A NEW REGRESSION MODEL FOR SHORT TERM LOAD FORECASTING

BY

M.Tantawy*

ABSTRACT:

This paper presents a suggested regression model for short term load forecasting. The different factors affecting the hourly load demand are analysed and taken into consideration. With special regard to weather sensitive load, a detailed study is made to have the accurate correlation factors between the load and the different weather parameters. An application of the proposed model on actual data bank is made. The length of historical past data used is three months for forecasting the hourly load demand. Comparing the resulted obtained with the actualvalues, the percentage absolute error given by the proposed model do not exceed 5%. This value of % error is satisfactory and represents high accuracy in forecasting the load domand.

1. INTRODUCTION

Load forecasting is an integral part of power system planning and operation. It did not receive much attention in the past as it deserves because the fuel costs were cheap, fuels were abundent and utilities could find funds for erecting enough gas oil generating plants at relatively short lead times. In last few years the conditions have considerably changed and the past practicies will have to be suitably modified. Load forecasting will assume greater importance and therefore it receives more attention. Fig.(1) shows the load forecasting problem as it is included in power system planning and operation.

---

* Lecturer, Faculty of Engineering, El-Mansoura University.

Mansoura Bulletin, December 1977.

2. CLASSIFICATION OF LOAD FORECASTING PROBLEM:

Load forecasting for electrical power systems can be broadly divided into three main catigories according to the future time ahead required for forecasting:-

- Very short time load forecasting:

This deals with forecasting the load for a few minutes to an hour ahead. This is needed for online operation and control of the power systems including security assessment, economic dispatch and rate of change of generator output.

- Short term load forecasting:-

This deals with the hourly forecast of up to 1 week ahead. It is needed for optimal generator unit commitment, start up and shut down of thermal plants, control of spinning reserve and exchanging the power in interconnected systems.

Long range load forecasting:-

Which concerns with the yearly system peak load up to 10 years ahead.

This is used in the planning and purchasing of new equipments and generator units to meet the load growth as projected in the forecast.

These problems are interrelated whever they are sufficiently distinct to have been previously treated separately.

Fig. (2) shows the classification of load forecasting problem.

3. METHODS ADAPTED FOR SHORT TERM LOAD FORECASTING:-

The problem of short term load forecasting has received some attention over the past few years. The methods previously developed for the solution of it can be put in the following two catigories:-

a) Statistical Methods:-

Which employs the recorded known past load data for extrapolation to obtain the future hourly loads. They include the orthogonal function methods which use functions like the sinusoidal to give the daily loads by means of linear combination of

