Coordinating Energy Based Business Models and Customer Empowerment in Future Smart Grids

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Abstract. Future sustainable energy systems are in focus of several national and international R&D programs. The transition from today's tariff-based energy systems towards future sustainable energy markets has to be supported by addressing and solving a range of challenges. Among the identified barriers are doubts of user acceptance of future Smart Grids due to lack of experiences, opportunities and possibilities: hence lack of experimental validations. Our suggestion of SLA-Agents experimental facility is aiming at filling some of those shortcomings, not the least issues related to trust by stakeholders.

Keywords: Smart Grids, Service Level Agreements (SLAs), Energy efficiency, Business models, Customer Empowerment.

1 Setting the Scene

The following Figure 1 adopted from deliverables from the EU funded TN SEESGEN-ICT (Supporting Energy Efficiency in Smart Generation grids through ICT) illustrates the main characteristics behind the transition of electric grids from today to tomorrow.

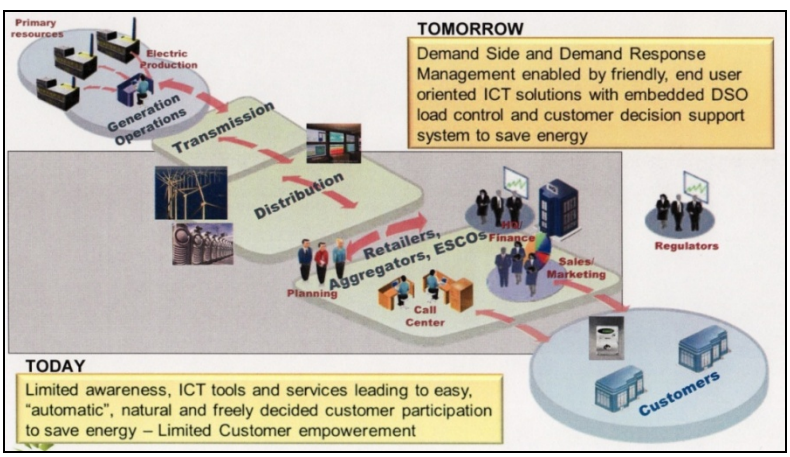

Fig. 1. Main drivers behind the transition towards Smart Grids

N. Hatziargyriou et al. (Eds.): E-Energy 2010, LNICST 54, pp. 44–53, 2011.

In Figure 1 the main stakeholders and roles are depicted as well as the path of transformation from Today to Tomorrow, related to effects due to the unbundling of the energy market. The deregulations and increased intelligence in the Transmission and Distribution networks enabled by smart programmable electronic components and smart ICT information management systems are the two main drivers of this transition. Figure 1 depicts the main architectural components related to the energy flow of the future Smart Grid. The following Figure 2 outlines the information flows between groups of stakeholders to enable and support new business models as well as empowerment of the customers.

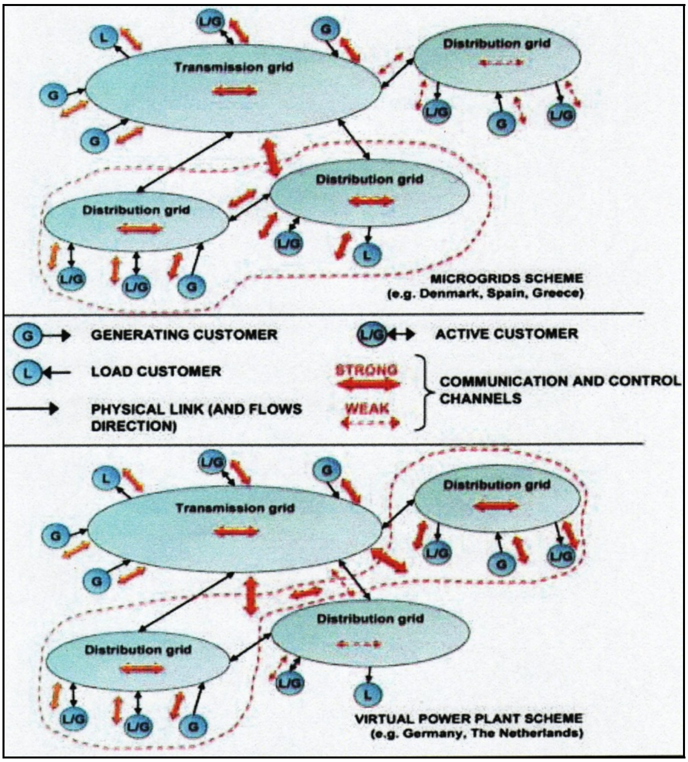

Fig. 2. Information flows in future Smart Grids (adapted from SEESGEN-ICT[1] deliverables)

