Ergonomic Studies in Brazil and Portugal in the Operators of Electric Power Control Centers

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ABSTRACT

The electricity sector has resulted in more sophisticated equipment and requires more attention from operators, bringing the monitor and operating a growing set of equipment. This results in increased workload with emphasis on cognitive and environments more conducive to error. The task of an operator, in the Electric Power Control Centers is very complex and specialized situation. They have the basic item, the prevention of incidents and errors that disrupt the operation of the electrical system, or when this is not possible, they attempt to make the process of returning to normal, which is called recovery. They have to do it by mobilizing knowledge and reasoning for which they received training, which, from the point of view of existing rules, are adequate. However, there are some factors that need to be improved because there are still accidents and incidents caused mainly by fatigue, lack of concentration, or inadequate human-computer interface. The aim of this paper is to evaluate workload and ergonomics aspects on the operators in the electric power control centers and analyze whether there are differences in two countries of different continents Brazil and Portugal.

Keywords: Workload in Electric Power Control Centers, Human-Machine Interface, Cognitive Ergonomics.

INTRODUCTION

Institutional changes currently underway in the global power sector are intended to establish a free market in energy, increasing the efficiency of the sector through competition and enabling raise funds for expansion. In this market, as in any other, participants and agents looking to improve their strategic position by obtaining competitive advantages over competitors in order to enable their survival and growth in free competition system.

With technological advancement tasks performed by humans are more complex and work environments increasingly automated. Similarly to systems developed for other industries, the automation of the electricity sector has resulted in more sophisticated equipment and requires more attention from operators, bringing the monitor and operates a growing set of equipment. This results in increased cognitive load and more prone to error environments. Electrical systems can be categorized as critical systems where failure can result in significant economic loss, physical harm or threats to human life (Lima, 2006).

By observing the activity of an operator of the Electric Power Control Center appears that they perform an intense activity in a complex, specialized and dangerous system. They have a basic item, the prevention of incidents and errors that disrupt the operation of the electrical system, or when this is not possible, try to make the process of returning to normal, which is called recovery. They have to carry it by mobilizing knowledge and reasoning for which they have received training, which from the point of view of the current rules are adequate, however, there are some factors that need to be improved, as there are still accidents and incidents, caused mainly caused by fatigue, lack of concentration or due to inadequacy of Human Computer Interface (HCI).

The impacts that may arise due to problems in electrical substations can cause serious disorders resulting from failures in electricity supply also affect the dealership itself , which is subject to fines and penalties by the regulator . Thus this fact drives the power companies to dispose of human resources capable of making decisions quickly and effectively in order to meet the occurrences, both as emergency contingency.

Among the factors involved in the decision-making capacity may be cited: 1 - postural requirements; existing 2 - Equipment, 3 - State continuous attention task; 4 - Fatigue for the worker and the same influences on health and productivity of the company; 5 - Difficulty in interpreting environmental information 6 - Conditions: Noise, lighting and inadequate temperature; qualitative and quantitative aspects of the 7 - Presentation of information.

The automated equipment currently perform more mechanical and repetitive activities, while humans perform activities in dynamic environments requiring rapid adaptation and flexibility to perform effectively occur. This adaptation to circumstances that become steadily due to the variability of processes and the supervisory role of workers requires complex skills and cognitive abilities. In this scenario, the incorporation of the cognitive component in the analysis of labour has become a necessity, so that we can satisfactorily respond to the complex skills involved in the operation of modern systems work (Oliveira, 2009).

ELECTRIC POWER CONTROL CENTERS ROOM

The introduction of new technologies is requiring operators to resolve problems of an intellectual nature , even those which might be regarded as less qualified. This means that many of the tasks rely more on reasoning than the layout and physical engagement .

A starting point of study that is directly related to the performance of the operator 's environment. In this environment the factors to be considered include: clarity, humidity, temperature , vibration and noise . By observing these factors should also examine the effect that they cause the performance of activities with the stresses exerted by time and complexity of operated equipment (Lima, 2006) .

The second point refers to the type of task operators , whose basic item, the prevention of incidents that disturb the normal course of the process or production step where they work or, when this is not possible, try to make the return to normal process, the so-called recovery. Salles (2008) analyzes several aspects about these technicians of the electricity sector and discusses aspects of cognitive ergonomics and its contribution in the areas of reasoning, comprehension and memory among others.

As for the reasoning employed by operators to solve the problems of operation and control has been studied primarily caused by verbalizations in a situation of simulation and the much rarer form, causing the operator to narrate their activity. However there is always an influence on the frequency of incidents on the reasoning of the operators , and in this case a situation that shows familiarity produces a habitual response, which may not be the most appropriate option quickly. There are sometimes shortcuts in reasoning which are explained by the experience of the operator (Vidal, 2008) .

