Application of Alignment Degrees to Electric Load Clustering

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Abstract **- In distribution system, bus load estimation is complicated because system load is unstable data and usually monitored at only a few points. As a rule receiving nodes are not equipped with stationary measuring instruments so measurements of loads are performed sporadically. In general, the only information commonly available regarding loads, other than major distribution substations and equipment installations, is billing cycle customer kWh consumption or load in per unit (p.u) term. In order to model system uncertainty, inexactness, and random nature of customers demand, an average alignment approach is proposed. This paper presents application possibilities of the alignment degrees method to the electrical load modeling. Clustering of load profiles in different part of system was used to classify the substations. Simulation studies have been performed to demonstrate the efficiency of the proposed scheme and an effect of different parameters on its accuracy on the basis of actual data obtained at distribution system substations.**

Keywords: Alignment Degrees, Fuzzy set theory, Load clustering, Power distribution systems.

1.0 INTRODUCTION

The knowledge of loads at system buses is one of the most important requirements for efficient operation of power distribution systems [1]. Estimation of loads is the basis for the system state estimation and for technical and economic calculations. This makes possible improvement in operation and maintenance of electrical equipment and in planning of network operating configurations.

The main difficulties in the modeling of loads at receiving buses in distribution systems result from the random nature of loads, diversification of load shapes on different parts of the system, the deficiency of measured data and the fragmentary and uncertain character of information on loads and customers. In the present stage of development of power distribution systems, the mathematical estimation of the loads at the system buses seems to be the most realistic strategy due to incomplete primary information on loads and customers. It demands earlier determination of the stable relations between bus loads and easier available data [1]. The probabilistic models are widely used to estimate system loads. In order to develop the relevant types and parameters of probability distribution, large numbers of recorded consumption values are required. To obtain the above data a special measurement project has to be considered. The use of statistical methods is not always possible due to occurrence of a large deficit of measurements. The fuzzy set theory is a convenient mathematical tool that allows us partially to eliminate unreliability from input information and to limit the influence of deficit of measurements. The most renowned method for expressing the uncertainty in load models is fuzzy set theory [2], [3]. For the purpose of simplicity of mathematical operation the trapezoidal and triangular forms of fuzzy numbers are usually used.

The paper presents possibilities of application of the fuzzy set theory to electrical load clustering. The clustering of the substations according to daily load curves is made on the base of the average alignment degrees. The studies have been performed to demonstrate the efficiency of the proposed scheme on the basis of actual data obtained at distribution system substations In practice the only information commonly available regarding loads in distribution substations is consumption in term of kWh or in p.u term. In modeling process other input quantities also can be used such as number of customers, rated power of transformers and installed capacity.

2.0 APPLICATION OF ALLIGNMENT DEGREES TO CLUSTERING

The loads on distribution transformers are the instantaneous summations of the individual demands of many customers. Since the pattern of electrical demand of each customer cannot be determined precisely, it is usually necessary to calculate system loadings on an estimation basis. Planning engineers use load modeling to predict the loads on different parts and different time of distribution systems. The load clustering can be done on the basis of the alignment degrees method with customers load profiles [1]. The 24-hour load curves of the different substation groups show the characteristic variation for each group. Example of a daily load profile for one substation is shown in Fig 2. There are three characteristic load values in the diagram:

- P_{dP} – the daily peak load,
- P_{dA} – the daily average load,
- P_{dB} – the daily base load.

On the basis of the analysis of the profiles from different days, the four characteristic intervals (columns) of the day are distinguished as illustrated in Fig.2

- night – **n**,
- morning – **m**,
- afternoon – **a**,
- evening – **e**.

