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PROPOSAL OF EFFECTIVENESS INDICATORS FOR THE REGULATION OF NON-TECHNICAL LOSSES IN THE ELECTRICAL INDUSTRY

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ABSTRACT

In recent years, the Brazilian electricity sector has been experiencing high levels of non-technical losses, impacting both the electricity tariff paid by the consumer and the financial balance of the distributors. The high levels of NTP have multiple causes, ranging from the management difficulties of the distributors themselves in the fight against losses, even to the regional socioeconomic complexities. Aneel is the entity responsible for regulating the levels of these losses, using an own methodology applied in each rate review cycle. In this context, the present article sought to develop a metric capable of evaluating, measuring and classifying the effectiveness of the regulatory methodologies of NTP treatment, according to the results obtained at the end of each regulatory period. For this evaluation, it was identified the possibility of using Multicriteria Analysis techniques, such as the TODIM method. Because of their ability to handle different perceptions of interest.

Keywords: Brazilian Electric Sector, Non-technical losses, Multicriteria Analysis

1. INTRODUCTION

The process of evaluating a public policy is not a trivial exercise, as there is no single objective metric that is capable of measuring its effectiveness. In this way, a given situation can be evaluated according to different perspectives and metrics. The Brazilian electricity sector (SEB) does not escape this rule, presenting a series of policies and measures of difficult measurement of its effectiveness in promoting well-being to society. Among these policies are those directed to the regulation of non-technical losses (PNT) implemented by the National Electric Energy Agency (ANEEL). In the case of the assessment of the impact of the NTP regulation on electric energy tariffs, it can be seen that this could occur, for example, both through the short-term reflection of the losses in the value of the tariff paid by the consumers, and by the effects of the losses in the finances and profitability of distributors.

In general, the PNT regulation methodology seeks to establish a feasible loss reduction path for distributors. For this purpose, a portion of the NTPs is recognized by the regulator for each distributor and passed on to the electricity tariffs of the distributors. The costs related to the unrecognized portion are borne by the distributor itself. In this context, it is possible to say that this methodology operates on three main fronts: (i) assigning goals consistent with the complexity of combating losses intrinsic to concession areas; (ii) establishment of starting point according to size, history and saturation in the fight against losses; (iii) establishment of reduction speed limits through company size.

However, the methodology has structural problems that may be reducing its effectiveness. In recent years, Brazil has shown a high average of distributors that are unable to meet NTP regulatory targets. As a consequence, the financial losses in the companies of the sector by the NWPs are high. Therefore, the effectiveness of regulation in encouraging the reduction of NTP is an expensive issue for electricity distributors, which questions its effectiveness in encouraging loss

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reduction and promoting improvement in service delivery.

In view of the mentioned problems, it is necessary to evaluate the methodologies used so far in the regulation of NTP, identifying potentially fragile elements and, therefore, require specific improvement. In this sense, the evaluation process can be based on factors such as: i) the weighting of different interests of the agents in different time scales; ii) the ability of regulation to deal with adverse situations, as in the case of economic contexts different from those expected; iii) the degree of induction to the efficiency of fight against losses due to the influence of the regulation on the behavior of the distributors; and iv) the regulatory capacity to adequately capture the specificities of concession areas.

Given this context, this work aims to develop a metric capable of evaluating, measuring and classifying the effectiveness of the regulatory methodologies of NTP treatment, according to the results obtained at the end of each regulatory period. For this evaluation, the possibility of using Multicriteria Analysis techniques is identified, considering its capacity to deal with the different interests of the agents of the sector. Having said that, a bibliographical survey was carried out about the different techniques of multicriteria analysis, in order to select a method that best covered the problematic under analysis. As a result, the TODIM method was chosen and, later, elaborated criteria / indicators and their respective weights to subsidize the application of the method. This process was based on the consultation of specialists in the national electricity distribution market. To validate the metric, this work proposes an additional exercise to the development of the metric, in which the practical application consists in evaluating ANEEL's tariff cycles as of the second tariff cycle.

