A holistic study on smart grids and a business case study of an energy management service provider

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Abstract

The subject of this thesis concerns the holistic study of Smart grids and to conduct a business case study and market analysis of Enervalis to determine its future business models.

Rise of renewables and its intermittencies has given rise to Energy management service companies which balance the load-generation in real-time using demand response actions. Such services enable the user to monitor and control the energy flow in their system. But are these services enough? Can there be other stakeholders involved? If so, who are they? And what kind of remuneration mechanisms exist to help develop new services?

To answer the above questions, the evolution of smart grids, enabling technologies and various stake- holders were studied. Using a case study of Enervalis, its solutions were thoroughly examined. A Business Model Canvas and a SWOT analysis further helped develop the company's profile. Enervalis participates in the electricity market by offering grid stability services through capacity reserves and demand response actions. Hence it's imperative to study electricity tariffs and cost structures of Capacity and Demand response markets to find out the possible business models.

During the research, it was determined that energy management service companies cannot operate on single business model but rather need multiple business models to sustain. Hence, all possible business models with all stakeholders were researched and explained. Furthermore, mechanisms to analyse the competitors of Enervalis and to determine its current position in the market were created. The results of these helped develop recommendations for the development of Enervalis.

Keywords: Smart Grids, Capacity Markets, Demand Response markets, Remuneration mechanisms, SmartPowerSuite®, Enervalis, Competitors analysis

1. Introduction

Our dependence on the electric grid has grown exponentially. We are surrounded by the necessities to power our devices, instruments and machines we are dependent on. We have come a long way from energy consumption of around 5000 MTOE to 13147 MTOE in 2015[1]. This brings us to the question 'How important is our electric grid?'

The production and distribution of electricity has had a top-down approach for several decades until now. It is a one-way energy flow channel, from the power-stations, via the transmission and distribution systems, to the final customer. There is little or no customer participation or end-to-end communications. This approach worked well for many years, and was responsible for the growth of industrial nations by making electricity omnipresent, but is now showing its age.

With the introduction of Renewable energy generation, the definition of the Electric grid is changed. It is no longer a one-way street. Distribution grids have become active and are operating under bi- directional power flows including multi stakeholders. The European electricity systems have moved to a market model where the generators are dispatched reacting to the market forces and the grid control center undertakes the supervisory role performing actions such as active power balancing, voltage stability etc. Higher grid control, automation and new technology has initiated the possibility to reduce the dependency from the grid. But does this make things easier?

Influx of Renewable energy brings a lot of interaction within the grid. As these sources are intermittent and their availability changes along with the weather and several factors, our existing infrastructure is not built to handle such interaction and hence needs an upgrade. There is an urgent need to alleviate grid congestion and improve our balancing capability. It is imperative to move from a traditional centralized generation approach to a distributed generation and user centric approach. It needs real time forecasting models, demand response actions to stabilise the grid at any given moment to protect it from overloading or underloading. Energy management service companies currently cater to provide these solutions at various levels. The future of these companies will determine the effectiveness of our grid.

2. Evolution of Smart Grid

The definition of smart grid as defined by ABB is '*A smart grid is an evolved grid system that manages electricity demand in a sustainable, reliable and economic manner, built on advanced infrastructure and tuned to facilitate the integration of all involved'*[2].

The current electricity market which operates in a way where the end user node is simply a 'sink' for electricity underwent a makeover resulting in rapidly growing distributed generation technologies some of it in the form of Renewable energy storage systems (RES). This enabled the user to no not only act as a sink but also as a source in the system. Smart metering, with its two-way communication capability and improved user information is now a reality and its deployment is taking place rapidly in several European countries

The formation of European union helped immensely in developing new policies providing various frameworks for the establishment of smart grids. The EU recognizes smart grids as the key infrastructure for the energy modernization of Europe. To develop this, a vision 'smart grids 2020' emerged[3] and 'smart grids task force' was created in 2009 which involved the European commission officials, policy makers, experts from industries, research centers and academia. National institute of standards and technology (NIST) establishes a concept model for smart grids by listing the seven domains of smart grids i.e. Power generation, transmission, distribution, customer, service provider, operations and markets [4]. The European energy policies at present relies on (i) security of supply, (ii) sustainability and (iii) market efficiency

2.1 Enabling Technologies: Evaluating the current technologies is an important step to develop the direction of future development. Delivering an adequate architecture will require a number of 'enabling' technologies. Several of them are already available to some extent; a few currently being deployed in other sectors. They are listed as following:

- Distributed generation(DG): Increase in small rating electricity sources be it conventional or renewable which provide a variety of advantages such as on- demand power, enhanced reliability, quality of supply, deferrals in transmission investment and meet the renewable mandates in times of increasing disinvestments from transmission assets [5].
- Energy storage: Storage technologies form the backbone of a smart grid. These provisions help in (i) making the grid smarter and more efficient (ii) it enables load levelling and peak shaving and replaces spinning reserve (iii) improves grid reliability and stability (iv) Enables supplementary services like providing reactive power for voltage regulation and (v) supports transmission and distribution deferring.