3. Mansoura Bulletin December 1977.

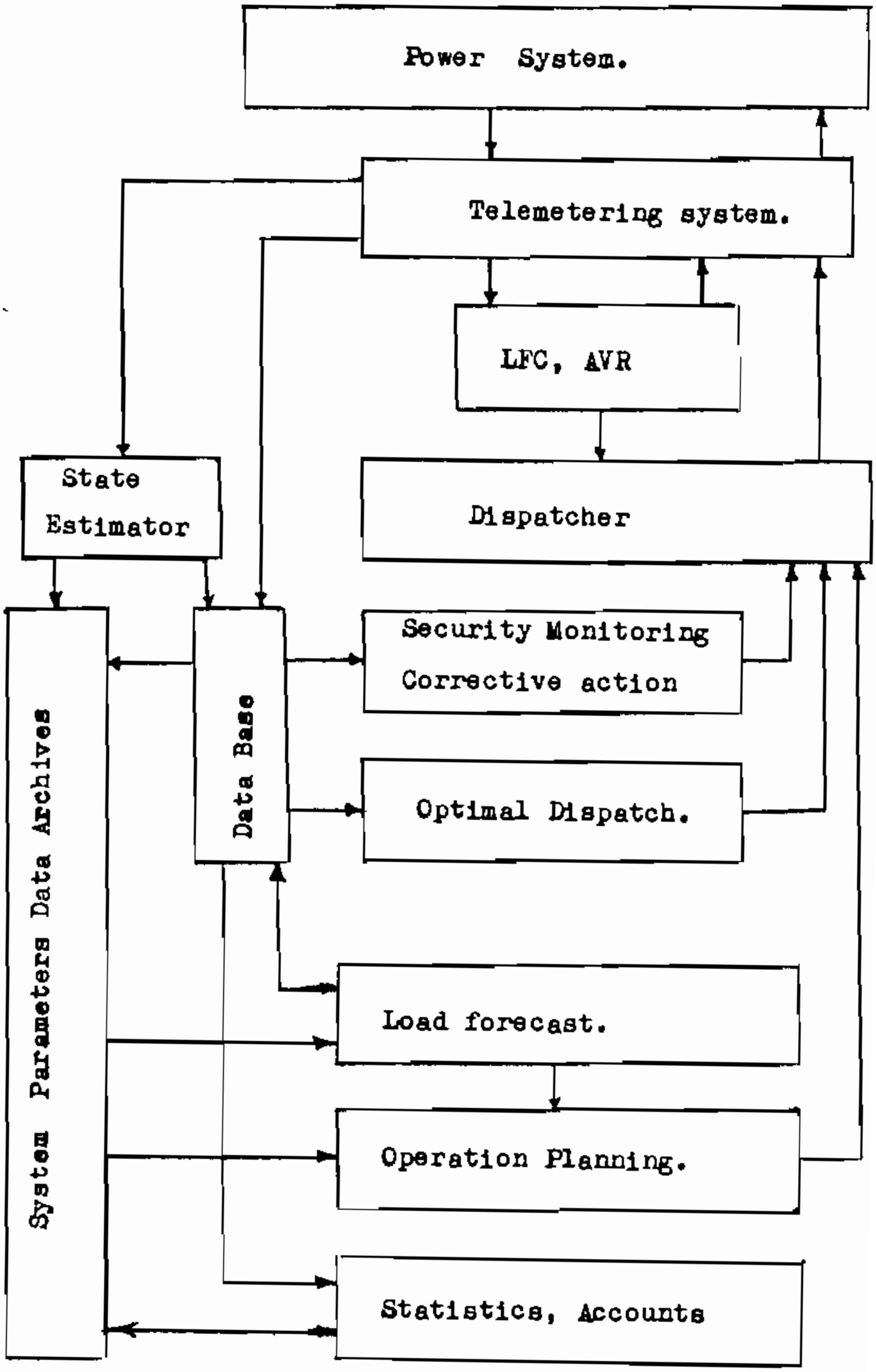

Fig. (1) Power System Operation.

