determine the requirements for additional transformer capacity at the bulk supply stations. For the generation-driven reinforcements, a range of plant sizes and locations will be defined during the initial assessment of generation expansion alternatives. For each of these plant sizes, a number of transmission alternatives will be developed taking into account the following factors:

- Plant size and unit size
- Location of the plant with respect to the grid
- Alternative voltage levels
- Number of circuits required
- Circuit capacity requirements

The results of these conceptual studies will be fed back into the generation planning studies so that the cost associated with transmission for each alternative plant can be properly taken into account in the generation planning studies. Given the limited number of sites that are available for new generating units (both at existing plants and for new sites), it is especially important to include the transmission and site development costs associated with each expansion alternative.

For the load-driven reinforcements to substation capacity, account will be taken of the following factors:

- Existing substation locations
- Existing transformer ratings
- Capacity for extension of existing substations
- Location of new substations
- Transformer ratings and arrangement for new substations
- Short circuit limitations

Each of these alternatives will be examined to determine the technical requirements (number of circuits, requirements for reactive compensation) and the impact of right-of-way requirements on the cost. This evaluation will enable the optimum transmission alternative for each generating plant to be determined together with the reinforcements required in existing substations and the need for new substations to feed loads in developing areas and to prevent overloads on existing substations.

The detailed transmission planning studies will involve the analysis of those alternatives selected from the conceptual studies and will concentrate on the overall reinforcement requirements of the system as a whole.

The detailed studies for the transmission network will comprise the following:

- Load Flow Studies
- Short Circuit Studies
- Stability Studies

Load Flow Studies

Load flow studies will be carried out for a selected number of years throughout the study period, 2008-2032. The years selected for analysis will be based on the increase in load in specific areas and on the rate at which generation is added to the system.

As a starting point, the existing system will be modeled first. This will serve as the basic building block for future additions. Load flow study will be carried out to check the integrity of the model and to ensure that it is free of errors. These studies will also indicate whether the existing system performs satisfactorily and will identify problems, if any, with the existing system. The data required for this analysis is readily available with the MOWE. Load flow studies will examine the peak load and minimum load conditions. Peak load conditions usually reveal areas of the system that need to be reinforced, while minimum load conditions usually indicate the need for reactive compensation. Contingency cases will be run in order to ensure that such events will not result in equipment overloading or unacceptable voltages.

Short Circuit Studies

Short circuit studies will be carried out to determine the maximum fault levels that the equipment will be subjected to. The maximum fault levels will be used to assess the ability of existing equipment to withstand the future operational stresses and to determine the short circuit capability required of any new equipment to be added to the system. The maximum and minimum fault levels also provide an indication of the sensitivity of the system to small disturbances such as reactive equipment switching. Where fault levels are seen to exceed the capability of existing equipment, adjustments to the system configuration, fault-limiting equipment, or replacement with higher-rated equipment will be investigated and a course of action recommended.

Stability Studies

The transient stability studies would be conducted to determine the dynamic performance of the system following a 3-phase fault and network element outages. The stability studies to be carried out would be selected based on the network configuration and the results of the steady state load flow studies. Various contingencies for each of the region for the spot years (every 5 years) would be

analyzed and the system performance would be evaluated. The East and the Central Region systems are proposed to be treated as a single model consisting of the bulk systems of the interconnected systems. Various level of power transfer would be taken into account. Studies would be conducted for various interconnecting links such as West-Central and West-South to check for the system performance for the maximum power transfer. The contingency cases to be studied would be finalized in consultation with the client. Most of the cases would correspond to the peak load condition. Some critical cases for the low load condition would also be performed.

Transmission planning studies will be carried out by utilizing ***PSS/E and TPLAN*** software. A brief description of the programs capabilities is included in Appendix C.

3.2.6 Economic and Financial Studies

This task will primarily be carried out by international consultant ***SNC Lavalin*** in close cooperation and consultation with the project team at KFUPM.

An overall method of financial analysis will be adapted to produce the impact of the investment plan at the national level. The investment plan of the project will be primarily derived from the data produced in the electricity generation and transmission studies.

Data Requirements

The input data for the financial model is derived from other reports that would be produced for this project. The data are taken from the load forecast, the investment (generation and transmission) plan, and estimates for distribution expansion investment requirements.

The load forecast (extracted from the load forecast report) provides data at three distinct voltage supply levels: high voltage level for the largest industrial consumers, medium voltage for the larger commercial and industrial loads and at low voltage level for the smaller commercial and residential consumers. At each voltage level, an estimate of the technical losses is required so that the net generation required to serve a particular consumer category can be determined. This ensures that the true cost of serving a kWh to the consumer includes the losses in the system and that these losses are assigned to the consumers.

Generation expansion data (extracted from the generation planning report) is required at the individual generating plant level. This entails listing each generation project with its capacity (MW), energy (GWh), investment cost, operation and maintenance costs, fuel costs, year in service, local and foreign content, and cash flow denoted in percentage of capital cost that is disbursed during the construction phase.

Transmission expansion data (extracted from the transmission planning report) is required at the high and medium voltage levels so that the costs are assigned to the different voltage levels at which the consumers are served. The annual investment in transmission, sub-transmission and substations is compiled and include in the overall investment plan, together with the annual operation and maintenance costs of the new investments.

Distribution expansion data (based on extrapolation of historical investment requirements) is applicable only at the low voltage level so that distribution costs are assigned only to the low voltage consumers. The planning of low voltage networks depends primarily on short term (3-5 years) requirements. An estimate of long term requirements will be based on historical ratios for the purposes of the financial analysis.

Historic data (based on extractions from Income Statements and Balance Sheets) will be consolidated into a uniform format. This data includes sales data (by customer category) and number of consumers per category.

Financial criteria will be based on the economic/financial data used in the development of the investment plans as well as prevailing financial criteria currently in effect in the Kingdom. This would include: discount rate; Zakat rate; inflation rate; interest rate (for new loans), interest rate on existing debt; public equity dividend yield; interconnector costs; existing tariffs and any electricity fees or taxes.

Financial Analysis Methodology

A financial analysis package for electric utilities developed by an international project team will be used to model the entire utility operation taking into account the load forecast and the investment requirements for the sector. To relate this data to the financial impact of the investment requirements, the future expansion and investment plans will be linked to the actual financial performance based on historical data extracted from audited financial statements.

The analysis package of the model is used to answer '***what if?'*** questions when the input variables are varied.

The review of the historical financial performance will include:

- Assets utilization
- Accounts receivable
- Debt Equity Ratios
- Profitability

A number of basic scenarios such as the following will be considered:

- Level of subsidies
- Impact of changes in tariffs
- Sensitivity analysis to test the impact of varying the main economic and financial parameters of the study

This analysis will provide information for future analysis on.

- Current tariff levels

- Impact of subsidies for loss-making regions
- Impact of cross-subsidization
- Potential time frame for implementing change
- Target financial performance for the sector
- Tariff structures

3.2.7 Fuel Needs

After finalizing the generation expansion plan and identifying the necessary generation units' type, locations, and time of installation, the project team will run production costing studies to calculate the required fuel needs; these studies will be run on monthly basis to estimate the fuel needs for the Kingdom during the study period (2008-2032). Generation and Fuel Module provided with STRATEGIST software will be utilized to conduct this study.

SECTION 4 STATEMENT OF WORK

The work involved for the proposed study is divided into the following Tasks:

4.1 TASK 1: DATA COLLECTION

1. Prepare data collection questionnaire.
2. Arrange a meeting to explain questionnaire and agree on the basis of the process of data collection.
3. Collect and update mainly the following data related to the Kingdom from the MOWE, SEC, ECRA, SWCC, Saudi Aramco, Marafiq, GCC grid authorities, Ministry of Planning etc.

    a. Demand forecast data

        - Energy consumption data (as per detailed in Section 3.2.3);
        - Demographic data (as per detailed in Section 3.2.3);
        - Economic data (as per detailed in Section 3.2.3).

    b. Existing and committed generation system data

        - Location and type of unit;
        - Unit capacity;
        - Fuel type;

- Operation and maintenance costs;
- Unit efficiency and heat rate;
- Remaining expected life time of the unit.

c. Existing and committed transmission system data including future planned international interconnections

- Transmission line data;
- Transformer data;
- Load data;
- Reactive compensation;
- Generator data.

4. Validate and formatting the collected data

5. Establish an updated coherent data base of all components in the Kingdom of Saudi Arabia electric power system;

6. Prepare the Milestone 1 report.

4.2 TASK II: DEVELOPMENT OF PLANNING BASIS

1. Specify generation planning criteria as depicted in subsection 3.2.2

2. Specify transmission planning criteria as depicted in subsection 3.2.2

3. Specify economic analysis criteria as depicted in subsection 3.2.2

4. Prepare Milestone 2 report 'Planning Basis Memorandum'.

4.3 TASK III: DEVELOPMENT OF ELECTRICITY DEMAND FORECAST

1. Analyze demand forecast data to reveal sectorial, regional, and Kingdom characteristics

2. Adjust load forecast model parameters and assumptions

3. Develop a global and disaggregated electricity demand forecast for the reference case (most likely condition)

4. Develop a global and disaggregated forecast for high growth scenario and low growth scenario (Sensitivity analysis)

5. Prepare Milestone 3 report.

4.4 TASK IV: DEVELOPMENT OF ELECTRICITY GENERATION PLANS

1. Collect all technical and cost data for the units that will be considered in generation expansion as agreed on planning criteria;

2. Validate and formatting the collected data;

3. Screen of supply side alternatives which include input from SWDP study;

4. Develop reference expansion plans for the regions with existing interconnections;

5. Develop unified expansion scenarios with future regional interconnections and any firm transfer with neighboring countries;

6. Develop a reference expansion plan for isolated load centers;

7. Run production and operation simulation models for the reference case (most likely scenario);

8. Conduct sensitivity analysis;

9. Estimate cost associated with the generation expansion planning;

10. Prepare the Milestone 4 report.

4.5 TASK V: DEVELOPMENT OF ELECTRICITY TRANSMISSION PLANS

1. Collect all technical and cost data for the transmission system components that will be considered in transmission expansion as agreed on planning criteria;

2. Validate and formatting the collected data;

3. Model the bulk transmission network;

4. Model different expansion scenarios;

5. Analyze system performance for alternative expansion scenarios;

6. Develop a bulk transmission requirement for the reference case (most likely conditions) for the study horizon, capacity, voltage levels, and timing taking into consideration input from electricity generation plan, regional interconnection, and GCC interconnection.

