# 37th

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# UPEC 2002

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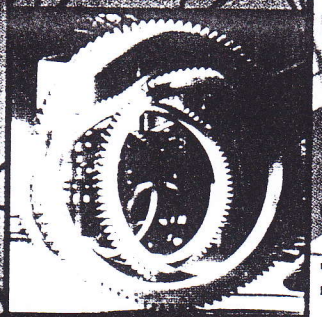

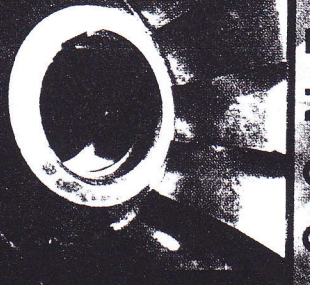

## 9th, 10th & 11th September 2002

## Volume 1 (Sessions 1a - 4b)

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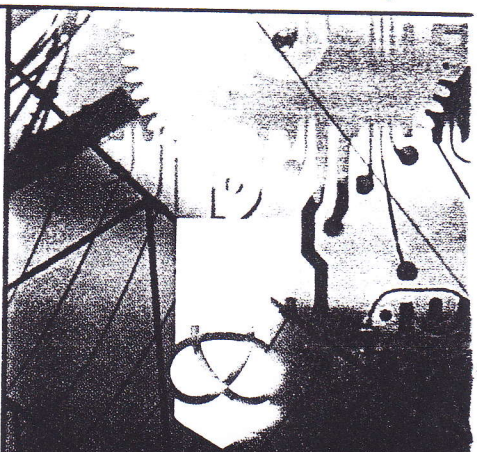

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# UNIFIED ENERGY NETWORK IN THE ARAB WORLD- FUTURE EXPECTATIONS

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## ABSTRACT

The unified power system network is one of the main features of the world policy for serving the electrical energy. One example for such a system is the unified Egyptian Jordanian electrical power system network, which aims to secure the supply of electrical energy for the two countries. This unified network has already been established and exists in service, connecting both Egypt and Jordan since 1998. In the near future other countries will be connected to this network, starting from Morocco in the west. Saudi Arabia in the east, Syria in the north down to Sudan in the south. This network, in turn, will be connected to the unified European network through Turkey in the north. A precise load forecasting study is necessary required for this unified network

This work concerns with the Egyptian Jordanian unified network, which is the first stage of the Unified Arab World Power System Network. The studies of this work are carried out using one of the econometric method techniques. which is called " Multiple Regression Curve Fit ". Using this technique, the peak load, generation energy and energy sales are estimated for the coming years. For the cases of the study, actual data of the unified power system, through the last few years are used, then the output results are compared with the input data for testing the accuracy of the technique used. The study also concentrates and highlights on the accuracy and sensitivity of the applied model used for this study. The proposed technique for the interconnected networks can be applied to simple as well as practical and complicated power system networks.

Key Words:

Planning. Egyptian-Jordanian Unified network, Load Forecasting, Econometric Method.

## 1. INTRODUCTION

In view of the time required for planning and constructing power plants, a plan for installing new power generation, transmission and distribution facilities should be established at least ten years in advance. Energy forecasts are needed to determine future fuel requirements and, if necessary when fuel prices soar, rate relief to maintain an adequate rate of return. In summary, a good forecast reflecting current and future trends, tempered with good judgment, is the key to all planning, for financial success.

The planning of an electric power system requires also forecasts of the future load demand. Load forecasting methodology, developed previously, may be classified into many models. Forecasts of peak demand and total energy consumption are the starting point in the planning cycle of an electric utility. This work concerns with load forecast for the Egyptian Jordanian unified network, which is the first stage of the Unified Arab World Power System Network.

The statistical approach may be divided into two broad categories: Econometric, and Extrapolation [1, 2, 3]. The choice of a methodology depends on the objectives of the analysis as well as the availability of data and the skills of the forecasters. The objective of the forecasting task is to provide energy and peak load forecasts that meet the planning requirements in an understandable, accurate, consistent and credible manner.

## 2. STATISTICAL APPROACH

This study concentrates on the methods for forecasting annual peak demand, Generation Energy, and Energy Sales over a lead-time of years. The following methods identify and name the forecasting technique used for the present study.

## 3. ECONMETRIC METHODS

Econometric methods are a correlation relationship between the peak load or the energy demand and some measures for the country under study [ 3, 4, 5] which is classified into two methods as:

a) Simple linear regression curve fit.
b) Multiple Regression curve fit.

