MULTICRITERIA MODEL FOR SIZING THE WORKFORCE OF ELECTRICIANS IN A POWER UTILITY

Fernando H. MOLINA
CELESC D - Brazil
fernandohm@celesc.com.br

Gilberto O. EGGERS
CELESC D - Brazil
gilbertoeggers@celesc.com.br

José Léo NESI
CELESC D - Brazil
joseln@celesc.com.br

ABSTRACT

This paper aims to present a multicriteria model used to perform the correct sizing of the emergency service teams, defining them in quantitative terms, their geographical distribution and coverage of service. The implementation of the multicriteria model to distribute the quantitative of operational resources aims to help the utility to reach a best service level, with lower operating costs, reduction of unscheduled overtime and increase consumer satisfaction.

INTRODUCTION

The sizing of the workforce is a continuous planning process with the evaluation of staffing needs, which should be aligned with the organization's strategy and goals, both in terms of their results, as to the limits set by the regulator agency. It is necessary to find an optimal point, analyzing all criteria and projected scenarios for the future, confronting what the company expects about their financial results and improving the quality of electricity supply for their consumers.

The current limits of reliability indicators and the need to reduce operating expenses, expose a growing need to improve the service provided, being a primary factor for this, the correct sizing of the teams of electricians, establishing criteria for the distribution of teams in quantitative terms, its geographical position in the concession area and the adoption of best work schedules for the site.

Celesc is responsible for providing electricity to 92% of the state of Santa Catarina, including the power supply to 262 cities, besides supplying other small power distributors in the state.

To serve about 2.5 million consumer units of its concession area, Celesc has a structure of 4,239 km of high voltage lines (69kV and 138kV), 154 substations, 124,740 km of medium and low voltage distribution lines and more than 170,000 distribution transformers.

This entire distribution system is subject to failures and consequent interruption in the supply of electricity to the consumer units. The distributor must, apart from acting in the management of the causes of outages, also act in its consequence, minimizing the amount of consumer units interrupted and restoring the others in the shortest time possible.

To minimize the amount of consumer units interrupted and the response time in case of failures, distributors must consider different factors, ranging from the project and construction of lines, installation of protective equipment, performing preventive maintenance and also provide teams to perform services field. All factors, applied correctly, add up to minimize outages to consumers of CELESC.

Figure 1 – State of Santa Catarina - CELESC service area

STRUCTURE OF SERVICE FIELD

Any execution of service, being emergency, commercial or technical, which will be performed in the distribution lines, substations and transmission lines, must be coordinated by operation centers. In the case of transmission lines and substations there is an unique and centralized operation center, and for the distribution lines there is 16 operation centers located one at each base of operation of the state.

A proper service structure should be assembled to meet the service demands, regulatory requirements, customer satisfaction and costs, optimizing characteristics that lead to a structure of excellent service to the company and customers.

Items such as distribution of service points, number of teams and their service coverage are essential to ensure a level of service and not negatively impact the company's operating costs, either with electricians costs or vehicle maintenance.

The key points that deserve to be taken into account in the optimization of service are as follows.

Location of service points

It must be defined an optimal location to reduce expenses with travel of teams (fuel, vehicle, so on.) and to reduce the mean travel time for a faster attendance of demands. Among the 262 cities it serves, Celesc had service points in 126 of them before the work, and the places that do not have local teams are assisted by neighboring cities.

Scales of field teams

Application of appropriate work scales for each location, taking into account the robustness of the electrical system and the service demand by time range. Allocation of a greater number of teams in the peak hours, reducing idleness of teams in off-peak times.
The scales used by CELESC for teams are as shown in the table 1.

Name	Work Time	Days of the Week	Min. Nº of Eletricians
HCL	07:30 TO 17:00	Mon to Fri	2
HE1	07:30 TO 17:00	all	3
HE3	08:00 TO 14:00 AND 15:00 TO 21:00	Mon to Fri + 8h Sat	4
HE4 - A	14:00 TO 22:00	all	3
HE4 - B	15:00 TO 23:00	all	3
HE4 - C	16:00 TO 24:00	all	3
TR2 - A	06:00 TO 14:00 AND 14:00 TO 22:00	all	6
TR2 - B	07:00 TO 15:00 AND 15:00 TO 23:00	all	6
TR2 - C	08:00 TO 16:00 AND 16:00 TO 24:00	all	6
TR1	06:00 TO 14:00, 14:00 TO 22:00 AND 22:00 TO 06:00	all	10

Table 1 - CELESC work scales

Period of attendance

Evaluation of historical events to determine which time ranges coverage is needed, especially checking the real need for coverage 24/7 in medium and big cities.

Average service time

Places with high average service or travel time have problems that need to be resolved with actions that involve best location of teams, increased availability of teams or change in the work schedule adopted.