In this way, the present article is structured in five sections, the first one being this introduction. The second section deals with the bibliographic review on multicriteria analysis and its different applications. Later, in the third section, the construction of the metric is presented, including the description of the stages of selection of the multicriteria method, definition of the indicators used, determination of their respective weights and application. The fourth section, in turn, refers to the discussion of the results of the evaluation of the tariff revision cycles. Finally, the fifth section presents a brief conclusion with the next steps of the project.

2. MULTICRITERIA ANALYSIS

According to Gomes (2009), the need for answers that encompassed several dimensions for decision making processes began a new theoretical field, the Decision Making Theory (DM). Decision problems are complex in nature because they are surrounded by uncertainties, conflicts of values and interests, asymmetries of power, multiple evaluation criteria and a large volume of data and information that may be incomplete.

To address these difficulties, a number of Decision Support Methodologies (MCDA) and Decision Making - Multiple Criteria Decision Making (MCDM) have been developed. In general, the MCDA and MCDM methods are applied in cases that involve problems of: selection, ranking, classification and decision. Since its inception in the 1960s, multicriteria analyzes have the objective of assisting the decision-making process by considering relevant and necessary aspects of the decision-making process. The analysis of a set of criteria allows a better understanding and contextualization of the problem as a whole, including as much information and contradictions as possible, both quantitatively and qualitatively. In this way, it is sought to reach the most desirable choice possible for the situation in question, by choosing one alternative over others or by ordering the best alternatives.

Multicriteria analyzes are characterized as comparison tools. These are often applied in questions involving: the search for solution of conflicting cases; elaboration of guidelines and operational recommendations; priority setting; and, mainly, the translation of the different opinions on a certain subject in a joint way, without disregarding the specificities of each interested agent.

Decision problems can be characterized by the presence of a finite number of alternatives and judgment criteria. It is possible to denote a DM problem by means of the mathematical representation of matrices. Thus, a decision matrix V: {Vk (a)} is constructed reflecting the viewpoint of DM, where element Vk (a) corresponds to the evaluation of alternative "a" with respect to criterion k. The alternatives are thus ordered according to the criteria and their respective weights. From this structuring, multicriteria methods are applied to the information processing in order to optimize the choice among the alternatives based on the established criteria and their relative weights.

Currently, there is a wide and diverse range of multi-criteria methods. These can be segregated, according to

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different approaches, in: (i) single criterion of synthesis, in which the criteria are then aggregated into a single synthesis criterion; (ii) synthesis subordination, for which a binary relation is used, considering the possibility of dominance of one alternative over the other and (iii) interactive local judgment, where preferences are not predefined, allowing intervention in the procedure and order of the calculation steps and taking into account the discussion and participation of the decision makers in the solution proposal [GOMES 2009]. Gomes and Rangel (2010) also categorize these methods among those developed by the French or European School and those of origin in the American School. The methods of the French School deal with the notion of overcoming relation and adopt a more flexible modeling starting from a constructivist referential. Meanwhile, the methods of the American School are grounded in the rationalist paradigm, in the notion of aggregation of information, and in the Theory of Utility. Other methods still present the techniques of both schools and are known as Hybrid methods.

3. CONSTRUCTION AND APPLICATION OF THE EVALUATION METRIC FOR LOSS REGULATION

The development of an evaluation metric makes it possible to compare different processes from the same reference dimension and can be used as a strategy to measure and monitor the results of a particular process, as well as to evaluate its performance against other comparable options. That said, the choice of multicriteria analysis, as the tool for calculating the effectiveness measure of regulation, is the first step in the development of this metric. To the total, four stages are defined as follows: 1) choose the multicriteria method to be used, 2) define the evaluation criteria, based on the general objectives of the regulation, 3) relate the criteria to indicators capable of quantifying them, 4) define the weights associated with each criterion / indicator. From these steps, the application of the calculations established in the multicriteria analysis results in a "score" relative to the set of rules imposed for each tariff cycle.

