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Patent Analysis for Smart Grid Development in the U.S

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Patent Analysis for Smart Grid Development in the U.S

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Abstract

By increasing demand for energy among nations the rate of fossil fuel consumption is boosting. The raise of fossil fuel consumption has motivated nations to gain some capabilities for the purpose of dealing with some consequences; the more fossil fuel consumption, the higher price for energy, and the higher rate of GHG as well. Recently smart grid technology has been introduced as a healing approach in terms of using energy more efficiently. This study made an effort to have some discussions around smart grid technology development in the United States by patent analysis and forecasting. The outcomes in both technology and company levels determined, although smart grid technology is growing up by 2015, it will still be at the first stage of its life cycle and to reach at its maturity phase several factors such as governmental support, standardization policies, and the nature of technology are involved in.

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1. Abstract

By increasing demand for energy among nations the rate of fossil fuel consumption is boosting. The raise of fossil fuel consumption has motivated nations to gain some capabilities for the purpose of dealing with some consequences; the more fossil fuel consumption, the higher price for energy, and the higher rate of GHG as well. Recently smart grid technology has been introduced as a healing approach in terms of using energy more efficiently. This study made an effort to have some discussions around smart grid technology development in the United States by patent analysis and forecasting. The outcomes in both technology and company levels determined, although smart grid technology is growing up by 2015, it will still be at the first stage of its life cycle and to reach at its maturity phase several factors such as governmental support, standardization policies, and the nature of technology are involved in.

2. Introduction

The ongoing increase in the fossil fuels' consumption, the many crises energy industry has been subjected to due to the uncontrollable rise in the price of crude oil, natural and logical increase in energy demand due to global population growth, and the general environmental awareness have led the developed nations and their energy industries to pursue alternative energy resources, mainly green ones. Solar, wind, tidal and other resources have been researched and developed in an effort to manage the challenging situation (1) (2). Efficiency has also been pursued by all energy related industries, and been promoted for its immediate and long term positive financial benefits.

Beside, generation diversification and other pressing issues that utility industry is trying to cope with, governments and industries have agreed that, electric power infrastructure that has served well so far, is definitely nearing its obsolescence and a major facelift is needed. The current inefficient grid has to be modernized in a way to handle the new renewable sources of generation, transmission, distribution, and real time monitoring, managing and self-healing (3).

For all of the mentioned functionalities, the expected grid has been called Smart Grid. It is a complex system made by several different subsystems. In other words, Smart Grid is the result of multiple industries' efforts.

Currently, many companies have been involved in various sectors of smart grid technologies that cover the wide spectrum from power generation to end customers. To understand the trend of smart grid technology and to predict its future evolvement more accurately, various methods and models have been developed. Some would rely on databases and the life-cycle approach where a technology has to follow an S-curve (4). Others would be engaged in bibliometric analysis, which is a quantitative method of evaluating literatures (5). Patent analysis is another powerful tool that could be used to understand competitor's positions as well as R&D efforts, and a complementary and supportive forecasting tool when assessing technologies (2) (6).

This work will utilize patent analysis methodology. A retrieved set of patents related to smart grid fields will be analyzed at two levels; the applicable technology (ies) as well as their appropriate company (ies). This will result in gaining insights to the technology (ies) competitive edge and R&D strategies behavior. The study will be conducted as follow:

- Collecting and purifying patent materials from USPTO database.
- Using CHI Research (7) patent indicators to perform the analysis in order to categorize companies whether on trend or falling behind.

- Technology trend forecasting by performing S-curve

3. Literature Review

3.1. Smart Grid

Grid is a serving infrastructure, carrying electricity from power plants to final users including residential, commercial and industrial customers. The current grid consists of power plants, transmission lines, distribution substations, transformers, switches and much more (8). For decades, utility companies have had to dispatch their employees out to gather needed data and find out problem sources. Also they have had to rely on customers' cooperation in reporting troubles. As a way to improve the efficiency of this ageing network and cope with the increase of demand, governments' agencies and all industrial players agreed on incorporating a computer-based remote control and automation technology into the electric utility delivery system. Therefore, the expected modernized electric network is being referred to as 'Smart Grid' for its ability of two-way communication, self-healing, handling wind & solar electricity sources, and enabling stakeholders to positively engage with the system (3).

3.2. Patents:

A patent is a legal document granted by a governmental agency to the inventor of a new device or a process, preventing others from producing the apparatus for a certain number of years. The inventor has the right to transfer the embedded rights in the patent to others via selling or licensing. A patent main purpose is the encouragement of invention and technical advancement by allowing a limited time monopoly for the inventor (9). Patents became so important and so valuable to the extent of measuring a firm competitive advantages based on this intangible asset (7). Patent statistics/analysis is helpful in identifying trends in industries as well as the competitive powers of enterprises or countries (2). Patent statistics have become widely used to classify technologies by highlighting their weaknesses and strengths. Patent databases have rich and broad content; rich by the quantity & quality of information available and broad by the range of topics covered. The availability, reliability and free access to patent data are facilitating cross countries technology comparison and it can also lead to cross technologies analysis (10).

3.3. Patent analysis:

Patent analysis is a method to transform patent data into useful information about a product development status, market competition etc. It is a useful and effective tool for R&D planning and intellectual property managing. Another effective use has been for competition analysis at both, process and product levels (2) (11). The main process of patent analysis is to use statistical analysis, multivariate analysis, or other quantitative models to analyze and interpret each field of a patent (such as the application date, assignee name, assignee country, and international classification). Patent analysis could be benefited from as follow.

<u>3.3.1 Patents as an R&D meter:</u>

As it has been mentioned earlier, patents are intangible assets of an enterprise that became the alternative input measure as well as the objective indicator of R&D or invention activities. They could also be used to examine and draw a relationship with a firm productivity; Trajtenberg (12) discussed the relationships among patent output, R&D expenditure, and profits; and Griliches (9) pointed out that patent data can be an alternative indicator of invention input and output when R&D data are lacking. So by analyzing patent data, we can acquire relevant information regarding a firm's R&D activities and outcomes (2).