In this paper, multiple regression curve fit is used, and is modified to apply for the case of the mentioned unified network.

### 3.1. Multiple Regression Curve Fit

This is to relate electricity consumption to national product and to national price. A mathematical relationship

can be established between the historical annual levels of electricity consumption, gross domestic product (GDP), population (POP), electrified population (Elect.POP), gross domestic for each one (GDP/Cap.), system losses, load factor and average rate per unit sales according to the shapes and form of equations. The relationship between the electrical power demand and its elements can be represented by the following equation:

**In case of considering forecasting for Egyptian network alone;**

The equation is given as:

$$Y_e = f(X1, X2, X3, X4, X5) \quad \text{.....(1)}$$
$$= a + b * GDP + c * POP + d * Elect.POP + e * GDP/CAP + ^2 * Load\ Factor$$

where,

Y is the peak load, or generation energy, or electrical energy sales, X1 is the deflated value of the gross domestic product (GDP), X2 is the population (POP), X3 is the electrified population (Elect POP), X4 is the gross domestic for each one (GDP/Cap.) and X5 is the system load factor, for Egypt. These are considered the most effective factors for peak load forecasting

**In case of considering the load forecasting for the Egyptian-Jordanian network.**

The equation could be developed to represent the various factors in the various countries, then,

$$Y_i = f(X1, X2, X3, X4, X5, X6, X7) \quad \text{.....(2)}$$
$$= a1 + b1 * GDP(EGY) + c1 * GDP(JOR) + d1 * POP(EGY+JOR) + e1 * ELECT.POP(EGY+JOR) + e1 * ELEC.POP(EGY+JOR) + f1 * GDP/CAP(EGY) + g1 * GDP/CAP(JOR) + h1 * LOAD\ FACTOR\ (AVERAGE).$$

where,

$Y_i$ is the peak load, or generation energy, or electrical energy sales for the interconnected system, X1 is the deflated value of the gross domestic product (GDP) for Egypt, X2 is the deflated value of the gross domestic product (GDP) for Jordan, X3 is the population (POP) for Egypt and Jordan, X4 is the electrified population (Elect POP) for Egypt and Jordan, X5 is the gross domestic for each one (GDP/Cap.) of Egypt, X6 is the gross domestic for each one (GDP/Cap.) of Jordan and X7 is the average load factor for Egypt and Jordan.

Table (1) shows the historical data for Egypt and Jordan for the period 1990-2001 and Table (2) shows the historical data for Egypt and Jordan unified network.

### 3.2. Test for Forecasts Accuracy

Multi tests are used in this study for the comparison between the Egyptian power system and the unified Egyptian Jordanian Electric Power System. The past and present economic conditions in this interconnected system, which are used for load forecasts, are proved to be very difficult [6-10]. Many load forecast studies undertaken in this paper are done for the determination of the electric power demand of the Egypt power system until 1999 as well as the general trend until the year 2010. The same studies are carried out for the unified Egyptian-Jordanian power system network using the data from 1990 - 2001. A regression equation is a mathematical procedure, where on basis of sample data, an approximating equation can be obtained, that relates the value of variable Y corresponding to a given value of a variable X (Last Square Technique) [11]. The approximating equation could be used for prediction purposes. Substitution for a value of X will result in an approximated response of the variable Y. However, the equation predicts the true mean value of Y rather than the actual one. The reason lies in the way the mathematical procedure calculates the model equation. This can only occur if the curve passes through the mean of the coordinate points rather than through the points themselves.

### 3.3. Absolute Percentage Error

Using the candidate forecast method; the present load can be predicated from past loads (eleven years old data, from 1990 - 2001). Comparing this forecast with the actual present loads gives the error [12]. A load forecast is generally tested by producing a forecast of the present load levels, using past 11 years of data. Comparison of this forecast with present actual known values of load is taken as an indication of the forecast procedure's probable accuracy over a future period of similar length. The same concept of error calculation can be used for calculation of the error in a forecast of future loads. This error cannot be calculated (because the actual values of the future are not known). This is an important aspect of load forecast error, which is called Average Absolute Value (A.A.V.). This is one of the statistical methods [13]. Using this method, the accuracy can be evaluated.

## 4. Application To Long-Term Planning

Application of the above suggested forecasting method to the Egyptian power system and to the unified Egyptian Jordanian power system as separates has been carried out. The forecasting of the Egyptian Electric power system future loads are tested and comparisons are made for forecasting error, accuracy and data needed. The results are indicated in the Table (3).

