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A comprehensive analysis of the Demand Response Program proposed in Brazil based on the Tariff Flags mechanism

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ABSTRACT

The Brazilian Electricity Regulatory Agency (ANEEL) presented a proposal to revise the tariff structure of distribution companies in Brazil. One of the main approved suggestions was to establish a mechanism called Tariff Flags, which aims to foster a Demand Response Program in Brazil via an increase in the energy tariff.

In this work, the proposed mechanism is reviewed in detail and the expected results of its application are simulated and analyzed under different perspectives. This paper shows that the system operation directly impacts the Demand Response Program, since the spot prices will define which Tariff Flag should be triggered. In order to encompass and assess the main consequences of its application, this paper presents the expected effects on energy spot prices, system operating costs, probability of triggering each flag, investment recovery for utilities and finally, the impact for the final consumers. The case studies presented in this paper were developed using real information about the Brazilian electrical system for each economic sector and the price-demand elasticity is discussed using the literature for this application. Finally, some conclusions and guidelines are provided to improve the application of the mechanism.

1. Introduction

Energy tariffs are the unitary cost of energy, which represents the energy price that consumers will be charged by utility distribution companies for the energy consumed. The challenge of designing Bulk Supply Tariffs (BSTs) consists of creating a model that sets different prices for consumers to influence their energy consumption pattern. This approach, ultimately, would (i) improve the grid utilization, (ii) reduce the operating costs and (iii) postpone investments in generation and transmission capacity. To achieve this goal, a Demand Response Program (DRP) can be applied.

The Brazilian DRP was implemented in early 2015. The new program, called Tariff Flags, is coming to fulfill an old requirement of the electricity sector, since the current rules has not been updated for quite some time and the captive market was blind to the current power generation costs. In this sense, the objective of this paper is to analyze in details the effect of Tariff Flags on the entire system and its economic effect on distribution companies and consumers, taking into account the price elasticity of demand (PED) of the consumers.

The system regulator can apply the DRP to curtail or shift loads instead of building more generation and/or transmission lines. According to Refs. [1,2], the DRP can be implemented in two different ways, the first based on an incentive mechanism and the second based on a price mechanism.

The incentive-based mechanism can be made through the Direct Load Control (DLC), Interruptible Curtailable Service (ICS), Emergency Demand Response Program (EDRP), Demand-Side Bidding (DSB), Capacity Market Programs (CAP) and/or Ancillary Services Market Programs (ASMP).

The DLC is a service usually offered to residential customers in which the system operator remotely shuts down or cycles a consumer's electrical equipment (e.g., air conditioner, water heater, etc.) to reduce the consumption during certain time of day or the peak demand time. To encourage the costumers to reduce their consumption, a tariff discount or a bill credit is offered. A similar incentive is applied through the ICS for larger customers (industrial or commercial) who agree to reduce their consumption during system contingencies.

Through the EDRP application, the distribution company pays eligible business customers to temporarily cut back energy use during power shortages or other emergencies. Through the DSB mechanism, the customers offer bids to curtail their loads to the distribution company based on wholesale electricity market prices. A bid will be accepted if its value is smaller than the market price.

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When the bid is accepted, the customer must curtail the load by the amount specified in the bid, or penalties will be faced. This program is usually offered to large customers.

According to Ref. [2], in the CAP, customers commit to pre-specified load reductions when system contingencies arise and are subject to penalties if they do not curtail their use when requested. This mechanism can be seen as a form of insurance. Finally, in the ASMP, the customers bid load curtailments to the ISO (Independent System Operator) as operating reserves. If their bids are accepted, they receive to the market price for committing themselves to be on standby, i.e., if load curtailments are required, they are called by the ISO and will be paid based on the spot energy market price.

Price-based mechanisms can also be an alternative for promoting the consumption optimization of the demand. The price-based mechanism uses the tariff system to incentivize the customers to change their consumption pattern to improve utilization of the system resources. Although it takes time to recruit customers for a DRP, a well-structured pricing and incentive-based DRP can produce significant savings close to real time, often at lower costs than supply-side resources [1]. According to Refs. [3,2], the DRP based on a Price-Based Program (PBP) may present different approaches: Time of Use (TOU) [4], Critical Peak Price (CPP) [5] and Real Time Pricing (RTP) [6].

The TOU mechanism defines the energy price ex-ante for each period. The period can be hours (peak and off-peak) in a day, days in a month (weekdays and weekend) or even different seasons in a year. The CPP scheme establishes that during a critical period, usually related to extreme weather conditions, a higher price is set for consumers. Finally, the RTP mechanism defines that the tariff should reflect the real-time system conditions, i.e., the economic signals provided to the market should consider the balance between supply and demand for each time period.