3.3.2 Patents as a firm's technical ability indicator:

Using patent analysis, Jaffe (13) characterized the technological position of U.S. manufacturing firms. It was proved that the productivity of a firm's R&D is affected by the R&D of its technological spillovers. It was also concluded that, further analysis of a company's patents category, quantity, content, and portfolio can lead to a better understanding of the abilities and strategy of that company (2).

3.3.3 Patents as a candidate technology forecasting mean:

Patent analysis has been determined as a necessary tool to be used by companies when evaluating R&D projects. In order to decide whether adopting a technology or not, companies should perform some sort of patent statistics & analysis to be able to foresee the short and long term of the technology in question (6) (14).

3.3.4 Patents as the firm financial performance judge:

Griliches (15) used Tobin's Q to measure the achievement of R&D output and the value of patents. Ernst (16) examined the relationship between patent applications and the performance of 50 German machine tool manufacturers. These papers mainly discussed the relationship between patents and company value.

The majority of the conducted research, dealing with patents data, has mainly elaborated on the application of patent information or has used statistical methods to conduct empirical analysis of the companies' patent information (17). Consequently, very few efforts were spent to investigate the patent strategies or technological positions of companies (2). Therefore, this work will aim at measuring the technological ability of a number of companies that are involved with Smart Grid technologies. The study will do so by the use of a suitable set of patent indicators with the intention of providing objective information regarding each firm's technological strategies.

3.4. Patent indicators:

To be able to analyze and put the patent data into good use, a set of indicators is very crucial and must be established. The majority of studies conducted by most scholars fit one of three categories describing attribution and purpose (2). In other words, they addressed one of the following questions: Why, how, and what; (motives, technological strategy, and the value-added (2) (7) (9) (18) (19) (20) (21) (22) (23) (24)). In a couple of research papers (17) (18), patenting motives were studied and multiple categories were created; protection, reputation, and economic to name few. Other studies addressed the strategy part and the commercialization part (value-added) by suggesting a set of indicators and analyzing them to understand the strategy and extract the economic value-added (2) (7) (9) (21) (22) (23) (24) (25).

3.4.1 CHI indicators[1]:

The Patent Board™, formerly known as CHI Research, benefited from the CHI indicators in its corporate patent analysis as well as technology strength analysis (2) (7). As a consulting company established in 1968, CHI Research developed and provided indicators for multiple disciplines or industries such as technology, science, and finance. Later, the company suggested "*innovative quantification indicators*" for objective patent quality

[1] F.Narin, "Tech-Line Background Paper", CHI Research Inc., 2000. Available at: http://www.chiresearch.com/techline/tlbp.pdf, viewed May 30, 2012

appraisal and future values of a firm (2). As reliable as they are for patent analysis, the CHI indicators have been adopted and widely used by the industrial sector for the past few decades and still. Three basic, four citation, and two science linkage make up the CHI indicators which will be described below.

3.4.1.1 Basic indicators:

As mentioned above, there are three CHI basic indicators; number of patents (NP), patent growth percent area (PGPA), and percentage of company patents in the area (PCPA). All three of them are of a quantitative nature and are indicative of companies' growth and diversification, firms' R&D efforts and technological trend, as well as technology maturity (2) (20).

3.4.1.2 Citation indicators:

The basic indicators described in the previous section are quantitative in nature and offer limited information about a patent strength that is embedded within the patent data. Patent citation is most indicative of a technological development and can point out patent's value and quality via the citation index (CI), current impact index (CII), technology strength (TS), and technology cycle time (TCT). A minor drawback for citation is the lag time required, a two year period, before a patent starts getting cited (2) (14).

3.4.1.3 Science linkage indicators[2]:

The last group of CHI indicators represents the scientific base of a patent as well as the extent to which a firm is actively involved in a specific science domain. Namely they are the science linkage (SL) and the science strength (SS) (2).

All of the CHI indicators, with the exception of the technology cycle time (TCT), have a positive relation to patent and company; a higher indicator value reflects a more influential patent and a more valuable company. As for TCT, a low value is a reflective representation of a healthy (faster, shorter) cycle time.

Other indicators, such as the number of citation (NC), and technology independence (TI) which have not been included in the CHI indicators, have been addressed by other research papers and been categorized as being suitable for patent data analysis (2) (9) (21).

3.5. Patent portfolio analysis

By definition, a portfolio is a set, or an organized collection of related items. Therefore, a patent portfolio is a collection of a company's related patents addressing a specific technology or subject of interest. Patent data analysis could be dealt with at a company level (24) or at a technology level (26). Patent portfolio analysis combines the two levels and leads to the achievement of multiple benefits such as evaluating strengths and weaknesses of a firm, understanding competitors strategies and R&D focus, and most importantly, using the information by interested companies to rank themselves and take appropriate actions in order to close gaps with competitors if not bypass them (2).

When performing a patent portfolio analysis, both company and technology levels will mapped in two dimensions. At company level, the two dimensions of the technology strategic map are the patent activity that represents the level of R&D activities, and the impacts of these activities characterized as the patent quality (2) (24). At technology level, the two dimensions are *"the relative patent position and the technology attractiveness"* (2). Relative patent position is calculated by deriving a company's NP applications relative to the NP applications of its most active competitor; whereas attractiveness is assessed via the growth rates of patent applications (2).

[2] F.Narin, "Tech-Line Background Paper", CHI Research Inc., 2000. Available at: http://www.chiresearch.com/techline/tlbp.pdf, viewed May 30, 2012

4. Methodology

The main steps followed in this research are:

- Patents Collection
- Patents processing and purifying
- Selecting a Classification
- Patents Analysis
- Technology trend analysis

4.1. Patent Collection

Many patent databases are available worldwide, but since the focus of this research is the investigation of the U.S Smart Grid status, the authors defaulted to the USPTO; the database of The United States Patent and Trademark Office. To elicit related patents from USPTO, the *Patent Guider* software was used; Chinese software developed to analyze patents. For search query, “Smart Grid" was used as a main keyword. Retrieved data were loaded into an excel sheet for further analysis.

4.2. Patent processing and purifying

Data accuracy in patent analysis researches is vital because the quality of data has a direct effect on final result. Since patents are organized and codified based on general rules considering technological aspects, finding all patents related to the complicated systems like smart grid is very difficult. In order to understand which patent is related to smart grid and eliminate the non-related ones, it was required to carefully review the abstract fields for every single retrieved patent from the database.