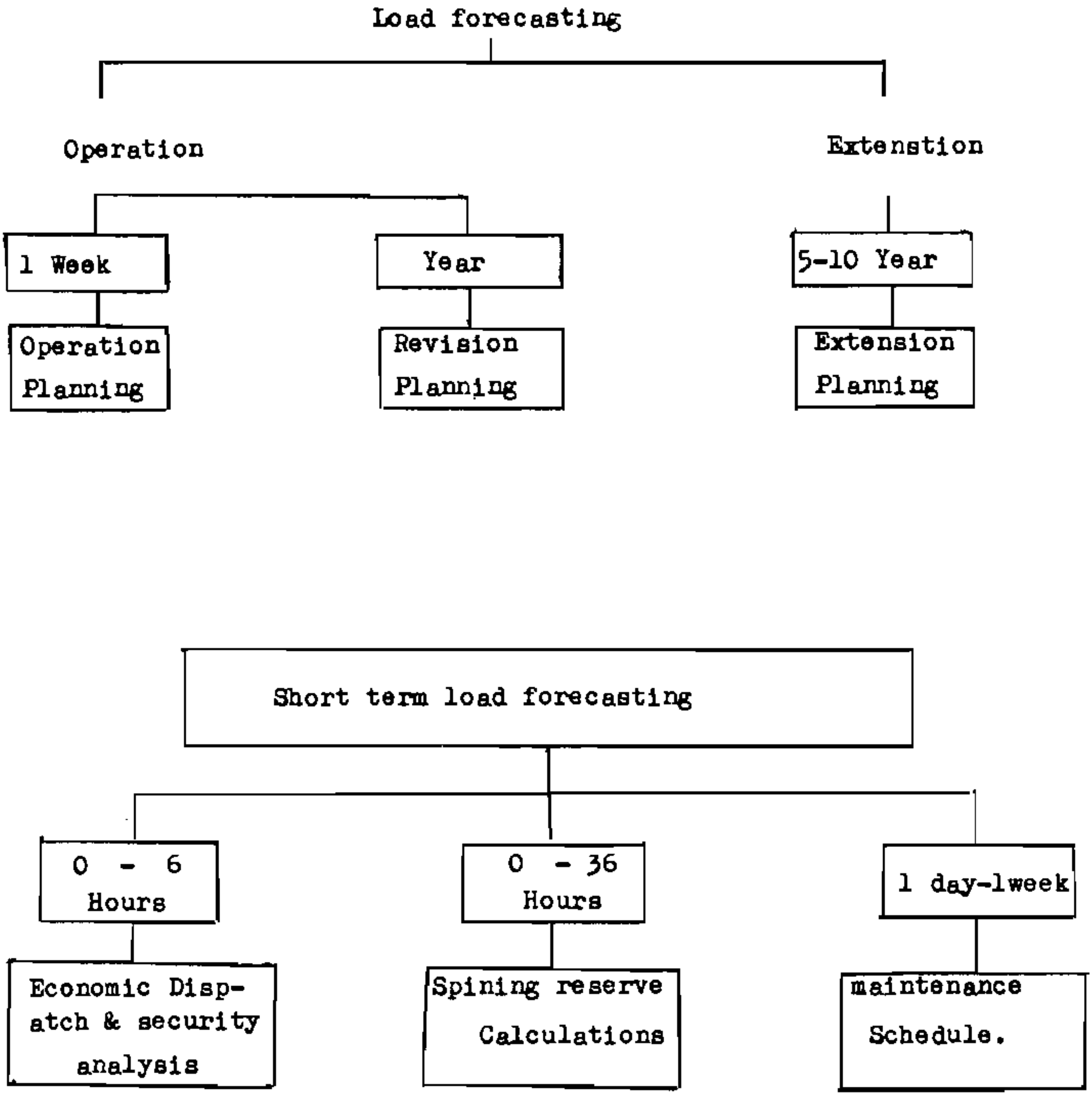

Fig. (2) Classification of load forcasting Problem.

these functions with appropriate weights. These methods assume that the load is stationary in character and regard any abnormal data points as random noise corruption to be ignored. Weather data is not utilized. Thus, the predictions are necessarily purely mathematical extrapolation common.

b) Regression methods:

These methods attempt to analitically reconstruct the causal function relationship between the load and the influential factors such as weather which includes temperature, wind velocity and humidity, Normally in these methods non-linear models are postulated and the parameters are to be estimated using approximation techniques the approximating functions employed are generally simple to facilitate easy computations. The main disadvantage of these methods is that they seek to represent the complex relationship between load and meterological data by simple models often chosen arbitrarily. Interaction between the various factors is either expressed or ignored.

4. THE RELATIONSHIP BETWEEN WEATHER AND ELECTRICAL DEMAND:-

To study the relationship between weather and electrical demand, the different items of weather which affects the demand must be studied. These factors can be classified as:-

1- Temperature
2- Wind speed
3- Clouds
4- Visibility and precipitation

The temperature and wind speed controls the heating demand regarding that the wind speed controls the disipating heat from buildings.

The rest of these items are used to estimate the day light illumination which determines the lighting demand.
Each of these factors will have be taken in details as:

4.1) Temperature:

Temperature las a large influence on the demand, but owing to the thermal storage in the fabric of buildings the demand does not respond immediately to temperature changes.