At first, a bibliographic review was done to choose the theme. Faced with the very subjectivity of the topic and the strong tendency for conflicting points of view to arise from particular political positions and interests, a Multicriteria Decision-Making (MCDM) method was chosen that could solve problems of ranking in a simple and efficient, considering the presence of quantitative and qualitative indicators. Among the methods indicated for the question raised, the TODIM was selected.

In general, the TODIM method demonstrates the ability to easily align the expectations and preference structures of the actors involved, supporting professionals in decision making, making the selection process fast and accurate [GOMES and LIMA 1992b; GOMES and RANGEL 2009; ZINDANIA et al. 2017]. The literature on the method converges when demonstrating the success of the application of the methodology in ranking problems, as it could also be observed in this study. In addition, the method has simple application and easy understanding of the results, being possible to apply it through known software, such as Microsoft Excel.

Initially developed in 1992, TODIM is a decision-making method that uses decision makers' preference and is based on the Prospect Theory (OPT), as well as on the difference model for multicriteria discrete decision analysis [GOMES and LIMA 1992a]. The method was created with the proposal of modeling the human judgment from the use of ranking models [GOMES and LIMA, 1992]. In addition to the Theory of Prospects, the TODIM method presents theoretical bases of the European and North American School, adding elements of the Theory of the Multiattribute Utility of the AHP and ELECTRE Methods. The TODIM is a non-compensatory method that provides a global ordering of alternatives through the preferences made explicit by a decision-maker or group of decision-makers - crucial elements in this decision-making method. In this way, decision-makers participate directly in the decision-making process, declaring the values of their preference regarding the criteria.

In general, the stages of development of the TODIM method begin with the determination of the weights of the criteria through the construction of a matrix of comparison by pairs of criteria, preserving the transitivity. Consider, for example, a set of n alternatives, which one wishes to order in the presence of m criteria, where one of them is referred to as a reference. The values of each column of the corrected matrix are summed, then the reciprocal of these sums are calculated and divided by the reciprocal sums. After defining the weights, the contribution of an alternative i to the objective associated with the respective criterion c [RANGEL et al, 2013, p.312] is estimated for each of the criteria. Then, the evaluation matrix is elaborated and, after its normalization, the partial desirability matrix is obtained. Complementarily, the partial and final dominance matrices are calculated to finally reach the global values of each alternative.

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The multi-attribute value function of TODIM is constructed in parts, in order to represent the gains and losses observed in the value function of the Prospects Theory, as described in the graph of Figure 1. In this way, equations 1 and 2, extracted from GOMES et al. (2009), provide the expression of the value function of the TODIM method, in which (a) it describes gains, (b) indifference and (c) losses.

$$\delta(A_i, A_j) = \sum_{c=1}^{m} \phi_c(A_i, A_j), \forall (i,j) \quad (1)$$

$$\sum_{c=1}^{m} \phi_c(A_i, A_j) = \begin{cases} \sqrt{\frac{w_{rc}(P_{ic} - P_{jc})}{\sum_{c=1}^{m} w_{rc}}} & se\ (P_{ic} - P_{jc}) > 0, \ (a) \\ 0 & se\ (P_{ic} - P_{jc}) = 0, \ (b) \\ \frac{-1}{\theta}\sqrt{\frac{(\sum_{c=1}^{m} w_{rc})(P_{jc} - P_{ic})}{w_{rc}}} & se\ (P_{ic} - P_{jc}) < 0, \ (c) \end{cases} \quad (2)$$

Where, δ (Ai, Aj) is the measure of dominance of the alternative Ai over Aj; ϕ (Ai, Aj) measures the value of the alternative Ai when compared against the alternative Aj according to criterion c; Wrc is equivalent to wc divided by wr, where r is the criterion of references; Pic and Pjc are the performances of the alternatives Ai and Aj with respect to c; θ is the loss attenuation factor. According to Rangel, et al. (2013), the attenuation factor θ makes it possible to obtain different forms of the value function of the prospect theory in the third quadrant. This factor represents how much the decision maker is willing to consider in evaluations between two alternatives of the decision-making process in which loss occurs. The expression of equation 2 can be simplified in equation 3 which, in turn, is used to calculate the global value of an alternative i through the values found in the dominance matrix. It is these global values that will allow the ordering of the existing alternatives.