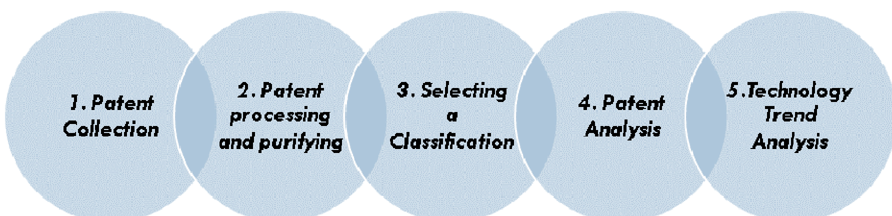

Figure *1- The steps of the research*

4.3. Selecting a Classification

Since Smart Grid is a sophisticated system, it is indispensable to have a classification introducing the main components of smart grid to assign each patent to each of the components. Otherwise we cannot have detailed analyses regarding to the main components. To have an appropriate classification, International Energy Agency (IEA) classification was used. IEA is a subsidiary office of the Organization for Economic Cooperation and Development (OECD) (27). The classification is shown in Figure 2.

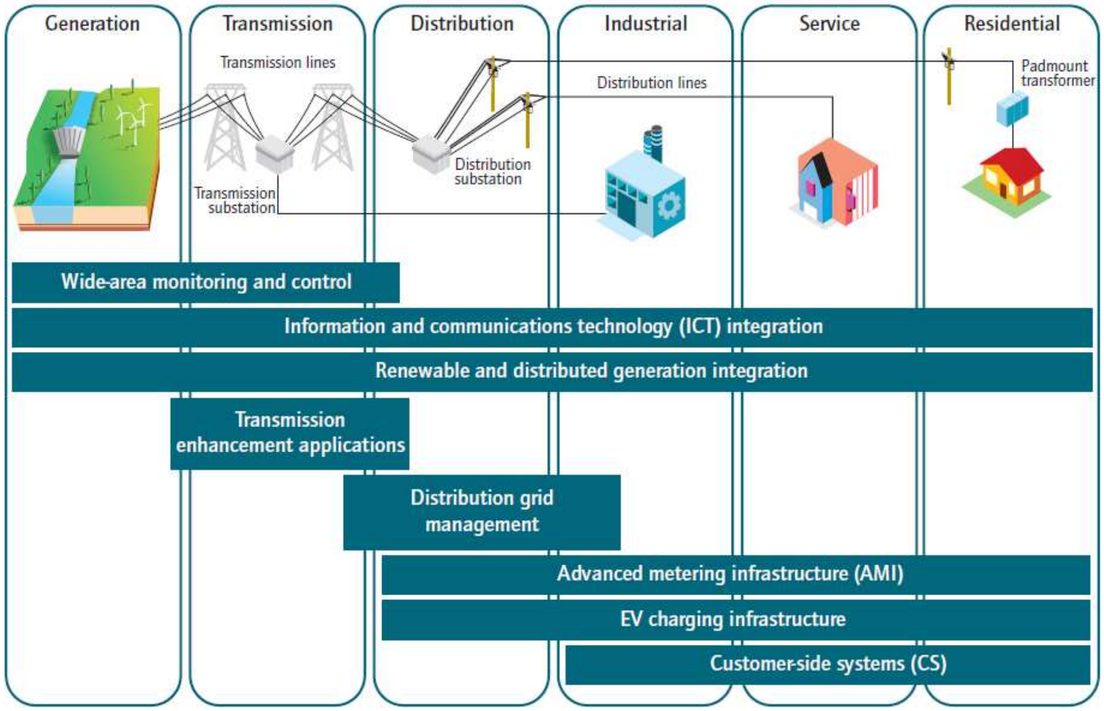

Figure *2- The selected classification for smart grid* **(27)**

4.3.1. Wide-area monitoring and control

WAMC focuses on real time monitoring different sections in a power system to optimize the performance of the system. It collects data through the power system and converts it into the applicable information in order to improve the quality of system in terms of transmission capacity, and reliability (27).

4.3.2. Information and communications technology integration

ICT is an infrastructure for transmitting data through a network. The network can be either a public transporter such as internet or a private carrier such as a radio network. Other communication components such as communication devices, controlling software, and other facilities to support two-way exchanging information are allocated to this class (27).

4.3.3. Renewable and distributed generation integration

There is a challenge to control and dispatch the electricity from renewable energy sources. This class considers those technologies which make a balance between supply and demand (27).

4.3.4. Transmission enhancement application

TEA encompasses transmit technology in order to maximize power transmit abilities. This class of technology is responsible for identifying the current transmit capacity to optimize consumption of available transmission assets (27).

4.3.5. Distribution grid management

DGM includes sensors to realize the malfunctioning through the system, doing self-healing, reducing repair time, outage, and maintaining voltage level (27).

4.3.6. Advance metering infrastructure

ADI class deploys different technologies in order to create a bidirectional flow of information about the rate consumption in terms of time and price, between users and utility companies (27).

4.3.7. Electrical vehicle charging infrastructure

EVC provide a class of technology to handle the facilities for smart charging in terms of billing, and charge scheduling while considering demand peak time (27).

4.3.8. Customer-side system

CSS focuses on managing consumption technology at the customer side including industry and residential. The main technologies in this class are related to the technology of energy storage equipment, smart appliances, and managing energy efficiency in peak time of demand (27).

4.4. Patent Analysis

As mentioned in literature review, there are three main indicators in patent analysis, which are basic indicators, citation indicators, and scientific indicators. Since there are not adequate data about the second and the third indicators, this study is confined just to basic indicators.

4.5. Technology trend analysis

After purifying the excel data base from non-related patent to smart grid technology, data was categorized into two levels; technology and company, in order to forecast smart grid development in upcoming years. In technology level there has been a data set of total number of smart grid patent through 2004 to 2011 and in company level, five data sets were extracted for the top five companies based on the total number of smart grid patents they have possessed between years 2004 and 2011.

