LOAD MODELING BASED ON FIELD SURVEY OF ELECTRIC APPLIANCES OWNERSHIP AND CONSUMPTION HABITS

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ABSTRACT

This paper presents a methodology that characterizes the load profile of each electricity consumer (residential, industrial, commercial, rural, etc.), according to its daily load curves for each period (dawn, morning, afternoon and night), and has been based on field assessments of consumer habits and ownership of consumers´ equipment / appliances.
The work is the outcome of a research and development project, carried out by Daimon Engineering in partnership with CELPE, a utility company located in northeastern Brazil and supplies over 3 million consumers (approximately 8.8 million inhabitants).

INTRODUCTION

This paper presents the results of field survey in the concession area of CELPE, which aimed to characterize the use of electricity by the different consumer sectors, through their equipment ownership and consumption.

Later on, with the results obtained through the interviews campaign, one has specified to each type of customer, the correspondent load model, to each level of daily load curve (dawn, morning, afternoon or night).
This load is represented by concentrated demand of each load point (public transformer or private transformer), whose input data are the consumption values of each consumer, their respective type (residential, commercial, industrial, or other) and the most appropriate load model (constant current, constant power or constant impedance as a function of voltage, or more likely a combination of them).

Thus, the load flow software may use this characterization in each load point to determine some network variables (loading, voltage levels and losses).

In another stage further on, the project developed a model to allocate automatically the reactive support (capacitor banks and / or voltage regulators), aiming to improve the aforementioned variables.

It should be pointed out that the adoption of appropriate load model for each consumer type is crucial to yield consistent results.

OBJECTIVE

This paper aims to characterize the form of daily use of electricity of various types of consumer, through their appliances and equipment consumption available in each level of the daily load curve.
A field interview campaign has been proposed with pre-established assessment questionnaires, covering each type of consumer (both, in low and medium voltage), in order to depict properly the composition of CELPE´s electricity market.
Later on, with the results obtained through the interviews campaign, one has specified to each type of customer, the correspondent load model, to each level of daily load curve (dawn, morning, afternoon or night).
This load is, then, represented by concentrated demand of each load point (public transformer or private transformer), whose input data are the consumption values of each customer, their respective type (residential, commercial, industrial, or other) and the most appropriate load model (constant current, constant power or constant impedance as a function of voltage, or more likely a combination of them).

METHODOLOGY FOR OBTAINING THE CONSUMPTION PATTERN OF VARIOUS CONSUMER CLASSES

Initial Approach to the Consumers

Through past similar experiences [1], one knows the high degree of rejection and / or low result in the acquisition of reliable data from interviews with consumers, when there is not an adequate planning for the initial approach to the interviewee. This low performance is due to several reasons:
• Consumer database outdated;
• Interviewee apprehension in answering the interviewer, due to violence issues, particularly in urban areas;

• Absent consumer;
• Unqualified interviewee to provide correct information;
• Lack of available time of the customer and / or very extensive questionnaire, inducing the interviewee to provide unreliable information, etc.

Therefore, to establish fruitful field interviews by the team of interviewers in order to obtain an acceptable amount of answered questionnaires, one has recommended the adoption of a few measures which contributed to the quality of the responses:
• Initial contact between the utility and the consumer (preferably through letters with utility letterhead - alternatively by telephone), informing the client about the nature of the foreseen visit, formalizing initially thus, a commitment between the interviewer and the interviewee. Since the provision of information from the consumer to the utility is an optional action, an initial adequate approach may bring good results regarding the quality of responded questionnaires.
• Assessment performed preferably by Electrotechnical Technology or Electrical Engineering students, who can discuss with the consumers in case of more technical issues;
• Interviewers properly dressed and holding a utility badge, to provide a sense of security to the interviewee and keep a professional relationship between interviewer and interviewee;
• Criterion for selecting the consumers (particularly those of commercial, industrial and service sectors), on the occasion of consulting the database, avoiding choosing customers:
  - From difficult places to access or located in remote areas;
  - From areas of alleged criminality level;
  - Located in regions with characteristics of electricity theft, which could compromise the evaluation of the load curve.

Methodology for Consumption Habits Assessment

The methodology aimed to perform a field assessment of the consumption habits of different LV and MV consumer types in the concession area of CELPE, contemplating the following aspects:
• Appropriate representation of CELPE´s market, and its different bands of consumption / demand;
• Possibility of validation and adjustments of theoretic load curves obtained from the interviews, compared to the load curves obtained from measurements;
• Increase the rate of answered questionnaires, avoiding cases of database errors, unwillingness to be interviewed, hard to reach places, etc;
• Reduce the number of interviews, and consequently the costs of this interviews campaign.
Therefore, one has chosen to carry out this field assessment, contemplating three (3) basic assumptions in order to obtain more consistent results:
a) Customers have been interviewed from a sample of participants of measurements campaign to characterize the consumers load, regarding the 2nd tariff revision of CELPE, occurred in 2008. According to [2], the utilities should carry out measurement campaigns, aimed at characterizing the load of their customers to calculate tariffs and losses, regarding the 2nd tariff revision.
Additionally, [3] stipulated that CELPE undertook the field assessment, segregating the consumer types in bands, as follows:
• Low voltage residential consumers:
  - Monthly consumption up to 79 kWh;
  - Monthly consumption from 80 to 140 kWh;
  - Monthly consumption from 141 to 500 kWh;
  - Monthly consumption from 501 to 1,000 kWh;
  - Monthly consumption over 1,000 kWh.