7. Conduct standard transmission studies such as load follow, short circuit, and stability analysis for various scenarios;

8. Optimize the transmission planning;

9. Estimate cost for Transmission Line expansion plan;

10. Prepare the Milestone 5 report.

4.6 TASK VI: ECONOMIC AND FINANCIAL STUDIES

1. Collect relevant historical and current financial data;

2. Validate and formatting the collected financial data;

3. Prepare the relevant data from Generation and Transmission plans;

4. Financial modeling operation;

5. Perform sensitivity analysis and "what if" scenarios;

6. Develop final investment plan.

7. Prepare the Milestone 6 report.

4.7 TASK VII: DETERMINATION OF FUEL NEED

- Determine fuel needs based on most likely scenario

4.8 TASK VIII: REPORTING

Report covering each of Tasks 1 – 6 will be submitted after completion of each task as Milestone 1 – 6. A final report covering the entire project will be submitted at the end of project as Milestone 7. An internal report indicating the fuel requirement will be submitted, however, this report will not be included in the final report. The details of reports to be submitted are as follows:

1. Milestone 1: Electricity Generation Transmission Plan (EGTP) Data report.

2. Milestone 2: Planning Basis report.

3. Milestone 3: Electricity Demand Forecast report.

4. Milestone 4: Electricity Generation Plans report.

5. Milestone 5: Electricity Transmission Plans report.

6. Milestone 6: Economic and Financial Studies report.

7. Internal Report: Fuel Needs for Electricity Generation based on the EGTP.

8. Milestone 7: Electricity Generation and Transmission Plan Final report.

SECTION 5 DELIVERABLE ITEMS

The proposed study will be carried out through a close association and partnership between KFUPM/RI and the Ministry of Water and Electricity (MOWE). For effective and efficient communication, the Project Manager at KFUPM/RI will act as the principal contact point. Similarly, the MOWE will assign a senior-level executive as the project coordinator.

Items to be provided during the proposed work are shown in the project deliverable item list (PDIL) in Tables 5.1 and 5.2. The items to be delivered by KFUPM/RI to MOWE and by MOWE to KFUPM/RI are as follows:

A: KFUPM/RI will provide the following items to the MOWE:

1. Electricity Generation Transmission Plan (EGTP) Data Report, Milestone 1.
2. Planning Basis Report, Milestone 2.
3. Electricity Demand Forecast Report, Milestone 3.
4. Electricity Generation Plans Report, Milestone 4.
5. Electricity Transmission Plans Report, Milestone 5.
6. Economic and Financial Studies Report, Milestone 6.
7. Internal Report, Fuel Needs for Electricity Generation Based on the EGTP.
8. Final Report, Electricity Generation and Transmission Plan for the Kingdom of Saudi Arabia, Milestone 7.
9. A complete set of soft copy of all data, reports of each milestone, as well as final master plan.

B: KFUPM/RI will receive the following items from the MOWE:

1. Data as indicated in Section 4.1 above available with MOWE.
2. Letter of introduction and support to collect data from SEC, Saudi Aramco, MARAFIQ, SWCC, and other relevant ministries and governmental organization in Saudi Arabia and GCC states.
3. Input from the Saline Water Desalination Plan (SWDP) regarding their electric generating capacities from Co-generation units and locations of these units after approval from the steering committee.
4. Data related to the firm power exchange agreements with neighboring countries.
5. Approvals of Milestone 1.

6. Approvals of Milestone 2.

7. Approvals of Milestone 3.

8. Approvals of Milestone 4.

9. Approvals of Milestone 5.

10. Approvals of Milestone 6.

Table 5.1. Project deliverable items list:
Items to be provided by KFUPM/RI.

Item	Description	Quantity	Delivery (in working months)
A-1	Electricity Generation Transmission Plan (EGTP) Data Report, Milestone 1.	10	7
A-2	Planning Basis Report, Milestone 2.	10	7
A-3	Electricity Demand Forecast Report, Milestone 3.	10	12
A-4	Electricity Generation Plans Report, Milestone 4.	10	16
A-5	Electricity Transmission Plans Report, Milestone 5.	10	21
A-6	Economic and Financial Studies Report, Milestone 6.	10	23
A-7	Internal Report, Fuel Needs For Electricity Generation Based On The EGTP.	10	22
A-8	Final Report, Electricity Generation and Transmission Plan for the Kingdom of Saudi Arabia, Milestone 7.	10	24
A-9	Complete set of soft copy of all data, reports of each milestone as well as final master plan.	20	24

Table 5.2. Project deliverable items list:
Items to be provided by MOWE.

Item	Description	Quantity	Delivery (in working months)
B-1	Data as indicated in Section 4.1 above available with MOWE.	1	1
B-2	Letter of introduction and support to collect data from SEC, Saudi Aramco, MARAFIQ, SWCC, and other relevant ministries and governmental organization in Saudi Arabia and GCC states.	1	1
B-3	Input from the Saline Water Desalination Plan (SWDP) regarding their electric generating capacities from Co-generation units and locations of these units after approval from the steering committee.	1	8
B-4	Data related to the firm power exchange agreements with neighboring countries.	1	8
B-5	Approvals of Milestone 1.	1	8
B-6	Approvals of Milestone 2.	1	8
B-7	Approvals of Milestone 3.	1	13
B-8	Approvals of Milestone 4.	1	17
B-9	Approvals of Milestone 5.	1	22
B-10	Approvals of Milestone 6.	1	24

Prior to contract signature, the calendar dates for start and end of the project as well as for all deliverables (PDIL) shall be determined. A schedule showing all these dates as well as a payment schedule shall be part of the contract documents at the time of contract signature. Any subsequent changes during project execution shall be made by mutual agreement and will be accomplished by means of a change order.

SECTION 6 SCHEDULE

The proposed research project will be carried out over a period of twenty four working months. The Research Institute will be closed for annual vacation during the month of August. The locations of any other holidays in the work schedule will be determined at the time of signing the contract.

KFUPM/RI will do its best to strictly adhere to the project schedule. The strict adherence to the project schedule will be facilitated if the deliverable items from MOWE are received in a timely manner. Various tasks of the project including schedule of accomplishment are summarized in Figure 6.1, which also gives the detail work involved in each task.

SECTION 7 MANAGEMENT PLAN

A joint team from the Research Institute, the Department of Electrical Engineering (EE), King Fahd University of Petroleum & Minerals and SNC-Lavalin, Montreal, Canada will conduct the proposed study. Participating from the Research Institute will be the KFUPM/RI Center for Engineering Research (CER).

The work shall be coordinated by the project team as per a project coordination chart (Figure 7.1). Dr. Ibrahim M. El-Amin is expected to be the project manager and will be responsible for the day-to-day management aspects of the project. Specifically, he will be responsible for:

1. The technical quality of the work,
2. The timely and comprehensive reporting of work progress and results,
3. The timely completion of individual tasks and of the entire project,
4. The control of costs, and
5. The coordination of the work of the project team.

The following personnel will be involved in conducting this study:

1. Dr. Ibrahim El-Amin, Project Manager, Professor, EE Department,
2. Dr. A. H. Abdur Rahim, Professor, EE Department,
3. Dr. Ibrahim Habiballah, Associate Professor, EE Department,