To find smart grid development behavior in the future first it is required to find its historical trend and then assign it to the best fit curve. Regarding this matter, this study tried three different types of trend models including S-Curve, quadratic, and exponential growth on both technology and company levels. The data were loaded into Minitab software for finding the best trend model. The desired fit curve is the curve with the lowest value for accuracy measure. This study made a judgment for the best fit by considering the lowest value for *mean absolute deviation (*MAD) accuracy measure.

MAD = $\sum |f_t - a_t| / n$

Where:

a_t : the actual value of the quantity which is being forecast;

f_t: is the forecast value;

n: number of periods;

Since the history of smart grid patent in the data base gets back to the last 8 years (which in the first three years there were only 1 or 3 patents), there was not enough data to forecast for a long future. For a long-term forecast, a great enough number of data points is needed which helps for the forecast analyzer to estimate all the patterns in dataset. Here the trend models to predict the development of smart grid in the United Sates is considered for next four years (2015).

The first fitted function to the 8 years dataset of technology level is s-curve function. One of the factors, which change the shape of fitted function dramatically, is the highest possible value of the data points. Based on the current dataset, Minitab software found out the best fitted s-curve function with a maximum of 141.6 patents in future; which is a low value to believe that smart grid patent will reach to its maturity stage by 2015. Although this s-curve provided the lowest MAD value (appendix 2, figure 1), it has been decided to continue with other possible functions.

The next functions that seem appropriate to fit to the data points are exponential and quadratic functions. Due to the nature of exponential and quadratic trends the maximum value (asymptote) is not applicable for these models; therefore there is no concern of limiting the best fit curve into an upper value. Between the two other trend models quadratic provided the best fit curve with the lower MAD value of 11.53 (appendix 2, figures 2 and 3).

In the company level, s-curve and exponential growth trend models did not work due to lack of data. Through the year 2004 to 2011, most of the companies received their patents in 1, 2, or 3 years so the number of data points was less enough not to fit them into an s-curve or exponential growth. For example Intellon Corporation possessed its 12 smart grid patents only in year 2008. Regarding to this issue quadratic trend model again considered as the best model for predicting looser or winner in smart grid technology by 2015.

5. Results

Since each of the quintuplet steps of this research has its own results, each is explained in this section distinctively.

5.1. Patent Collection

To find how many patents have been applied for or issued for smart grid in the U.S., Patent Guider, Chinese software, was used. The software searched for smart grid key word through USPTO database and pulled up 615 applied patents and 54 issued patents, totally 669 patents. The patents are related to years between 2004 and 2011.

5.2. Patent processing and purifying

To understand which patent was related to smart grid technology, patents' abstract were precisely reviewed. After this processing of eliminating unrelated patents, 313 applied patents and 39 issued patents were retained for the final analysis. The proportion of applied and issued patents are shown in Figure 3- *The proportion of applied and issued patents*Figure 3.

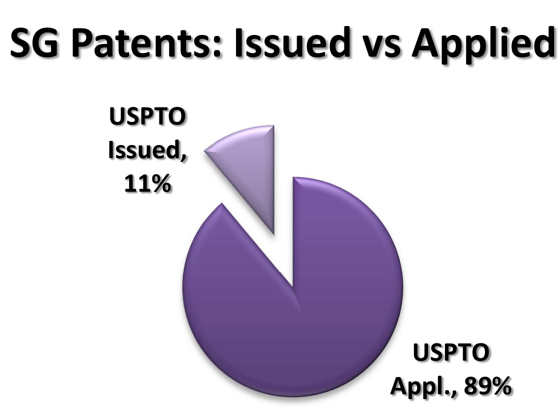

Figure 3- *The proportion of applied and issued patents*

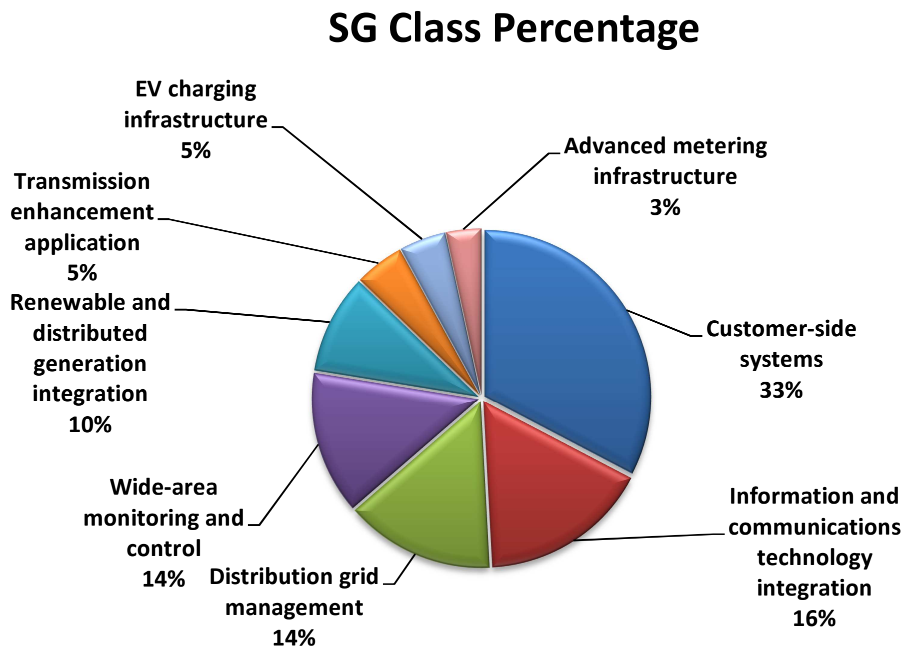

Figure 4- *The percentage of each class in smart grid patents*

5.3. Selecting a classification

According to the introduced classification in methodology section, each patent was assigned to its proper smart grid technology class. The portion of each class is illustrated in Figure 4.

5.4. Patent analysis

The basic indicators calculated for smart grid are "number of patents" (NP), "patent growth percent area" (PGPA), and "percentage of company patents in the area" (PCPA). All basic indicators related graphs are displayed in appendix 1.

5.5. Technology trend analysis

It is learned from technologies lifecycle that the development of a technology increases with a smooth upward trend in introductory stage, and then an exponential growth happens in growth stage. The growth stage will be followed with lower rate of growth in the maturity stage and in the decline stage the other alternative technologies will be replaced.