• Low voltage rural consumers:
  - Monthly consumption up to 200 kWh;
  - Monthly consumption from 201 to 500 kWh;
  - Monthly consumption from 501 to 1,000 kWh;
  - Monthly consumption from 1,001 to 5,000 kWh;
  - Monthly consumption over 5,000 kWh.

• Low voltage commercial and industrial consumers:
  - Monthly consumption up to 500 kWh;
  - Monthly consumption from 501 to 1,000 kWh;
  - Monthly consumption from 1,001 to 5,000 kWh;
  - Monthly consumption from 5,001 to 10,000 kWh;
  - Monthly consumption over 10,000 kWh.

• Medium voltage consumers:
  - Monthly demand up to 50 kW;
  - Monthly demand from 51 to 100 kW;
  - Monthly demand from 101 to 200 kW;
  - Monthly demand from 201 to 300 kW;
  - Monthly demand from 301 to 500 kW;
  - Monthly demand from 501 to 1000 kW;
  - Monthly demand over 1,000 kW.

Thus, consumers have been selected (previously included in the 2008 measurements campaign) to assess their equipment and electrical appliances to complement the information already collected in 2008 (measured load curve of the customer). Each band has samples of consumers who have been visited again.
Through the installation of meters made in the 2008 campaign, 20 classes of low voltage consumers have been established (5 residential, 5 commercial, 5 industrial and 5 rural), as well as 7 classes of medium voltage consumers. It has been estimated that there would be about 8 to 10 visited customers per band, which would result in a total sample of 250 consumers, according to the financial resources available to fund the field interview campaign.

b) An assumption has also been used in this work: should

the field assessments did not present quantitative, qualitative and consistent results to write the report referring to the residential consumers, it would be formulated based on the results of field assessment realized in 2004-2006 by [4];

c) In order to avoid some inconvenience previously mentioned in relation to data acquisition, specifically regarding consumers supplied in medium voltage when the interviewee has no qualification to provide correct information, or due to the lack of time to answer a very detailed and lengthy questionnaire, inducing him to provide unreliable information, it has been decided to elaborate two (2) types of forms: one for low voltage consumers (more detailed form) and the other for consumers supplied in medium voltage (less detailed, however, requiring a higher degree of judgment by the interviewer).

Forms for Consumption Habits Assessment

Questionnaires have been prepared by Daimon Engineering to carry out the field assessment of CELPE´s consumers consumption habits, in order that the field crews could perform this survey.
The model questionnaire developed by [1] has been taken as a reference, which realized similar assessment in the state of São Paulo some time ago.
Due to the shortage of time, lack of financial resources to perform a very comprehensive assessment, and also due the apprehension of not obtaining reliable data from medium voltage consumers (greater amount of equipment, greater area to be covered in the building, longer time for the survey, more complexity in contrast with dubious results), one has opted to present two types of questionnaire:

a) For low voltage consumers: The form has a pre-formatted list of electric equipment and appliances, on which the interviewer will tick accordingly as the interviewee provides the answers and / or through the visits carried out within the consumer unit;

b) For medium voltage consumers: The form has only a few major topics, such as lighting, motors, heating, electrolysis, etc. Additionally, because these consumers have greater loads, greater amount of equipment and components, larger constructed area, the assessment of the most significant loads is the most important task and thus, lower power and / or lesser used equipment may be neglected, avoiding time loss by the interviewee and the interviewer.

Therefore, the correct filling of the medium voltage form depends much more on the interviewer´s insight / knowledge, than the information provided by the interviewee.
Regarding the usage time of the equipment or electrical component by both consumers (low and medium voltage ones), one has chosen the quarter hour as the minimum value, because it would be a consistent and intermediate value. For example: One hardly imagines an electric shower being used for a full hour, or for just one minute.
Thus, the questionnaire with the described code is presented as shown in Table 1, according to the time of usage of the equipment / electrical component of the consumer´s facility.

USAGE TIME	
Code	**Meaning**
blank	Do not use the equipment / appliance
1	Up to 15 minutes
2	From 16 to 30 minutes
3	From 31 to 45 minutes
4	Full hour

Table 1 – Meaning of used codes

RESULTS FROM THE FIELD SURVEY

The sample has been drawn randomly from participants of the measurement campaign to characterize the load on the 2nd tariff revision of CELPE, occurred in 2008. Therefore, besides the information resulting from the present field survey, one has had the information already collected in 2008 (load curve of consumers).

