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INTERNATIONAL REVIEW OF REGULATORY ASPECTS RELATED TO ELECTRICITY LOSS IN DISTRIBUTION SECTOR

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ABSTRACT

Non-technical losses (NTL) in the Electricity Sector are all the waste of energy that occurs in the electricity distribution grid because of commercial and manageable aspects.. Losses are a problem in many countries, but some have managed to incentivize the distribution companies to combat these losses effectively. Thus, in order to broaden the debate on the topic, this article develops a mapping of different experiences in the regulatory treatment of NTL. A comparison of experiences in 13 countries shows six major innovative approaches: individualized treatment, efficient company model, treatment based on companies' similarity, specific treatment based on companies' individual performance, and specific treatment for areas with high criminality.

Keywords: Non-technical Losses, Economic Regulation, Electricity Distribution

1. INTRODUCTION

The phenomenon of energy loss is intrinsic to any process of transformation and transport of energy. In the electricity sector, the energy distribution segment does not escape this rule. The distribution losses result from the difference between the energy injected into the grid of the distributor and the energy supplied through it.

Loss of electricity in distribution may occur for technical or non-technical reasons. The technical losses (TL) are the portion of the losses caused by physical factors mainly associated with the resistance of the conductors in the distribution cables. Non-technical losses (NTL), the focus of this study, are the remaining losses, caused by measurement problems, clandestine connections in the distribution network and / or meter tampering, and are therefore associated with the commercial management of the distributor [1]

A higher level of electricity losses is reflected in an increased demand for power generation. In terms of NTL, who pays for this additional power generation is an issue that the power sector regulator must deal with, given the fact that part of these losses may not be caused by the distributor's inefficiency. The regulator must thus try to estimate the share of these losses associated with causes that lie outside the control of the distribution companies. Electricity rates incorporate the cost of this portion as a mechanism to allocate it among all consumers [2]. Consequently, one of the negative impacts of losses is the increase in rates for regular consumers.

Due to these negative impacts for the sector, the issue of NTL deserves close attention, in order to identify innovations that may induce the reduction of these losses over time. In the regulatory sphere, the major question regarding loss treatment is the design of incentives that reward distributors for operational and investment decisions that limit or reduce NTL volume and costs in an economically efficient way.

As the continued theft of energy causes a number of negative impacts on society (such as stimulating the waste of energy resources, resulting in losses for concessionaires and for regular consumers, as well as inefficiently raising the growth rate and costs of the electricity system), it is clear that the electricity sector's

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economic regulation must effectively signal fair limits of losses and encourage the reduction of waste in distribution. In this context, this paper aims to investigate different international experiences in the regulatory treatment of NTL, in order to allow a critical analysis of this issue at a global scale that can identify the best international practices and their implications for NTL regulation.

The section that follows introduces the regulatory aspects related to NTL, followed by a discussion of the key lessons from the comparative analysis of 13 cases around the world. The last section concludes.

2. REGULATORY ASPECTS OF NTL

Losses are a problem in many countries. Thus, in order to broaden the debate on the topic, this article maps different experiences in the regulatory treatment of NTL around the world.

With some exceptions, where only TL are considered, most countries include NTL in their regulatory frameworks. In fact, when considering NTL, it becomes clear that there are huge differences in the components that are included in estimates of energy losses. Although our focus is on aspects related to NTL, it is necessary to consider the experiences with treatment of both TL and NTL, since the regulation of some countries considers a joint approach to total losses.

In comparing regulatory approaches across countries, we examined overall levels of losses, the regulatory definition and estimation of losses, and the regulatory practices followed with regard to losses. . From a regulatory perspective, three kinds of practices strongly affect the incentives of distribution companies regarding losses:

i. whether losses are an allowable cost that can be included among the costs of electricity distribution that can be recovered though the rates charged to consumers;
ii. if losses are an allowable cost, the maximum level of losses that can be included in rates;
iii. the rewards or penalties) associated with specific levels of losses.

Through these general practices, in the next section we compare the regulations developed by each, taking into account the specific challenges they face.

3. MAIN INSIGHTS FROM THE INTERNATIONAL ANALYSIS

In this section, we describe the results of the international comparison, organized around the main innovative aspects for the regulatory treatment of losses. The choice of countries was based on the existence of a formal regulatory system, the availability of information about the regulation of losses in a language spoken by the research team, and the diversity of loss levels and country contexts, in order to seek greater variation in approaches and thus greater scope for learning new insights. The 13 countries we analyzed for this study are: Australia, Canada, Chile, Colombia, El Salvador, Guatemala, India, Italy, Panama, Peru, Portugal, Spain, and USA.