If T_o is the ambient temperature, the simple imperical equation which express the lag of internal temperature θ is the 1st order lag equation.

$$\frac{d\theta}{dt} + \lambda \theta = \lambda T_o \qquad (1)$$

where $\lambda = \frac{1}{\tau}$ (τ is the thermal time constant).
In this equation, it is assumed that the time constants for cooling and heating are the same.
So,

$$\theta = \lambda e^{-\lambda t} \int_0^t e^{\lambda t} T_o(t)\, dt \qquad (2)$$

If t is measured towards the past and θ is the room temperature at t = 0, we have

$$\theta = \lambda \int_0^\infty e^{-\lambda t} T_o(t)\, dt \qquad (3)$$

Replacing the integral by summation over sufficiently small unit time intervals, then:

$$\theta = \lambda \left[T_o + e^{-\lambda} T_{-1} + e^{-2\lambda} T_{-2} + e^{-3\lambda} T_{-3} + .. \right] \qquad (4)$$

where,
T_o, T_{-1}, T_{-2},.... are the external air temperature at times t = 0, 1, 2.... and θ is the effective temperature.
If

$$\beta = e^{-\lambda} \qquad \& \qquad \alpha = 1 - \beta$$

Therefre,

$$\theta = \alpha \left[T_o + \beta T_{-1} + \beta^2 T_{-2} + ... \right]$$

$$T_E = \alpha T_o + \beta T_{E\ -1} \qquad (5)$$

Applying these equations for actual data, the values of α & β could be determined (1) as:

$$\alpha = 0.045 \qquad \beta = 0.955$$

$$T_E = 0.045\ T_o + 0.955\ T_{E-1} \qquad (6)$$

4.2) Cooling Power of wind:-

The heating power demand may be divided into thermal storage component and a component due to the cooling power of wind in association with temperature So, the first component is controlled by direct effect of temperatre. Experiments on heat transmission through walls have shown that the effect of wind speed is negligable (1).
The heat loss from bodies exposed to wind is given by:

$$W^m (T_s - T) \tag{7}$$

where:

T_s body temperature
T ambient temperature
W wind speed
m constant

The value of m can be obtained from experimental data

$$m \simeq 0.5 \longrightarrow 1$$

4.3) Day light Illumination:-

The lighting component of the demand is determined by the day light illumination received at the earth surface. The factors effecting the daylight illumination at any time are:

Clouds, atmospheric turbidity and the reflection at the ground. studies of the weather conditions gives the relation between the sun elevation and the illumination in cloudless conditions as shown in the following Table 1:

Sun elevation °	0	5	10	15	20	25
Mean illumination (kilolox)	0.5	6	14	22	31	40

Sun elevation °	30	35	40	45	50	55	60
Mean illumination (kilolox)	48	57	66	74	82	89	93

Table (1)

The sun elevation can be calculated from the following relation

$$\text{Sin } h = \cos \delta \cdot \cos \phi \cdot \cos H + \sin \delta \cdot \sin \phi \qquad (8)$$

where

ϕ is the latitude

H local hour angle

δ sun declination

H = Greansh hour angle + east longitude

The effect of clouds and visibility must be taken into consideration. It is found that the day light illumination (I) can be expressed on a logarithmic scale as:

$$\text{Illumination index} = \log_{10} I \qquad (9)$$

where (I) is the illumination in kilolox. Fig. (3) gives the relation between the demand and the illumination.

5. PROPOSED ALGORITHM:

The week days are classified such that we have

- Working days.
- Week end days.
- Holidays and special days.

