D4.5.2.1

Demand Response Event Flow in a distributed market environment

Version 1.0

Created:	2013-11-28
By:	Joni Aalto, Empower IM Oy Jan Segerstam, Empower IM Oy Pekka A.Pietilä, Empower IM Oy Mikko Gröhn, Empower IM Oy

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1. Preface

This report is a part of the results from the fourth funding period of the Finnish national research project ”Smart Grids and Energy Markets”. The project has been funded by Tekes – the Finnish Funding Agency for Technology and Innovation. This report is based on the development work of Empower IM Oy in close co-operation with Oulu Energy. This report is related to SGEM's Demand Response theme, while being also part of the results of work package 4 “Active Customer, Customer Interface and ICT”.

The system environment and event flow descriptions of this report are a basis for later pilot work. The pilot will include a block of flats with electric floor heating systems. These loads will be enabled to be controlled with the AMR system. The end customers will have active customer energy portal based functionalities to control the heating loads, while the electricity supplier will have load control tools built in EDM system. The tools to estimate the demand response effect will be also tested.

2. Introduction

In the near future the interface between the electricity suppliers and end customers will become growingly significant as the supplier centric market model is currently gaining support. This means that the primary contact party for the end customers in the electricity market related issues would be the electricity supplier, while the DSOs would handle only the issues related to physical electricity delivery and to distribution network. Also, the general aim is to make the supplier switching as easy as possible for the end customers, by removing additional costs for supplier switching and by making the comparison between different electricity suppliers easier e.g. by providing internet portals for this purpose. The goal is to increase competition between the electricity suppliers, thus raising pressure to lower the electricity prices and to intensify the electricity market processes.

Traditional electricity transmission and distribution networks will be further developed and new possibilities to utilize advanced ICT-solutions and distribution automation will emerge. Currently in Finland, the great majority of metering points are already equipped with a remotely readable electricity meter, a smart meter, which registers the consumption data on hourly basis. This gives a plenty of new possibilities to develop new products and functionalities as it is possible to receive more accurate consumption data from the consumers' premises than ever before. While the installed metering devices are already equipped with comprehensive measurement capabilities and also with a load control possibility with additional relay outputs, some of the more sophisticated future product structures and functionalities may require even more smartness from these devices. While it is important to collect requirements for the next generation smart meters, which could be installed in the 2020s, home automation solutions can provide support for the current smart meters to enable the development of new electricity market products and functionalities.

The goals to reduce emissions require actions on a power system level. Therefore, electricity needs to be generated by using more less-polluting renewable energy sources, while the overall peak power demand should be also decreased. Increased amount of renewable energy requires also investments on regulating power capacity, as the power production of renewable energy sources is highly fluctuate depending on the weather conditions. Increased responsiveness on the electricity demand side is offered as a one potential solution. Currently, the large share of available demand response capacity of large-scale industry is already utilized in the electricity market by the balancing market. There is a need to promote the possibilities of demand response also to the SME sector companies and eventually for the private end customers, thus enabling them to become more active players on the electricity markets.

The availability of new smart technologies will increase possibilities to plan and implement demand response actions, while it also enables to estimate the effects of different demand response actions. This is highly important in order to utilize demand response in a controlled way and to continuously develop demand response utilization processes. Since it is desired that the demand response would benefit the overall efficiency of the electricity market and the power system, the demand response capacity should be included already into the price formation process, which practically means the day-ahead trading in Nordic electricity market. Therefore, the electricity supplier could use demand response capacity of the end customers to steer the consumption to the times of lower electricity prices. This would lead to lower electricity retail prices and thus benefits for the end customers. Alternatively, the electricity supplier could allocate some of the market price risk to the end customer by using dynamic pricing structures, thus motivating the end customer to adjust the electricity consumption according to fluctuating electricity prices. Additionally, the possibility to control the electricity demand would enable the electricity supplier to correct its electricity balance position if the electricity procurement does not seem to correspond to the realizing electricity sales. This way the demand response would help the electricity supplier to fulfill the balance responsibility, thus helping the overall power balance management on the system level. TSOs and DSOs could naturally have incentives to utilize demand response and load control capabilities from their own perspective and it is possible once it is decided in which way the demand response capacity should be allocated to achieve the best result from power system management and electricity market efficiency point of views. This report will focus on demand response from electricity supplier's and end consumer's points of view.

