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Conversion Factors Behavior in Medium Voltage Rural Networks

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Abstract: Conversion factors $\mathbf{C}_f$ are common coefficient factors used by engineers to estimate the load of the distribution networks, especially the peak on the sub-transformers. In this Paper load data are used for the calculation of these factors based on different type of days, months and number of feeders at Substation in Irbid at the north of Jordan. The results based on monthly dimension show that the number of feeders does not play an effective role in computation of $\mathbf{C}_f$ factors.
Key words: Power distribution networks, Diversity factor, Conversion factor, Peak demand.

1 Introduction

The total demand for electricity on a power system varies as a function of time on both daily and a seasonal basis. An electric utility must construct and operate equipment sufficient to meet the peak. Peak load is reached only occasionally, and generally occurs for only a few hours at any given period of time. The essential point in designing and planning power distribution systems is the estimation of the load. This estimation allows the determination of the size and location of substation and the capacity of the associated transmission lines (Gönen 1986).

Planning engineers use load estimation to predict load shape on different parts of the distribution systems. Availability of information of load data enables the calculation and analysis of distribution power system more precisely and it is stated to be an essential requirement. The acquisition of data on power system distribution is complex because of a large number of nodes and their area distribution.

In Jordan, for example Electric Utilities are not adapted for collecting and transforming a vast amount of data. In addition to that, the power distribution systems have a great deficiency of real time measurements, and the large part of information on elements' load comes only from sporadic measurements carried out through different time intervals. Moreover, load data for the performance calculation and analysis of distribution systems are usually acquired from the power utility operation staff. The load is evaluated on the basis of the staff utility knowledge as a result of sporadic measurements from some transformers.

A most popular coefficient factors used by engineers to estimate the load on the distribution power system are the diversity factors ($\mathbf{D}_f$) and conversion factors ($\mathbf{C}_f$). Conversion factors $\mathbf{C}_f$ are defined to be the sum of all individual customer peaks divided by the total energy usage of the group over a given period (Westinghouse corp. 1965). In general, the only information commonly available regarding loads at locations, other than distribution substations and major equipment installation, is billing cycle customer kwh consumption. Conversion factors for residential customers have been investigated by Tawalbeh (2003). The results of this work show that conversion factors are independent of the number of customers. In this paper the similar methodology has been used to investigate medium voltage rural networks. Data from the SCADA on Control Systems Department of National Electric Company (NEPCO), in Jordan are used for the calculation of the conversion factors. These data belong to Irbid Substation which contains thirteen feeders that supply Irbid District. In this District the Network is long and mostly rural.

Actual power distribution system exhibits numerous parameters and phenomena that are non-deterministic or so complex, and depend on many diverse processes that may readily be regarded as non-deterministic. Power system loads, for example, are non-deterministic because the active and reactive power levels are functions of many loads which are activated and deactivated depending on time parameters, (hours, day of week, season, etc.), weather (temperature, humidity), class of customers (residential, commercial, and industrial), social-economic factors, and other numerous factors. The decomposition of the load variation phenomena is mentioned. For example, the demand on the residential sector is sensitive to temperature, industrial loads are sensitive to economic factors, and commercial demands are sensitive to day-of-the-week and the occurrence of holidays (Heydt 1986).

2 Conversion Factors Estimation

The hourly demand data for each Feeder is given for 8760 hours from April, 2003 till December, 2003 should be rearranged into type of days within the month under consideration.

The conversion factors $\mathbf{C}_f$ are given by

$$\mathbf{C}_f = \frac{\sum \text{Individual Peaks}}{\text{Group Energy}} \quad (1)$$

The $\mathbf{C}_f$ factor is calculated as a function of the number of customer in a group given by N_g and all customers are of the same class, and $\mathbf{C}_f$ is derived from a randomly selected sample consisting of N_g customers. The number of l such samples are chosen as indicated by

$$l = 1, 2, \ldots, N_{l,max} \quad (2)$$

where $N_{l,max}$ is the maximum number of samples, given by the combinations of all feeders with number of feeders in a group as follows

$$N_{max} = \begin{pmatrix} N_f \\ N_g \end{pmatrix} = \frac{N_f!}{N_g!(N_f - N_g)!} \quad (3)$$

A customer j is randomly selected for the group consisting of N_g customers in the sample space S_l, and j is an element of S_l as given below

$$j \in S_l(N_g) \quad (4)$$

Each random group is selected such that each customer is unique within that group. The size of randomly selected groups, N_g varies from 2 to 30 customers.