The problem of short term load forecasting for the holidays and special days was treated separately by the author (4). With respect to the working days, it is suggested that:-

The load at hour "h" and day "d" in the week (n+1) can be predicted from the known past data for the loads at the same hour "h" in the day "d" in the weeks n, (n-1), (n-2),......., 2,1 and a component represents the weather sensitive load as it will be cleared after. The length of past data used is for one season to have approximately similar weather during that season i.e. the data for the hourly loads and weather conditions for the previous three months is used.

hence,

$$n \simeq 12 \qquad (10)$$

So, mathematically, it is proposed that:

$$P_{h,\ d,\ (n+1)} = P_{h,d;n} + \frac{1}{n-1} \sum_{i=2}^{n} (P_{h,d,i} - P_{h,d,(i-1)})$$

$$+ W_{d,(n+1)} \qquad (11)$$

where,

$P_{h,d,n+1}$ is the forecasted load demand in hour h, day d and week (n+1)

$P_{h,d;n}$ load at hour h, day d and week n

$\frac{1}{n-1} \sum_{i=2}^{n} (P_{h,d,i} - P_{h,d,i-1})$ is the average of the differences in load demand at hour h, day d in the successive weeks.

$W_{d,n+1}$ Weather sensitive component

Computation of Weather sensitive component:

$W_{d,n+1}$ can be predicted as it will have two parts. The 1st is weather senstive component of the previous day and the 2 nd is the average of the differences of the weather senstive components for the day "d" in the previous weeks. So, mathematically we have

$$W_{d,n+1} = W_{d-1,\ n+1} + \frac{1}{n-1} \sum_{i=2}^{n} W_{d,i} - W_{d,i-1} \qquad (12)$$

where:

$W_{d,n+1}$ Weather sensitive component for the day d in week n+1 in which load is to be predicted

$W_{d-1,n+1}$ Weather sensitive component in the day before the day loads are to be predicted

$\frac{1}{n-1} \sum_{i=2}^{n} W_{d,i} - W_{d,i-1}$ is the average of the differences between weather senaitive components in day d and in the previous weeks.

6. NUMERICAL APPLICATION

Applying the suggested algorithm on actual data of a certain

Day	Mon day			Tues day			Nenes day		
Hour	actual Load MW	forecasted Load MW	% error	actual Load MW	forecasted Load MW	% error	actual Load MW	fore casted Load MW	% error
12	163	169	3.7	160	163	1.9	166	162	-2.6
1	160	162	1.25	155	156	0.7	158	155	-1.8
2	158	152	-3.8	156	150	-3.5	157	154	-1.8
3	158	162	2.5	156	151	-2.9	159	156	-1.6
4	172	178	3.5	157	162	3.2	169	164	-3.00
5	228	235	3.1	222	227	2.2	224	226	0.8
6	317	325	2.5	316	320	1.4	320	324	1.1
7	369	384	4.2	363	379	4.5	366	370	3.00
8	357	348	-2.6	355	357	0.5	354	339	-4.1
9	394	380	-3.3	396	404	2.1	392	407	3.9
10	401	403	0.5	393	386	-1.7	396	406	2.5
11	376	380	1.1	377	363	-2.1	383	390	1.9
12	382	389	1.9	381	377	-1.1	381	387	1.7
1	373	367	-1.6	367	366	-0.3	383	385	0.5
2	372	380	2.1	372	378	0.2	373	373	0.0
3	342	333	-2.7	342	355	3.7	342	325	-5.1
4	320	326	1.8	319	327	2.5	324	315	-2.9
5	298	299	0.3	299	308	3.00	312	304	-2.7
6	303	317	4.5	287	292	1.7	335	345	2.9
7	279	289	3.7	273	278	1.7	295	291	-1.4
8	289	299	3.6	283	295	4.1	289	282	-2.4
9	261	257	-1.4	260	255	-1.8	260	255	-2.1
10	209	208	-0.4	219	225	2.6	209	205	-1.9
11	178	180	1.3	178	179	0.5	181	175	-3.2

Table (2)