The control room operator has particularities in the development of his work , considering that usually needs to manage and regulate complex systems. Therefore, when trying to analyze the mental processes in the development of the tasks performed by this worker, the cognitive analysis presents itself as a very useful methodological tool , since it has a theoretical and methodological support that provides greater reliability of data being obtained , despite the subjectivity of these hamper its applicability (Ku et al ., 2010) .

In Figure 1 is shown a typical room of Electric Power Operation and Control Center where there are individual monitors in the background and monitors and General Frames and Panels System . There is in general that there is a complex information system with which the operator is at the center of decisions between different monitors and tables and diagrams that occupies your entire field of vision .

Figure 1 - Room of Electric Power Operation and Control Center

The human-machine interface in the electricity sector has activities that use a large amount of multivariate data. As simple example information on freight flows of electricity, there are a potentially large number of dependent variables, such as the flows in transmission lines, bars, generators, active and reactive power, data processors and generators. With systems containing many bars, the biggest challenge is to present this data in a quick and intuitive way (Wiegmann et al., 2006, 2005).

In these systems, operator interface that presents confusing can result in misinterpretation and induce errors during decision making. Therefore these systems are required, among other quality features, security, adaptability to different users and levels of experience and training facility associated with their learning and use (Lima, 2006; Vieir et al. 2009).

May (2008) in turn underscores the complexity of the Human-Machine Interface (HMI) in operation and control Centers for the following reasons:

1. Demand for sustainable energy generation leading to an increased amount of variable sources of power generation with low predictability like wind energy
2. Further integration and increase the size of national and regional networks
3. Increased level of automation involving distributed measurements and automatic decisions
4. Increased complexity of coordination arising from the implementation of optimal power flow based on the electricity markets
5. Increased demand for resilient networks of energy, in the form of permanent micro-networks or islanding that may help protect the larger instabilities voltage networks. Other complications include the state maintenance of transmission and distribution and the lack of qualified operators in the control and updated procedures and training room.

The information associated with energy systems has generally been shown using a two-dimensional interface (2D) display often consisting of a one-line diagram of a system as shown in Figure 2. In this diagram the black bars mean substations, lines are transmission lines of electricity and the largest circles generations. In the same figure the smaller circles with internal insertion Blue inform the system load, turn the arrows indicate the direction the flow of electrical power, and pink and gray bars represent the power generation.

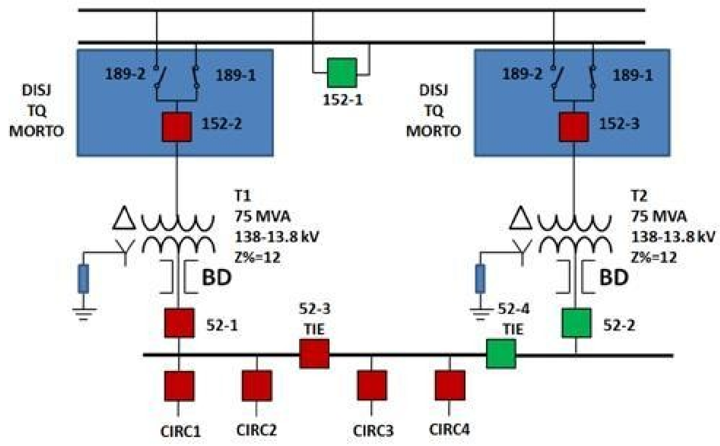
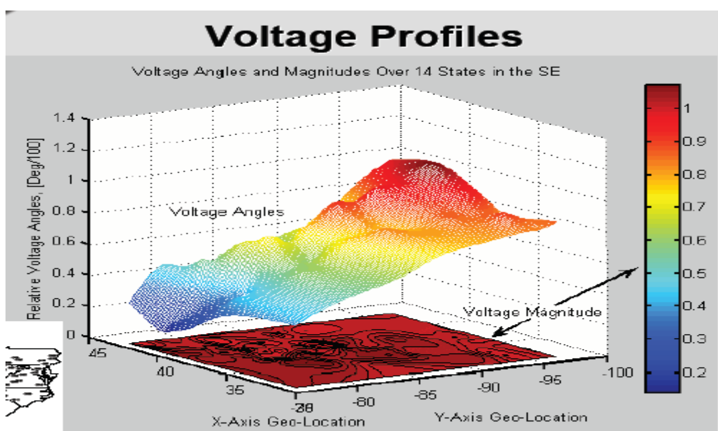


Figure 2 - Single Line Diagram of a 2D substation

Over the past few years have begun to be developed and integrated into Operation and Control Centers interactive interface in three dimensions (3D) with the information system, as shown in Figure 3.



