Heuristics to Assist in Overcoming the Complexity of a Restructured Electricity Industry

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***Abstract*—Electricity industry restructuring involves reorganizing a formally centralized monopoly to facilitate decentralized decision-making while also ensuring that the industry is planned and operated in a way that benefits society as a whole. This occurs in an environment that lacks the sound theoretical basis on which other forms of engineering are based. The purpose of this paper is to consider the issues inherent in the organisation of a restructured industry from a conceptual perspective, with particular emphasis on the areas that will assist in the formulation of useful mathematical models of restructured electricity industries. Where possible, linkages to concepts arising in systems theory are observed. It is not contended that systems theory is capable of addressing all aspects of the electricity industry restructuring process; instead it is hoped that new insights into the restructuring process may be gained if the concepts are pursued rigorously.**

***Index Terms*—Restructuring, industry organization, system theory, design objectives**

I. Introduction

Electricity industry restructuring involves reorganizing a formally centralized monopoly to facilitate decentralized decision-making while also ensuring that the industry is collectively planned and operated in a way that benefits society as a whole. Issues that must be addressed during the electricity industry restructuring process include the assignment of decision-making responsibilities between industry stakeholders, the design of mechanisms that constrain, inform and coordinate centralized and decentralized decision-makers, and the specification of interfaces or protocols between various bodies in the industry.

Industry stakeholders include market participants that own and/or operate portfolios of electrical equipment under competitive regimes, non-market participants that own and operate electrical equipment under regulatory regimes, the market operator, system operators and regulatory bodies that oversee the operation of the industry. The decision-making mechanisms that are required to support a restructured electricity industry include laws, electricity market rules, electricity spot market processes, settlement rules and the establishment of markets that allow for the sale and purchase of physical and financial contracts that enable market participants to hedge risks such as spot market price uncertainty. These complement or supercede the mechanisms of the traditional electricity supply industry including power system operating procedures, grid connection standards, reliability standards and power system performance measures.

From time to time, mathematical models that characterize the electricity industry are proposed in the literature (for example [15], [16], [17], [18]). Such models have the potential to offer fundamental insights into how to organize a restructured electricity industry or how to design decision-making processes in a way that is commensurate with societal objectives. However, it is contended here that for the models to be useful in the electricity industry restructuring process they need to account for a broader range of issues. As a result, the restructuring process proceeds in an environment where existing mathematical models that aim to capture the overall behaviour of the industry lag behind practice.

The purpose of this paper is to consider the issues inherent in the organisation of a restructured industry from a conceptual perspective, with particular emphasis on the areas that will assist in the formulation of useful mathematical models of restructured electricity supply industries. In so doing, consideration is given to the nature and purpose of industry restructuring; and where possible linkages to concepts arising in systems theory are identified. It is not contended that systems theory is capable of addressing all aspects of the electricity industry restructuring process; instead it is hoped that new insights into the restructuring process may be gained if systems concepts are applied rigorously. The result of this paper is therefore a list of heuristics or concepts that could be investigated further and used to enhance existing mathematical models and thus advance the theory and practice of electricity industry restructuring.

II. Objectives of Electricity Industry Restructuring and Industry Organisation

Electricity industry restructuring is a never-ending, evolving, multi-objective, politically oriented process that is usually concerned with achieving the following ([1], [11]):

- *Reduce public expenditure by allowing private ownership and operation of a subset of electricity industry infrastructure and functions*. The risks/rewards associated with owning and operating a subset of electrical