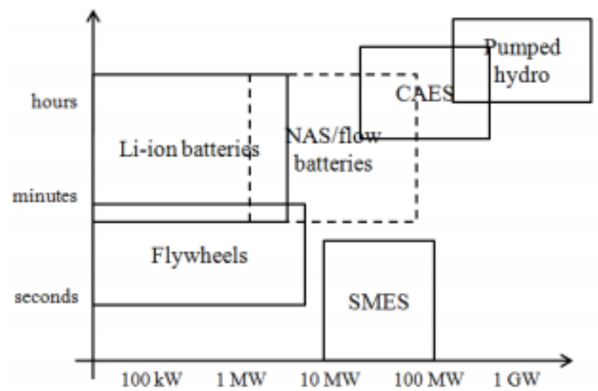

Figure 1: Comparison of discharge duration versus rated power for grid energy storage technologies [6]

- Power electronics: Concepts of power electronics are one of the most fundamental aspects in development of smart grids as there is an increase in the number of renewable power generation sources within the grid. A power electronics converter will allow energy storage during surplus input power and provide compensation in case of lack of input power
- Control, Automation and Monitoring: The difference between an existing grid and a smart grid is the existence of intelligent control.

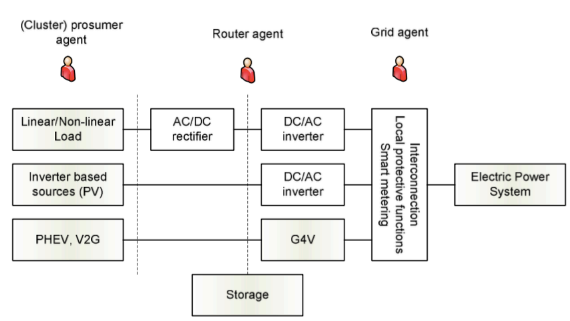

Figure 2: Intelligence-based control structure for power electronics in smart grids [6]

A smart grid is very complex, nonlinear dynamic network by nature that needs capabilities for monitoring and control which gives the ability of self- healing, self-organizing, and self-configuration. It can be achieved by a combination of power electronics and agent based control techniques which create a complex yet flexible interface between different elements of the grid like consumers, storage, network areas etc.

- Distributed automation and protection: To achieve continuity, reliability and security of supply it is necessary to design applications such as self-healing and protection mechanisms using the advanced distribution systems (ADA). It deals with detection and clearing of abnormal anomalies such as faults and overloads. Local controllers ensure that each island grid will operate within its security while safeguarding the electricity supply[7]. A smart self-healing system should incorporate a wide variety of sensors over a large area and should be able to sync with each other through the global positioning service (GPS)[8].
- Communication: The signals obtained from sensors be it in a digital/analog format can be used by the controllers to enable the self-healing of the system in times of anomalies. IEEE standard 1451.4 [9] advises analog sensors to have a transducer electronic data sheet (TEDS) to provide the required calibration information to the data acquisition system.[10]. Figure 3 shows several communication technologies that can be applied for various data formats, according to their characteristics.

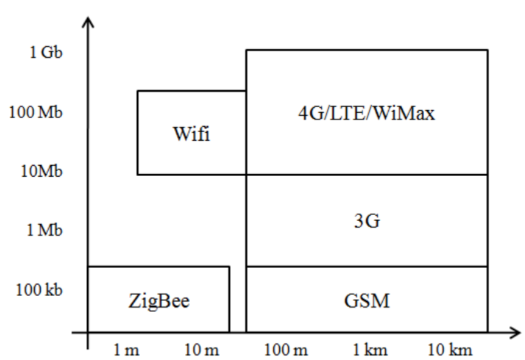

Figure 3: Characteristics of some wireless communication technologies: bandwidth vs. transmission range [6]

Stakeholders: The rise of liberalized and dynamic markets has led to an increase in the number of players involved within. The future smart grids will involve governments to everyday users and every stakeholder will be imperative in shaping this system. The various stakeholders in the system are:

- End user
- Electricity network owners
- Energy service companies
- Technology providers
- Researchers
- Traders
- Generators
- Regulators
- Governmental agencies
- Adequate workforce and continuous education
- Advanced energy management service providers

3. The SmartPowerSuite®

Enervalis develops the operating system (SmartPowerSuite®) of the future energy systems for the mass markets to enable maximum green energy within the system.