$$\frac{\sum_{j=1}^{n} \delta(A_i, A_j) - min \sum_{j=1}^{n} \delta(A_i, A_j)}{max \sum_{j=1}^{n} \delta(A_i, A_j) - min \sum_{j=1}^{n} \delta(A_i, A_j)} \quad (3)$$

The main motivation for the construction of the TODIM method was the creation of a relatively simple analysis tool that used basic concepts of linear algebra. After choosing the method, the criteria were defined. According to Chankong and Haimes (2008), decision problems must be linked to general objectives, which are generally abstract and difficult to operate. The authors further argue that in order to efficiently execute the multicriteria technique, the analysis must comprise a hierarchy of objectives, where, under general objectives, more specific and operational lines of objectives would be included.

As a strategy to support the definition of the general objectives to be considered in ANEEL's assessment of losses regulation, it is considered that the theoretical basis should consider the logic used for the formulation of the principles of governmental action of the sector, defined by the Ministry of Mines and Energy (MME). According to Law 10848 of 2004, the current model of the electricity sector was established according to the following main guidelines: (i) security of supply, (ii) tariff modality, (iii) universalization of access and social inclusion. Currently, the guiding principles of the sector have been discussed in light of the new drivers for restructuring the sector model. In these discussions, the formulation of these principles is based on the macro-objectives of: efficiency of actions (productive, allocative and distributive), equity of decisions and sustainability of the regulatory framework.

From these dimensions, the intermediate objectives, henceforth called criteria, were created, respecting the premise of orthogonality among them. In this way, it was tried to guarantee the independence between the criteria by means of the analysis of the correlation between the concepts of each one, in order to avoid overlapping effects that could come to skew the calculation. Finally, six central criteria were defined to measure the effectiveness of the methodologies adopted in tariff review cycles. These are: i) Criterion 1: Guarantee Modular Fees; ii) Criterion 2: Promote Energy Efficiency; iii) Criterion 3: Guarantee Economic-Financial Sustainability of the market; iv) Criterion 4: Establish regulatory incentives consistent with companies' responsiveness; v) Criterion 5: Establish comprehensive regulatory incentives to the different challenges of the sector; vi) Criterion 6: Ensure quality of information regarding practices in the sector;

In order to operationalize the measurement of the presented criteria, operational indicators were constructed, which in the hierarchy defined at the beginning of this section, work as the subjective ones. It is worth noting that, as argued by Chankong and Haimes (2008), a subobjective can be present in more than one criterion. To meet the six established criteria, eleven indicators were elaborated, which are related to the criteria.

Based on the considerations presented, the 11 indicators were determined, being 8 quantitative, that is, they can be calculated using a set of available and available data, and 3 qualitative, due to the impossibility

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of adding numerical data that could portray them. For this reason, the latter are valued by means of a subjective scale ranging from 1 to 5, in which the value 1 represents a very poor rating and the value 5 represents a very good evaluation. To evaluate the tariff cycles through this scale, a survey was conducted with a sample of industry experts, which included professionals from the regulatory agency and distribution companies. At the end, all the indicators are standardized for the implementation of the multicriteria method.

According to the characteristics and specific purposes of each indicator, ways of calculating them are evaluated. Indicator 1 represents the level of effectiveness of the sector in reducing total losses. In order to measure it, it is necessary to measure the difference between the beginning and the end of the regulatory period, in terms of the ratio of global losses on the injected energy of all companies. Indicator 2 describes the level of feasibility of the targets, measured by the distance of the targets from the actual values of global losses, verified during the regulatory period. To simplify this calculation, a scenario is adopted as a premise in which regulation, in fact, is encouraging all companies to operate efficiently, and with this, the non-achievement of the goals by the companies occurs, exclusively, due to the lack of feasibility of goals. Thus, the construction of this indicator considers the ratio between how much each company reduced global losses at the end of a tariff year and how much they should have reduced to reach their targets in the same tariff year.