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- equipment or undertaking related functions (such as trading companies that participate in the industry on behalf of another entity that owns the physical assets) are managed/captured by corporations rather than by the government. This effectively diffuses risks that were formally managed by a single centralized entity to a set of risks that are divided across numerous decentralized decision-making entities. This is because regulated cash flows are replaced with decentralized, market-based risks/rewards. The transfer of risk from a centralized body to a set of industry participants creates new risks that must be managed including the risk of not being able to create and target incentives sufficiently and appropriately for the industry participants to collectively operate the industry in a way that benefits society as a whole.
- *Ensure continuity in the delivery of end-use energy services, when cost-effective to do so.* The lack of a commercially viable method for storing AC electrical energy makes it difficult to maintain electrical energy flow. However, rather than focusing on electrical energy flow per se, the industry should be structured in a way that mitigates the risks associated with interruptions to the delivery of end-use energy services. This involves all parts of the energy conversion chain, including end-use equipment. The traditional equivalents are the notions reliability and security of supply. The former is a measure of the long-term historical performance of the system's success in maintaining continuity of electricity supply to end-users; the latter is concerned with operating the system in a way that ensures it will be able to reject a set of predetermined credible disturbances that threaten to disrupt supply in the future. A restructured industry should use more inclusive criteria and measures that focus on end-use energy service delivery.
- *Ensure efficient and economic use of resources.* The cheapest means that are in line with societal preferences should be used in preference to more expensive options to meet the demand for energy services. A supply option with low direct costs may not necessarily be the one that benefits society the most, for example society may prefer to utilize generation resources that have the lowest environmental impacts or to adopt end-use options such as enhanced end-use efficiency. This concept should extend from the shorter-term operational horizon to the longer-term industry planning and investment horizon to encompass both operation and investment decision-making.
- *Ensure the industry is operated in a socially responsible way.* The electricity industry exists only because it is deemed to benefit society. Thus the industry is accountable to society and should be operated in a way that is in line with social preferences. These are generally reflected through government policies or initiatives that in turn influence the rules that govern the way in which the industry operates. It also means that the benefits of competition introduced for the wholesale part of the industry should flow on to end-users. That is, end-users should be given greater discretion as to how their energy-related expenditure is directed.

In practice a restructured electricity industry can be thought of as a complex system characterized by interactions between centralized and decentralized human decision-making processes, automatic control systems (a form of decision-making) and the physical processes of the energy conversion chain that are governed by the unique characteristics of that conversion chain. From a processes and information flow perspective the system can be depicted as in Fig 1 (at the end).

The diagram is organised in a way that draws a clear distinction between centralized regulatory functions, centralized market and system operation processes and the decentralized decision-making processes of commercial entities that participate in the industry.

The goal of a "restructured electricity industry designer" is to specify and arrange these processes in a way that satisfies the on-going objectives of restructuring. As discussed this requires defining and assigning decision-making responsibilities of industry stakeholders, the design of decision-making mechanisms including the protocols and interfaces between stakeholders and assigning accountabilities to various industry participants. It is worth observing that while the objectives of restructuring can be stated, the overall process itself evolves and proceeds indefinitely and gives rise to decision-making mechanisms that can never be completely divorced from the social context within which they operate. Thus we can never guarantee what the outcomes of a restructuring process will be.

III. The Role and Nature of Theoretical Models

In practice there is only a limited amount of theory to rely on in terms of designing the decision-making processes that ultimately govern the way in which a restructured electricity industry will operate. For example, it is not possible to guarantee (prior to implementation) whether a given spot market design will satisfy societal objectives for a restructured industry once it goes live. However, a theoretical model that adequately captures the relevant behavior of the key attributes of the industry (such as participant behavior, uncertainty in load profiles and the actions resulting from system operators) may be able to illuminate, in an objective way the strengths or weaknesses of one market design compared to another; it may turn out that some conditions that cause the market mechanism to fail can be identified and rectified prior to implementation, or in turn used to inform the process of constructing market rules.

Such theory would enable the restructuring of electricity industries to proceed in a similar way to other areas of engineering, where systems are designed, tested and then implemented using insight from an underlying body of theory. The theory of restructuring an electricity industry has yet to advance to the stage where this can occur. For example the design of aircraft control systems proceeds in an environment that can leverage results from systems theory where performance bounds and criteria are specified and the appropriate system is designed to satisfy the specification; this does not occur with the same degree of rigor in electricity industry restructuring.

A review of the literature available from both academic sources as well as the material produced by industry practitioners reveals that theoretical frameworks for the electricity industry can be broadly classified into two categories; those that propose mathematical models (such as [17]) and those that comprise commentary on the electricity industry restructuring process with conclusions drawn from the analysis of actual industry outcomes to date (such as [19]).

