Mansoura Engineering Journal

Volume 3 | Issue 2 Article 4

12-1-1978

A Proposed Methodology for Medium-Range Maximum Demand Anticipation and Application.

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Mansoura Bulletin December 1978.

"A PROPOSED METHODOLOGY FOR MEDIUM-RANGE MAXIMUM DEMAND ANTICIPATION AND APPLICATION"

BY

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ABSTRACT

One to three years anticipation of monthly and weekly peak demand are required to: prepare maintenance schedules, develop power pooling agreements, select peaking capacity and provide data required certain reliability coordinating centers. The total monthly forecast of the maximum demand (m.d.) is deduced and computed along the future three years till April 1981. This is accomplished for a one of vital important electrical network in EGYPT. The anticipation is executed for El-Mehalla El-Kubra City network. This network has an industrial and residential daily load characteristics Direct monthly m.d. forecasting is executed by separate treatment of non-weather (NW)and weather-induced (W) demand. The forecast required is derived through this paper by two methodologies: the probabilistic extrapolation - correlation and that suggested by the authors Data collected for our work is the daily and monthly data for more reliable determination of weather load models. Complete analysis, discussions and comments on the results are exhibited. An entire comparison is also made between the results. This comparison reveals an acceptable and reasonable percentage error obtained on applying the proposed methodology.

1. INTRODUCTION

Load forecasting is the first step in power system planning. Forecasting of both demand and energy requirements is very necessary to determine the capacity of generation, transmine the capacity of generation, transmission, and distribution system additions, as well as the energy forecasts determine the type of facilities required.

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Medium range forecasting of maximum demand (m.d.) is required to: preare maintenance schedules, develop power pooling agreements, select peaking capacity and provide data required certain reliability co-ordinating centers.

Previous work in m.d. anticipation[1,3] has adopted the probabilistic extrapolation - correlation technique. This method has been used in this paper and applied to a practical network in EGYPT. The paper also introduces a new methodology for deriving the monthly forecasting of m.d.

2. Computation of m.d. by probabilistic extrapolation - correlation technique.

The goal of this section is to compute the m.d. anticipation for certain month in the future time for the electrical distribution network of El-Mehalla El-Kubra City. The data required is the daily m.d. and the corresponding appropriate weather variable which is taken the dry-bulb temperature.

The single line diagram of the electrical distribution network taken is revealed in "Fig. 1".

This methodology comprises[1]: (a) the derivation of the weather load model for each season of the historical period.
(b) the determination of the mean and variance of NWS component along the past period taken.
(c) the forecasting of the mean and variance of NWS component.
(d) the estimation of the mean and variance of WS component.
(e) the deduction of the mean, variance, and probability density function total anticipation.

The complete scheduling of the results obtained is tabulated in the following manner:

Table (1)

Month	Month No(x)	$\bar{\Theta}$ (MW)	σ_Θ^2	σ_Θ (MW)
May 1978	25	15.40	1.557	1.247
June	26	15.58	1.567	1.252
July	27	15.77	1.619	1.272
Aug.	28	15.95	1.665	1.290
Seb.	29	16.32	1.765	1.328
Oct.	30	16.32	1.765	1.328
Nov.	31	16.35	1.328	1.152
Dec.	32	16.52	1.357	1.165
Jan.1979	33	16.99	1.384	1.176
Feb.	34	16.86	1.413	1.188
March	35	17.02	1.441	1.200
April	36	17.19	1.469	1.212