4. Dr. M. A. Abido, Associate Professor, EE Department,

5. Dr. Tarek K. Abdelgalil, Research Engineer-III, CER,

6. Mr. Mohammed Arif Abdul-Majeed, Research Engineer-III, CER,

7. Mr. Firoz Ahmad, Engineer-I, CER

8. Mr. Khaled Al-Soufi, Research Engineer-III, CER,

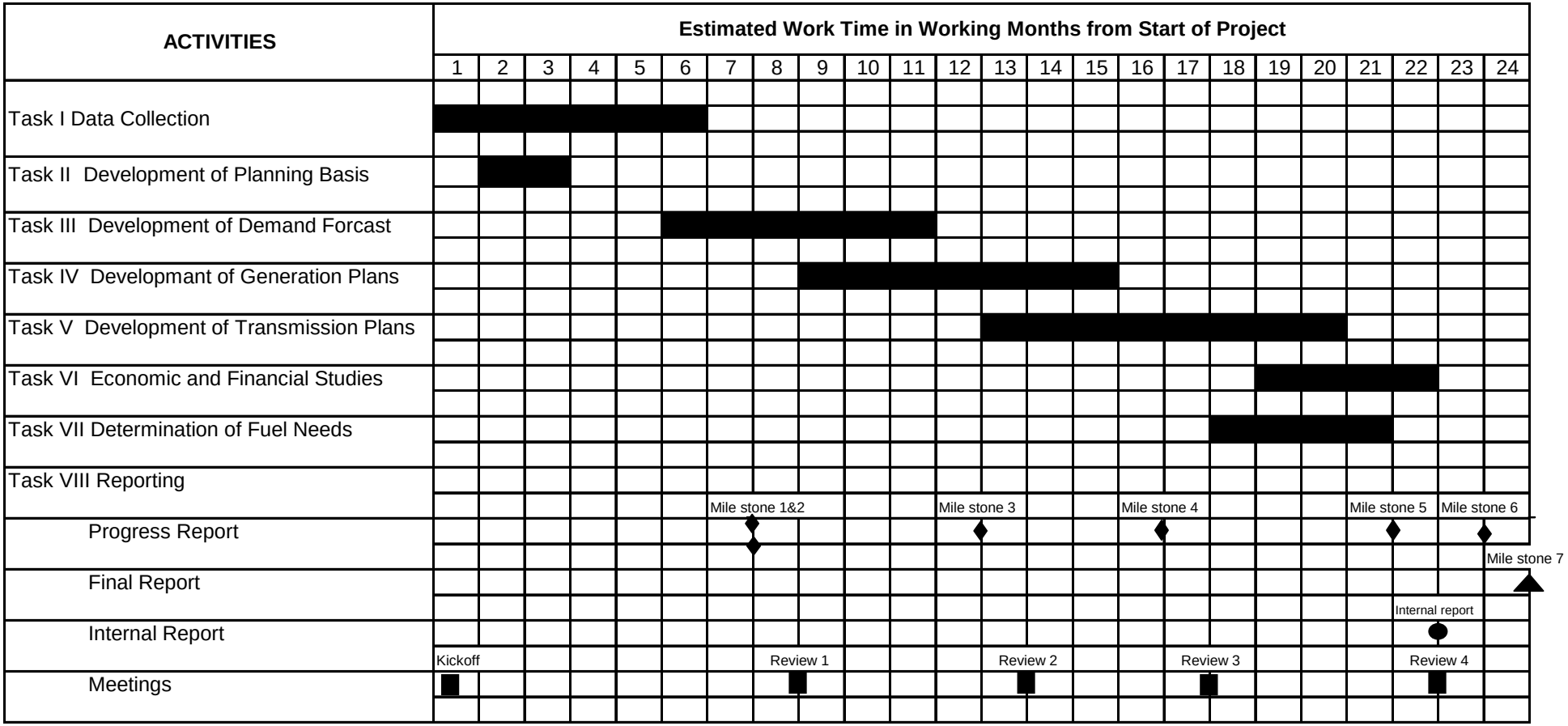
9. Dr. Mahmoud Kassas, Assistant Professor, EE Department,

10. Dr. Zakariya Al-Hamouz, Associate Professor, EE Department,

11. Mr. Ali T. Al-Awami, Lecturer, EE Department,

Additional support staffs are also available with KFUPM/RI such as software programmers, data loggers, draftsmen, secretaries, etc. Their services will also be utilized during the course of the study.

The resumes of the personnel who will be associated with this project are given in Appendix B.



The Research Institute observes official vacation periods during which work on contract research is ordinarily suspended. These periods are the month of August and official government holidays such as the two Eids. At the beginning of the execution of this proposed project the position of these breaks with respect to the project schedule will be determined and the due dates of project milestones will be set accordingly. The time periods noted in the above schedule are working periods and do not incorporate the official vacation periods.

Figure 6.1. Work schedule.

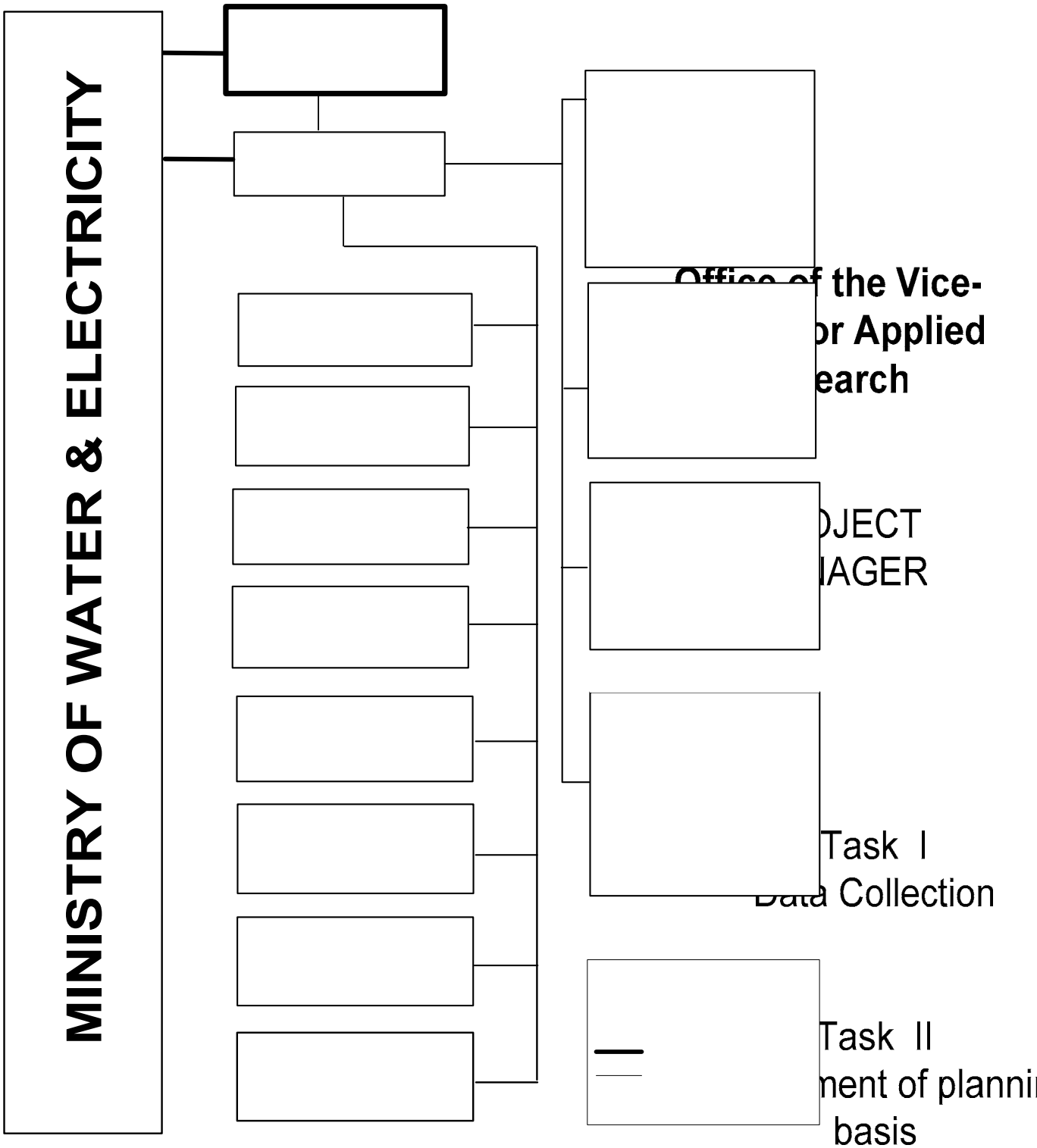


Figure 7.1. Project coordination chart.

SECTION 8 PROJECT CONSULTANT

SNC-Lavalin, Montreal, Canada will be the project consultant, they will be in-charge for Task III, Development of Demand Forecast and Task VI Economic and Financial Studies, in close corporation and consultation with the KFUPM team. Moreover, advisory consultancy may be sought as and when required. However, it should be noted that the KFUPM team will conduct all the other tasks and as indicated in Section 7 the project manager at KFUPM will be overall in-charge for the project. It should be noted both KFUPM and SNC Lavalin will work in very close cooperation during the execution of the study.

The company profile of SNC-Lavalin and CV of their experts in the field of demand forecast and economic and financial studies are attached in Appendix D.

SECTION 9 COST

The proposed work will be performed at a lump sum price of SR 7,000,173 (Seven million, one hundred and seventy three Saudi Riyals). This proposal and the price quoted herein are valid for period of 90 days from the date of submittal. The cost breakdown of different items is as follows:

Description	Cost
Manpower, Travel, and Other	SR 3,567,173
International Consultant	SR 1,800,000
Software	SR 1,633,000

SECTION 10 GENERAL TERMS AND CONDITIONS

The services and products described in this proposal are offered under the General Terms and Conditions of the Ministry of Water and Electricity as given in the Terms of Reference and KFUPM/RI General Terms and Conditions as described in Appendix E. However, it should be noted that KFUPM cannot be held responsible for delay in project execution for reasons beyond its control.

SECTION 11 RESOURCES AND FACILITIES

11.1 PAST AND ON-GOING ACTIVITIES OF THE ENERGY SYSTEMS SECTION

In the power-system area the Energy Systems Section, has worked on several projects. The first important two-year study dealing with the feasibility of interconnecting the GCC electrical networks was completed in August 1986. It was followed by a related two-year feasibility study of interconnecting the power systems of the Mashreq Arab countries, involving 12 countries and 17 electric utilities. The study was successfully completed in April 1991. The study objectives were to assess the future expansion plans of individual utilities, propose alternative expansion plans with interconnection(s), determine engineering and economic feasibility, and provide necessary recommendations. These studies encompassed many areas of power engineering, such as demand forecasting, generation and transmission expansion planning, production costing, AC/DC conversion, network analysis, electrical interconnection, and economic analysis.

