A FRAMEWORK FOR ELECTRICITY MARKET MONITORING

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Abstract – The experiences to date with the implementation of electricity markets are indicative of less than true competition. Such results are symptoms of flaws in market design which allow market players to behave strategically by exercising market power and, in some extreme cases, manipulating markets. Such behaviors impede the attainment of vibrant competition, which was a key goal in restructuring electricity. The market monitoring notions used in securities and commodity markets can be adapted to electricity markets to minimize the impacts of such misconducts. However, due to the uniqueness of electricity and its markets, market monitoring needs to explicitly take into account the salient features of electricity including its *extreme perishability* as a commodity and the reliable system operations in parallel with market operations. This paper's objective is to describe a framework for market monitoring that takes explicitly into account the unique characteristics of electricity and electricity markets, the interrelationships of these markets and time-dependent nature of market participants' behaviors. The modular structure of the framework provides good flexibility and sufficient generality in allowing the incorporation of particular models and metrics appropriate for specific jurisdictions. We apply the proposed market monitoring framework for comparatively assessing existing monitoring structures. We discuss some of the associated challenges, including seams issues and effective metric requirements for electricity markets.

Keywords: competitive electricity markets, market monitoring, market power, market manipulation, integration of market and system operations

1 INTRODUCTION

Past experiences with the electricity industry restructuring implementation indicate that market design flaws and subsequent market failures are seriously harmful to consumers as well as to market participants. The ability to prevent such outcomes may be ensured by an effective market monitoring mechanism [1].

The well-functioning of the electricity markets depends on how effectively the market design marries the salient characteristics of the electricity as a commodity with the needs of a workably competitive market and aligns market operations with system operations. When a market design is flawed, market participants may exploit such flaws by behaving strategically. In some extreme cases, there may also be market manipulation. This type of undesirable behaviors impedes the attainment of vibrant competition, which was a key goal in the electricity restructuring**.** The outcome can be a market meltdown, as was the experience in the California crisis. The extraordinarily high spot market prices during a nearly twelve month period were accompanied by several blackouts and the bankruptcy of the state's largest investor-owned gas and electric utility [2]-[5]. Unfortunately, there was no effective defense mechanism existed to mitigate the problems during the crisis.

The market monitoring concept is used in the policing of security and commodity markets. The U.S. Securities and Exchange Commission (SEC) oversees participants in the securities world and each year brings hundreds of civil enforcement actions against participants that break the securities laws [6]. Typical breaches include insider trading, accounting fraud, and providing false or misleading information about securities and the companies that issue them. The U.S. Commodity Futures Trading Commission's market surveillance program is over all active futures and option contract markets[7]. The Commission's market surveillance staff monitors the daily activities of large traders, key price relationships, and relevant supply and demand factors in a continuous review for potential market problems. The regulative initiative for electricity market monitoring was established by the Federal Energy Regulatory Commission (FERC). In Order 2000, FERC acknowledged that market monitoring was a core function of newly forming regional transmission organizations (RTO)[8]. A key challenge is to effectively adapt market monitoring to electricity markets in a way to take into account their salient characteristics.

Electricity as a commodity exhibits unique characteristics because of how it is produced, delivered and consumed. The flows of electrons on the transmission system obey the Laws of Physics instead of man-made mandates. There is no economic solution available to store electricity yet, which is a key difference from other commodity markets. The electricity market competition is enabled through the transmission system in which any market participant's conduct affects others instantaneously, such that reliable system operation is enjoyed by each market participant. The alignment of reliable system operations with effective market operations is achieved by introducing markets additional to

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energy markets, such as ancillary services and capacity markets. These electricity markets are interrelated to each other, providing opportunities for market participants to conduct multi-market strategies. Furthermore, there exist inter-temporal relationships in electricity markets, such that all conducts may invoke repercussions in later markets. Consequently, electricity market monitoring needs to explicitly take into account these considerations.

