Inter-Organizational Demand Response Applications: How to Address Moral Hazard in Smart Grids

Completed Research Paper

Strüker, Jens
Fresenius University of Applied Sciences,
Limburger Str. 2, 65510 Idstein, Germany
jens.strueker@hs-fresenius.de

Reichert, Stefan
University of Freiburg, Department of Telematics,
Friedrichstrasse 50, 79098 Freiburg, Germany
stefan.reichert@iig.uni-freiburg.de

Brenig, Christian
University of Freiburg, Department of Telematics,
Friedrichstrasse 50, 79098 Freiburg, Germany
christian.brenig@iig.uni-freiburg.de

ABSTRACT

Intermittent renewable energy sources such as wind and solar are increasingly integrated into the power grid. So-called Demand Response (DR) applications are a relatively low-cost and quick means to balance the resulting generation fluctuations. Against this background, the allegation of fraud against a large DR provider in 2011 gives rise to questions about a systematic cooperation problem. We address this potential market failure and analyze the demand response business model by using the principal agent theory (PAT). We show that hidden action can indeed lead to market failure. Among the possible PAT solutions we show that *monitoring* can be realized based on a combined openADR protocol and data integrity approach. Finally, we highlight the prospects of a standardized and automated IS-based solution and provide an outlook of current research gaps.

Keywords

Demand Response, IS for Green, Principle Agent Theory

INTRODUCTION

The energy sector is in a transition process from fossil fuels to renewable energy sources. Many nations around the globe changed their policy towards energy significantly. Good examples for this paradigm shift are the different 'Renewable Portfolio Standards' that have been set around the world. The standards generally place obligations on electricity supply companies to produce a certain amount of their energy from renewable sources. For instance, the Californian legislators have required that 33 percent of the state's electricity procurement comes from renewable sources. Similarly, the European Union's "20-20-20 goals" demand a 20 per cent increase in energy efficiency, a 20 per cent reduction of CO2 emissions, and 20 per cent use of renewables by 2020. To accomplish these ambitious goals, governments and private market actors are formulating visions for future energy systems. However, the integration of fluctuating electricity generation has already proposed many challenges for the energy supply. Successful transformation of energy systems is inseparably linked to a smarter grid, because the principle that production follows demand no longer holds and there arise questions about the ideal incorporation of renewables. Information systems (IS) are going to play an important role in making electricity grids smarter by solving issues such as accurate prognosis, measurement of electricity consumption and the design of adequate data exchange infrastructures. Automated information exchange is a main challenge in this context (e.g. Strüker et al., 2011).

A key concept of intelligent grids is the active integration and involvement of the demand side. Stabilizing grids with a high share of renewable generation by managing the demand side is seen as a promising solution (FERC, 2009). Demand response plays an important role in this context and provides opportunities for attractive business models. In the USA, the DR market is estimated at around 8 billion dollars (PJM, 2013). PJM, a large US Transmission System Operator defines demand response as end-use customers reducing their use of electricity in response to power grid needs, economic signals from a competitive wholesale market or special retail rates (PJM, 2013). It creates not only financial rewards for participating entities, but also significant social and environmental benefits. Accordingly, reduced consumption in response to grid emergencies or market-price events enables utilities to substitute expensive power plants only used in times of peak demand (Johnson Controls, 2012).

Although demand response programs offer many benefits for the involved parties, there are potential conflicts of interest that must be considered thoroughly. The participation of different market roles, like Independent System Operators (ISO), Regional Transmission Organizations (RTO), aggregators, retailers or end-consumers with diverging interests is typical for business relationships in demand response programs. Furthermore, they are characterized by asymmetric information, what describes a situation where there are different knowledge-levels. A dispute between PJM and the aggregator EnerNOC about the measurement of demand response programs illustrates the conflict-potential caused by diverging interests of the involved parties under asymmetric information, which may lead to market failure in the worst case. We show that these relationships can be modeled as a principal agent problem providing several solutions to this moral hazard phenomenon. We then examine how information systems can contribute and provide a monitoring solution based on data integrity and the OpenADR standard specifying applications and the exchange of messages for demand response services.