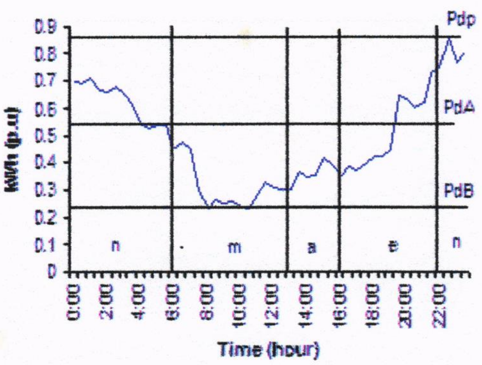

Fig.2 Example for 24 hours load profile in substation

The clustering of the substations based on the average alignment for each column. To avoid the influence of the instantaneous values on power changes consumed from substations, the average load of twenty four hours should be taken as reference quantity. The average alignment degree for each column is defined as ratio of the average load in the column to the daily average load:

$$l_c = \frac{p_{jA}}{P_{dA}} \qquad \text{Equation (1)}$$

where:

c – the column index (n, m, a, e),
P_{jA} – the average load in the column c,
P_{dA} – the daily average load.

The load diagrams are regarded as similar ones when their average alignment degrees for each column have similar values [1].

The right selection of the investigating objects to build the model is an important factor in load clustering process. The use of data from substations that belong to different classes can cause difficulties in working out a method to practical application.

3. PROJECT IMPLEMENTATION

This project was tested on 24 hour load data for 20 substations. The aim of this project was to cluster the substation data into their belong group.

The project started by collecting the substation load data and using determine the parameter such as P_{dP} (the daily peak load), P_{dA} (the daily average load), P_{dB} (the daily base load) and P_{jA} (the average load in the column c) since this parameters are needed to perform the alignment degrees method for electric load clustering. The data used for this project is in per unit (p.u) values.

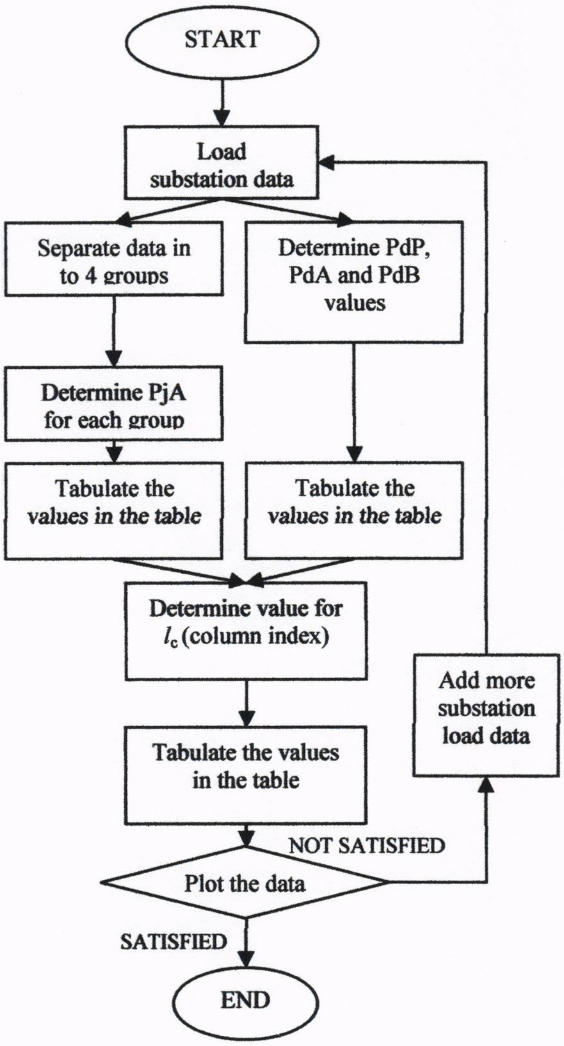

Fig. 3 Flowchart of the simulation

3.1 Procedure

1. Load the substation data and determine the value of P_{dP}(the daily peak load), P_{dA}(the daily average load) and P_{dB} (the daily base load).

2. Separate the data into 4 groups morning, afternoon, evening and night). Determine the value of P_{jA} (the average load in the column c)

3. Determine value for ratio of the average load in the column to the daily average load (l_c).

4. Tabulate all value obtain above in the table and plot graph of:
   - l_n and l_a
   - l_e and l_m

5. Compare the result obtained and plot the graph with 24 hours load curve of the substation.

4. RESULT AND DISCUSSION

This are the data obtained from the simulation that needed to perform the alignment degrees method.