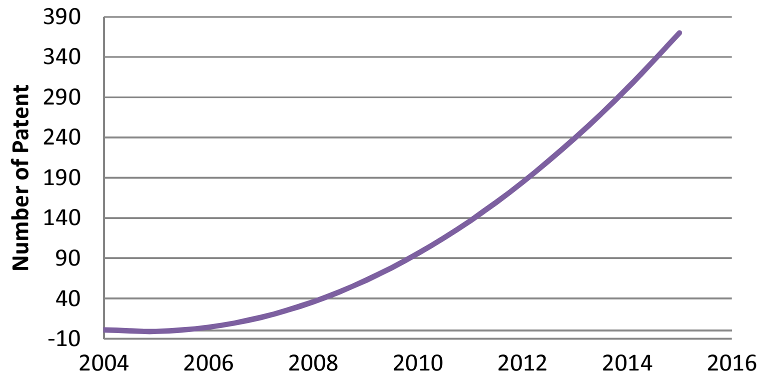

Figure 5- *Smart grid technology trend development*

Choosing of the quadratic function seems appropriate as the curve in figure Figure 5 matches the first level of the technology development, called introductory stage. Therefore smart grid trend is at the first stage of its life cycle and yet it has not reached to its sharp growth which is assumed to follow the exponential stage of an S-Curve and then continuing in its maturity phase.

According to the forecast analysis shown in figure Figure 6, LSIS will take over the other top four companies whereas V2Green and Intellon will not have a contribution in the near future. Of course these results are subject to be changed in future by other factors like governmental support, or standardization policies.

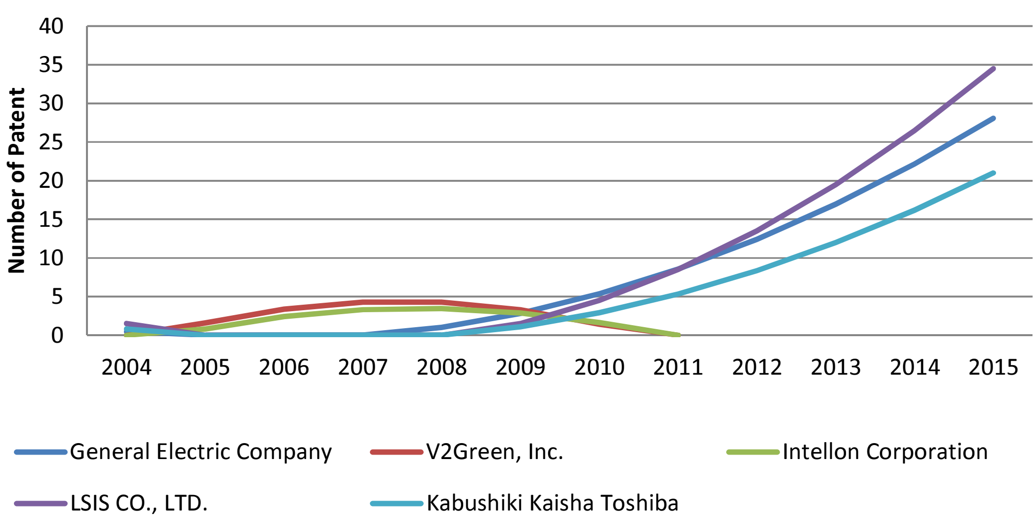

Figure 6- *Top 5 Companies Development in Smart Grid by 2015*

6. Discussion

Discussion 1- the maturity of Smart Grid

According to the forecast analysis, Smart grid is a new phenomenon and is considered in its emerging phase. The main reasons of this acclamation are:

- The number of issued patents is too low. 39 issued patents in comparison to other industries having thousands patents is trifle.
- Interoperability and integration among various parts of smart grid is an important factor to have a reliable development path.

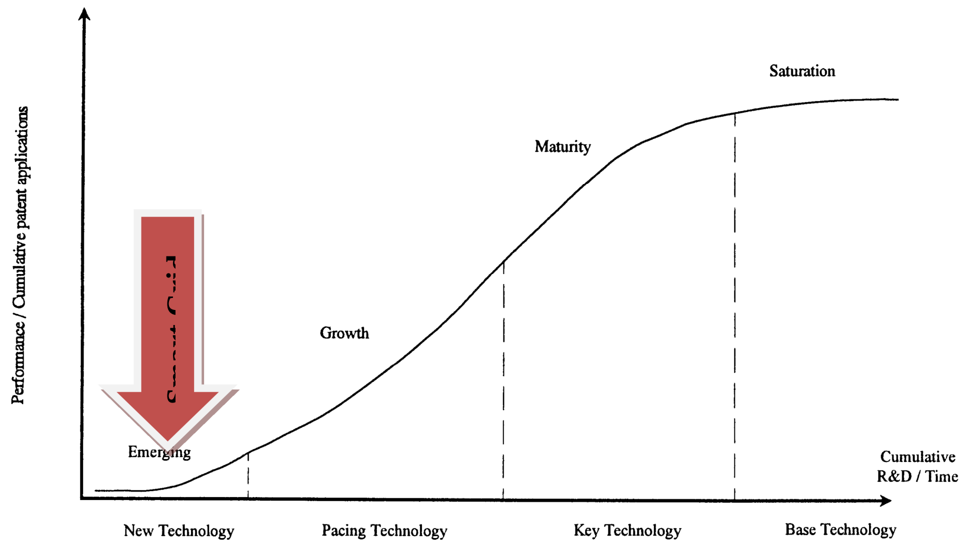

Figure 7- *Smart grid technology life cycle*

Discussion 2- big .vs. small and American .vs. international companies' behavior

Among the top 5 companies, General Electric (GE) and Toshiba are the big ones, and the rest are small, see figure 6. GE and Toshiba have concentrated on "customer-side systems" and "information and communication technology" (ICT) and "wide area monitoring". This fact shows that big companies are reluctant to enter all areas in smart grid. Basically, smart grid is one of several technologies domains that big companies are involved in whereas small companies have just concentrated on a fewer number of technologies including smart grid. The difference between the total number of issued patents to small and big companies, shown in Table 1, supports this assertion.

