Load Control in Real Time Price Prediction

A framework combination of Real Time Pricing and Inclining Block Rates

for the Switzerland's power grid

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Executive summary

Switzerland's electricity consumption in 2014 was 59.3 TWh (Abrell, 2016) and continues to rise every year. As residential needs for electrical energy increase, so does the demand (Abrell, 2016; Filippini, 2011; IEA, 2012; Zhao et al, 2013). As a result, the necessary energy for meeting the demand cannot be provided by the power grid (Abrell, 2016; Filippini, 2011). The Swiss government has tried by applying new methods in price calculation for electricity to help shift the loads to different times (Abrell, 2016). Nevertheless, over- loadings and blackouts occur several times per year creating high maintenance costs (Abrell, 2016; Filippini, 2011), for the production companies which reflects to the users' payments as well. On the one hand consumers' demand aims at electrical energy of high quality and reliability (Abrell, 2016), but on the other hand producers' aim in less maintenance costs. A clear solution is needed for the demand and supply of Switzerland's grid to balance.

A new solution, a new methodology based not entirely in technology but also in the correct use of Information Systems. This paper will describe a new proposal, solution for the Swiss energy production and consumption to balance through energy scheduling and flexible pricing. Smart buildings and smart appliances, will provide users, with an ECO efficient use of the energy through the Information. The users can create their own demand schedule, in accordance to the calculated prices by the combination of RTP and IBR and their actual needs. During Real Time Electricity Pricing (RTP) prices can be generated hourly and transmitted to users.

A problem that increases with RTP is that users tend to maximize the use of their appliances during the low peak prices and potentially create overloads, which could lead to instability of the grid or even a power blackout. In order, to avoid such problems, and secure except of flexible prices also reliability and stability for the system, RTP needs to be combined with the Inclining Block Rate (IBR) methodology. During IBR pricing prices can be calculated according to the loads. The combination of the two methodologies give the possibility to the users not only to schedule their energy use by time but loads as well.

An important fact that rises through this proposal is the possibility, given to the energy production companies and the government, to balance the maintenance costs

which will lead in saving thousands of francs every year by simply involving the end-users in the electric grid operation. Simply by giving the possibility to users to control their appliances' consumption, for different periods, by reducing their consumption or shift their loads to low peak periods.

Abbreviations

- RTP Real Time Pricing
- IBR Inclining Block Rate
- DR Demand Response
- IS Information Systems
- ICT Information Communication Technology
- RTEP Real Time Electricity Prices
- PAR Power Peak Ratio
- TOU Time of Use
- TOUR Time of Use Pricing
- CPP Critical Peak Pricing
- kWh Kilowatt- hour
- TWh Terawatt- hour
- RES Renewable Energy Sources
- WEM Wholesale Energy Market
- ES Energy Scheduling
- FBE Free Basic Electricity
- TSO Transmission system operator
- RA Regulatory authority
- ElCom Federal Electricity Commission
- EMS Energy management system
- EMC Energy management controller
- AOA Automatically operated appliance
- MOA Manually operated appliance
- LOT Length operation time
- OTI Operation time interval

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Chapter 1: Introduction

1.1. Introduction

The world is in a forward speed and the fast pace of the climate changes are calling for essential solutions, deriving not only from renewable energy systems or gadgets and engines, but also from the information that can be extracted and exchanged from those (Khan et al., 2013; Kurkinen, 2016; Suryanarayanan et al., 2013; Zhao et al., 2013). The urge of handling the situation (Zhao et al, 2013), to bring sustainability onward (Filippini, 2011), has been in the centre of the attention for many industries and corporations (Samadi, Member, Mohsenian-rad, Wong, & Schober, 2012; Mohsenian-Rad et. al, 2010; Zhao et al., 2013). Several studies have been done for understanding energy saving, by using renewable energy sources, but not many are there, that show us how others in need, could use energy correctly at the best possible and flexible prices (Dang & Ringland, 2012; Darghouth et al, 2011; Hopper et al., 2007; Horowitz, 2012). And more importantly the need and the money spent every day for maintenance of the power grid and the power lines are just increasing.

There are several methodologies used to calculate prices for the consumed electricity. Different methodologies are being studied such as Time of Use Pricing (TOUR), Critical Peak Pricing (CPP), Real Time Pricing (RTP) or Inclining Block rates (IBR) (Zhao et al., 2013) that are used for calculating prices for the electricity energy consumed. Some of these methods are calculating prices depending on the time, or season and others according to the loads used (Zhao et al., 2013). All methods though when used individually cover a few aspects. As a result, there is always an aspect that affects the price calculation. Renewable energy sources, smart homes, automated smart houses, energy savings are some of the important aspects that should be taken under consideration (Dang & Ringland, 2012; Roscoe & Ault, 2010; Samadi et al., 2010).

This master thesis will study two of these methodologies, the Real-Time Pricing and the Inclining Block Rates and the difference they will make if implemented correctly in the Swiss grid. The main point of the thesis is that the author will argue that a combination of these two models which is shown in the framework representation in the later chapters, can affect the electricity pricing of Switzerland and heal the system from its imbalance problems. There are different aspects that need to be taken under consideration to create the new framework from which the flexible prices will be calculated.

The main topic that will be discussed is the combination of RTP and IBR in one framework that could be adopted by the Swiss grid. The combination of the two methods in one, will give the possibility to the users not only to schedule their energy consumption according to the time of use but also loads. An important fact that raises, is that the energy production companies and the government will gain the ability to balance the maintenance costs, which will lead in saving thousands of francs every year (grid maintenance costs are very high in Switzerland, thus, by decreasing the costs thousands of francs can be saved), by simply involving the end-users in the electric grid operation. Simply by giving the possibility to users to control their appliances' consumption, for different periods, by reducing their consumption or shift their loads to low peak periods.

The thesis is based on a literature review, mainly the research of Zhuang Zhao et al, titled "*An optimal power scheduling method for demand response in home energy management*" and the research of Amir-Hamed Mohsenian-Rad et al, titled "*Optimal residential load control with price prediction in real time electricity pricing environments*". With this research, I will argue that in Switzerland this combination methodology, is the best solution to balance the grid hence the costs, for different reasons that will be explained thoroughly in the later chapters. Although Switzerland has the most reliable grid system in the world (Abrell, 2016; Filippini, 2011) several problems occur every year. Several damages to the grid, such as blackouts and that cause instabilities and power losses (Filippini, 2011).

The need of grid stability and a secure and safe connection between the power production and power consumption is rising everyday (Abrell, 2016), not only from the users' point of view but from the production companies' as well which because of failures are increasing (Abrell, 2016). Solutions such as the smart grids with the use of smart communication tools and smart meters are not enough. Although with the smart grid, users have all the necessary data (such as the hourly prices), to understand when is the best time to use their utilities over consuming tendencies and overloading problems still occur. Power scheduling is the new add in the price prediction, as shown in the framework representation, which is possible because of the smart two-way communication (the user receives data from the utility company such as the flexible prices and the utility company receives data from the users about when and how they use their appliances which helps them evolve the price calculation).

The research described in this paper will focus in that point, where the smart houses/ smart buildings, in combination with the two methodologies create a fully automated smart system, that ultimately provides the consumer with the best prices and all the necessary information about low and high peak prices according to times and loads. In details, through this system/ model, users can learn load control, as well as fully understand the importance and benefits of doing so. The new framework that will be created from this research, will ultimately lead to the balance of the grid system. By balancing the grid system, the over-loadings will be minimized. As a result, the maintenance needs and costs will decrease.

1.2. Problem statement

In the last one hundred years, life has changed in an exponentially increasing rate (Lazar & Colburn, 2015). While in the beginning the needs of the people were summarised to some light bulbs around the house nowadays it seems that everything needs electrical energy (Lobaccaro et al., 2016), smart phones, computers, heating, cooling, washing machine, robotics, 3D technologies, etc., all need energy to function. Although by using new technologies efficiency and productivity should be risen, more and more environmental problems occur. It seems that energy is lost as it is not used or on the opposite overused (Alexander, 2007).

All researchers agree that the Smart Grid and the Information Communication Technologies (ICT's), provide many advantages (Alexander, 2007), such as the capability of improving performance and the users' responsiveness (Lobaccaro et al., 2016). When users have the possibility to schedule their consumption and assign their appliances correctly according to the time of use and the load control system, then, they are able to decrease their energy consumption, resulting to an increase of network reliability and efficiency (Nader, 2011), thus a decrease of the maintenance costs (Zhao et al, 2013).

The basis of a power schedule is Demand Response (DR), which is the changing of the electricity demand according to the Real Time Pricing (RTP) (Zhao et al, 2013) and it consists of both interruptible and non-interruptible loads (Zhao et al., 2013). The evidence of this research show that although with the use of smart grid the power scheduling is enabled price flexibility is still an issue (Sioshansi & Short, 2009). An efficient and effective way to solve this problem is the real-time pricing model. In RTP the price can change in an hourly basis, such as twenty-four times in a single day or even four times in an hour, every fifteen minutes, such as ninety-six times in a single day which is predefined and communicated continuously to the users. It is the most economical and efficient way to meet users' demand response (Zhao et al, 2013).

The problem that raises from, is that although RTP is adapted to the system and the users are getting flexible prices for the electricity use, they tend to work their appliances at the same time (Mohsenian-Rad et al, 2010), which results to an irritation of the system. RTP provides the ability to reschedule and effectively shift the loads in a way that the costs are minimized. But the disadvantage is that RTP may make the users to choose to maximize their usage during the low price time (Mohsenian-Rad et al, 2010), creating an overload which could lead to a crash or an instability of the system or even a power blackout (Zhao et al., 2013).To avoid such an over-loading problem and secure the reliability and stability of the system as well as safety and security for the users' usage, (Zhao et al, 2013) RTP needs to be combined with the IBR methodology (Samadi et al, 2012; Zhao et al, 2013). The decrease of this problems will reach the desired result which is minimized costs for both users/ consumers and producers (Filippini, 2011; Samadi et al., 2012).