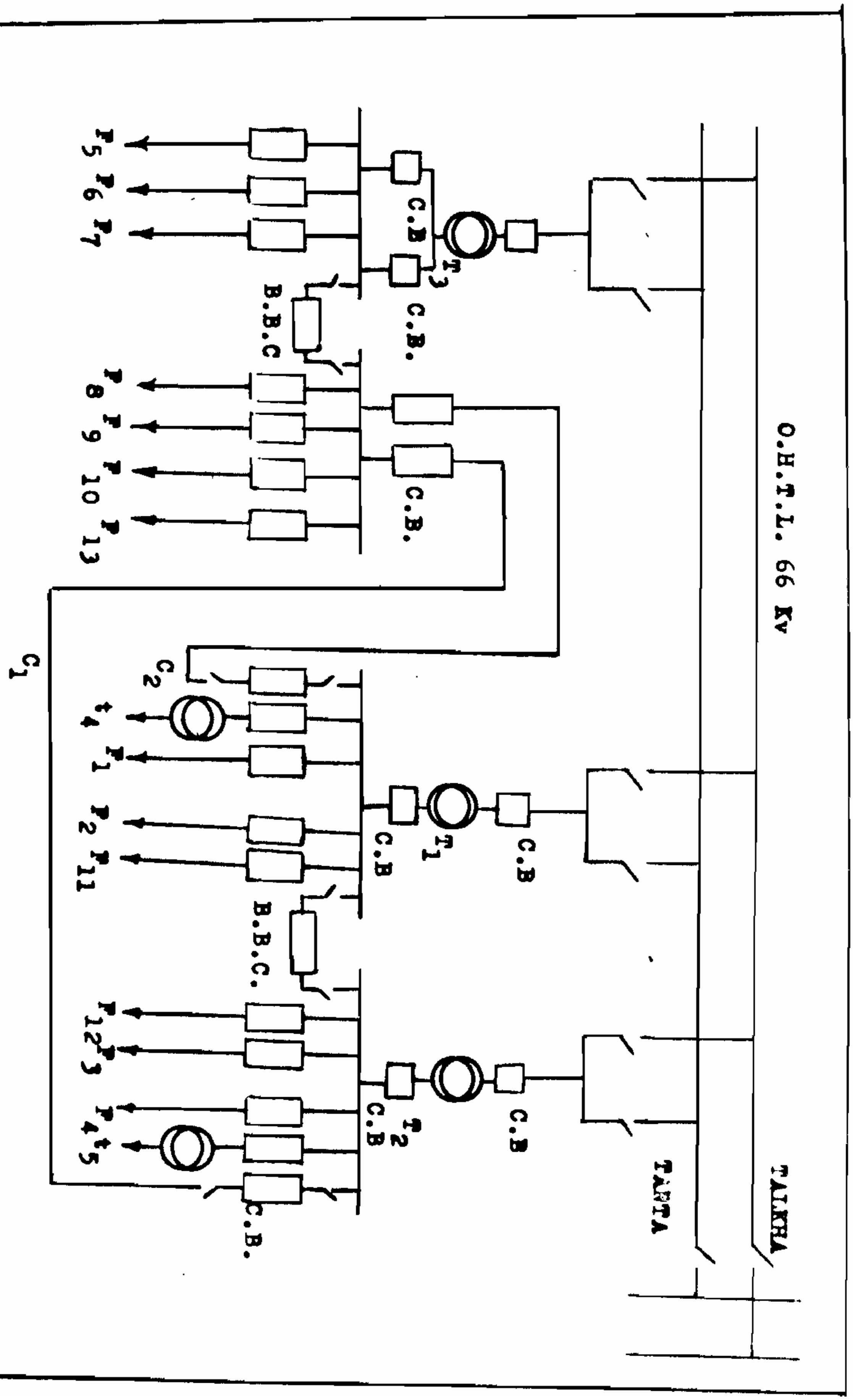

Fig (1) Single line diagram of El-MEHALLA El-KUBRA CITY SUBSTATION.