Indicators of continuity collective and individual

The solution for service should reflect the ANEEL regulation on the goals of global and collective continuity indicators, improving quality service level and reducing the impacts of the financial penalties applied.

Overtime costs

The solution must reduce the current costs with overtime and on call, increasing the availability of employees to perform the activities in the time of bigger demand.

Emergency crews

Basically we highlight four types of teams for intervention in the distribution system:

a) Emergency Teams - Formed by a pair of electricians and midsize vehicle (pickups and small trucks), fitted with ladder, turntable ladder or aerial basket (most common).
b) Heavy Maintenance Crew - Formed by a team of electricians (4-6 electricians), large size vehicle (trucks), fitted with winch for moving heavy equipment.
c) Live Line Teams - Formed by a team of electricians (3 or 5), large size vehicle (trucks) equipped with dual basket area for works on energized lines.
d) Crew Technical Services and Administrative - Formed by company employees, of all backgrounds, with light vehicle size.

WORKFORCE

CELESC currently have in your own workforce 1204 electricians, plus about 315 outsourced employees, totalizing a workforce of 1519 electricians. After a Voluntary Dismissal Program the own workforce will be reduced to 1031 electricians in mid-2013.
The workforce is distributed unevenly in the various bases of operation in the state and has age distribution as shown in figure 2, which shows how the current workforce is aged for a fieldwork activity involving physical activity.

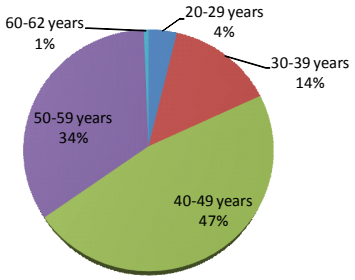

Figure 2 - Workforce per age

Another concern in the sizing of the workforce is the amount of absenteeism of employees, whether for health reasons, absences, vacations or other, causing problems on the scales, in the formation of teams and generating a high cost with overtime hours. To minimize these problems in defining scales are sized reserves electricians to cover absences.
It is noteworthy that any decision on hiring professionals must be analyzed with great care, since being a public company, the employees cannot be fired if there are productivity gains in their activities, and they should be relocated in other functions.

MULTICRITERIA MODEL

The use of multicriteria model aims to provide a mechanism to establish a workforce of electricians at each service point, taking into account the limited amount generally defined by the regulator for operating expenses with the workforce of electricians and practical experience of the participants of the group, to thus quantify the number of employees needed for each activity.
The model is based on a survey of relevant data, especially those related to the need to perform tasks on the lines, as the number of consumers, poles, medium and low voltage lines, transformers, so on.

The criteria for sizing electricians workforce for operation bases and service points and the methodology presented is being developed in works in Celesc since 2005. The method was applied to define the distribution of the workforce required to perform the following activities:

a) Multitasking (emergency, commercial and technical);
b) Maintenance on de-energized lines;
c) Maintenance on energized medium voltage lines;
d) Maintenance on energized high-voltage lines (69kV and 138kV);
e) Inspection of distribution lines;
f) Low voltage inspection lines and consumer installations.

The model results bring the distribution of the workforce by service point that, considered together with service history and performance indicators, enable an optimum design teams, concentrating then on peak hours of events and increasing their productivity.

Inputs

To define the number of workers for each activity was elaborated a matrix containing the data per city of variables described below:

1. Consumers (LV/MV – Urban/Rural);
2. Medium Voltage Lines (Urban/Rural – Phases);
3. Low Voltage Distribution Lines (Urban/Rural – Phases);
4. Distribution transformers (Urban/Rural – Phases);
5. Number of poles (Urban/Rural);
6. Number of feeders;
7. Minimal structure;
8. Number of special equipments (reclosers, voltage regulators, so on);
9. Number of medium voltage substations;
10. Data of 69kV and 138kV system:
    - *Number of substations;*
    - *Number of equipments;*
    - *Extension of transmission lines;*
    - *Structures (wood, concrete or steel).*

The variables selected were those that were directly related to each activity under analysis, establishing weights (percentages) according to the relative importance of that variable for the activity in question, defined based on various discussions and consensus established between professionals, and relevant work experience, past and present.

Table 2 is an example of variables and the weights assigned to the quantitative distribution of workforce between bases of operation for multitasking electrician activities.

These variables were chosen taking into account the factors that contribute to the execution of activities and events in the system, evaluating the activities performed for each function, and what criteria are subject to contribution.

The weights used for each variable for the distribution of positions were established on the basis of practical experience and analysis of the failure average rates of system components.