In the initial implementation of the Independent System Operators (ISO) concept in the U.S., much of the focus was on the modification and enhancements to the conventional power system operation and control systems as well as market driven scheduling and dispatch processes [9]. Market monitoring was not an initial concern and the existing market monitoring mechanisms were developed gradually, after concerns arose about specific problems. The large part of the literature on electricity market monitoring research is concerned with the detection of market power exercise under strategic bidding [5],[10],[11]. Market design flaws and consequent market manipulation issues are also addressed in [4],[12]. In addition to these researches, market monitoring organizational and policy issues are also examined. Critical policy issues that must be undertaken for an effective monitoring are examined in [13]. The role of market monitoring by Regional Transmission Organization (RTO) is analyzed in [14],[15]. Furthermore, a review of different market monitoring organizational structures is presented in [16]. A comparison of existing market performance monitoring and mitigation policies is presented in [17]. A rigorous and systematic approach to monitoring activities is presented in [9].

The objectives of this paper are to provide a general overview of electricity market monitoring activities and to propose a conceptual framework for market monitoring, taking explicitly into account the uniqueness of electricity, its markets, their inter-relationships, and the time-dependent nature of market participants' strategic conducts. The paper describes a market monitoring framework considering these issues and provides a comparative assessment of existing market monitoring units by the proposed framework. There are six additional sections in this paper. Section 2 describes the scope of market monitoring activities and outlines the temporal characteristics of monitoring. The key requirements for market monitoring analysis are addressed in section 3. Section 4 discusses the models and tools needed for monitoring. Section 5 presents the proposed electricity market monitoring framework. We use the proposed framework for a comparative assessment of some of the implemented market monitoring units in section 6. We conclude with a discussion of the associated challenges, including seams issues and effective metrics for electricity markets.

2 THE SCOPE OF MARKET MONITORING

To accomplish the market monitoring objectives, the market monitoring unit (*MMU*) of an RTO performs a range of diverse activities. These activities encompass all electricity markets and their relationships across time. The core market monitoring activities include, at the least, the following:

- detection of attempts to exercise market power and to engage in fraudulent behavior and the implementation of appropriate mitigation schemes;
- data collection, processing and storage;
- the dispatch of appropriate responses in terms of punitive actions to address observed market participants' conducts; and,
- identification of market design flaws and development of proposed approaches to address them.

The data activities encompass the data gathering, processing and storage. The collected data consist of both public domain information (wholesale electricity market outcomes, network measurements, interconnected RTOs information, other commodity market outcomes and weather information) and confidential information (market participants' asset information and their bids/offers). Data processing activities consist of the organization of the large amounts of data involving time stamping, classifying, sorting and cleansing. All processed data are stored for future access for review and analysis purposes.

The collected data in the internal database serve the screening tests implemented for identifying anomalous conducts/market outcomes. These tests serve to flag those market participants' conducts that may indicate "inappropriate" competitive behavior and those unusual market outcomes that pinpoint the need for additional analysis. For each flagged market conduct/outcome, an in-depth off-line analysis is executed to identify the nature of the problem and to quantify the impacts on market performance. The *MMU* utilizes various tools including metrics, market simulations, market scenario studies and sensitivity analysis [18],[19].

A critical *MMU* off-line analysis activity focuses on the identification of market power exercise, the strategic behavior of a market participant in an attempt to gain excessive wealth transfers from other participants, typically from demand-side entities. The analysis results indicate whether such strategies are implemented by physical withholding, economic withholding or creating local transmission congestion, and what their impacts are to the market outcomes. The *MMU* is also responsible for identifying any design flaws that may create opportunities for market manipulation. As such, the *MMU* analysis is also aimed at the identification of market conducts that take unfair advantage of market rules. Such conducts may result not only in market inefficiency but also reduced system reliability.

The *MMU* takes appropriate responsive activities to address the undesired impacts of a strategic conduct and market design flaws. These responsive activities include mitigation and punitive responses in the short-term and market redesign proposals in the long-term. The objective of the mitigation activity is to effectively address market power exercise attempts by attenuating possible repercussions on the other market participants. Two different mitigation schemes are price cap and offer cap. Although we provide a detail explanation of the offer cap mitigation scheme in section 4, we can summarize the process having three steps: a conduct test to determine if there exist offers that deviated from prespecified thresholds, an impact test to quantify such offers' impacts on market outcomes and the corrective response imposition whenever there exists a substantial impact on market outcomes.