The paper is structured as follows: First, we describe the controversy between the demand response aggregator EnerNOC and PJM about the measurement and billing of demand response services. This is followed by an analysis of the relevant business processes and the potential added value. On the basis of our case study, the asymmetric relationship and potential conflicts caused by moral hazard will be illustrated as a principal agent model. The next part develops the solution concept based on an incorporation of OpenADR with a data integrity approach. The last section highlights perceived strengths of OpenADR and the data integrity approach and discusses why they are suited for combining them. Finally, we give an outlook about additional research requirements regarding the valuation of switched loads and opportunistic behavior based on revenue sharing with more than two parties.

DEMAND RESPONSE AND ENERGY MARKETS

Demand Response describes all kinds of intentional modifications in consumption patterns of customers that are intended to alter the timing, level of instantaneous demand or the total electricity consumption (Albadi and El-Saadany, 2007). There are several instruments which create economic incentives in order to manage the demand-side. Current literature mostly discusses price incentives in the form of variable tariffs like real-time, time-of-use or critical peak pricing (e.g. Borenstein et al., 2002, Joskov and Tirole, 2005). However, there are also far-reaching opportunities for Direct Load Control programs, where certain energy consuming devices are externally controlled (Faruqui, A. et al., 2009). Covering areas of 13 different states in the Eastern US, PJM operates the world's largest energy marketplace. Classified as a Regional Transmission Operator (RTO), it manages the high-voltage electricity grid within its service area and interacts with more than 800 different members. PJM operates a competitive wholesale electricity market where producers can offer their energy supply. Equivalently, the market rules also allow offers from demand response resources as capacity, energy or ancillary services which then can be used by retailers or grid operators to balance demand and supply. These offers are set by aggregators, who represent and bundle individual end-use customers. According to their reduction of consumption, the aggregators compensate the consumers for their participation. The largest aggregator in the market is EnerNOC, with which PJM had a strong controversy in the last years about the measurement of demand response participation. The dispute began in February 2011, when PJM first accused EnerNOC of "double counting" some of their customers participation of certain demand response programs (John, 2011). According to PJM, this technique was a way of market manipulation which not only allowed EnerNOC to reap undeserved financial rewards, but furthermore threatened grid stability. PJM stated that the double counted megawatts allowed EnerNOC to compensate for underperforming demand response participants who did not meet their contractual agreed target level by over-counting the participation of others. Therefore, those megawatts would not have reduced overall consumption in times of peak demand but instead expose a risk for the grid stability for which PJM had to pay twice (Sutherland, 2011).

	Emergency Load Response Programs			**Economic Load Response Programs**
Capacity/ Energy	Capacity only	Capacity & Energy	Energy Only	Energy Only
Mandatory/ voluntary	Mandatory Curtailment	Mandatory Curtailment	Voluntary Curtailment	Voluntary Curtailment
Capacity payments	Capacity payments based on Reliability Pricing Model clearing price	Capacity payments based on Reliability Pricing Model clearing price	No capacity payment	No capacity payment
Energy payments	No energy payment	Energy payment based on submitted higher of "minimum dispatch price" and Locational Marginal Price Energy payment during PJM declared Emergency Event mandatory curtailments.	Energy payment based on submitted higher of "minimum dispatch price" and Locational Marginal Price. Energy payment only for voluntary curtailments.	Energy payment based on Locational Marginal Price less generation and transmission component of retail rate. Energy payment for hours of voluntary curtailment.