First case, Egypt network: According to a suitable range of growth, the deflated value of the gross domestic product (GDP) for the forecasting period from the confidence interval estimations, these different growth scenarios were chosen of 2.5%, 3.5% and 4.5%. Applying the different values for the eleven years period from the year 2000 to the year 2010 and substituting the values of the different growth scenarios, for the deflated value of the gross domestic product (GDP) for Egypt, the

population, the electrified population, the gross domestic for each one, the load factor for Egypt, the peak load forecast for the period 2000 to 2010, could be obtained.
Second case. Egypt-Jordan unified power network: According to the suitable range of growth, the deflated value of the growth of the domestic product (GDP) is 4.5% for Egypt and Jordan network. However, applying the different factors for the eleven years period from the year 2000 to the year 2010 and substituting the values of 4.5% growth scenario, for the deflated value of the gross domestic product (GDP) for Egypt and Jordan, the population for Egypt and Jordan, the electrified population for Egypt and Jordan, the gross domestic for Egypt, the gross domestic for Jordan, the average load factor and the GDP for Jordan, one can obtain the peak load forecast for the period 2000 to 2010.

## 5. RESULTS OF LOAD FORECASTING

The investigation described here, is devoted to comparing between the load forecast for two aspects, the first one, the load forecasting of the Egyptian power network demand as a separate and the load forecast of the Egyptian-Jordanian as a unified network aspect. The choice of planning forecasting method, from among the many available is a decision that must be carefully made on a case-by-case basis. In the Egyptian network as well as Egypt Jordan network, historical growth of the peak load, during the preceding eleven years is as in Tables (1, 2). The long-range forecast results for yearly peak load demand, using econometric model-multiple regression are shown in figure (1), for different GDP values, for. Egyptian power system, Jordan power system and for the Egyptian-Jordanian interconnected power system demand forecasting. Meanwhile, Table (3) shows the results obtained from the studies for load forecasting, fore the time period 2000 to 2010, for Egypt network, Jordan network and the Egyptian-Jordanian unified power network.
The error values, the average absolute percentage (A.A.V) and peak load forecasted values are widely different, due to the wide different in the used factors.

## 6. CONCLUSION

The forecasting of the annual electricity power demand (Peak load) of the national unified power system of Egypt is found to well depend on the parameters, of the deflated value of the gross domestic product (GDP), the population, the electrified population, the gross domestic for each one and the load factor. The Egyptian-Jordanian unified power system is also, found to depend on the deflated value of the gross demostic (GDP) of each of Egypt and Jordan, the population of Egypt and Jordan, the electrified population of Egypt and Jordan, (GDP/Cap) for each of Egypt and Jordan and average load factor of Egypt and Jordan.
Further, this investigation supports the belief that the Econometric methods analysis of yearly peak loads is considered one of the best and common techniques used for long-term demand of a power system in developed countries as well as for the interconnected systems in these countries.

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Table (1)

Historical Data for Econometric model

| | EGYPT | | | | | | | JORDAN | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| YEAR | PEAK LOAD | GDP M L E | GDP % | POP | ELEC POP | GDP /CAP | LOAD FCATOR % | PEAK LOAD | GDP M L E | POP | ELEC POP | GDP /CAP | LOAD FCATOR % |
| 1990 | 6664 | 31726 | | 53 59 | 47 96 | 592 | 71 34 | 588 | 15971 .5 | 3 431 | 3 36 | 4655 06 | 69 |
| 1991 | 7004 | 32799 | 3 382084 | 54 66 | 50 58 | 600 02 | 70 86 | 619 | 17165 .8 | 3 683 | 3 6 | 4686 25 | 67 8 |
| 1992 | 7215 | 33448 | 1 978719 | 55 76 | 52 74 | 599 9 | 71 96 | 721 | 21173 .5 | 3 804 | 3 75 | 5566 11 | 70 |
| 1993 | 7503 | 34282 | 2 493423 | 56 87 | 54 58 | 602 8 | 71 65 | 740 | 23098 .8 | 3 95 | 3 91 | 5847 78 | 71 8 |
| 1994 | 7857 | 35624 | 3 914591 | 58 01 | 56 48 | 614 12 | 72 46 | 825 | 25423 .5 | 4 139 | 4 1 | 6142 43 | 69 6 |
| 1995 | 8149 | 37298 | 4 699079 | 59 17 | 56 48 | 630 37 | 71 9 | 894 | 27310 .5 | 4 288 | 4 25 | 6369 05 | 71 |
| 1996 | 8491 | 39161 | 4 994906 | 60 35 | 58 54 | 648 87 | 72 23 | 934 | 28207 .3 | 4 442 | 4 42 | 6350 12 | 73 5 |
| 1997 | 9235 | 41241 | 5 311407 | 61 45 | 59 61 | 671 13 | 71 29 | 1003 | 29605 .5 | 4 604 | 4 59 | 6430 39 | 71 5 |
| 1998 | 9850 | 42684 | 3 493648 | 63 69 | 61 7793 | 683 16 | 72 27 | 1060 | 31343 .8 | 4 755 | 4 75 | 6591 75 | 73 |
| 1999 | 10919 | 44178 | 3 500141 | 64 83 | 62 8851 | 708 05 | 71 07 | 1137 | 32920 .5 | 4 9 | 4 9 | 6718 47 | 7 2 |