The former are more closely aligned with the way in which engineers often solve problems; they have the advantage of being objective and are probably well suited to the task of feeding into the industry design process; however, as contended in this paper they don't presently account for the full range of issues inherent in electricity industry restructuring. Thus their predictive power is limited.

The latter are typically developed by economists or industry practitioners and have the advantage of being able to make broader conclusions on the restructuring process and are better able to account for the behaviour of human decision-makers; however they can often be subjective in nature or make inferences based on a sample of data for a single electricity industry. The real world is not a controlled experiment, thus such inferences may not be generalisable.

Models of restructured electricity industries need to overcome a number of difficulties, including:

- *Establishing the purpose of the model*. The electricity industry restructuring process has multiple objectives that are often difficult to prioritize, let alone systematically address within a single model. It is therefore important to keep the ultimate purpose of the model in mind during model-building and recognise the parts (and implications thereof) of the industry that are not incorporated.
- *Overcoming complexity*. A restructured industry is a complex system comprising many processes that interact with each other to varying degrees. In order to establish a model of the overall industry it is necessary to capture its essential features without making inappropriate simplifications. Having said that, it is also necessary to arrive at a model that is no more complex than necessary. The purpose of the model can act as a guide as to the features of the industry that should be included and the degree of detail required for a given model and purpose.
- *Reconciling differences between problem-solving approaches.* Different disciplines offer different modeling and problem solving paradigms. For example, engineering is primarily concerned with describing the operation of electrical equipment while economics addresses human decision-making behaviour. The implication is that different problem solving approaches can lead to different and potentially incompatible conclusions; thus it is important to determine the domain over which a given approach is valid and recognize when its underlying assumptions become invalid.

IV. Heuristics for Advancing the Theory of Electricity Industry Restructuring

To assist in the task of developing theoretical models of a restructured electricity industry and to also help in managing the complexity of the industry, a number of design considerations (or *heuristics*) will now be discussed in two broad categories: managing the physical processes of the energy conversion chain and coordinating the decision-making behavior of humans. The discussions will draw out the implications for the design of restructuring. We acknowledge that the following suggestions do not constitute a complete list of the concerns relevant to the process of electricity industry restructuring.

A. Managing the physical processes of the energy conversion chain

Today's electricity industries deliver end-use energy services by maintaining a continuous flow of electrical energy through the energy conversion chain [2]. The energy flow must be continuous because there are no cost-effective storage mechanisms for electrical energy. This has implications for the way in which the physical processes are modeled and for the resulting decision-making processes.

- *Consider the timescales of the physical processes involved and relate those to the decision-making processes that are to be designed.* Some decision-making processes are best implemented as continuously acting automatic control systems such as for frequency and voltage regulation. Such systems make decisions on a timeframe that is consistent with the bandwidth of the process they control. Where decisions involve humans, there is a lower bound on the period of time required for a human to make a well-informed decision; this needs careful consideration in the design of interfaces between faster-acting automated decision-making and slower-acting human decision-making. Thus the automated or human decision-making relevant to a particular timescale can be considered in isolation only if the interactions with slower and/or faster decision-making timescales are adequately taken into account. Discussions of this issue as it applies to power system dynamics are common in the power systems literature [9], [10] however the topic is less frequently addressed in the economics and management science literature.
- *Decouple the physical process management problems into those related to voltage and those related to real power supply and demand balance and consider them in isolation before recombining to form an overall view on systems operation.* It is often observed [9], [10] that, from a physical perspective, there is only loose coupling between these management aspects of a power system thus treating them as separate problems can be a useful way to reduce problem complexity; although it should be recognized that the two will interact under some circumstances and on

certain timescales.