In addition, indicator 2 should consider some restrictions intrinsic to its purpose. For a goal to be feasible, the loss reduction must be equal to or greater than the distance to the target, which results in a 100% feasible value (regardless of exceeding the target). Likewise, if a company has already presented an initial value of real losses equal to or lower than the target, it is assumed that this goal is 100% feasible, since the company already reached this goal previously. On the other hand, a target will be totally non-feasible (0% feasible) if it imposes a reduction path for a company that does not present a reduction in the loss ratio.

Following the order of description of indicators, indicator 3 consists of the level of adhesion of companies to the goal of reducing NTP. In other words, this indicator counts the number of companies, in the universe of companies that had PNT reduction targets, that managed to reduce the percentage of NTP in the market, regardless of how much this reduction was. The final value of the indicator for the regulatory cycle is given by the average of this amount of companies between the tariff years of the regulatory period, weighted by the total company of the universe examined in each year.

Indicator 4 describes the level of feasibility of achieving the goals by companies. The formulation of indicator 4 seeks to account for the number of companies that have met the targets imposed by the regulator. This calculation is similar to the one performed for indicator 3, in which the final value of the indicator is given by the average of this amount of companies between the tariff years of the regulatory period, but now, the weighting considers the total market in each year.

Indicator 5 shows the degree of feasibility of the minimum limits of PNT, defined by the regulator for the sector. For this, the number of companies that, within the regulatory period analyzed, reached these values (assumed to be 7.5% for the large group of companies and 2.5% for the small according to the current model). The final value of the indicator is given by the average of this amount of companies between the tariff years of the regulatory period, weighted by the total number of companies in the market each year.

Indicator 6 corresponds to the level of uniformity of the reaction of the companies in response to the incentive established. That is, it seeks to assess whether regulatory incentives are promoting a similar response movement among firms through a measure of dispersion around the mean. For this, the indicator measurement consists in calculating the standard deviation of the sample of companies' performance against the target, measured by the difference between the variation of real losses and the variation required by the target.

Indicator 7 measures the level of financial impact on distributors caused by NTP regulation. Of course, the measurement of this indicator considers the monetary value of the financial frustration given by the NTPs not recognized in the sector for each year of the tariff cycle and weighted by the regulatory EBIT of each company for the respective years. For comparison purposes, minimum and maximum limits for this indicator were established on the basis of the extreme results of 2 CRT.

Closing the quantitative indicators, indicator 8 represents the inverse view to that evaluated by indicator 7. It deals with the level of impact for consumers, through the effects caused on the tariff modality. The calculation of this indicator corresponds to the mean of NTPs recognized in the sector during the regulatory cycle.

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Finally, indicators 9, 10 and 11 were defined as qualitative indicators and, therefore, are measured by the perception of specialists regarding the aspects treated by each indicator. In descriptive terms, the aspects treated by indicator 9 reflect the level of effectiveness of regulation in modeling the socioeconomic context to consider regulatory analyzes based on the complexity of combating losses associated with each concession. Indicator 10 depicts the level of quality of the information used by the regulator based on the visibility of the data and on the ability to satisfactorily segment PT and PNT indices. In order to further analyze the quality of information processed by the regulator, indicator 11 corresponds to a consolidated assessment of the level of accuracy of the regulatory model estimates based on the segmentation capacity of the manageable and unmanageable determinants of losses.

The last stage of construction of the metric consists in the distinction of the importance relative to each criterion and the respective indicators. With this purpose, a workshop was held with the attendance of experts to discuss the theme and assign the weights related to the 11 indicators developed. Among the specialists, professionals from distributors were present, as well as members of the regulatory agency and academic researchers.

The workshop was structured in rounds of discussions, following the approach of the "World Café" method, which allowed to approach the various aspects related to the regulation of the losses and to obtain the contributions of the experts through debates that helped in the understanding of the problem. The method used to determine the relative weights for each criterion was the direct rating, where the invited experts attributed an importance to each criterion in a scale of zero to a hundred. To achieve greater consensus, the questionnaire was applied in two stages. Considering the uniformity of knowledge and competence of the respondents, the final weight for each criterion was obtained by aggregating the weighted average of the evaluations. These weights will be fundamental parameters for the purpose of applying the selected multicriteria method.