Table (2)

Historical Data for Econometric Model

| | Egypt +Jordan | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | YEAR | PEAK LOAD | GDP (EGYPT ) M L E | GDP % | GDP (JORDAN ) M L E | GDP % | POP (EGYPT ) | ELEC POP (EGYPT ) | GDP /CAP (EGYPT ) | GDP /CAP (JORDAN ) |
| | 1990 | 7252 | 31726 | | 15971 .5 | | 53 .59 | 47 .96 | 592 | 4655 .06 |
| | 1991 | 7623 | 32799 | 3.38 | 17165 .8 | 7.48 | 54 .66 | 50 .58 | 600 .02 | 4686 .27 |
| | 1992 | 7936 | 33448 | 1.98 | 21173 .5 | 23 .35 | 55 .76 | 52 .74 | 599 .9 | 5566 .11 |
| | 1993 | 8252 | 34282 | 2.49 | 23098 .8 | 9.09 | 56 .87 | 54 .58 | 602 .8 | 5847 .80 |
| | 1994 | 8482 | 35624 | 3.91 | 25423 .5 | 10 .06 | 58 .01 | 56 .48 | 614 .12 | 6142 .43 |
| | 1995 | 9043 | 37298 | 4.70 | 27310 .5 | 7.42 | 59 .17 | 56 .48 | 630 .37 | 6369 .05 |
| | 1996 | 9425 | 39161 | 4.99 | 28207 .3 | 3.28 | 60 .35 | 58 .54 | 648 .87 | 6350 .14 |
| | 1997 | 10238 | 41241 | 5.31 | 29605 .5 | 4.96 | 61 .45 | 59 .61 | 671 .13 | 6430 .39 |
| | 1998 | 10910 | 42684 | 3.50 | 31343 .8 | 5.87 | 63 .69 | 61 .7793 | 683 .16 | 6591 .76 |
| | 1999 | 12056 | 44178 | 3.50 | 32920 .5 | 5.03 | 64 .83 | 62 .8851 | 708 .05 | 6718 .47 |

## Table No( 3 )

### Output Results Of Egyptian Network for Peak Load Forecasting

### Egyp, Jordan & Egy Jordan

| | | Egypt Only | | | Jordan Only | | Egypt+ Jordan |
|---|---|---|---|---|---|---|---|
| Items | | Peak Load | | | Peak Load | | Peak Load |
| | | GDP=2.5% | GDP=3.5% | GDP=4.5% | GDP=4.5% | | GDP=4.5% |
| | a | 8150509 | 8150509 | 8150509 | 2051778 | a1 | 104171 |
| | b | 1.9711 | 1.9711 | 1.9711 | 0.1016298 | b1 | 2.732 |
| Equation | c | -9226 | -9226 | -9226 | -1206978 | c1 | 0.2585 |
| Forms | d | 37.92 | 37.92 | 37.92 | 797.476 | d1 | -1517447 |
| | e | -11861 | -11861 | -11861 | -0.302 | e1 | 51.329 |
| | f | -2739 | -2739 | -2739 | -3.183 | f1 | -15558 |
| | | | | | | g1 | -0.6166 |
| | | | | | | h1 | -125398 |
| | | | | | | | |
| | | | | | | | |
| R^2 | | 0.998422 | 0.998422 | 0.998422 | 0.9987 | | 0.9969 |
| E (%) | | 4.84 | 4.84 | 4.84 | 5.54 | | 7.95 |
| Forecast at 2000 | | 11172051 | 10831074 | 11335848 | 12491509 | | 12929 |
| Actual at 2000 | | 11736 | 11736 | 11736 | 1238 | | 12974 |
| A.A.V. % | | 11.1188683 | 17.84160095 | 7.889432177 | 1.715523077 | | 0.786438308 |
| Forecast at 2001 | | 1141316 | 11117932 | 11947064 | 12350872 | | 139755 |
| Actual at 2001 | | 12619 | 12619 | 12619 | | | |
| A.A.V. % | | 12.773729 | 159011 | 11.28356003 | | | |
| Forecast at 2010 | | 1517242 | 17181916 | 23285546 | 12533768 | | 28836199 |
| EEHC at 2010 | | 21521 | 21521 | 21521 | | | |
| A.A.V. % | | 42.7312378 | 29.2056539 | 11.87686612 | | | |

