Renewable and Sustainable Energy Reviews 117 (2020) 109468

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: http://www.elsevier.com/locate/rser

New commercial arrangements and business models in electricity distribution systems: The case of Brazil

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ARTICLE INFO

Keywords:
Aggregators
Business models
Demand response
Distributed generation
Intelligent buildings
Microgrids
Storage systems
Virtual power plants (VPP)

ABSTRACT

The purpose of this article is to explore some business models suitable for medium- and low-voltage electricity consumers and analyze the risks and opportunities associated with the diffusion of distributed generation. The approach considers demand response mechanisms that contribute to mitigating commercial risks and overcoming the operational challenges arising from large-scale integration of distributed generation. In particular, the study assesses new application opportunities for distributed generation of renewable energy and examines related measures to mitigate possible market risks associated with the intermittency characteristics of this type of sources. This research has a global perspective but focuses on the case of Brazil. The article proposes four business models to address the issues of small consumers (residential and commercial) as part of the demand response program established in the country. Two of these models are found adequate to reflect the current electricity market, but the existing regulations may require some modifications before the other two could be applied. However, these latter models can be applied to more mature markets. Moreover, the article describes a demand response pilot program that is already in operation, which could serve as a platform to preprocess the proposed business models.

1. Introduction

The electricity sector around the world is undergoing a process of transformation driven by the growth of distributed energy resources (DER), such as distributed generation (DG) from solar or wind power, electric vehicles (EV), and electrical storage systems (ESS).

Microgrid (MG) schemes are electricity distribution systems that contain loads and distributed energy resources. These facilities can be run on an islanded operation mode or a grid-connected mode in a low-voltage (LV) or medium-voltage (MV) network, thus increasing the energy management capability, energy use efficiency, and system resilience [1–3]. A comprehensive review of microgrids and virtual power plants (VPPs) can be found in Ref. [4]. In addition, a stochastic profit-based scheduling of industrial VPPs using the best demand response strategy is presented in Ref. [5]. Some incentive mechanisms such as net metering and feed-in tariff (FiT) [6] have allowed DER connected to local power supply networks (both electrical and thermal) to be installed near buildings or homes. In this context, some types of wind generators, called urban rooftop wind turbines, can be installed at the top of some buildings [7,8]. These wind turbines exploit the frequent strong winds at the top of buildings, and do not need large towers to support them [9–11].

Currently, the building sector as a whole accounts for approximately 30% of the final energy consumption and more than 55% of the global electricity demand [12]. The progressive implementation of DER in buildings can be seen as a good opportunity to turn these consumer facilities into prosumers [13].

On the other hand, the introduction of DG into the distribution system may significantly affect the energy flow and voltage at the substations of distribution companies. These impacts can be positive or negative, depending on the operational characteristics of the distribution system and the characteristics of the DG [14]. Power production from renewable energy sources (RES) is intermittent and difficult to forecast, presenting serious challenges for the system operators [15,16].

Therefore, some regulatory agencies are increasingly considering the

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https://doi.org/10.1016/j.rser.2019.109468
Received 20 March 2019; Received in revised form 16 September 2019; Accepted 3 October 2019
Available online 22 October 2019
1364-0321/

Abbreviations

ADR	Automatic Demand Response
ANEEL	National Electric Energy Agency
BIS	Brazilian Interconnected System
BRP	Balancing Responsible Party
BSP	Balancing Service Provider
CCEE	Electric Energy Commercialization Chamber
CPP	Critical Peak Pricing
DER	Distributed Energy Source
DG	Distributed Generation
DLC	Direct Load Control
DR	Demand Response
DRM	Demand Response Mechanism
DRP	Demand Response Program
DSR	Demand Side Response
ESS	Electrical Storage Systems
EVs	Electric Vehicles
FRE	Free Contracting Environment
IPP	Independent Power Producer
LV	Low Voltage
MV	Medium Voltage
ONS	National Electric System Operator
RES	Renewable Energy Sources
RHS	Renewable Hybrid System
RTO	Regional Transmission Operator
RTP	Real-Time Pricing
SCEE	Electric Energy Compensation System
SEDC	Smart Energy Demand Coalition
SISO	Supply of Isolated Systems
SRMC	Short Run Marginal Cost
TOU	Time Of Use

application of load flexibility policies, also known as demand response (DR), to improve system coordination. DR can be defined as the change in energy use by the end consumers, who modify their normal consumption patterns in response to energy prices [17,18].

Together with the DR resource, new models such as the establishment of market aggregators, virtual power plants (VPP) and other system resources are currently being explored to alleviate the constant increase in system demand.

For example [19], presents an empirical analysis of the most common business models for the deployment of distributed energy resources. Although this article constitutes a milestone for the exploration of business models, it does not address the problem from the viewpoint of the DER regulatory framework.

Some possible business models that demand-side management providers can adopt for different electricity market stakeholders are discussed in Refs. [20,21]. Reference [22] proposes four business models for building participation in aggregated Nordic markets through flexible loads and DERs.

A business model for DR under three economical dispatch modes in regulated power markets is presented in Ref. [23]. An analytical framework to assess the consumer potential and willingness to participate in active DR from a contract perspective is provided in Ref. [24]. It also presents some policy recommendations to empower and protect consumers as they shift to active DR.