In December 1992, the Energy Systems Section became engaged in a 15-month study dealing with the evaluation of electric energy trading benefits within some Mashreq Arab countries. The objectives of the study were to evaluate the potential benefits, which could be realized through energy trading within an interconnected Mashreq Arab electric power system involving Saudi Arabia, Egypt, Kuwait, and Qatar. The study was completed in a timely manner. In March 2006 the section completed a study entitled Updated Generation Planning for the Saudi Electricity Sector. The objective of this study was to develop a 15 years generation plan for KSA and to determine required investment costs.

The Energy Systems Section has also conducted a study related to the interconnection of the power systems of SCECO West and SCECO Central. The objectives of the study were to review the generation expansion plans of the four major electric utilities in Saudi Arabia, and to determine the transmission capacities that would be needed to link SCECO West, SCECO Central, and SCECO South. Another study related to the benefits of interconnecting MAYS with SEC West system. In this study the potential benefits of the existing interconnecting link between the Madinat Yanbu Al-Sinaiyah (MYAS), Yanbu power system and the Saudi Electricity Company - the Western Region Branch (SEC-WRB), Jeddah were determined.

Energy Systems Section

The Energy Systems section provides consulting services and conducts research in the areas of electric power systems and high voltage engineering. Its activities cover all aspects of generation, transmission, and utilization of electric power and many types of high voltage equipment tests. Major clients served by the Energy systems Section include electric utilities, governmental organizations and private industrial establishments.

The section has expertise in electrical network-related studies such as generation capacity planning, transmission network analysis, reliability evaluations, power system interconnection, production costing, harmonics analysis, transients, and electric energy conservation. The section has well-equipped computational facilities for carrying out such studies. The section undertakes research and provides services in high voltage equipment testing and insulator contamination studies utilize a high voltage laboratory.

The electric section has completed several client-funded projects. Some of the recent ones include: refinery residue reduction with three power generation options, peak load reduction by load management, frequency conversion at an industrial complex, and energy trading benefits among countries in the region.

Two laboratories support the work of the Energy Systems section:

- Power System Computer Simulation Laboratory
- High Voltage Measurements Laboratory

APPENDICES

APPENDIX A
REQUEST FOR PROPOSAL

APPENDIX B
RESUMES OF PROJECT PERSONNEL

IBRAHIM M EL-AMIN

Electrical Engineering Department
King Fahd University of Petroleum and Minerals

Personal Information

Date of birth: 1948
Place of birth: HasHESA, Sudan
Languages: Arabic and English

Qualifications

Ph.D.: University of Manchester Institute of Science & Technology (UMIST), 1978
Thesis title *"Security Assessment of AC-HVDC Power Systems"*

M.Sc.: University of Manchester Institute of Science & Technology (UMIST) UK in Power Systems, 1975

B.Sc.: University of Khartoum Sudan, 1971

Area of Specialization

- Power systems planning
- Electric power system interconnection
- Production costing study
- Power system economic

Job History

1971-73 **Assistant Electrical Engineer, Central Electricity & Water Corp**., Khartoum, Sudan. The work involved was - supply distribution to residential and industrial areas at 33, 11, 0.415 kV levels.

1973-74 Teaching Assistant, University of Khartoum, Sudan.

1974-78 Graduate Student at UMIST (UK) for M.Sc. and Ph.D. degrees

1978-To date Faculty Member at King Fahd University of Petroleum & Minerals, Dhahran, Saudi Arabia.

RANK : PROFESSOR ELECTRICAL ENGINEERING

Membership in Professional Societies

IEEE: Senior Member, The Institute of Electrical and Electronics Engineers (USA).
IEE: Associate member, The Institute of Electrical Engineers (UK).

Consultancy Projects

Project	Funding Agency
Updated Generation Planning for the Saudi Electricity Sector. *A study to develop a-15 years generation plan for KSA and to determine required investment costs*	Electricity and Co-Generation Regulatory Authority (ECRA), Riyadh
Electric energy production costing for the Saudi Electricity Sector (Phase-I). *A study to determine and evaluate the electric energy production cost in each of the power stations in KSA.*	Electricity and Co-Generation Regulatory Authority (ECRA), Riyadh
Evaluation of The Plan for Restructuring The Activities of Saudi Electricity Company. *A study to evaluate a report on the restructuring of Saudi Electricity Company.*	Saudi Electricity Company
Wind Energy for Remote Villages *As study to evaluate the potentials of utilizing wind hybrid systems for remote settlements in Saudi Arabia*	Saudi Electricity Company
Utilization of Peak & Off-Peak Electricity Pricing *To develop a time of use tariff for industrial consumers in Saudi Arabia***.**	Saudi Electricity Company
The Benefits of Interconnecting MAYS with SCECO West. *Study to determine the potential benefits of the existing interconnecting link between the Madinat Yanbu Al-Sinaiyah (MYAS), Yanbu power system and the Saudi Electricity Company - the Western Region Branch (SEC-WRB), Jeddah.*	Royal Commission for Jubail and Yanbu.
Test and Evaluation of Harmonic Flicker Levels at Hadeed – Jubail.	Hadeed Company, Jubail
Electric Energy Conservation and Management Within KFUPM Campus. *A study to present and discuss the experience of several organizations in electricity efficiency programs and policies.*	KFUPM, Dhahran
Voltage Dip Study for Jubail Industrial Area. *Study to identify the causes of voltage dips resulting in loss of load in the Jubail industrial area and to provide recommendations that will help minimize the disruption of industrial facilities resulting from the voltage dips.*	Saudi Electricity Company (SEC), Dammam
Energy Trading Benefits Among Mashreq Arab Countries. *The objectives of the study were to determine the potential for electric energy trading among the power systems of the Mashreq Arab countries and to evaluate the viability of an additional interconnection linking Saudi Arabia and the northern Mashreq countries (Egypt, Jordan, Lebanon, and Syria).*	ARAB FUND for Economical and Social Development, Kuwait.
Feasibility Study for the Interconnection of Arab Mashreq	ARAB FUND for

States Electrical Power Systems. A *study to investigate technical and economic feasibility of interconnecting Arab Mashreq States electrical power system.*	Economical and Social Development, Kuwait
Feasibility Study for Interconnection of Arabian Gulf States Electrical Power Systems. *Study to investigate technical and economic feasibility of interconnecting Arabian Gulf electric power systems.*	Saudi Industrial Development Fund
Peak Load Reduction by Load Management. *The main objectives of this project are to review the state of art on Demand Side Management and to propose appropriate procedure for applying these techniques within the Saudi electric utilities.*	KACST
Renewable Energy Power Supply for a Remote Settlement.	KACST
Optimal Planning of Transmission Systems.	KACST
A Master Plan Study of Saudi Arabian Extra High Voltage Transmission System Requirements. *The main objective of this study was to build up a master plan for Saudi Arabia's extra high voltage transmission system.*	KACST
Electrical Energy Conservation At SABIC Affiliates Case Study Petrochemical.	KFUPM
Electric Energy Conservation and Management Within KFUPM Campus. *A study to present and discuss the experience of several organizations in electricity efficiency programs and policies.*	KFUPM
A Survey of Power System Harmonics at SABIC Industrial Facilities –Jubail.	KFUPM
Control of High Voltage DC System in Power Systems.	KFUPM

ABU HAMED M. ABDUR-RAHIM

Electrical Engineering Department
King Fahd University of Petroleum and Minerals

Personal Information

Date of birth: January 11, 1945
Place of birth: Bangladesh
Languages: English and Bengali

Qualifications

Ph.D. (Electrical Engineering):	University of Alberta, Edmonton, Canada (1972)
B.Sc (Electrical Engineering):	University of Engineering & Technology, Dhaka, Bangladesh (1966)

Areas of Specialization

- Power system control
- Power system analysis
- Power system transients and stability
- Optimization and optimum control
- Artificial intelligence in power systems

Job History

1) Lecturer in Electrical Engineering, Engineering University, Dhaka, January 1967 - August 1968, also September 1972 - November 1972.

2) Part-time teaching assistant at the Department of Electrical Engineering, University of Alberta, Canada, September 1968 - January 1972.

3) Research Associate at the Department of Elect. Engineering, University of Alberta, Edmonton, Canada, February 1972 - August 1972.

4) Assistant Professor of Electrical Engineering, Engineering University, Dhaka, and November 1972 - May 1976.

5) Associate Professor of Electrical Engineering, Engineering University, Dhaka, May 1976 - December 1977.

6) Commonwealth Academic Fellow at the Univ. of Strathclyde, UK, January 1978 - September 1978.

7) Assistant Professor of Electrical Engineering, K. F. University of Petroleum and Minerals, Dhahran, October 1978- June 1982.

8) Associate Professor of Electrical Engineering, K.F. Univ. of Petroleum and Minerals, Dhahran, July 1982 - Aug. 1988.

9) Associate Professor of Electrical Engineering and Computer Science, University of Bahrain, Sept. 1988 - Jan., 1991.