Fonte: DAGLE (2006)

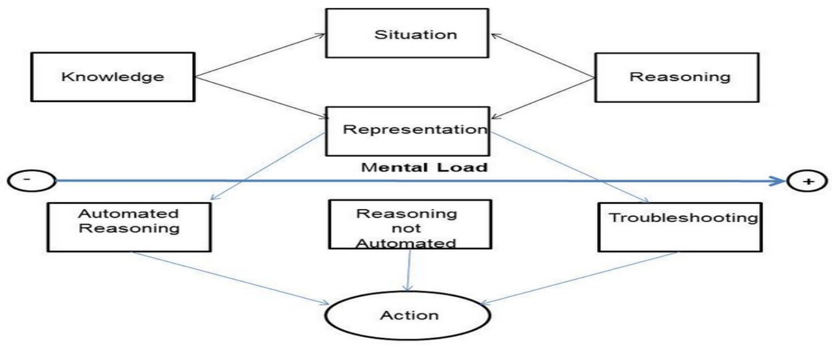
Figure 3 - Data Specific Electrical Parameters (voltage profile and angle) in 3D

Workload: The Fatigue and the Mental Load

Fatigue is quite common in the workplace and should be understood as a set of signs and physical and mental symptoms, which if not properly observed and reversed potential repercussions in several body systems. Excessive fatigue can cause an overload and underload it also marks as well, factors such as boredom, monotonous work are sources of fatigue. It is noteworthy that the monotonous drudgery and fatigue more than the work interesting and brings harmful implications both on the viewpoint of quality of work, either in the health of the performer. Fatigue showed a risk 5.8 times higher than appearing in workers who had little creative work than in those who had higher labor content (Noriega, 2004). Rebelo et al. (2003-1, 2003-2) analyze aspects of fatigue from the point of view of ergonomics and Carvalho et al analysis. (2003) discuss the interaction between fatigues, workload with the physical aspects.

The causes of fatigue can be summarized: Time availability, Equipment, Instruments, Securities; quality of the physical environment (temperature, noise, vibration, air quality); technical pressures, managers, strategies, organizational policies, work in shifts. As a result workers have various disorders: sleep, gastrointestinal, cardiovascular and psychiatric. On social and family life, we highlight the damage in organized social activities such as education, culture, sports, among others. Also, night work can cause severe drowsiness, reduced performance, and the risk of major accidents (Akerstedt, 1998; Baulk, 2009).

With regard to the concept of mental workload it appears that there is a direct relationship with the cognitive ergonomics since this branch deals with the cognitive aspects of the task (Murata, 2005). Several studies address this topic as research with Cañas et al. (2010, 2009), Di Stasi (2012, 2010). Meiman (1997) in turn analyzes the correlation between aspects of the task time and Noriega (2000, 2004) addresses the relationship with the psychic aspects of the worker. We highlight some studies conducted in the railways sector (Pick up 2010, 2005). Quesada and Cañas (2003, 2001, 2000) analyzed the mental aspects and defined models relating them to the working memory. On the other hand, a concept using the relationship between mental and cognitive aspects a cognitive load is architecture, which refers to the description of the various components of the cognitive system and their relationships. This association between cognitive and mental burden architecture has been proposed by Richard (1990) and is shown in Figure 4.



source: Richard (1990)

Figure 4 - Cognitive Architecture Associated to Mental Workload Concept

In this model it is the consideration that automated reasoning has lower mental workload than those associated with problem solving. This initial guess can be confirmed or not in a particular work situation. At this point we have an interface of cognitive and physical aspects. It can be assumed, for example, automated reasoning produce a mental burden less than or not automated reasoning to solve problems. However, this may not be true if the executors of this task have an automated training and education far above the demands of the task.

This research aims to evaluate human factors, ergonomics and workload of the technical of operation and control centers through a multi case study in Portugal and Brazil.

METHODS AND MODELS

The research used a sample of total sample of 54 operators of the selected region of Brazil, 27 in Brazil and 27 in Portugal. Interviews were also conducted to enable a better understanding of the factors intervening between the work situation and ergonomic aspects: Gender and age of the sample; Marital status; Educational level; Working time in the company; Experience time in the activity; Adjustment of seats; Seat length; Shape and size of chair backs; Height of armrest chairs; Appropriateness of the computer for the mouse position; Adequacy of computer keyboards on the position; Position of the monitors; Intensity and pace of activities in the workplace.

