The role of imbalance settlement mechanisms in electricity markets: a comparative analysis between UK and Brazil

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***Abstract*—The present work aims to analyze UK's and Brazil's wholesale electricity trading models. UK's model, also known as New Electricity Trading Arrangements (NETA), can be considered a reference for the present day electricity markets. Recently UK has implemented a market reform that, while maintaining UK's market structure, introduced several strong regulatory economic signals in order to foster new investments, both in thermal and in low carbon emission electricity generation. Brazil's wholesale market model is also noteworthy as it managed to promote large scale investments in low carbon generation in a liberalized market environment. However, Brazil's regulatory framework design proved fragile during a recent long draught period when short term financial obligations related to imbalance settlements soared and led to financial stress and, eventually to a market halt.**

***Index Terms*-- Energy Market; Energy regulation; commercialization; Short Term Market; Balancing Power Market**

I. INTRODUCTION

This paper is part of a GESEL (Electric Electricity Research Group of the Institute of Economy of the Federal University of Rio de Janeiro) research project to promote regulatory innovations in the Brazilian Electrical sector, based on the experience of several International regulatory frameworks. The focus of this paper is to propose regulatory improvements to Brazil's trading arrangements inspired partly on UK's current imbalance settlement rules, since these rules provide an economic incentive for agents to avoid imbalances, something that could be useful to improve Brazil's market design. Firstly the paper presents the basic concepts of UK's current market arrangements. Then the Brazilian electricity trading regulatory framework is presented, highlighting some important aspects related to current crisis (2013-2016), triggered by a long drought period. Finally the article proposes some regulatory innovations, to be detailed and enhanced in future studies, in order to mitigate the financial risks experienced during the crisis period.

II. ENGLAND: FORWARD MARKET AND IMBALANCE SETTLEMENT

After privatization of the electricity industry in England and Wales, in the 1990s, the System Operator (SO) centrally dispatched generation and transmission. Currently in the UK's the electric system is no longer centrally dispatched, as a result from a subsequent reform carried out in 2001 known as the New Electricity Trading Arrangements (NETA). In the NETA framework, that serves as a proxy for the European Electricity Markets, both generators and suppliers are induced to contract 100% of their energy production/supply in each market time interval. In this design, market prices guide the behavior of agents and imbalance prices act as a punishment element in case of imbalances, i.e. when agents are not able to contract all their electricity output/need at the electricity market [13]. NETA comprises three commercialization tools: (i) Forwards and Futures Markets; (ii) Balancing Mechanism, and (iii) Imbalance Settlement. [11].

Agents (generators, suppliers and traders) transact energy contracts so that electricity supply and demand have to match at every market period [14]. Electricity contracts are negotiated bilaterally at the **Forward Market**, where energy is traded before delivery. The negotiations can be held "Over the Counter", on terms agreed between the parties, or at the Power Exchange [8; 14].

The SO handles differences between contracted consumption and production. In the **Balancing Mechanism**, the SO balances electricity supply and demand in real time [8]. The Balancing Services Market was developed so that the SO could promote these real time adjustments. In the Balancing Services Market, agents submit to the SO electricity sale offers (Offer to sell), to increase production or reduce consumption, or energy purchase bids (Bids to buy), to reduce production or to increase consumption. These proposals are equivalent to the prices at which agents are willing to change, if instructed by the SO, their generation or consumption in relation to contracted levels.

For instance, a generator that is contracted to generate at a certain level at a given market period can increase or decrease its generation, within limits of variation reported to the SO, receiving as compensation the price specified in its offers or bids in the Balancing Services Market. In real time, the SO balances the generation and consumption, using the purchase and sale proposals that represent the lowest final cost [8; 11; 14]. Therefore, the system is self-dispatched through a set of Forward Contracts and the SO achieves the fine adjustment between supply and demand through the Balancing Services Mechanism.

When agents use or generate amounts of energy that are different from their contracts for some reason than an SO request, they are exposed to the **Imbalance Settlement**. The differences between contracted energy and actual energy are exposed to the Imbalance Price or "Cash-out" price – a price that reflects the costs that the SO incurs in balancing the system. As agents that have a contractual imbalance have to pay the cost of balancing the system, agents financially exposed to the imbalance price are worse situation than fully contracted agents. The imbalance price works as an economic incentive for market participants to be fully contracted through market mechanisms as it penalizes agents that have not met this requirement [12].

The cash-out mechanism is now under an evaluation and restructuring process. The main reason is the significant increase in system balancing costs, associated to the increasing participation of renewable generation (mainly wind generation) in UK's generation mix [14]. This type of generation has a low hourly predictability and therefore generators become exposed to the Imbalance Settlement.