- *Characterize the relevant uncertainties associated with a particular aspect of the industry being examined.* Electricity industries are subject to a range of uncertainties that need to be carefully modeled and incorporated in any theoretical framework that aims to design decision-making processes to manage those uncertainties. Some uncertainties correspond to frequently occurring events that have well-defined probability distributions; thus statistical techniques can be used to understand and design systems that protect against such uncertainties. Other uncertainties are governed by non-stationary processes (for example extreme weather events, the failure of the software used for control purposes or the introduction of a new class of technology) and consequently need to be dealt with differently; either by examining the impact of a particular sequence of events (as per the analysis of cascading outages) or as in the control systems literature where only minimal information about the nature of a potential disturbance is assumed ([21], [22]).
- *The uncertainty that is to be managed has implications for the decision-making mechanism that is relevant.* The behaviour and implications of stationary processes are largely predictable and it is thus possible to design tools that deal with the uncertainty on a repeated basis; for example electricity spot markets tend to function well when they address the predictable nature of electricity demand but are less able to address situations where cascading outages result in abnormal system conditions. Managing the financial impacts associated with the occurrence of rare events that have ill-defined probability distributions is more likely to require one of the approaches used in insurance [12].
- *Consider the aggregation of uncertainties.* Within network flow constraints, electrical networks naturally aggregate nearly instantaneously the uncertainties associated with both the demand and supply of electrical energy. For instance the combined effect of many end-use decision-makers in the retail sector of the industry gives rise to an aggregate demand profile that exhibits smooth and recurring patterns, which are usually predictable with a level of accuracy sufficient for the purpose of managing aggregate supply-demand balance on an hourly basis [8]. In a similar way the correlation of the random processes that describe wind energy generation when aggregated to a sufficient level give rise to an overall pattern of generation that is relatively smooth and can be managed in a systematic manner [3].

  This has implications for the design of the forecasting algorithms, which in turn will have implications for the decision-making processes that use the forecasts, such as demand in spot markets and projections of future supply-demand balance. A specific example is the degree of aggregation used in forecasting wind power and the corresponding network model that is used in a spot market. Forecasting the overall injection of power due to many wind generators will give rise to a forecast that is less variable than a set of forecasts for the power injections from each wind turbine. A regional spot market model that supports the overall aggregate forecast is less likely to produce volatile pricing patterns than a finer grained nodal spot market network model that requires a set of individual forecasts. While these are two extremes, it demonstrates that there is a trade-off between the aggregation of uncertainties, the type of forecasting that is used and the types of spot market that might be implemented.
- *Distinguish between end-use energy service delivery and service acquisition.* In order to satisfy the end-use service continuity objective of a restructured industry, it is necessary to acquire and when necessary, deploy ancillary services. Ancillary services protect the system against a variety of uncertainties such as small deviations in the electrical supply-demand balance and large deviations that result from the failure of a critical component in the energy conversion chain. Some ancillary services are deployed on a continuous basis (such as those concerned with frequency and voltage regulation) while other ancillary services are deployed only in the event that they are required (such as frequency-sensitive load shedding and network switching schemes).

  The way in which the ancillary service is physically implemented and the conditions under which it is required have implications for the mechanisms that are used to acquire the service and the process concerned with monitoring its delivery. In some situations it is difficult to confirm whether a service that was acquired but not used would have been required. For instance, it is difficult to audit the state of a generator’s control system and implement rules to penalize the participant if the service could not actually have been provided if required.
- *Consider the application of hybrid systems theory: analysis of interactions between discrete and continuous time systems.* An AC power system operates with oscillating power flows but for most purposes can be modeled as continuous unidirectional energy flow from generators to loads. The key inputs into the system comprise controller set points and the main disturbances are exogenous effects on generation and load equipment. Typically a low-order power system model is sufficient for capturing the system normal behaviour [14] and has a process bandwidth that occupies the electromechanical portion of the spectrum. In order to facilitate the decision-making processes of humans, the electricity spot market should occur on a time frame that is in line with the time required by market participants and the market operators to make informed decisions; this implies that the market must operate more slowly than the underlying process dynamics.

  If we separate the market from the underlying continuous time system then an interface between the two must be established. A design choice is to consider the market to be a discrete time process, thus the overall system is a hybrid. Consequently there are limits on the extent to which the market can control the continuous time power system as a consequence of Shannon's reconstruction theorem. This implies that a sample period of around ten times the process bandwidth is required for good controller performance [13] with slower sampling periods resulting in degradation of the controller performance. Thus an electricity spot market set up as a discrete time system can't be expected to provide good control of the underlying continuous-time physical process.