The hourly peak power consumption for a given customer j on a given type of day d during a month m may be found by the following relation

$$P_{j,max}(m, d) = \max_{\substack{h \\ D\in d}} \{P_j(m, D, h)\} \quad (5)$$

All hourly measurements for the customer are analyzed where the corresponding day of the month, D, matches the type of day specified by d.

The daily energy usage of customer j is calculated by summing the hourly results, as indicated by

$$E_j(m, d) = \sum_{h=1}^{24} P(m, D, h)(1hr) \quad (6)$$

Using the results from (5) and (6) the conversion factor $\mathbf{C}_f$ for sample l is given by

$$\mathbf{C}_{fl}(m, d, N_g) = \frac{\sum_{j=1}^{N_g} P_{j,\max(m,d)}}{\sum_{j=1}^{N_g} E_j(m,d)} \quad (7)$$

The dominator and numerator of the above equation must be calculated for a group of customers and not for one customer. After calculating conversion factors $\mathbf{C}_f$ for $N_{l,max}$ samples of customer group, the average conversion factor for a customer group is given by

$$\overline{C}_f\left(m,d,N_g\right) = \frac{\sum_{l=1}^{N_{l\,max}} C_{fl}(m,d)}{N_{l,max}} \quad (8)$$

For the calculation of conversion factors a computer program in visual basic has been written in cooperation with the Control Systems Department in NEPCO. The results are plotted in Figures 1 and 2. Figure 1 shows the $\mathbf{C}_f$ factors in both types of days. From the figure one may conclude that $\mathbf{C}_f$ factors depend on season and type of days. This also must be influenced by the class of customers. Figure 2 shows the $\mathbf{C}_f$ factors for different number of feeders in a group. It's clear from the figure that the number of feeders (customers) does not play any role in values of $\mathbf{C}_f$ factors.

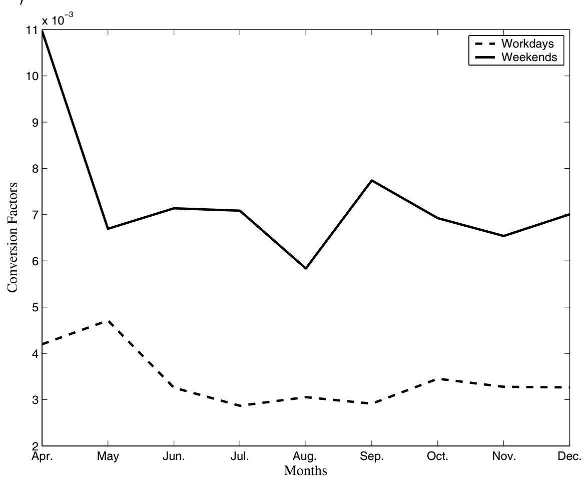

Figure 1: Monthly $\mathbf{C}_f$ Factors for workdays and weekends.

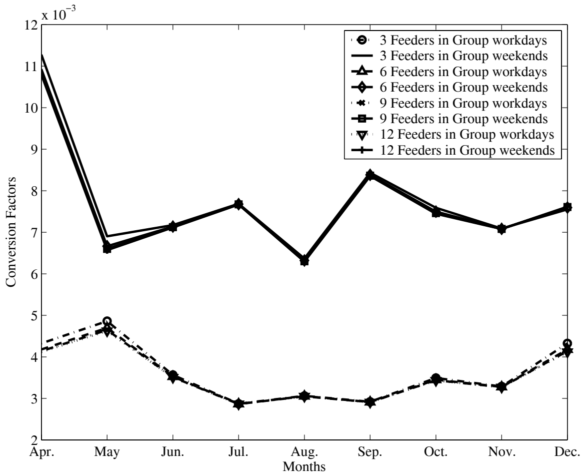

Figure 2: Monthly $\mathbf{C}_f$ Factors for 3, 6, 9, and 12 feeders in a group for workdays and weekends.