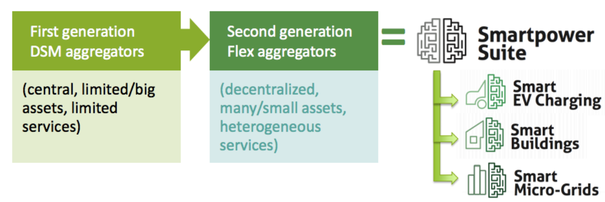

Figure 4: Proposed solution of Enervalis. [11]

Enervalis currently focuses on 3 market segments: Smart Electric vehicle (EV) charging, Smart buildings and Smart Micro grids as shown in figure 4. SmartPowerSuite® can be defined as a single, comprehensive hardware agnostic system for HVAC, EV charging and other systems. In simple words 'It is an energy management software for your home/building/locality'. Its core element is 'Internet of Energy', which by design has the same key values as of internet; resilience, redundancy, security and low- barrier enablement for mass market service adoption. There are several applications and features of SmartPowerSuite and it brings several benefits such as better indoor comfort, reduced energy bills, energy efficiency, and a better management of all the systems under one unified system. It also supports efficient functional system integration with existing Building management systems (BMS) and provides maximum flexibility to support any future changes in building use. The feature elements of SmartPowerSuite are:

- Energy monitoring
- Forecasting of availability and usage
- Data visualisation of all systems
- Heating and Ventilation control (HVAC)
- Flexibility control
- Energy trading

3.1 System architecture: The system is designed to be completely modular in structure and easily expandable at any stage. To ensure fault toleration and robust system design, the system incorporates distributed control techniques and apply principle of distributed intelligence when applicable. The system also enables remote monitoring, connectivity and other value- addition services. The SmartPowerSuite is installed on a physical router which is called the gateway. It is a node (router) in a computer network, a key stopping point for data on its way to or from other networks. It interacts with various devices such as storage devices, heat pumps, sensors etc. It is connected to the cloud platform of Enervalis using existing internet solutions such as Wi-Fi or 3G. It communicates with devices in the building using other protocols such as ZigBee, Z-wave, Modbus, BACnet etc. The gateway is also capable of operating independently without interference from master controllers or management applications. It supports distributed intelligence and centralised systems alike. It is possible to distribute the gateway at electrical switchboards or cabinets close to the control system to minimize cabling. An overall outlook of the system is presented in figure 5

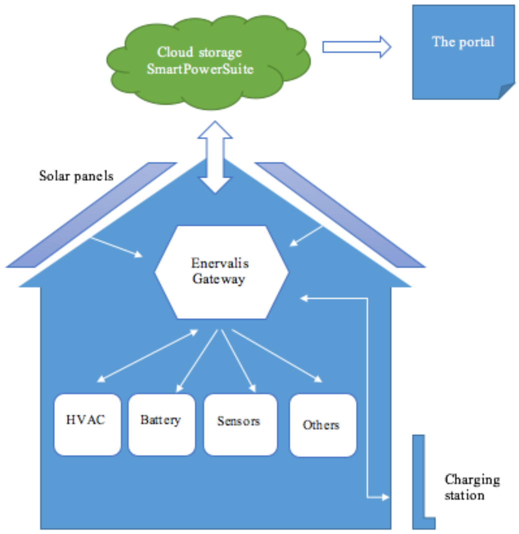

Figure 5: Overview of system architecture

4. Industry cost structure

Despite several efforts on part of the EU to move towards a common European legislation there is a wide disparity in terms of the cost structures of each member states. The conditions of each market are different and it is necessary to analyse and compare these to develop future business strategies. The market analysis will focus on the geography and as well as following important parameters to identify current market conditions. They are;

a) Average electricity prices: There is a co-relation between average energy prices and potential demand for energy management services. Private and industrial consumers develop their energy consumption patterns based on these prices

