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Use Cases and Business Models of Multi-Agent System (MAS) ICT Solutions for LV Flexibility Management[1]

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Abstract
This paper describes the use cases and business models opportunities of a Multi-Agent System (MAS) ICT solution for LV Flexibility Management. The MAS platform provides a technological solution that enables new collaboration opportunities between actors in the LV portion of the grid, namely, distribution system operators, ESCOs (in particular Telecoms) and consumers/prosumers. MAS have potential for efficient decision-making in the LV part of the grid due to the large number devices, users and variables and which makes more efficient a decentralized decision making approach. To support the new collaborations and business strategies amongst these actors, new business models are required and the ecosystem forms series of multi-sided platform business models. In this paper, the approach to business model development is detailed and 17 resultant business model opportunities are identified. These business models are then mapped to the use cases for future analysis.

Keywords: Smart Grid, Multi-Sided Platform Business Models, Flexibility Management, Capacity Management, Multi-Agent System, Optimization, Aggregators

1. Introduction

The Mas[2]tering project is centered upon the development of a multi-agent system (MAS) ICT platform [1] for use by local flexibility

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aggregators to conduct the flexibility management of local energy communities in the low voltage (LV) portion of the grid. It is this part of the grid that is most changed by the transition to the smart grid and where decentralized decision making has the most potential to bring value and competitiveness. In addition, this ICT platform provides a technological solution (smart grid access point) to connect to the smart grid.

In the smart grid and in simple terms, flexibility can be defined as changes to the consumer or prosumer planned consumption, production or storage profiles. If aggregated and managed properly, flexibility can be a tool to increase grid efficiency, reduce peak demand and defer or avoid expensive grid reinforcements. In the USA, one study estimates that residential flexibility can avoid $9 billion in planned grid investments, avoid $4 billion in energy production and ancillary service costs and reduce consumer energy bills by between 10-40% [3]. In Europe, 2015 communications from the European Commission call for a consultation for energy market redesign [4] and new deal for Europe's energy consumers [5]. In both communications, flexibility concepts and access to participate in the smart grid are central themes and a clear need to address capacity management is cited as the grid's most pressing challenge (e.g. the need for solutions to answer increased electrification, increased urbanization, and the increased connection of intermittent renewable energy technologies to the low and medium voltage parts of the distribution grid infrastructure). Mas^{2}tering provides solutions to these challenges using a multi-agent system approach to optimize the shift of controllable loads from prosumers in the LV grid in order to achieve a set of goals (reduce energy bill, maximize self-consumption, optimize efficiency of a local energy community, optimize efficiency of a local area of the grid, reduce LV congestion, increase grid reliability, and others). The solution connects consumers to the grid in a new way, facilitates the aggregator role, and provides a service to DSOs for capacity and congestion management.

Equally important as the technological solutions are the market model framework, interactions between market participants and business models to make the system viable. In this paper, the project use cases and initial business model opportunities are detailed. The use cases expand upon a progressive project vision and storyline by which:

- Consumers/ prosumers lower their individual energy bills by using flexibility to maximize self-consumption and to adapt consumption to variable tariff schemes
- Consumers/ prosumers forming local energy communities (as islands) where flexibility can be managed to lower the energy bills of the community and also to create benefits to the grid
- Local energy communities considered with grid constraints where Distribution System Operator (DSO) capacity management, other local energy communities or the flexibility market at large may create flexibility requests.

The primary actors involved in enabling residential flexibility are utilities, DSOs, telecoms and local flexibility aggregators. Together with consumers and prosumers they form a multi-sided platform with the value flows of electricity, data and revenue. This ecosystem and the resultant multi-sided business models are consistent with recent advances in smart grid business model development work [6].

Through literature review, stakeholder consultation and following the approach detailed in Section 3, 17 individual primary and secondary business model opportunities are identified and mapped to the project uses cases. They are clustered by (*Primary*): flexibility as a product, in-home optimization services, flexibility services to the DSO, joint services business models, and (*Supporting*): knowledge and data services, telecom services, security services and referral services. These business model opportunities will later be constructed into actor specific multi-sided platform business models.