Table (1) Continue

Month	Month No.(x)	$\bar{\Theta}$ (MW)	σ^2_Θ	σ_Θ (MW)
May	37	17.59	2.165	1.471
June	38	17.78	2.223	1.491
July	39	17.97	2.284	1.511
Aug.	40	18.15	2.342	1.530
Seb.	41	18.32	2.431	1.559
Oct.	42	18.53	2.490	1.578
Nov.	43	18.31	1.658	1.287
Dec.	44	18.48	1.686	1.298
Jan. 1980	45	18.65	1.714	1.309
Feb.	46	18.82	1.742	1.320
March	47	18.99	1.770	1.330
April	48	19.15	1.798	1.341
May	49	19.73	2.657	1.630
June	50	19.91	2.717	1.648
July	51	20.10	2.777	1.666
Aug.	52	20.29	2.836	1.684
Sept.	53	20.48	2.898	1.702
Oct.	54	20.66	2.998	1.731
Nov.	55	20.33	1.990	1.411
Dec.	56	20.50	2.021	1.421
Jan.1981	57	20.67	2.049	1.431
Feb.	58	20.84	2.077	1.441
March	59	21.01	2.105	1.450
April	60	21.17	2.133	1.460

where $\bar{\Theta}$ is the total monthly estimation of the mean (MW)
$\bar{\Theta} = \bar{M}$ (NWS) + $\bar{W}$ (WS)

σ^2_Θ is the total monthly estimation of the variance $(MW)^2$

$\sigma^2_\Theta = \sigma^2_M$ (NWS) + σ^2_W (WS)

Since the total monthly forecast is Gaussion and its mean and variance are demonstrated, then the probability density function for any future month is computed by the aid of the following equation[1]:

$$f(\Theta, \bar{\Theta}, \sigma_\Theta) = \frac{1}{\sigma_\Theta \sqrt{2\pi}} \ \text{Exp}\left(-\tfrac{1}{2}\left(\frac{\Theta - \bar{\Theta}}{\sigma_\Theta}\right)^{+2}\right)$$

3. Computation of m.d. by the proposed methodology

The probabilistic extrapolation correlation approach needs daily data for reasonable past years. Sometimes, this data is not available in EGYPT. This leads us to think about a new methodology which requires monthly data rather than daily one because of its availability.

Thus, the data required here is the entire monthly m.d. in (MW) and the corresponding temperature in (°C). This temperature is deduced by averaging three registered temperatures three hours before, at, and after the instant of attaining the m.d. of certain month. This method of having this temperature is ascribed by the fact that the effect of weather appears not only at the instant of having the m.d. but also extending to the time preceding and following this instant. This data is gathered along the past five years beginning with May 1973 till April 1978.

The suggested methodology may be explained as follows:

1) The NWSC of the m.d. anticipation is deduced by passing an appropriate polynomial curve (trend) through the available historical data by the application of the least squares technique. Thus, we derive an appropriate trend for each individual year of the 5 years taken as a historical period. The following equations represent the mathematical expressions of these polynomials:
   First year (May 73 - April 74): $T = 4.7941+0.3533x -0.0136\ x^2$
   Second year(May 74 - April 75): $T =-0.8749+0.3754x$
   Third year (May 75 - April 76): $T =-0.6119+0.3776x$
   Fourth year(May 76 - April 77): $T =-15.6157+0.6139x$
   Fifth year (May 77 - April 78): $T =-248.3050+8.8029x-0.0734\ x^2$

2) The separation of this trend from the weather and noise components is attained by subtracting it from the historical characteristics. This separation is executed for each month of the past 5 years.
   The weather and noise components are designated by the fluctuation component (F).

3) The characteristic relating the weather and noise components and the temperature for each month is plotted by the aid of the historical data. Then, an adequate curve is passed through This characteristic for each season, representing the weather load model for this season. We have three distinct regions: the first one has the range of $t \geqslant 24$°C while the second belongs the range of $17 < t < 24$°C and eventually the region of $t \leqslant 17$°C. For each of these regions, we have three different fitting linear relations using the least squares method. Also the slope of each weather model is derived for each season along the past period. Table (2) Summarizes the weather load model coefficients for the preceding period (May 1973 - April 1978).

Table (2)

Year	Summer K_{so}	Summer K_{s1}	Winter K_{wo}	Winter K_{w1}
May 73 - April 74	4.2445	-0.1584	-1.4162	0.1036
May 74 - April 75	7.0067	-0.2601	-5.1183	0.3323
May 75 - April 76	18.3352	-0.7079	-1.9304	0.1726
May 76 - April 77	36.7734	-1.3372	-14.1822	0.9358
May 77 - April 78	25.5837	-0.9483	-5.9149	0.4045

Thus, the complete scheduling is now available for the NW (trend), W and noise (E) components for each month of the historical five periods. Note that the difference between this component and the historical fluctuation one results in the noise or the error component at the consideredtemperature.