As it is indicated in Figure 1 and Figure 2 the role of new stakeholders, i.e. Aggregators and Retailers will interact in Smart Grids between Distribution System Operator (DSOs) and Customers, and *secondly*, we will have *flexible configuration* of stakeholders, such as *Virtual Power Plants* (VPP). *Finally*, we will need communication networks that must support the energy flow as well as the customer based business information flows. In short, present Supervisory Control and Data Acquisition (SCADA) systems have to be supported by novel ICT based information systems to meet the requirements of future Smart Grids for empowerment of customers [1].

[1] SEESGEN-ICT home page: `http://seesgen-ict.erse-web.it/`

As a consequence, the *monitoring task* of present day energy systems has to be *re-assessed* and re-designed. To that end we propose to extend the monitoring task by introducing the concept and mechanism of *Service Level Agreements* (SLAs) to:

- Allow flexible grouping of stakeholders
- Allow flexible empowerment of users

1.1 Identified Barriers

Several international assessments of the transition from present day energy systems towards future Smart Grids have identified a set of barriers that have to be resolved, for instance[2]:

- *Regulatory barriers*. New types of stake holders and new kinds of business processes[3]
- *Technical barriers*. Architectures and technologies supporting new kinds of ICT systems complementing and enforcing SCADA systems[4]
- *Customer acceptance*. Trust in value-added services provided[5]
- *Lack of experiences*. Today, there is a lack of experience from large-scale field tests or demonstrators addressing key challenges on the road towards smart grids. For instance, the roles and amounts of DER or RES that can be utilized and trustworthy managed[6].

In this paper we describe a configurable agent-based platform addressing coordination in future smart grids in the form of monitoring SLAs (Section 2). The initial focus is on customer acceptance and to gain experiences of possible new business processes in Smart Grids.

2 Service Level Agreements as a Basis for Coordination in Smart Grids

Classical SCADA systems are tailored to monitor the energy flow processes in energy systems. The need of supplementary ICT support for information management related to business cases and customer support is indicated in figure 1 and figure 2.

Of course, there are interdependencies between monitoring energy flows and information flows [2]. For example, increasing the amounts of Distributed Energy Resource (DER) and Renewable Energy Systems (RES) requires additional voltage control/frequency control to maintain the quality of service. We also have to address several aspects of data protection and data integrity [2, 3], not the least since we have

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[2] *Technology Action Plan: Smart Grids*. Report to the Major Economies Forum (MEF) on Energy and Climate by Italy and Korea, December 2009.

[3] SEESGEN-ICT home page: `http://seesgen-ict.erse-web.it/`

[4] INTEGRAL homepage: `http://www.integral-eu.com/`

[5] Smart Grids home page: `http://www.smartgrids.eu/`

[6] The EUROPEAN future INTERNET initiative: `http://www.future-internet.eu/news/view/article/the-europeanfuture-internet-initiative-effi.html`

different (potentially competing) stakeholders and customers (prosumers) in each *Virtual Power Plant* configuration (Figure 2). Identification of and harnessing such interdependencies are key challenges in future Smart Grids [4].

To attain system flexibility, a good approach is to *virtualize the physical system components* and *groups of stakeholders* into different non-overlapping *virtual infrastructures*. We propose that the coordination in those virtual infrastructures can be modeled as bundles of services under SLAs related to given business processes [4].

Our starting point in setting up SLAs is thus:

- Business process
- Stakeholders
- Services
- Contract (Key indicators)
- Monitoring parameters
- Assessments of contract
- Billing
- Non-compliance of SLAs

Tight coupling of components provides stable platforms like current SCADA systems; however, there is lack of flexibility to add more stakeholder and business needs. A new approach towards improvement in Smart Grid is to restructure controlling and monitoring mechanisms accordingly to the present day need of customer empowerment from change in tariff based system to service based system. It is desirable for Smart Grid to have a flexible ICT platform by loose coupling the component to achieve the objectives. The ICT infrastructure provides more abstraction layers where components can collaborate and coordinate in a trustworthy and flexible way [4].