The first chapter will introduce the system environment in a distributed market environment, which means that the electricity supply and the electricity distribution businesses are separated in the energy companies allowing electricity suppliers to sell electricity regardless of the network boundaries of the DSOs. This structure is selected to form a basis for the demand response event flow validation, which means that the focus is on the additional functionalities to the current information systems, which are required to handle demand response capacity from the electricity supplier's and end customer's points of view. In this case, the entity which implements the actual demand response actions is a DSO with a smart AMR system infrastructure.

The next chapter will demonstrate the demand response event flows by walking through selected demand response utilization chains. This illustrates the information and event flows through the system environment starting from the supplier's or end customer's decision to utilize demand response, eventually finishing to a smart meter implementing the actual load control action and to estimation process for the achieved demand response effect. This kind of system environment and event flow structures are a basis for real life demonstrator work. The focus of this deliverable report is on the AMR system based demand response actions, as also the real life demonstrator work will be done by utilizing the AMR system provider's current load control functionalities. Still, HEMS is an important part of future smart grid resources and therefore the opportunities from this kind of technology are also considered during the development work.

3. System environment in a distributed market environment

Different information systems form the basis for the operation of different electricity market actors such as electricity suppliers and DSOs. Efficient information exchange between the market actors has always been an enabler of efficient electricity markets. The liberalization of the electricity retail markets and the smart meter roll-outs have only reinforced the importance of effective information systems and functional information exchange processes, thus the amount of available data has significantly increased which also increases the volume of information exchange between different market actors. Handling of demand response in a distributed market environment requires new functionalities to the current information systems as well as new kind of information structures and information exchange practices in order to enable the handling of distributed demand response capacity.

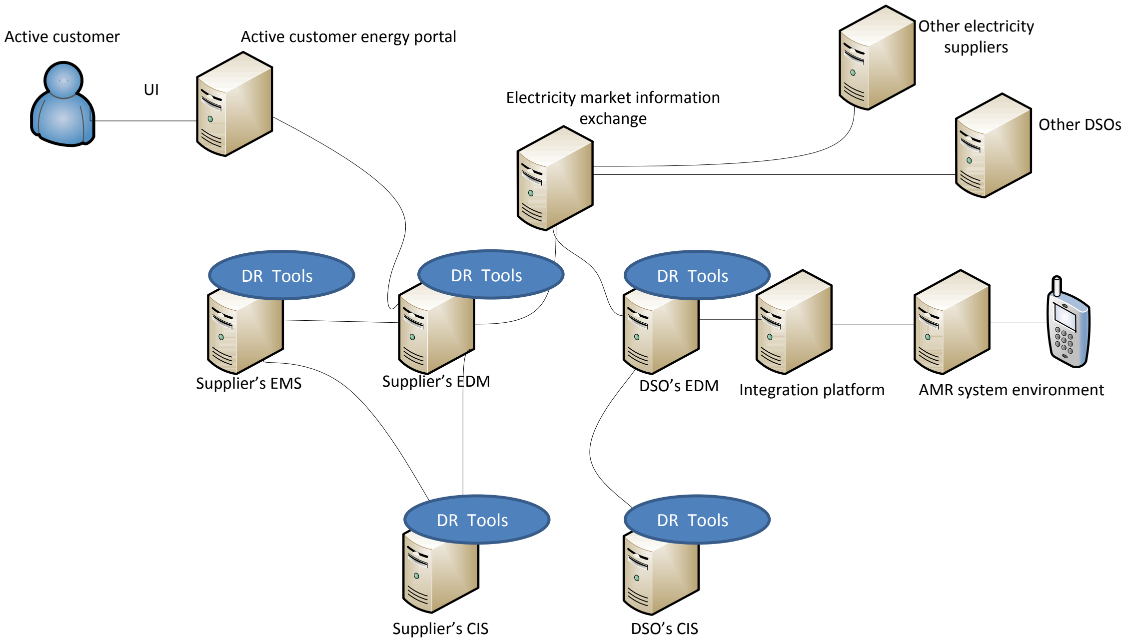

Figure 1. System environment in a distributed market environment

The following sub-chapters introduce the information systems which are currently used by the electricity supplier's and the DSO's to manage the information related to end customers and their electricity consumption. Also, the electricity supplier's energy management system, EMS, is included. Electricity market information exchange is included into the system map to illustrate the communication with other electricity market parties, which is an important part of future market-wide demand response solutions.