10) Professor of Electrical Engineering, University of Bahrain, February 1991- Sept. 1995

11) Professor of Electrical Engineering , K.F. University of Petroleum and Minerals, Dhahran, Saudi Arabia, September 1995

12) The DeVry Institute of Technology, Calgary, Alberta, Canada, February 1998 – October, 1998

13) Visiting Scholar, Department of Electrical Engineering, University of Calgary, Calgary, Canada, August 2003-January 2004 & June-August 2005

Consultancy Projects

Project	Funding Agency
Control of HVDC Links in Power Systems.	King Fahd University of Petroleum & Minerals
Control Design for Large Power Systems: A Case Study on SCECO East.	Saudi Arabian National Center for Science & Technology (SANCST)
Feasibility Study for Interconnection of Arabian Gulf States Electrical Power Systems.	Gulf Cooperation Council
A Master Plan Study of Saudi Arabia's Extra High Voltage Transmission Requirements.	Saudi Arabian National Center for Science & Technology (SANCST)
Robust Shunt Connected FACTS Devices for Power System Damping Improvement.	King Fahd University of Petroleum & Minerals
Voltage Unbalance: Causes, Effects and Mitigation Techniques.	Saudi Electric Company, Riyadh
Self-Tuning Adaptive Stabilizer for a Unified Power Flow Controller.	King Fahd University of Petroleum & Minerals
Investigation of Voltage Unbalance and Harmonics on Transmission Networks.	Saudi Electric Company, Riyadh

IBRAHIM O. HABIBALLAH

Electrical Engineering Department
King Fahd University of Petroleum and Minerals

Personal Information

Date of birth: 1961
Place of birth: Makkah, Saudi Arabia
Languages: Arabic and English

Qualifications

Ph.D.: University of Waterloo, Waterloo, Canada (1993). Thesis title *"Efficient Decentralized Two-Level Power System State Estimation Technique".*

M.Sc.: University of Waterloo, Waterloo, Canada (1989). Thesis title *"Fast-Decoupled Power System State Estimation with An Efficient Data Structure Management".*

M.Sc.: King Fahd University of Petroleum & Minerals, Dhahran, Saudi Arabia (1987). Thesis title *"Power System Generation Reliability".*

B.Sc.: King Abdul-Aziz University, Jeddah, Saudi Arabia (1984).

Area of Specialization

- Power systems interconnection
- Transmission planning studies
- Power quality
- Feasibilities studies
- Power system production costing

Job History

Manager, Energy Systems Section: Research Institute, King Fahd University of Petroleum & Minerals, Dhahran, Saudi Arabia (1998 - 2005).
Associate Professor: King Fahd University of Petroleum & Minerals, Dhahran, Saudi Arabia (June 1998 - To Date).
Teaching Assistant: University of Waterloo, Waterloo, Canada (1987 - 1993).
Graduate Assistant: King Fahd University of Petroleum & Minerals, Dhahran, Saudi Arabia (1984 - 1987).

Membership in Professional Societies

IEEE: The Institute of Electrical and Electronics Engineers.
IEC: International Electromagnetic Commissioning.
SASO: Saudi Arabian Standards Organization.

IASTD: International Association of Science and Technology for Development

Consultancy Projects

Project	Funding Agency
Updated Generation Planning for the Saudi Electricity Sector. *A study to develop a-15 years generation plan for KSA and to determine required investment costs*	Electricity and Co-Generation Regulatory Authority (ECRA), Riyadh
Feasibility study for establishment of an electrical central *laboratory in Saudi Arabia*. *A study to conduct a research project for a consortium that was established by users, importers, and manufacturers of electrical equipment. The consortium was created for studying the feasibility of establishing an electrical testing laboratory in Saudi Arabia*	Consortium of 11 organizations
Electric energy production costing for the Saudi Electricity Sector (Phase-I). *A study to determine and evaluate the electric energy production cost in each of the power stations in KSA.*	Electricity and Co-Generation Regulatory Authority (ECRA), Riyadh
Electric and Magnetic field guidelines evaluation and magnetic field exposures. *A study to evaluate the EMF guidelines and calculate the induced currents for different exposure scenarios of power workers for a typical transmission line.*	Saudi Electricity Company (SEC), Riyadh
Power Quality standards. *A study to review various PQ standards, evaluate the potential PQ monitoring schemes and suggest the available most effective countermeasures to mitigate power quality problems.*	Saudi Electricity Company (SEC), Riyadh
Environmental Effect on Polymer insulators properties power quality standards. *A study to investigate the technical performance of the polymeric insulators in comparison to ceramic insulators and to evaluate the effects of the environmental parameters on the properties of the polymer insulation.*	Saudi Electricity Company (SEC), Riyadh
Electric Energy Conservation and Management Within KFUPM Campus. *A study to present and discuss the experience of several organizations in electricity efficiency programs and policies.*	KFUPM, Dhahran
Voltage Dip Study for Jubail Industrial Area. *An applied research study to identify the causes of voltage dips resulting in loss of load in the Jubail industrial area and to provide recommendations that will help minimize the disruption of industrial facilities resulting from the voltage dips.*	Saudi Electricity Company (SEC), Dammam
Inspection of High Voltage Insulator Test Sites. *A study to evaluate the condition of 10 existing high voltage insulator field test stations for use in future studies.*	Electricity Corporation, Riyadh
Refinery Residue Reduction with Three Power Generation Options. *A study that presents the engineering and economic evaluations and analysis for electricity generation using refinery residues as fuel sources. It focuses on the technical aspects and the economic performance of various conceptual residue-to-power technology options.*	Saudi Aramco, Dhahran
Feasibility Study "Frequency Conversion at the Military	Military Industry

Factory Complex in Al-Kharj. *A study to investigate the engineering and economic merits of three electric energy supply options for the MIC Factory Complex, compare their engineering and economic viability with the existing conditions at the MIC plant, and to provide the client with a basis for making a decision as to the best supply option.*	Complex, Al-Kharj

MOHAMMAD ALI Y. ABIDO

Electrical Engineering Department
King Fahd University of Petroleum and Minerals

Personal Information

Date of birth: 1963
Place of birth: Egypt
Languages: Arabic and English

Qualifications

Ph. D. (10 courses 4/4 GPA, Electrical Engineering) **June 1997,** King Fahd University of Petroleum and Minerals, Dhahran.

M. Sc. (Electrical Engineering) **May 1989,** Faculty of Engineering, Menoufia University, Egypt.

B. Sc. (Dist. with Honor, 1/250, Electrical Engineering) **May 1985**

Faculty of Engineering, Menoufia University

Area of Specialization

- Power systems planning and operations
- Power system dynamic and controls
- Transmission studies

Job History

January 2004 – Present **Associate Professor,** Electrical Engineering Department, King Fahd University of Petroleum and Minerals, Dhahran, Saudi Arabia.

June 1999 – Dec. 2003 **Assistant Professor,** Electrical Engineering Department, King Fahd University of Petroleum and Minerals, Dhahran, Saudi Arabia.

Sep. 1997 – May 1999 **Research Associate,** Electrical Engineering Department, King Fahd University of Petroleum and Minerals, Dhahran, Saudi Arabia.

Sep. 1992 – Aug. 1997 **Lecturer-B,** Electrical Engineering Department, King Fahd University of Petroleum and Minerals, Dhahran, Saudi Arabia.

May 1989 – Aug. 1992 **Assistant Lecturer,** Electrical Engineering Department, Faculty of Engineering, Menoufia University, Shebin El-Kom, Egypt.

Dec. 1985 – May 1989 **Graduate Assistant,** Electrical Engineering Department, Faculty of Engineering, Menoufia University, Shebin El-Kom, Egypt.

Membership in Professional Societies

1. Member of the Egyptian Engineering Society
2. Member of the Institute of Electric and Electronic Engineers [IEEE]
3. Member of the IEEE Task Force on "The Need to Assess Higher Order Terms for Small Signal (Modal) Analysis"
4. Member of the GCC CIGRE Study Committees, Work Group (WG 4-2), "Power System Dynamics,"
5. Member of the Saudi Scientific Society for Electrical Engineers (SSSEE)

Consultancy Projects

Project	Funding Agency
"*Robust design of power system stabilizers for multimachine power systems using intelligent search algorithms*," Project # EE/POWER SYSTEMS/212. A study to design the power system stabilizers using intelligent techniques for power system dynamic stability enhancement.	King Fahd University of Petroleum and Minerals
"*Power system stability enhancement via coordinated design of PSS and FACTS-based stabilizers*," Project # FT/2000-25, A study to evaluate the effectiveness of recently developed FACTS devices to enhance the damping characteristics to low frequency oscillations.	King Fahd University of Petroleum and Minerals
"*Power System Stability Enhancement Via Coordinated Design of Excitation and STATCOM - Based Controllers*," A study to examine the second generation of FACTS – based damping stabilizers and test the coordinated design approach with the power system stabilizers.	Deutscher Akademischer Austauschdienst, DAAD, Lehrstuhl für Elektrische Energieversorgung, Friedrich-Alexander Universität Erlangen-Nurnberg, Erlangen, Germany,
"*Multiobjective Environmental/Economic Power Dispatch Using Evolutionary Algorithms*," Project # FT/2001-19. A study to minimize the environmental impact of power generation and reduce the atmospheric pollutants and emission caused by thermal power plants.	King Fahd University of Petroleum and Minerals
"*Dynamic Stability Study of Saudi Electric Company-Eastern Branch (SEC-ERB)*," Project # ARI-001, A study	Research Institute, King Fahd University of

to increase the power transfer capability through the tie line between SEC-ERB and SEC-CRB via tuning of power system stabilizers and increasing the stability limit of the interconnected system.	Petroleum and Minerals
"*Power Quality Standards*," Project # S0502, *A study to review various PQ standards, evaluate the potential PQ monitoring schemes and suggest the available most effective countermeasures to mitigate power quality problems.*	Saudi Electricity Company (SEC)
"*Robust Load Frequency Controllers for Multiarea Interconnected Power Systems*" Project # FT/2003-13. A study to design automatic generation control scheme in presence parameter uncertainties.	King Fahd University of Petroleum and Minerals
"*Power Systems Stability Enhancement Using Unified Power Flow Controllers*," Project # INT-282. A study to assess the effectiveness of the unified power flow control on power system stability and design different control schemes.	King Fahd University of Petroleum and Minerals

TAREK ABDEL-GALIL

Center for Engineering Research
King Fahd University of Petroleum and Minerals

Personal Information

Date of birth: 1970
Place of birth: Egypt
Languages: English and Arabic

Qualifications

Ph.D., Electrical Engineering, Distribution System Operation and Power Quality, University of Waterloo, Waterloo, Ontario, Canada (2003)

M.Sc., Electrical Engineering, Power System Stability, Ain-Shams University, Cairo, Egypt (1998).