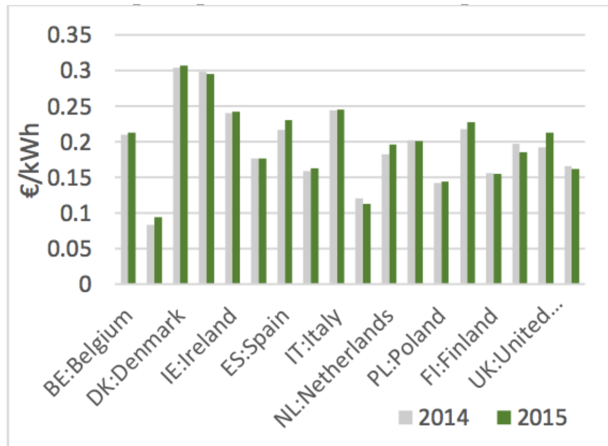

Figure 6: Average electricity prices for private customers [12]

For private consumers; The prices are high in Denmark, Germany, Italy, Spain, UK and Portugal. In comparison, prices in Poland, France, Norway, and Finland are on lower end of scale. In countries like Bulgaria and Hungary the electricity prices are the cheapest

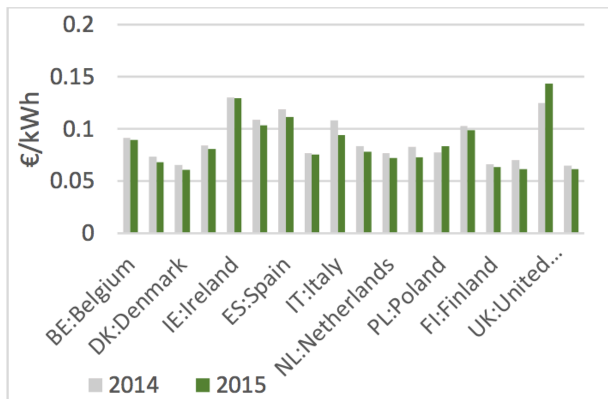

Figure 7 : Average electricity prices for Industrial customers[12]

Industrial consumers: The industrial electric prices are very high in UK and Ireland followed by Spain, Greece and Portugal. The northern countries Denmark, Finland, Sweden and Norway have very low prices compared to the rest of Europe. The prices of rest of the countries lie between these two ranges.

To understand these pricing mechanisms, it is important to know what constitutes them. The pricing mechanisms comprise of three components as seen below in figure 25. Each of these is driven by several market and legislation driven factors

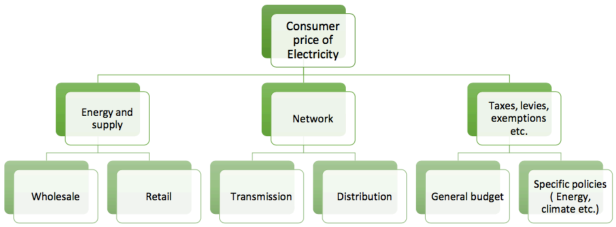

Figure 8: Elements of consumer prices

Out of these three components, Network tariffs is the key component here. DSO's ability to recover costs through network tariffs will be the key to companies such as Enervalis who provide energy management services. They are further subdivided into (i)Fixed charge(FC) (ii) Capacity charge(CC) (iii) Energy charge(EC) and (iv) Reactive charge(RC). A brief outlook of network tariffs of private consumers in selected few countries is shown in table 1.

Private customers				
Country	Fixed charge [€]	Capacity charge [€/kWh]	Energy charge [€/kWh]	Reactive charge [€/kvarh]
Belgium	✔	-	✔	-
Denmark	✔	-	✔	-
Finland	✔	-	✔	-
France	✔	✔	✔	-
Germany	✔	-	✔	-
Ireland	✔	-	✔	✔
Italy	✔	✔	✔	-
Netherlands	✔	✔	-	DSO specific
Norway	✔	seldom	✔	-
Poland	✔	-	✔	-
Portugal	-	✔	✔	-
Spain	-	✔	✔	-
Sweden	✔	seldom	✔	-
UK	✔	-	✔	-

Table 1: Electricity network tariff structures[13]

Capacity markets have a high influence on our energy prices and yet private customers are spared from such tariffs in several countries like Germany, Ireland, Poland and UK. It is observed that Capacity charges are more acceptable in France, Italy, Netherlands, Portugal and Spain. With regard to industrial consumers, capacity charge tariff is applied in almost all EU member states.