Among small companies, LSIS, a foreign company from South Korea registering its patents in the U.S., has a distinct strategy by being present in six areas of smart grid. According to this study forecast analysis it is expected that LSIS will overtake the other four top companies by 2015. This LSIS diversification may be attributed to the fact that few companies in South Korea are involved with smart grid activities, therefore companies like LSIS were forced, in a way, to support multiple, if not all, parts of smart grid. Small companies from developed countries, like LSIS, feel a sense of urgency to be present in many areas in smart grid in order to support the developing process and integration of smart grid in their countries.

On the other hand, V2Green and Intellon, as two small American companies, have participated in fewer areas of smart grid in comparison to the foreign LSIS Company. Each of the two has focused on specific areas. V2Green has concentrated on "distribution grid management", while Intellon has paid particular attention to "distribution grid management" and "wide area monitoring and control". It could be concluded that, due to the nature of the American large and competing market, American small companies tend to focus on few specific areas of the smart grid in order to guarantee success, survival, and a steady growth of their market share.

Company	Number of all Types of Patents
General Electric Company	57749
V2Green, Inc.	15
Intellon Corporation	113
Lsis Co., Ltd.	63
Kabushiki Kaisha Toshiba	11548

Table 1- *The number of patents issued in whole areas by each of top 5 companies*

Discussion 3- who is leader?

Smart grid, as a complex system, has many components and parts that require to get integrated. Developing standards is one of the vital actions to integrate smart grid components; therefore many national and international companies have launched plans for the purpose of smart grid technology standardization. It would be fair to state that one of the reasons why smart grid related services and products producers are not practicing extreme efforts is waiting for emerging standards. Ultimately, it is premature at this point to name one or few leaders in smart grid area to lead technological advances.

Discussion 4- affecting factors in smart grid development

There are some factors delaying technological development in smart grid. Interoperability, standards, governments support, and the nature of technology are the main contributing factors that will be detailed below.

First, smart grid is much more complicated than any individual industry by itself since it requires a close cooperation among multiple ones. Smart grid technology umbrella covers mainly four industries: ICT, electrical equipments, consumer products, and building, .To integrate all of different parts in smart grid, *interoperability* is a basic factor, so developing *standards* is a prerequisite.

Second, governments have a main role to stimulate technology development in smart grid. USA government started "Recovery Plan" (28). South Korea and Japan have launched vast plans to promote smart grid in whole area in their country (29), and, finally, EU is determined to develop smart grid (29). All these governments try to stimulate smart grid development by developing standards, preparing financial stimuli.

Third, some parts in smart grid have been developing slowly due to the nature of their technology. For example, EV charging structure is following evolutions in EV industry. Since EV technology is being gradually evolved, EV charging infrastructure is being developed slowly.

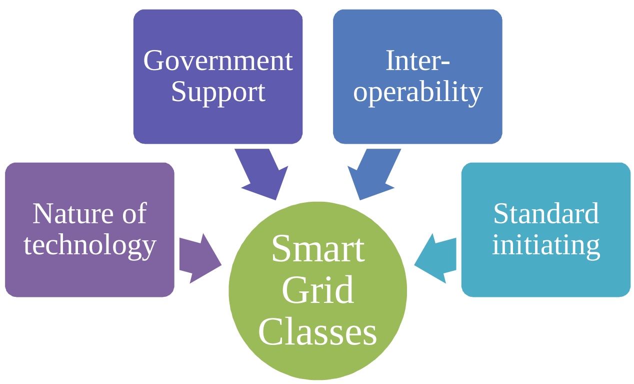

Figure 8- *affecting factors in technological development in smart grid*

7. Restrictions

Patent analysis is one of most powerful tools for analyzing R&D strategies and technology life cycle forecasting, but having an available and valid data set is a prerequisite. Since smart grid is a too young technology, some limiting factors were faced and are listed below:

- There was not a standard classification for smart grid technology; to cope with the issue, this study chose a classification from International Energy Agency report.
- Allocating each patent into smart grid technology and assigning it into the proper class was done by personal judgment so there might be an unknown percentage of errors in the recognition process.

- Due to software licensing restrictions, citation and scientific indicators were not deployed in this study which jeopardized patent portfolio analysis.

8. Conclusion

Smart grid is a complex system containing various technologies. The main concept of smart grid is managing all of its parts in a smarter way by benefiting from how the internet revolutionized the phone system. More than a decade has passed since the introduction of the smart grid concept and yet the related technologies still in their early stage of emerging phase due to lack of standards that make Smart Grid various components more interpretable. It is expected that smart grid will be matured by 2030 (28). Small and big companies have different strategies in developing smart grid technologies. Big companies are reluctant to enter all areas in smart grid whereas small companies from developed countries, like South Korean LSIS, are present in many areas of smart grid. American small companies intend to be present in fewer specific areas in comparison to foreign ones. Since smart grid is newbie in comparison to matured technologies, it is too soon to judge about who is the leader; especially many companies are waiting to understand what is going on with standards policies.

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Appendix 1- Basic indicators