Table 1: Overview of PJM's demand response program, table based on (PJM, 2012)

The problem of double-counting came up because of two different ways in which PJM measured demand response participation (John, 2011). The first one is called peak load contribution (PLC), which measures the reduction of consumption in relation to the consumption of the customer during its five peak hours the year before. This could yield financial benefits for the consumers which were not directly considered as demand response. Only reductions in consumption below the PLC should be counted as demand response. However, the second measurement option, called the Guaranteed Load Drop (GLD), worked differently. It aimed to measure how much demand response is contributed by individual customers compared to reference consumption data which included the PLC-based reductions. This way, the results from over-responding consumers in the GLD program could be used to compensate for nonresponsive participants in the PLC program. Because of the use of reference data in the GLD program, this would not necessarily lead to actual reductions, as it is required for PLC. As a result, the GLD numbers could overstate the reductions of individual consumers.

These differences in the measurement system could allow EnerNOC not only to get paid twice for the same reduction, but also to cover underperforming customers elsewhere in the portfolio. The financial rewards earned from the double-counted megawatts could easily be kept within the company and not be forwarded to the consumers, since they are simply not informed about the compensation mechanism at the wholesale market. The knowledge of the aggregator about the differences in the measurement systems could also allow getting new customers in some areas which might never have to deliver their reductions as long as they are covered by the extra capacity (John, 2012). At the core of the problem is therefore the unique knowledge of the aggregator which of its customers contributes how much to the overall reduction. In the beginning of the dispute, the Federal Energy Regulatory Commission (FERC) sided with EnerNOC and ordered PJM to keep its existing market rules. In November 2011, however, it approved PJM's proposal of a change in how to measure demand response activities. Furthermore, in February 2012 the FERC accepted PJM's compliance filing and the proposed market rules completely, which ordered EnerNOC to bid in an auction for the double-counted megawatts.

This case illustrates the complexity of the American demand response market. Programs are listed in a wide array of names and categorized differently by individual market actors. Whereas ISO/RTOs usually classify their programs by purpose, such as load as a capacity or demand response resource, retailers generally classify programs according to the mechanism employed for reducing load (FERC, 2012). Already in 2011, the FERC made a public acknowledgment in their annual report that the variety of demand response programs causes a big challenge for the utilities and grid operators to correctly account demand response. This lack of transparency can lead to opportunistic behavior by different market actors and, as a result, to market failure.

ANALYSIS

Before we provide an analysis of this impending market failure, we first have to look both at the different market actors and their interests and the revenue sharing models in place. There are several opportunities for an ISO/RTO to benefit from demand response programs. One aspect is the access to more precise usage of data collected by the aggregator, which can contribute to better forecasts of future energy consumption and therefore stabilize the grid. An additional point to consider is that if the grid operator recognizes potential grid-instabilities, it is his responsibility to provide compensation-capacities for such situations. As shown in Figure 1, there now are two possible alternatives to resolve the problem. Firstly, he might rely on existing power plants, which are available for backup purposes. However, these plants require high investment costs and only used for a few hours per year on peak load periods. Secondly, he can use demand response programs in order to shift load and therefore stabilize the grid. The decision criterion is the costs associated with both alternatives. If it is cost-efficient to use demand response, the ISO/RTO contacts the aggregator and requests to shift load. The aggregator then automatically or manually informs the participating end-consumers, to shift their energy demand. End-consumers have financial incentives, because they get compensated for the provision and the aggregator is paid by the ISO/RTO.