3.1. AMR system

The AMR system consists of remotely readable AMR meters i.e. smart meters and a system which is used to collect the measurement data from the meters, AMR reading system. It also includes the required communication solutions/network between the AMR reading system and the AMR meters, which can be implemented by using different communication technologies. AMR system produces consumption data for the EDM system to be further processed and delivered to other information systems or other market actors via electricity market information exchange.

DSOs' AMR systems are currently seen as one alternative to be utilized when new demand response operations are being developed. Some of the companies which are specialized in AMR meters and systems have already designed new softwares and meter functionalities to support more versatile load control mechanisms. Some of the development projects have already proceeded into piloting phase. More in detailed information about the AMR system based load control can be found e.g. from research report by Koponen et al. (2012).

3.2. Energy data management system

Energy data management system, EDM, is a long-term storage for electricity consumption data. The DSO's EDM system contains information about the metering points belonging to the DSO's distribution area, while the electricity supplier's EDM contains information about the end customers which can be located in the network areas of multiple DSOs and have an electricity supply contract with this electricity supplier. The AMR meter roll-outs and hourly consumption metering have multiplied the amount of data, which needs to be handled in the systems and delivered to other electricity market actors. Briefly, the management, handling and storing of energy data is made with EDM as well as different kinds of data based calculation operations and finally the delivery of the data via electricity market information exchange by using the established message structures. One example of these calculation processes which are done with EDM is the DSO's balance settlement process. Outcome of this process is the electricity supplier specific sums of overall electricity delivery in a certain DSO network area.

SGEM Task 4.5.2 studied the possibilities to build EDM based tools for an electricity supplier which could be used to handle the loads which are included in the supplier's demand response customer portfolio. Demand response customer portfolio includes the customers with a demand response contract. The outcome of the studies was that these tools should include functionalities for at least customer grouping, receiving the information about the amount of required demand response e.g. from energy procurement processes, division of group specific load control requests to measurement point specific load control requests, creating the load control command messages to be delivered to the system which executes the load controls, receiving corresponding response messages and estimation tools to evaluate the achieved change in the electricity consumption.

The approach of Task 4.5.2 is based on load control calendars. The idea would be that metering point specific load control calendars would be created and stored in the electricity supplier's EDM system. The electricity supplier would have the tools to determine the load control calendars in the EDM. This could be done in a metering point specific way, but this could turn out to require too much manual work and therefore the connection to energy procurement with automatic demand response utilization processes are needed. The electricity supplier's incentive for demand response is always formed during the electricity procurement or balance management processes. Therefore, there needs to be a connection between suppliers EDM based DR tools and energy management system, which is used to handle the electricity procurement. This is discussed also in the later chapter. The current AMR based load control systems are focused on handling hourly based time series which include the state information for the relays, which can be steered. This calendar is usually defined for the coming day or other future time period. When considering the possibilities of HEMS system, the determination of load control calendars could be done locally at the metering points, based on the delivered initial data, while the planned actions would be delivered to the upper level system to be stored for future use.

The electricity supplier should be able to control the loads in any DSO network area. This would mean that the supplier's demand response tools enable the communication with the load control equipment in any DSO area, via electricity market information exchange. In addition, the supplier needs to be able to monitor the state of the load control requests. This could also be seen as a part of load control calendars, thus they could include a status information for each hour's request, stating the phase of the request in overall load control process. This information would mean statuses like "sent", "confirmed" and "rejected", based on the responses from the load control systems which have been handled and processed with the demand response tools.

The possibility to estimate the effect of the requested load controls is a highly important functionality. This enables to evaluate what kind of load control actions produce a certain effect on the consumption side, thus enabling to learn about the response effect of the controllable loads. With the current EDM functionalities and information structures this kind of estimation tool could be built as follows. First, EDM would create a consumption forecast for consumption place/consumption place group. This forecast can be based for example on new types of updated load curves, which are also studied in SGEM project or historic consumption data. This data would be stored as time series. Another time series would be created to store the planned and requested load control actions (e.g. on/off), the load control calendar. Finally, there would be a time series for the actual consumption data from the DSO. With these time series it would be possible to calculate the estimation of realized effect of load control actions.