It was used in this research the NASA-TLX method that is part of a multidimensional measure arising from a global score (minimum 1 to maximum 20) balanced workload guided the weighted average of reviews of six sub - scales. The NASA-TLX has shown appropriate, taking into account its practicality and simplicity in the questionnaire and for assessing globally the workload. These six factors involve: Levels of achievement (LA), effort (LE) and frustration (LF), which have strong influence on the individual characteristics of the operators. The mental demands MD), physical (RP) and temporal (TR) which are determined by the work situation. The level of achievement (LA) refers to satisfaction with personal performance to the achievement of the task. The level of effort (LE) refers how much you have to work physically and mentally to achieve a good performance. The level of frustration (LF) is the factor that inhibits completion of the work as insecurity, irritation, lack of stimulation, setbacks. The mental requirement (MD) involves mental activity required to perform the work. The physical requirement (RP) corresponds to physical activity required for execution of the work and the time requirement (TR) for the level of pressure imposed for the completion of the same, according to Table 1 (Diniz, 2003).

Table 1 - Factors considered in the NASA-TLX Instrument

Factors considered	Low Limit Level 1	High Limit Level 20
Mental Demand (MD)	Tasks considered easy, simple, goals achieved without difficulties	Tasks difficult, complex, requiring much mental effort to achieve the goal
Physical Requirement (RP)	Light, slow, easily accomplished tasks	Heavy, quick, strong, and lively tasks
Temporal Requirement\ (TR)	Slow and relaxed pace, with low pressure to the termination of activities	Fast and furious pace, with lots of pressure for completing the activities
Level of Effort (LE)	You become no satisfied and almost no one notices your work	You feel very happy and are praised when it reaches the goals
Level of Achievement(LA)	For the task to be performed successfully, surface concentration, muscle strength light weight, and simple reasoning are required (lack of skills)	Deep concentration, muscle strength, intense, complex reasoning, and great skill are needed
Level of Frustration (LF)	You feel safe, happy, and relaxed when you run the task	You feel insecure, discouraged, angry, and bothered with the task

Source: Diniz (2003)

RESULTS

In this section the results of the research are presented. In Figures 5 to 8 are shown the comparative data from Portugal and Brazil. Adequacy of the computer and organizational and psychosocial factors conditions, the characteristic data of the sample environment and the workplace are presented.

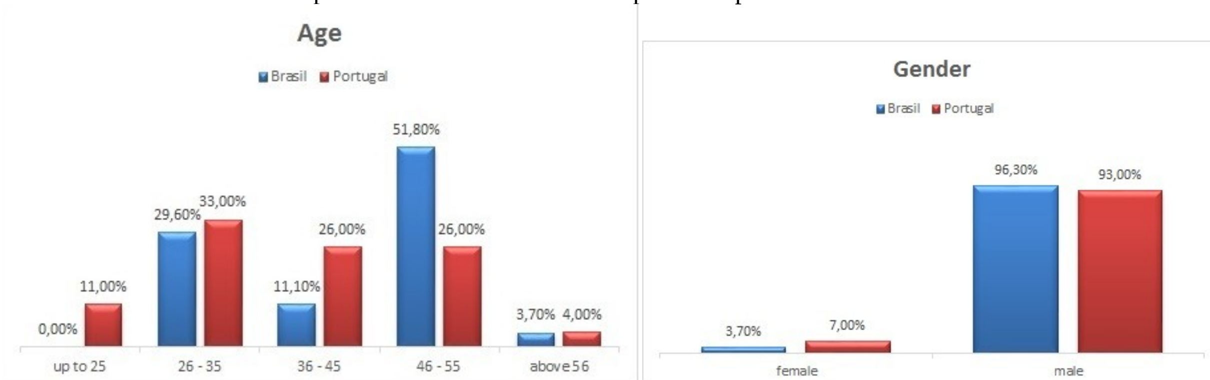


Figure 5 - Gender and age of the sample

It was observed that 56% of shows in Brazil have aged above 46 years and 30% in Portugal.