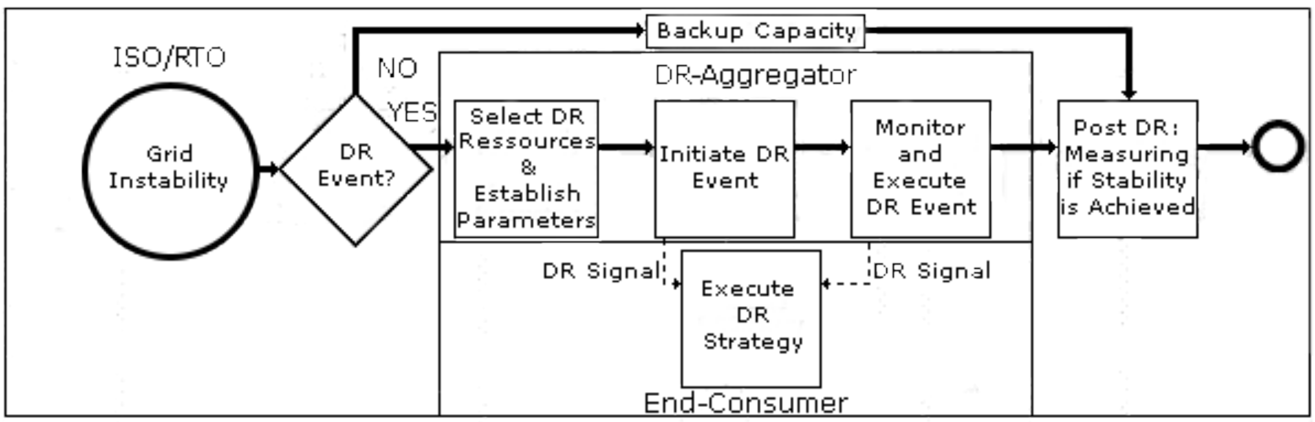

Figure 1: ISO/RTO-Aggregator-End-Consumer, based on (UCA, 2011)

As the PJM-EnerNOC dispute illustrates, asymmetric information is often prevalent in markets for demand response. This is mainly due to the fact that the measurement of actual delivered demand response megawatts is difficult and errors are to some extent unavoidable in the verification process (Borlick, 2010). In contrast to consumed energy, non-consumed energy can often only be approximated via reference load curves. This leaves the aggregator as the supplier of demand response services with a decisive informational advantage over the principal, which can be used for opportunistic behavior. In fact, several cases of gaming activity have been recognized by the FERC, which made attempts to reduce the chances for such behavior (FERC, 2008).

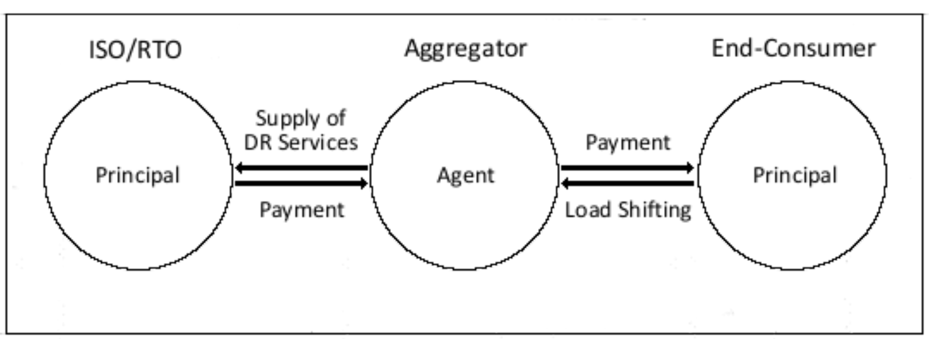

Figure 2: Relevant Case of the Principal Agent Model

The problematic relationship between the market actors has two sides. The one side is the relationship between the buyer of demand response services and the aggregator. The other is between the aggregator and the consumer. The interconnection between these two relationships can be illustrated as a common agency problem, where both principals independently try to influence the decisions of a common agent. Existing literature provides evidence that an efficient solution under these circumstances can be found (Bernheim and Whinston, 1986). When an ISO/RTO wants to buy demand response services in order to balance the grid, the needed quantity is requested on the market. Then it is left to the aggregator's discretion on how to reduce load. The aggregator has the unique information about the individual involvement of the participating consumers. The chance to over-count the contribution of some of the consumers by using overlaps between existing programs can then induce moral hazard. Simultaneously, the aggregator also has an informational advantage over the participating consumers. As the real providers of demand response services, they authorize the aggregator to offer their reductions at the energy market. The consumer therefore takes the role of a principal who only has a limited chance to oversee the agent's behavior. In fact, most of the industrial and commercial consumers have only little knowledge of how their reductions are used on the energy market.