The framework of figure 5, is a representation of the above. There are several reasons why this solution should be embedded in the Swiss grid. On one hand Switzerland is a country that new technologies such as smart appliances are embraced (International Energy Agency (IEA), 2013), a great number of houses have already embraced these new technologies in their households, on the other hand the need for an energy strategy based in the costs (Abrell, 2016). It is important to mention here, that while other countries such as China are searching for ways to become more sustainable Switzerland has become an inspiration for their high efforts and submission towards energy efficiency (IEA, 2012; International Energy Agency (IEA), 2013). During the last years, Switzerland has invested in new policies towards radical changes on the energy consumption reduction (Abrell, 2016; International Energy Agency (IEA), 2013), which makes the country to have a clear advantage with regard to the proposed solution. Furthermore, according to the Swiss federal office of energy, "on April 13 of 2016 the Federal Council adopted the dispatch on the Federal Act on the modernization and expansion of the electricity grids (Electricity Grid Strategy) and submitted it to the Parliament" (source: http://www.bfe.admin.ch/netzentwicklung/index.html?lang=en), which makes the proposal in this paper a possibility to be adapted as an electricity grid strategy.

Finally, another important reason for this solution to be embedded by the Swiss grid, is the need for the energy production and energy consumption to be balanced always. As said before Switzerland is providing energy to several European countries (Abrell, 2016), especially at the dawn of the creation of the new power grid by Europe, (source: https://www.swissgrid.ch/swissgrid/en/home/future/supergrid.html; "RGI_Annual report 2016", 2016), the super-grid, the transmission system of

Switzerland needs to be strong and balanced, as the demand is rising, to cope with possible failures (Abrell, 2016; Filippini, 2011).

1.3. Thesis statement and Research question

1.3.1. Thesis statement

The thesis statement, which reflects the research information for the problem is stated as following:

“Combining Real Time Pricing (RTP) and Inclining Block Rates (IBR) models in one framework embedded in the Swiss grid, will lead to a secure and reliable grid in which over-loadings will be avoided and costs will be minimized for both consumers and producers.”

The thesis statement as it is stated above summarises in one sentence all the aspects of this research. It is not too broad and it covers exactly the point that will be discussed and further analysed, on the master thesis paper. It summarises the research problem description in one sentence and it builds a pattern for further discussions. It starts with a clear statement for what the research is talking about which is the combination of RTP and IBR, it continues with the goal of the study which is the finding of an ultimate solution that will secure the reliability and sustainability of the Swiss grid and it finishes with the results of the usage of this new framework which are the avoidance of overloads and the minimization of electricity costs for the users as well as the maintenance costs for the utility companies.

This thesis is built on an existing idea which is the combination of two models, a combination that can change the wholesale electricity market of Switzerland. The statement is about a new idea, on how to embed this existing knowledge in the existing system. The result as it is stated limits the scope of the statement. From this research, the framework from the combination of RTP and IBR will be created. From the statement the effects of this idea are provided, the exact effects of what will happen by combining these two models, which are the minimization of the over-loading of the grid and the cost reduction, which will lead to the increase of the reliability and stability of the grid. By combining the models the distributors will be able to not only understand the changes of the energy consumption according to the time of use but according to the loads as well, which will help them model it (model energy consumption will allow the production companies to evolve the price prediction model). That way the consumers will be supplied with all the necessary data to create a power schedule that fits their utilization needs. As a result, the distributors will be able to stabilize production, according to consumption, thus provide users with the best flexible price with the goal of minimizing the costs.

1.3.2. Goals

The goal of this master thesis is initially to understand in depth the models of Real Time Pricing and Inclining Block Rates. Specifically, understand how the models work separately/ individually, the reason that make them so important and the ways they can be used to ensure the security of the grid, hence, the balance of energy consumption and energy production when combined in one concrete framework. The representation of which is shown in chapter 4, paragraph 4.2.

The scope of the framework is to argue, that by using these models in combination, and by adapting the new combination we can secure the reliability of the grid and the balance between energy consumption and energy production. The framework is covering two different aspects, the time of use (through RTP the time changes every hour) and the loads needed during the use (through IBR the price changes according to the loadings). In conclusion, the goal of this research is not only to identify the effects of the adaptation of the framework combination in the Swiss grid but also understand and identify the reasons that make Switzerland a fitted candidate for this solution.

1.3.3. Research questions

The research question derived from the thesis statement explained in chapter two is stated as following:

“How will the combination of RTP and IBR establish the security and reliability of the Swiss grid by reducing the costs and the overloading of the grid?”

Sub questions of the research question:

i. How can RTP and IBR be combined?

ii. How can the new framework be embedded in the Swiss electricity wholesale market?

iii. How can this framework provide users with a secure and reliable system, where consumption and production are balanced always?

iv. How can over loading of the grid be avoided?

v. Why should this method be adapted in the Swiss electricity wholesale market?

Chapter 2: Research Design

2.1. Research Objectives

The objective of this research paper is to study and understand the effects of the combination of RTP and IBR pricing models generally and specifically the effects of the adaptation in the Swiss grid. The framework combination of RTP and IBR that calculates flexible prices, the architecture of which is shown in chapter 4, can solve vital matters/ problems occurring at the Swiss grid system. Vital issues such as over-loads of the system or blackouts resulting to unsatisfied customers, over-costly repairs to maintain the grid functioning, etc.

The objectives of the current study, initially, is to provide a comprehensive review of literatures and real practices, related to real time pricing and the ways with which electricity prices can become more flexible by combining RTP and IBR. The second step, that will be described in this paper, will be to present and argue why this framework-solution is a strong alternative of how the Swiss electricity market is functioning today which could give the desired solutions in all the problems that the Swiss grid is facing. Finally, the third step is to identify why Switzerland is the perfect candidate for this adaptation.

The result of this study will be a valuable add to the body of knowledge for the industry of energy production, and consumption as well. This research, if successfully done will change the way things are done in the energy industry, as it will balance the energy production and energy consumption, create a reliable and secure grid by reducing PAR and avoid over- loadings that could potentially lead to energy loss or even blackouts, hence, high production and maintenance costs.

2.2. Research methodology

For this master thesis, an extensive literature review will be executed in order, to search the existing theory and existing theoretical frameworks. Mainly, to identify a cost based solution for the problems that the Swiss Grid is facing and understand the reasons and the effects of this new adaptation into the Swiss system. With the literature review, a systematic search of the existing scholar work will be held and afterwards a set of arguments will be provided, for the theoretical discussion that will take place. My research draws from a one-tier methodological approach, it is based on an extensive literature review. Specifically, in the beginning a literature review will be performed to study the existing theory and existing theoretical frameworks, to discover the most fitted solution for the existing problem. After the identification of the solution, I will analyse the effects of its adaptation in the Swiss grid as well as the reasons that make this solution fitted. This is where I will build my argumentation theory. An argumentation theory is a set of arguments with which one can reason an idea as well as cite evidence to support this idea/ solution (Rich, 2013).

Thoroughly, I will start by studying the two different models which are the Real-Time Pricing (RTP) and the Inclining Block Rates (IBR). To understand exactly how they work, I will perform an in depth textual analysis. Conscientiously, I will try to understand what the models are about, how they are used separately and what are the advantages and disadvantages gained by using them. Through my investigation, I will study and understand the ways the combination of the models functions and the reasons for which this combination should be adjusted in the Swiss grid. This research will not only focus in what others have written but also in the ways that they wrote and analysed their findings.

Accordingly, I will continue with the literature review, to find literature about the Swiss grid and the wholesale electricity market of Swiss as it is today. The reason is that before I can argue that the new framework is indeed a strategic move, a fitted solution for the misfits of the grid, I need to understand the real energy needs and the way that the Swiss grid functions. From the literature review I will identify concrete examples (thoroughly described in the "Research Background" chapter), which will improve my insights for the effects such a combination has in generally and more specific in the Swiss grid. Effects such as the balance and sustainability of the grid, the decrease of PAR and the decrease of costs.

In summary, with this master thesis, I am going to try to search firstly for the ways to adapt the IBR method to the RTP model to create a concrete and adjustable combination, from which one can get to grid sustainability, focusing in Switzerland. Secondly, I will search for the reasons why this solution is a strategic decision to be made, that will be explained thoroughly later. Thirdly, an important aspect that will be researched are the effects of the adaptation of the combination which are the point where the consumption and production of electricity are balanced and the minimization of the costs. Finally, this research paper is based in the literature review research methodology and the building of a set of arguments formulating the argumentation theory, from which the findings will be derived and the research questions will be answered.

2.3. Strengths and weaknesses

As already described above, for this master thesis I will follow a one single research methodology, which is literature review. There are several reasons for one to choose literature review as a methodology, reasons that can be identified as strengths or weaknesses. Conscientiously, a literature review discusses topics that have been already researched and analysed and it is widely used by researchers as the starting point for further research as Creswell states in his book "Research design: Qualitative, quantitative, and mixed method approaches" published in 2013. Literature review can be the connection to bind different methodologies such as qualitative, quantitative or design research says Jay K. Lesson et al in their book titled "Doing Your Literature Review: Traditional and Systematic Techniques" published in 2011, a link between existing theory/ knowledge and future research that can add new data in the body of knowledge. According to Creswell a quality literature review requires focus on the topic and a high resistance in the temptation to use everything that you read.

Specifically, for this research paper an extensive literature review will be performed, from which arguments will be derived, an argumentation theory will be built. My findings will be extracted from this argumentation theory. Argumentation theory is a set of arguments with which one can reason an idea as well as cite evidence to support it (Rich, 2013). This method (argumentation theory), is widely used in research not only in philosophy and life sciences but computer science and engineering as well (Rich, 2013). I mainly chose this methodology because while, literature review provides valuable information from the existing knowledge, patterns, frameworks, models or use cases for understanding how the models work and why the combination of the models should be chosen as Creswell describes in his book. The argumentation theory which doesn't rely in deduction can bring meaning into the balance of traditional logic and real life argumentations (Rich, 2013), from which our findings will be derived. In specific, the argumentation theory will be used to explain the reasons for which this solution should be chosen, hence, the research questions will be answered.