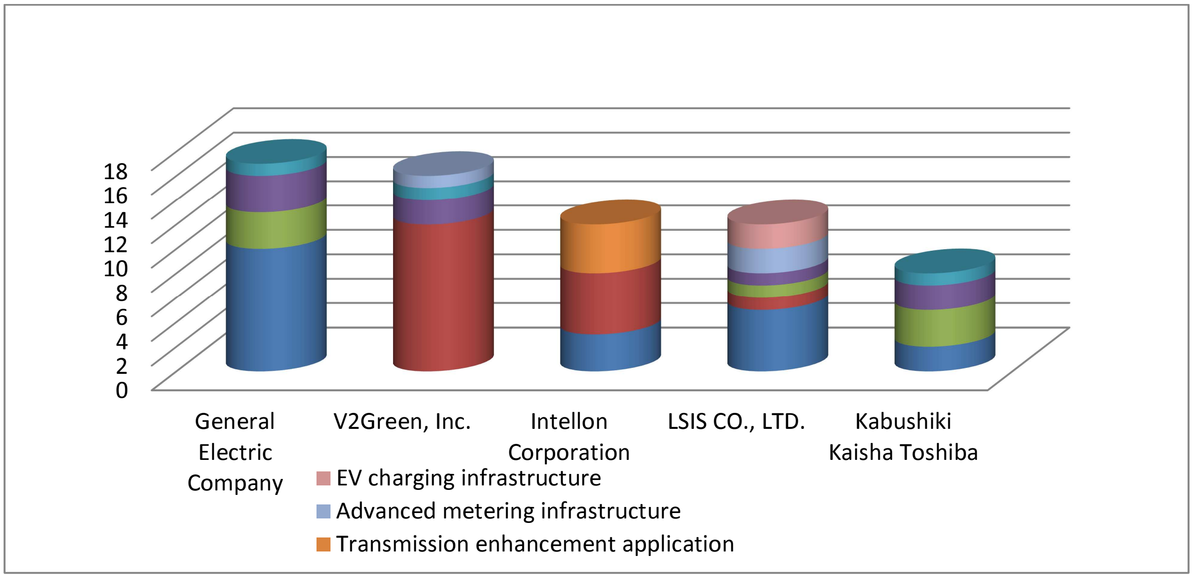

Figure 9- *Patent Number for 5 top companies*

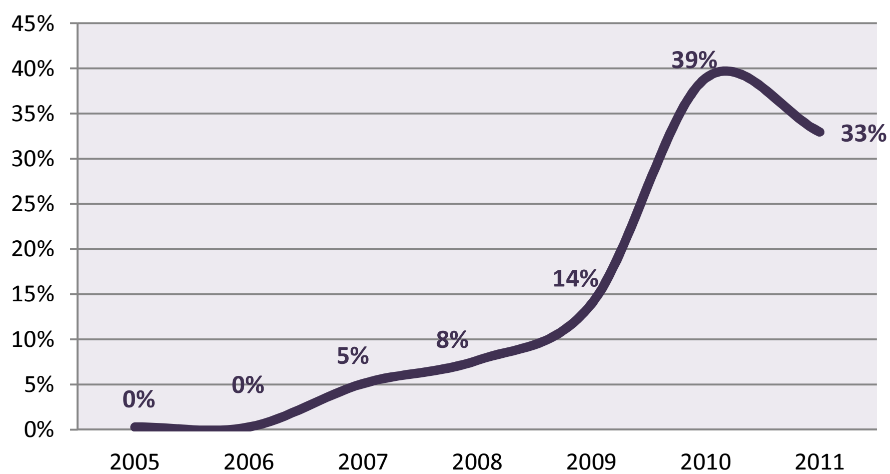

Figure 10- *Patent growth percent area*

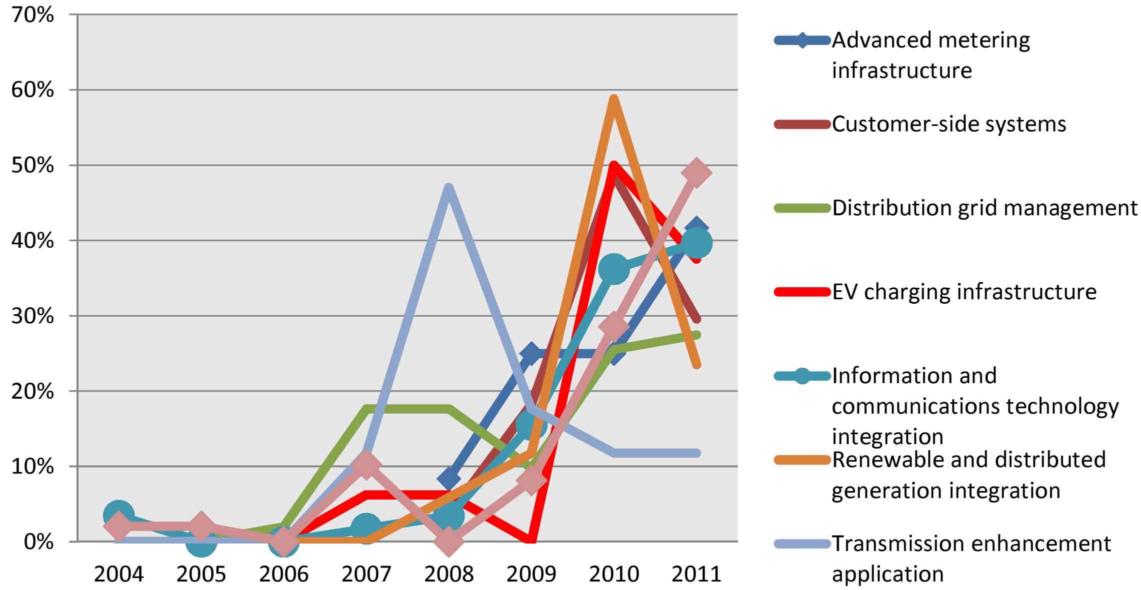

Figure 11- *Patent growth percent area in each class*

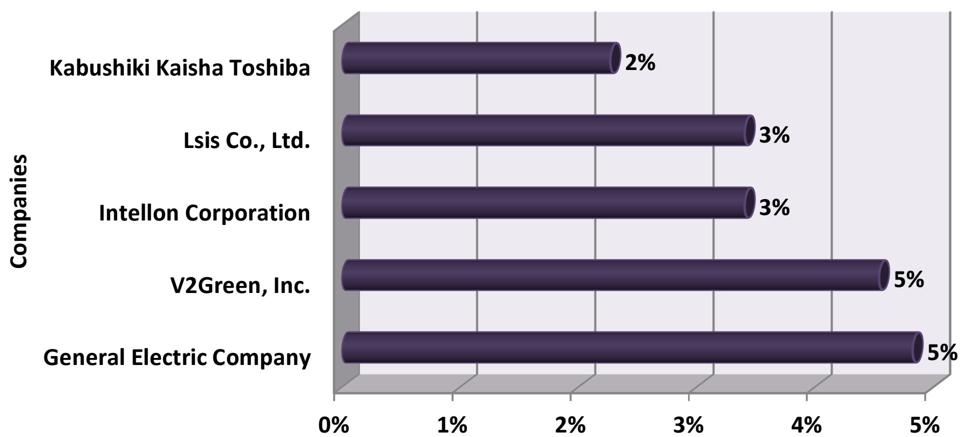

Figure 12- *Patent growth percent area (PGPA) for top 5 companies*