Table 1 Value of P_{dP}(the daily peak load), P_{dA}(the daily average load) and P_{dB} (the daily base load) for 20 substations

Substations	P_{dP}	P_{dB}	P_{dA}
1	0.7201	0.0453	0.3329
2	0.6944	0.0422	0.3071
3	0.7082	0.0402	0.2898
4	0.6972	0.0375	0.2838
5	0.6599	0.0325	0.2705
6	0.6774	0.0333	0.2667
7	0.6515	0.0265	0.2561
8	0.6133	0.0249	0.2465
9	0.6126	0.0233	0.2409
10	0.5823	0.0235	0.2404
11	0.6933	0.2459	0.4950
12	0.6583	0.2994	0.5114
13	0.7545	0.3076	0.5068
14	0.7814	0.3547	0.5179
15	0.7657	0.3917	0.4979
16	0.6903	0.2507	0.4958
17	0.7460	0.2343	0.5050
18	0.1092	0.0422	0.0725
19	0.0733	0.0285	0.0354
20	0.2304	0.0067	0.0712

Table 2 Value of average load in column c for 20 substations

	P_{jA}			
Substation	Morning	Afternoon	Evening	Night
1	0.3113	0.4779	0.4542	0.2563
2	0.2804	0.4240	0.4281	0.2441
3	0.2702	0.3863	0.4056	0.2343
4	0.2686	0.3765	0.3994	0.2197
5	0.2573	0.3691	0.3768	0.2138
6	0.2438	0.3588	0.3805	0.2143
7	0.2485	0.3648	0.3545	0.1960
8	0.2317	0.3389	0.3525	0.1858
9	0.2374	0.3304	0.3375	0.1711
10	0.2318	0.3263	0.3445	0.1688
11	0.4332	0.2828	0.4618	0.6469
12	0.4893	0.3831	0.4789	0.6056
13	0.4452	0.3302	0.4714	0.6731
14	0.4566	0.3757	0.4765	0.6705
15	0.4426	0.4078	0.4338	0.6446
16	0.4814	0.2901	0.4202	0.6420
17	0.4272	0.3726	0.4516	0.6651
18	0.0599	0.0917	0.0946	0.0669
19	0.0335	0.0457	0.035	0.0319
20	0.0918	0.1398	0.0875	0.0109

Table 3 Ratio value of the average load in the column to the daily average load (l_c)

	l_c			
Substations	Morning	Afternoon	Evening	Night
1	0.9351	1.4356	1.3644	0.7699
2	0.9131	1.3807	1.3940	0.7949
3	0.9324	1.3330	1.3996	0.8085
4	0.9464	1.3266	1.4073	0.7741
5	0.9512	1.3645	1.3930	0.7904
6	0.9144	1.3453	1.4267	0.8035
7	0.9703	1.4244	1.3842	0.7653
8	0.9400	1.3748	1.4300	0.7538
9	0.9855	1.3715	1.4010	0.7103
10	0.9642	1.3573	1.4330	0.7022
11	0.8752	0.5713	0.9329	1.3069
12	0.9568	0.7491	0.9364	1.1842
13	0.8785	0.6515	0.9301	1.3281
14	0.8816	0.7234	0.9201	1.2947
15	0.8889	0.8190	0.8713	1.2946
16	0.9700	0.5851	0.8475	1.2949
17	0.8459	0.7378	0.8943	1.3170
18	0.8262	1.2648	1.3048	0.9641
19	0.9463	1.2910	0.9887	0.9011
20	1.2893	1.9635	1.2289	0.1531

The ratios value in Table 3 was used as the basis of load clustering in substations. On the ground of determination of the profiles, average alignment degrees for each column were calculated. The clustering of load profiles on the plane l_e (the average alignment degree at the column **e** –evening) and l_m (the average alignment degree at the column **m** – morning) is shown in Fig.4. The clustering of load profiles on the plane l_n (the average alignment degree at the column **n** – night) and l_a (the average alignment degree at the column **a** – afternoon) is shown in Fig.5.