The possible solutions to the principal-agent problem depend on the underlying characteristics. If asymmetric information arises *ex ante*, prior to a contractual agreement, the principal would not know the type of the agent. He could then look for forms of signaling, which would indicate the characteristics of the agent (Maskin and Tirole, 1990). Alternatively, the principal could use screening methods to evaluate the quality of different agents. In both cases, costs play a crucial role of whether or not the players can overcome the problem. Whereas in the first case the agent has to acquire a type-related costly signal, it is the principal in the second case that has to decide if the costs of screening outweigh the disadvantages related to the asymmetric information. Since asymmetric information mainly occurs *after* a demand response event is scheduled, the ex-ante case only takes on a minor role in the demand response market. Signaling and screening do therefore not offer sufficient solutions in this particular case.

Thus, *ex post* asymmetric information cases are of much greater interest for the potential solution of the problem. This is because the demand response aggregator tries to shift load only after a buyer has made a request for demand response. Consequently, the aggregator sells the reduced megawatts into a specific market program. When an aggregator is double-counting megawatts, we would have a case of hidden action rather than hidden information. This is because the aggregator has the discretion of how to fulfill demand response services. There are two distinct kinds of solutions for this case of moral hazard. The first solution is an incentive based contract design, which entails that the principal rewards the agent for the performance, instead of fixed compensation. Properly designed, incentive based contracts can be an effective and inexpensive way of eliminating the divergence of interests. However, since in many markets the megawatts simply get bid into the market, there are often no specific contracts between the actors. We will therefore not focus on contract design in this paper.

Instead, the second potential solution might be most promising for this kind of moral hazard. Thorough and consequent monitoring of the aggregator as an agent could reduce the chances for opportunistic behavior. By carefully measuring and controlling the actions undertaken by the aggregator it might be possible to completely eliminate this problem. This requires investments in new technological standards. It is furthermore desirable to increase transparency in the complex demand response market by simplifying existing market rules. The question of whether or not monitoring can help to overcome the moral hazard problem crucially depends on the costs that arise through monitoring. Information systems can help to significantly lower these costs. In the following we will therefore discuss potential solutions through monitoring over the use of information systems.

ENSURING DATA-INTEGRITY IN INTER-ORGANIZATIONAL DEMAND RESPONSE APPLICATIONS

Our solution concept is based on the monitoring of the agent with help of a data integrity approach. Data integrity hereby refers to the overall completeness, accuracy and consistency of data (CIDA, 2005). The integrity problem in information technology security concerns the unauthorized modification of data and how to preserve data integrity where the data is subject to modifications (Moss, 2005). Over the last years, the question of data integrity in smart grids has slowly moved to the center of attention. Increased security concerns led to a variety of attempts to make smart grids safe against attacks from the outside (Sridhar and Manimaran, 2011). While there exist plenty of well-known integrity mechanisms to choose from, Karwe and Strüker (2012) illustrated that the necessary precondition for any data integrity mechanism for measurement data is the digitization of demand response processes. Accordingly, they addressed this issue by looking at the so-called openADR protocol and could show its appropriateness.