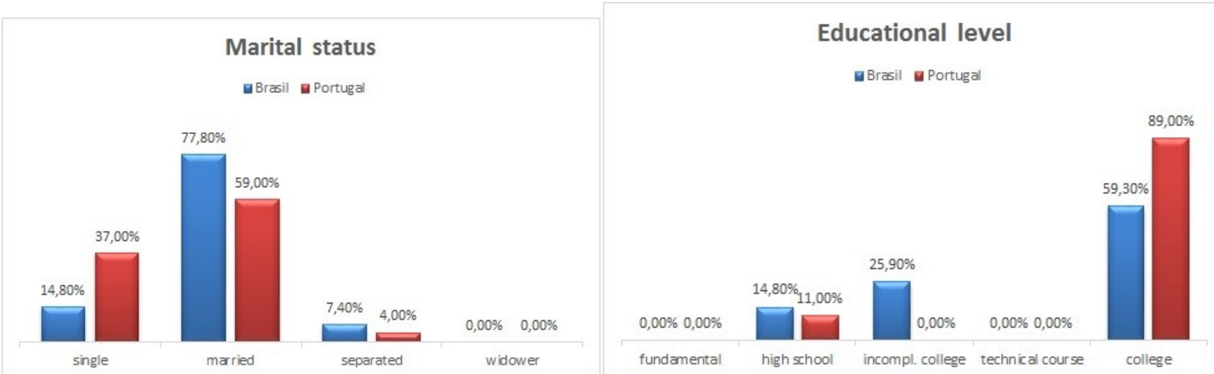


Figure 6 - Marital status and educational level of the sample

From Figure 6 we observe a significant difference in education of operators in Portugal where 89% have a college degree and 59% in Brazil.

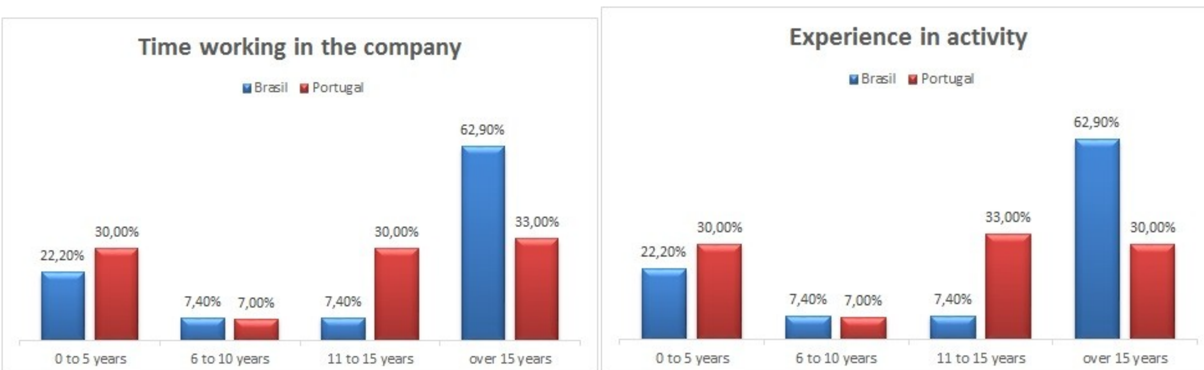


Figure 7 - Time working in the company and experience in the activity

It was observed a significant difference in length of experience in the position where 62.9% in Brazil has more than fifteen years and in Portugal is 30%. Regarding the length of experience in the position in Brazil 62.9% has more than fifteen years and in Portugal 30%.

In Figures 8-11 the results of ergonomic aspects related to the job are presented