The dispatch of appropriate responses in terms of punitive actions encompasses both financial and/or operational punishments. The penalties provide feedback to market participants, so as to deter them from repeating such conducts in the future. For a repeated uncompetitive conduct, a higher penalty is applied. Depending on the analysis, there may arise a need for the development for market redesign, however, any structural design need to be approved by the RTO and also the appropriate regulatory bodies.

The role of the *MMU* as a "watch dog" for the electricity markets is further complicated by its accountability to its patron RTO and FERC. Consequently, market monitoring activities also include the preparation of monthly and annual reports to provide the status and developments in the monitored markets with the analyses of market trends and early warning of market conditions that could create problems [20]-[23].

An important aspect of market monitoring is the temporal characteristics associated with the time delay between the actual determination of an anomalous conduct/result and the dispatch of the response. This delay may decrease the effectiveness of market monitoring activities, particularly when we consider the price volatility of electricity markets. Mitigation schemes can be effective during this time delay to address market power exercise strategies. We illustrate market monitoring activities in a precedent relationship for a particular market monitoring incident at time $\hat{t}$ in Figure 1. The order of the duration of each activity is shown on a logarithmic time scale.

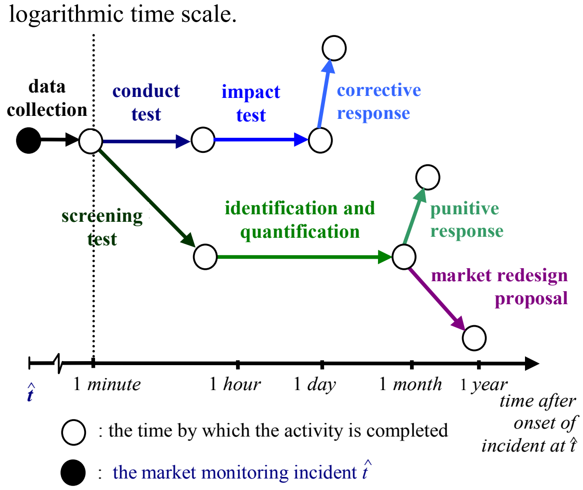

Figure 1: Precedent relations in market monitoring activities on logarithmic time-scale

This figure stresses out the fact that a market redesign proposal can take considerable amount of time than imposition of mitigation as a corrective action.

3 MARKET MONITORING ANALYSIS REQUIREMENTS

The *MMU* analysis must explicitly take into consideration several important issues. These are specifically: the reliability impacts on market performance, exogenous parameters that shape market participants' strategic behaviors, interrelated electricity markets and their relationships across time, the unique structure of various market participants, and the evolving behavioral nature of market participants.

The identification process needs to be able to distinguish between actual market participants' unbecoming conducts and scarcity conditions. High prices in markets are not necessarily an indication of market power exercise; such conditions may result from inadequate available generation or impacts of reliability criteria used for security constraint system operations.

Exogenous variables, such as other commodity markets' outcomes, emission credits and weather, shape participants' behaviors. For example, higher fuel and emission costs may result in higher priced offers to sell energy than under the opposite conditions. Weather conditions, such as a dry season, impact the unit commitment decision making of entities with hydro resources. Market monitoring analysis needs to address such effects on market participants' conducts.

Market monitoring analysis needs to consider the interrelations between electricity markets for the identification of uncompetitive multi-market strategies. For that reason, monitoring analysis needs to examine market participants' conducts in each market, identify their relationships and determine if there exists an undesired impact of such conducts.

Monitoring analysis also needs to identify the uncompetitive strategies based on the inter-temporal relationships in electricity markets. This requires analyzing market participants' conducts across time, identifying their influences on present market outcomes and determining their impacts on market outcomes.

Some of the market participants have affiliates with different business practices. Consequently, monitoring analysis needs to address the collective capability of such players to exercise market power, manipulate market rules or even to engage in discriminatory practices against other participants to the advantage of the its generation affiliates.