The Demand Response eXchange (DRX) concept is proposed in Ref. [25]. The DR is considered as a virtual resource allowing exchange between two groups of players. One is the DR user group (i.e., those who need DR to improve the reliability of their related business and systems, for example, market operators, transmission system operators, distributors, and retailers), and the other is the DR supplier group (i.e., those capable of negotiating DR with the users, for example, aggregators and consumers), thus, establishing a bilateral business model and a pool-based business model (with the system operator as participant).

In most developed countries, the implementation of DR is progressing very rapidly In the case of Brazil, there has recently been an advance in the regulation of DR through a specific Normative Resolution of the National Electric Energy Agency (ANEEL), which establishes the criteria and conditions for implementing a demand response pilot program [26].

In light of these changes, this article examines alternative business arrangements for the electric power distribution segment (exploring new business opportunities and mitigating the risks from the emerging technologies) with emphasis on programs to promote the demand response and the diffusion of distributed generation. Furthermore, the increasing emergence of LV solar consumers in the Brazilian market and worldwide presages a significant growth in the short term for VPPs and solar & wind generation devices located in smart condominiums. Hence the importance of stepping up the establishment of business models for the power industry.

2. Demand response programs (DRPs)

In recent years, DR has played an important role in several electricity markets worldwide. Demand response has been significantly present in the sector to satisfy electricity demand and comply with quality, reliability, and environmental sustainability requirements, allowing the consumer to more actively engage in the market and participate in the integration of wholesale and retail price signals. As with DG, demand management plays an important role in improving the performance of the distribution system, helping to reduce peak demand (also known as peak shaving) and, consequently, contributing to the reduction of spinning reserve (SR) requirements.

According to Refs. [27,28], a DRP has six objectives: reduce peak demand, fill low consumption valleys, shift maximum demand, create a flexible load curve, and increase or decrease total consumption.

Demand response is applied in different ways throughout the world [29], with industrial electricity users being the main providers of flexibility on the demand side [30], wherein optimum models of industrial load scheduling are presented. The US is one of the top investors in DRPs [31]. Other regions showing substantial growth are Australia [32], New Zealand [33], South Korea [34], China [35], and Japan [36]. A specific study on the demand-side response in the UK is presented in Ref. [37].

In the US, the interest in DRP increased in the early 1970s due to the high demand peaks resulting from the diffusion of air-conditioning systems. DR programs have been implemented mainly through direct load control (DLC) methods, which allow the utility to remotely control the operation of certain devices [38]. The DLC is based on an agreement between the distributor and the consumer. The latter receives a credit in the electricity bill in terms of US$/kW/month or US$/kW*hour [39].

In recent years, DR has mainly addressed wholesale markets, accounting for much of the reduction in non-residential loads. A study carried out in the US in 2014, focused on the savings obtained with DRPs, has shown that although residential customers constituted the majority of participants in these programs, the industrial sector contributed with more than half of peak demand savings [40]. However, this scenario will expectedly change with the diffusion of these programs among residential customers and their participation, especially in price-based programs, which can potentially lead to significant reduction in peak demand.

In Europe, policy makers have shown strong support for demand response [31]. This is reflected in several existing legislative texts, such as The Electricity Directive 2009/72/EC and The Energy Efficiency Directive (EED) 2012/27/EU [41]. According to the European Energy

Commission [42], the European DR potential should reach 160 GW in 2030, from 100 GW in 2016. The residential sector is expected to increase its participation as part of this growth scenario.

Despite the existence of a legal framework that allows the use of DR, most consumers do not have the means to trade directly into the energy market because they are too small to manage the complexity of such a legal process, thus requiring the service of an aggregator to help them in this task [43]. According to a survey by the Smart Energy Demand Coalition (SEDC), France, Ireland, the United Kingdom, Belgium, Switzerland, and Finland are the countries with active demand response programs (Table 1).

2.1. Qualification of demand response programs

DR programs are considered important elements for reliable and economical transmission operations for the wholesale power market [44]. DRPs reduce energy costs, provide ancillary services [45], and help to increase system reliability [46].

Currently, there are several ways to classify DRPs, depending on the stated objectives [47], the type of market [48], and the type of resource [49]. According to the traditional classification, DRP can be implemented in two different ways: Incentive-based demand response and price-based demand response [50,51].

Price-based programs are directed to lower consumer demand through price signals. In incentive-based demand response, a fixed or time-varying incentive payment is offered to consumers to diminish their load.

Moreover, in price-based programs, consumers are directly informed of the changes in the electricity market price so that they pay different electricity prices along the day. To participate in price-based programs, consumers can opt for a tariff with hourly differentiation and reduce the total amount of the electricity bill by shifting consumption to more attractive tariff hours (lower $/kWh). The applied tariffs differ by time (i.e., according to the hours of day, days of week, and months of year), the number of components (i.e., demand price, consumer price, or price as a function of consumer classes), and type of membership (voluntarily or mandatory) [27,28]. Some authors classify this mode of DRP as market-led, stating that the user responds directly to market prices, which can vary in real-time pricing (RTP), time-of-use (TOU) pricing, and critical peak pricing (CPP) [52]. According to Ref. [53], the TOU mechanism is considered the simplest to apply. The authors suggest that DR programs start with this type of mechanism until the user becomes familiar with the DRP and then migrate to more complex programs (RTP). This situation results from the fact that more complex tariffs can produce a phenomenon called "response fatigue" in customers. This behavior was evidenced in Salt Lake City (Utah) and Puget Sound (Washington), where approximately 98% of customers returned to the TOU tariff [54,55].