The DRP has been explored in other publications. In Ref. [7], a DRP is analyzed considering the impact of an Advanced Metering Infrastructure to encourage consumers to reduce their consumption on peak hours. In Ref. [8] the authors presented how to incorporate the benefits of distributed Photovoltaics in the tariff of residential customers in California. The results were compared to the tariff applied by the distribution company. The Time-of-Use (TOU) tariff was studied in Ref. [9] in the context of high penetration of Electric Vehicles. The authors presented recommendations in terms of policy and regulations as well as the TOU mechanism and smart meter deployment. In Ref. [10] the authors addressed the impact of Renewable Energy Penetration in DRP. To accommodate the renewable energy intermittency, they proposed: (i) a change in the regulatory framework of the electricity market in order to enhance the DRP; and (ii) the use of AMI systems. In Ref. [11], a DRP was analyzed in the non-domestic sector of UK. According to the authors, these analyses pointed that the demand response measures tend to incentivize stand-by generation capacity rather than load shifting. Additionally, in Ref. [12], a review of DRP costs and benefits is presented for the electricity market of UK, pointing out the benefits of the program. A perception of the residential costumer was studied in Ref. [13] and their findings showed that the households as a whole have a fairly high opinion about the demand-based tariff and react based on the energy price change by decreasing their peak demand and shifting electricity use from peak to off-peak period.

In this paper, a new mechanism called Tariff Flags is analyzed and explained in detail. The mechanism has been proposed in Brazil and started to be implemented in 2015. The objective of this paper is to analyze the effect of Tariff Flags on the entire system and its economic effect on distribution companies and consumers, taking into account the utilities' contract portfolio and the price elasticity of demand (PED) of the consumers. The paper is organized as follows: Section 2 presents the Tariff Flag mechanism proposed in Brazil and the assumptions considered to simulate the Tariff Flags' impact. Section 3 presents the discussion of these simulations and the results. Finally, conclusions and recommendations for DRP improvements are presented in Section 4.

Table 1
Brazilian electricity matrix [29].

	2014		2023	
	MW	%	MW	%
Renewable sources	110,335	83.20%	164,135	83.80%
Hydro	88,661	66.90%	116,894	59.70%
Wind	5452	4.10%	22,438	11.50%
Others (Small Hydro, Biomass and Solar)	16,222	12.20%	24,082	12.30%
Conventional sources	22,224	16.80%	31,748	16.20%
Total	132,559	100%	195,883	100%

2. Methods

Brazil has large and varied energy resources, particularly hydro, which represents a 67% of the installed capacity and the remainder part coming from thermal plants and others. Table 1 summarizes the aforementioned:

As the Brazilian system is basically hydrothermal and the short-term operation is centrally coordinated by Independent System Operator, the minimal cost dispatch model is used to define the generation of Hydro and conventional sources. The other sources (Small Hydro, Biomass and Solar) are not centrally dispatched. A byproduct of this model is the operational marginal cost, which defines the Energy Spot Price. As it can be seen in the results, the Energy Spot Price defines the triggering of the Tariff Flags and, as a conclusion, the renewable energy plays an important role in the application of the DRP.

Currently, a different pricing mechanism has been applied for high voltage consumers, i.e., those that are connected at 2.3 kV or higher. The mechanism is based on the TOU, and it is known as the Hour-Seasonal Tariff. It was established in the late 1980s. The energy tariff, defined to be used either in the dry season (from May to November) or in the wet season (from December to April) was designed based on simulation studies of the Brazilian Electricity System and takes into account the effect of the demand increase on the short run marginal costs (*CMO*) for each month of the year.

The average *CMO* for these two seasons resulted in a fixed tariff rate for dry and wet seasons used until today, where current dry season tariffs are 12% more expensive than the wet season tariffs. Because hydroelectric power plants supply mostly the Brazilian Electricity System, this value (12%) represents the expectation of the water usage benefits to generate electricity.

A public hearing (#120/2010) [14] proposed by *ANEEL* was held to analyze the *CMO* historical behavior since May 2003 and to assess if there was a relationship between it and the tariff signal introduced by the fixed rate within the different seasons of the year. *ANEEL* concluded: "The *CMO* does not show a standard pattern in dry and wet seasons. Consequently, the tariff signal applied today does not represent the expectation of the water usage benefits flagged by the *CMO* price."

ANEEL argues that the contracts between distribution companies and generators do not have different prices for the aforementioned seasons because the price of the energy contract was set in an auction.[1] Furthermore, although the energy tariff for

[1] In Brazil, the energy contracts between generators and utilities are settled by auctions. The type of energy contract is defined before the auction, and it can be in quantity, in which the delivery energy obligation is of the generator, or availability,