As a result of the contributions of the discussions, indicators 10 and 11 (previously presented) originated, which became the set of indicators to be weighed by the experts in the second evaluation round. In this second moment of evaluation, the means of the weights given for each indicator were presented, according to the values obtained in the first round of evaluations.

The results of the debate were positive in generating greater convergence in the opinion of experts. Despite this, there is still a great deal of heterogeneity between expert evaluations, with high standard deviations and large divergences between maximum and minimum values, even after the rounds of discussions. It should be emphasized that Indicator 11, included after the discussions, was the one that presented the greatest relevance on average, reflecting a positive point of the debate for the inclusion of a new variable of great importance. In general, the qualitative indicators presented a greater importance on average, which adds complexity to the analysis.

It is then necessary to transmit the results of the indicators to determine the relevance of the criteria that fit them. Thus, the mean values of the second round will compose the weights associated with the criteria. As a result of these processes the following normalized values of the weights associated to each criterion were obtained: i) Criterion 1 - Guarantee Modular Fees (0.077); ii) Criterion 2: Energy Efficiency (0.076); iii) Criterion 3: Establish consistent regulatory incentives for companies' responsiveness (0.357); iv) Criterion 4: Establish regulatory incentives that cover the entire sector (0.179); v) Criterion 5: Ensure quality of critical information (0.207); vi) Criterion 6 Ensure economic-financial sustainability (0.104). This matrix of normalized weights will support the calculations of the multicriteria analysis, in order to guarantee that the evaluation of the regulatory cycles prioritize the performance in the most relevant criteria. This will enable the final analysis result to be broken down to identify the points at which each regulatory cycle has performed well or poorly.

After its construction, the metric was applied to evaluate the effectiveness of the regulation of losses adopted in each regulatory cycle of ANEEL. In other words, the set of rules and regulations imposed in a given regulatory cycle results in an overall performance of the industry measured by the metrics developed in this paper. That said, the first step consisted in the elaboration of a database containing the necessary variables for the calculation of the quantitative indicators. These were collected based on the Technical Notes of ANEEL regarding the Adjustment and Tariff Review processes. Qualitative information was obtained through questionnaires answered by experts from the sector, in a workshop or via e-mail. Subsequently, the calculation of indicators 1 to 8 was developed in software R. The calculation of indicators 1 to 8. In relation to the qualitative indicators, the evaluation was obtained

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through an opinion survey answered by specialists. As with the determination of weights, there was no judgment on the answers obtained by the specialists, in order to consider them equally competent. With this, the final value of each indicator corresponds to the simple average of the answers.

The evaluation of the grades shows regular or below average results for all the criteria between the different tariff cycles. In addition, it is possible to observe a significant standard deviation in the evaluations and great distances between the maximum and minimum limits. From the measurement of all the indicators, these values are inserted in the TODIM Model calculations for the execution of the multicriteria analysis. The score is defined based on the results of the matrix of final dominance elaborated through the aggregation of partial dominance matrices. Partial dominance matrices are constructed from the relative performance between the Tariff Review Cycles (CRT) for each of the criteria, following equation 2. The final dominance matrices were later normalized according to equation 3, generating the standardized scores between 0 and 1, where 2 CRT presented a 63% result, 61% 3CRT and 72% 4CRT. Therefore, 4CRT was the best ranked, followed by 2CRT. 3CRT was the worst ranked for the criteria adopted. A sensitivity analysis was performed by changing the parameter θ of the multi-attribute value function, without modification in the ordering of the alternatives.