Table 1
Current status of the demand response activity in Europe [43].

Country	Commercially active	Partial opening	Preliminary development	Closed
Austria		✓		
Belgium	✓			
Denmark		✓		
Estonia				✓
Finland	✓			
France	✓			
Germany		✓		
Great Britain	✓			
Ireland	✓			
Italy			✓	
Netherlands		✓		
Norway		✓		
Poland			✓	
Portugal				✓
Slovenia			✓	
Spain				✓
Sweden		✓		
Switzerland	✓			

Incentive-based programs are more easily accepted by consumers because no punishments are involved [56]. Programs of this type include schemes such as direct load control, interruptible/curtailable service, demand bidding or buyback, and emergency demand response program. An incentive-based DR program has three key components: (1) a baseline, (2) a payment scheme, and (3) terms and conditions (such as penalties). According to Ref. [57], the baseline is defined as an estimation of the energy usage that would have been consumed by demand in the absence of DR. This quantity is often based on the average historical consumption of a consumer or a customer group on days that are similar to the forthcoming DR event. Therefore, a counterfactual model is developed to estimate the customer baseline [57].

2.2. Demand-side response (DSR) aggregator

The aggregator can be defined as an agent that directly or indirectly groups the services of the distributed energy resources to be offered in several markets (i.e., retailer or wholesale), including a service offered directly to the system operator. By performing this aggregation, this agent allows the distributed energy resources to scale and be able to compete in the market with less risk [58]. Considering that an aggregator should have different types of energy resources in its portfolio, it becomes possible to manage risk and explore complementarities (portfolio effect) [59].

According to Ref. [60], aggregators of DR programs are also referred to as "curtailment service providers" in the U.S. and are relatively well established within the marketplace. In Europe, they are called "independent aggregators." An independent aggregator is an agent that is not affiliated with a marketer or any other market participant. They are new market players who take on the role of a balancing service provider. By contracting an independent aggregator, the end-user signs a separate contract with the energy supplier (marketer) and another with the aggregator.

2.3. Demand response program in Brazil

Currently, the regulatory framework in Brazil is being adapted to include DR mechanisms. Brazil has used DR instruments through regulated prices varying as a function of the hour of the day and the season of the year (dry or wet period). It is a kind of TOU tariff [61], but the tariff value for each hour/period is adjusted by the regulator only once a year.

According to Ref. [62], this tariff structure encompasses the hourly signaling (peak and off-peak time) and, as stated above, seasonal signaling (wet and dry periods) tariff, and is applied to medium- and high-voltage consumers. It was designed based on simulation studies of the Brazilian Electricity System, and the effect of a demand increase on the short-run marginal costs (SRMC) was considered for each month of the year [61]. Recently, the so-called white tariff, a measure derived from the TOU tariff, was implemented to enable consumers connected to low-voltage distribution networks (retailers) to manage consumption themselves, thus contributing to the efficient use of the distribution network, specifically, by reducing the system load at peak times [63]. This involved the establishment of three tariff levels: peak, intermediate, and off-peak. For the feasibility of the new tariff structure, the currently used conventional meters need to be replaced by electronic measurement systems that provide detailed consumption information [64]. According to Ref. [65], however, migration to the white tariff would not result in immediate systemic improvements as many consumers would benefit without investing any effort or changing their energy use habits.

2.4. Brazilian demand response pilot program

Demand response regulation in Brazil improved with the Normative Regulatory Resolution of December 2017, which established the criteria and conditions for a Demand Response Pilot Program. The program aims to reduce the consumption of previously authorized consumer agents as an alternative to thermoelectric dispatch outside the order of merit [26]—a thermal dispatch focusing on system security, and therefore disregarding the economic dispatch indicated by the optimization models.

The initial proposal, which is under discussion, envisages the use of two products to encourage consumption reduction, one for the current day (intra-day) and another for the next day (day ahead). Therefore, the National Electric System Operator (ONS) and the agents will evaluate both demand reduction and complementary thermal generation based on the short-term marginal cost of generation and determine which is more advantageous to balance generation with the predicted load.

Consumers propose the amount of reduction and the desired price for this reduction. The ONS in turn identifies, through a load reduction auction, the agents that should effectively reduce their demand and be compensated for doing so to maximize the efficient and economical use of the energy resources available in the Brazilian Interconnected System (BIS).

Moreover, the DRP was developed, in the light of some implementation aspects, with the participation of various agents according to a Brazilian model illustrated in Fig. 1. Distribution companies find elements to look for new business opportunities in this scenario with demand response and load aggregators [66].

The aggregator participating in the pilot project must be an agent of the Electric Energy Trading Chamber (CCEE) [67] operating in a free contracting environment (FCE).