3. Characteristics of the Conversion Factors

In this section the Run test to show the relationship of conversion factors with the number of feeders, as well as the goodness-of-fit for normality within a group is done. A Run test is defined as a sequence of identical observations that is followed and preceded by different observations or no observations at all. Run tests above and below the median count the number of runs that are completely above or completely below the median (Guttman & al., 1982).

The expected number of runs is given by

$$\mu_r = \frac{2n_1 n_2}{n_1 + n_2} + 1 \qquad (9)$$

The estimated variance of the runs is given by

$$\upsilon_r = \frac{2n_1 n_2 (2n_1 n_2 - n_1 - n_2)}{(n_1 + n_2)^2 (n_1 + n_2 - 1)} \qquad (10)$$

The test statistic for the runs is given by

$$Z = \begin{cases} \dfrac{|r - \mu_r| - 0.5}{\sqrt{\upsilon_r}} \, for \quad r > \mu_r \\ -\dfrac{|r - \mu_r| - 0.5}{\sqrt{\upsilon_r}} \, for \quad r \le \mu_r \end{cases} \qquad (11)$$

where n_1 n_2 the number of observation above and below the median, respectively, r the number of runs, μ_r the expected number of runs or the mean value of runs, υ_r the variance of runs, and N denotes the number of observation.

The hypothesis can be tested at any desired level of significance α by comparing the observed runs to the interval between the ranges shown in the following equation (Bendat & al., 1986)

$$r_{n,1-\alpha/2} < r \le r_{n,\alpha/2} \qquad (12)$$

where $n = N / 2$.

Figures 3 and 4 show the average of different samples of both types of days for different groups of feeders in August 2003. These results have been verified by the Run test as presented in Tables 1 and 2.

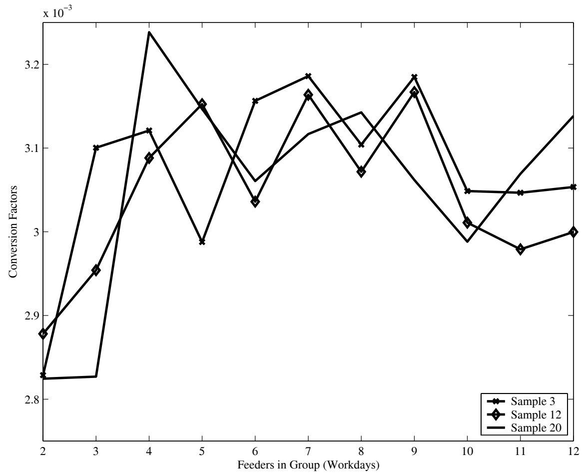

Figure 3: $\mathbf{C}_f$ Factors versus different samples of feeders in group for workdays.

Workdays					
Month	Median	Expect.	Runs	Z stat	2 TP
Apr.	4.15E-03	11	7	0.029	0.977
May	4.24E-03	11	7	0.29	0.977
Jun.	3.555E-03	11	5	-0.612	0.540
July	2.864E-03	11	7	0.029	0.977
Aug.	3.083E-03	11	6	0.0	1.0
Sept.	2.932E-03	11	5	-0.612	0.54
Oct.	3.43E-03	11	3	-1.895	0.058
Nov.	3.267E-03	11	7	0.029	0.977
Dec.	3.25E-03	11	8	0.671	0.502

Table 1: Wordays independency test.