There are actually two imbalance prices, the System Sell Price (SPP) and the System Buy Price (SBP) [9]:

- If there is an electricity surplus, for example if a supplier consumes less than its contracted level, this surplus will be valued in the Imbalance Settlement at the System Sell Price, which is usually lower than the forward market price for the same market period;
- If there is an energy deficit, for example, if a generator's output is below its contracted level, this generator will have to buy energy at the Imbalance Settlement paying the System Buy Price, which is higher than the forward market price.

SSP and SBP are distinct from one another in order to reflect the costs, expressed in pounds/MWh, incurred by the SO to balance the system. Agents with a deficit at the Imbalance Settlement pay more per MWh than agents that have a surplus receive and the difference reflects exactly the cost of balancing the system. Agents exposed to the Imbalance Mechanism bear an extra cost (or have smaller revenue) in relation to agents that are fully contracted at the electricity market. The Imbalance Settlement is designed to provide a stimulus for market agents is to use forward contracts in order to be fully contracted. As all agents are led to trade energy and avoid imbalances, the electricity market has good liquidity and it can transmit right economic signals to the agents [13]..

III. Brazil: Trading and the Settlement Price for Contractual Differences

Brazil's system is centrally dispatched by the Independent System Operator (ONS). The Brazilian generation mix is based mainly in a Hydro Power, with several large reservoirs (the total storage capacity is currently equivalent to five months of total electricity consumption). Hydro generation accounts for more than 90% of total generation in normal hydrological years. Brazil's Thermal Power Generation is mainly used as backup for hydro generation in dry years.

Brazilian power mix is essentially renewable, with low levels of carbon emissions, which is due mostly to Brazil's large hydro potential, but also due to the continuous efforts to promote other renewable projects. According to the projections made by the Energy Planning Company (EPE) for the next 10 years, wind generation will grow from 5 GW to 24 GW, reaching 11.6% of installed capacity by 2024. Photovoltaic, otherwise, is expected to achieve an amount of 7 GW, representing 3.3% of total generation capacity [2].

Brazil's current electricity trading model dates from the 2004 with the Electric System Reform that was an evolution from the 1995 liberalized electricity sector model [3; 4]. The new regulatory framework established the parameters for electricity trading, including risk allocation and rights and obligations applicable to generators [10].

Brazil's wholesale electricity trading is based in compulsory financial contracts. Consumers should contract all its consumption or face severe penalties. Electricity can be contracted in two different market environments [3]:

- The Regulated Contracting Environment (ACR), where bilateral long-term contracts with distribution companies are auctioned by the government among generating companies;
- The Unregulated or "Free" Contracting Environment (ACL), where contracts are traded among generators, traders and "free" (unregulated) consumers. Free consumers are normally large industrial and service companies that have more than 3MW of energy demand.

All contracts must be registered at Commercialization Chamber of Electrical Energy (CCEE) who is also responsible for the Imbalance Settlement Mechanism.

Brazilian wholesale electricity contracts are not physical energy supply contracts. The Brazilian electrical system is centrally dispatched by ONS and electricity can be produced by any generator. The generator who sells a contract is responsible financially – not physically – for the transaction. Due to this fact the Imbalance Settlement Mechanism has a central role. As technical dispatch does not reflect contracts, financial imbalances are frequent, usually more than 10% of the total generation.

Contracts for the regulated market are auctioned by CCEE and regulated by Brazilian Regulatory Agency (ANEEL) [6]. There are two basic types of electricity contracts:

(i) "New Energy Contracts" (i.e. contracts for new power plants) are auctioned for energy starting date within five years (A-5) or three years (A-3). The delivery time obligation can vary from 15 to 35 years;

(ii) "Existing Energy Contracts" aim to meet utilities' current load with electricity from existing power plants and they must take place a few months after the auction.

Regulated Electricity Contracts (ACR) can be of two types [4; 15; 10]:

- Energy Quantity Contracts: usually for hydro generation, where risks (mostly exposure to imbalance settlement and imbalance prices) are allocated to the generator;
- Energy Availability Contracts: where generators, usually thermal plants, offer their plant's available capacity to the Distribution companies and receive a constant revenue. As the plant is dispatched, the Distribution companies are also responsible for paying a variable costs (fuel) and imbalance settlement costs/revenues.

Distributors provide electricity to low voltage regulated consumers and wholesale electricity costs are passed through to these consumers. ACL Contracts are freely negotiated among the agents, who define prices and energy volumes according to any agreed criteria.