4) NW anticipation is accomplished by the aid of extrapolating the unified trend which fits all the historical predetermined component for each month along the five years of research to the required future month from May 1978 till April 1981. We then apply the well-known least-squares method to determine the coefficients of the fitting function of the historical period. The general equation of this function is then:

$$T = 4.6729 + 0.1793\ x$$

Thus, the monthly forecasting of NWS component is derived by extrapolating to the future required month - the fitting function deduced as before.

5) The predication of the WSC is executed through the following three steps:

a) by extrapolating the coefficients of the weather load model for each season (K_s for summer and K_w for winter seasons), to get them at the required future month.

b) by forecasting the weather variable (temperature) to the future required month. This is executed by the calculation of $\bar{T}_s$ (for summer), $\bar{T}_w$ (for winter), σ_s^2 and σ_w^2 i.e. the mean and variance of temperature for the summer and winter seasons respectively along the five years of the historical period.
Then a reasonable fitting function is passed through the points of each of the preceding parameters. The future values are deduced by extrapolating each curve. The forecasting of the temperature at any future month is deduced by assuming the temperature distribution to have the Gaussion (bell) shape during

each season. Then, the probability density function $f(t_s)$ is calculated from the relation:

$$f(t_s) = \frac{1}{\sqrt{2\pi}\,\sigma_{TS}} \; \text{Exp.} \left(-\tfrac{1}{2} \left(\frac{\bar{T}_s - T_{si}}{\sigma_{Ts}}\right)^2\right)$$

for summer season - similarly, this expression is applied for the winter season.

We compute the factor $\frac{\bar{T}_s}{\bar{f}(t_s)}$ which gives the value of $\bar{T}_s$ per unit $\bar{f}(t_s)$. The temperature anticipated for each month of multiplying this factor with $\bar{f}(t_s)$ corresponding to that month.

c) By deriving, eventually, the WSC forecast simply by the direct substitution of the extrapolated coefficients of certain season and the corresponding temperature at any future month in the weather load model.

6) The noise component forecast is attained by means of Fourier series analysis which leads to three main items: d.c., Sine and cosine components. This is derived as follows:

a) This component is deduced along the historical period simply by subtracting the WSC out of the fluctuation one(F)for each month of this period.

b) This results in the noise components along the months of the past period. With regard to the wave form of this component against the month number, we note that it satisfies the conditions of analysis by Fourier series.

c) The coefficients of each harmonic are then calculated for each season of the historical and future period. The higher harmonics are omitted because of having very small values.,
By graphical means, we demonstrate the Fourier Series of each Season of the future years.

d) For the year (May 1978 - April 1979)

Summer:

$$E_s(t) = -0.780 + 2.1633 \text{ Sin } (x' - 33.69) + 0.3635 \text{ Sin } (2x' - 7.9070)$$

Winter:

$$E_w(t) = -0.065 + 0.9962 \text{ Sin } (x' + 72.47) + 0.3687 \text{ Sin } (2x' - 12.53)$$

For the year (May 1979 - April 1980)

Summer:

$$E_s(t) = 0.70 + 1.0632 \text{ Sin } (x' - 16.3895) + 0.2920 \text{ Sin } (2x' - 30.9640)$$

Winter:

$$E_w(t) = 0.30 + 0.8490 \text{ Sin}(x' + 57.9900) + 0.9024 \text{ Sin } (2x' - 12.8000)$$

For the year (May 1980 - April 1981)

Summer: $E_s(t) = 0.0500 + 1.5075 \sin(x' + 5.7100) + 0.6500 \sin(2x' - 22.62)$

Winter: $E_w(t) = 0.080 + 1.1100 \sin(x' + 35.8370) + 0.5467 \sin(2x' - 39.8100)$

7) The monthly total anticipation of the m.d. along the next three years (May 1978 - April 1981) is derived by summing up the various components: NWS, WS and E components for each month. This sum is registered through Table (3).

