AN EFFECIENT METHOD FOR LOAD FORECASTING OF NON-WORKING DAYS

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Abstract: A new efficient method is proposed to forecast the non-working days load demand at Ruiru substation which is a 66/11kv; 66/33kv distribution substation located along Thika road. The forecasts are based on the total daily load the substation supplies in the area which constitutes domestic, commercial and industrial loads. It is based on making the non-working days load demand a function of working days load. This method simplifies the load estimation of load demand on weekends. A lot more time is spent in computation of working days load demand using classical methods. Weekends loads are made a function of load forecasts for normal working days. This simplifies load forecasts for non-working days in that the rigorous computations are avoided thus saving time in load prediction. Through this method the numerical coefficient of weekends loads(C) is determined for its ith hour of the load for the chosen day in a month for a particular substation. The result has shown that the method is efficient with high accuracy and robust. The error margin of the weekend loads estimates was established as 1.69%.

Keywords: load forecast, working days load demand, no-working days demand load, numerical coefficient.

1.0 Introduction:

One of the most important operational control activities in power systems is forecasting of the load demand for the next day (24hrs). At present time, there are attempts to develop new methods of load forecasting and improving the already existing ones [1, 2, 3] with the aim of improving the accuracy and applicability so as to employ digital computers in their applications. The process of load change (increase/decrease) with time carries clear expression of non stationary characters [4]. Analysis methods of non stationary random process have not been developed sufficiently and are more complex than the stationary ones. In the available literature, the non stationary process is made stationary as follows:

$$Y(t) = f(t)X(t) + g(t)$$

Where $X(t)$ is the stationary random function

$f(t)$ And $g(t)$ are some real non-random function

Non stationary of system load is conditioned by the change of the consumers load over a day, week or year which depends on the operations of the industries, transport, domestic and connection of new consumer loads [5].

Consequently, the load is homogeneous in functional moments of the day for similar days for a period of time or the year, which defines the seasonal change of the load composition (Load components). The system load may be expressed as a sum of certain deterministic function which represents the mathematical expectation of the load and random component [6].

2. Representation of mathematical expectation of the load and the random components.

$$P_i(t) = M[P_i(t)] + P'_i(t)$$

Where $P_i(t)$ is load of i[th] time, t[th] day, i =1,2...24and t = 1, 2 ...n(n is the number of days in set)

$M[P_i(t)]$ Is the mathematical expectation of the load.

$$P'_i(t) = p_{(i)}(t) - M[P_i(t)]$$

Load forecast for every hour is done by chosen loads for the corresponding hour relative to the previous day's load at a similar hour.

For forecast, we have selected the data value **for Wednesdays and Sundays for year 2010 & 2011 for similar hours indicated in the table below.** We have limited our data collection to two months. Figures are in Amperes (A).

SUNDAY 2010					
HOUR	SUN 1	SUN 2	SUN 3	AV	DEVIATION
1	320	310	330	320	126.11
3	300	290	300	296.67	149.44
5	430	440	430	433.33	12.78
7	430	420	410	420.00	26.11
9	460	450	470	460.00	-13.89
11	430	430	420	426.67	19.44
13	450	440	450	446.67	-0.56
15	440	430	420	430.00	16.11
17	470	460	450	460.00	-13.89
19	580	580	590	583.33	-137.22
21	590	570	580	580.00	-133.89
23	500	490	500	496.67	-50.56
Average	450.00	442.50	445.83	**446.11**	0.00

Table 1

$$\sigma = \sqrt{\frac{\sum(\bar{x} - x)^2}{n}} = 0.00$$

WEDNESDAY 2010					
HOUR	WED 1	WED 2	WED 3	AV	DEVIATION
1	320	320	310	316.67	131.67
3	310	300	310	306.67	141.67
5	400	390	410	400.00	48.33
7	470	460	480	470.00	-21.67
9	450	460	440	450.00	-1.67
11	440	430	420	430.00	18.33
13	440	430	440	436.67	11.67
15	420	410	430	420.00	28.33
17	450	460	440	450.00	-1.67
19	570	570	560	566.67	-118.33
21	630	620	600	616.67	-168.33
23	530	500	520	516.67	-68.33
Average	452.50	445.83	446.67	**448.33**	0.00