There are for tasks that belong to the argumentation theory, the identification of the problem, the analysis of the possible solution, the evaluation of the findings and the invention. All tasks will be described and analysed in the thesis. Each existing research approach has strengths and weaknesses, and each of them can asset from combining them with one another.

In my project the product that will be created is the framework that will be created from the combination of the two models with which I will argue that the over loadings and the maintenance costs of the Swiss grid can be decreased. Patricia Rich states in her article "Literature Review: Argumentation Theory" that the bigger picture of the argumentation theory is to focus in finding those arguments that stem from the real-life events and the traditional sense of logic and that there is the strength for using the argumentation theory for writing this research paper. Problems such as over loadings, blackouts, over costing maintenance of the grid, over costing services not only for the production companies and the government but also for the consumers, are the problems that the Swiss grid is facing. Those are real life problems that need an explanation that stems from the problems faced and the logic that is gathered from the literature review.

Chapter 3: Literature review

3.1. Research Background

A basic understanding of the pricing methods is a vital step for the reader, to get familiarized with the topic. Specifically, the ways the methods behave/ operate individually, as well as the advantages of combining the methods in one functional concrete framework. Thus, in this part of the thesis important information will be provided, such as the literature review, the keywords and key elements used for the research, a short introduction to the smart grid, a detailed description of the RTP and IBR methods, the Swiss grid and its pricing system as it is now and finally the idea behind the combination (research gap) of the two models as well as the advantages.

3.2. Keywords/ key elements

For this master thesis, several key elements will be used through the research. Keywords and key elements such as:

- Carbon productivity
- Smart homes, smart grid
- Smart technologies and signals
- Flexibility in the electricity markets
- Reliability, efficiency of the energy network
- Home energy management systems
- Green IS and environmental sustainability
- Real time pricing
- Inclining block rate, demand response
- Swiss Grid
- Swiss wholesale electricity market
- Electricity price in Swiss
- Electricity pricing methods
- Power saving and energy recycle
- Smart grid/ Automated buildings

3.3. Smart grid

As energy and specifically electricity cannot be stored in an economical sense (Mohsenian-Rad et al, 2010), price prediction and real time electricity pricing environments can be used in order to define flexible prices for all users. As needs are changing so is the knowledge of the users, with the creation of the smart grid as the power grid was renamed in the last years, users can have all the necessary information (Suryanarayanan et al., 2013), in order to understand the energy that they are consuming, and answer simple questions such as "when they should operate the best" or "when and what happens when they over consume energy" (Moslehi, 2012), (Vehbi C Gungor et al., 2011). Smart grid can combine communication technologies, distributed systems, advanced metering, distributed storage, automation as well as safety and security (Roozbehani et al, 2011; Zhao et al, 2013), automated systems, renewable energy source systems, buildings, smart homes, plants communicating as one (Mohsenian-Rad et al, 2010).

An important part of the smart grid is the smart homes and smart technologies. With the use of smart technologies and smart homes, the users are provided with *automation*, as they can work with appliances from distance at any time, *multifunctionality*, as they can perform different jobs at the same time, *adaptability* and *interactivity*, as they can learn by using how to be more efficient (Lobaccaro et al., 2016). Though, with the use of smart grid the user's behaviour toward efficient energy performance changes (users gain a greener attitude and a wiser use of energy through self-involvement) (Alexander, 2007), it also enables providers to find certain ways to better control the production in an even more effective way, as well as it enables them to adjust the prices (Lobaccaro et al., 2016). It provide users with the flexibility to choose when and how much energy they can use (power schedule) in order to pay as less as possible (Lobaccaro et al., 2016).

Smart grids are consumer oriented as they interact with the consumers, they are less centralised than the power grid, the consequence of which is that generated data is not only sent to the consumers but the consumers as well can send data to the utility in different forms such as over consuming, etc.(Kohen, 2015; Roozbehani et al., 2011), a two way communication as it is shown in the figure below.

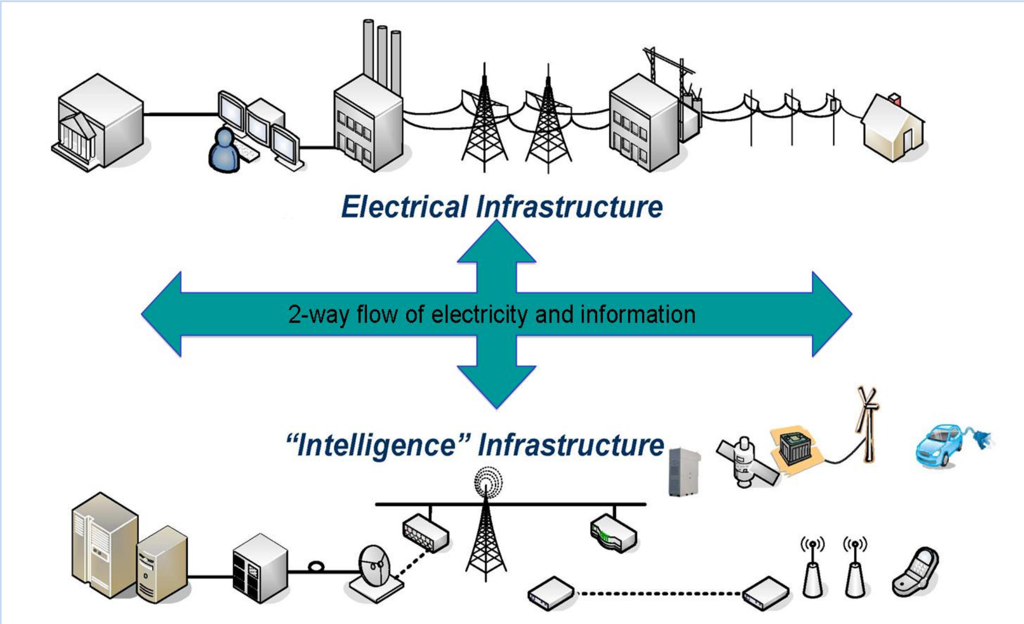

Figure 1: Smart grid dual communication (Source: Environment Entrepreneurs 2014)

3.4. Real time pricing

Smart grid allows users to schedule their power usage. The prices can be managed by turning on and turning off the appliances when necessary which means that an efficient scheduling method has to be adopted (Zhao et al., 2013). This method is RTP which should be based on an energy schedule and controlled by an energy management system (Barbose et al., 2005). The basic component of a power schedule is Demand Response (DR), which is the changing of the electricity demand according to the RTP (Zhao et al., 2013). Smart grid combines a power physical system with an information system and reduces costs by creating a pattern of the energy usage at a home or building, etc. based on real time electricity prices (RTEP) (Allcott, 2012). A power schedule consists of both interruptible and non-interruptible loads (Zhao et al., 2013) for calculating the prices in the best ways.

Residential real time pricing refers to an electric supply rate possibility, different utilities offer, in which customers have the ability to pay electricity supply rates that vary for every hour (Zhao et al., 2013). It is the continuing changing of prices according to the use of energy, which is a critical fundamental of a restructured efficient market (Borenstein, 2005). In RTP the price can change in an hourly bases meaning twenty-four times in a single day or even four times in an hour, every fifteen minutes, meaning ninety-six times in a single day (Kohen, 2015), which is predefined and communicated continuously to the users in a two way communication (Roozbehani et al., 2011), like it is shown in figure 1, the users create their power schedule and they communicate it, afterwards the utility changes the prices according to the schedule (Kohen, 2015). RTP is being promoted as the most economical and efficient way to meet users' demand response and invoke its benefits, yet actual data about customers' experience is limited and almost no documented (Borenstein, 2005).

RTP can change the market. In his article "The long run efficiency of Real Time Electricity Pricing, published in 2005" Borenstein provides the readers with a real example, from the California 2000 - 2001 crisis, where RTP was used as the ultimate solution. As a result, the power of the energy sellers was reduced. From the economical point of view, according to Borenstein most economists in their researches support the RTP concept since its early days, as it is believed that it benefits on one hand the wealth transfers that it can bring in the short run while in the long run it is changing the beliefs and behavior of the society, due to the competitive equilibrium that the method proposes (Borenstein, 2005). At the same time Hogan in his article, "Time of Use Rates and Real Time Prices, published in 2014" argues by saying "Where real time prices are available, it seems that it worth's the effort to remove all obstacles from going all the way to RTP". RTP is currently being used in several countries such as the USA, where users can choose which methodology they prefer for the providers to use for their electricity price calculation.

The use of RTP can not only change the market and the economy but also the practical and more technical way of how things are done (Alexander, 2007). This methodology (RTP) provides not only the ability of rescheduling the loads and all the necessary data (knowledge) of how to do it but also with the energy management systems and the control systems the users can effectively shift their loads (Barbose et al., 2005). All researchers agree that RTP delivers the best benefits of all existing methods, it best reflects the wholesale market prices (Allcott, 2012), it reduces prices for the end consumers, reduces the loads as well as the peak demand (Roozbehani et al., 2011). It is clear that in the long run planning it will change the fundamentals of the architecture of the system by creating a " closed loop dynamic system based on mutual feedback (Borenstein, 2005; Hogan, 2014; Roozbehani et al., 2011). For the readers to have a better understudying, the following examples will be provided.

Example 1:

This example is a made-up case extracted from the theory of the articles provided above.

For a normal day of the year the prices would be 23rp/KWh during midday between 12:00pm - 13:00pm.

During the night between 2:00am – 3:00am the price would fall up to 17rp/KWh.

This happens because the price changes according to the season and the time. During midday, the peak demand price of energy is much higher than during the night.

Example 2:

The second example is a real example provided by a utility company in Illinois, USA. The company traditionally charges their customers with a fixed price that changes only by the season, meaning four times per year. Nevertheless, the company owns an hourly pricing program that bills the users at a price that changes every hour according to the real market price. As mentioned before in several areas of the USA electricity providers give their customers the possibility to choose which pricing model they prefer to be used.