Y = a+ b*GDP+c*POP+d*ElectPOP+e*GDP CAP+f*Load Factor

Y = a1+ b1*GDP(EGY)+c1*GDP(JOR)+d1*POP(EGY+JOR)+e1*ELECPOP(EGY+JOR) f1*GDP CAP(EGY)+g1*GDP CAP(JOR)+h1*LOAD FACTOR(Average)

Y= Peak Load

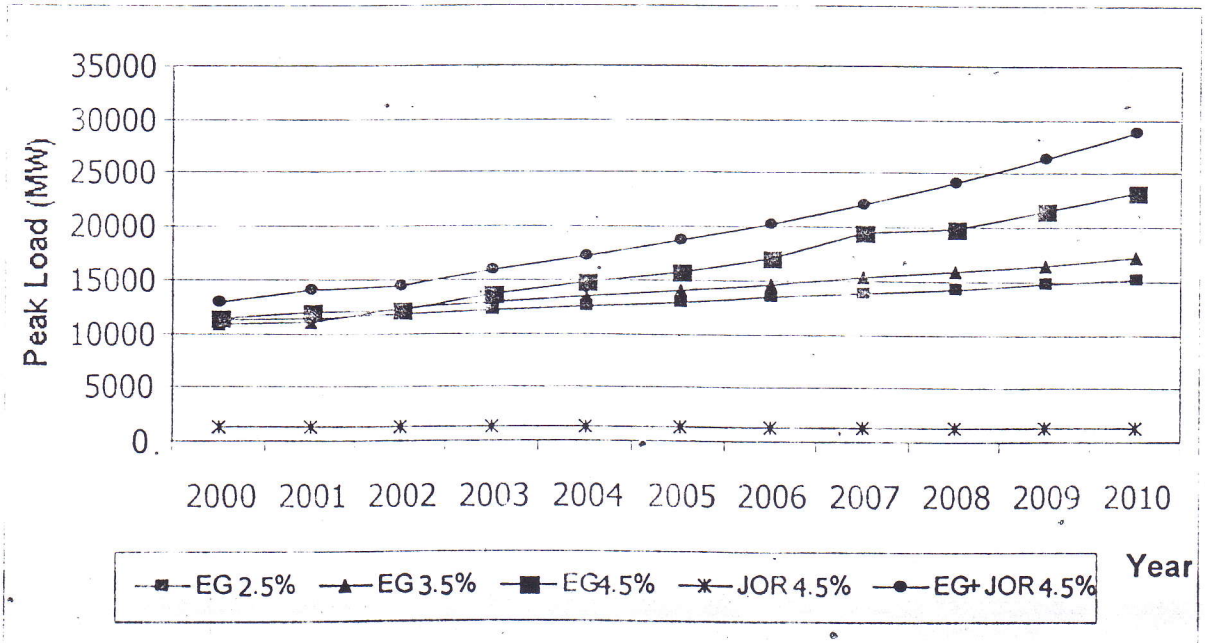


Fig 1: Load Forecasting For the Egyptian Network and Unified Egyptian, Jordaian & Egyptian + Jordian Network for Different GDP Values

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# Confirmation Letter

From:
Professor Moofik Al-Tai, BEng(Hons), PhD, CEng, FIEE
To:
Professor S. El-Debeiky

Dear Dr S. El-Debeiky
This is to confirm that the paper entitled "Unified Energy Network in the Arab World-Future Expectations " by A. S. Hafiz Hamza, N. M. Abdel-Gawad, M. M. Salama, Ahmed Hegazy and S.El-Debeiky has been presented orally at the 37the International Universities Power Engineering Conference (UPEC 2002) Which was held at Staffordshire University, UK, 9 -11 September 2002.
This paper was also included in the Conference Proceedings (Hard Copy and CD Rom).

Your Sincerely
Professor Moofik Al-Tai
Conference Chairman

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