Table 2

$$\sigma = \sqrt{\frac{\sum(\bar{x} - x)^2}{n}} = 0.00$$

Sunday 2011					
HOUR	SUN 1	SUN 2	SUN 3	AV	DEVIATION
1	320	310	310	313.33	149.17
3	280	270	280	276.67	185.83
5	410	400	410	406.67	55.83
7	470	480	460	470.00	-7.50
9	490	460	470	473.33	-10.83
11	460	450	460	456.67	5.83
13	470	470	460	466.67	-4.17
15	440	450	430	440.00	22.50
17	510	500	500	503.33	-40.83
19	600	590	580	590.00	-127.50
21	650	650	640	646.67	-184.17
23	510	500	510	506.67	-44.17
Average	467.50	460.83	459.17	**462.50**	0.00

Table 3

$$\sigma = \sqrt{\frac{\sum(\bar{x} - x)^2}{n}} = 0.00$$

WEDNESDAY 2011					
HOUR	WED 1	WED 2	WED 3	AV	DEVIATION
1	310	300	320	310.00	145.28
3	280	290	280	283.33	171.94
5	400	390	380	390.00	65.28
7	480	470	470	473.33	-18.06
9	480	460	470	470.00	-14.72
11	450	450	440	446.67	8.61
13	440	430	450	440.00	15.28
15	430	420	430	426.67	28.61
17	500	480	500	493.33	-38.06
19	590	570	580	580.00	-124.72
21	620	600	610	610.00	-154.72
23	540	540	540	540.00	-84.72
Average	460.00	450.00	455.83	**455.28**	0.00

Table 4

$$\sigma = \sqrt{\frac{\sum(\bar{x} - x)^2}{n}} = 0.00$$

CALCULATION OF (C)

HOUR	COEFFICIENT	
1	320.00 / 316.67 =	1.0105
3	296.67 / 306.67 =	0.9674
5	433.33 / 400.00 =	1.0833
7	420.00 / 470.00 =	0.8936
9	460.00 / 450.00 =	1.0222
11	426.67 / 430.00 =	0.9922
13	446.67 / 436.67 =	1.0229
15	430.00 / 420.00 =	1.0238
17	460.00 / 450.00 =	1.0222
19	583.33 / 566.67 =	1.0294
21	580.00 / 616.67 =	0.9405
23	496.67 / 516.67 =	0.9613

Table 5

2011 PREDICTION		ACTUAL 2011	% ERROR
1.0105 * 310.00 =	313.26	313.33	0.02
0.9674 * 283.33 =	274.09	276.67	0.93
1.0833 * 390.00 =	422.50	406.67	-3.89
0.8936 * 473.33 =	422.98	470.00	10.00
1.0222 * 470.00 =	480.44	473.33	-1.50
0.9922 * 446.67 =	443.20	456.67	2.95
1.0229 * 440.00 =	450.08	466.67	3.56
1.0238 * 426.67 =	436.83	440.00	0.72
1.0222 * 493.33 =	504.30	503.33	-0.19
1.0294 * 580.00 =	597.06	590.00	-1.20
0.9405 * 610.00 =	573.73	646.67	11.28
0.9613 * 540.00 =	519.10	506.67	-2.45
Table 6		**Average**	**1.69**