As described by the company:

"The summer market price may dip to about 2 cents per kilowatt-hour (kWh) just after midnight, when electricity usage is at its lowest. However, as the day progresses, demand for power could push the price to 13 cents per kWh—or much more—during "peak" electricity-usage times in the late afternoon and early evening."

As expected winter prices are higher than summer prices. In winter people tend to spend more time in the house and do less outdoor excursions therefore they use more appliances thus, energy. As identified, from the figure below, the key for the users to save money is to reduce electricity usage during the peak times, as the price is higher and increase their usage at the lowest peak times.

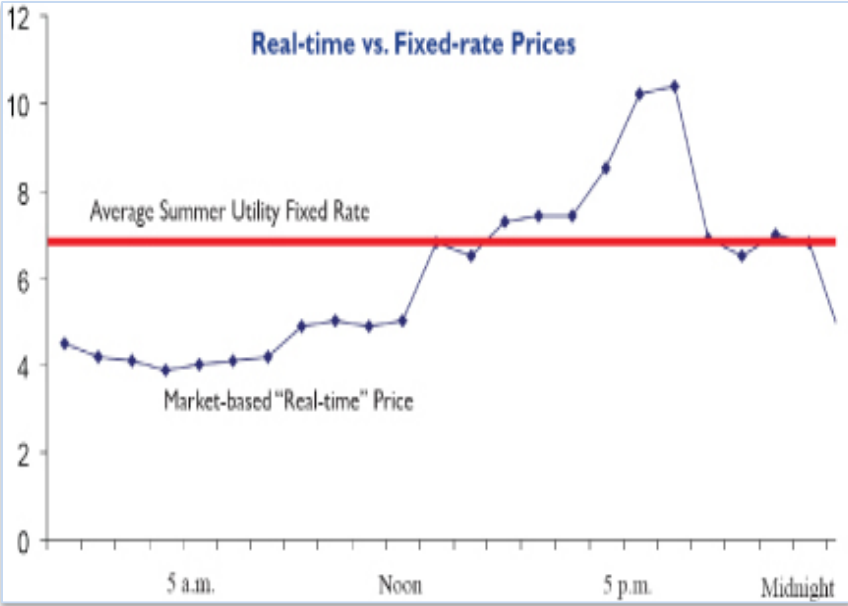

Figure 2: Real time vs fixed rate prices (Source: (Citizens Utility Board, 2015))

Nevertheless, there are two sides on a coin, likewise RTP has strengths but also weaknesses. Although RTP has been found to be the best possible solution. It has been researched again and again by many, modelled and simulated several times practically it has not been used as it should(Weisbrod et al, 1996; Kohen, 2015). There are still weaknesses that should be solved, as for the users it is important to know the risks of using such a system, the structure as well as the awards of adopting the pricing model and most importantly the calculation of the baseline load (Darghouth et al, 2011), RTP can accomplish load management till one extend. Especially when there is a high demand, and shift of the load when necessary, but gaps such as identifying the right customers (Horowitz, 2012) or designing a concrete price schedule that fits all customers and at the same time secure that the users and the providers will be equally satisfied (Darghouth et al., 2011). Equally satisfied by using a tangible model that can provide users with a flexible price and reduce electricity costs but at the same time increase reliability and stability of the grid (Zhao et al., 2013).

3.5. Inclining block rates

The Inclining Block Rate (IBR) methodology refers to the rising of the price caused by electricity usage increase (increases with the total quantity that is consumed) (Zhao et al., 2013), which just like RTP promotes energy efficiency, and can be used as an efficient solution to influence the consumption of electricity and energy savings (Suryanarayanan et al., 2013). Loads are assets that can participate to using electric energy efficiently (Dang & Ringland, 2012)., such as thermal loads, electrical vehicles or other smart appliances, when controlled correctly can lead to consumption decrease and efficient use (Suryanarayanan et al., 2013). The model is designed in such ways to discourage high consumption of electricity, and it creates a non- linear relationship between cost and energy use (Suryanarayanan et al., 2013).

The model is targeting not on the decrease of the demand but on the decrease of the energy consumption (Suryanarayanan et al., 2013). The model consists of peak demand rates, depending on the case it can consist of two, three or more tiers/ layers. The peak demand rates are price sets scheduled in advance, thus they cannot always meet the operating needs of the users as they are not flexible enough (Dang & Ringland, 2012; Suryanarayanan et al., 2013). The most common is a three-block representation. In addition, to the three main sets low peak, medium peak and high peak there is one more set used for the very high costs called "super peak".

According to the researchers real time feedback can effectively change residential electricity consumption by decreasing consumption from 4% up to 10% (Cappers et al, 2016; Suryanarayanan et al., 2013), while other studies confirm that residential heating savings in the USA the last years decreased by 10% or more (Cappers et al., 2016). One can argue that IBR not only helps balancing the load of the grid but also reduces PAR (Zhao et al., 2013). For the better understanding, the following examples will be provided.

Example 1:

This example is a made-up case extracted from the theory of the articles provided above.

During summer, there are three block rates from which the price is calculated.

- Block one- Low Peak Demand Rate: up to 100KWhrs, for the first 100KWhrs the user pays 16rp/KWh
- Block two- Medium Peak Demand rate: up to 300KWhrs for the next 200KWhrs the user pays 20% higher meaning 19.2rp/KWh
- Block three- High Peak Demand rate: up to 500KWHhrs for the next 200KWhrs the user will pay 80% higher from the initial price of 16rp/KWh meaning 28.8rp/KWh

The price calculation per month starts from Block one, when a certain amount is reached the price calculation moves to block two where the price is 20% higher than block one. When the limit of block two has been reached then the price calculation moves to block three where the price is much higher, 80% of the initial price.

Example 2:

The second example is a real example provided by Eskom Hld SOC Ltd, main electricity Production Company in Africa, mainly in South Africa. Escom is generating approximately 95% of the Electricity needed for South Africa, and 45% of the electricity needed all around Africa. As a company, they could generate, transmit and distribute electricity all around Africa. Although, their involvement is limited, to projects about areas connected to the grid of Africa. Escom is using the IBR methodology to generate the tariffs for the residents that they work with.

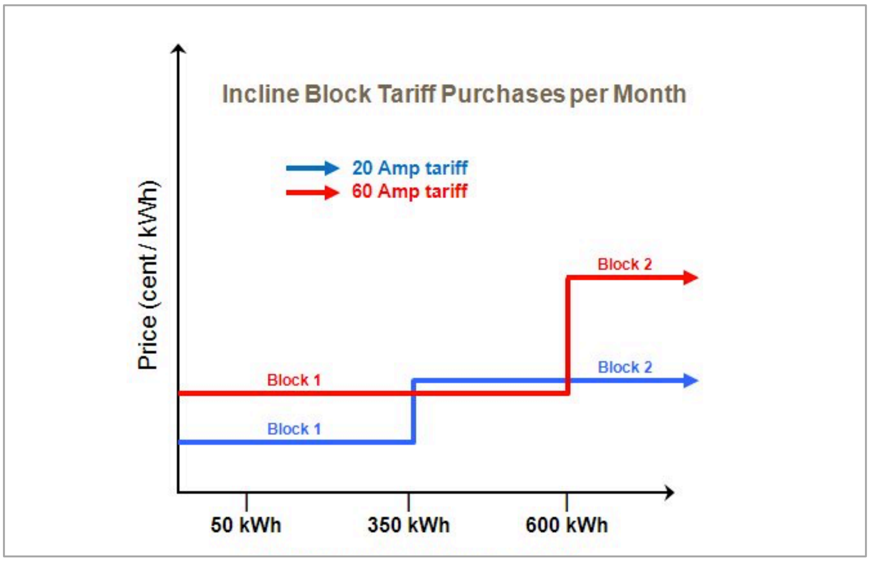

Figure 3: IBR representation (source: Escom study research, http://www.prepayment.eskom.co.za/IBT.asp)

Block one concern the lowest prices, as the use of electricity increases during the month, the price will increase and the residential consumption moves to Block two. The electricity consumption is measured in KWh (Kilowatts per hour). At the end of the month, the system restarts and calculates the electricity consumption starting from Block one. Depending of the contract some of the residents receive Free Basic Electricity (FBE), in that case they will receive their free amount in the beginning of the month, afterwards the system starts calculated as already described. Following the tables concerning the exact calculated prices for the periods 2015/2016 and 2016/2017.

An important aspect of IBR is the feedback that they can provide regarding the loads of the past and present as well (Suryanarayanan et al., 2013), which is an important aspect for consumers/ users to have a complete and clear idea of their energy consumption and create the power schedule.

Tariffs from 1 April 2016 until 31 March 2017	
Electricity Purchase Blocks for 20 Amp tariffs	**Price (cent / kWh)***
Block 1 [0 - 350 kWh]	104.26
Block 2 [> 350 kWh]	118.00
Electricity Purchase Blocks for 60 Amp tariffs	**Price (cent / kWh)***
Block 1 [0 - 600 kWh]	117.86
Block 2 [> 600 kWh]	200.34

Tariffs from 1 April 2015 until 31 March 2016	
Electricity Purchase Blocks for 20 Amp tariffs	**Price (cent / kWh)***
Block 1 [0 - 350 kWh]	97.22
Block 2 [> 350 kWh]	108.25
Electricity Purchase Blocks for 60 Amp tariffs	**Price (cent / kWh)***
Block 1 [0 - 600 kWh]	107.74
Block 2 [> 600 kWh]	183.13

Figure 4: Actual Tariffs generated by the IBR methodology as provided by Escom Ltd (Source: http://www.prepayment.eskom.co.za/IBT.asp)

3.6. The Swiss grid

Switzerland has one of the most reliable power grids in the world and is producing energy for several European countries as well (Filippini, 2011). Nevertheless, power failures, blackouts, power losses and several damages occur every day in the system, resulting in high costs. In 2014 Switzerland produced 78TWh of energy from which 25TWh where distributed to neighboring countries in the north (Abrell, 2016). The need for a secure and safe relation between production and consumption is rising (Filippini, 2011). Jan Arbell in his research about the wholesale electricity market of Swiss, done in 2016 in collaboration with the ETH university, states "Electricity demand and supply need to be balanced in every instance in time avoiding failures of the electricity system". According to the research of Jan Arbell in 2016, although the Swiss system is focusing in biding the prices every hour to give the possibility of fare and low prices, the prices do not always reflect the true production costs.