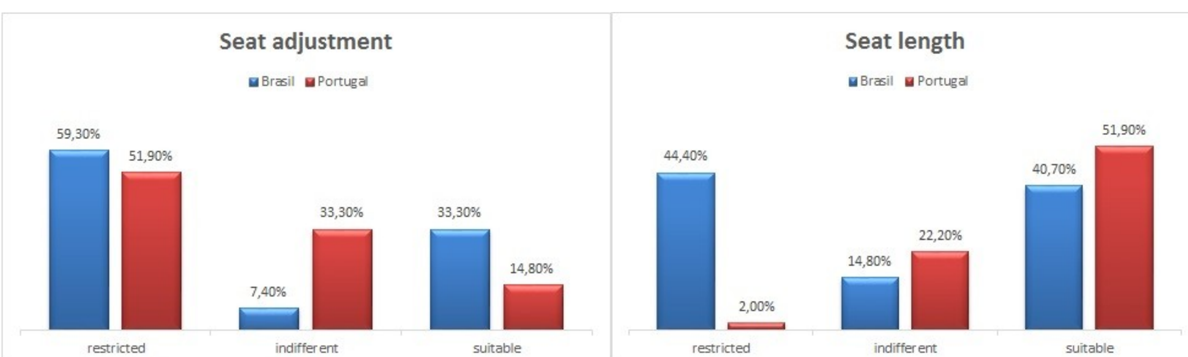


Figure 8 - Adjustment of seats and seat length

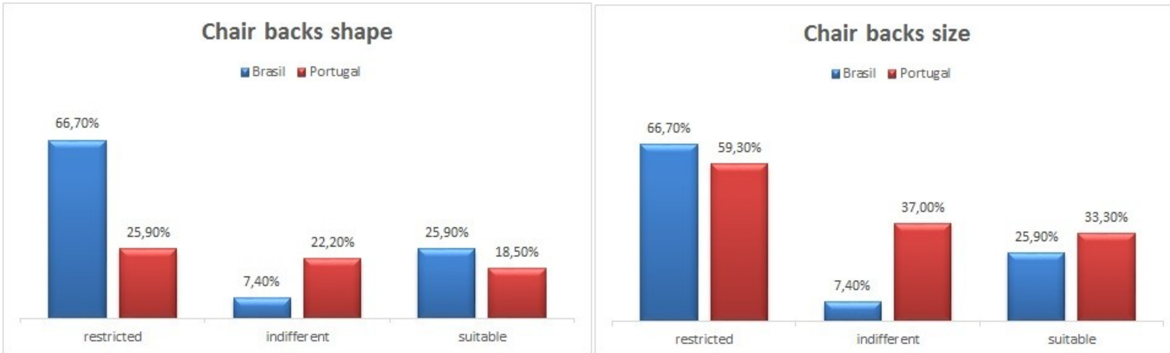


Figure 9 - Shape and size of chair backs

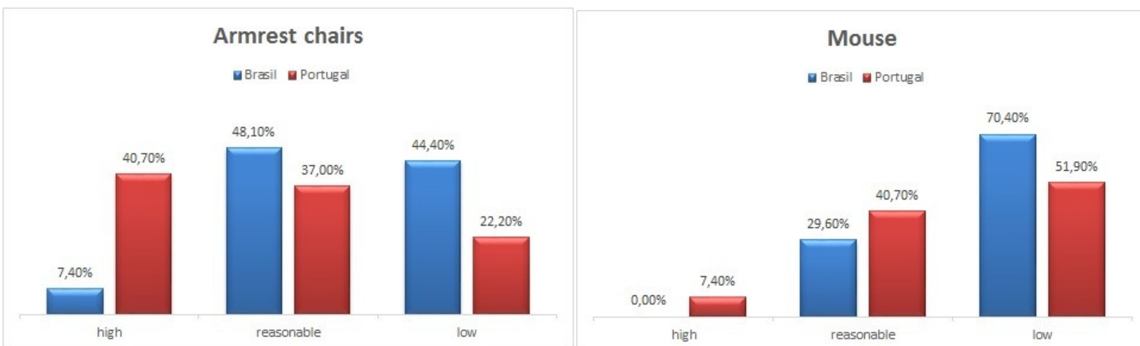


Figure 10 - Height of armrest chairs and appropriateness of the computer for the mouse position

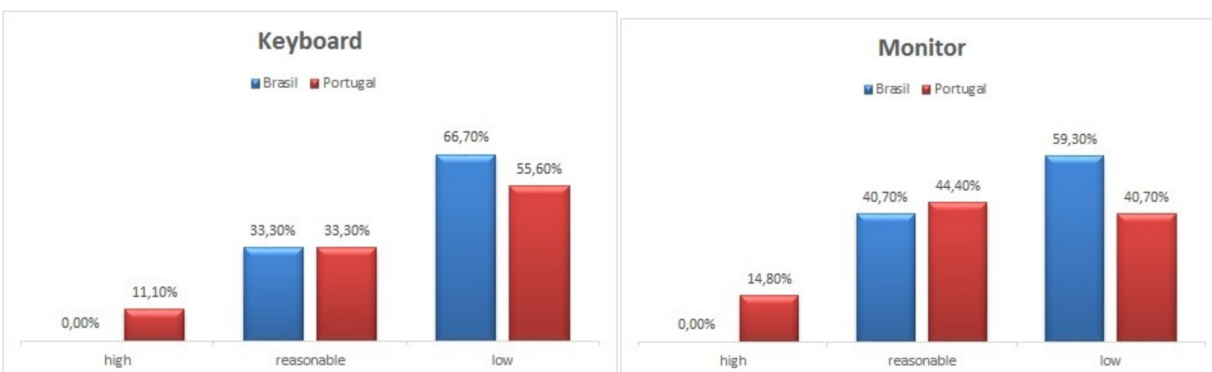


Figure 11 - Adequacy of computer keyboards on the position as the position of the monitors

Analyzing Figures 8 to 11 regard to ergonomic chairs, seats and appropriateness of computer and monitor aspects were considered adequate and the data obtained in both countries were similar.