Brazilian electricity wholesale contracts are backed by the so called "Physical Guarantee" which corresponds to the generator's maximum amount of energy capacity that can be traded in long term contracts [10]. Each power plant's "physical guarantee" is defined by the Department of Energy (Ministério de Minas e Energia) using an official modeling methodology [5]. Distribution companies must prove full contractual coverage or bear stiff penalties. Sellers (mostly generators and traders) must back their contracts at CCEE either by "physical guarantee" from their own power plants or by energy purchase contracts.

Imbalances between contracted and measured energy are settled in the Imbalance Settlement Mechanism (Mercado de Curto Prazo, or MCP) and they are valued at the Imbalance Settlement Price (PLD) [1, 3].

Additionally, there is a structural hedging mechanism for hydro power plants called Energy Relocation Mechanism (Mecanismo de Realocação de Energia, or MRE), managed by CCEE. In the MRE all the hydro generation is treated as a pool. Each hydro plant has, through this mechanism, a fraction of total hydro output, based not on its physical output, but on its share in total hydro Physical Guarantee. Through MRE hydro plants located in regions affected by a drought are usually not penalized because the Imbalance Settlement for hydro plants is based not on physical output but on energy redistributed by the MRE.

Imbalance prices (PLD) are set for each load step, based on the Marginal Cost of Operation (CMO) calculated by dispatch optimization models [3]. These models optimize the use of reservoirs' water and calculate both dispatch and marginal costs for each period in each one of Brazil's four submarkets [15]. There is just one price for buying and selling electricity at the MCP [1].

In a severe drought the Brazilian Market setup proved to be problematic as imbalance prices skyrocketed for a very long-time with severe consequences for all the stakeholders involved, included the final consumer, who were affected by tariffs increases in some cases exceeding 80%.

IV. Present Trends in the UK and Brazilian Market Setup Models

UK's NETA market design served as a reference for electricity wholesale markets for a long time. But recently the UK wholesale has undergone another reform. The main motivation behind this reform was the need to substitute an ageing thermal power plant fleet and to promote a substantial increase in renewable generation in UK's generation mix.

UK's Department of Energy and Climate Change found that the NETA market scheme alone would not be sufficient to promote these tasks. It therefore introduced several changes to the energy market that, without eliminating the existing basic market setup, make new investments more likely.

The main new features are: a price floor for carbon emissions, promoting investments in low carbon emission technologies; contracts for differences for new renewable projects, leading to more predictable revenues for projects that are essentially fixed-cost based investments; capacity contracts for controllable generation, through which the System Operator can safely operate the electrical system even with an increasing participation of non-controllable generation (wind and solar).

The new UK market reform introduces a considerable level of state intervention: prices formed in the electricity market are no longer considered as sufficient to induce sound investment decisions and optimal allocation of resources.

Brazil's electricity market, based on long-term contracts, has been acknowledged as a good model for using market tools (auctions) to promote investments in new generation projects in a wide scale. Recently, with a dry sequence of years, the Brazilian market design proved to be risky: with very high imbalance prices for an extended period of time, agents subjected to the imbalance mechanism bore very high short-term financial costs and there was severe impact over the electricity price for consumers. This eventually led to several legal battles where agents sought for legal protection against the surge in short term electricity costs, leading ANEEL to halt the CCEE's imbalance settlements.

V. Brazilian Hyidro Crisis

The current Brazilian power sector crisis started with the massive baseload dispatch of virtually all thermal plants beginning in October, 2012, as a result of an unfavorable hydrologic scenario that lasts until now (Jan/2016). The lack of financial risk mitigation mechanisms, associated with higher generation costs, exposed the current commercialization model weaknesses.

Table 1 shows CCEE settlements per year between 2009 and 2014, and also their main components. The CCEE Settlement involves only short-term obligations (the costs of energy contracts themselves are not included in the table, only imbalance costs, system services charges and other smaller charges). CCEE Settlement is calculated at the end of each month and payments are due the following month. "Imbalance Price" and "Imbalances" columns show average prices and average quantities of the Imbalance Market for each year. In 2014 both Imbalance Price and Imbalances surged (723/MWh and 8,921 MWavg). "CCEE Settlement" column shows the total financial volume for each year. In 2014 the total settlement was R$ 42,897 million (approximately 12 Billion USD), much higher than the total settlement for the previous five years. The data demonstrate the exceptional nature of the financial obligations related to Imbalance Market in 2014 [6]