The Swiss electricity market includes the energy only market and the reserve market. There are four different actors interacting in the grid (Abrell, 2016), the suppliers, the final demand, the transmission system operator (TSO) and the regulatory authority (RA) (Abrell, 2016; Filippini, 2011). The suppliers or generators, supply electricity, which is produced in power plants and transferred by storage facilities. Technological characteristics are used for the determination of the generation flexibility (Abrell, 2016), which is important for the reliability of the electricity demand in order to reach the final demand. The TSO concerns the operation of the transmission system and is responsible for the reliability of the grid. Finally, the RA is the big “eye” which monitors the market and is responsible for the reliability of the market.

The Swiss electric power industry includes about 900 public and private sector firms that generate, transmit and distribute electricity all around Switzerland (Abrell, 2016; Filippini, 2011). The great number of producers and distributors of the system can lead in tremendous inequalities in the prices (Abrell, 2016; Filippini, 2011). One main factor for the price disparity is because of the monopoly in the operation of the distribution system by the local municipalities (Filippini, 2011; V.C. Gungor et al, 2010). Although, the Federal Electricity Commission (ElCom) supervises the network and electricity tariffs for big scale and small scale consumers these disparities tend to create misunderstandings and several other problems (Abrell, 2016; Filippini, 2011). The pricing model used in Switzerland as well as several other European countries, is the TOU model (Filippini, 2011), which means that the price is calculated according to the time of using the appliance.

These companies are usually applying TOU tariffs resulting from two different pricing periods, the peak period (high use leads to high prices) and off- peak period (low use leads to low prices). For example, in the weekdays till 9 p.m. is a peak price period while after 9 p.m. till 7 a.m. and during weekends is an off- peak period. This method was introduced in the Swiss Grid system to help shift the demand from the peak times to the off- peak times with the goal of decreasing the high loads (Filippini, 2011). During the last years as the population of Swiss has increased so does the electricity needs.

3.7. Research problem

Although the use of the TOU pricing model should be able to increase the public welfare (Filippini, 2011) and satisfaction (Abrell, 2016) this pricing policy seems that is creating imbalances as well as time and money loses, which, affect the grid. Time and money loses, not only for the suppliers/ generators/ producers but consumers as well. “How can an incentive compatible and cost based system be created which also reflects the cost?” Abrell is asking in the end of his research paper about the Wholesale electricity Swiss market which was published in 2016. “The dilemma for the electricity companies is to choose between investing in new peak capacity or to adopt some policy instruments such as load control or rates?” Filippini says in his research paper about the Short and long run time of use price elasticities in Swiss residential electricity demand, which was published in 2011. From the analysis in the literature review the real problem raised, is the imbalance of the Swiss power grid.

Because the grid is unbalanced, it is not reliable, thus not secure and sustainable opposing to the real needs for high quality energy providing services as already explained before. Thus, nor the consumers or the producers can rely for constant electricity distribution without problems. From the imbalances of the grid two main problems need immediate attention. From the consumers’ point of view, the consumer needs to be sure that one can rely on the distributor to have energy at any time one needs to use an appliance. On the other hand, from the producers’ point of view, such instabilities on the grid, create high costs in maintenance because of the temporary solutions.

Despite the fact, that the TOUP model was introduced in Switzerland some years ago (Filippini, 2011), and fixed prices were calculated according to time of use and seasons, over- loadings still occur in the system, (Switzerland changed the pricing policy to reach stability, thus a TOUP model was adopted). This paper is suggesting a new pricing model which is RTP. With RTP like TOUP prices are calculated according to the time of use, but in this case the prices are calculated hourly, they are not fixed. Though, with RTP prices are flexible, calculated hourly or even several times during an hour, loading problems still trouble the system. Thus, we can argue that implementing only a rate method is not enough to change the system. A combination of the models, though, when applied, the desired changes in the grid would be reached. From the analysis and examples already provided in the previous chapters, it is clear, that, both models (RTP & IBR) should be implemented in the Swiss grid.

Finally, by combining these two models (RTP & IBR) in one concrete framework, that will be explained in the next chapter, the consumers have all the necessary data to create a power schedule that fits to their needs. At the same time the energy consumption is balanced to the energy production. As a result, the grid will be more reliable. Able to cover all needs at any time. Similarly, problems such as over loading or overpriced bills will be avoided. A successful combination of the models will profit not only the consumers but also the distributors. Since the users will get low flexible prices and the distributors will avoid certain problems from which they lose money by restoring the damages.

Chapter 4: Framework

4.1. Framework description

It is important to have in mind that all the percentages figuring in the framework, concern real numbers as they were found in the research about the Wholesale electricity market in Switzerland by Jan Abrel, published in 2016. The framework is a representation of the combination of the two models (RTP & IBR), and is composed by three important parts, the producers on the left, the consumers on the right and the power grid in the middle. The reason this framework was created, is to give an overview of the architecture of the combination of the two models for the readers to have a full image of the solution. The left side involves the energy production part or simply supply part. The right side involves the energy consumption part or simply the demand. And of course, the middle introduces the combination of RTP and IBR in the power grid. The combination of RTP and IBR is replacing the method that is used now which is the TOU model. Although, the combination of the two models has been studied by other researchers for different countries, the representation of this combination was not found in any paper/ article or book.

In details:

- The energy production part (on the left) is separated in two categories the energy only market and the reserve energy. The energy only market includes all the energy production methods, used today in the Swiss grid production plan, such as renewable energy sources, thermal generation, hydro power and of course nuclear energy which the Swiss government has decided to reduce as much as possible in the next years. The reserve energy includes the reserved power for the Swiss grid available to be used to decrease or increase the energy generation.

- The energy consumption part (on the right) concerns the different categories of consumers in need of continues energy use. Such as household needs, industrial needs, public transportation needs and other services. Finally, in the middle, the entrance of the combination of RTP and IBR takes the place of the TOU method, which is needed to meet the demand response of the users. Through the combination of RTP and IBR two new insights are possible. Power scheduling which gives to the users the ability to schedule their needs/ consumption needs. And the continuous price prediction according to the time, day, season, use and loads. With these, new insights that enter, and the new system of electricity price calculation the balance of the grid (f=50Hz) can be secured.

The power grid through the installation of automated appliances, smart meters, etc. becomes a smart grid which is controlled by an energy management system and an energy management controller. In details, hourly electricity prices for the next day are supplied to the customers (the process is called price prediction). When the customer receives the prices, he can plan his energy use for the next day, which means that the customer has the possibility, to plan for example, at what time he wants to start his dishwasher. Hence, the customer sets the time parameters for his appliances, which are the start time and the end time (the process is called power energy scheduling). The data from the power scheduling can be gathered and they serve as a base for evolving the price calculation methodology/ algorithm. The data gathered from the power scheduling is real data from the previous years which is crucial for the mathematical analysis and simulation to be more efficient. Additionally, the relationship between the user and his utility centre is a two- way communication. Finally, with the price prediction and the power scheduling as it is shown in the framework the demand response can be met successfully, and the prices provided are based in the cost. Thus, the smart grid system is working effectively and efficiently.

As already mentioned, the concept of the combination of the two models (RTP & IBR) has been studied by other researchers for different countries such as China and the US. Specifically, in the US there are some utility companies that give the possibility to their customers to choose between a fixed price method or a real- time prediction method (RTP). Nevertheless, the representation of this combination was not found in any research paper/ article or book in generally or even according to the needs of the Swiss grid. For, this reason as well as for the better understanding of the readers, the architecture representation was created and adapted to the Swiss grid reality. Which means, that the framework as it is shown in the next paragraph, was created based in the real data from energy production and energy consumption of the Swiss grid. In conclusion, though, the concept already existed in general, the adapted representation of the Swiss grid was created (figure 5) for the purpose, of this research paper and it is a new entry in the body of knowledge.