Table (3) Monthly total anticipation of maximum demand (m.d.)

Month No. x	Year	Trend NWS	Weather WS	Noise E	Total (m.d.) (M)
65	May 1978	16.3253	0.4208	-1.3339	15.4122
66	June	16.5045	-0.9740	-0.0443	15.4863
67	July	16.6838	-2.3364	0.9087	15.2561
68	Aug.	16.8630	-1.2973	1.1298	16.6955
69	Seb.	17.0423	-0.8128	0.4449	16.6745
70	Oct.	17.2216	-0.7862	0.5843	17.0197
71	Nov.	17.4008	0.1971	-0.9213	16.6707
72	Dec.	17.5801	-0.6072	-0.5834	16.3895
73	Jan.1979	17.7594	-0.7049	-0.3735	16.6809
74	Feb.	17.9386	-0.0394	-0.2477	17.6515
75	March	18.1179	-1.9564	0.0291	16.1906
76	April	18.2972	-1.2933	0.5484	17.5523
77	May	18.4764	-0.9286	0.6693	18.2171
78	June	18.6557	-1.4537	1.4595	18.6615
79	July	18.8349	-2.4117	1.8629	18.2862
80	Aug.	19.0142	-3.1434	1.7678	17.6384
81	Seb.	19.1935	-1.8173	1.3829	18.7593
82	Oct.	19.3728	-0.8306	0.9985	19.5407
83	Nov.	19.5520	-0.5233	-0.2450	18.7838
84	Dec.	19.7313	-0.8015	0.3527	19.2825
85	Jan.1980	19.9106	-0.8746	0.2921	19.3281
86	Feb.	20.0898	-0.9769	-0.2152	18.8977
87	March	20.2691	-1.0195	-0.3891	18.8604
88	April	20.4484	-0.6561	0.2658	20.0580
89	May	20.6276	-1.5579	0.6666	19.7363
90	June	20.8069	-2.7692	2.3173	20.3549
91	July	20.9862	-3.2747	2.0542	19.7657
92	Aug.	21.1654	-3.3443	1.3766	19.1977
93	Seb.	21.3447	-0.3943	0.4046	21.3551
94	Oct.	21.5239	0.2716	-0.2231	21.5724
95	Nov.	21.7032	-0.5852	-0.8738	20.2442
96	Dec.	21.8825	-1.0735	-0.5959	20.2131
97	Jan.1981	22.0618	-1.5676	-0.4474	20.0380
98	Feb.	22.2410	-1.5779	-0.5346	20.1285
99	March	22.4203	-1.0840	-0.5253	20.8109
100	April	22.5996	-0.5909	-0.0464	21.9622

4. Comparison between the two methodologies

A complete comparison is made between the probabilistic extrapolation-correlation and proposed methods to display the comptibability of the latter for computing the monthly total anticipation of m.d. Table (4) reveals the entire scheduling of the m.d. for each month in the period of forecasting initiated with May 1978 till April 1981 as computed by means of the two techniques. The percentage error for each month is derived on the basis of the former method. This error has the range of 0.0147% and + 5.4333% which explains that the suggested methodology has a comparable results and practically, it has the same anticipation as the present technique.

Table (4)