TABLE I. CCEE SETTLEMENTS AND THEIR MAIN COMPONENTS BETWEEN 2009 AND 2014

Year	Imbalance Price	Imbalances	CCEE Settlement
	R$/MWh	MWavg	R$ million
2009	42	5.669	2.585
2010	73	6.282	5.071
2011	29	8.322	3.928
2012	143	7.279	8.998
2013	279	5.906	15.405
2014	723	8.921	42.897

Source: [6]

In addition to the CCEE transactions, distribution companies are also responsible for another kind of short-term cost: fuel cost payments related to availability contracts with thermal power plants. These payments are calculated in a monthly basis by CCEE and are settled bilaterally between distribution companies and generators. In 2014, these costs reached R$ 17.5 billion (approximately 5 Billion of US Dollars), which is the highest financial volume for expenses under this item from 2009 to 2014. Adding CCEE settlements and fuel expenses, short-term costs associated with electricity purchases in 2015 exceeded R$ 60 billion (approximately 17 Billion of Us Dollars). As a comparison, Brazil's 62 distribution companies, that are responsible for 75% of electricity sales, had in 2014 a combined turnover of R$ 62 billion.

Facing a huge and unexpected rise in short-term electricity costs obligations, which were not covered by tariffs, for several months distributors did not have enough cash to settle their short-term financial obligations. In order to avoid widespread defaults on the Electricity Market, the government and the regulator postponed for several times the CCEE's monthly settlement date, meanwhile elaboration new regulation to provide financial resources to distributors. Since 2013, a series of regulatory changes were adopted in order to allow distributors to pay their obligations, keeping the system solvent [6]:

(i) In 2013, the National Treasury was authorized to make extraordinary contributions to CDE Fund (Conta de Desenvolvimento Energético, an electricity sector fund) in order to pay distributors short-term obligations;

(ii) Decree No. 8221/2014 created the ACR-Account, a mechanism that backed several large scale bank loans to CCEE, securitizing future increases in distribution electricity tariffs, in order to settle obligations of distributors at CCEE;

(iii) At the end of 2014 ANEEL, reviewed the upper and lower limits of the Imbalance Price, decreasing the ceiling price to less than half of its original value;

(iv) In 2015 ANEEL introduced the Tariff Flags mechanism, allowing regulated consumer tariffs to be adjusted monthly according to hydrological conditions, charging a higher rate in case of drought;

In 2015, with the continuity of the hydrologic crisis and the accumulation of liabilities in the CCEE, especially by hydro generators, many agents sought legal protection to avoid large payments at CCEE. The large number of injunctions led to a huge increase in defaults in the CCEE and by the end of the year completely paralysed CCEE settlements. The government tried to solve the problem by issuing the MP 688/2015 that allowed the relocation of hydrologic risk for hydro generators, transferring part of it to consumers. As a compensation for the risk relocation, Hydro generators had to accept lower prices for their long-term contracts with the regulated market.

The need of several regulatory changes to keep the system solvent shows that Brazilian Imbalance Market was not designed to settle, in one year, amounts of tens of billions of Reals. Thus, it is important to seek structural solutions to minimize financial impact of hydrological crisis on the Imbalance Market.

VI. CONTRIBUTIONS OF UK FRAMEWORK TO BRAZILIAN MARKET MODEL

The level of financial risk in Brazilian market model is inherently high, given the mismatch between contracts and technical dispatch, resulting in large volumes of imbalances, and also given the high volatility of thermal dispatch and associated variable costs. Expressive amounts of energy are settled in the imbalance settlement (CCEE) being subject of an imbalance price that always soars during dry periods.

Brazilian short-term market Imbalance Settlement includes imbalances that can be classified in two different groups: non-manageable and manageable imbalances. The first group is composed by thermal generation in excess of physical guarantee (GF) and reserve energy generation (reserve energy is constituted by power plants with an Unitary Variable Cost equal to zero, as wind and biomass plants, that have priority dispatch). The second group includes merchant thermal generation (thermal generation that settle all energy produced in the Imbalance Settlement Mechanism), uncontracted hydro generation and unregulated consumers that are over contracted. The table below shows an estimate of the amount of each kind of imbalance generated in 2014 [7].

To minimize short term financial cash flows during severe draughts, as in 2014, it is possible to decrease the value of non-manageable imbalances and decrease the volume of manageable imbalances.