3.1 *Individualized treatment in large countries*

Due to its high losses, the Indian case demonstrated a regulatory treatment based on the promotion by the Government of financial resources to reduce losses. These incentives came from distributor assistance programs, such as the UDAY (Ujwal Discom Assurance Yojana) emergency plan and the financing program to projects that combat losses, known as the R-APDRP (Restructured Accelerated Power Development and Reforms Program). In the UDAY, the government assumes 75% of the debts of the distributors that guarantee to reach the level of losses of 15% in the tariff year 2018-2019. In addition to the UDAY, R-APDRP can support companies though the financing of projects to reduce losses. This is possible for the distributors that meet the conditions of maintaining a loss reduction path of 3% per year, for companies with more than 30% of technical and commercial losses, or 1.5% per year, for companies with more than 15% but less than 30% of losses.

Although losses in the electricity sector in India are still at very high levels, they have been on a downward trajectory. However, this process is not uniform among the different Indian states and there is a strong inequality in the indices of losses, which is quite correlated with socio-economic inequality. Regions such as Arunachal Pradesh have technical and commercial loss rates above 75%, while states such as Goa have losses of less than 15%. This high heterogeneity in the socio-economic context presents a widely diverse set of challenges for the operation of energy distributors [3].

Therefore, the regulation of the electric sector in India recognizes the need of specific regulations for each location. In this sense, India establishes a state-segregated regulation model, in order to share the

responsibility for tariff regulation, including the treatment of losses, with state agencies. Indeed, a single, regulatory treatment in India could lead to distortions in service delivery in each region. In other words, it would be quite complex, or even infeasible, to set regulatory goals based on the same metric for such different areas.

This model of sharing the sector's regulatory responsibility with sub-national states is common across all the countries with the greatest territorial extension in our sample. Australia, Canada, and the USA also have different regulatory methodologies in each state in order to treat satisfactorily regions with distinct characteristics. In all these countries, the losses recognized in the tariff are determined by state or regional agencies that have autonomy to define appropriate strategies to the local context. These methodological strategies are based on general guidelines established by a central institution to ensure regulatory harmonization across states [4][5][6].

This type of segregated regulatory model avoids treating different problems in a single methodology at the national level. In addition, this model promotes a closer and more participatory relationship between regulators and their stakeholders. After all, this strategy allows the regulator to know closely the reality of regulated companies and to maintain a more constant interaction between the parties.

3.2 Efficient Company Model and NTL complement

In view of the variation in regulatory approaches across states, in the case studies of Canada, USA and Australia, the experiences analyzed were limited to specific subnational governments—respectively, Ontario, Massachusetts and the NEM states (National Electricity Market in Australia). In all these countries, since the levels of losses are low, the cost-effectiveness of reducing them becomes disadvantageous for companies and the regulator does not prioritize any special treatment for losses. Distributors develop the methodologies used to calculate the losses to be included in the tariffs, after this methodology then needs to be approved by the regulator. These methodologies consist of calculations of TL through power flow models and grid energy balances. Based on the company's historical data, the regulator evaluates the calculations presented and, if the proposed losses are above acceptable levels, the company must explain the reason and present a plan of action to reduce them. The inclusion of the additional cost in the tariff only occurs through the fulfillment of these requirements. This methodology makes it possible to evaluate losses on a case-by-case basis, and to set targets considering the historical data of the companies individually.

Since there is no greater concern about NTL in these countries, the regulator recognizes only at best a residual increase to the value proposed by the distribution company. In the case of Ontario, the regulator criticized the separation of TL and NTL, since existing data leave too much uncertainty in this calculation. However, by increasing the capacity of measurement systems and the complete implementation of smart meters, more accurate measures can make the distinction feasible.

In a similar methodology, companies in Chile, Guatemala and Peru also present proposals for tariff losses to be approved by the regulatory agency. However, a consulting company contracted by the distributor develops the calculation methodologies. The regulator also hires an independent consulting company to perform the calculations and, in the end, the amount recognized in the tariff is composed of a weighting between the results of each consultancy. In general, weighting considers a greater weight for the value found by the regulator, who may choose to accept only this value [7][8][9][10][11].

The calculation methodologies are based on equations for the determination of TL. For NTL, an additional loss percentage is included for the low voltage network, referring to a residual value whose elimination is not economically feasible. The final values are set on the basis of a fictitious model company whose efficient loss value is given as a function of the costs associated with combating the losses. In other words, the regulatory methodology performs a calculation to quantify the cost of actions to combat losses, and the point at which this cost is higher than the cost of loss represents the allowed regulatory ceiling.