OpenADR is a protocol that defines the interaction between the demand side manager (DSM), who performs demand response and the demand side management client. It is the only existing open data model to exchange messages for demand response events, designed for the use between a service provider, aggregator and end-user in commercial, industrial and residential markets (OpenADR Alliance, 2012). One key point why OpenADR benefits all involved parties is, that one common communication standard reduces costs for the integration of different demand response programs and technologies the more products implement the protocol. PJM piloted OpenADR 2.0 for wholesale DR market communication 2012 and tested the security capabilities implementing their own DR programs. Three use cases were tested: a traditional demand response event, a price based load response event and the verification of load shed with real-time meter telemetry. As expected, the participants indeed appreciated the use of one single open standard, instead of being forced to implement heterogeneous protocols for every energy market they decide to participate in (Holmberg et al., 2012). The same argument can be applied for the monitoring of information streams. One common protocol potentially reduces monitoring costs through standardization and makes it practicable for implementation. Additionally, the opportunity to participate in multiple demand response programs increases competition and simultaneously reduces incentives for opportunistic behavior. Another point why OpenADR seems suitable as platform for a data integrity approach is the OpenADR Alliance, formed in 2010, with more than 70 members (including software vendors, electricity-service providers/operators and research institutions) by now. They are already spending effort in questions of cyber security to ensure secure deployments of applications using the OpenADR standard (Holmberg et al., 2012).

DISCUSSION

One of the main problems in evaluating demand response solutions is the different values it is presenting for different market actors. A grid operator who is mainly focused on grid reliability has completely different benefits from demand response than retailers. Those would primarily benefit from the potentially cheaper alternative to energy generation. End-use customers on the other hand are mainly concerned with the trade-off between their revenues and opportunity costs. Besides the non-monetary values of demand response, it is also very difficult to accurately measure shifted loads itself. As the PJM vs. EnerNOC case illustrates, it is a big challenge for the participating market actors to find a consensus of how to correctly account demand response. Different measurement and verification options make this a very difficult task. However, the accounting process between the aggregator and the buyer of demand response services is not the only problematic one. The relationship between the aggregator and the end-use consumer is similarly complicated. Industrial consumers do often not want to reveal the true marginal costs of their machines. This makes it a big challenge for the aggregator to evaluate the actual potential of demand response. Therefore, the optimal solution is twofold. Firstly, it is needed to find a common standard to accurately measure and account demand response. Secondly, we need to find a way to determine the specific value of demand response for the different market actors.

To define a common basis for correctly measuring demand response we suggested openADR as the most advanced communication standard. For the second step we can use the evaluation framework that was introduced by Baars et al. (2009) to shine a light on the multi-faceted benefits of Radio Frequency Identification (RFID) deployment. They divided the framework into three steps, benefit identification, benefit forecast, and benefit assessment. The identification schema is subdivided into automation, information and transformation, which can be further specified into the two benefit categories direct-indirect and operational-managerial. Using this approach for demand response it maybe is possible to conduct a step-by-step identification of the various values for different market actors. It raises awareness to the benefits which might otherwise be neglected, such as the handling of unforeseen shortages. In the benefit forecast the relevant indicators are selected and approximated by using specific simulation models depending on the benefit type. In the benefit assessment it is then possible to convert the outcome into monetary terms. Applied on the demand response market this helps to reveal the specific valuations for the corresponding market actors. These valuations can then be used to adjust the pricing mechanisms for demand response services. When we have achieved such a level of transparency within the market, we would have significantly reduced the chances for moral hazard.

CONCLUSION AND OUTLOOK

Starting point for our attempt to address moral hazard in smart grids was the ongoing transformation of energy systems around the globe. In context of the energy turnaround, demand response is seen as an important contribution to ensure the proper integration of volatile energy resources into electricity grids by balancing resulting energy fluctuations. Driven by the dispute between PJM and EnerNOC about double-counting of reduced megawatts arose the question, if there exists a systematical information problem between aggregators and principals. We used principal agent theory to reveal moral hazard and incentives for opportunism in the corresponding business processes. Principal agent theory was applied to many types of business relationships with diverging information levels before (e.g. Scoot and Vick, 1998), but scarcely literature could be found out there with reference to the energy sector.