- *Consider the use of switching control to understand the implications of regime-shifts [23].* The successful operation of a restructured electricity industry requires a set of decision-making processes that manage particular extreme events when they occur. Sometimes a transition from a "system-normal" decision-making regime to another is required. For instance different processes are often established to overcome severe disturbances, allocate standby resources and address the issue of restarting the system following a partial or total blackout. The use of switching control systems theory may assist in understanding how to design schemes that are capable of transitioning from one set of decision-making constructs to another, in a robust and stable manner.

  In a restructured industry, significant pressure is imposed on system operators because commercial outcomes must also be kept in mind when resolving technical issues. Placing regime shifts into an objective framework should provide insights into the design of decision-support systems that assist operators in identifying the conditions under which to shift from one regime to another. This will also assist in making it clear to market participants the conditions under which operators may intervene or suspend the market and thus reduce the uncertainty of the environment within which market participants make commercial decisions.

B. *Coordinating participant behavior*

Electricity industry restructuring overlays commercial, policy and regulatory decision-making on the technical operation of an electrical power system. Theoretical models that seek to capture this paradigm need to account for the behaviour of humans or at least make an assessment of the extent to which a design accounts for human decision–making. Some heuristics that address this aspect of modeling human decision-making are as follows:

- *Distinguish between centralized and decentralized decision-making processes but recognise a combination of both will be required.* Electricity industry restructuring is in part motivated by a transfer of the responsibility and associated risk management of electrical equipment asset ownership and operation to industry participants. A restructured industry is thus a movement away from centralization toward a system that facilitates decentralized decision-making. However the successful operation of an electricity industry requires portfolios of equipment to operate in a coordinated manner. Therefore some level of coordinated (or centralized) control is needed. In some situations a market-based outcome can't provide the required degree of coordination or control and thus there is a need for procedures or rules that enable system or market operators to override or at least strongly influence the decentralized decision-making autonomy of market participants.

  Furthermore, to the extent that a restructured industry is planned and operated in a way that is accountable to society there will be a need for centralized processes that in some way enforce societal preferences and impose a preferred direction on the industry. In practice this becomes the role and responsibility of policy makers and regulatory bodies. Consequently, it is not possible to dispense with centralized decision-making processes within the context of electricity industry restructuring; successful operation of the system will require both forms of decision-making and it is critical to understand how best to organize the system to balance the trade-off between centralized and decentralized processes and to manage the inevitable overlap between them. Thus the interplay between centralized and decentralized decision makers should be reflected in mathematical models of restructured industries.

- *Prices can be thought of as a form of control – but be careful*. Prices induce participant responses; economics is concerned with developing ways of encouraging participants to reveal their true preferences thus causing participants to converge on market prices and volumes that are competitive and efficient. An analogy can be drawn to multi-variable feedback control systems, where the objective is to design control schemes that maintain stability as well as other objectives such as minimizing a cost function. While the specific details of control theory may not apply in a verbatim manner to the design of pricing techniques for use within a restructured electricity industry, the insights remain useful provided the areas where differences arise are observed and accounted for.

  A significant difference is that there is no guarantee that the subsystems (decentralized market participants) that accept a price signal (or a control signal) will respond. It is also unlikely that a single control variable (or pricing signal) is sufficient to coordinate the actions of the decentralized subsystems because it may not communicate all that is required to ensure the system remains stable (which reflects the objective supply continuity objective) or that efficient resource allocation will occur. The analysis of the controllability and observability requirements and investigation of different control system architectures may provide insights into the information flows that are required between market participants and system/market operators or provide insights into the way in which different architectures overcome different types of disturbance. For example, it appears that the existence of efficient derivative markets is a prerequisite for efficient investment decisions in a restructured electricity industry [24].