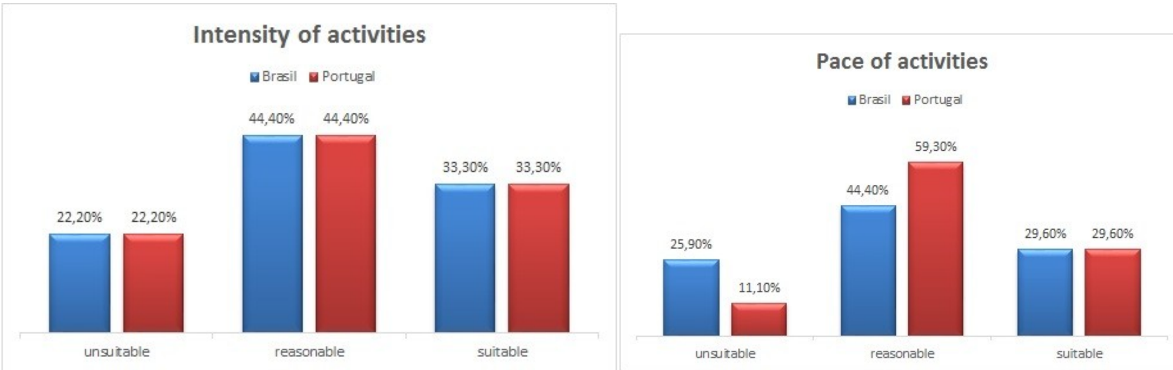


Figure 12 – Intensity and pace of activities in the workplace

By the data of Figure 12 is a similarity between the data of both countries regarding the intensity of work where around 77% considered reasonable and appropriate. Regarding the pace of work 89% of operators consider reasonable and appropriate in Portugal and 74% in Brazil.

The Figure 13 shows the data of the six variables MD (mental demand), RP (Requirement Physics), TR (Temporal Requirement), LA (Level of Achievement), LE (Level of Effort) and LF (Level of Frustration). The scale corresponds to the first minimum value 1 and the maximum index 20.

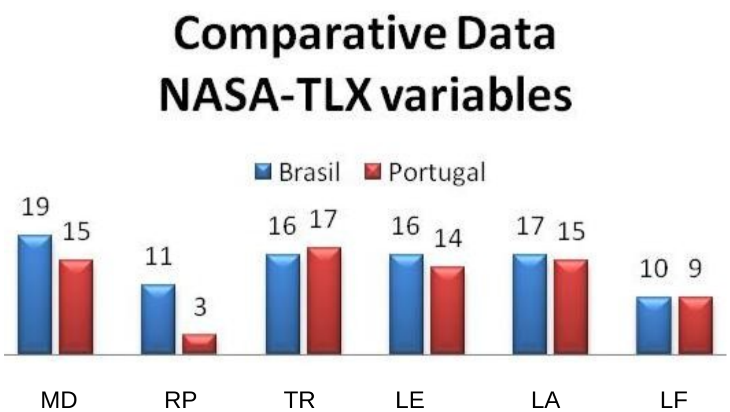


Figure 13– Comparative data between Brazil and Portugal of NASA-TLX variables (MD, RP, TR, LE, LA and LF)

The linear correlation between the six variables, considering the data for both countries, was analyzed. The results are as follows:

Table 2 – Correlation coefficients of the variables (Portugal)

	Portugal (PT)					
	MD	**RP**	**TR**	**LE**	**LA**	**LF**
MD	1	0,073	**0,789**	**0,771**	0,441	-0,010
RP	-	1	-0,011	0,125	-0,105	-0,283
TR	-	-	1	0,564	0,460	-0,047
LE	-	-	-	1	0,300	0,248
LA	-	-	-	-	1	-0,317
LF	-	-	-	-	-	1

Table 3 - Correlation coefficients of the variables (Brazil)

	Brazil (BR)					
	MD	**RP**	**TR**	**LE**	**LA**	**LF**
MD	1	0,260	**0,738**	**0,804**	-0,078	0,399
RP	-	1	0,175	0,343	0,311	-0,063
TR	-	-	1	0,625	-0,147	0,448
LE	-	-	-	1	0,018	0,168
LA	-	-	-	-	1	-0,129
LF	-	-	-	-	-	1

Analyzing the data in Tables 2 and 3 it was concluded that there is a linear correlation between the variables MD-TR (0.789, 0.738). The simple linear regression analysis between the three variables that were correlated MD-TR and MD-LE are show in the Figure 14.