Months	m.d. by Prob. Extr. correl. method (MW)	m.d. by the Suggested method. (MW)	Error %
May 1978	15.4037	15.4122	0.0552
June	15.5869	15.4863	-0.6459
July	15.7708	15.2561	-3.2636
Aug.	15.9546	16.6955	4.6438
Seb.	16.1385	16.6745	3.3213
Oct.	16.3228	17.0197	4.2695
Nov.	16.3566	16.6767	1.9570
Dec.	16.5225	16.3895	-0.8049
Jan. 1979	16.6939	16.6809	-0.0778
Feb.	16.8616	17.6515	4.6846
March	17.0295	16.1906	-4.9262
April	17.1972	17.5523	2.0649
May	17.5994	18.2171	3.5098
June	17.7852	18.6615	4.9271
July	17.9725	18.2862	1.7454
Aug.	18.1589	17.6384	-2.8664
Seb.	18.3205	18.7593	2.3951
Oct.	18.5337	19.5407	5.4333
Nov.	18.3144	18.7838	2.5630
Dec.	18.4813	19.2825	4.3352
Jan. 1980	18.6552	19.3251	3.6070
Feb.	18.8213	18.8977	0.4059
March	18.9922	18.8604	-0.6939
April	19.1584	20.0580	4.6956
May	19.7334	19.7363	0.0147
June	19.9159	20.3549	2.2043
July	20.1069	19.7657	-1.6969
Aug.	20.2938	19.1977	-5.4012
Seb.	20.4808	21.3551	4.2689
Oct.	20.6683	21.5724	4.3743
Nov.	20.3333	20.2442	-0.4392
Dec.	20.5032	20.2131	-1.4149

Table (4)(Continue)

Months	m.d. by Prob. Extr. correl. method (MW)	m.d. by the Suggested method. (MW)	Error %
Jan. 1981	20.6719	20.0380	-3.0665
Feb.	20.8407	20.1285	-3.4174
March	21.0115	20.8109	-0.9547
April	21.1783	21.9622	3.7014

Along the future three years, the error fluctuates between positive and negative percentages. The m.d. is plotted versus the time expressed in months (Fig. 2) for the two methodologies to display the extent of convergence between the results attained (Fig. 3) shows the behaviour of variation of percentage error along the months of the period of forecast.

5. Conclusions

The main conclusions of this article may be summarized as follows:

a) The suggested method introduced in this paper gives accurate results compared with the probabilistic extrapolation correlation method.

b) The data required for the proposed methodology is the monthly one rather than daily data. Thus, this methodology is more adequate in our country, at present, due to lack of daily data.

c) The WSC has a few percentage of the total monthly mean forecast (Θ) in the range of about 0.65 to 3%. The lower figure belongs the winter season meanwhilethe higher one is obtained for the summer season. This means that the latter has a more influence on the humanbeing than the winter one, so this reflects the increase of the utilization of the electrical energy during the summer season.

d) Also, this ratio (3%) (the higher limit) reveals a very small portion weather component with respect to the total mean forecast, while the major part is a non-weather component i.e. independent of the weather component. This is ascribed by the fact of the nature of load taken which is mainly non-weather industrial factories.

e) The noise component in the probatulisticextrapolation correlation technique is not analysed in detail. However, in the proposed methodology, Fourier series concept is utilized for the analysis this component in the historical period to facilitate the forecasting operation of that component along the future period.