- *Understand that commercial contracts cannot dictate physical outcomes they can only determine financial outcomes.* Restructuring is concerned with the introduction of commercial contracts that are imposed over the top of the energy conversion chain physical processes. The contracts have financial implications some of which are linked directly to physical process outcomes while others are purely financial derivative products that have outcomes that are dependent only on financial outcomes (typically spot market prices). In practice, participants need to construct portfolios of these products and are concerned both with controlling their exposure to financial outcomes and influencing physical outcomes. It is useful to keep this distinction in mind as different portfolios will hedge exposure to different aspects of risk and can therefore be used to mitigate or hedge against different forms of uncertainty.
- *Recognize that human behaviour is complex and may not be rational.* Experiments conducted in the field of psychological economics [4] reveal that decision-making humans often fail to make rational decisions, in the sense of profit-maximizing behavior. Consequently game theoretic models for human behavior that are based on the concept of a Nash-equilibrium are useful in finding benchmarks but often fail to account for all of the different ways in which participants may make decisions and "stress the system". For example another type of participant decision-making is that of tacit collusion [5] where participants are able to use market outcomes to effectively signal to each other when to exhibit a particular behavior that will enhance their ability to exercise market power.
- *Representation of market power and recognizing the various forms of market power*. There are numerous ways in which market power can be exercised and analyzed. It is important to select a model that is appropriate for a given purpose. For example, assessing the robustness of the short-term operation of a power system against the exercise of market power requires different metrics to those used to detect market power on longer timescales. In this context, [7] advocates the use of real-time market power metrics in preference to the traditional indices like hedge ratios or market concentration indices while [6] observes that market power assessment needs to account for inter-temporal linkages and suggests the use of techniques that measure deviations away from benchmark prices based on marginal costs. It is also important to recognise that the portfolio and hence the technology mix that is owned and operated by an industry participant has direct implications for the exercise of market power; an industry with a small number of large (and varied) asset portfolios is unlikely to be as competitive as an industry where there are many small portfolios.
- *Recognise that the ongoing evolution of a restructured electricity industry is based on a process that includes the opinions of industry participants and stakeholders, including the public at large.* The electricity industry restructuring process normally involves consultation processes that allow representatives from all sectors of the industry to influence outcomes, for example, in terms of market rules or regulatory arrangements. This is a necessary part of the successful functioning of a market, however the process may also be subject to gaming by organizations that participate in the relevant electricity market as well as from non-market participants that are pursuing their specific interests. Consequently, the consultation process should also be designed in a way that is robust against such forms of gaming and such that the ongoing evolution of a restructured industry doesn't deviate substantially from its objectives.
- *Recognize that system and market operators are also human-decision making agents.* The human decision-making involved in system and market operators is also extremely important in the successful functioning of a restructured electricity industry. When emergency conditions arise system operators may need to take corrective actions rapidly in order to stabilize the power system before a complete or partial system collapse occurs.

  This is an example of where the importance of the objective of ensuring supply continuity (an engineering issue) may conflict with that of ensuring the industry allocates resources in an economically efficient manner. This has implications for operating practices as well as for the design of market mechanisms that resolve the potential loss of autonomy experienced by market participants in clearing the disturbance or in resolving inconsistencies between market outcomes and actual physical outcomes.

V. A Brief Case Study From the Australian National Electricity Market

In the Australian National Electricity Market (NEM), a spot market process is solved on a 5-minute cycle, resulting in generator dispatch targets that are to be tracked by the generators. Generators are allowed to modify their offers every 5 minutes. Generators that fail to follow their dispatch instructions for a long enough period with a large enough discrepancy between the target and actual generation may be penalized [25].

Fig. 2 [20] compares the spot market targets and measured generation for a peaking generator in the NEM. In this case, the non-compliance of the generator with targets would not have been significant enough for the owner to incur a financial penalty; however it raises the question of the consistency between the physical behavior and the spot market solution.

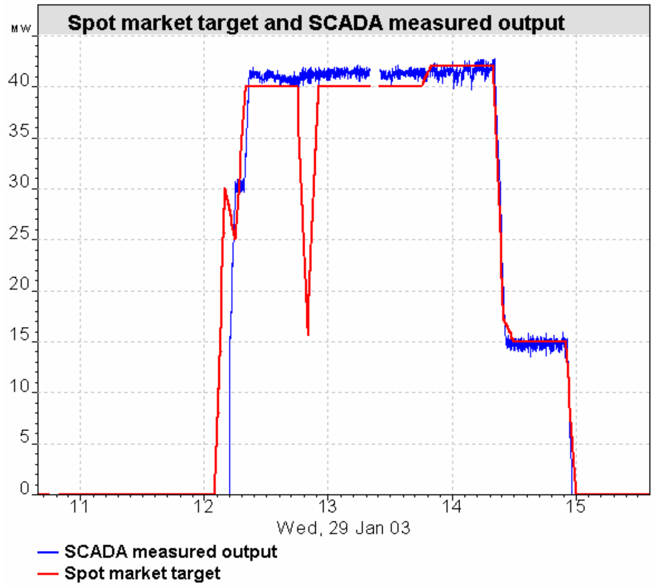

Fig. 2. Graph illustrating market targets and actual SCADA generation for a generator in the Australian NEM [20]