4. RESULTS

In general, regulatory cycles obtained a median evaluation of the effectiveness of regulation. Of course, there is still a lot of room for improvements that will ensure improvement in performance. Based on the application of the metric, it is possible to perform an analysis of the results segregated by the evaluation criteria of the regulation. The performance in each criterion indicates the fragility or adequacy points associated with each regulatory methodology. For this, it is important to identify the causal relationships, according to the evolution of the regulation. However, this exercise is not trivial and the application of the metric only allows initial assumptions about causes of worsening or improvement in assessment between cycles. Evidence of these assumptions is only possible through a thorough study of the cause-effect relationship of regulatory changes, which is beyond the scope of this work, as it should also include analyzes of exogenous factors that may have influenced the results of each regulatory cycle (for example, a crisis economic).

The application of the metric serves to map the aspects to be improved in each tariff process. In general, 4CRT achieved the best performance between cycles, which indicates an evolutionary progress in the effectiveness of the regulation. However, there are criteria where this progression did not occur. Therefore, it is necessary to evaluate the reasons for this worsening in the specific performance, as a way to identify effective improvements for the next tariff cycle. In addition, the historical analysis of the cycles makes it possible to carry out a survey throughout the PNT regulatory model, in which it is sought to identify changes that may explain the performance of each cycle in relation to each criterion. This process may indicate measures that were adequate or that should be avoided for proposing innovations.

The reason for the superior performance of 4CRT in its best comparative result is that it shows a better performance in all indicators, with the exception of indicators 1 (reduction of losses), 2 (degree of feasibility of imposed targets) and 7 (vulnerability companies). On the other hand, the best comparative performance in relation to indicators 11 (ability to estimate manageable and unmanageable losses), 9 (sensitivity to socioeconomic context) and 10 (accuracy of segregation of technical and non-technical losses), in this order of importance, were determinant for this better cycle performance.

It can be observed that poor performance in indicators 1 (reduction of losses), 2 (degree of feasibility of imposed targets) and 7 (financial vulnerability of companies) reflected in a deterioration in the evaluation criteria of 1 - Energy Efficiency, 2 - Sustainability of the Market and 4 - Coherence of Incentives. Therefore, it can be assumed that 4CRT pushed distributors with goals that were not so consistent with company performance, given the result in criterion 4. This may have undermined the financial performance of the industry, as indicated in criterion 2. In contrast, these measures did not result in a loss reduction higher than previous cycles, as demonstrated by the result in criterion 1.

However, it is worth reiterating that this logic of events is about assumptions, which require an in-depth assessment of causal relationships. In fact, externalities to the sector, such as the economic crisis of the last years in the country or the increase of energy acquisition costs in the period of water scarcity, may have affected, to some extent, the quantitative results of the sector performance, regardless of effectiveness of 4CRT regulation. That said, the assumptions mentioned here

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serve only to reflect on possible effects to be considered as points of attention for the proposition of regulatory innovations that guarantee a better regulation performance.

It is worth mentioning that, for the global evaluation, it was defined that the effectiveness of regulation passes through its capacity to be prepared and adjust to these variations in the socioeconomic context. This measure is evaluated by indicator 9 (sensitivity to the socioeconomic context), which was measured qualitatively by a specialist. In addition to indicator 9, indicators 10 (accuracy of segregation of technical and non-technical losses) and 11 (ability to estimate manageable and non-manageable losses) were also measured through a qualitative evaluation, in which the specialists were oriented to respond based only in the strict effects of regulation effectiveness. Therefore, it is considered that, although there are external factors, the final value, consolidating all the criteria, minimizes inaccuracies in the comparison caused by externalities.

By extending the analysis to the other cycles, 3CRT showed the best performance in indicators 1 (reduction of losses), 2 (degree of feasibility of imposed targets), while 2 CRT demonstrated the best performance in the indicator 7 (financial vulnerability of enterprises). Indicator 2 had a significant weight to compose Criterion 4 - Coherence of Incentives, therefore, 3CRT had the best performance in this criterion.