Consumers	**35%**	
	Low voltage	***80%***
		Urban 78%
		Rural 22%
	Medium voltage	***20%***
		Urban 70%
		Rural 30%
Extension of medium voltage lines	**18%**	
	Urban	**24%**
		1 Phase 2%
		3 Phases 98%
	Rural	**76%**
		1 Phase 40%
		3 Phases 60%
Extension of low voltage lines	**7%**	
	Urban	**50%**
		1 Phase 5%
		2 Phases 2%
		3 Phases 93%
	Rural	**50%**
		1 Phase 15%
		2 Phases 35%
		3 Phases 50%
CELESC Distribution Transformers	**11%**	
	Urban	**35%**
		1 Phase 2%
		3 Phases 98%
	Rural	**65%**
		1 Phase 50%
		3 Phases 50%
Particular Distribution transformers	**1%**	
	Urban	**70%**
		1 Phase 0%
		3 Phases 100%
	Rural	**30%**
		1 Phase 1%
		3 Phases 99%
Number of Poles	**15%**	
	Urban	**40%**
	Rural	**60%**
Minimal structure	**10%**	
Number of special equipments	**3%**	

Table 2 – Multicriteria model for multitasking eletricians

All inputs and resulting multicriteria model are discretized per municipality and can be grouped by service point or base of operation in order to find the best condition for improving the service level.

DATA OF SERVICES PERFORMED

There is a set of services that, by their characteristic of cycle time, criticality and predictability, offer the possibility of a preliminary planning for its implementation without impacting violations, for example, scheduled maintenance, inspections, connections, energy disconnection and inspections of irregular consumption.

Moreover, given the inherent instability of the electrical system, there are a number of unexpected events that do not offer the same anticipation as to the accuracy or predictability to perform ancillary services, denominated emergencies. In this class are usually derived services of consumer complaints about the outages, and threats perceived by consumers, staff or third part.

For purpose of validation of workforce distribution, better distribution of service points and definition of the scales was conducted survey of services related to the activities planned for the operational assistants, with data between 2007 and 2012, noting the following items:

a) Type of service (emergency or commercial);
b) Time of entry of the complaint;
c) Average length of travel and execution;
d) Place of performance of service.

Table 3 shows the summary of the average daily distribution of services in each time range. It is clear the concentration of services in business hours (94%) and low rate of outages in the night.

The values presented were collected per municipality and grouped by operation basis, assisting to define the scale and concentration of teams in time of greater demand, in order to reduce the queue of events waiting to be solved, reducing the total time service and improve continuity indicators.

Average daily distribution of services by time range							
	00 to 07		07 to 17		17 to 24		Total
Emergency	31	5%	363	62%	191	33%	585
Commercial	-	-	2895	100%	-	-	2895
	31	1%	3258	94%	191	5%	3480

Table 3 – Average daily distribution of services by time range

To evaluate the sizing of teams at weekends is important to know the data of Table 4, which shows the percentage distribution of emergency services per weekday and it can be seen that there is a reduction of emergencies on Saturdays (about 15%) and Sundays (above 30%) when compared to the average working day.

Distribution of emergency per weekday								
	Sun	Mon	Tue	Wed	Thu	Fri	Sat	Total
2007	11,35%	16,12%	14,48%	15,05%	14,15%	15,24%	13,62%	100%
2008	10,48%	15,15%	15,44%	15,40%	14,81%	14,72%	14,00%	100%
2009	10,51%	15,35%	15,66%	15,40%	15,94%	14,56%	12,58%	100%
2010	10,46%	16,37%	16,21%	15,92%	14,35%	14,41%	12,30%	100%
2011	10,16%	15,79%	16,13%	14,91%	15,15%	14,61%	13,25%	100%
2012	10,45%	16,14%	14,69%	14,91%	15,68%	15,44%	12,69%	100%
Average	10,57%	15,82%	15,44%	15,27%	15,01%	14,83%	13,07%	

Table 4 – Distribution of emergency per weekday

The current distribution of teams in most places are not correlated with the demand for services, creating a queue and a long waiting time for occurrences during business hours, which often end up accumulating to the next range of service hours, generating excessive costs with overtime and penalties for violations within the deadlines set by ANEEL for inspection and connection of consumer units.

For each service point was analyzed the relationship between the demand for services and distribution of teams, as can be seen on figure 4, in order to validate the quantitative defined by the multicriteria model.