Consequent monitoring of the agent might increase transparency and therefore significantly reduce chances of opportunistic behavior from the aggregator. We showed that the OpenADR standard can be easily combined with a data integrity approach to provide an IS based monitoring solution incorporating already existing and established concepts. The research in questions of data integrity is well advanced, because it is one of the main security issues in spatial information systems. OpenADR is developed to offer one common open source communication standard for demand response applications, and thus, the PJM pilot was illustrated to demonstrate implementation in practice. Nevertheless, nobody used OpenADR and a data integrity solution together in one model so far.

In a next step, additional research needs to be done in light of the complex relationships involved combined with proper benefit assessment. In our analysis, we focused on a single-stage principal agent problem in terms of information asymmetry between the aggregators' role as agent and ISO/RTO, acting as principal. The aggregator has an information advantage over demanders of demand response services just as over the end-consumers. Our approach treats both business relations individual to allow a separate view. In line with the section concerning business processes, value added and revenue sharing, that is only one part of the issue. Including the end-consumer perspective, there are at least three different market roles, with each diverging interests and information levels about shifted loads and their monetary valuation. It is appropriate, as a consequence, to expand the model in terms of a second-stage principal agent relation, which offers some new and different insights about the problem, but makes it also more complicated for examination. Collusion and revenue sharing between two parties at the expense of the third one seems to be a reasonable scenario for opportunistic behavior on a multi-stage level and has to be addressed in order to prevent market failures. The challenging part is how to get correct information about consumption from all participants supported by IS and the establishment of criteria to ensure a universal valuation in monetary units.

REFERENCES

1. Albadi, M. H., El-Saadany, E. F. (2007) Demand Response in Electricity Markets: An Overview, *IEEE*.
2. Akerlof, G.A.: The Market for Lemons: Quality Uncertainty and the Market Mechanism, *Quarterly Journal of Economics 84*, Nr. 3, 1970, S. 488–500.
3. Baars, H., Gille, D., Strüker, J. (2009) Evaluation of RFID applications for logistics: a framework for identifying, forecasting and assesing benefits, *European Journal of Information Systems*, 1-14
4. Bernheim, B. D., Whinston, M. D. (1986) Common Agency, *Econometrica*, Vol. 54, No. 4 (July, 1986), 923-942
5. Borenstein, S., Jaske, M., Rosenfeld, A. (2002) Dynamic Pricing, Advanced Metering, and Demand Response in Electricity Markets, Center for the Study of Energy Markets.
6. Borlick, R. (2010) Pricing Negawatts - DR design flaws create perverse incentives, *Public Utilities Fortnightly*, August 2010
7. Canadian International Development Agency (2005) Data Integrity Control Framework - Internal Audit Report, July 7, 2005
8. Faruqui, A. et al. (2009) A National Assessment of Demand Response Potential. Federal Energy Regulatory Commission.
9. FERC (2008) Order Accepting Tariff Revision, Docket No. ER08-538-000, Issued April 4, 2008
10. FERC (2009) „National Assessment of Demand Response Potential (June 2009), available at http://www.ferc.gov/legal/staff- reports/06-09-demand-response.pdf, accessed July 2011.
11. FERC (2012) Assessment of Demand Response and Smart Metering Staff Report 2012(December 2012), available at http://www.ferc.gov/legal/staff-reports/12-20-12-demand-response.pdf, accessed February 2013.
12. Holmberg, D. G., Ghatikar, G., Koch, E. L., Boch, J. (2012) OpenADR Advances, *BACnet Today and the Smart Grid, ASHRAE Journal, B16, November 2012*.
13. IEA – International Energy Agency (2007) Mind the Gap Quantifying Principal-Agent Problems in Energy Efficiency, IEA Publications, Paris. Available at http://www.iea.org/publications/freepublications/publication/mind_the_gap.pdf, accessed February 2013.
14. John, J. (2011) Trouble for EnerNOC in Market Manipulation?, available at http://gigaom.com/2011/02/14/trouble-for-enernoc-in-market-manipulation/, accessed February 2013.
15. John, J. (2012) EnerNOC misses Q4 estimates, loses "double-counting" dispute with PJM, available at http://www.greentechmedia.com/articles/read/enernoc-misses-q4-estimates-loses-double-counting-dispute-with-pjm, accessed February 2013.