The ability to address the evolving nature of market participants' strategies is an important requirement for the monitoring analysis. As market rules or the market structure changes, the strategies of market participants evolve. Consequently, the tools and models utilized for monitoring analysis needs an ability to identify evolved uncompetitive strategies and provide appropriate responses so as to deter market participants from uncompetitive conducts.

4 BASIC COMPONENTS OF MARKET MONITORING

In this section, we discuss the modeling and tool needs for market monitoring activities. Models are used in monitoring analysis, monitoring response activities and mitigation. We briefly describe the functional aspects of each model.

The market monitoring analysis process is outlined in Figure 2. The collected data, consisting of market and system measurements, serve to drive the process. If an anomaly is detected, the process continues with calculation of appropriate metrics and their reference values in parallel. Calculating of an appropriate metric is based on a key step, which is the analysis of the exogenous inputs' effect on market participants' conducts and system conditions. Using these metrics, the investigation assesses the nature of the anomaly, be it collusive behavior, affiliate discrimination or particular participants' conducts across markets and time.

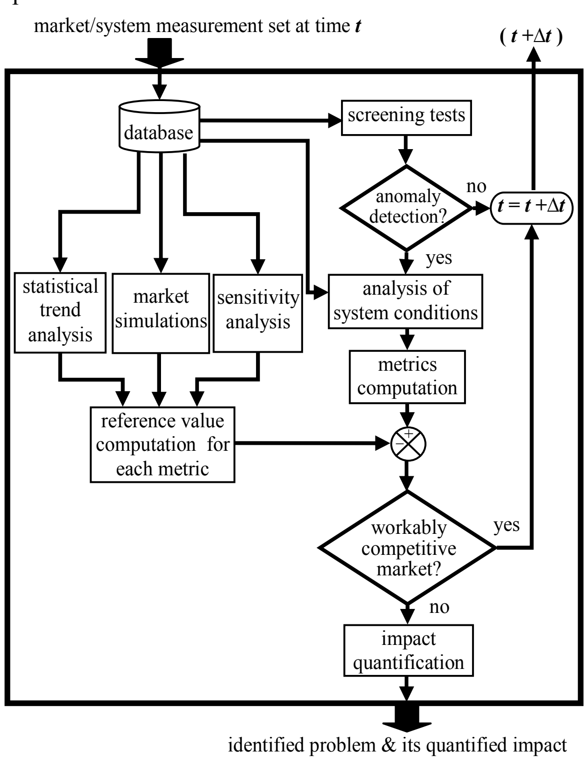

Figure 2: Market monitoring analysis process

Each reference metric value is based on previous market outcomes, monitoring analysis results and characterization of a competitive electricity market by RTO and FERC, and computed by various tools, such as statistical trend analysis, market simulations and sensitivity analysis. Each metric is compared to its reference value to determine whether or not the behavior is uncompetitive. Whenever the deviation of a metric is above a prespecified level, additional quantification of the impacts of the identified problem is undertaken.

Appropriate punitive responses are based on the monitoring analysis results of the uncompetitive conduct's quantified impact. Then, the RTO decides whether a financial or an operational punishment is appropriate. The repeated uncompetitive conducts affect the decision for the amount of penalty imposition.

Mitigation schemes are utilized to prevent uncompetitive outcomes in commodity markets by effectively addressing market power exercise attempts so as to attenuate possible repercussions on other market participants. Two mitigation scheme types are price caps and offer caps. A price cap focuses on the price nature of the offers, and acts as a filter by not allowing the accepted offers to be higher than a preset threshold. On the other hand, an offer cap focuses on each individual offer. This type of mitigation is implemented in two phases: a conduct test and an impact test. The conduct test screens the offers and identifies the ones that exceed well defined thresholds based on individual reference levels which are based on the previous accepted offers or frequently updated marginal cost calculations. Then, the impact test is applied to quantify a particular offer's impact on market outcomes. If the offer impacts the market outcomes substantially, then the mitigation measure is executed as a corrective action, such as replacing the current offer by the reference offer.