Fig. 2(a)–(c) present some examples of an aggregator's performance in a DRP implemented by the National Electric Energy Agency (ANEEL) [67].

Any eligible load will be represented only by an aggregator with no quantity or power limit. The input/output of loads in an aggregator can occur within deadlines that must be set by CCEE/ONS.

3. New requirements and challenges stemming from the application of intermittent renewable sources

Several agents are emerging worldwide who focus on new business models to promote DER and services that go beyond meters.

The analysis of these business models reinforces the importance of adequately structuring the electrical industry to create an environment in which different business models vie with each other to provide a range of services desired by the markets, electric companies, and consumers.

New business models are initially necessary to provide a panoramic view of the new electric sector environment, which is being consolidated and driven by rapid technological evolution (e.g., the smart grid technology) in the context of large-scale diffusion of distributed generation; primarily based on non-dispatchable intermittent renewable energy sources.

3.1. Evolutionary cycle for the participation of renewable energy sources in the energy matrix

If the energy matrix of a country has a large RES participation, it progresses through the following evolutionary stages toward meeting its energy demand:

Stage 1: With less than 10% of the energy supply (niche) from RES, there is generally no need for *fundamental* adaptations as the existing network has the capacity to accommodate the additional installed capacity.

Stage 2: With 10%–40% of the energy supply, RESs become important players in the market.

Stage 3: With more than 40% of the energy supply, RES become the dominant market players.

3.2. Challenges to Be faced

The impact of increasing the participation of RES in energy supply translates into multiple challenges for the system operation, among which the following stand out:

- Substantial increase in volatility in energy production;
- Increased uncertainties and operational risks;
- Reduction of dispatch from conventional sources[1];
- Significant participation as DG in distribution networks;
- More dependency on long-distance transmission (EHV/UHV)[2];
- More intense and volatile power flows in T&D networks[3];
- Network expansion with short-term vision[4];
- Restricted offer of ancillary services by RES.

Uncertainties and fluctuations in renewable energy as opposed to conventional power generation may pose serious challenges to system operators. The unpredictability of renewable energy generation can lead to instability in energy systems and imbalance in the supply-demand equation. To provide a more flexible power system and to address the operational complexity of modern power systems, three key solution classifications are proposed for power system operators [68]:

- Integration of renewable energy with energy storage systems (ESSs).
- Use of additional reserve in electricity markets and development of market rules and structures.
- Use of demand with flexible consumption.

The valuation of distributed services depends on the investment requirements of wire (cable) services and the operational costs, whose quantification requires methodologies and models adjusted to the emerging characteristics of the system.

Moreover, to stimulate and adapt the demand response from the viewpoint of economic regulation and signaling, policy makers should correct some cost distortions in using distribution networks (wire services), caused by.

- Discrepancy between regulatory peak-time and actual peak-time;
- Excessive price at peak times[5];
- Monomial tariff.[6]

The impact of DG on distribution network loading, in response to adequate signals, can be observed in Fig. 3. Storage systems can respond to peak and off-peak periods at an hourly basis. DG systems can bring down the peak demand approximately between 11:00 and 16:00 h. Another issue to be highlighted is that the peak load in physical terms has moved to the afternoon time, at least at present, while the regulatory peak (i.e., in terms of the tariff's economic signal) has not changed from night-time.

Resources for renewable energy generation have increased significantly in the last decades, causing a dramatic loss of participation of conventional generation compared to wind and solar generation, whose intermittent nature makes the generation of these sources practically

[1] RES systems generally have priority in dispatch.
[2] Depending on the distance between generation and load locations.
[3] Increases the risk of supply insecurity.
[4] Due to the short maturation period of RES.
[5] Distortion of the load curve.
[6] Distortion of incentives: does not consider load profile and applies net metering to the wire service.

Fig. 1. Demand response model [66].

unpredictable, thus, representing serious challenges to system operators.

On the other hand, the effects of wind and irradiation fluctuations can be mitigated through the integration of solar and wind DG to DRP, which has led policy makers, system operators, and investors to evaluate the advantages and challenges of DR schemes in line with the proposed objective of new business models in distribution.

4. Proposed DR schemes for business models

4.1. DR scheme for solar or wind DG

For small consumers (residential and commercial) in the electricity sector, the so-called solar roofs and wind microgeneration represent a profitable investment opportunity. This business model has been growing in the Brazilian energy distribution sector. It is characterized by the implementation of the so-called solar or wind condominiums. The commercial management of this model is described as follows:

- Tenant: rents a lot from the generating unit, paying a fixed price per lot (power rent); in return, the tenant receives the energy produced (seasonal). The energy injected into the grid is added to the billing of the Electric Energy Compensation System (SCEE), based on the "net-metering" concept.
- Entrepreneur: rents a lot from the generating unit; receives a fixed monthly amount (income); contractual clauses may be offered as a form of generation risk mitigation.

In the model allowed by the current regulation, the entrepreneur must sign availability contracts. Resolution no. 482/2012 of ANEEL (Article 6) prohibits contracts in monetary units for energy units. However, energy condominiums can rent their installed power.