This model based on estimation by external consultants was developed in Chile and has been adopted by several countries in Latin America. The differences between its application across countries is basically the maximum percentage allowed for NTL. In addition, the Chilean model also introduces the concept of "typical areas", which allows for differentiation of maximum allowable losses according to the geographic characteristics of areas within the service concession, specifically urban vs rural areas.

3.3 Treatment based on companies with similar characteristics

The concept of “typical areas" has the purpose of clustering the companies according to the difficulties of combating the losses of each locality. Thus, the regulator recognizes that there are differences in complexity of performance between regions and proposes a specific calculation for each group of comparable companies.

In Italy, due to the socioeconomic differences between the more developed North and the poorer South, the regulation of losses also considers a differential treatment for companies according to the reality of each concession area. Differentiation in the regulatory treatment is made through the application of regulatory loss factors for TL (based on the national average) and regulatory loss factors for commercial losses, differentiated by macro zones. In the Italian case, there are only 3 macro zones, North, Center and South, with higher factors in the South [12].

This concept of macro zones is also applied to O&M costs associated with combating losses. As a result, the Italian regulation demonstrates the concern to ensure adequate rules for the reality and context of the different regions. Another interesting regulatory innovation of the Italian case highlights a similar concern, allowing for differentiated TL standard loss factors caused by net flow inversion due to the uneven impact of distributed generation across regions.

3.4 Flexible strategies on rewards or penalties

In Europe, there is also a harmonization of policies for the electricity sector, although each country has the autonomy to define its own regime. The other two European countries in the sample, Portugal and Spain, present different regulatory treatments from Italy, but very similar to each other. These countries do not make a differentiated allowance for NTL, as in Italy. However, there is a specific incentive mechanism for fraud reduction, in which the distributor receives, as an additional revenue in the current year, 20% of the value of reductions in fraud achieved in the year before last, up to a limit of 1.5% of the distributor’s revenue excluding the incentive.

In addition to this incentive to reduce fraud, Spain implements incentive or penalty schemes to improve supply quality and reduce losses. In general, companies are subsidized or penalized in amounts within a percentage range in relation to the distributor's allowed revenue, according to the degree of attainment of goals imposed by the regulator in previous years [13].

In Portugal, this incentive mechanism is applied exclusively for reducing losses, with the loss target determined not as a single value, but as a range of values (deadband), within which allowable revenues do not vary. The parameters that define the intervals of values are reviewed for each tariff period, and may also occur in extraordinary revisions [14]. This ensures that there is flexibility in the goals imposed, as a recognition that there are inconsistencies in setting a single value from estimation methodologies. This was particularly important during the period of economic crisis experienced by the country after 2008, in which there was a significant deterioration of the levels of losses in the country [15].

3.5 Specific treatment based on company performance

Colombia is undergoing a process of restructuring the sec-tor's standards through Resolution CREG 015 of 2018, in order to make the regulation of losses more flexible. Initially, the country had established a reduction trajectory for the annual losses regulatory targets. However, the companies were not able to follow this path. As a result, the government chose to set the value of the company with the lowest losses at the moment for all subsequent years. This measure encouraged some companies to attain levels lower than this fixed value, which allowed them to earn the difference between their actual losses and the target. However, most companies were still above the target [16].

The new proposal of the Colombian regulator (CREG Order 015/2018), which went into effect in 2018, is to determine a national target value and classify the companies into two categories, above or below this value. Companies below the target are said to be "in maintenance of losses" and companies above the set value are referred to as "in reduction of losses”. For companies "in reduction of losses", the regulator recognizes in the tariff the percentage of actual losses related to 2017, which is the starting point for a downward trajectory for the coming years. These companies are required to present loss reduction plans, which must be approved by the regulatory agency for recognition of the associated costs in the tariff. If the company does not succeed in reaching the targets, the compensatory revenue allowed in the plan is suspended and can be canceled [17].

In order to approve the proposed value for the plan, the regulator performs an efficiency analysis based on the development of mathematical models that describe efficient costs. More specifically, the model uses as an input the history of all companies to run an analysis based on neural networks and obtain the loss

trajectories and associated investments. Among the input variables used are historical data on consumption and elasticity of demand, investment per kWh, energy recovered, and network size. Regarding the definition of specific targets for NTL, the Colombian regulation develops a formulation based on parameters of each company related to the kilometers of rural lines and the service of users in "special areas" defined by socioeconomic criteria. However, the incidence of violence, a key issue for the distribution companies in Colombia, does not receive any specific treatment in the regulation of losses in the country.