While mitigation schemes assure that prices do not migrate above a certain level, there are side effects to mitigation dispatch. The most important one is that mitigation overrides price signals that are useful for asset valuation. Suppressed price signals may result in diminished investment in needed infrastructure. Price volatility truncation may result in less than sufficient generation attraction to the markets which would enable reliable system operations. Mitigation measures may also create perverse incentives for an uncompetitive conduct, such as a bidding behavior resulting in offers within a narrow band just below the cap. The time specific nature of the mitigation fails to capture the inter-temporal market relationships. Additionally, such schemes are not particularly useful if the RTO heavily depends on energy imports. In summary, such mitigation schemes may not be appropriate to foster competition among participants. For example, there may be a need to modify them to allow opportunities for market participants to earn legitimate scarcity rents.

Another responsive activity is to propose market redesign to overcome market design flaws. This activity requires considerable amount of time and involvement of both RTO and FERC. There may be more than one approach to address market design flaws. The appropriate one can be determined by comparison of the magnitude and the likelihood effectiveness of each candidate. The *MMU* also needs to consider each candidate's impact on system reliability, implementation feasibility and the uncertainties posed on market participants.

5 A FRAMEWORK FOR ELECTRICITY MARKET MONITORING

A key objective in the construction of the proposed framework is to develop a tool capable of dealing with all the aspects of market monitoring. To meet this objective, the detailed representation of each market, the modeling of various aspects of the power system and the modeling of market monitoring activities are required. However, market models may vary in various jurisdictions. Consequently, a flexible framework is required to accommodate such differences. Then, market monitoring activities can be comprehensively presented in this framework, taking into account the salient features of electricity markets.

A natural setting for the systematic study of the interactions between market monitoring and electricity markets is an appropriate framework that represents these models and their interactions. We use as a starting point for the construction of the proposed framework the layer structure developed in [24] and provide an additional layer to represent market monitoring activities. The interactions between these layers are through the information flows, as shown in Figure 3.

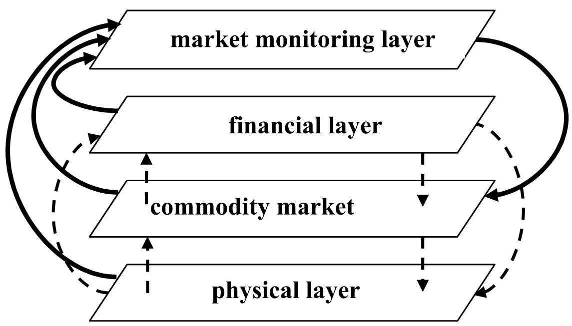

Figure 3: Layer structure framework

The physical layer represents the transmission system, the generation resources and load demand. The relationship between the nodal power injections/withdrawals and the line power flows associated with energy markets are established and various operating and physical network constraints are acknowledged by the RTO. The commodity market layer contains the information on all electricity trades in energy markets, capacity markets and ancillary services markets. The financial layer is compromised of the representation of financial transmission rights (FTR), which are financial instruments issued by the RTO that entitle the holder to be reimbursed for the congestion charges collected by the RTO in energy markets. The information flows are represented by the dashed lines between these three layers. We add an additional market monitoring layer, which is constructed by the components presented in section 4. It gathers information from all layers and provides monitoring responses to the commodity markets layer as mitigation and punitive responses. These information flows are represented by the solid lines in Figure 3.

The monitoring responses are based on a dichotomous outcome—the electricity markets are either workably competitive or uncompetitive markets. We define two competitive levels, workably competitive market level and uncompetitive market level. Each level is a property of a set of market outcomes. In a workably competitive market level, market design features produce "just and reasonable prices", market power exercise issues are small enough not to be considered, and market manipulations are not present. The monitoring response objective is to prevent the electricity markets from uncompetitive market outcomes through the dispatch of appropriate mitigation schemes. On the other hand, the uncompetitive market level can be characterized with the presence of excessive market power exercise and market manipulative behaviors. The monitoring response objective is to change the uncompetitive market level back to the workably competitive market level with an appropriate choice of punitive response.