2. Use Cases of Multi-Agent System ICT Solutions for LV Flexibility Management

Three use cases are used to develop and validate project results. Each use case deals with a portion of the LV grid and has specific general and quantified objectives. Each use case is an enabler to the subsequent one as each analysis deals with a portion of the LV distribution network that is gradually wider than the previous one. The project use cases are:

Use Case 1: This UC focuses on the Home Area Network and the services that involve the LV end user (domestic and small commercial); the scope is the interoperability between the HAN management system, the smart meter and a technical interface (gateway) which allows the bi-

directional communication between the end user and the rest of the LV grid. The enabled communication is a prerequisite to the local optimization proposed in the other UCs and, for the prosumer, to enter the market of flexibility products.

Use Case 2: This UC focuses on the district, intended as a community of prosumers represented by a local aggregator in a local area of the LV grid; the scope is to demonstrate that MAS optimization performed at this local level is effective for energy management and local balancing, as an alternative to traditional centralised optimization. The objective is to maximise revenue for prosumers belonging to the local community when coping with variable external conditions and conflicting requests from the DSO and the other grid actors.

Use Case 3: This UC is an extension of UC2 and is the union of multiple districts in a given area (represented by a MV/LV substation). The UC targets in particular DSOs and aims at demonstrating that the local optimization enabled in UC2, coupled with proper grid monitoring can be a cost-effective way to deal with local congestions and globally increase grid performances, reliability and resilience.

3. Business Models of Multi-Agent System ICT Solutions for LV Flexibility Management

The approach to construct business model opportunities was:

- Value Flow Analysis: In multi-sided business models an actor may both a buyer and a seller. Mapping the flows (data, energy, revenue) in the multi-sided business model and identifying what each actor's role might entail within each flow.
- Value Proposition Generation: The overall value proposition towards the buyer needs to be able to answer: What customer problem is being solved; what customer needs are being satisfied; what segment-specific products and services can be offered to customers; and what value is generated for customers?
- Value Chain Delivery Analysis: The value chain behind the creation of the value flow needs to account for internal resources; activities and competencies; partners; and distribution channels.
- Value Chain Capture: The revenue model needs to answer: Principle costs are in the proposed business model; what are the proposed

sources of revenue; what is the customer willing to pay for; how do customers pay at present; and how should they pay in the future?
- Constraint Analysis: The constraints in the delivery of each model will vary based on several factors from individual national regulations, market conditions and the stakeholders' willingness to collaborate and engage with the opportunity.

3.1. Business Model Opportunities

Following the methodology explained above and consulting the multi-disciplinary consortium of EU Mas^{2}tering project (Telco, DSO, retailer, research centers, small and medium enterprises), this research has identified 17 business model opportunities to investigate surrounding district flexibility management services. These opportunities are separated into primary and supporting business models. Primary business models are those that directly relate to the grid efficiencies possible by unlocking consumer/prosumer flexibility. Supporting business models are those associated with entering or facilitating the ecosystem. The business model opportunities are intentionally disaggregated to facilitate the identification and consideration of market analysis aspects, strategy options and collaboration opportunities.

- *Primary Business Models*

Flexibility as a Product

- ***B1. Sale of Flexibility by a consumer/prosumer to a Local Aggregator*** is appropriate for consumers/prosumers that do not require services related to in-home optimization and desire to gain value from offering flexibility to the market through an aggregator.
- ***B2. Sale of Flexibility by a Local Aggregator to the Flexibility Market*** deals with flexibility that a local aggregator may sell for purposes other than DSO Services. This flexibility is made available to the flexibility market where the buyer may be a DSO who does not require services, an aggregator of aggregators, a BRP or other market participant.
- ***B3. Sale of Flexibility by a Local Aggregator Service Contract to a predetermined buyer (DSO, Aggregator of Aggregators or BRP)*** deals with the predetermined sale of flexibility to a contracted buyer.

Consumer: In home optimization services

- ***B4. Time-of-use (ToU) optimization*** is based on load shifting from high-price intervals to low-price intervals or even complete load shedding during periods of high prices.
- ***B5. Self-balancing*** is typical for Prosumers who also generate electricity (for example, through solar PV or CHP systems). Value is created through the difference in the prices of buying, generating, and selling electricity.
- ***B6. Control of the maximum load*** is based on reducing the maximum load (peak shaving) that the Prosumer consumes within a predefined duration (e.g., month, year), either through load shifting or shedding. By lowering maximum load the consumer benefits from lower tariffs.
- ***B7. Bundled Flexibility Management Service*** the combination of optimization services coupled with flexibility sales to a LFA.