In this chapter the focus has been on the electricity supplier's EDM based DR tools. Already during the previous SGEM research it has been stated that the DSO could have incentives to monitor the planned demand response actions in the network and even demand a possibility to refuse to implement all the requested load controls if the DSO's view is that it could cause troubles from the electricity distribution point of view.

The tools for the DSOs could also be located in the EDM system, as it already has communication channels to the AMR system, which would be used for load control implementations. DSOs could use EDM to group the customers according to their load control possibilities and publish the information about the consumers which have load control possibilities to be utilized by the interested electricity suppliers. Once the electricity suppliers start to use the load control in the DSO's network area, the DSO should be capable to receive measurement point or measurement point group specific load control requests and to reply these requests with response messages. Once the load control requests are received from the suppliers, the DSO should be able to monitor and review these requests. If the DSO has a right to refuse from implementing some of the requests, this could be enabled for example by designing a functionality which requires the DSO to review and accept all the requests, before the commands are delivered onwards to the AMR system. In order to reduce manual work, some automatic processes could be designed so that the requested load controls would be handled as a whole and compared to pre-defined restrictions.

3.3. Active customer energy portal

The active customer energy portals are web based services, which have become a common part of the service offering of the energy companies. Portals provide functionalities to view different information regarding the customership with the energy company. These functionalities include e.g. a possibility to view and update general customer information, billing monitoring and consumption monitoring during different time periods.

Recently, the functionalities which enable to compare the energy consumption during a certain time period to a similar time period from the past or to a similar electricity consumer have become increasingly common. These kind of functionalities as well as tools to estimate and improve the efficiency of the electricity consumption can be predicted to become more common. Usually these kind of customer energy portals utilize the databases of the energy company’s customer information system and energy data management system.

Task 4.5.2 studied the possibilities to provide demand response related functionalities for the end customers via these kind of active customer energy portals. In this study case, the end customer would be enabled to determine load control calendars for the loads which can be steered with the DSO’s AMR system. Therefore the most suitable loads would be the electric heating loads.

The following issues emerged during the studies. The customer could be enabled to monitor the consumption forecast without demand response actions, and the possible dynamic prices e.g. for the coming day and determine the load control calendar based on this information. Naturally, the determination process could be automated so that the end customer would not be required to do manual work and could only focus on occasional monitoring of the load control actions when desired. After the actual load control actions the active end customer would be enabled to monitor the estimated achieved savings with the demand response actions. On the other hand, if the load control calendars are determined only by the electricity supplier, energy portal would be the place for the end customer to monitor the supplier initiated actions and finally the activated monetary compensations from the electricity supplier.

In a case of an additional HEMS system in the end customer premises, which provides additional local smartness, it could plan and implement the load control actions according to price or other external signal for the loads which are not steered by the AMR system. In this case, the schedules about planned actions could be delivered to the electricity suppliers EDM and thus they could also be utilized by the electricity supplier.

3.4. Customer information system

The customer information system, CIS, is used to handle contract- and customer information related issues. Therefore, it is commonly used to handle also the information exchange messaging related to contracts. CIS also forms the bills for the end customers, based on internal data or data which is received from other systems. Thus, from the demand response perspective, CIS would be a natural system to store the information related to demand response contracts/agreements. This information would include the terms for the possible compensations, restrictions for load control actions and other relevant information.

These contract structures have been also previously studied and related information can be found from SGEM research report by Joensuu et al. (2012a). In addition to storing this information, CIS should be able to deliver the required information to other systems which need the information. These include the systems which are active in planning the demand response utilization and creating the actual load control commands. Billing process requires information about the implemented demand response actions which activate compensations for the end customers.

3.5. Energy management system

In this report an energy management system, EMS, is an electricity supplier's system, which is used to handle the energy procurement, balance management and risk management processes related to procurement. EMS enables to create the required long- and short-term production and consumption forecasts, to be used as a basis for energy procurement planning and balance management. It also allows to monitor the intraday energy balance, based on the short-term forecasts and possibly available real-time measurements.