We start constructing the framework by considering only one market at time t_p. In this market, there exists a set of market outcomes that can be deemed as workably competitive market outcomes. We represent market power exercise and manipulative behavior as anomalous behaviors, causing a transition to the set of uncompetitive market outcomes. Since there may be several market outcomes that may be deemed as workably competitive market outcomes, the corrective response represents the transition between such desired market outcomes. On the other hand, the punitive response represents the transition to the workably competitive market outcomes. These relationships between two competitive levels are shown in Figure 4, where "α_i" and "α_j" represent workably competitive market outcomes; on the other hand, "β_k" and "β_l" represent uncompetitive market outcomes.

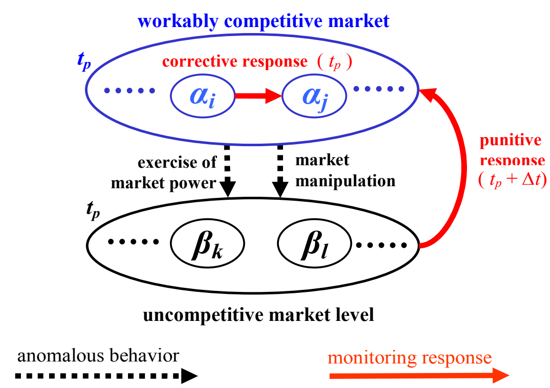

Figure 4: Competitive market levels at time t_p

Since electricity markets are interrelated, a conduct in one market may affect the outcomes in one or more of the other markets at the same time or in any of the markets subsequently. Hence, each market's competitive levels are affected by the conducts in other markets. With the same analogy of a single market, there is also a set of market outcomes that can be deemed to be workably competitive. Now, the monitoring objective is to keep each market's competitive level at the desired workably competitive level. Any undesirable outcome includes at least one uncompetitive market outcome. We represent these relations in Figure 5.

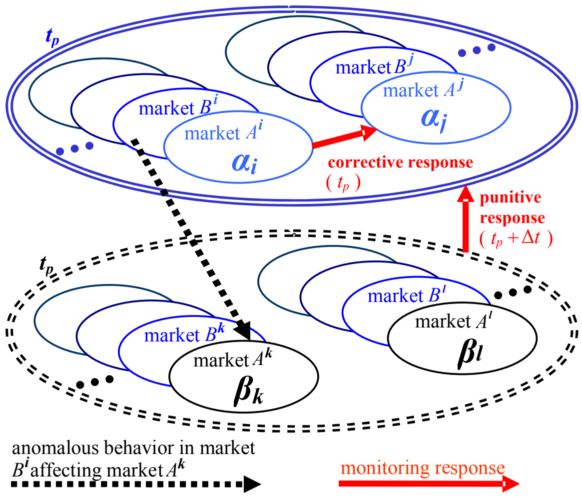

Figure 5: Competitive market levels for each market at time t_p

To be able to capture the inter-temporal relations, we use the multi-market representation for each time, so that it includes previous competitive market levels. Therefore, we have a comprehensive framework showing the effects of past conducts on the present competitive levels of the multi-market structure. The evolved conceptual market monitoring framework is shown in Figure 6.

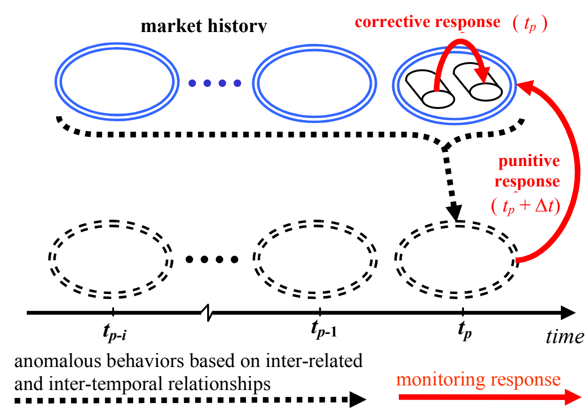

Figure 6: Market monitoring framework

This framework approach for the market monitoring activities is advantageous in many aspects. The modular structure provides analysis of various electricity markets and their interrelationships. The comprehensive analysis characteristics provide representation of different monitoring activities. The proposed market monitoring framework can be used for:

- defining the requirements for monitoring implementation and tools
- representing inter-temporal and inter-market market manipulation and exercising market power strategies and appropriate monitoring responses
- creating adaptive responses for minimizing anomalous conducts impacts on market performance
- identifying the needs for and comparing the existing market monitoring units, and constructing the new ones

In this section, we developed a framework for electricity market monitoring by using the monitoring analysis requirements and the models presented in the preceding sections. We use this framework for a comparative analysis of market monitoring activities for selected RTOs in the next section.

6 COMPARATIVE ANALYSIS OF IMPLEMENTED *MMU*s

The Order No. 2000 and the wide ranging discussion on FERC's attempt of establishing a standard market design have brought to prominence the market monitoring issues. Virtually, every ISO/RTO which has received FERC authorization has implemented a *MMU*. In this section, we deploy the framework described in Section 5 to study comparatively representative samples of *MMU*. Specifically, we study the commonalities and differences of the *MMU*s in NYISO, ISO-NE, CAISO and PJM. The experiences we gain from *MMU*s in U.S. would be also useful to analyze electricity markets in different countries.

The proposed framework provides us a guidance to systematically study the implementations of monitoring analysis process, the mitigation schemes and the monitoring responsive activities of the selected *MMU*s. Each *MMU*'s monitoring analysis includes screening tests which take into account the previous market outcomes and market participants' conducts. These tests include, but not limited to, load & price comparisons, marginal generation tests and out of merit dispatch. Similar tools are utilized for the identification and quantification process, such as market simulations, scenario analysis and sensitivity analysis.

NYISO, ISO-NE and CAISO decide whether the market outcomes are workably competitive market outcomes or not in a similar way [20]-[22]. There exist very well defined thresholds for market participants' conducts and the monitoring response actions whenever such thresholds are violated. For example, in NYISO, if a physical withholding that exceeds the lower of 10 percent of a generator's capacity or 100 *MW*, then NYISO may impose a financial penalty. Another example of such financial penalty is that if the real-time output from a generator that exceeds 110 percent of the ISO's real-time dispatch instruction, and causes or contributes to transmission congestion. If such conducts continue, participants may be assessed multiple amounts of such financial penalty charges. On the other hand, PJM *MMU* does not have the punitive response ability and its responses mainly depend on mitigation activities and market redesign proposals [23].

The market monitoring framework also provides us to easily compare the differences in mitigation schemes. For example, the price cap at CAISO is set to 250 *\$/MWh/h* for energy and ancillary services whereas in the Northeast U.S. markets this is set to 1000 *\$/MWh/h*.

An interesting difference in mitigation activities is that PJM handles mitigation in the Office of Interconnection instead of its *MMU*. PJM automatically mitigates offers that are dispatched "out of merit" to relieve congestion to their highest "in-merit" accepted bid or their cost-based reference levels. Whereas, NYISO, ISO-NE and CAISO executes conduct and impact tests for local market power mitigation. Participants' offers failing both the conduct and market impact tests would be mitigated to the average of previously accepted "in-merit" offers or their cost-based reference levels. Based on this preliminary analysis PJM mitigation scheme has the tightest conditions because of the automatic mitigation imposition to the "out of merit" generators.

The monitoring framework provides us the capability to comprehensively and systematically address the different approaches to market monitoring activities in the selected *MMU*s.

7 CONCLUSION

In the proposed comprehensive market monitoring framework, we describe the competitive market levels, the transitions between these levels considering the inter-market and inter-temporal relationships. This modularity provides good flexibility and sufficient generality in allowing the incorporation of particular models and metrics for different jurisdictions. We use the framework to compare on a uniform basis the monitoring activities in the selected *MMU*s.

Future research needs to focus on the implementation issues and the role of *MMU*s for addressing "seams issues". In addition efficient data collection, market analysis taking account of network topology impacts on market participants' behavior and adaptive monitoring responses need to be addressed.

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