DSO: Flexibility services for DSO

- ***B8. Congestion management*** deals with the use of flexibility to attain the benefits of peak reduction, local balancing, the reduction of losses and voltage management in a discrete timeframe of high demand to avoid the thermal overload of system components.
- ***B9. Grid capacity management*** deals with the use of flexibility to conduct congestion management but also in a longer-term horizon to defer grid investments to ensure future capacity needs and to extend the operational lifetime of system components.

Joint Services Business Models

- ***B10.Bundled Contracts (Phone-Internet-Energy) for the providing of In-Home Optimization and Flexibility Management Services*** deals with strategic alliances between utilities and telecoms to offer bundled services or with 3rd party organizations that self-organize to offer holistic bundled solutions.

- *Supporting Business Models*

Knowledge & Data Services

- ***B11. The sale of congestion point forecasting to local aggregators as a service*** deals with the ability to create and deliver a competitive advantage and work avoidance via forecasting services.
- ***B12. The sale of consumer / prosumer consumption data to Local Aggregators or Common Reference Point Operators as a service*** deals with the data flow concerning consumer/prosumer load profiles and/or flexibility potential.
- ***B13. The sale of MAS IP to Local Aggregators to maximize price differentials between flexibility purchases and flexibility sales*** deals with the business model for the exploitation of the MAS foreground as it relates to the ICT platform / MAS IP.
- ***B14. The* sale *of MAS IP to In-Home Agent Manufacturers (white goods and renewable energy technologies) to increase product competitiveness and differentiation*** deals with the exploitation of the foreground MAS IP.

Telecom Services

- ***B15. Broadband Content, VAS and OTT sales*** deals with the sale of content licensing, Value Added Services(VAS) or Over the Top Content (OTT) subscription-based services by Telecom Operators to combined energy suppliers / LFA for enhanced device abstraction interoperability within major smart appliance categories connected to ZigBee, Energy@Home, 5G, cloud access channels, etc.
- ***B16. HAN Sales*** deals with the provision of Smart Gateway and related products / services in the HAN. According to the specific country and type of market the Telco company may also be the owner of the device and ask the final user to pay a fixed rate.

Security Services

- ***B17.The sale of security software to ensure the secure transport of consumer/prosumer data*** deals with how software and data security providers add and take value from the system.

3.2. Use case / business model opportunities mapping

Table 1 Business models mapping into use cases

Business Model Opportunities	UC1	UC2	UC3
B1. Sale of Flexibility by a consumer/prosumer to a Local Aggregator	x	x	
B2. Sale of Flexibility by a Local Aggregator to the Flexibility Market		x	
B3. Sale of Flexibility by a Local Aggregator Service Contract to a predetermined buyer		x	x
B4. Time-of-use (ToU) optimization	x		
B5. Self-balancing	x		
B6. Control of the maximum load	x		
B7. Bundled Flexibility Management Service	x		
B8. Congestion management			x
B9. Grid capacity management			x
B10.Bundled Contracts (Phone-Internet-Energy) for the providing of In-Home Optimization and Flexibility Management Services	x		
B11. The sale of congestion point load profile forecasting to local aggregators as a service			
B12. The sale of consumer / prosumer consumption data to Local Aggregators or Common Reference Point Operators as a service	x		
B13. The sale of MAS IP to Local Aggregators to maximize price differentials between flexibility purchases and flexibility sales		x	
B14. The sale of MAS IP to In-Home Agent Manufacturers to increase product competitiveness and differentiation	x		
B15. Broadband Content, VAS and OTT sales	x		
B16. HAN Sales	x		
B17.The sale of security software to ensure the secure transport of consumer/prosumer and aggregate data	x	x	x

4. Conclusions

This paper presented the business model scope of a multi-agent system ICT platform for LV flexibility management in the form of 17 collaboration opportunities. There are 10 primary business models (including “Flexibility as a Product”, “Consumer: In home optimization

services", "DSO: Flexibility services", and "Joint Services Business Models"), and 9 supporting business models (Including "Knowledge & Data Services", "Telecom Services", Security Services", and "Referral Services). This extensive approach of business models is the first step to consolidate final business models through further studies. The main benefit of identifying the business models is to provide a competitive edge. Implementing unique business model can give companies a unique reputation in the marketplace, creating buzz among consumers and encouraging first-time purchases.

A mapping between the business model opportunities and the use cases is presented, which facilitates the alignment of business models and technical architectures and therefore the gap between the research and the market is reduced.

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