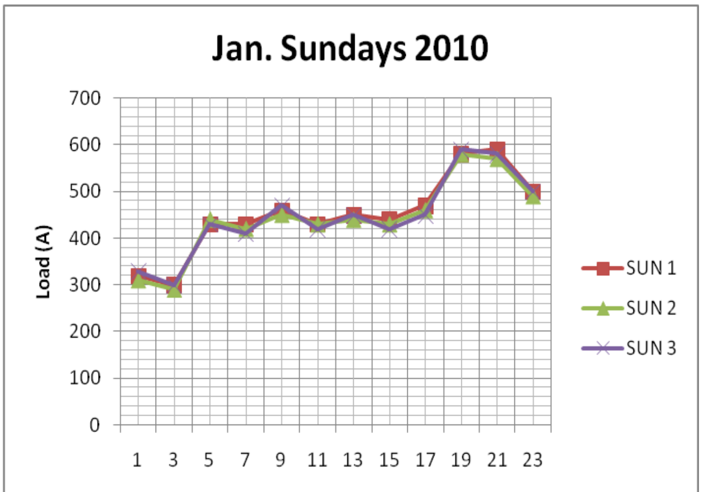

Chart 1

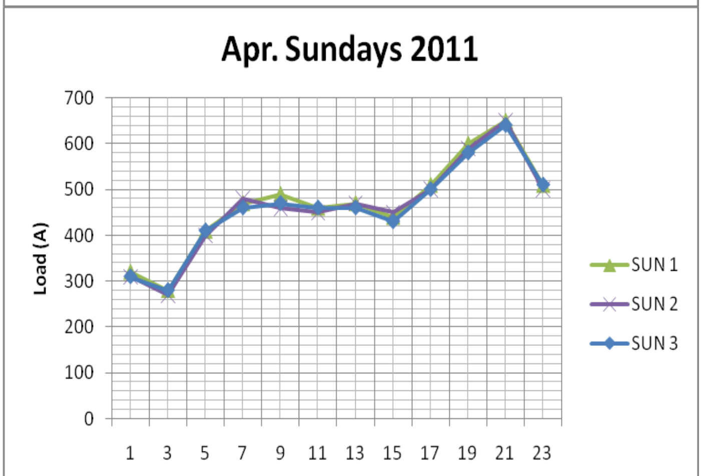

Chart 2

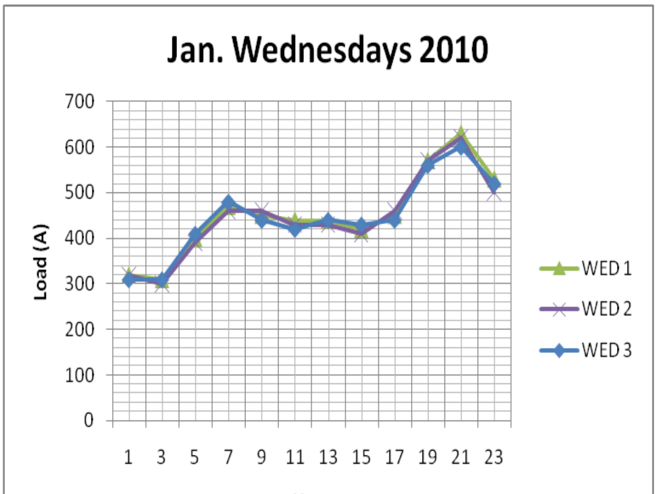

Chart 3

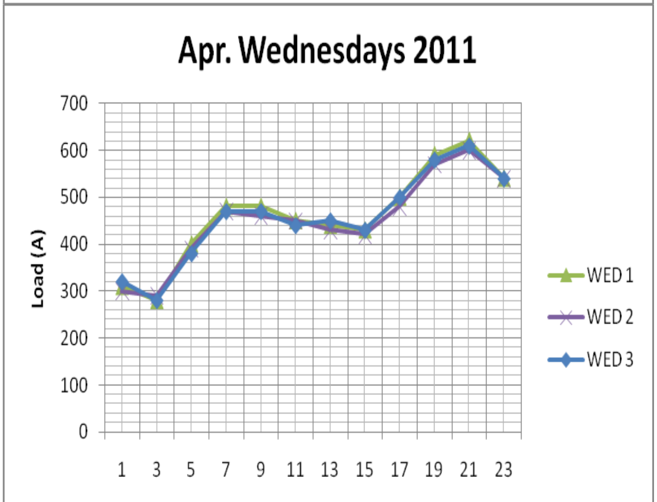

Chart 4

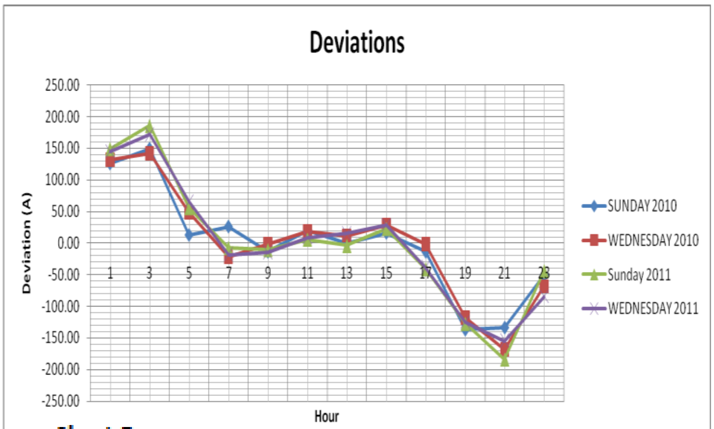

Chart 5

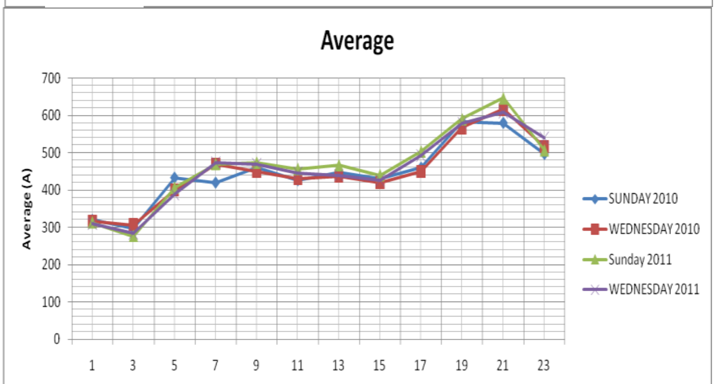

Chart 6

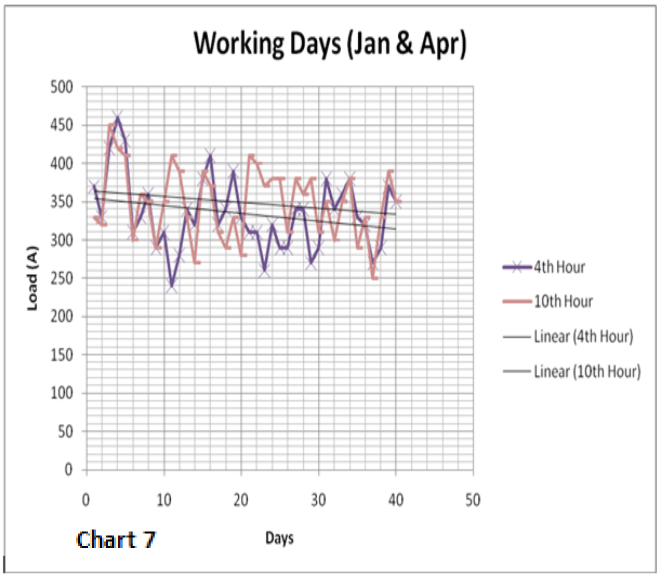

Chart 7

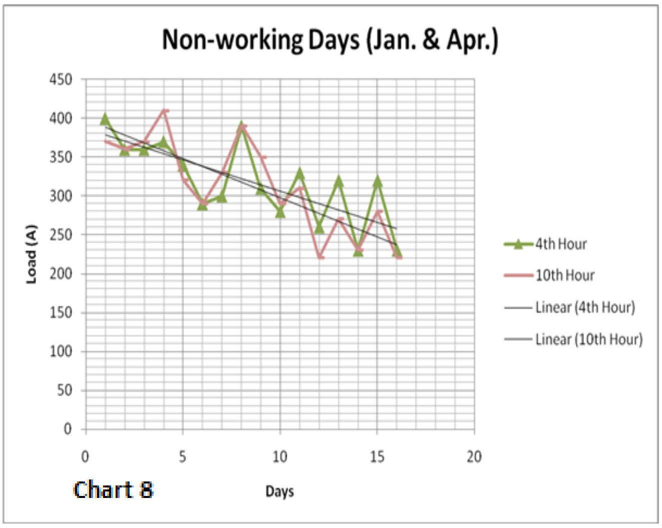

Chart 8

In the above graphs it is shown presentation of correlation and two chosen times of normal working days and no-working days of one of the substation. As indicated there are those correlations which correspond to 10^{th} hour of the day for the months of January and April and that 4^{th} hour of the same period. See charts 1,2,3&4. To find deterministic component of the load, it is necessary to choose an approximating function of linear regression of the load with time. From the graph, regression time can be approximated by a straight line. [8]

Procedure of determining the coefficient:

1. The data from the chosen substation is taken for two different months and years for a similar hour of the day. See table 1, 2, 3&4.
2. The data for working days is then analysed classically and compared with then one recorded for non-working days. See table 5& 6.
3. The coefficient of rate of change of non-working days to that of working days is then computed and compared with that for the following year. See table 5&6.
4. Individual coefficients for various similar hours are calculated and the trend determined. This has also be shown by plotting different points and approximating with a straight line. See chart 7.
5. The results are illustrated graphically and the error determined.