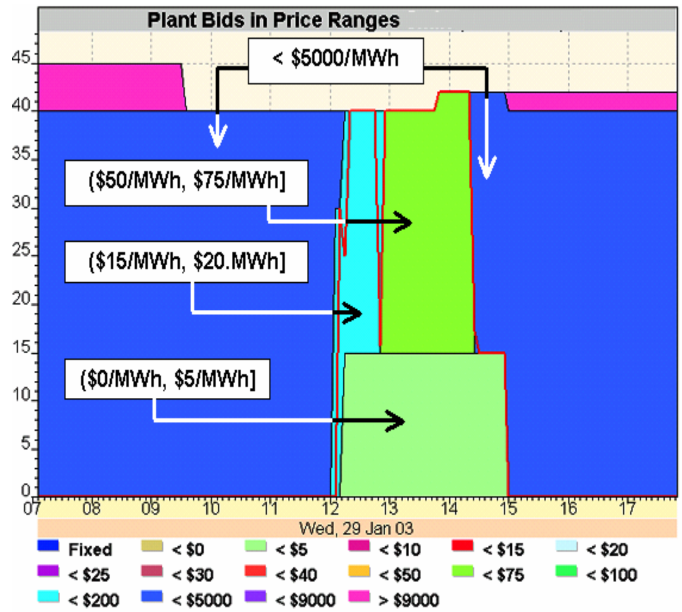

Fig. 3. Graph illustrating market targets and actual SCADA generation for a generator in the Australian NEM [20]

Because generators are paid on the basis of metered energy, had the generator followed the dispatch instruction exactly it would have lost spot market revenue. Thus there is an incentive to generate while prices are high and ignore dispatch instructions to the extent that the generator can avoid loss in revenue. However, the threat of being identified as a non-conformer means that such a strategy is unwise in the long run and so, as is shown in Fig. 3, in this case the generator modified its offer strategy to offer more generation at a lower price. This resulted in the generator receiving a target that was consistent with its present output.

As shown in Fig. 4, the price in the generator's market region fell as a result. This demonstrates that the economic mechanism of the spot market combined with rules based on the physical performance of the generator resulted in a reasonable outcome. However it is also worth observing that in this case the gain in revenue for this generator would have resulted in a loss of revenue for the other generators in the system and under a more extreme situation it may have violated security criterion.

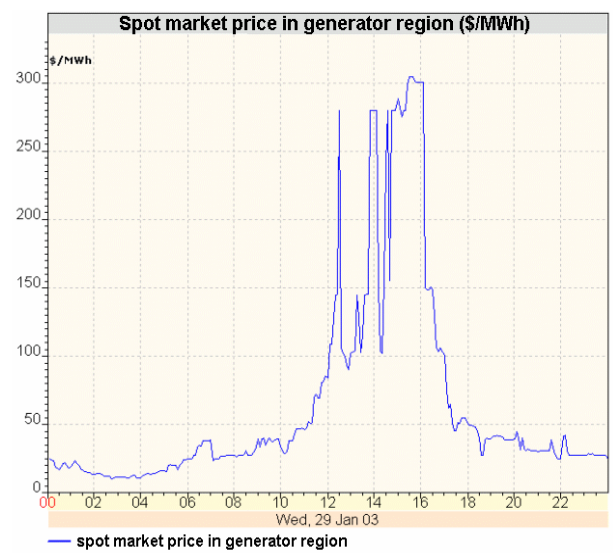

Fig. 4. Spot market price in region of the generator [20]

This brief case study demonstrates how a number of processes interact; namely the spot market, rules governing non-conformance and the threat that such non-conformance may result in a financial penalty. It demonstrates an interaction between the physical operation of the system and the commercial decision-making of humans. Generator owners participating in the Australian NEM can only achieve their desired physical generator behavior through their spot market offer functions.