Hora	2ª		3ª		4ª		5ª		6ª		Sáb.		Dom.	
	Eqps	Servs	Eqps	Servs	Eqps	Servs	Eqps	Servs	Eqps	Servs	Eqps	Servs	Eqps	Servs
00:00 às 00:59	1	0,29	1	0,29	1	0,29	1	0,29	1	0,29	1	0,27	1	0,21
01:00 às 01:59	1	0,20	1	0,20	1	0,20	1	0,20	1	0,20	1	0,19	1	0,15
02:00 às 02:59	0	0,16	0	0,16	0	0,16	0	0,16	0	0,16	0	0,15	0	0,12
03:00 às 03:59	1	0,17	1	0,17	1	0,17	1	0,17	1	0,17	1	0,16	1	0,12
04:00 às 04:59	1	0,17	1	0,17	1	0,17	1	0,17	1	0,17	1	0,16	1	0,13
05:00 às 05:59	1	0,26	1	0,26	1	0,26	1	0,26	1	0,26	1	0,24	1	0,19
06:00 às 06:59	1	0,61	1	0,61	1	0,61	1	0,61	1	0,61	1	0,57	1	0,45
07:00 às 07:59	2	1,22	2	1,22	2	1,22	2	1,22	2	1,22	2	1,15	2	0,91
08:00 às 08:59	9	30,13	9	30,13	9	30,13	9	30,13	9	30,13	2	1,98	2	1,57
09:00 às 09:59	9	30,54	9	30,54	9	30,54	9	30,54	9	30,54	2	2,37	2	1,88
10:00 às 10:59	8	30,46	8	30,46	8	30,46	8	30,46	8	30,46	1	2,29	1	1,82
11:00 às 11:59	8	30,08	8	30,08	8	30,08	8	30,08	8	30,08	1	1,93	1	1,54
12:00 às 12:59	2	1,51	2	1,51	2	1,51	2	1,51	2	1,51	2	1,42	2	1,13
13:00 às 13:59	9	29,79	9	29,79	9	29,79	9	29,79	9	29,79	2	1,66	2	1,32
14:00 às 14:59	9	30,20	9	30,20	9	30,20	9	30,20	9	30,20	2	2,04	2	1,62
15:00 às 15:59	9	30,20	9	30,20	9	30,20	9	30,20	9	30,20	2	2,04	2	1,62
16:00 às 16:59	9	30,22	9	30,22	9	30,22	9	30,22	9	30,22	2	2,06	2	1,64
17:00 às 17:59	2	2,20	2	2,20	2	2,20	2	2,20	2	2,20	2	2,07	2	1,64
18:00 às 18:59	1	2,34	1	2,34	1	2,34	1	2,34	1	2,34	1	2,20	1	1,75
19:00 às 19:59	1	2,01	1	2,01	1	2,01	1	2,01	1	2,01	1	1,89	1	1,50
20:00 às 20:59	2	2,08	2	2,08	2	2,08	2	2,08	2	2,08	2	1,96	2	1,56
21:00 às 21:59	2	1,29	2	1,29	2	1,29	2	1,29	2	1,29	2	1,22	2	0,97
22:00 às 22:59	2	0,86	2	0,86	2	0,86	2	0,86	2	0,86	2	0,81	2	0,64
23:00 às 23:59	1	0,52	1	0,52	1	0,52	1	0,52	1	0,52	1	0,49	1	0,39

Figure 3 - Relation between the distribution of teams and demand for services in the point of service

CONCLUSIONS

The results in the application of multicriteria model diverged from the model practiced by the company, where the criteria are not well defined and is basically a division in a large linear part and another part weighted by the number of consumers of each region.

In comparison with the established quantitative demand for services can be clearly observed problems historically practiced scales, especially in medium and large cities, where there were less than the required number of teams working on business hours, day's range that has the greatest demand for services.

This problem increases the service time, violation of deadlines and increased overtime pay for electricians. With an analysis for each point of service was possible to do a better definition of scales, adjusting the amount established by multicriteria model for a better distribution of teams by time range to attend the services. It was further verified the need to increase by 8 service points, passing to 134, with opening new locations in places with service demand and high travel time.

In meetings with teams from all operational bases, the model was validated in 95% of locations, requiring occasional adjustments focusing on a better coverage against the demand occurrences.

The work still prioritized actions that must be performed to be achieved productivity gains in teams, such as finalizing the implementation of new communication system and digital dispatch, the use of automatic dispatch of business and programmed services, automation distribution lines project and automatic routing system of teams.

The final number of electricians was 2.5% lower than the current, but with the implementation of improvements identified can be captured a productivity gain after retirement professionals in the coming years.

Every time there are significant changes in technology that affect the performance of the system and services teams, multicriteria model should be further analyzed in order to capture productivity gains and evaluated the weights for redistribution of the workforce.

REFERENCES

[1] L. F. MOURA, 2012, "Otimização da logística das equipes de plantão através da aplicação de teoria das filas – Caso CELPE", *Proceedings of SENDI, São Paulo, Brazil*

[2] E. JAEKER, 2011, "Multi-criteria optimization in workforce management", *Proceedings of 21st CIRED,* Frankfurt, Germany.