To encourage investors, several member states have introduced capacity remuneration mechanisms (CRM). Current direct and indirect remuneration mechanisms to increase facility revenues vary significantly between the member states. Table 2 depicts the current, planned capacity remuneration mechanisms for a selected few countries.

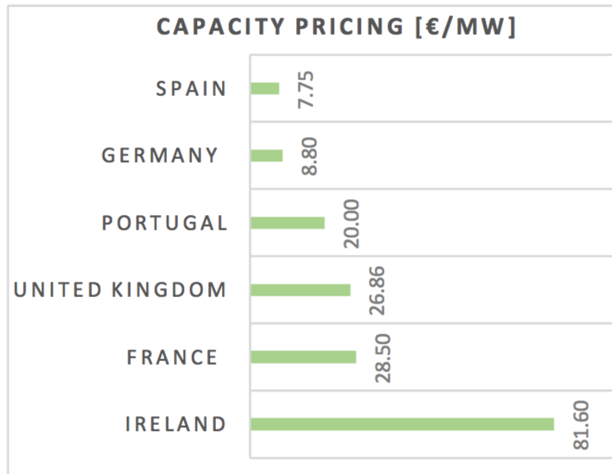

Table 2: Comparison of existing CRM in terms of capacity pricing. [13]

The two ends of extremes are represented by €7.75/MW in Spain and €81.6/MW in Ireland. In other member states, factor of the actual amount of energy provided is considered and accordingly regarded as an indirect form of CRM.

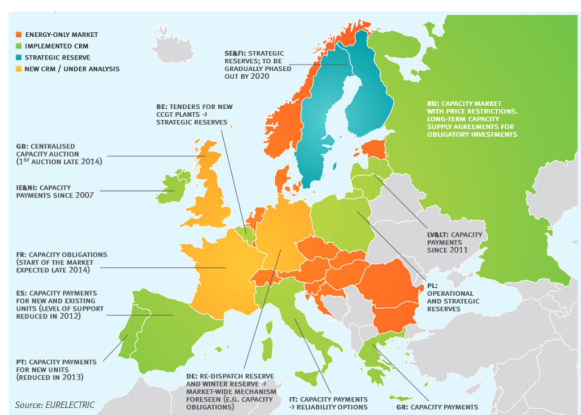

Figure 9: State of CRM in Europe [14].

Scope of Enervalis: Enervalis has a bright potential in the near future to enter this market using EV optimization techniques. With the number of EV vehicles on road, it is only a matter of time before the full potential in utilizing as a capacity reserve is realized. The requirement for such targets is to have a large customer base. It can be realized through partnering with charge pole companies and their energy service providers. Ability of Enervalis to predict energy consumption patterns will prove to be a game changer in achieving the above targets.

Demand response (DR) is expected to play a path breaking role in transformation of energy markets. It also addresses short-term capacity constraints by providing stable, flexible and efficient solutions. As awareness among the public increases regarding the role of demand response services and their potential financial benefits, the market for such services is expected to grow rapidly. Smart energy demand coalition (SEDC) oversaw the evaluation of existing national regulatory frameworks based on the below four criteria for demand response activities in 2014. The criterions are; (i) Consumer access (CA) (ii) Program requirements (PR) (iii) Measurement and Verification(MV) and (iv) Finance, Risk (FR) and Total score (TS)

Country	CA	PR	MV	FR	Total score
Belgium	↑↑	↑↑	↑	↑↑	↑↑
Denmark	↓	↓↓	↑	↑	↓
Finland	↑↑	↑	↑	↑	↑↑
France	↑↑	↑↑	↑	↑↑	↑↑
Germany	↓	↑	↓	↑	-
Ireland	↑	↑	↑↑	↑↑	↑↑
Italy	↓	↓	↓↓	↓	↓
Netherlands	↑	↑	↑	↓	↑
Norway	↓	↑	↑	↑↑	↑
Poland	↓	↑	↑	↓↓	↓
Spain	↓↓	↓	↓↓	↓	↓↓
Sweden	↓	↑	↑↑	↑↑	↑↑
United Kingdom	↑↑	↑	↑	↑	↑

Table 3: Status Quo of Demand Response Activity[15]

From table 3, favourable conditions can be found in Belgium, Finland, France, Ireland, Sweden and United Kingdom. Market environments in Denmark, Italy, Poland and Spain is rather deterring for services of Enervalis. Conditions in Germany are both favourable and unfavourable depending on specific criteria's. Various Business models can be adopted as a Demand response program (DRP) in the market. They are further discussed in the next section.