Residential Class

The field survey conducted by Daimon has shown that about 86% of electricity consumption is made by household appliances (air conditioning, showers, refrigerators, freezers, lighting and ventilation), whose typical values of alpha (α) and Beta (β) exponential load model have been found in the technical literature [5], and may thus, be used to characterize the residential loads and run a power flow program.
However, one point outs that the issue of interest that characterizes the load on the power flow calculation is the distribution transformer (either public or private), there is no great benefit in correctly estimating the residential load parameters of a distribution transformer, if the parameters of the other classes are not. Although the residential class contribute a great deal to CELPE´s energy market (about 35.6%, according to data obtained from the website of the utility), the industrial, commercial and others classes represent 21.4%, 20 6% and 22.4% respectively to the market. Thus, about 64.4% of the energy market should also be correctly simulated to obtain the desired results.

Thus, to standardize the treatment of residential consumers in relation to other ones, the electric load modeling could only be defined from the performance of field survey regarding the other consumers (commercial, industrial,

rural and MV clients), as well as the availability in the technical literature of the Alpha (α) and Beta (β) exponential load model values of consumers of these classes.

Commercial, Industrial and Rural Classes

Through the assessment accomplished in the field, it has been possible to verify that the consumption profile of the three classes differs from one another. Hence, it has been possible to define a pattern for the usage of electrical equipment by these different classes (for example, the use of intense motor loads in rural areas). However, it has not been possible to find the typical values of Alpha (α) and Beta (β) of most of the industrial and commercial loads. Additionally, one has observed that many devices have ambiguous features (e.g. motor and heating, such as dryer, or motor and cooling, such as a cold storage). Therefore, the commercial, industrial and rural loads have been reclassified to major categories through their predominant character (for example, the dryer has been reclassified as heating). Thus, it has been possible to assign the values of α and β for the components / equipment found in the field assessment.

However, by reclassifying them to the major categories, one has conceived the possibility of employing the ZIP model not directly applied to the components / equipment, but rather to the usage form of them (motor loads, heating, lighting, etc), using the α and β coefficients, with their integer values.

CONCLUSIONS REGARDING THE INTERVIEW CAMPAIGN AND CONSUMMERS LOAD MODELLING

Regarding the interview campaign, it has been decisive to establish an initial contact between the utility and the consumer in order to bring good results regarding the quality of responded questionnaires.

The field results accomplished by Daimon has shown that about 86% of electricity consumption of the residential class is made by household appliances (air conditioning, shower, refrigerator, freezer, lighting and fan), whose typical values of Alpha (α) and Beta (β) exponential load model, have been determined in the technical literature.

It has not been possible to find in the literature, the values of Alpha (α) and Beta (β) exponential load model, regarding the electrical equipment of the other type of consumers. Thus, one cannot use them directly to the representation of commercial, industrial and rural loads in the power flow program.

As the distribution transformer is the remarkable point that characterizes the load into the power flow calculation, there is no great benefit in correctly estimating the residential load parameters of a distribution transformer, if the parameters of the other classes are not.

Therefore, to standardize the treatment of residential consumers in relation to the other ones, it has been established that the electric load modeling should be implemented considering the values of Alpha (α) and Beta (β) of static ZIP model (also known as polynomial load model), as applied to the usage of components / equipment, as follows:

• Motor loads, ventilation and cooling: α = β = 0;
• Heating and incandescent lighting: α = β = 2, and;
• Fluorescent lighting, special loads, leisure/others: α =β= 1.

An excerpt of the results from the field survey work is presented on Table 2, featuring the values of Alpha (α) and Beta (β) of polynomial load model, as applied to the usage of components / equipment of the MV and LV residential consumers, during the night level (from 17:00 - 01:00), i.e., load peak.

Type of Consumer	Consumption (kWh) or Demand (kW) Bands	Motors (%)	Heating (%)	Illumination (%)			Leisure & Others (%)
		α=β=0	α=β=2	TOTAL	Composition		α=β=1
					Fluorescent α=β=1	Incandescent α=β=2	
MV Consumer	0 – 50	45.46	13.62	26.18	26.16	0.02	14.74
	51 – 100	72.05	0.00	12.36	12.12	0.24	15.59
	101 - 200	86.10	0.57	5.23	5.15	0.08	8.10
	201 - 300	89.37	0.31	7.49	7.49	0.00	2.84
	301 - 500	75.06	1.17	22.74	22.74	0.00	1.04
	501 – 1,000	71.98	7.94	10.15	10.11	0.04	9.93
	> 1,000	77.76	5.88	11.20	11.20	0.00	5.16
	Average	77.59	3.44	14.19	14.17	0.02	4.79
LV Residential Consumer	0 – 79	35.86	16.71	30.16	19.42	10.74	17.28
	80 – 140	41.32	1.28	33.28	9.21	24.07	24.12
	141 – 500	68.08	1.13	15.14	11.45	3.69	15.66
	501 – 1,000	52.66	17.26	15.43	13.92	1.51	14.65
	> 1,000	72.15	5.51	9.46	9.46	0.00	12.87
	Average	59.82	9.52	15.61	11.33	4.28	15.05

Table 2 – Load Modeling Results from the Field Survey Applied to Night Level (from 17:00 - 01:00)

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