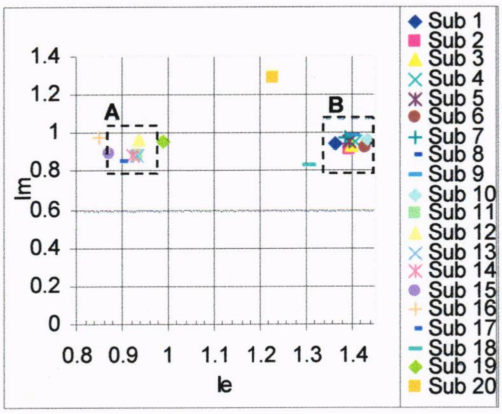

Fig.4 The clustering of load profiles on the plane le and lm

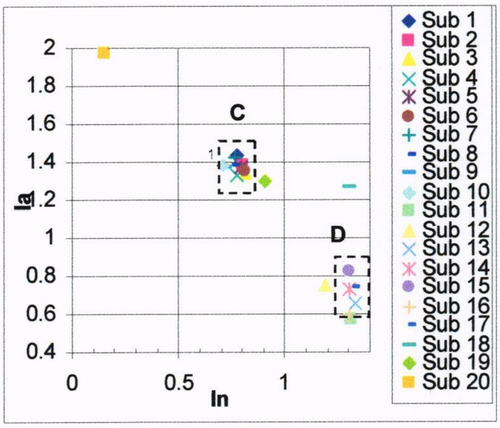

Fig.5 The clustering of load profiles on the plane ln and la

From Fig.4 and Fig.5 it can be seen that the spread of alignment degrees is the difference between max and min value for each substation. In accordance with above approach to load profiles clustering, there are two main clusters. Substations no. 1 to 10 belongs to Cluster I (B and C) and substations no. 11, 13, 14, 15 and 17 belong to Cluster II (A and D). Substation no. 16 belongs to (D) only and Substation no. 12 belongs to (A) only. This is because the load diagram had the same pattern in certain part of the load (it depends on the alignment degrees). While substation no. 18, 19 and 20 do not belong to any cluster because they have unique pattern. From the graph it can prove that the load diagrams are regarded as similar ones when their average alignment degrees for each column have almost similar values by looking at the load diagram of the substations.

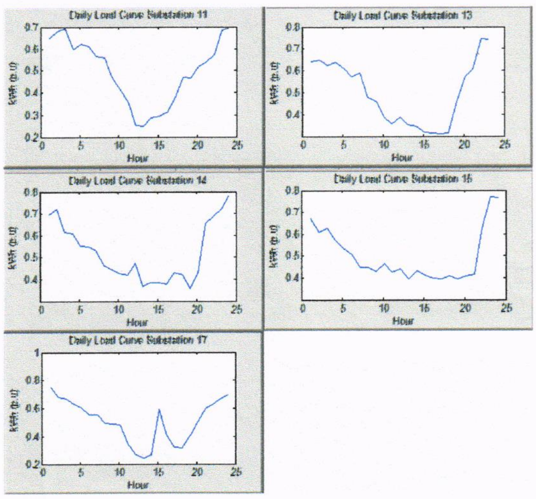

Fig.6 Load Diagram belong to Cluster II (A and D)

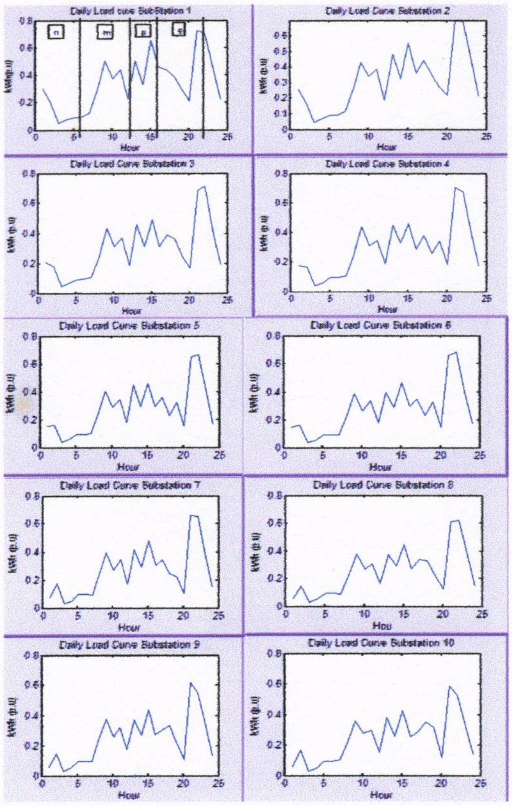

Fig.7 Load Diagram belong to Cluster I (B and C)