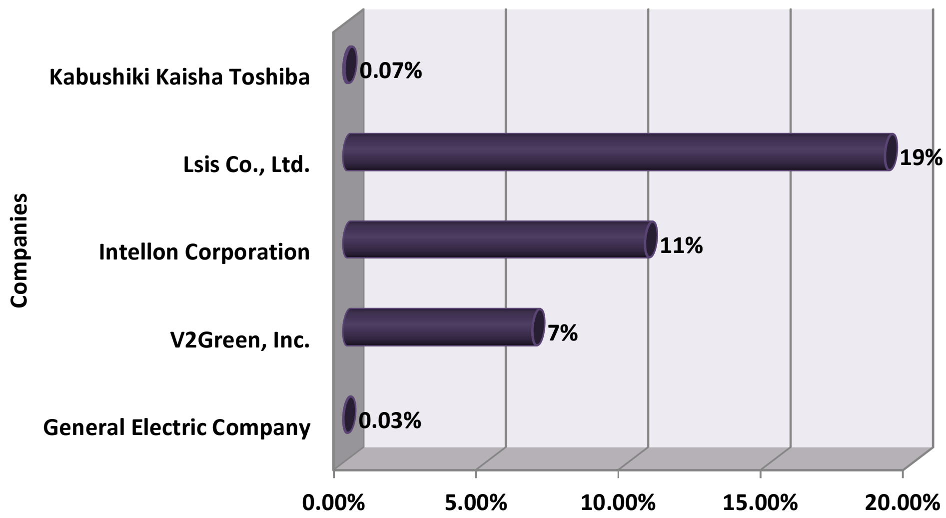

Figure 13- *Percentage of company patents in the area (PCPA)*

Appendix 2- Trend Analysis Plots

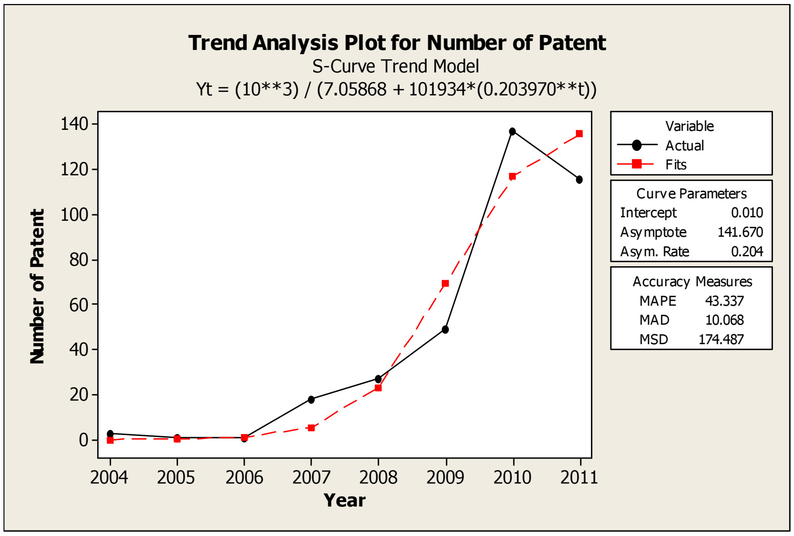

Figure 14. *S-Curve for SG Technology lifecycle*

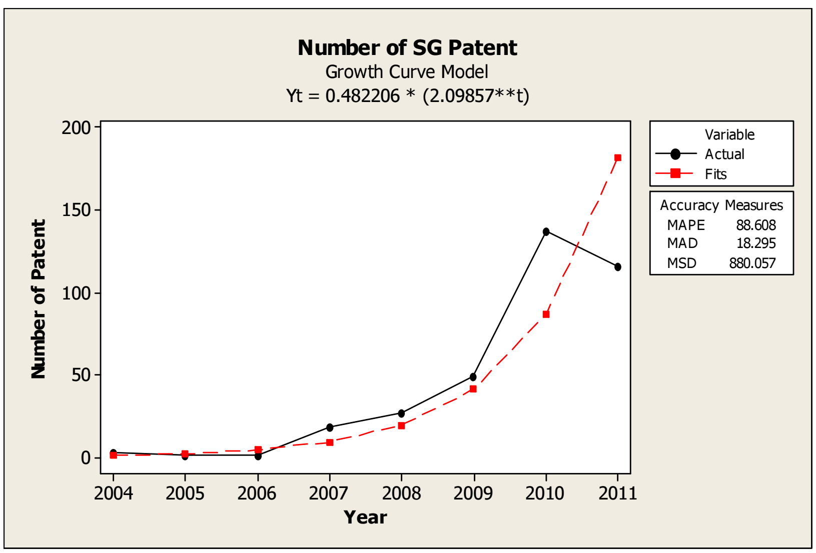

Figure 15. *Exponential growth for SG technology*

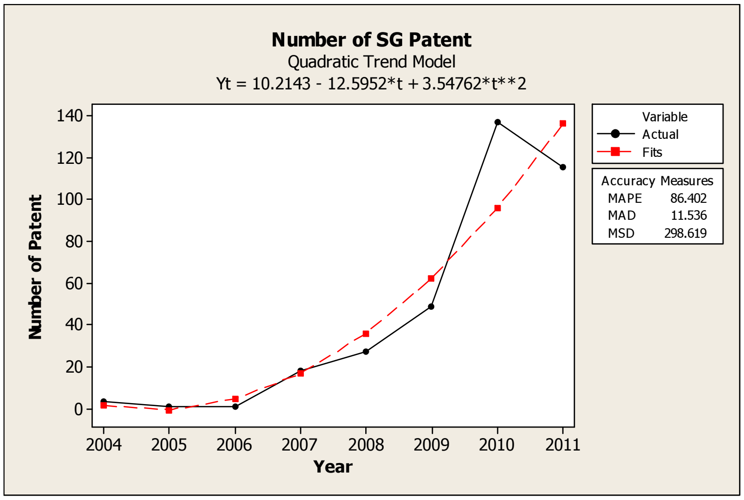

Figure 16. Quadratic *for SG technology*