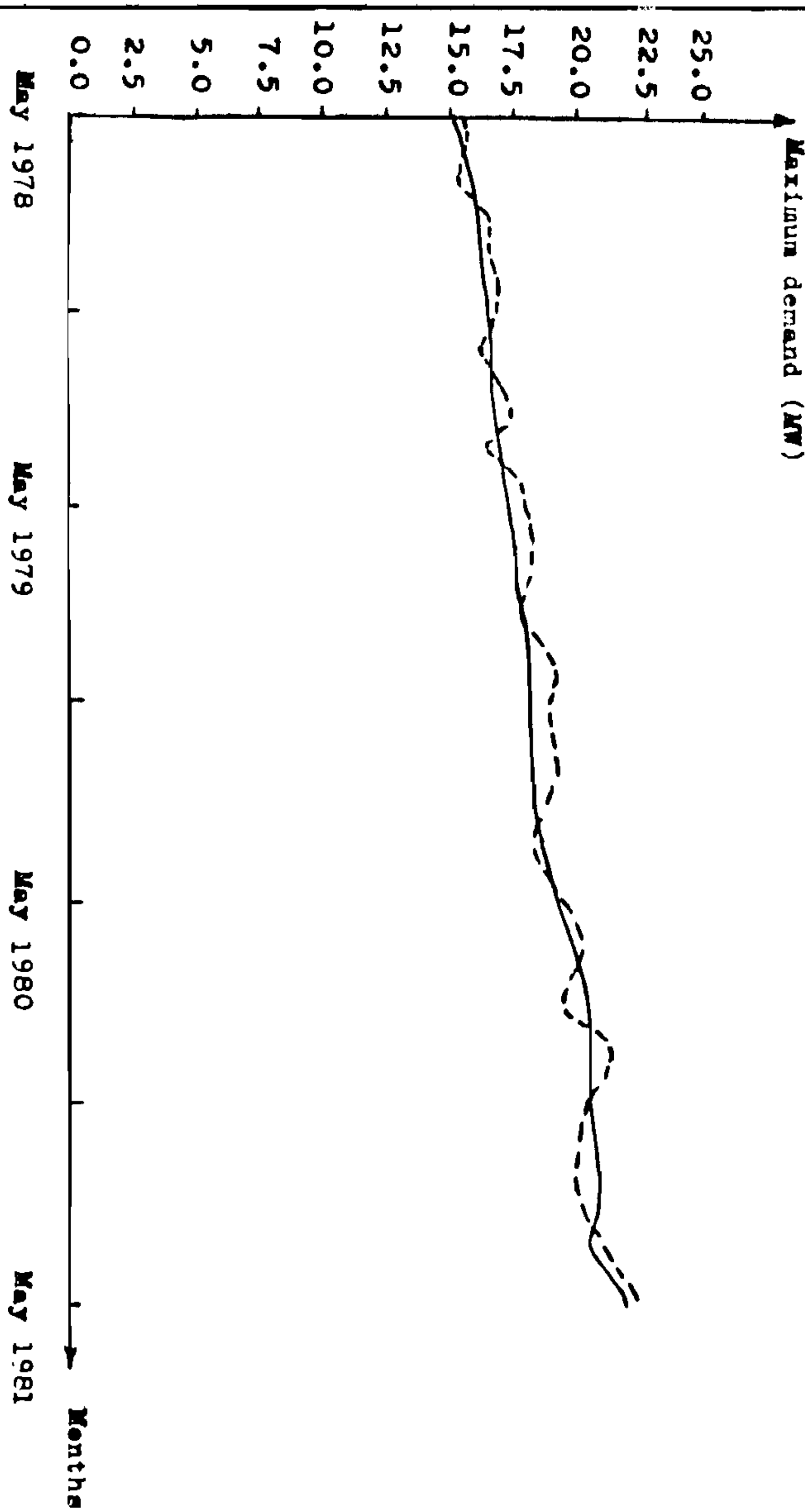

Fig. (2) Replesentation of (m.d.) by two techniques:

— By existed method.

- - - By suggested method.