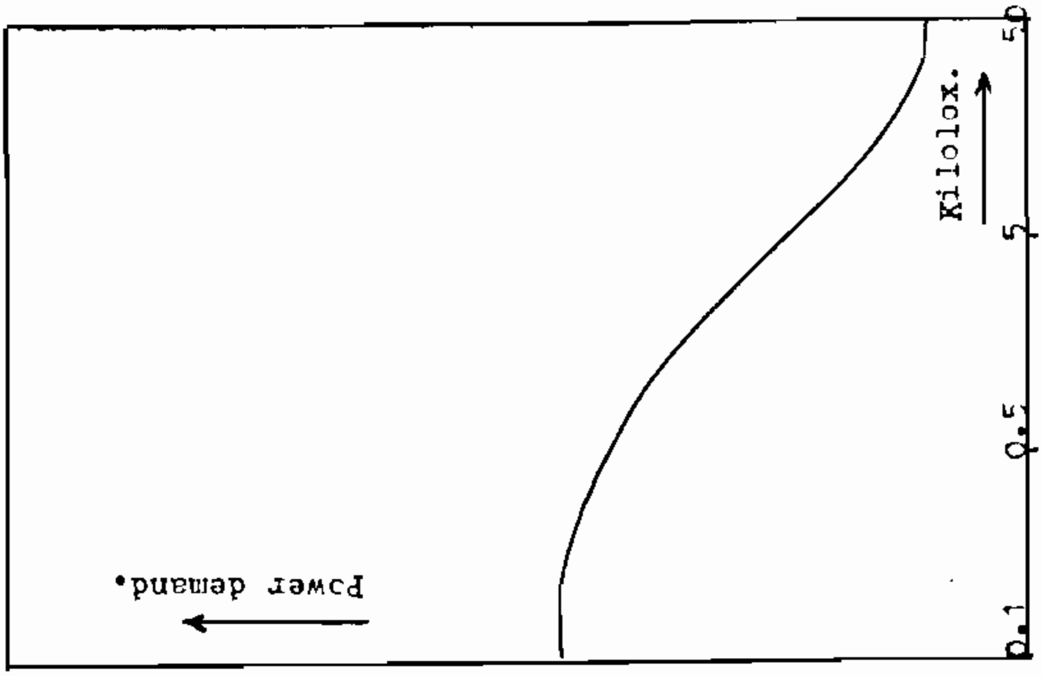

Fig. 3: Day light illumination - Power demand curve (1).