B.Sc., Electrical Engineering, with distinction, Ain-Shams University, Cairo, Egypt.(1992)

Area of Specialization

- Electric load forecasting
- Power System Analysis
- Transmission Planning
- Power quality
- Distribution system evaluation and analysis
- High voltage

Job History

Research Engineer III, Center for Engineering Research: Research Institute, King Fahd University of Petroleum & Minerals, Dhahran, Saudi Arabia (Sept, 2004 - To Date).

Research Associate, University of Waterloo, Waterloo, Ontario, Canada (2003-2004)

Research and Teaching Assistant, University of Waterloo, Waterloo, Ontario, Canada (2000-2003)

Research and Teaching Assistant, Ain-Shams University, Cairo, Egypt.(1992-1999)

Consultancy Projects

Project	Funding Agency
Updated Generation Planning for the Saudi Electricity Sector. *A study to develop a-15 years generation plan for KSA and to determine required investment costs*	Electricity and Co-Generation Regulatory Authority (ECRA), Riyadh
Electric energy production costing for the Saudi Electricity Sector (Phase-I). *A study to determine and evaluate the electric energy production cost in each of the power stations in KSA.*	Electricity and Co-Generation Regulatory Authority (ECRA), Riyadh
Environmental effect on polymer insulators properties The objectives of this study are to investigate the technical performance of the polymeric insulators in comparison to ceramic insulators, and to evaluate the effects of the environmental parameters on the properties of the polymer insulation	Saudi Electricity Company (SEC), Riyadh
Power quality monitoring and standards This proposal was prepared in response to a request from Saudi Electricity Company to conduct a study on the different power quality standards and equipment.	Saudi Electricity Company (SEC), Riyadh
Effect of extremely low frequency-electromagnetic fields on electric utility workers. This study was prepared for Saudi Electricity Company to study the effect of low frequency electromagnetic field on electric utility worker.	Saudi Electricity Company (SEC), Riyadh

MOHAMMED ARIF ABDUL-MAJEED

Center for Engineering Research
King Fahd University of Petroleum and Minerals

PERSONAL:

Date of Birth *November 24, 1957*
Nationality *Indian*
Religion *Islam*

EDUCATION

Master of Science in Electrical Engineering, received from King Fahd University of Petroleum and Minerals, Dhahran, Saudi Arabia, 1985.

Areas of specialization: Electric Power Systems.

Bachelor of Engineering in Electrical Engineering, received from Nagpur University, Nagpur, India, 1980.

Area of Specialization

- Power systems planning
- Electric power system interconnection
- Production costing study and economic studies
- Power Quality
- Demand Side Management
- Energy Conservation

EMPLOYMENT

June 1985 - to Date

Research Engineer-III (Assistant Prof.); Center for Engineering Research, Research Institute, King Fahd University of Petroleum and Minerals, Dhahran, Saudi Arabia.

April 1982 - June 1985

Research Assistant, Electrical Engineering Department, King Fahd University of Petroleum and Minerals, Dhahran Saudi Arabia.

May 1981 - April 1982

Junior Engineer, 400 kV Receiving Station Construction Division, Maharashtra State Electricity Board, Nagpur, India.

Consultancy Projects

Project	Funding Agency
Updated Generation Planning for the Saudi Electricity Sector. *A study to develop a-15 years generation plan for KSA and to determine required investment costs*	Electricity and Co-Generation Regulatory Authority (ECRA), Riyadh
Electric energy production costing for the Saudi Electricity Sector (Phase-I). *A study to determine and evaluate the electric energy production cost in each of the power stations in KSA.*	Electricity and Co-Generation Regulatory Authority (ECRA), Riyadh
Electric and Magnetic Field Guideline Evaluation and Magnetic Field Exposures for Live-Line Workers. *An applied research to evaluate the EMF guidelines and exposure levels for power workers.*	Saudi Electricity Company
Voltage Dip Study for Jubail Industrial Area. *Study to identify the causes of voltage dips resulting in loss of load in the Jubail industrial area and to provide recommendations that will help minimize the disruption of industrial facilities resulting from the voltage dips.*	Saudi Electricity Company-East
The Benefits of Interconnecting MYAS with SCECO West. *Study to determine the potential benefits of the existing interconnecting link between the Madinat Yanbu Al-Sinaiyah (MYAS), Yanbu power system and the Saudi Electricity Company - the Western Region Branch (SEC-WRB), Jeddah.*	Royal Commission for Jubail and Yanbu.
Interconnection of Power Systems in SCECO Central and SCECO West. *The objectives of the study were to review the generation expansion plans of the four major electric utilities in Saudi Arabia, and to determine the transmission capacities that would be needed to link SCECO West, SCECO Central and SCECO South.*	Zedan Consultant
Peak Load Reduction by Load Management. *The main objectives of this project are to review the state of art on Demand Side Management and to propose appropriate procedure for applying these techniques within the Saudi electric utilities.*	KACST
Energy Trading Benefits Among Mashreq Arab Countries. *The objectives of the study were to determine the potential for electric energy trading among the power systems of the Mashreq Arab countries and to evaluate the viability of an additional interconnection linking Saudi Arabia and the northern Mashreq countries (Egypt, Jordan, Lebanon, and Syria).*	ARAB FUND for Economical and Social Development, Kuwait.

Electrical and Physical Properties of Soils in Saudi Arabia. *The overall objective of this project was to establish a simple and accurate method with which the utility industry can predict the occurrence of thermal instability along the existing and proposed underground cable routes.*	KACST
High Voltage Insulator Performance in the Kingdom of Saudi Arabia. *The main objectives of the project was to investigate the relative performance of various prospective insulator designs, to establish major contamination zones to facilitate future insulation design practices of overhead transmission systems in the Kingdom of Saudi Arabia and to provide recommendation for insulation standardization of Saudi transmission systems.*	Electricity Corporation
Feasibility Study for Interconnection of Arabian Gulf States Electrical Power Systems. *Study to investigate technical and economic feasibility of interconnecting Arabian Gulf electric power systems.*	Saudi Industrial Development Fund
A Master Plan Study of Saudi Arabian Extra High Voltage Transmission System Requirements. *The main objective of this study was to build up a master plan for Saudi Arabia's extra high voltage transmission system.*	KACST

FIROZ AHMAD

Center for Engineering Research
King Fahd University of Petroleum & Minerals

Personal Information

Date of birth: 1965
Place of birth: India
Languages: English, Urdu and Hindi

Qualifications

Master of Science (Electrical Engineering): King Fahd University of Petroleum & Minerals, Dhahran, Saudi Arabia (1996)

B.E. (Electrical & Electronics): Birla Institute of Technology, Mesra, Ranchi, India (1987).

Area of Specialization

- Transmission network analysis and planning
- Power system interconnection
- Production costing study for single and interconnected systems
- Power system transients
- Distribution system evaluation and analysis

Job History

Engineer-I, Center for Engineering Research: Research Institute, King Fahd University of Petroleum & Minerals, Dhahran, Saudi Arabia (April, 2003 - To Date).

Senior Electrical Engineer and Manager, System Studies Department: Fareed M. Zedan Consultants, Al-Khobar, Saudi Arabia (October 1996 – March, 2003).

Research Assistant: Department of Electrical Engineering, King Fahd University of Petroleum & Minerals, Dhahran, Saudi Arabia (January, 1994 - September, 1996).

Senior Project Executive: Protech India Limited, Delhi, India (July, 1993-December, 1994).

Lecturer: Asian College of Engineering Technology, Patna, Saudi Arabia (December, 1989 - June, 1993).

Assistant Engineer: Tata Iron and Steel Company, Jamadoba, Dhanbad, India (July, 1987 - November, 1989).