4.2. Framework Architecture

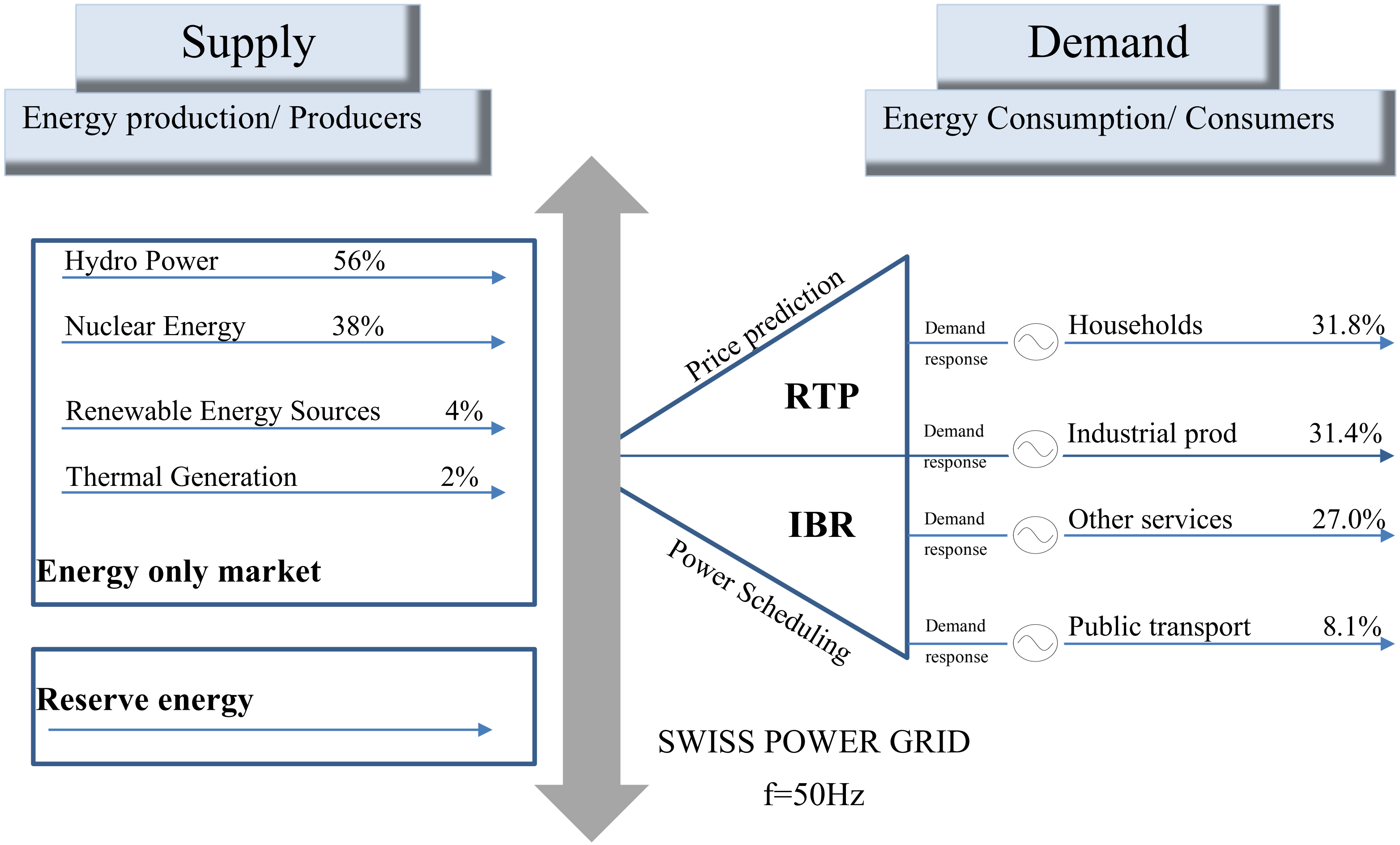

Figure 5: Framework combination of RTP and IBR models adapted in the reality of the Swiss grid

Chapter 5: Research findings

5.1. Description of the solution

To summarise the previous chapters in some short sentences, residential electricity demand is rising, the consumer's behaviour must change towards energy sustainability, blackouts and over- loadings must be avoided, imbalances lead to high costs. These are the keywords that one must keep in mind while reading this research paper. In the previous chapters I argued that the combination of RTP and IBR in one concrete framework is the best solution to bring the desired stability to the Swiss grid.

The era of Information systems is on our doorstep. And it is Information systems in which this solution is based on. As everything flows in the form of information nowadays, so should electricity usage data. For this solution to be successful several changes should be implemented in households or buildings in general, so users can have the ability to use this information effectively (Zhao et al, 2013). To create a smart grid through which the desired results will be achieved. Changes such as the installation of smart meters and smart controllers on appliances, to exchange data with the users and the other way around. Through the smart grid users can create a pattern for the usage of their appliances (Filippini, 2011), based on the real- time pricing by simply using information systems reasonably (Zhao et al, 2013). This means that from exchanging information from the two- way communication the users can create a plan for when they want to use their appliances. From this in time, the users can create different usage patterns according to the season, month, etc. thus, although in the beginning it will take some time for them to learn, in time the planning will become faster and faster and as the costs will be reduced the users' satisfaction will rise.

Furthermore, in a smart building, there are both interruptible and non-interruptible loads (Samadi et al, 2010) as well as automatically operated (AOAs) and manually operated appliances (MOAs) (Zhao et al, 2013). For this solution, all loads are taken into consideration but only AOAs matter the most for the calculation of the prices correctly (Zhao et al, 2013). The difference is that AOAs, such as washing machine, oven, electric charger for the bike or the car etc., can be scheduled, can be automatically turned on and off according to the willing of the user. On the other hand, MOAs such as hairdryer, laptop, TV, printer, etc., cannot be scheduled as users tend to turn them on or off spontaneously when needed.

The power consumption need to be constant for each appliance at any moment (Zhao et al, 2013), for that demand response should be met at any time by the grid. Demand response should be changed according to the electric price (Vehbi C Gungor et al., 2011; Mohsenian-Rad et al, 2010; Zhao et al, 2013). Demand response can be met at any time through the power scheduling. For the power scheduling to work correctly an energy management system (EMS) must be installed in the smart building together with an energy management controller (EMC) with which users will be able to take all the necessary data and real time prices and together with the personal preferences they can schedule their power usage. For EMS to work efficiently smart appliances should be put into the building for use (please see figure 6 below).

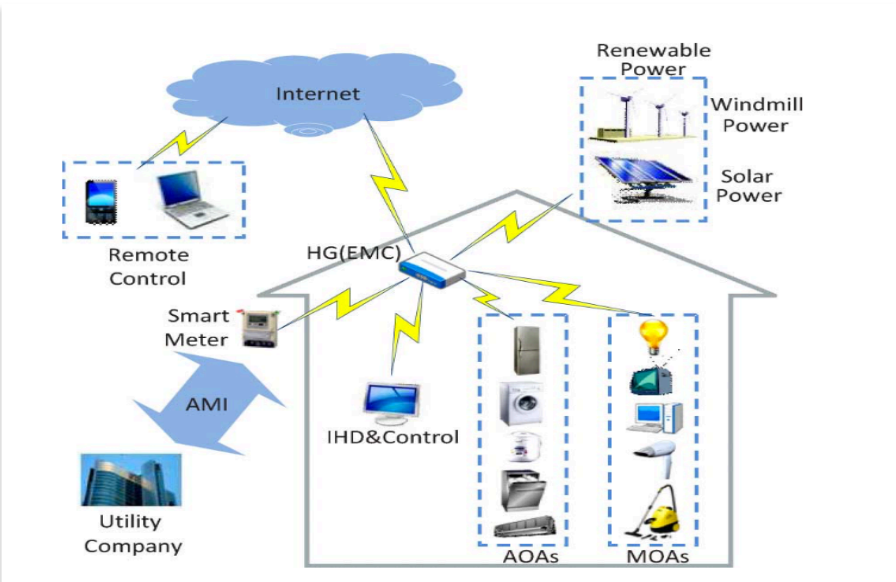

Figure 6: Architecture of energy management system in the house ((Zhao et al., 2013)

RTP together with IBR should be used for the power peak ratio to be reduced. Therefore, the cost and most importantly the stability and reliability of the whole system will be increased. To prove this theory two researches will be taken under consideration and explained in detail. Both researches are based in a system such as the one in figure 6.

The first research paper that was written by Amir Hamed Mohsenian-Rad et al is titled "Optimal residential load control with price prediction in real time electricity pricing environments" which was published in 2010 three years in prior. Mohsenian-Rad in his research is using non- linear formulas to prove his optimization problem, which later uses to create a generic algorithm, which he simulates with the help of MATLAB. Mohsenian-Rad and his team followed basically the same idea as Zhao and his team did three years later (the second research will be described later), with small differences due to the different technologies were available at that point.

Mohsenian-Rad in his research argues that the lack of automated buildings leads to the lack of basic knowledge about energy sustainability. Mohsenian-Rad and his team applied the combination framework to a chosen household according to the data they received by the Illinois power company from January 2007 to December 2009. Mohsenian-Rad in his research as well states that by using the framework combination the power peak ratio and the cost gets reduced and he went one step forward by arguing that the application of this model combination would potentially not only change the wholesale electricity market but also decrease the emission levels. His main argument was that this new model combination would potentially help the environmental sustainability move one step forward.

The energy use scheduling is done with the help of smart meters connected to a smart power distribution system. Most importantly there is a two- way communication in-between. The users receive the prices via internet on their smart phone, computer, etc. and the utility company receives the schedule from the users. Each smart meter includes a power scheduling unit from which energy consumption is decided. After the real- time prices become known by the utility company the users go on with the energy scheduling according to their needs. The team focused their research in one household which they studied for four months, from September 1st 2009 to December 31st 2009. In total, they studied the household for 122 days. During these days, the household was using between 10 and 25 appliances. The appliances shown in table 1, had fixed consumption schedules as well as appliances with flexible power consumption.

To compare the new estimated numbers, they used the numbers from the same months of the previous years. According to their findings the mean daily cost dropped from 108cents per day to 81cents per day as shown from the simulation results in figure 7. From applying the real- time pricing in combination with the load control the power peak ratio is decreased thus the cost, which leads to a secure and reliable smart grid system.

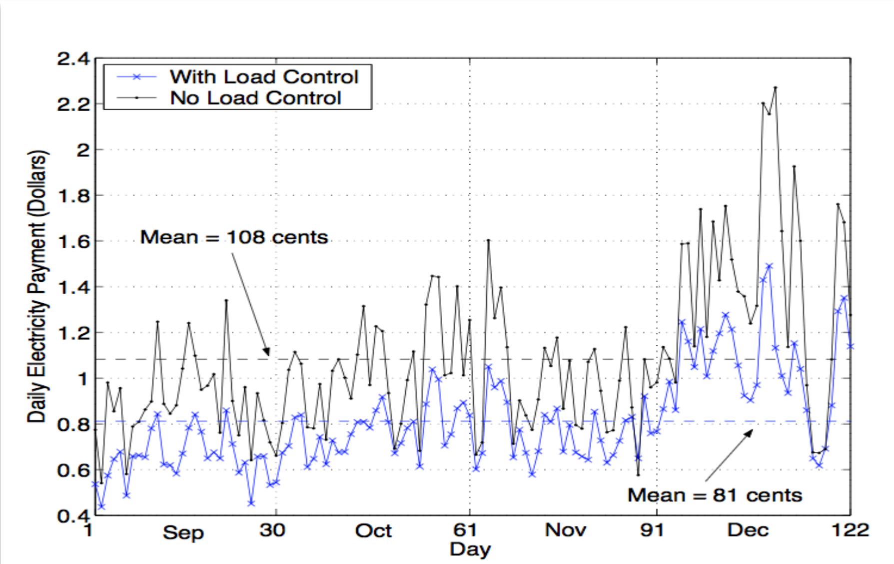

Figure 7: Daily electricity charges after the application of RTP and IBR

Fixed power consumption		Flexible power consumption	
Appliance	**Energy in KWh**	**Appliance**	**Energy in KWh**
Fridge- Freezer	1.32	Dishwasher	1.44
Electric stove (Self-cleaning)	1.89	Clothes washer (energy star)	1.49
Electric stove (Regular use)	2.01	Clothes washer (regular)	1.94
Lighting	1	Clothes dryer	2.5
Heating	7.1	PHEV	9.9

Table 1: Appliances with energy needs used in the simulation

The second research paper that was written by Zhuang Zhao et al is titled "An optimal power scheduling method for demand response in home energy management system" which was published in 2013. Zhang in his research is using non- linear formulas to prove his optimization problem, which later uses to create a generic algorithm, which he simulates with the help of MATLAB. Basically, what he says in his analysis is that when EMC receives the demand response from the users and the real-time prices from the energy provider the usage schedule for all the AOAs can be created. Through the power scheduling the time parameters are set together with the length operation time (LOT) and the operation time interval (OTI). A valid schedule according to the needs of the system's sustainability. The electricity price changes within the slot based on the total consumption. For this research one hour has basically five slots, which means that every slot concerns 12min.