5. Future Business models

Demand side management activities (DSM) are organized into 'Energy efficient' (EE) and 'Demand response' (DR) business models as seen in figure 10.

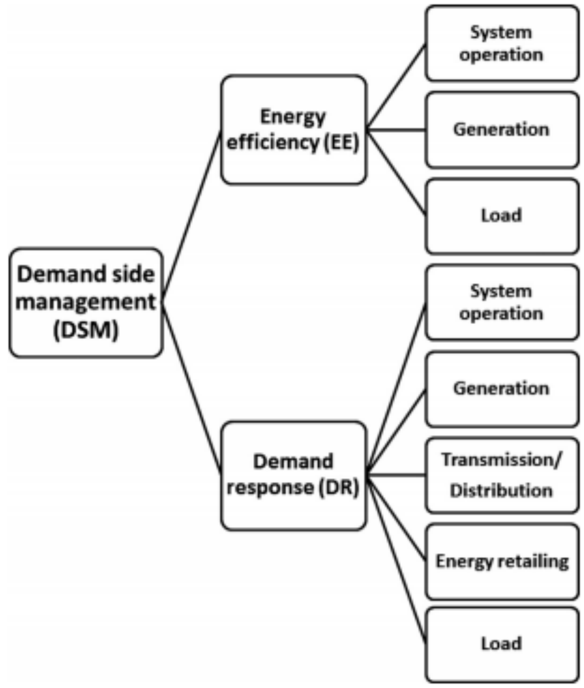

Figure 10: Electricity market related DSM business models

With regard to **Energy Efficiency** business models, we shall only discuss the business models related to load control currently. They are (i) Energy saving performance contracts (ii) Energy efficiency service and device sales.

As we move further, **Demand response** actions market is explored and studied. To start with, the different options available under **System operation** are described next.

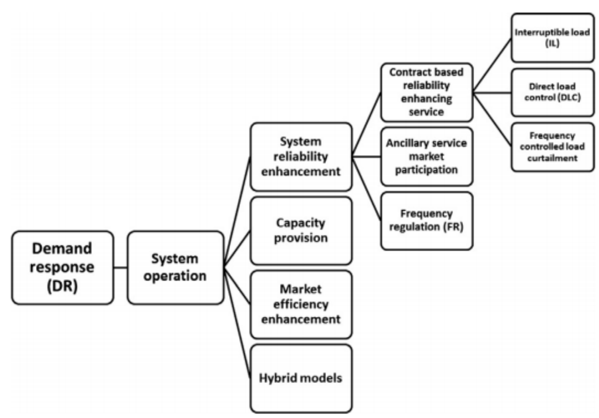

Figure 11: System operation segment related DR business models

It is a very well established business model for DR players all across. Here the DRP would sell its ability to change the demand profile based on several agreed conditions and circumstances with the System Operator (SO). The SO would utilise the services of DRP when the grid reliability is in jeopardy or the operation margin is lower than desired. The merits offered by DRP are fast response, high ramp rate and a relative lower cost than an additional generating unit. DRP with its aggregator capabilities offers higher reliabilities to the SO as it is one of the most important targets of an SO stakeholder. Several different mechanisms are present to maintain such services and hence creates several business models as depicted in the figure 11.

Here, reserves can be sold in ancillary markets or sign a direct contract with the DRP for interruptible loads, direct load control or frequency based load control. There can also be Capacity provision mechanisms that are established to ensure adequacy of the system for medium and long term load-generation balance. Here, the 'capacity' payment is more important than the energy payment which is an extra payment in case the DR is actually used. Further, Flexibility is also offered in terms of energy consumption patterns as it helps the SO to have a more efficient and economic operation and scheduling[16]. it is difficult to draw a rigid boundary line between these business models as DR actions affect multiple aspects of SO or an SO could use DR for multiple purposes. This could create hybrid business models.

Continuing the various business models from Figure 10, We shall further discuss models related to **Generation**.