Considering this fact, the entrepreneur needs to generate contracts based on the available installed power (or part thereof). The tenant pays a fixed amount for the use of the generation equipment and receives a share for the energy produced. Fig. 4 illustrates the concept of a solar/wind condominium.

4.2. Trading arrangement based on the aggregator role

The trading arrangement (business model) mediated by an aggregator will most often be associated with a VPP. However, VPP involvement is not required for business models that are more specific to small consumers. This is the case, for example, with LV consumers in a free market where the aggregator contracts small demand responses, setting a rate such that installation of storage devices becomes economically feasible even at the residential and small business levels.

Another business model intrinsic to the aggregator would be the technical and commercial link between distribution system operators (DSOs) and the regional transmission operator (RTO), as shown in Fig. 5. As shown in the figure, the model includes several negotiable aspects of interest for the aggregator, among which the following stand out: services to reduce peak demand (peak shaving), system flexibility and balancing services, services for network decongestion and voltage control, balancing responsible party (BRP), and renewable energy control centers. The first business case is related to the aggregator (red box in Fig. 5). Four main services can be observed:

1. Peak shaving service to the market considering the day-ahead market prices.

By shifting the consumption toward hours with lower prices, customers can reduce their energy cost. Participation in the capacity market could also be a source of revenue.

2. Energy balance service to the TSO.

Different kinds of reserves can be offered for the TSO- or DSO-connected demand.

3. Congestion management and voltage control for the DSO.

By using flexibility, DSOs can avoid grid reinforcement investments.

4. BRP portfolio balancing.

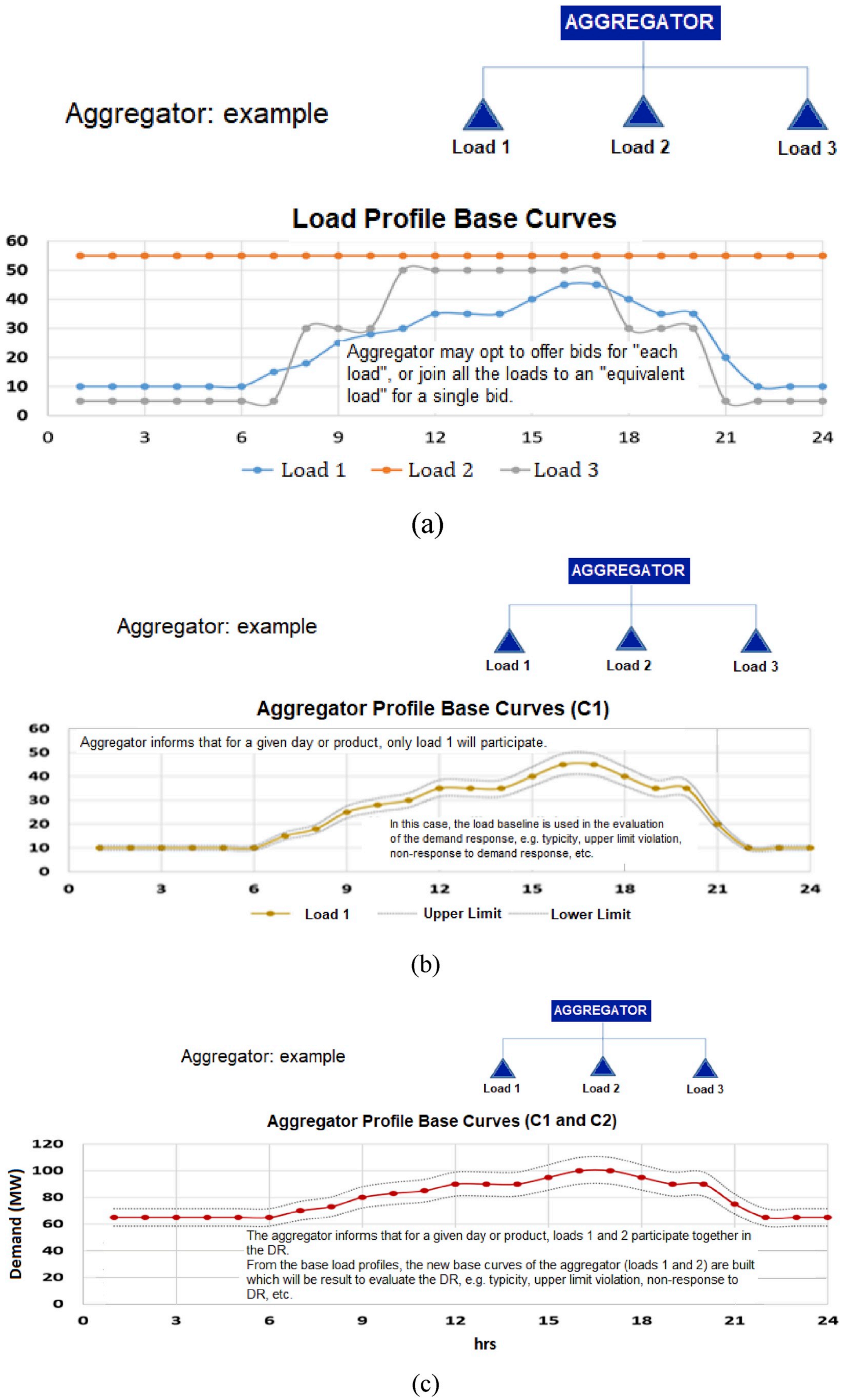

Fig. 2. Examples of aggregator performance in a DRP implemented in Brazil [67].