Fig.6 and Fig.7 show all the substations that have been grouped together in one cluster have the same pattern of load diagram. This are the two main cluster:

- Cluster I (Substation 1 to 10)
- Cluster II (substation 11,13,14,15 and 17)

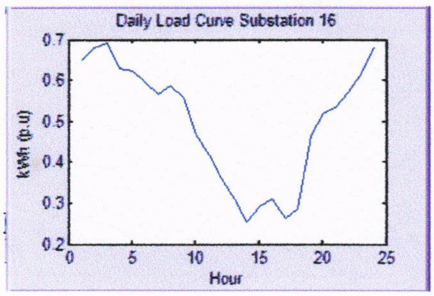

Fig.8 Load Diagram belong to (D) only

Fig.8 shows that substation 16 was not counted in a main cluster because the substation was grouped in (D) only. This meant that the substation *just had the same pattern in certain part of the loads.*

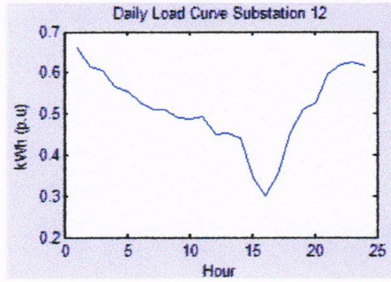

Fig.9 Load Diagram belong to (A) only

Fig.9 shows that substation 13 was not counted in a main cluster because the substation was grouped in (A) only. This meant that the substation just had the same pattern in certain part of the load.

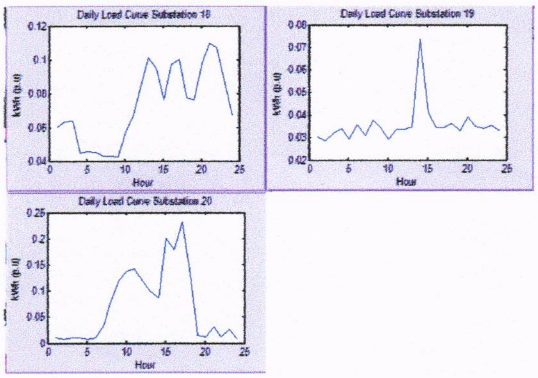

Fig. 10 Load Diagram that do not have a cluster

Fig.10 shows that substation 18, 19 and 20 were not counted in a main cluster because the substation was scattered far away from the group (A, B, C, and D). This meant that the substation had the unique pattern of load diagram compared to other substations.

5.0 CONCLUSION

This paper presents possibilities of load clustering with alignment degrees method. The study was aimed to demonstrate the efficiency of the proposed method. Achieved results show the usefulness of these kinds of methods in two following cases:

- Formulation of the substation classes.
- Load estimation for substation clusters such as max peak and min peak load.

Taking into account changes of energy policy, effective classification and modeling tools could helpful in reorganizing of tariff systems, price strategies and capacity planning.

The proposed method allows us to estimate daily peak power demand for several distribution transformers during normal state conditions, on the basis of the energy consumption in p.u that is the most correlated factor with the peak load demand.

The presented results show that right selection of investigated objects has a large influence on the accuracy of proposed method. The specification of the presented approach using day and season load diagram make the results more precise. Also the usage of clustering method gave interesting results.

The presented method may be a useful tool in supporting planning distribution engineers especially in determining the rated of the transformer and capacity planning of a substation.

6.0 FUTURE DEVELOPMENT

For the future development, the fuzzy expert system approach can be added after clustering the electrical load in order to perform load curve prediction or peak load estimation in distribution system substations. This method very useful by applying fuzzy inference and local fuzzy regression analysis with alignment degrees clustering method to analyze the problem of load forecasting and load estimation in power distribution systems

7.0 REFFERENCES

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