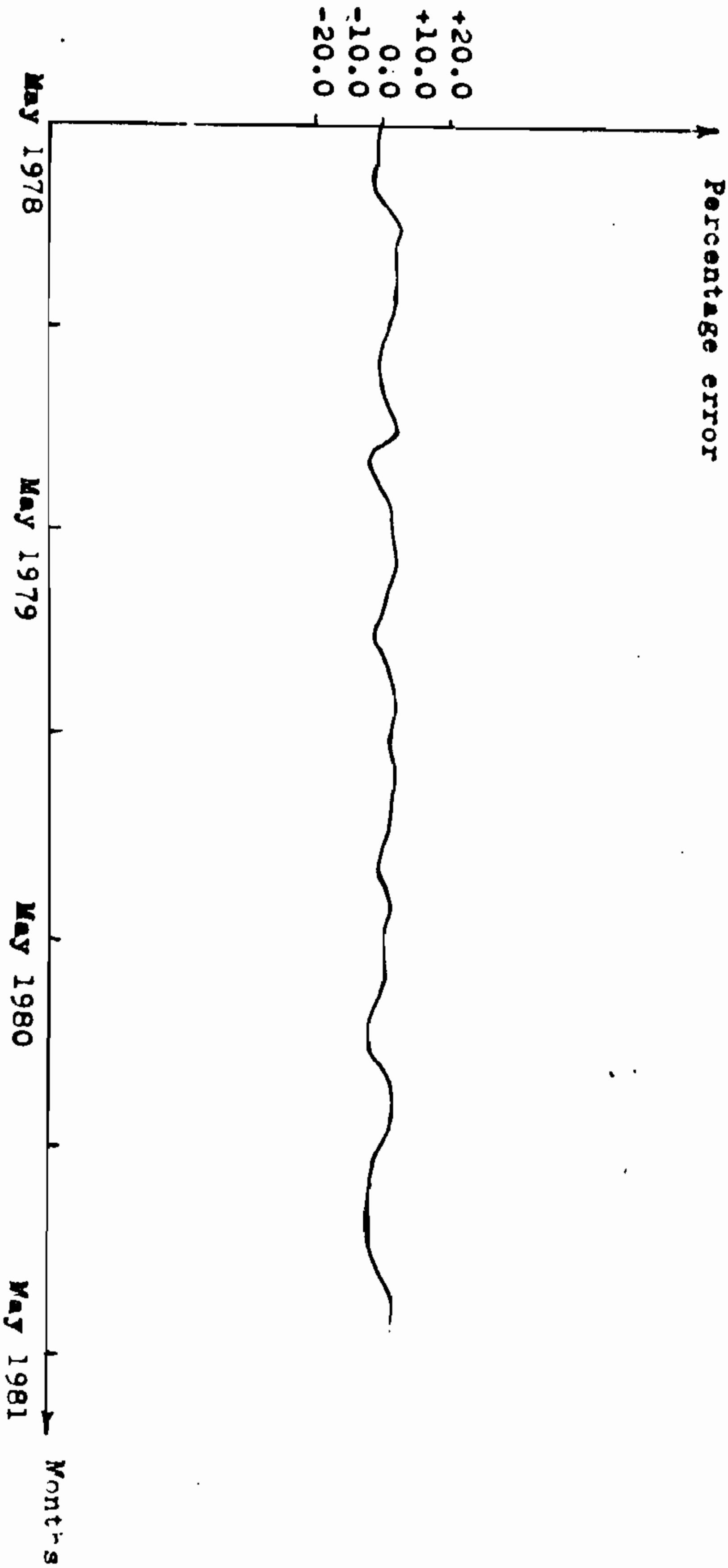

Fig. (3) Percentage error versus months .

6. Bibliography

1. SULLIVAN, R.L. "Power System planning", Book, McGraw Hill International book company, New York, pp. 33, 1977.
2. TOWILL, S. "Estimation of maximum demand on a British electricity - board system, Forecast periods of 1-3 years", PROC. I.E.E., Vol. 121, July 1974.
3. NEIL STANTON K. "Medium-Range, weekly and seasonal peak demand forecasting by probability methods", IEEE Transactions on Power Apparatus and system, pp. 1183, Published 1971.
4. HUSSIEN EL-DOSOUKY SAID, "Medium - Range Anticipation of Maximum demand on the electrical power network of El-Mehalla El-Kubra City". M.Sc. Thesis under the supervison of Dr. M.S.Kandil and Dr. M. Helmy El-Maghraby, at Faculty of Engineering El-Mansoura University, EGYPT, 1979.
5. NEIL STANTON, AND GUPTAC., "Forecasting annual or seasonal peak demand in electric utility systems", IEEE Transactions on Power Apparatus and system, Vol. PAS-89, No. 5/6, May/June 1970.
6. HEINEMAN G.T., NORDMAN D.A., and LANT E.C.P., "The relationship between summer weather and summer loads - Aregression analysis", IEEE Transactions on Power apparatus and system, Vol. PAS. 85, No. 11, No. 1966.
7. HOOKE, "Forecasting the demand for electricity" Page 993, published at October 1955.
8. BESSONOV, "Applied Electricity for Engineers", book, page 275, published in 1968.