The actual need/opportunity for demand response utilization can arise during the operation in different electricity market levels i.e. demand response can be used as a tool in different electricity market levels. It can be used during the planning of electricity procurement hedging levels, during the actual day-ahead trading and during the intraday actions, as a part of the balance management. SGEM research report by Valtonen et al. (2012) is a good source for further information.

As an outcome from the Task 4.5.2 work it was found out that in order to handle demand response capacity, at least following functionalities are needed. EMS is required to handle the forecasts about the loads/production which can be controlled. It could be effective, if the EDM system would provide aggregated forecasts for pre-defined metering point groups. Therefore the demand response actions could be allocated to a certain group in EMS, while the measurement point specific load control commands would be created in EDM. After the planning of demand response utilization, the original consumption/production forecasts need to be updated based on the planned load control actions. Finally, EMS needs to be capable to receive and store the information about estimated effect of demand response actions, which is delivered from EDM.

3.6. Electricity market information exchange

Efficient electricity market information exchange in Finland is currently arranged by using centralized information exchange model. This means that the information exchange between the electricity market parties is handled by service companies which are specialized for this kind of operation. This removes the need from the energy companies to build and maintain communication channels between each other. The communication between messaging operators is done by using the established message structures.

Market-wide demand response utilization will set new requirements also for the electricity market information exchange. It would be beneficial and efficient if the communication processes and information structures, which would be used between the parties which are actively utilizing the demand response and the parties which are managing the actual loads, would be based on standardized principles. This would remove unnecessary complexity around the operation. The development work around the demand response information exchange and the load control message structure is mainly done in SGEM FP4 Task 4.5.3, which will also include demonstrator work in real system environment.

4. Demand response event flow

The previous chapter introduced information systems which are active in electricity supplier initiated demand response and explained the new requirements for these systems. This chapter walks through couple of example event flow cases where the electricity supplier and the end customer initiate demand response actions. This way it is possible to form an event flow which illustrates the connection between different events and sets them in chronological order.

The integration between the electricity supplier's and DSO's information systems and the data which is shared between the systems in demand response actions was previously studied in SGEM FP2. Research report by Joensuu et al. (2012b) is based on these studies and provides information which is partially relevant also with this research report about demand response event flows. On the other hand, as these event flow descriptions include information exchange between electricity supplier's and DSO's EDM systems with load control messages and load control response messages, the work is connected to SGEM FP4 Task 4.5.3 work around demand response information exchange and load control message structure. Preliminary results of this development work can be found from the SGEM research report by Aalto et al. (2013).

4.1. Example case of electricity supplier initiated action

Starting point for this example case is that the end customer and the electricity supplier have agreed about demand response and it gives electricity supplier the right to steer the end customer loads within the agreed limits. In this case, the end customer is provided with a functionality to monitor the electricity supplier's planned actions, while there is no possibility to interfere them. Naturally, it can be predicted that if the end customer would be provided with this kind of opportunity, it will increase the willingness to participate in demand response actions, while it increases the complexity of the process and risks for the electricity supplier.

This example event flow (see Appendix 1.) starts as information about the customers with a demand response contract is delivered to electricity supplier's EDM. This way it is possible to group the customers based on e.g. load types or based on the type of demand response contract. The idea is to form customer groups with similar characteristics. This same grouping can be used in the EMS as demand response group can form one of the procurement portfolios. Next, EDM defines consumption forecasts for single measurement points and aggregate these forecasts to form a portfolio specific consumption forecasts. Forecasts can be based on historic data or updated load profiles. Forecasts can be long term or short term. Long term forecasts are used for defining the hedging levels for each procurement portfolio, while short term forecasts are made closer to the day of delivery, when it is possible to adjust the hedging levels and implement actual electricity procurement actions by placing bids to the market place.

EMS generates the demand response utilization plan, based on the needs from the electricity procurement. The situation can be for example that it is beneficial from the overall procurement portfolio (including all separate portfolios) point of view, that all available demand response capacity of the demand response portfolio is used to shift the consumption from the hour 01-02 to later hours. Therefore, demand response utilization plan would include a request to switch of the loads from corresponding measurement points during that hour.