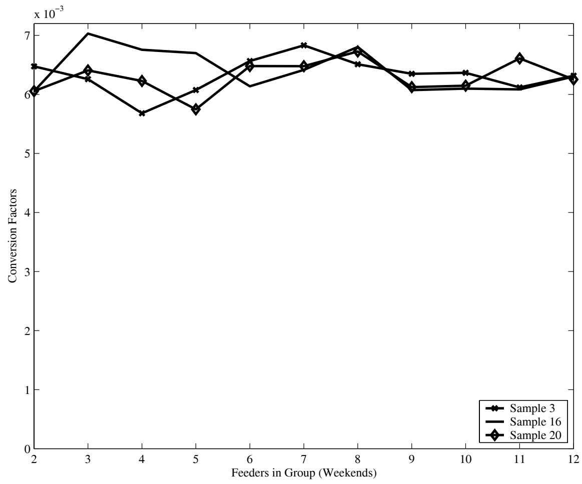

Figure 4: $\mathbf{C}_f$ Factors versus different samples of feeders in group for weekends.

Weekends					
Month	Median	Expect.	Runs	Z stat	2 TP
Apr.	1.086E-02	11	5	-0.612	0.54
May	6.655E-03	11	4	-1.254	0.210

Jun.	6.755E-03	11	4	-1.254	0.210
July	7.787E-03	11	7	0.029	0.977
Aug.	6.161E-03	11	6	0.0	1.0
Sept.	8.27E-03	11	5	-0.612	0.54
Oct.	7.524E-03	11	5	-0.612	0.54
Nov.	7.327E-03	10	3	-1.677	0.94
Dec.	7.624E-03	11	6	0.0	1.0

Table 2: Weekends independency test.

The conversion factors distribution for different samples of feeders in group is investigated using the Kolmogorov- Smirnov Test. The basic procedure involves the comparison between the experimental cumulative frequency and an assumed theoretical distribution function

$$D_n = \max_x |F(x) - S_n(x)| \qquad (13)$$

Here

$$S_n(x) = \begin{cases} 0 & x < x_1 \\ \dfrac{k}{n} & x_k < x \le k+1 \\ 1 & x \ge x_n \end{cases}$$

where D_n is the large discrepancy between the theoretical model and observed data (Alfredo 1975). $S_n(x)$ denotes the stepwise cumulative and $F(x)$ is the theoretical distribution function. For a specified significance level α, K-S test compares the observed maximum difference of Equation (13) with critical value D_{cr} which is defined by $P(D_n - D_{cr}) = 1 - \alpha$. For $n = 60$, $\alpha = 0.05$. The computational results are shown in table 3 and 4. The normality of distribution of the conversion factors in most cases and for both types of days has been verified by the results shown in these Tables.

Workdays					
Month	$\|D_n\|$	D_{nmax}	D_{nmin}	Z stat	2 TP
Apr.	0.082	0.082	-0.049	0.781	0.575
May	0.054	0.054	-0.046	0.476	0.977
Jun.	0.078	0.078	-0.060	0.688	0.731
July	0.082	0.052	-0.082	0.782	0.574
Aug.	0.056	0.053	-0.056	0.530	0.941
Sept.	0.073	0.071	-0.073	0.697	0.716
Oct.	0.103	0.103	-0.077	0.979	0.293
Nov.	0.104	0.055	-0.042	0.524	0.947
Dec.	0.134	0.134	-0.124	1.277	0.077

Table 3: Workdays Kolmogorvs-Smirnov test for normality.

Weekends					
Month	$\|D_n\|$	D_{nmax}	D_{nmin}	Z stat	2 TP
Apr.	0.126	0.126	-0.076	1.202	0.111
May	0.1	0.1	-0.084	0.952	0.326
Jun.	0.073	0.073	-0.061	0.693	0.722
July	0.113	0.095	-0.113	0.995	0.276
Aug.	0.089	0.089	-0.088	0.788	0.564
Sept.	0.123	0.123	-0.123	1.087	0.188
Oct.	0.048	0.048	-0.048	0.421	0.994
Nov.	0.104	0.104	-0.104	0.921	0.365
Dec.	0.097	0.097	-0.088	0.860	0.451

Table 4: Weekends Kolmogorov-Smirnov test for normality.

4. Conclusion

Calculation of conversion factors for the medium voltage network in Irbid substation in the North of Jordan has done. Results show that these factors are affected by month and type of days. The number of feeders does not play effective role in values of the aforementioned factors.

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