In short, the regulator creates a form of incentive for companies according to the level of investment they make in the distribution network. In addition, starting from a cutoff level based on a national target, the regulation treats companies differently if they are above or below this reference value. This is an important consideration, as the regulator recognizes that the challenges are quite different and should be considered according to the circumstances of each group of companies.

Companies "in maintenance of losses" are not required to submit loss reduction plans and are recognized for the loss maintenance costs at verified levels. For some companies, the allowed loss level was reduced because they were well below the national target.

3.6 Specific treatment for areas with high criminality

The only country among those surveyed that performs a specific approach to violence is Panamá. The definition of regulatory goals for losses in Panamá uses a formulation obtained by regression models based on an international benchmarking methodology, with US companies selected through the Efficiency Frontier Analysis model. Since the country has few distribution companies, the use of international companies is a valid alternative to apply the benchmark model [18].

The application of this methodology is not affected by the actual losses of the companies with the objective of establishing a goal that induces companies to achieve a more adequate level of efficiency in their operations. However, when using American companies, the reality faced by such companies is quite different from that found in Panamá. In fact, US companies operate in areas with better socioeconomic conditions, greater income development, and lower rates of violence, so the regulation of the sector would be making a very simplified calculation in view of the complexity of the companies' performance.

Based on this argument, the regulator started to allow an additional percentage to the value estimated by the model, referring to the existence of areas of operational restrictions, called "red zones". These zones are defined according to several criteria, such as a tendency to steal energy and vandalism, high dangerousness, impediment of access to field crews, need for police support to carry out network inspections, high crime levels, and other public safety indicators. In order to obtain the extraordinary recognition of the regulator, the distributors must prove the existence of restrictions to operation in these zones by means of network mapping, detailed losses measurements, georeferenced surveys of critical events, and evidence of extra costs to combat losses related to insecurity [19].

El Salvador is often at the top of international indicators of criminal violence. Yet even with the growth of losses in recent years, the country's energy theft rates are still relatively low, resulting in a still incipient NTL regulation [20]. Despite unfavorable socio-economic conditions, there appears to be a culture of not stealing energy. Some factors may explain this situation: rate subsidies, the small size of the country, rigid supervision, and a strong policy of penalizing fraudsters, allied with the support of the judiciary in favor of punishment of fraudsters and the speed of prosecution.

4. CONCLUSION

The topic of losses assumes special relevance in a context of global concern with the reduction of resource consumption. NTL of electricity are all the wastes of energy that occur in the electricity distribution related to commercial aspects. The determinants of these losses are strongly associated with socioeconomic factors that are unmanageable by the distributors.

In order to incentivize concessionaires to have a good performance in combating these losses, regulatory practice often imposes specific targets issue. Not surprisingly, the association of NTL with socioeconomic issues means that there is wide variation across countries and even within some countries in the level of NTL. As a result, regulatory treatments are also quite different.

In view of this variation, this paper proposed to broaden debate on the topic by mapping different experiences around the world. The objective was to examine different international experiences in the regulatory treatment of NTL, in order to carry out a

critical analysis of the topic at a global level and to identify the best international practices and their implications for NTL regulation. For this purpose, the article considered the experiences of 13 countries, discussing the main innovative aspects for the regulatory treatment of losses.

The analysis distilled many regulatory mechanisms into six innovative aspects for the regulation of losses. These aspects are: individualized treatment, efficient company model, treatment based on companies' similarity, specific treatment based on companies' individual performance, and specific treatment for a areas with high criminality.

Large countries tend to adopt individualized mechanisms by concession area or by subnational region. In these countries, regional or subnational agencies determine the losses recognized in the tariff and have autonomy to define appropriate strategies considering the local context. These methodological strategies are based on general guidelines established by a central institution to ensure regulatory consistency across states.

Another important approach is the use of efficient company models. This mechanism allows companies to calculate their own allowed losses in the tariff subject to approval by the regulator. In some cases, regulation adopts clustering strategies for companies or areas within the concessions, in an effort to promote a comparison between similar contexts.

In addition to these treatments, the paper highlighted the differentiated treatment strategy according to specific company performance. For this purpose, the agency defines a cutoff level based on a national target and treats companies differently if they are above or below this reference value.

For innovative aspects that introduce flexibility mechanisms of model estimates, the article highlighted the elaboration of a loss level deadband rather than a specific point level. Another mechanism that makes compliance more flexible is the recognition of the incidence of criminal violence on NTL, resulting in the allowance of losses to deal with crime-related factors that place NTL outside the control of distribution companies.

Therefore, all these innovations together represent robust measures to improve the regulatory framework for the treatment of non-technical losses in the distribution of electricity.

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