In the comparison between 2CRT and 3CRT, 2CRT performed better in indicators 3 (business reaction to incentive), 5 (evolution of the number of companies within the NTP limits), 7 (financial vulnerability of companies), 9 (sensitivity to socioeconomic context), 11 (ability to estimate manageable and non-manageable losses), related to criteria linked to consistent regulatory incentives, guarantee of economic sustainability of companies, and guarantee of quality information. However, the best performance of 2CRT in relation to indicators 3 (business reaction to incentive), 5 (evolution of the number of companies within the limits of NTP), was not enough to make the criterion of guarantee of consistent regulatory incentives overcomes the relatively better results of 3CRT in relation to indicators 2 (degree of feasibility of imposed targets) and 4 (achievement of targets by companies). The same occurred with regard to the criterion related to the establishment of comprehensive regulatory incentives to the distribution sector. Although 2CRT showed a better relative performance of indicator 9 (sensitivity to socioeconomic context), the good result of 3CRT in indicator 6 (Similarity of reaction to the incentive) made this performance better in this criterion.

In summary, the analysis of the results of the application of the metric developed allows us to suppose that 2CRT brought innovations important for the improvement of the treatment of PNT, which, at first, induced the evaluation relatively good for the cycle. However, the development of this regulatory model for 3CRT did not signal improvement in important aspects, which led to a worse evaluation for this regulatory period. From the failures of 3CRT, 4CRT appears to perform better by just trying to adjust the weaknesses observed in the previous cycle. In fact, it is possible to note the innovations introduced by 3CRT, such as the use of 3 models (C, G, K), the insertion of more variables, the starting point rules and cluster analysis of companies, were later improved in the 4CRT. In addition, ANEEL extended the specific treatment for some companies, with exceptions from the model, which led to a greater adherence of the regulatory goals to the context of each company and a better evaluation of the specialists regarding the scope of regulation.

Therefore, the metric is important to try to identify these adjustments from one cycle to another that made varying grades. With this, it is possible to map the best paths for the development of regulation enhancement propositions. In addition, the individualized analysis of the result of the indicators allows addressing the prioritization of regulatory alternatives, based on the identification of the indicators that are worse scores in the evaluation scale.

5. CONCLUSION

The present study had as main objective the elaboration of a metric able to evaluate the effectiveness of the regulator in the treatment of PNT by cycle of tariff revision. To achieve this, a methodological framework was built consisting of a set of steps that allowed measuring and ranking the performance of ANEEL's tariff cycles, based on 2CRT. It is a critical historical analysis to guide the proposition of innovations, based on a clear, exempt and pre-established evaluation metric.

Due to the complexity of the evaluation, derived from the subjectivity of the concepts involved, the methods of multicriteria analysis were used. Within this area of knowledge, the TODIM model was identified as being appropriate to deal with this challenge due to its vocation to deal with classification problems with qualitative and quantitative criteria and its simplicity. After the selection of the multicriteria method, the criteria / indicators and their respective weights were

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defined through the application of rounds of discussions and the collection of primary data with experts of the sector through questionnaires.

The results of the application of the metric show that the 4CRT presented the methodology of better performance among the other tariff review cycles analyzed (2CRT and 3CRT). This result was obtained thanks to the superior performance of the cycle in 8 of the 11 indicators, being exceeded only in the indicators of reduction of losses, degree of feasibility of imposed targets and financial vulnerability of companies. The observed 3CRT showed a better performance in the first 2 indicators (reduction of losses and feasibility degree of imposed targets), while the 2CRT cycle in the latter (accuracy of segregation of technical and non-technical losses).

In this way, the built metric was efficient in meeting its objective of evaluating the efficiency of the methodologies of tariff revision cycles, allowing to identify the magnitude of the efficiency level, the cycles of better and worse performance and the criteria / indicators that contributed the most with the result found. As a result, the analysis revealed possible improvement points for future cycles, particularly those related to the promotion of loss reduction, the guarantee of the financial health of the distributors and the consistency of the goals imposed. In addition, the weight associated with each criterion denotes the importance of the effectiveness of regulation in ensuring the definition of coherent goals and guaranteeing the use of quality information, which is mainly measured by the accuracy of the model in estimating manageable losses and not manageable, and this is a point of extreme relevance for the proposition of regulatory innovations. It is hoped that, based on the performance of the sector, each regulatory cycle will update the database used and the metrics developed will contribute to further analysis of future revision cycles.

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