Generation stakeholders are obliged to stick to their schedule, if not they are encountered with heavy losses. A DRP can create a business model with a generation stakeholder to reduce the loss of revenue. Intermittent energy resources are the best choice for such business models [16]. Here, the DRP installs an energy storage or another DR resource to increase flexibility and will use this to compensate for intermittencies of the 'variable generation units' (VGU). This will allow VGU to be more efficient and gather more revenue[17]

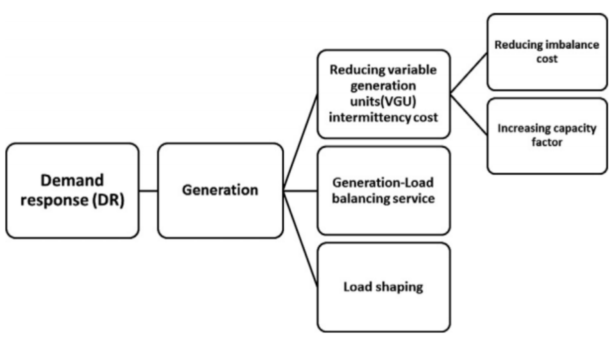

Figure 12: Overview of generation segment DR business models

In certain markets, generation units do not own the transmission lines and are required to supply power to the contracted loads. This may cause a drop in power over long distances. Here a DRP can provide load balancing services to save the generation units from penalties by the transmission provider. A DRP can also provide its flexibility for load shaping services. Here, DRP is expected to increase/decrease loads in certain periods to reduce operation costs to the generation stakeholder. Such models were uncommon earlier as it required sudden increased loads at the given time. However, due to increase in storage devices and Electric vehicles (EV) on the road, these services can now be operated easily, as DRP can control centralised and decentralised EV charging scheduling.

We shall further discuss business models related to **Transmission/distribution** segments.

Figure 13: Transmission/Distribution related DR business models

Congestion of transmission infrastructure can have undesirable effects on the systems operation, stability and economy. Add to that an ageing infrastructure and integration of renewables, the problem becomes bigger. A fast and proven method for congestion mitigation is to use DR actions [18]. It is also shown that the effect of DR increases the life cycle of a transformer [19]. In this model, The DRP offers its flexibility in energy consumption while having the locational merit of being in the same location as of the congestion in return for certain incentives. A bilateral auction mechanism is used to have a contract with the DRP[20].

Continuing further, we shall now discuss business models related to **Energy retailing** segments as shown in Figure 14.

An error in load forecasting or change in load behaviour may force the energy retailer to purchase the energy shortfall form spot markets or a balancing market. These markets could be volatile with high price fluctuations. In such cases, retailers could face fluctuating energy prices for the provision of energy shortfalls. But, retailers generally have a contract with the loads for fixed or more stable tariffs. This will expose retailers to revenue losses. Here, there is a business opportunity for the DRP to help the energy retailer reduce its losses

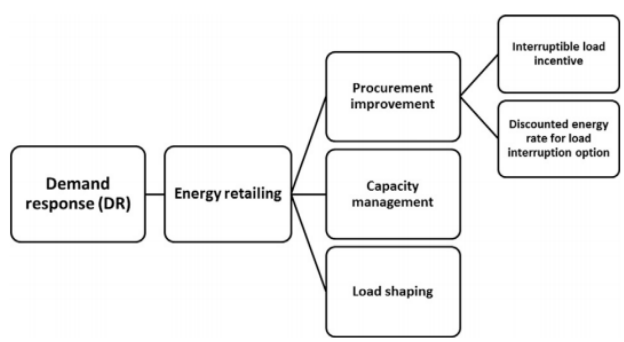

Figure 14: Energy retailing segment DR models

The incentives for this can be in the form of (i) Interruptible load incentive and (ii) Discounted energy for load interruption options. In certain markets, retailers are expected to secure system capacity based on their peak contribution. In case the retailer needs more capacity, it should be purchased through a bilateral contract or market mechanism. If the retailer goes over its provided capacity, it would expose itself to extra payments due to capacity override. Hence, a DRP can be used to address the capacity provision. Apart from these a DRP can also offer several Load shaping options.

Further on, we shall address the last section of the Figure 10; **load segment** related business models.

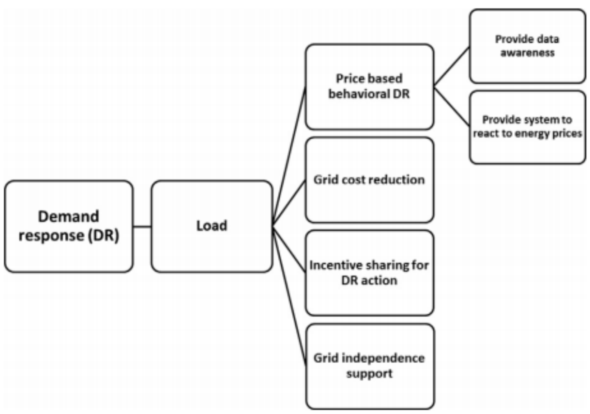

Figure 15: Load segment related DR business models

Currently the market of DRP having the business models with Load is on the rise. The main target here is to reduce the electricity costs of the load stakeholder or act as a medium to sell its flexibility in the right market.