In such complex system the internal and external dependencies create a global phenomenon that is unable to comprehend without actually running of the system. Simulation is a viable alternative for examining these types of complex systems, which will help the researchers to learn more about the occurring problems and to provide solutions. To cater for that, the best available practices are to use *Service Oriented Architecture* [5] or *Agent Systems* to model the information processing systems as needed. The change of system control component from physical to more logical and distributed emphasis that the quality aspects must to be redesigned. We argue to manage such a complex system a better approach is to define and use Service Level Agreements (SLA). SLAs are mutually agreed contract between the service providers and the service users for the quality aspect in provisioning of services.

2.1 Business Cases as High-Level Goals

The business case sets the goals, constraints, pre- and post conditions of the SLAs. In service oriented computing SLA is presented in the Figure 3 below. Normally the SLAs represent an agreement between two parties, one is the producer and the other is consumer/client to exchange values/services in the presence of Publisher that can act as a market. In order to facilitate negotiations/transactions different parameters or Service Level objectives (SLOs) defines the measurement and monitoring criteria for effective and efficient delivery of the services. In our case we will extend the SLAs to typically involve more than two stakeholders. Occasionally the stakeholders can be grouped as classes of consumers or providers.

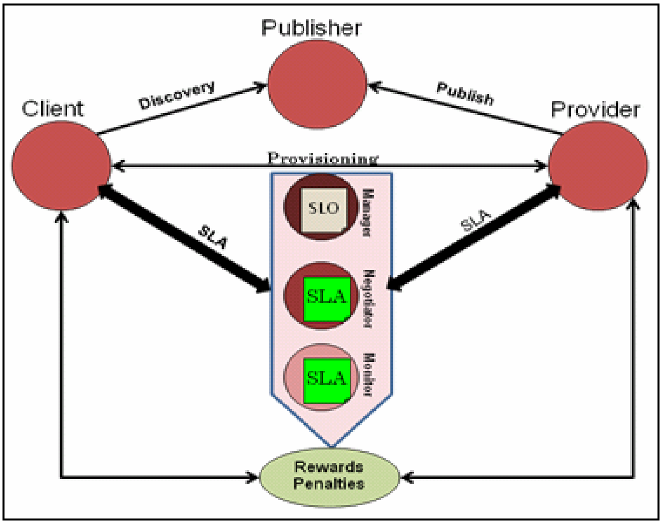

Fig. 3. Model of Service Level Agreements (SLAs)

A business use case can be presented on a template identifying stakeholders, their roles and responsibilities, action points and the flow of information within the specified entities. In the next section we have included a business model from the EU project FENIX and indicate a translation based on that business model into a SLA. A business use case has the following general sets of parameters in the corresponding SLA.

- Descriptions of the activities involved in the business processes (Goals/Objectives)
- The actors involved: (roles and responsibilities)
- Coordination of tasks and responsibilities to achieve a goal
- Billing
- Conflict resolution

The SLAs also defines the types and parameters to be monitored such as set points (allowed intervals) and Key Performance Indicators (KPI). Furthermore, it may have rules for SLA violation criteria's to apply at breakdowns.

3 Case Study: Customer Empowerment Enabling Increased Energy Efficiency in Smart Grids

Business case from the FENIX[7] project is stated below

Business Case: *Access to the Market through commercial aggregator, in* ***absence*** *of strong pressure to integrate DER.*

[7] FENIX Project Homepage: `http://www.fenix-project.org/`

Short description: *"A Commercial Virtual Power Plant (CVPP) is a competitive market actor that aggregates DER units (not necessarily constrained by location). This kind of aggregator helps the DER to gain market access with the optimal returns prospective and market visibility. It carries out the economical transactions between the market and the DER and so it looks to the market like an imaginary single physical plant. The DER units, through this kind of aggregation, are enabled to participate not only in the wholesale market but also in the TSO-organized balancing market and in the Guarantees of Origin (GO) market. Note that, in this business model, the CVPP does not absorb the balancing risks but shifts them to his clients. So, in this scenario, there will be only a financial aggregation of DER units without an operational integration. It is policy scenario that assumes the absence of strong societal pressures to really integrate DER into the electrical grid. Under these conditions, the current "fit and forget" practices will endure in the European operational network management. So distributed generation will penetrate fast, but it will not change the passive network operating philosophy."*

Further details can be viewed in the FENIX documentation.