VI. Conclusions

Electricity industry restructuring is a complex task that would benefit from improved understanding that could assist in the design of decision-making processes that are efficient and effective in meeting industry objectives. Theoreticians should recognize the multidisciplinary nature of the restructuring process, combine the understandings of different disciplines and consider both the equipment and the human dimensions of the industry.

This paper first highlighted the importance of keeping the objectives of electricity industry restructuring in mind in the design and implementation of the decision-making processes. It then provided some heuristics that can assist in advancing the theory of restructuring. Where relevant, the paper identified insights from system theory that may assist in overcoming the complexity of a restructured electricity industry or that may lead to alternative ways of formulating the problems to reduce the gap between engineering and economics as it applies to electricity industry restructuring. A simple case study from the Australian NEM provided an example of interaction between the engineering and economic models of a restructured electricity industry.

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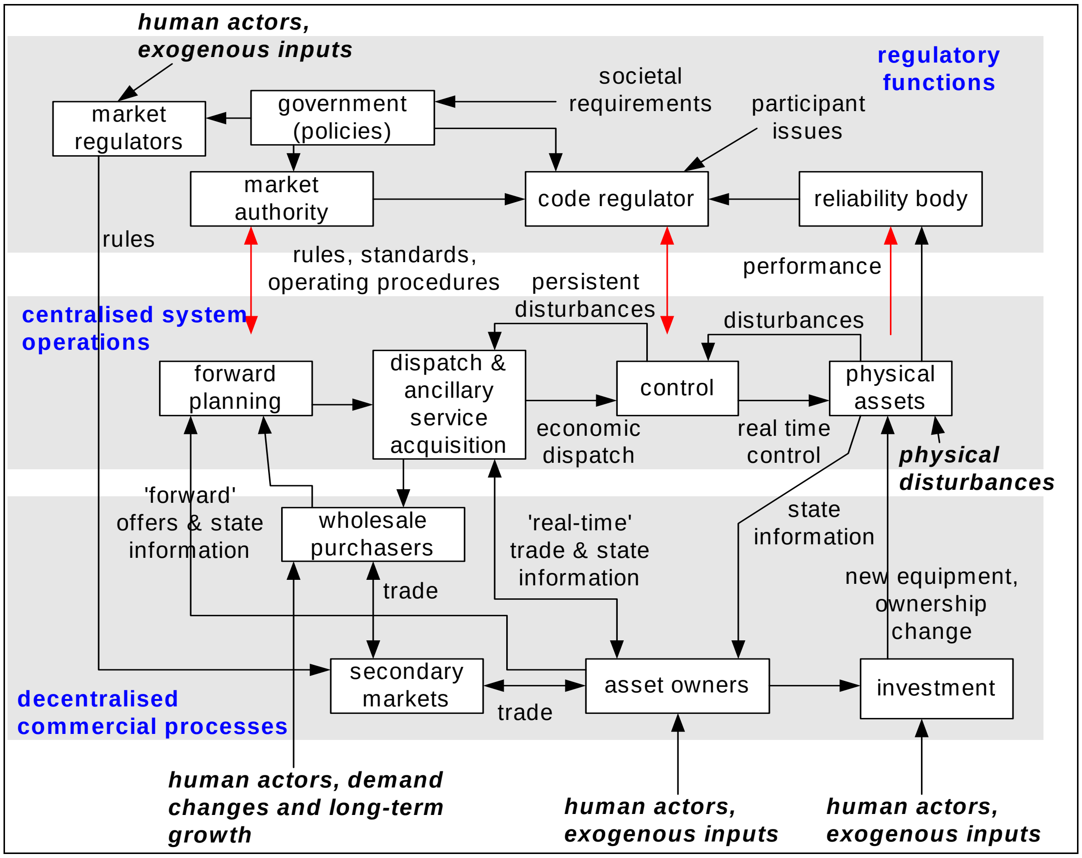

Fig 1. Processes and information flow diagram for a restructured electricity industry.