By providing data awareness and systems to react with change in energy prices, DRP can have priced based DR contracts. Also, as discussed earlier, the user pays not only for the energy consumed but also for the usage of the transmission/distribution grid. This is in form of 'base payment' which is calculated on their peak loads, or a load coincident with the system peak in addition to the energy they consume. Therefore, reducing the peakloads can reduce the grid cost for the user. Here, the DRP would commit to reducing the load at suitable times and thereby the grid costs, and it can share the savings. Further on, the load can share its flexibility to the DRP. The DRP will further sell it to the right DR purchaser based on its business decisions and market constraints.

Also, If the user has access to an energy generation resource, the user would prefer to increase the energy consumption primarily from the renewable resource and reduce his dependency on the grid. In remote areas and islands, grid independence is the only available solution. In this business model, DRP can help achieve this load-generation balance by offering the required platforms, infrastructure to the user. With growing renewable energy generation resources worldwide, this business model is expected to rise rapidly.

6. Conclusions and Recommendations.

As we are moving towards integration of Renewable energy as our primary energy generation sources, there is an urgent need to develop Smart grids. To establish the smart grids of tomorrow, we need smarter technologies; devices which communicate with each other. Energy storage systems are needed to backup during critical times and the growth of Electric vehicles has prompted industries to consider the huge potential they can offer to various stakeholders of the grid. Enervalis as an energy management service needs to work with several of these stakeholders together to provide insights into the range of benefits an intelligent grid can offer.

Analysis of SmartPowerSuite® concluded that Enervalis is a value driven company. The value proposition is unique and has the ability to cater to several stakeholders while improving the grid. It was found out that different laws of the land are currently delaying the entry of Enervalis into certain markets. However, as long as the European Union remains one entity it is expected to receive support and direction with introduction of new laws and frameworks to bring their solutions to the forefront of energy markets

Electricity prices and their components were also discussed to explore the possible countries through financial perspective. Capacity remuneration schemes of different countries have determined that the markets in Belgium, Ireland and France are supportive in terms of legal frameworks and public acceptance. The incentives in Spanish market is comparatively lower but is expected to rise in the future given its rise in share of renewables in the grid. Energy storage and aggregation techniques combined with wind and solar are expected to provide the backbone for developing such solutions. In the Demand response market, Belgium, France, Finland, Sweden and UK provide maximum support to DRP's. Germany scored favourable in terms of program requirements whereas the consumer access is very limited and hence is termed nether favourable nor unfavourable currently It has been upheld that one business model does not fit the growth of Enervalis. It is a challenging task to develop business opportunities for sustainable growth of energy management services. Hence, several different possible business models for Demand response services in relation with System operator, Generation, Transmission and Distribution, Energy retailing and Loads were discussed in detail. The number of business models possible with a SO are higher than any other segments. With a SO, Enervalis can participate in ancillary market services offering flexibility of Electric vehicles or aggregated loads. This business model also provides DRP the freedom to choose its own time periods in advance. There are also other business models possible where the load control and frequency control services are offered to the SO. By offering these services, Enervalis can help SO make better decisions and save costs in the long run. It is noted that the primary motive for the SO is the reliability DRP provides during various situations and Enervalis can capitalise on the requirements of the industry. For transmission and distribution segment Enervalis can provide services such as congestion management to protect the grid from overloading. Using Energy generation and consumption forecasting, it can advise energy retailers in making smart decisions regarding energy procurement. Enervalis can provide its energy consumption flexibility to reduce the peak prices and fluctuations in the energy market and reduce costs incurred by several segments of the grid. Enervalis currently participates with the end users directly to minimize their electricity costs while increasing the overall performance efficiency of their loads. However, to proceed, further research is needed to look into the structure of electricity markets of individual countries to determine which of these business models can be applied. It can be started with the markets where the remunerations for capacity pricing and DR actions are higher. A detailed study on each individual markets is necessary to build the roadmap for attaining economic feasibility of the company

To sum up, this paper has conducted a case study of Enervalis determining its role in the market while analysing possible future sustainable business models. The success of Enervalis depends on catering to the multiple services of different segments of the energy industry while building the smart grid of tomorrow.

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