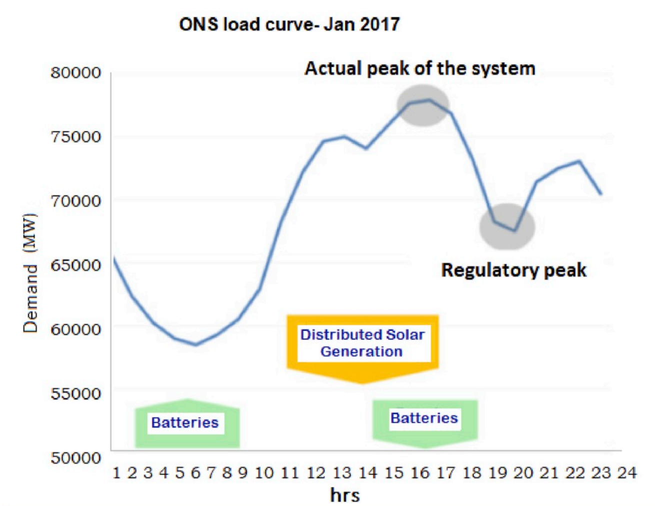

Fig. 3. Impact of DG with storage facilities and price response incentives in the load curve profile.

A BRP can use flexibility from aggregators to correct imbalances in its portfolio.

The second trading arrangement relates to the link between a renewable control center and independent power producers (IPPs). The renewable control center can interact with the TSO and the IPPs to negotiate the energy from solar, wind power, and another renewable source type. They can provide aggregation forecasts of RES production and offer controllability to the TSO. Further, they can assist IPPs or RES producers with connection requirements and system integration.

4.3. Association of an aggregator and a VPP

A virtual power plant aggregates DERs and offers energy blocks to the energy market [69]. It consists of a consumer load management system to optimize energy supply according to the demand profile of participating consumers. It provides ancillary services such as voltage control, reactive power, and frequency control through generation and storage sources to distribution companies.

A VPP can be managed by aggregators, BRP, or third-party vendors [70–72]. The VPP concept enables the implementation of several business models, such as.

- Trader-aggregator (T-A): buys and sells energy in the market; supplies energy to the loads; establishes contract models for MV consumers, etc.
- System manager and operator: can be a T-A itself or a third-party entity.
- Prosumer: some, but not all, account for generation plant costs; provides flexible loads and evaluates utility contracting models (demand response mechanism).
- Utility: an agent with a fundamental role, with varying degrees of involvement and several attraction factors: deferment of investments, reduction of demand during peak hours, improvement of operational performance (voltage and reactive power control, etc.), purchase of T-A services.

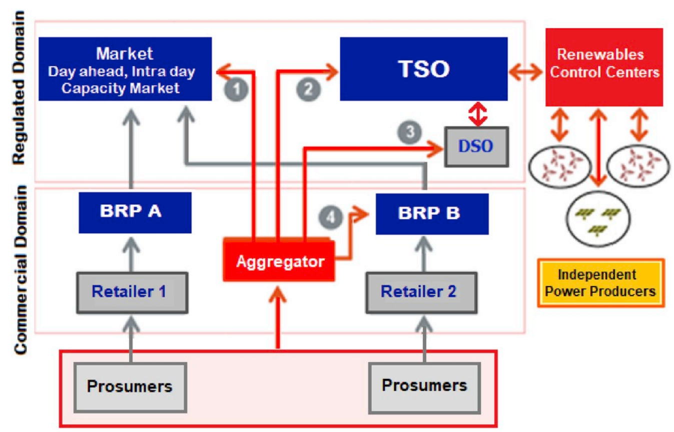

Fig. 5. Interaction between distribution and transmission operators through aggregators (adapted from Ref. [73]).