Consultancy Projects

Project	Funding Agency
Updated Generation Planning for the Saudi Electricity Sector. *A study to develop a-15 years generation plan for KSA and to determine required investment costs*	Electricity and Co-Generation Regulatory Authority (ECRA), Riyadh
Electric energy production costing for the Saudi Electricity Sector (Phase-I). *A study to determine and evaluate the electric energy production cost in each of the power stations in KSA.*	Electricity and Co-Generation Regulatory Authority (ECRA), Riyadh
Utilization of Peak and Off-peak Electricity prices. *A study to develop the time of use tariff for industrial, commercial and residential consumers in Saudi Arabia.*	Saudi Electricity Company (SEC), Riyadh
Study of grid connected wind farm. *A techno economic feasibility study to look into the feasibility of setting up a grid connected wind farm.*	Saudi Electricity Company (SEC), Riyadh
Wind Energy for remote villages. *A techno economic feasibility study to look into the wind energy supply option for a remote settlement in Saudi Arabia.*	Saudi Electricity Company (SEC), Riyadh
Electric Energy Conservation and Management Within KFUPM Campus. *A study to present and discuss the experience of several organizations in electricity efficiency programs and policies.*	KFUPM, Dhahran
Feasibility Study and Conceptual Design for the HVDC Interconnection between Central and western region of Saudi Arabia. *Generation and Transmission Planning study to size the link capacity, voltage level and economic analyses followed by developing the conceptual design for the selected corridor.*	SCECO-West, Jeddah
Riyadh - Qassim Interconnection Tie Capacity Study. *Transmission Planning studies such as load flow, short circuit and stability analysis to size the capacity of the second 380kV double circuit line.*	SCECO-Central, Riyadh
SCECO-East /SCECO-Central Joint System Interconnection Study. *Transmission Planning studies such as load flow, short circuit and stability analysis to check the system performance and the protection system assessment for the existing link. Study done in collaboration with GE-Power Systems Consulting Division.*	SCEOC-East, Dammam
Electrical System Audit for the Saudi Petrochemical Company (SADAF). *Review of past system outages and performance and carrying out studies for load flow, short circuit, motor starting, relay co-ordination etc. to define system performance improvements so as to minimize outages.*	Saudi Petrochemical Company (SADAF), Jubail
Voltage Dip Study for SABIC Affiliates in Jubail Industrial Area. *A study to identify the causes of voltage dips resulting in loss of load in the Jubail industrial area and to provide recommendations that will help minimize the disruption of industrial facilities resulting from the voltage dips.*	SABIC Head Office, Riyadh

KHALED YOUSEF AL-SOUFI

Center for Engineering Research
King Fahd University of Petroleum & Minerals

Personal Information

Date of birth: 1957
Place of birth: Zerka, Jordan
Languages: Arabic and English

Qualifications

M.S., King Fahd University of Petroleum and minerals, Dhahran, Saudi Arabia, Electrical & Electronics Engineering, 1985. Thesis title "*Performance of insulators in contaminated areas*".

B.Sc.: King Abdul-Aziz University, Jeddah, Saudi Arabia (1981).

Area of Specialization

- High voltage engineering studies and testing
- Power system equipment failure analysis
- Insulator contamination studies
- Electric power system interconnection

Job History

Research Engineer (Assistant Prof.); Center for Engineering research, Research Institute, King Fahd University of Petroleum and Minerals, Dhahran, Saudi Arabia. (1/3/1985 – To date)

Research Assistant: Electrical Engineering Department, KFUPM, Saudi Arabia. (1982-1985

Job responsibilities*:*

Conduct applied research and consultancy in the following areas of electric power engineering:

(1) High Voltage Insulators Pollution Study
(2) High Voltage studies
(3) Supervising the High Voltage Laboratory activities
(4) Testing high voltage equipment at the High Voltage Laboratory
(5) Electric Power System Interconnection,
(6) Power Quality

Membership in Professional Societies

IEEE: The Institute of Electrical and Electronics Engineers.
CIGRE: International Council on Large Electric Systems

Consultancy Projects

1. **Environmental effect on polymer insulators properties:** *An applied research to evaluate the actual performance of polymeric insulators at the High Voltage Laboratory, Aging facilities and at the field with respect to Saudi environment.*

2. **Electric and magnetic field guideline evaluation and magnetic field exposures for live-line workers.** *An applied research to evaluate the EMF guidelines and exposure levels for power workers.*

3. **Feasibility study for establishment of an electrical central laboratory in Saudi Arabia.** A *study to conduct a research project for a consortium that was established by users, importers, and manufacturers of electrical equipment. The consortium was created for studying the feasibility of establishing an electrical testing laboratory in Saudi Arabia*

4. **High Voltage Insulator Performance in the Kingdom of Saudi Arabia, RI project.** *The main objectives of the project was to investigate the relative performance of various prospective insulator designs, to establish major contamination zones to facilitate future insulation design practices of overhead transmission systems in the Kingdom of Saudi Arabia and to provide recommendation for insulation standardization of Saudi transmission system.*

5. **Electrical and Physical Properties of Soils in Saudi Arabia.** *The overall objective of this project was to establish a simple and accurate method with which the utility industry can predict the occurrence of thermal instability along the existing and proposed underground cable routes.*

6. **Study of Water Trees in Underground High Voltage Cables Using Nuclear Microscopy.** Evaluation of the water trees contents using PIXE nuclear technique and the *Electrical testing of the cable..*

7. **Inspection of High Voltage Insulator Test Sites.** *A study to evaluate the condition of 10 existing high voltage insulator field test stations for use in future studies.*

8. **Evaluation of Electric Energy Trading Benefits within Mashreq Arab Countries.** *The objectives of the study were to determine the potential for electric energy trading among the power systems of the Mashreq Arab countries.*

9. **Voltage Dip Study in Jubail Industrial Area**. *Study to identify the causes of voltage dips resulting in loss of load in the Jubail industrial area and to provide recommendations that will help minimize the disruption of industrial facilities resulting from the voltage dips.*

MAHMOUD KASSAS

Electrical Engineering Department
King Fahd University of Petroleum and Minerals

Personal Information

Date of birth: 1956
Place of birth: Syria
Languages: English and Arabic

Qualifications

Ph.D. Electrical Engineering, Vanderbilt University, Nashville, TN, USA. *Area of specialization:* Power Electronics and Motor Controls, 1991.

M.S. Electrical Engineering, Vanderbilt University, Nashville, TN, USA. *Area of Specialization*: Power Systems and Control Systems, 1986.

B.S. (First Honor) Electrical Engineering, Aleppo University, Aleppo, Syria. *Area of Specialization*: Power Systems, 1979.

Area of Specialization

- Power Quality
- Production costing study for single and interconnected systems
- Power system Analysis
- Distribution system evaluation and analysis
- Demand side load management

Job History

Assistant Professor, Electrical Engineering Department, KFUPM, Dhahran, Saudi Arabia, 1994-present.

Associate Professor of Engineering Technology, Austin Peay State University, Clarksville, TN, USA, 1992-1994.

Adjunct faculty member of Electrical Engineering, Vanderbilt University, Nashville, TN, USA, 1991-1992

Research, Consultant, and Teaching Assistant, Electrical Engineering Department, Vanderbilt University, Nashville, TN, USA, 1985-1991.

TECHNOLOGY AND SCIENTIFIC RESEARCH CENTER, Aleppo, Syria, 1981-1983**.**

INDUSTRIAL STEEL CO., Aleppo, Syria, Director of Maintenance, 1979-1981.

Consultancy Projects

Project	Funding Agency
Electric energy production costing for the Saudi Electricity Sector (Phase-I). *A study to determine and evaluate the electric energy production cost in each of the power stations in KSA.*	Electricity and Co-Generation Regulatory Authority (ECRA), Riyadh
Power Quality Standards. *A study to identify the power quality issues and their indices for the Saudi Eclectic Company*	Saudi Electricity Company (SEC), Riyadh
Study of Voltage Dips in Jubail Industrial Area. *A study to identify the causes of voltage dips resulting in loss of load in the Jubail industrial area and to provide recommendations that will help minimize the disruption of industrial facilities resulting from the voltage dips.*	Saudi Electricity Company (SEC), Riyadh
Air-Conditioning Load Control at KFUPM Campus. *A feasibility study to look into the air-conditioning load control to reduce the consumption during the peak time.*	SABIC/FAST-TRACK

DR. ZAKARIYA M. AL-HAMUOZ

Electrical Engineering Department
King Fahd University of Petroleum and Minerals

Personal Information

Date of birth: 1963
Place of birth: Nablus, Jordan
Languages: Arabic and English

Qualifications

Ph.D, King Fahd University of Petroleum and minerals, Dhahran, Saudi Arabia, Electrical & Electronics Engineering, 1994.

M.S., Jordan University of Science & Technology, Irbid- Jordan, Electrical Engineering, 1989.

B.Sc.: Yarmouk University, Irbid, Jordan, (1986).

Area of Specialization

- Transmission network analysis and planning
- Operation of HVDC transmission system
- High voltage insulator performance

Job History

Associate Professor, Electrical Engineering Department, KFUPM (Feb. 2000 – Date**)**

Adjunct Associate Professor, Electrical Engineering Department, American University of London, UK, (March 2001- July 2004)

Assistant Professor; Electrical Engineering Department, KFUPM (Sept. 1995 – Jan. 2000)

Instructor, Electrical Engineering Department, KFUPM (Sept. 1994 – Aug. 1995)

Lecturer-B, Electrical Engineering Department, KFUPM (Sept. 1989 – Aug. 1994)

Research Assistant: Electrical Engineering Department, KFUPM, Saudi Arabia. (1982- 1986)

Membership in Professional Societies

IEEE: The Institute of Electrical and Electronics Engineers (Senior Member)

Consultancy Projects

1. **Optimal Transmission Systems Planning (KACST Funded),** *This project aims at proposing a new and optimal algorithms for transmission expansion planning considering many practical constraints. The developed algorithms were tried on the Jordanian transmission network and a reduced model of the SEC Eastern branch.*

2. **Environmental effect on polymer insulators properties (RI Project):** *An applied research to evaluate the actual performance of polymeric insulators at the High Voltage Laboratory, Aging facilities and at the field with respect to Saudi environment.*

3. **Feasibility study for establishment of an electrical central laboratory in Saudi Arabia (RI Project).** A *study to conduct a research project for a consortium that was established by users, importers, and manufacturers of electrical equipment. The consortium was created for studying the feasibility of establishing an electrical testing laboratory in Saudi Arabia*

4. **Study of Water Trees in Underground High Voltage Cables Using Nuclear Microscopy (KACST Funded).** Evaluation of the water trees contents using PIXE nuclear technique and the *Electrical testing of the cable..*

5. **Inspection of High Voltage Insulator Test Sites (RI Project).** *A study to evaluate the condition of 10 existing high voltage insulator field test stations for use in future studies.*

6. **Management of Ash Waste Generated at Rabigh Power Plant (RI Project)**. *Investigating the performance of one GPP in SEC-West in terms of efficiency of the electrostatic precipitators and proposing the best way of disposing the fly ash.*

7. **Finite Element Computation of Corona Power Loss on Bundled Bipolar Transmission Lines KFUPM Funded),** This project aims at computing the corona power loss and evaluation the electric field and current density associated with HV transmission lines.