Supplier's EDM creates a general empty load control calendar and then determines the states to the calendar according to the demand response utilization plan. This calendar is allocated to required measurement point groups. Next, EDM stores the measurement point specific load control calendars for later use. EDM calculates the updated consumption forecasts and delivers them to the EMS. Now, with this updated information, which includes the forecasted effect of demand response, it is possible to implement the actual electricity procurement actions in the market. It must be noted that this process is iterative, as if the bids do not go through as planned, the planned demand response utilization plans may have to be updated. To simplify this event flow description the situation is that the electricity procurement bids go through as planned and the process can continue. At this point, active customer energy portal can pull the load control calendars, enabling the end customer to view the planned load control actions.

Now, the actual load control message can be formed based on the load control calendars. This load control message includes multiple measurement points from different DSO areas. Therefore, the electricity market information exchange service provider divides the load control message to the messages which can be distributed to the corresponding DSOs. At this point, like discussed in the previous chapter, the DSO can review the planned actions and store the load control information for possible later use. DSO can for example check whether all of the measurement points in the load control message are located in the DSO's network area, or if the electricity supplier truly is the supplier of the metering point and if there are some restrictions in some of the measurement point's load control possibilities. DSO's EDM creates the load control commands to be delivered to the AMR system, which will activate the load controls according to the plan. Finally, the load control response messages are sent from the DSOs back to the electricity supplier via electricity market information exchange. The information in the response messages is dependent on the AMR system and the DSO's EDM system, but in this case it means information about the feasibility of requested load control actions (request received, request delivered to the AMR meter etc.). Again, this example case represents a successful operation. If the DSO decides to interfere the planned demand response actions, negative response message will be sent back to electricity supplier which needs to start an iterative process to update the electricity procurement plans according to the new updated situation.

After the time period, when the demand response actions were planned to be implemented, the actual realized consumption have been registered by the AMR meters. This data is handled by the DSO and it is delivered to the electricity supplier's EDM. Now it is possible to calculate estimates of the achieved demand response on the consumption of the affected customers. Electricity supplier is mainly interested about the overall effect to the demand response customer portfolio and therefore also to the whole electricity procurement portfolio. Still, if the demand response contract includes some volume or energy based compensations for the end customers, the metering point level calculations are needed. This data is delivered to the CIS to be used for billing. In this example case, the activated compensations are also visible to the end customer via active customer energy portal. Demand response event flow example ends to the formation of the end customer's electricity bill.

4.2. Example case of end customer initiated action

Starting point for this example case is that the end customer and the electricity supplier have agreed about dynamic retail pricing of electricity. Therefore, the demand response actions are made by the end customers or by the home automation system in the end customer premises. The incentive for these demand response actions is based on the dynamic retail prices, defined by the electricity, which represent the electricity supplier's electricity procurement costs and profit needs, thus steering the end customer to use electricity when the prices are low. In this example case, the electricity supplier does not determine direct load controls, but only monitors the end customer's actions.

The beginning of this example event flow (Appendix 2.) is similar to the first example event flow (Appendix 1.). In this example case, the determination of electricity retail prices means the determination of dynamic retail prices for the coming day. This would mean hourly prices series for the day, but in the future the pricing could become even more dynamic. The dynamic retail prices are delivered to CIS for the billing purposes and to the electricity suppliers EDM to be further utilized.

At this point, active customer energy portal pulls retail prices, load control calendar and the consumption forecast from the EDM. Based on this information the end customer/active customer energy portal defines the most profitable load control calendar for the loads which can be steered with AMR system. Active customer energy portal also displays an estimate about the cost benefits with the defined load control calendar. By using these load control calendars it is possible to update the electricity supplier's overall consumption forecasts and thus plan the actual electricity procurement actions.

It is important to understand that these event's need to be synchronized with the time windows in which the electricity supplier operates in the electricity market. This can be challenging as the information exchange between the systems, possible end customer's response time and other similar issues set requirements for the adjustment of event times. Currently, in the Nordic electricity market the electricity supplier needs to place bids for physical electricity deliveries concerning the coming day during the current day at noon. Therefore it would be beneficial to be able to form the consumption forecasts including the planned demand response before that deadline. This way the demand response would be included already in the formation process of the electricity day-ahead prices and also otherwise the effect of demand response can be taken into consideration not until intraday market place.