Zhang applied the combination model to one household with certain specifications (please see table 1) to a 90-day plan. With the statistical analysis and the simulation in MATLAB he proved that when the delay time rate increases the electricity cost decreases. The household that they studied was using several smart appliances (specifically he made the analysis for 16 AOAs) as shown in table 2, and was fully connected to an energy management system. More specifically for this household that he and his colleagues studied the average electricity cost per day was 48.65cents, after the power scheduling and the application of the proposed model the electricity cost per day decreased to 35.97cents per day. This means that the household could save in three months 1,166.6cents as it is shown in figure 8.

AOA	**OTI**	**LOT**	**Power(KWh)**
Air conditioner 1	41≈60	5	1
Air conditioner 2	61≈80	5	1
Air conditioner 3	86≈120	10	1
Electric radiator 1	1≈30	5	1.8

Electric radiator 2	91≈115	10	1.8
Rice cooker 1	1≈25	2	0.5
Rice cooker 2	41≈60	2	0.5
Rice cooker 3	71≈90	2	0.5
Water heater	86≈105	3	1.5
Dishwasher	101≈120	2	0.6
Washing machine	1≈60	5	0.38
Electric kettle 1	1≈25	1	1.5
Electric kettle 2	66≈85	1	1.5
Humidifier 1	1≈30	10	0.05
Humidifier 2	91≈120	10	0.05
Clothes dryer	71≈91	5	0.8

Table 2: Table with AOAs used for the analysis of Zhao in his research. The reason that the appliances have number next to the name is because they are used for more than once during the day.

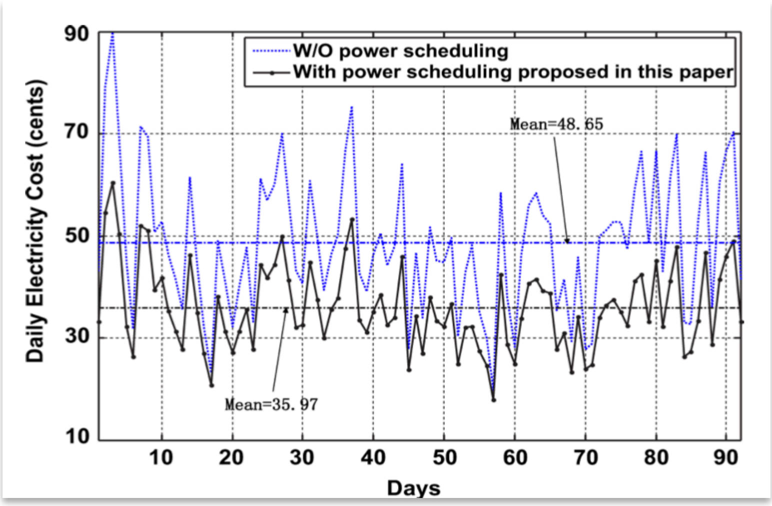

Figure 8: The impact of the proposed power scheduling by (Zhao et al., 2013)

From the research background and the analysis of the solution in this chapter, there is strong evidence that this solution will indeed stabilize the grid and reduce the costs, by balancing the energy consumption and the energy production, simply by teaching the users how to be more efficient through the power scheduling. In the contrary, there is no evidence to prove that the users will surely use the data correctly, we can only assume, that by minimizing their costs and by improving their satisfaction, their general behavior towards sustainable energy production and consumption will get improved and become more efficient and effective, thus, the improvement of environmental sustainability. As already mentioned before, although the knowledge of the combination already exists, and has been studied by two research teams, with similar characteristics and same basis, this research paper contributes to the body of knowledge in two ways. Firstly, the creation of the framework which was adapted in the Swiss reality, and shows the input and output of the Swiss grid as well as the energy demand/ needs of the consumers in Switzerland, which is a new entry in the body of knowledge. Secondly, the framework combination contributes by aiding Switzerland's efforts to control the energy costs and stabilize the energy consumption and energy production, which is a big problem, at the moment.

Chapter 6: Evaluation

6.1. Argumentation theory

The argumentation theory doesn't rely in deduction and it can bring meaning into the balance of traditional logic and real life argumentation. For years, researchers, philosophers, scholars, etc. are building new theories, new ideas, innovative products and services, all build upon real life arguments (Rich, 2013). Through real arguments, this research paper seeks to investigate, discuss and evaluate the framework combination of RTP and IBR and its potential positive effects to the identified problems of the Swiss grid electricity costs. To fully understand the role of the framework in the reduction of the electricity costs, this chapter aims to provide a discussion of the development of the smart grid and the application of the framework which would result to a decrease of the over- loadings and the maintenance costs.

Firstly, this paper examines the need to build a smart grid by encouraging households to take advantage of their smart appliances. The creation of the smart grid links with the application of the RTP model as it provides the energy consumers with real time electricity prices giving them the possibility to shift their loads to the lowest prices. The problem that rises from applying the RTP methodology is that users tend to work their appliances at the same time (Mohsenian-Rad et al, 2010), resulting to an over- loading of the system. While with RTP the price changes hourly according to the time of use, it seems that users tend to overuse their appliances during the low prices (Mohsenian-Rad et al, 2010), which creates an overload in the system, even resulting to a crash of the system. An instability of the system or even a power blackout (Zhao et al., 2013) which leads to spending more and more money to bring back the grid into balance.

Next, it closely examines the adoption of the IBR method (Mohsenian-Rad et al, 2010; Zhao et al, 2013), in relation to security and stability of the loadings thus the grid itself. With IBR ensuring that the price increases according to the total quantity of the load of the energy consumed simultaneously (Mohsenian-Rad et al, 2010), users have the ability not only to plan their usage according to time but also to load consumption (Vehbi C Gungor et al, 2011; Hledik, 2008). This motivates users to perform their tasks in different times, administer their loads in different times through the day, thus pay less (Mohsenian-Rad et al, 2010).

From the examples provided in the previous chapters both methods, have an important role in providing all the necessary information to the users, to make the correct choices towards, greener behaviour and sustainability (Nader, 2011; Porter & Roach, 1996). Most importantly for the users to get the best, for the lowest prices but also for the providers to minimize their maintenance costs. It is clear, by now, that with the use of RTP and IBR models, users have all the necessary data to understand how the prices change hourly thus when they should operate their appliances to catch the lowest prices (Darghouth et al., 2011) but also use their loads correctly. Specifically, there is no proof that users will entirely use the data correctly, we cannot be sure that the users will be willing to make so crucial changes to their everyday life. Nevertheless, we can only assume, that by minimizing their costs and by improving their satisfaction, their general behavior towards sustainable energy production and consumption will improve and become more efficient and more effective. By improving their behavior towards energy sustainability, it would result to the improvement of environmental sustainability.

One aspect which illustrates the combination of RTP and IBR can be identified in the adapted framework which was described in detail in the previous chapters. The idea of the combination has been studied by two research teams in 2010 and 2013. Both researches have mathematically proved that when the households are automated by smart appliances, and the framework is applied, price prediction according to time and loads is possible, thus power scheduling becomes a possibility for users. The relationship between the consumers and the producers is a two- way communication, as the users are continuously provided with new prices and the providers simultaneously extract data from the power scheduling, which gives them the possibility to evolve the system. The arguments presented in this chapter, clearly show the reasons this research paper is a strong contribution in the body of knowledge regarding the grid balancing problems that Switzerland is facing. Although, methodologies such as RTP, etc. have been studied and proposed as solutions, no other research paper has been written in which the framework combination has been adapted to the Swiss reality and presented.

6.2. Findings/ Research questions' answers

In the previous chapters I described individually the real- time pricing as well as the inclining block rates methods. As well as the reasons and the ways for the combination to be adapted and finally effects in the consumption and the production of energy when combined. I described what the power grid of Switzerland looks like now and how it could be transformed into a smart grid by simply adopting smart appliances at homes (or buildings in general). I identified and described in details the main problem of Switzerland's grid which is, mainly, the high costs and the imbalances that occur in the electric system. Through literature review, I researched, identified and described two approaches, similar but with certain differences, one was published in 2010 and the second one was published in 2013, three years after. Furthermore, using the existing knowledge from the two researches I argued that this combination is indeed the necessary solution for the problems of the power grid in Switzerland. To base my arguments, and show my idea in one concrete image I created the framework representation (figure 5). The framework representation has been adapted in the Swiss reality.

There are several reasons that make this research a new contribution. The main reasons are two. Firstly, the framework that was created is adapted and represents the reality of the energy production and energy consumption relationship in Switzerland, a representation of the framework was not found in any research paper. Secondly, although many researches have written about the wholesale electricity market in Switzerland and many potential ideas have been exposed through these researches, all end in the same conclusion, which is that in the end nothing big changes. Over- loading and over- costing problems that trouble the producers and the consumers involved in the Swiss grid remain a big issue. Therefore, this fresh and new idea that is proposed in this paper comes to bring that solution, that so much is needed.