3. Procession of the data.

Let $M[P_i(t)] = P_{io} + \Delta P_i t$ (4)

Where P_{io} and ΔP_i are parameters of the straight line.

$$\Delta P_i = \frac{\sum_{t=1}^{n} [P_i(t)\, t] - n\bar{P}_i \bar{t}}{\sum_{t=1}^{n} t^2 - n\bar{t}^2} \quad (5)$$

Where

$$\Delta P_i = \frac{1}{n} \sum_{t=1}^{n} P_i(t) \quad (6)$$

$\bar{t} = (n+1)/2$ For odd n

The deviation of the load from the regression line represents the stationary random process. The second component which forecasts the load is determined by extrapolation stationary random process using the method

$$P'_{np} = \sum_{j-0}^{n-1} r_{j+1} P'(n-j) \quad (7)$$

Where P'_{np} = forecast of random component of the load;

$P'(n-j)$ = the deviation of the load from regression line;

r_j = weighting coefficient.

The weighting coefficient is chosen such that the dispersion of departure of the forecasted random value of P* from its forecast becomes minimum [ ]

$$\delta^2 = M[P^* - P'_{np}]^2 \rightarrow min \qquad (8)$$

Let us take partial derivative $\frac{\partial \delta^2}{\partial r_{j+1}}$ and equate it to zero.

$$\left.\begin{aligned} 2M\left\{\left[P^* - \sum_{j=0}^{n-1} r_{j+1} P'(n-j)\right] P'_{(n)}\right\} = 0 \\ 2M\left\{\left[P^* - \sum_{j=0}^{n-1} r_{j+1} P'(n-j)\right] P'_{(n-1)}\right\} = 0 \\ 2M\left\{\left[P^* - \sum_{j=0}^{n-1} r_{j+1} P'(n-j)\right] P'_{(1)}\right\} = 0 \end{aligned}\right\} (9)$$

Taking into account that

$$M[P'(n)\ P(n-j) = K(j)$$

Where $K_{(j)}$ is the auto correlative coefficient of the system (9) and may be put in the form

$$\left.\begin{aligned} r_1K(0) + r_2K(1) + \ldots\ldots + r_nK(n\text{-}1) = K(1) \\ r_1K(0) + r_2K(2) + \ldots\ldots + r_nK(n\text{-}2) = K(2) \\ r_1K(n\text{-}1) + r_2K(n\text{-}2) + \ldots\ldots + r_nK(0) = K(n) \end{aligned}\right\} (10)$$

For calculation of coefficients r_{j+1} is necessary to find the corresponding correlation moment K (j) of considered random process. Knowing that the dispersion of stationary random process is constant, therefore, in equation (10), instead of K(j), we can normalize the correlation coefficient:

$$K(j) = \frac{K(j)}{K(0)} = \frac{(n-1)\sum_{t-1}^{n-j} P'(t)P(t+j)}{(n-1-j)\sum_{t=1}^{n}[P'(t)]^2} \qquad (11)$$

Solving the above system of equations, we get our interested r_{j+1} .In this case the choice of data for forecast of non working days of the week is small in volume and therefore when analyzing them, the quantitative value of parameter assessment is of small accuracy. This method is based on making the forecasts of non-working days as a function of normal working days for the ith hour.

For simplified calculations, the forecasts for non working days are based on forecast of working days.

$$P_{isP} = C_i M[P_{inP}(n)] \qquad (12)$$

Where P_{isP} is the load at i[th] hour of the special/non -working day forecast.

P_{inP} Is the load at i[th] hour of a normal working day of the previous day.

C_i Is the coefficient of special day i[th] hour.

$$C_i = \sum_{t=1} \frac{P_{isP}(t)}{P_{i\ n\ day}(t-l)} \qquad (13)$$

Where $P_{isP}(t)$ = the ith load of the present day

$P_{i\ n\ day}(t-l)$ =the ith load of the previous day.

Based on the suggested method and processed data for working days, the non-working day's forecasts are determined. A minimum of 10 points must be plotted to achieve realistic correlation coefficients. The average error ε for a normal day obtained by averaging absolute values of the errors of forecast was established as **1.69%.**

Conclusion and Recommendations.

A method has been developed for determination of load forecasts for non-working/special days. The errors for forecasts were established to be 1.69% .One parametric model was used in the analysis, for more accurate load forecasts multi parametric models should be used.

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