TABLE II. SOME IMBALANCES IN IMBALANCE SETTLMENT IN 2014

Kinds of Imbalances	MWavg	% Total
Non-manageable imbalances	3,523	39.5%
Thermal generation beyond GF	2,415	27.1%
Reserve Energy Generation	1,108	12.4%
Manageable imbalances	5,398	60.5%
Merchant thermal generation	1,266	14.2%
Uncontracted hydro generation	518	5.8%
Free consumers over contracted	729	8.2%
Total Imbalance Settlement 2014	**8,921**	**100%**

Source: [7]

Reducing non-manageable imbalances physical volume does not seem practical given that they result mismatch between contracts and dispatch and also from Brazil's generation mix. On the other hand, it is possible to reduce non-manageable imbalances' value, through a change in their pricing. Given they are structural, it doesn't seem to make sense to continue using an imbalance price based on marginal costs. Marginal cost-based prices can be very effective as economic signals for market participant's behavior. But with non-manageable imbalances there is no need of economic signal for agents as it is not in their power to reduce or increase imbalances. Therefore, it would be better if the non-manageable imbalances were valued at their cost and not by the system marginal cost.

On the other hand, manageable imbalances result from agents decisions (generators' and consumers' contracting strategies), and also from unpredictable small variations in consumption and generation. These imbalances are valued today at the PLD and borne, in part, by consumers through system charges. But Brazilian regulatory framework doesn't have today any economic signal penalizing contracting strategies that produce this kind of imbalance. Thus, agents who have an energy surplus can sell it Imbalance Settlement (CCEE) with no penalty. There are many examples of agents who adopt this strategy in order to profit from imbalances, such as merchant generators and over contracted consumers. The main problem of this strategy, however, is that it creates obligations to third parties, increasing financial risk for the wholesale electricity market [7].

Thus, considering the regulatory problems that were pointed out, some modification to Brazilian trading arrangements are suggested based partly on the English model. In this alternative regulatory design, non-manageable imbalances would be valued at the Unitary Variable Cost (CVU) and would be divided among generators, proportionally to their physical guarantee, through the MRE (Energy Reallocation Mechanism), which would include all generation agents and not only hydro generators, as in the current model. Generators with a surplus at the MRE would receive their CVU or the Optimization Energy Tariff (TEO that correspond to a tax that hydro plants pay per MWh produced and therefore is the equivalent of a variable cost for a hydro plant in Brazil), while generators with a deficit would pay the Average Variable Cost (CVM). As the CVM is lower than the imbalance price (PLD), this design for settling non manageable imbalances would lower the overall financial risk. However, given Brazil's high thermal plant variable costs, maybe it wouldn't be possible to eliminate the ESS (a system service charge payed by consumers, that currently covers part of the variable costs). It is important to mention that, in this alternative, all generators would share the market risk, because if consumption decreases, all generators would receive less energy at the MRE than their physical guarantee. Generators would be induced to adjust their contracts to available energy through market mechanisms. The Imbalance Settlement Price would be redesigned to penalize imbalances, as in the UK model, so that agents would pay (receive) the imbalance price (PLD) plus (minus) a spread. As non-manageable imbalances would be settled at the MRE, the Imbalance Settlement Mechanism would settle only manageable imbalances. It would become the last option for agents, who would be induced to adjust manageable imbalances through market mechanisms, leading to increased liquidity in the energy market. The funds rose through the spread between buy and sell Imbalance prices could, in turn, could relieve MRE costs [7].

The expected results of the commercialization regulatory model proposed is the minimization of non-manageable imbalances value, a great decrease of manageable imbalances (due to a strong economic sign to avoid imbalances), a huge growth of the energy market, as the agents would seek to constantly balance their portfolios in order to avoid the imbalance settlement, and, finally, the dilution of market risk among all generation agents and its dissociation from the hydrology risk.

VII. CONCLUSIONS

The paper points out the need to implement regulatory innovations in Brazilian commercialization model, in order to reduce the value of non-manageable differences, decrease manageable differences volume and also induce manageable differences conciliation through the energy market.

The Brazilian energy wholesale market requires to be improved based on the recent experience. The market crisis is related to a surge in short term costs related to the Imbalance Settlement Mechanism, a revision on the regulatory signals concerning imbalances should be implemented. Agents should be able to use market tools to avoid or hedge against imbalances – those alternatives are virtually impossible in the current market setup.

Brazil's imbalance settlement model could be redesigned based partially on the British Imbalance Settlement design. The following design is proposed: non-manageable differences could be settled by the CVU (Unitary Variable Cost), so as energy generation, which is managed by the SO and not by generators, would be assigned to individual generators proportionally to physical guarantees. In this case, generators would take market risk and the hydrology risk would be valued by the cost. Manageable imbalances would be penalized and agents would be induced to adjust their contract portfolios in order to avoid imbalances.

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