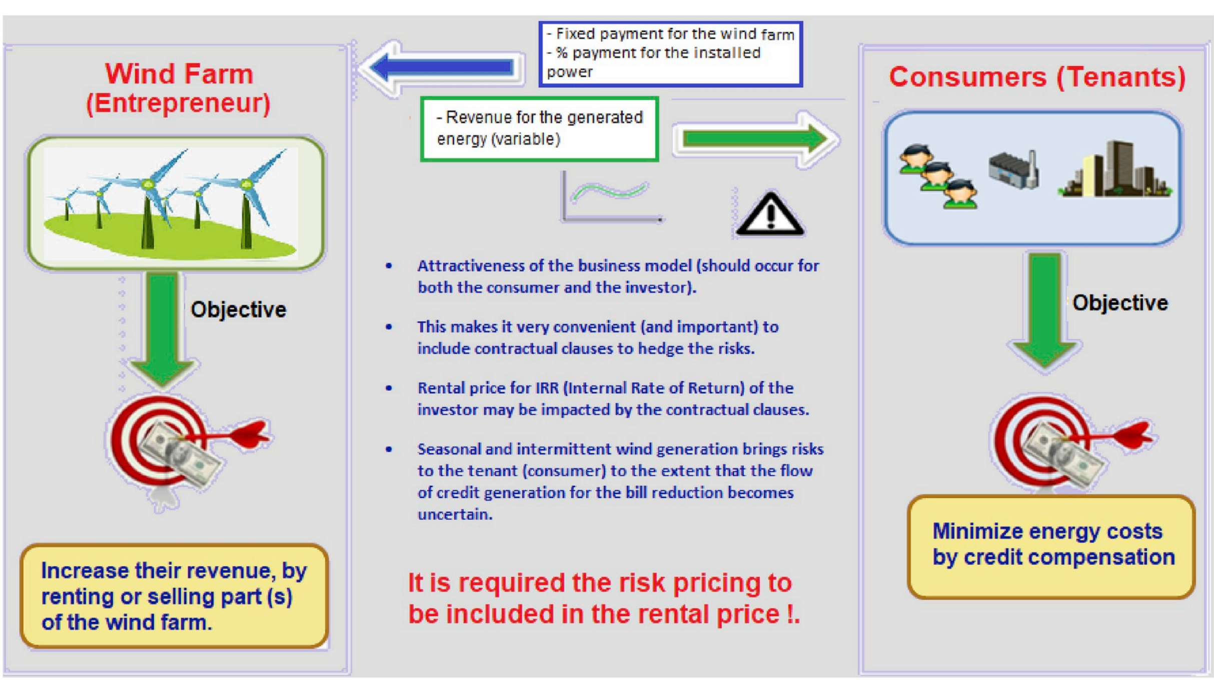

Fig. 4. Possible business model according to current regulations – wind farm.

4.4. VPPs in islanded systems

An islanded system operates in a condition in which it is disconnected from the grid provided that it has a generation source to feed its load. This condition can also occur during contingency periods when a system gets separated from the grid due to faults, avoiding power interruptions to critical loads.

The model should focus on evaluating the operation of renewable hybrid systems (RHS; solar/wind power plants and storage devices) and on scaling the expansion of generation supply in isolated systems or even in the case of systems supplied by substations weakly connected to BIS or its distribution network.

Fig. 6 presents the development structure of the proposed business model for the operation and expansion of the supply of islanded systems (SISO) or to control the remote points of the BIS. This model could be applied to the Brazilian system, considering its potential to reduce the operational costs of supply to remote (islanded) systems (i.e., cost reduction resulting from the substitution of renewable energy generation for diesel generation). The idea is to promote the contribution of renewable sources while reducing the diesel generator power injection to the load. The optimization process of this model is carried out at an hourly basis considering the subsystem power capacity (dotted area) and the different load profiles existing along the year. Likewise, the various wind and solar generation profiles are taken into account in this model.

4.5. A business model involving distribution utilities

Initially, one distinguish several potential participants in the new business models for distribution utilities:

- DG service providers without asset ownership
- DG investors aiming to provide premium DG services
- Investors in DG assets not providing related services
- Grid modernization investors
- DG investors aiming to reduce the energy contracted by distribution utilities or to mitigate the need to expand the distribution network
- DG financiers aiming to reduce the energy contracted by consumers or to mitigate the need to expand the distribution network.

These models would better suit mature markets characterized by solid smart-grid initiatives, sales and network services, energy efficiency, and demand control, in addition to financial and regulatory incentives to expand DG, which is not yet the case of the Brazilian market.

Brazilian regulation only allows a business model based on energy compensation for a utility as the owner of assets. Distributors can create new companies under the umbrella of the Economic Group Holding, which controls distribution utilities as separate operations, to assume ownership of the generating plant infrastructure. One possibility, depending on the future evolution of regulation, would be the provision of ancillary services, which would allow the distributor to buy equipment for insertion in strategic points of the electricity grid.

One applicable business model for utilities would be the acquisition of a DG portfolio under a multiannual plan. This alternative, envisaged since 2004 and regulated under Law 10,848, is based on contracts (by distributors) for distributed generation produced by third parties from their facilities through long-term bilateral contracts. One benefit is that distribution utilities do not assume the risks of operation and maintenance of distributed generation, which is restricted to energy providers. The advantage of this model lies in long-term negotiations, shielding the prices of the energy contracted from any market oscillation.

However, in practice, the only new business model allowed by the current legislation is the public supply of electric vehicles through electric stations. Although technologies used in electric vehicles on a global scale are mature, or close to maturity, aspects related to the integration of these vehicles into electric distribution systems are still in the early stages of development and will certainly require large investments so that their potential can be fully realized in the coming years.

In the case of Brazil, fully electric vehicles are not yet commercialized because of the difficulty in finding recharge points for batteries due to the lack of autonomy. The vision for the future includes a fleet of electric vehicles, but this scenario is a distant dream considering the cost of these vehicles, which does not fit into the current extremely limited power purchase patterns of the Brazilian society.