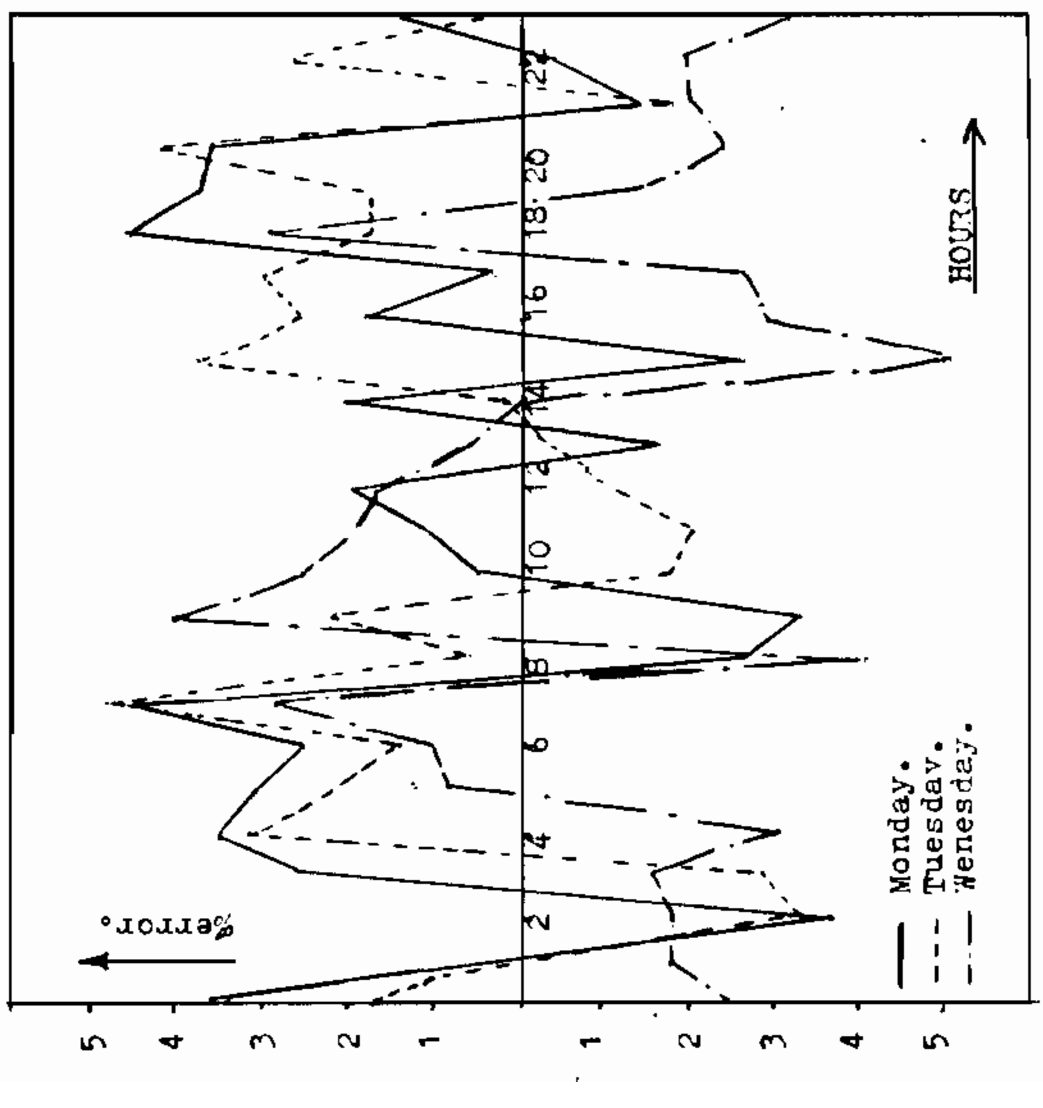

Fig. 4: %error against hours for three working days.

load. The hourly loads for different days are computed by the aid of past historical data. Table 2 gives the results obtained for the hourly forcasted loads using the computer for a data length of 12 week. The predicted hourly loads for 3 successive days at the end of May are compared with the actual data of these loads and percentage of error is also given. The historical past data used is for months March - April and May.

It could be noticed that the holidy data are excluded from the past data used. Fig. (4) shows the percentage error in the predicted load at the different hours for the three successive working days.

7. CONCLUSIONS:

From the previous analysis and computer results we have:-

1. A detailed analysis for factors affecting the weather sensitive component in load is made and equations relating these factors with electricity demand is derivated.
2. The weather effect must be taken into consideration in the models for short term load forecasting.
3. The application of the proposed model to actual data shows that the maximum absolute percentage error does not exceed 5%.
4. The proposed algorithm is distinguished by simplicity and high accuracy.
5. The effect of weather on load demand is treated in the proposed model accurately.

13. Mansoura Bulletin December 1977.

REFERENCES

1. Davies M. "The relationship between weather and electricity demand". IEE. Proc. Oct. 1958.

2. Galiana.D. "Identification of stochastic electric load models from physical data". IEEE Trans. Dec. 1974.

3. Phua, Dillon: "Power sytem load models suitable for use in generation, planning and maintenance scheduling". IEEE Trans. March 1977.

4. M.Tantawy "Short term load forecasting for holidays and special days". Jahresbericht 1976 der Forschungsgese llschaft Energie an der RWTH Aachen s.v. 1977.

5. El-Sayed "Ein model Zur kurzfristigen prognose der elektrischen leistung". Ibid 1977.

6. R.P.Thomson "Weather sensitive electric demand". IEEE Trans 1976 P. 385.