16. Johnson Controls (2012) Demand Response and Sustainability, available at http://www.energyconnectinc.com/pdf/HowDemandResponseSupportsSustainabilityInitiatives-10102012.pdf, accessed February 2013.
17. Joskov, P., Tirole, J. (2005) Reliability and competitive electricity markets, *Rand Journal of Economics 37 (4)*, 799-815.
18. Karwe, M, Strüker, J. (2012) Maintaining Privacy in Data Rich Demand Response Applications. First Open EIT ICT Labs Workshop on Smart Grid Security − SmartGridSec12. Berlin, Germany.
19. Kwomey, P., Green, R., Neuhoff, K., Newbery, D. (2005) A Review of the Monitoring of Market Power: The possible Roles of Transimission System Operators in Monitoring for Market Power Issues in Congested Transimission Systems, *The Journal of Energy Literature XI. 2 2005*.
20. Maskin, E., Tirole, J., (1990) The Principal-Agent Relationship with an Informed Principal: The Case of Private Values, Econometrica, Vol. 58, No. 2 (Mar., 1990), pp. 379-409.
21. Moss, B. (2005) The data integrity problem and multi-layered document integrity, PhD thesis, University of Nottingham, available at http://etheses.nottingham.ac.uk/538/1/bxm-thesis-corrected.pdf, accessed February 2013.
22. OpenADR Alliance (2012) OpenADR Alliance Releases 2.0a Profile Specification and Compliance Test Suite, available at https://openadr.memberclicks.net/openadr-alliance-releases-20a, accessed February 2013.
23. OpenADR Alliance (2013) The OpenADR Primer –An Introduction to Automated Demand Response and the OpenADR Standard, available at http://www.openadr.org/assets/docs/openadr_primer.pdf, accessed February 2013.
24. PJM (2012) State of the Market Report for PJM, Monitoring Analytics, LLC
25. PJM (2013) Demand Response, available at http://www.pjm.com/markets-and-operations/demand-response.aspx, accessed February 2013.
26. Spence, M. (1973) Job Market Signaling, *Quarterly Journal of Economics*, The MIT Press 87 (3), pp. 355–374.
27. Sridhar, S., Manimaran, G. (2011) Data Integrity Attack and its Impacts on Voltage Control Loop in Power Grid, *Power and Energy Society General Meeting, 2011 IEEE*, pp. 1-6
28. Stigler, George J. (1961). "The Economics of Information". *Journal of Political Economy* 69 (3), pp. 213–225.
29. Strüker, J., Weppner, H., Bieser, G. (2011) Intermediaries for the Internet of Energy - Message Distribution between Smart Objects and Enterprise Applications as a Business Model, *Proceedings of the 19th European Conference on Information Systems (ECIS)* Helsinki, Finland.
30. Sutherland (2011) PJM Moves to Rein in Demand Response "Double Counting", Sutherland Asbill & Brennan LLP
31. UCA - International Users Group (2011) Security Profile for OpenADR, available at http://osgug.ucaiug.org/sgsystems/OpenADR/Shared%20Documents/OpenADR%20Phase%202/Reference%20Documents/Security/OpenADR%20Security%20Profile%20-%20v0_02.pdf, accessed February 2013.
32. Watson, R. T., Boudreau, M.-C., and Chen, A. J. (2010) Information systems and environmentally sustainable development: energy informatics and new directions for the IS community, *MIS Quarterly,* 34, 1, pp. 23–38.
33. Wright, P., Mukherji A., and Kroll, M. (2001). A reexamination of agency theory assumptions: extensions and extrapolations. *The Journal of Socio-Economics 30*, pp. 413-429.