ALI TALEB AL-AWAMI
Electrical Engineering
King Fahd University of Petroleum and Minerals

PERSONAL:

Date of Birth *March 31, 1978*
Nationality *Saudi*
Religion *Islam*

EDUCATION

Master of Science in Electrical Engineering, received from King Fahd University of Petroleum and Minerals, Dhahran, Saudi Arabia, 2005.

Areas of specialization: Electric Power Systems and Control Systems.

Bachelor of Science in Electrical Engineering, received from King Fahd University of Petroleum and Minerals with first honors, Dhahran, Saudi Arabia, 2000.

Area of Specialization

- Power System Control and Dynamics
- Power System Operations
- Optimization and Artificial Intelligence

EMPLOYMENT

July 2005 - to Date

Lecturer; Electrical Engineering Department, King Fahd University of Petroleum and Minerals, Dhahran, Saudi Arabia.

February 2002 - July 2005

Graduate Assistant, Electrical Engineering Department, King Fahd University of Petroleum and Minerals, Dhahran Saudi Arabia.

August 2000 - February 2002

Power System Control Engineer, Power Dispatch Division, System Operations Department, Saudi Electricity Company – Eastern Region Branch.

AWARDS

Advanced Electronics Co.: Received certificate from Advanced Electronics Co., (AEC) in association with IEEE-Saudi Arabia in recognition for academic achievement.

KFUPM: Appeared on the Dean's List of Honors ten times, eight as First Honors and two as Second Honors.

Consultancy Projects

Project	Funding Agency
Power System Stability Enhancement Using Unified Power Flow Controllers. *A study to investigate the potential of unified power flow controllers in damping low frequency oscillations using a simultaneous stabilization technique.*	KFUPM

LIST OF SELECTED PUBLICATIONS

- **Ali T. Al-Awami**, Y. L. Abdel-Magid, M. A. Abido, 'Simultaneous Stabilization of Power Systems Equipped with Unified Power Flow Controller Using Particle Swarm,' the 15th Power Systems Computation Conference, PSCC'05, Liège, Belgium, August 22-26, 2005.

- M. A. Abido, **Ali T. Al-Awami,** Y. L. Abdel-Magid, 'Power System Stability Enhancement Using Simultaneous Design of Damping Controllers and Internal Controllers of a Unified Power Flow Controller,' Accepted in the 2006 IEEE PES General Meeting

- **Ali T. Al-Awami**, Y. L. Abdel-Magid, M. A. Abido, 'Simultaneous Stabilization of Power System Using UPFC-Based Controllers,' Accepted in the Electric Power Components and Systems.

- **Ali T. Al-Awami**, Youssef. L. Abdel-Magid, M. A. Abido, 'Particle-Swarm-Based Robust Coordinated Design of PSS and SVC-Based Stabilizer,' Proceedings of The 2nd IEEE-GCC Industrial Electrical and Electronics Conference, Manama, Bahrain, Nov 23-25, 2004, pp 55-60.

- **Ali T. Al-Awami**, Y. L. Abdel-Magid, M. A. Abido, 'Simultaneous Stabilization of Power System Using Particle-Swarm-Based Robust Coordinated Design of PSS and SVC ,' submitted to the IEEE Transactions in Power Systems.

- **Ali T. Al-Awami**, Y. L. Abdel-Magid, M. A. Abido, 'A Comparative Study on FACTS Stabilizers Effectiveness in Enhancing Power System Stability Using Simultaneous Stabilization,' Submitted to the Electric Power Components and Systems.

APPENDIX C
DESCRIPTION OF SOFTWARES

C-1 STRATEGIST

Strategist from New Energy Associates is a fully integrated utility planning system that provided critical decision making information and insight for supply, customer, market, financial and risk based alternatives and their interactions. Its flexibility allows users to perform fully integrated production and financial analysis or run either the production or the financial analysis modules separately. Strategist is composed of multiple modules the module used for production analysis is described below.

Load Forecast Adjustment Module

The Load Forecast Adjustment (LFA) Module is a multi-purpose application for representing and modifying load forecasts and for evaluating marketing and/or conservation programs. Using the LFA, a strategic planner may address key issues related to future electricity or gas demand and evaluate the impacts attributed to each customer group. Results from this analysis can be automatically transferred to other Strategist modules to determine production costs, system reliability, financing and revenue requirements, and a variety of other indicators affected by loads. In conjunction with the Differential Cost Effectiveness (DCE) Module and the Generation and Fuel (GAF) Module, the LFA is used to screen marketing and/or conservation programs based on cost effectiveness tests and develop portfolios of DSM.

Generation and Fuel Module

The Generation and Fuel Module (GAF Module) provides the electric utility planner with the production costs, system reliability indicators, fuel usage, and emissions information that are critically important in evaluating long range system operating costs associated with particular generation plans. The GAF was designed to simulate the effects on an electric utility of changes in operating characteristics, fuel prices and availability, contractual energy and capacity sale and purchase arrangements including economy interchange, and alternative generation resource plans. The GAF Module will also dispatch and calculate interchange accounting for a multi-company system. Using proven probabilistic techniques, the GAF Module requires much less execution time than more detailed production costing models. This module provides the strategic planner with reasonably accurate calculations of production costs for alternate system configurations with fast turnaround. With the GAF Module's quick and flexible "screening" capabilities, only the most promising scenarios then require additional analysis.

PROVIEW

+The PROVIEW Module is an automatic expansion planning module which can determine the optimal balanced demand and supply plan for a utility system under a prescribed set of constraints and assumptions. PROVIEW enables planners to study a wide variety of long range expansion planning options including alternative technologies, unit conversions, unit capacity sizes, load management, marketing and conservation programs, fuel costs, reliability limits, and financial constraints in order

to develop a coordinated integrated plan which would be best suited for the utility. PROVIEW simulates the operation of a utility system to determine the cost and reliability effects of adding resources to the system or modifying the load through marketing or conservation programs, and it examines the impact on the construction budget of building new units.

Accurate results and quick turnaround time allow the strategic planner to evaluate numerous expansion scenarios quickly. A GAF database containing information pertaining to the utility system is directly used for a PROVIEW simulation. PROVIEW also analyzes demand side options in conjunction with the Load Forecast Adjustment Module. PROVIEW is the most flexible and comprehensive application available to met the requirements of Integrated Resource Planning.

Outputs produced include the generating capacity additions and/or load reductions in each year, total present worth of utility cost, present worth of average rates, annual capital requirements, annual operating cost, fuel requirements, reserve margin, and other detailed results that a user may require.

NETWORK ECONOMY INTERCHANGE

The Network Economy Interchange (NEI) feature of the GAF determines the interchange that should take place between interconnected power systems in order to minimize the total production cost of the system. The NEI seeks to balance the marginal costs across the system, subject to transmission constraints and losses, generating capacity limits, and transmission connection (or wheeling) charges. The NEI determines the optimum interchange between two connected systems, and then repeats this process for all connected systems until the entire system has been optimized. The marginal cost for all companies after optimization is the market clearing price, and will be used to determine the cost of the transactions. Interchange is economical as long as the difference in marginal cost is greater than the connection charges among systems.

The result of this process is that an hourly load adjustment profile for each system is developed. These load adjustment profiles are then used to modify each system's net thermal load shape. The GAF then executes the thermal unit dispatch for each company.

C-2 PSS/E

PSS/E™ from Siemens Power Transmission and Distribution Inc. Power Technologies International (Siemens-PTI), a world leader in power system analysis, provides users with power flow, short circuit, dynamic simulation (including long term), optimal power flow, linear network, and small signal analysis. The program employs the computer technology and numerical algorithms to efficiently solve network large and small. PSS/E includes modeling for advanced technologies, such as the application of FACTS devices and Voltage Source Converter HVDC Light systems. The program slows for a variety of analyses. When many cases must be analyzed quickly, "dc" load flow capability is provided. Dynamic modeling for PSS/E includes highly detailed governor models, allowing most standard boiler control strategies and very detailed HVDC models, which apply to specific installation.

PSS/E is being utilized by most of the utilities in the Kingdom for their network analysis. In this study the following modules will be used.

- Power Flow
- Fault Analysis
- Dynamic Simulation
- Open Access

C-3 TPLAN

TPLAN is an integrated, stand-alone computer software package for transmission reliability assessment. It is comprised of a variety of state-of-the-art analytical formulations, mathematical optimized solutions and simulations of system response, put together to address the key issues identified above. TPLAN provides for an easy, friendly but comprehensively featured environment for testing deterministic reliability as in (n-1) criterion, and others of this type such as (n-2), (n-1-1), etc.

In addition, this key capability of TPLAN provides a basis for expanded applications available as add-on modules. These include:

- Measuring available transfer capability, Transfer Limits assessment (TLA).
- Selecting effectively amongst transmission expansion option Interactive Expansion Planning (IEP).
- Identifying optimized, security-constrained generation dispatches Security-Constrained Economic Dispatch (SCED).
- Evaluating impact of substation reliability Substation Reliability Assessment (SRA).
- Identifying must-run resources, which provide for security in transmission constrained areas.

APPENDIX D
SNC-LAVALIN PROFILE AND RESUME

APPENDIX E
KFUPM/RI GENERAL TERMS AND CONDITIONS