The information exchange with the load control messages and response messages is similar to the first event flow. The actual consumption data is used by the electricity supplier's EDM to estimate the effect of demand response actions and by the CIS in order to define the electricity bill based on the dynamic prices. Active customer energy portal displays the estimated realized cost savings for the end customer.

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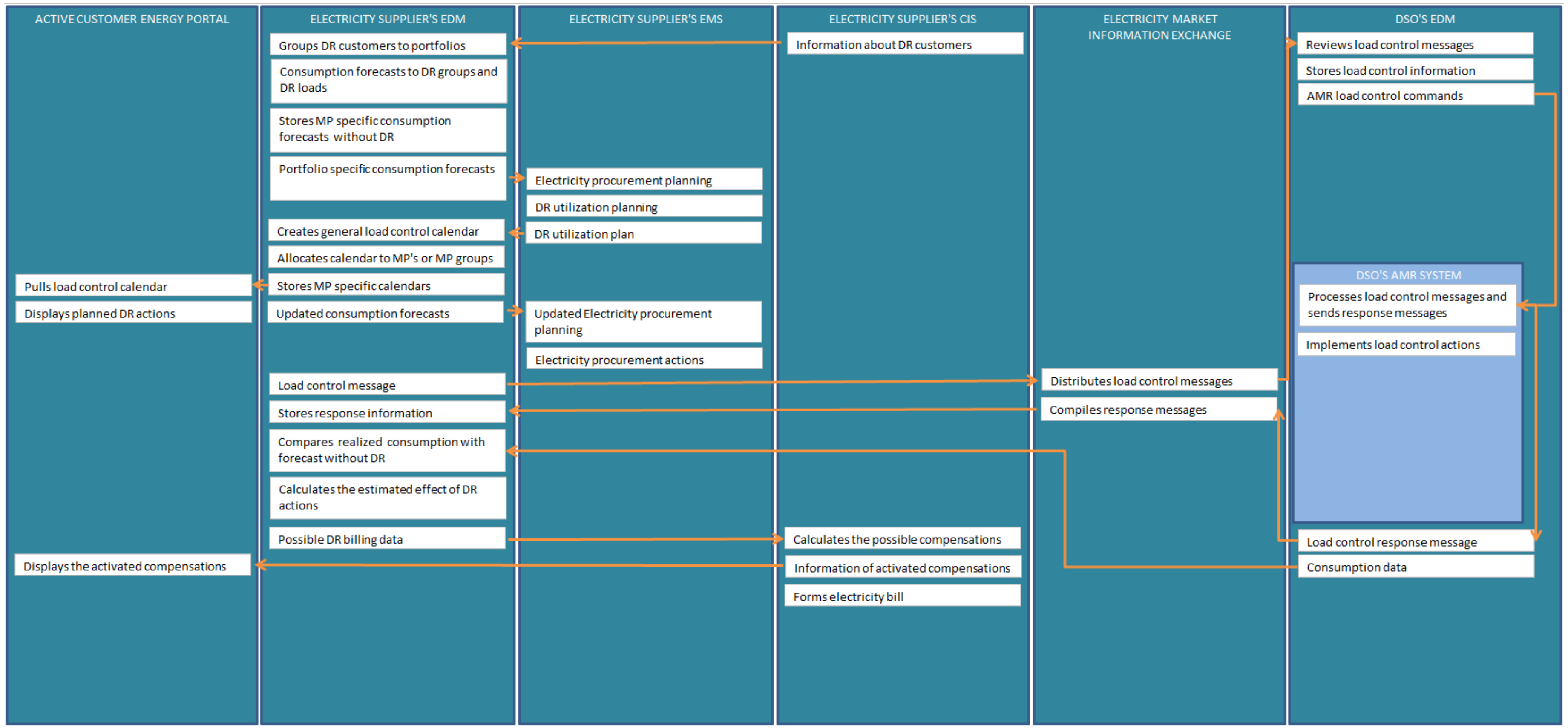
Appendix 1. Event flow diagram of electricity supplier initiated demand response action



Appendix 2. Event flow diagram of end customer initiated demand response action