Many will ask "Why Switzerland?". The answer is simple, Switzerland together with Austria and Germany are three of the strongest producers and distributors of electrical energy for European countries (Abrell, 2016; IEA, 2012; International Energy Agency (IEA), 2013), hence, Switzerland can afford to proceed with these changes. Switzerland is a country that new technologies such as smart appliances are embraced (International Energy Agency (IEA), 2013), a great number of houses have already embraced these new technologies in their households which makes it easier for the formula to work effectively. Another important reason is that during the last years, Switzerland has invested in new policies towards radical changes on the energy consumption reduction (Abrell, 2016; International Energy Agency (IEA), 2013), which makes the country, to have a clear advantage, with regard to the proposed solution, especially in the dawn of the new decision of the government to reduce nuclear energy production radically in the next years, the urge for grid stability is of great importance.

Another question that many would ask is “How can we make sure that users will actually change their every- day life?”. Well the truth is that we cannot. We can only assume that by minimizing the grid problems and potential blackouts, hence decrease the electricity costs, the users in time will learn how to use their appliances correctly. It has been proved that, when users have the possibility to spend less money for electricity they tend to change their every- day habits, towards a more efficient and sustainable way.

The main research question of this research paper is *“How will the combination of RTP and IBR establish the security and reliability of the Swiss grid by reducing the costs and the overloading of the grid?”.* The combination of the two models has been illustrated in figure 5. The idea has never been adapted and studied according to the data of the Swiss grid, has been evaluated though by two researches, by Zhao et al and Mohsenian-Rad et al. In summary, the establishment of the combination of the two models in the Swiss grid provides users the possibility to create a power schedule. A power schedule is a plan that shows when an appliance should be put into work (start, stop parameters have to be set), through real time prediction. Price prediction in combination with power scheduling, provides utility companies’ the opportunity to overcome grid over- loadings and blackouts, which results to less misfunctions of the grid, thus, less maintenance costs.

For the sub research questions stated in the previous chapters. The first sub research question is *“How can RTP and IBR be combined?”.* Although, the model combination has never been studied for the Swiss reality, from the researches we can see that RTP and IBR, are mathematical functions that calculate prices according to specific parameters set in prior. Though, what happens is that that the households receive price predicted by the framework in their smart devices, afterwards, the users set their time parameters for their appliances. the new data is transmitted back to the utility company via smart devices such as smart meters, where the new parameters are set and new price predictions are made and provided to the users. This partly answers the second sub question, as well, which is *"How can the new framework be adapted in the Swiss electricity wholesale market?".* A representation of the combination of the models was adapted, designed according to real data from the production and consumption in the Swiss grid, for 2014 (Abrell, 2016). Several technological changes must be done in the households as well as the electricity production and distribution processes in the form of new regulations and new policies.

The third and fourth sub research questions are *"How can this framework provide users with a secure and reliable system, where consumption and production are balanced always?"* and *"How can over loading of the grid be avoided?".* The second question is a follow- up of the first thus I will answer them together in one explanation. As partly explained by the main research question, if users can schedule their power usage (power scheduling) while receiving new flexible electricity prices every day that are calculated according to the time of use and the loads of use (price prediction), they can manage their appliance usage, by using them in different low peak times during the day and not the high peak times, in a way that the grid can manage over- loadings. Thus, the system can be more stable and more reliable. In conclusion, if the system is stabilized the consumption and production of energy is balanced.

Finally, from the research that was done one last research question was raised. *"Why should this method be adapted in the Swiss electricity wholesale market?".* The electricity market of Switzerland is now suffering. The utility companies and government are paying more and more to maintain the stability of the grid. At the same time, the continuous problems, increase the electricity prices making consumers more confused about when is the correct time to use their appliances, hence, unsatisfied. By adapting, the combination framework the wholesale electricity market will change, as it can reflect these costs to all users, producers and consumers.

Chapter 7: Conclusions

7.1. Further research proposal

This study only begins to reveal some of the positive effects of this combination framework to the power grid of Switzerland and not only. Some answers have been exposed by the theoretical analysis provided in this research paper, through literature review, but more questions were raised when writing it. Questions such as the effects of reducing costs and loads upon the power peak ratio. Or the true effects on users' behaviour towards environmental sustainability, or even the true changes on the legislation, organization and operation regarding utility companies and energy producers.

This study is based in a theoretical overview of the existing knowledge, a literature review, which helped me understand the problem in depth, as well as to find a solution with which the problem can be fixed. From the literature review, is where, the argumentation theory was built. In specific, the stability and reliability of the Swiss grid and the reduction of the costs is the main problem, for which the RTP and IBR framework combination could be the potential solution. The question that made this research start, was a phrase by Jan Abrel in his research paper about the wholesale Swiss electricity market published in 2016 with which he ended his research. He asked the readers *"How an incentive compatible and cost based system can be created which also reflects the cost?".* In this research paper evidence has been found, that this solution is that incentive that reflects the real costs of the Swiss grid and has been introduced.

Nevertheless, a concrete research has not only a theoretical part but also a practical one. Further research could be conducted for the exploration of the framework. Other recommendations for further research include the mathematical proof of the framework and the simulation in real automated basis households in the area around Switzerland. A certain limitation of this study was that the researcher couldn't practically apply the framework in a real household and study it, to get actual concrete data. There are two steps for the further research, the first step would be an empirical research focused on the creation of a generic algorithm (it's a simple linear problem that can be solved with a generic algorithm) and simulation in real- time conditions with real time parameters. The second step would be a real- life experiment, focused in several households that are willing to change their pricing model. The households must own new generation automated appliances. The framework must be applied for at least one year and the researcher must monitor the changes of the energy consumption during the whole process.

Finally, several changes must occur for the application of the framework to become functional. Such as the installation of smart meters and the wireless net. Additionally, an energy management system and an energy management controller is the basis of the two- way communication thus is the first step of the new installations that must occur before the research becomes possible. The gathered data will help prove that the framework is indeed the necessary solution for the Swiss grid as the findings, will show that the over-loadings will be decreased which means that the electricity costs and the system maintenance costs will be decreased.

7.2. Summary

There are four tasks that belong to the argumentation theory, the identification of the problem, the analysis of the possible solution, the evaluation of the findings and the invention (Rich, 2013). This research paper was built upon those tasks. To summarize my research and conclude my paper, I will go through these tasks.

For the identification of the problem. Although the use of TOU should be able to increase the public welfare (Filippini, 2011) and satisfaction (Abrell, 2016) this pricing policy seems that is creating imbalances, time and money loses. System over loading, grid imbalances which lead to high maintenance costs. Although power, energy, electricity is a good that everyone should have at any time. Most importantly in low affordable prices, the irregularities of the system and the high maintenance costs are making unsatisfied consumers. Thus, three big problems were identified in this research, the irregularities/ imbalances of the Swiss energy system, the high maintenance costs which burden the utility/ production companies and the government and finally the unsatisfied energy consumers. A sequence of a cause and effect situation that worsens more and more every year.

There are many reasons for which my research contributes to the body of knowledge. Through, my research, I designed the architecture of the combination of

RTP and IBR (image 5), which I adapted in the Swiss reality by filling up with the real numbers of energy consumption and energy production of the Swiss grid as well as show exactly how the energy is categorised and transmitted (energy only market and reserved energy market). A representation that was not found in any other scholar work before this paper. The idea to study the combination of these models, came to me while reading about the wholesale electricity market in Swiss and the problems that the grid is facing. Although Switzerland is technologically advanced it created so many questions about the reasons that Switzerland hasn't proceeded in such changes that the problems can minimize. Through my research, I realised that, though many researches have written about the wholesale electricity market in Switzerland and many potential ideas have been exposed through these researches, all end in the same conclusion, which is that in the end nothing big changes. Over- loading and over-costing problems that trouble the producers and the consumers involved in the Swiss grid remain a big issue. This fresh and new idea that is proposed in this paper comes to bring that solution, that so much is needed, a new contribution in the Swiss reality.

As already mentioned before, Switzerland is one of the three strongest distributors of electrical energy for European countries (Abrell, 2016; IEA, 2012; International Energy Agency (IEA), 2013), hence, the country can afford to proceed with these changes. Switzerland is a country that new technologies such as smart appliances are embraced (International Energy Agency (IEA), 2013), a great number of houses have already embraced these new technologies in their households which makes it easier for the formula to work effectively. Finally, in the last years, Switzerland has invested a lot in new regulations/ laws for the energy consumption reduction (Abrell, 2016; International Energy Agency (IEA), 2013), which makes the country, have a clear advantage, with regard to the proposed solution.

For the second task, the analysis of the possible solution. Two researches were identified and described in this paper that could possibly serve as one concrete solution. Both researches are discussing the same idea with small differences. The first research was published in 2010 and the second research three years later, in 2013. In both researches the authors identified that a combination of real- time pricing and inclining block rates could serve as a reliable solution based mainly to the costs. The author argued that a framework combination of the two models could potentially reduce the power peak ratio and delay time, which could lead to a reduction of the over- loadings and the costs. To prove their theory, they applied the models in households/ smart homes, in the form of a generic algorithm that was simulated under specific system changes and set parameters.

For the evaluation of the findings. The evaluation of the findings was done through a set of arguments. Through the paper, I argued that the establishment of the combination of the two models in the Swiss grid can provide users the possibility to use power scheduling in their day to day life which brings them in real- time prediction. With the use of price prediction and power scheduling, grid over- loadings and blackouts are avoided which results to less maintenance costs, thus lower prices and increased demand response thus grid reliability. For that reason, a framework was created from this research that shows how the idea of the combination reflects to the Swiss grid. As examples to my evaluation I used the described solutions from the two researches

Finally, the invention. A certain limitation was identified. This research was limited to a theoretical overview, an extended literature review. Nonetheless, a research to be concrete has to be driven upon practice as well. An emprical research was proposed as the next step. The built and simulation of a generic algorithm based in real time parameters, adapted to the Swiss reality, in order to prove that the framework does indeed reduce the costs and increases the reliabilty of the grid, through a set of experiments to take place in several households.

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