5. Discussions

Brazil regards only solar and wind generation as RES (since hydropower generation depends on the rainfall rate, so there can be periods of water shortage) and is therefore in Stage 1 of item 3.1 (i.e., less than 10% of the energy is supplied by RES to the energy matrix). Currently,

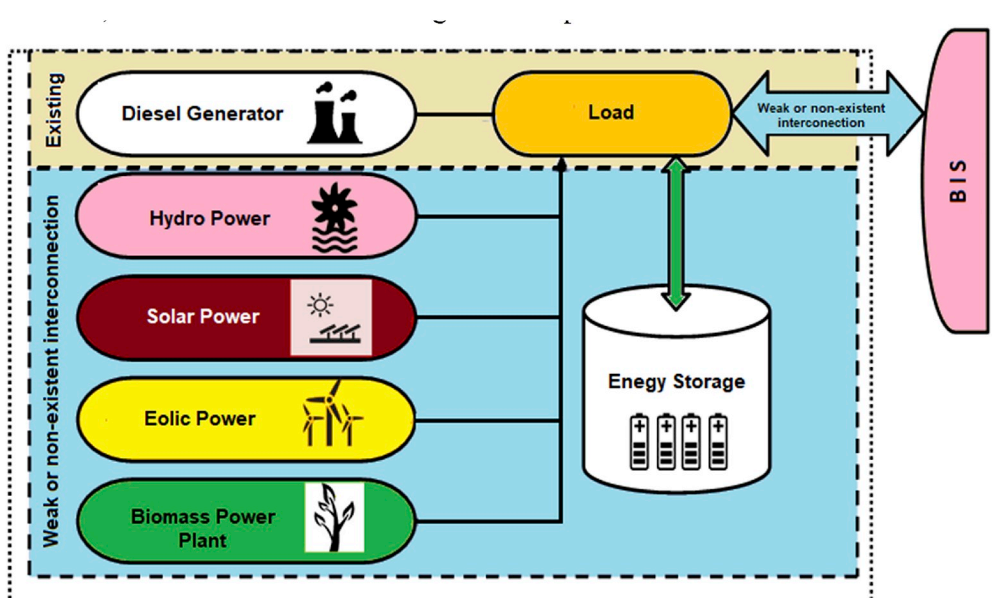

Fig. 6. Business model for islanded systems.

according to the national regulatory agency (ANEEL), the power injected by RES to the system is approximately 9.9%. Thus, the country's RES representing this niche is not significant.

More pilot projects linked to CCEE should be established to motivate the participation of aggregators (players) in the market. No VPPs are present in the system yet. Incentives and easiness for the adaptability of new players to enter the market are still unclear; thus, the regulations to cope with these issues with clear rules should be given priority by ANEEL.

New players are still unclear about how the energy produced will be measured (e.g., net metering) and whether they will need sophisticated equipment for metering and communication with the system operator, which may discourage their entry to the new market.

The pilot project referred to in Section 2.4 allows free (industrial) consumers located in the North and Northeast subsystems to reduce their demands for 1–7 h in the next day and even during the present day. The minimum demand to be reduced in a day is 5 MW, which will compensate for the intermittent generation of renewable sources (wind power) available mainly in the Northeast region. The model is predicted to extend to the whole country in the short or medium term, significantly affecting the electricity price nationwide. The long-term aim is to use these models to establish regulated LV consumers. Currently, these consumers (regulated LV consumers) contribute indirectly to a DR program through a flag pricing method (red, yellow, and green flags), which is applied according to the hydrological conditions driving the electricity price. Adherence to such flag prices (tariffs) is not voluntary but imposed by the distribution utility.

6. Conclusions and future work

The rapid development of intermittent renewable energy sources, such as wind and solar power, introduces new sources of uncertainty and complexity to balance generation and load in power systems and electricity markets. Demand response programs can provide significant benefits to utilities and consumers, reducing the consumption of energy during peak times.

The main vector for demand response success in Brazil will be an efficient pricing system capable of signaling an adequate use of system resources.

Recent technological advances and the smart-grid technology allow the emergence of new concepts related to demand response, such as automatic demand response (ADR) and open ADR, which are fundamental requirements to standardize applications and reduce not only the cost but also the difficulty of implementation.

Buildings, in general (e.g., residential, industrial, and commercial), may be potential participants in aggregation markets providing flexible loads and DERs.

Currently, the regulatory framework in Brazil is being adapted to include DR mechanisms. Pilot demand response programs would reduce the consumption of previously authorized agents (consumers) to provide an alternative resource for the thermoelectric dispatch outside the order of merit.

In particular, the model presented in Section 4.1 better fits the present conditions in Brazil. Other countries with different conditions may choose or even implement a combination of such models for a better response in their systems.

Another important point of the article is the model described in Section 4.4. This model could also be applied in the Brazilian system, considering its potential to reduce operational costs of supply to remote (islanded) systems. The idea is to increase the contribution of renewable sources while reducing the injection of diesel power.

A future work to better examine the demand response programs from the viewpoint of VPP and ESS participation and effects would be an interesting proposition. Moreover, more attractive incentive policies should be explored for commercial and residential customers, who are still reluctant to tap into demand response programs.

Acknowledgement

This study was developed within the scope of the Research and Technological Development Program of the Electric Energy Sector regulated by the National Electric Energy Agency (ANEEL) as part of the R&D project of Modernization of Tariffs for Distribution of Electric Energy coordinated by the Brazilian Association of Electric Energy Distributors (ABRADEE).

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