Analyzing the MD-TR and MD-LE variables analyses:

Results from Portugal (lower curve):

$$MD = \beta_0 + \beta_1 TR \rightarrow MD = 2{,}798 + 0{,}755TR \quad (1)$$

Multiple R-squared: 0.6222
p-value: 1.017e-06 < 0.05
Results from Brazil (upper curve):

$$MD = \beta_0 + \beta_1 TR \rightarrow MD = 6{,}322 + 0{,}641TR \quad (2)$$

Multiple R-squared: 0.5449
p-value: 1.106e-05 < 0.05

Results from Portugal (lower curve):

$$MD = \beta_0 + \beta_1 LE \rightarrow MD = 3{,}733 + 0{,}796LE \quad (3)$$

Multiple R-squared: 0.5937
p-value: 2.581e-06 < 0.05
Results from Brazil (upper curve):

$$MD = \beta_0 + \beta_1 LE \rightarrow MD = 5{,}641 + 0{,}759LE \quad (4)$$

Multiple R-squared: 0.6458
p-value: 4.474e-07 < 0.05

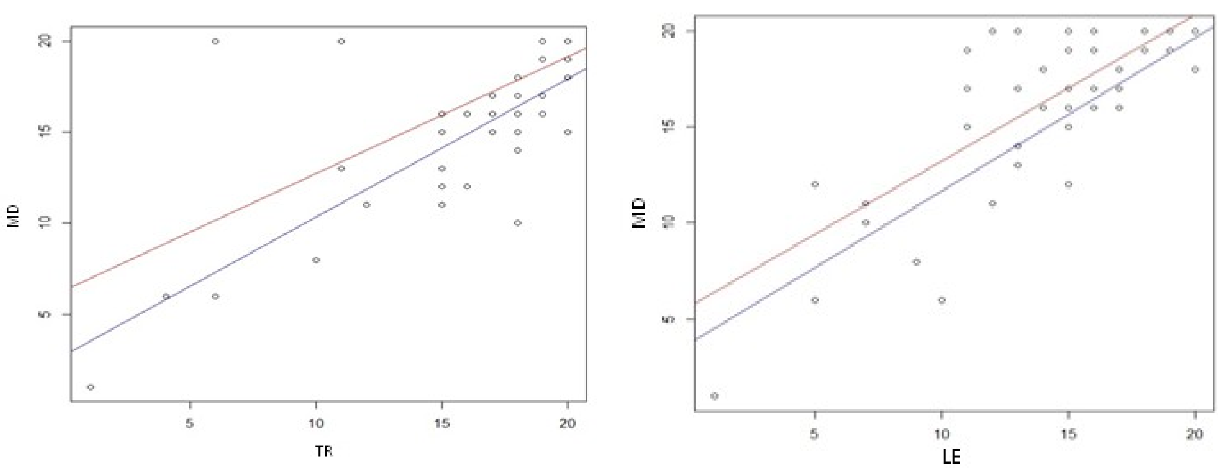


Figure 14 – Linear regression curve of TR-MD and LE-MD, upper curve (red)–Brazil; lower curve (blue)–Portugal

Analyzing the Figure 14 the models show that the LE and TR have an influence on the MD of the operators in the electric power sector of both countries. The LE of operators in Portugal contributes more 62% for mental MD compared with those in Brazil 54%) However the TR of operators in Brazil is slightly higher 64% than the operators in Portugal 59%. Take into account the variables LE and TR verifies that they have influences on MD 78% in Portugal and 74% in Brazil.

CONCLUSIONS

1. The Mental Demand (MD) indexes are high in both countries, although data in Brazil are higher than 25 % for Portugal. The high values found in both countries featuring a kind of work with difficult, complex task, requiring much mental effort to achieve the goal.
2. In the Physical Requirements (RP) the values were very low in both countries as to be expected since the activity requires little physical effort.
3. Regarding the Temporal Requirement (TR) also found high rates in both countries. Thus the types of operators of this task are characterized by a fast and frantic pace, with lots of pressure for the completion of activities.
4. As for the variable Level of Effort (LE) were moderate. It is emphasized that this index brings together internally to the mental and physical demands, although the value of Mental Requirement (MD) has shown high values the Physical Requirement (RP) had very low values leading the overall index value for moderate.
5. Analyzing the comparative figures for Portugal and Brazil the Level of Effort (LE), it appears that the data from Brazil are higher by 17% compared to the values in Portugal.
6. With respect to the content Level of Achievement (LA), the sample has a high score. This level features the activity in which the operator feels satisfied with his activity.
7. In the Level of Frustration (LF) the sample show low values both in Portugal and Brazil. It provides an indication that workers perform their activities when they feel safe and secure.
8. This research contributes with data to a better the strategic planning of electric power companies. Also to improvements of the activities of the operators of the Electric Power Control Centers and a reduction in operating errors.

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