3.1 Translation of Extended FENIX Business Case into SLAs

Adjusted Business Case: The case study addresses customer empowerment and constraints of DER inclusion. Customer empowerment will derive the future energy business by giving the customer more control of use of energy and also the type of energy to be utilized. *The energy flows* and *economic/information flows* between actors are as in Figure 1 and Figure 2.

Stakeholders

- *CVPP (Aggregator)*: Commercial Virtual Power Plant
- *DER* units: Distributed Energy Resources might include RES Renewable Energy Sources
- *TSO:* Transmission System Operator
- *DSO:* Distribution System Operator
- *Consumer/Prosumer*

The following adjustments of the FENIX business case are assumed:

- *The CVPP* will have the role of *Aggregato*r coordinating the energy between producers and the energy consumers by smart Demand Side Management (DSM).
- *The CVPP* will empower the *active consumer* to adjust their profile to meet Energy Efficiency criteria and/or other consumer related services.
- The CVPP will balance incorporating of (vast amounts) of DER while maintaining electrical constraints such as voltage/frequency control in the grid ensuring *quality of power service*.

The Product/Services related Transaction and Contracts from the FENIX case are replaced by several *Service Level Agreements* (SLAs):

- *SLA_Consumer_CVPP*: Coordinating services between the Consumer and the Aggregator CVPP. Supports *empowerment* of the consumer (active consumer)
- *SLA_CVPP_DSO*_DSO: Coordinating services between the CVPP and TSO/DSO mainly related to *energy balancing* (Voltage control/ frequency control)

Synopsis

Each CVPP is coordinating Group of Energy providers including a set of DERs and associated TSOs and DSOs, together with a set of Consumers. The associated set of services is coordinated with two reciprocal sets of Service Level Agreements. On one side we have the coordination of energy providers on the other side is the coordination of the corresponding consumers.

In the SLAs the energy profile of each consumer is specified: type and amount of energy per unit interval. The lower and upper bounds of allowed change of DER (ΔDER) per unit interval and other constraints are also specified.

At given time points t_0, t_1, ., the following control cycle is performed:

1. *Establishing energy balance of the CVPPs asserting Quality of power.*
2. *Collecting DDERs from empowered Consumers related to CVPPs.*
3. *Checking that the proposed changes in DDER are in accordance with the SLAs.*
4. *If YES, updating of databases.*
5. *Go to 1.*
6. *If NO, try to reconfigure the grid (eventually including load shedding) to achieve compliance with the SLAs.*
7. *Updating of databases.*
8. *Go to 1.*

Key parameters

- DER_j resource j: Geographic position in the network (Pos_j, t_0), Energy production (KWh (j, $\Delta t(t_0)$), Constraints (C, j, $\Delta t(t_0)$)) during time interval $\Delta t(t_0)$,
- ΔDERj: Amount of DER resources that could be changed by the Consumer j during a time interval $\Delta t(t_0)$ starting at time t_0.

Obviously, there are several ancillary services to be provided by different stakeholders in order to perform the tasks of the control cycle given above. The empowerment of the consumer could be provided by a support tool based on, e.g., a *Smart meter*. This support tool should then also include a SCADA system controlling smart equipment in the home and visualizing important status parameters of the equipment and networks. Of specific concerns for the empowered prosumer are:

- Information security and protection.
- Reliable and traceable consumption and billing.

4 The SLA-Agents Experimental Environment

The SLA-Agent tool is an effort towards trustworthy coordination between the stakeholders and especially focusing on empowerment of the customers. Our SLA-Agents platform is based on the JADE agent platform. However, we have improved the performance and scalability [6] by introducing and implementing distributed shared memory mechanisms in the Jade Directory component. Our SLA-Agents platform can be implemented as a distributed system, which allows us to perform experiments on a distributed agent environment where we can model and evaluate communication and connectivity models [7]. Having validated architectures and mechanisms of SLA-based coordination on SLA-Agents we can in a structured way deploy some of the virtualized components into physically grounded components of a virtual infrastructure. The environment itself provides the following functionalities:

- Support for dynamically changing of role of stakeholders.
- Measure the effects of customer empowerment on aggregator role and impact on DERS accordingly.
- Monitoring of information on business layers and effects on network configuration.
- Support of dynamic change of the Meta-Data information during run time and measure the impact.
- Produce alerts based on the threshold and penalty/reward the concern stakeholders.
- Multi-level coordination mechanism with feedback and calibration support.

5 Setting Up SLA Experiments

The above business case present a scenario where increased customer based demand for DER/RES integration in the energy sector is sustainable supported. This will eventually leads to higher energy efficiency and lower CO_2 emission partly due to empowering the customer. This in turn will increase customer awareness and acceptance of potentials of Smart Grids.

The SLA-Agents environment for experiments and exploring possibilities and challenges of future Smart Grids is based on extensions of the JADE agent platform[8]. The agents implemented are firstly, agents corresponding to stake holders, secondly, ancillary support agents. We thus have the following agents and databases in our SLA-Agents environment:

Agents:

- *Controller*: Configures and executes experiments
- *Setup SLA*: An ancillary service to the Controller
- *Change profile*: An ancillary service to the Consumer
- *Aggregator* (CVPP). Trusted third party between producers and consumers of energy

[8] `http://jade.tilab.com/`

- *SLA management*: Collects, processes and distributes data related to SLAs
- *TSO:* Transmission System Operator
- *DSO:* Distribution System Operator
- *Consumer/Prosumer:* Active end user
- *Monitor:* Collects data of delegated monitoring tasks by Aggregator, TSO or DSO
- *Billing:* Collect and validate data related to billing
- *Evaluator:* Evaluates the conformance of SLAs to business processes

Databases:

- SLA Database:
- Experiments: Configurations and data
- DER/RES: Capacities and positions
- Billing data: Verified against SLAs
- Network configurations: Position and distribution of network resources

The following Figure 4 depicts the main architecture of SLA-Agents. The main access points to the environment are by the *Controller* or *Customer*. The Controller sets up the preconditions for an experiment. That is, *configures* the experiment and *sets up* the SLA that is going to be tested. The customer initiates experiments based on profile changes by first invoking the agent/service *change profile*.

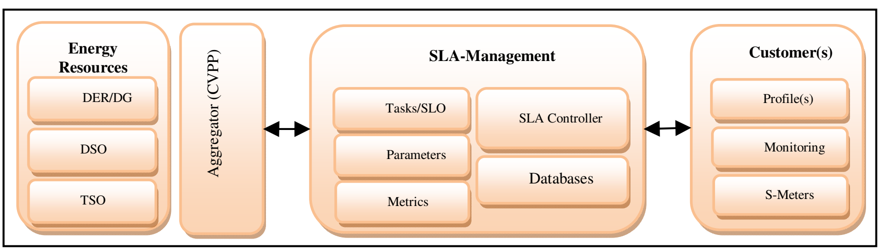

Fig. 4. Empowerment of customer by active participation in energy utilization based on SLAs

The request is sent to the Aggregator to verify the amount of resources required by this profile change, if the profile requirement is like more Green Energy than the Aggregator will calculate the existing amount of Green Energy and either allows the profile change requirement or put it on hold depending on the calculations. If more customers want to change their profiles due to some business incentive provided by the Aggregator or DSO then it is more feasible to allow that change based on the energy resources, instead of business incentives. With our flexible architecture design we can dynamically implement the changes and get the results by running the simulation using multiple time scales.

6 Conclusions and Future Work

We have proposed SLAs as a flexible approach to model and monitor inter-stakeholder coordination between different actors of future Smart Grids. Furthermore, we have presented a real case scenario from the FENIX project giving emphasis on customer empowerment. We present work in progress, specifying tools under development supporting identified models and methods of experimentation. Specifically, we will address traceability and trustworthy challenges of information exchange. Our emphasis is the necessity of real time experimentation in large scale is necessary for proper design and implementation of the future Smart Grid.

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