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A Study on Vehicle to Grid Technology and its Scope

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Abstract

Electricity is one of the forms of energy which is useful for society. Generation of the energy can be done through conventional and non-conventional type of sources. When we compare the two types of sources the non-conventional type reduces less global emissions. Grid technology a new invention of 20th century can help to correlate between the non-conventional. This paper describes about the study of the Vehicle to Grid (V2G) technology in brief way and presents the scope and the advantages with which this can be implemented in India. Study describes about the technology, its necessity, its economic impact factor and its advantages.

Keywords: Vehicle to grid(V2G), plug-in-Electrical Vehicles, Reliability, stability

I. INTRODUCTION

Electricity which is considered to be the heart of the modern technology has become so vital now, the whole world depends on it. Used for big applications like aircrafts and industries to small household purposes like television, computer, mobile and etc. [1]. Usually the electricity can be generated from three known forms such as

- Generation through the turbine/generator in the generating stations usually a conventional energy
- Chemical reaction through a fuel cell or battery
- Last but not least, generation through renewable energies such as PV cell, wing energy etc.

The automobile industry is shifting towards more sustainable economy which will be driven by new technologies including renewable energies that would change the value of society. With the increasing price and non-availability of the petroleum, the policy makers and the manufacturers are moving more towards the less emission generation vehicle such as EV would benefit the users and encourage them by using the EV more. It is estimated to have all the EV in world by 2030 which would consume more of the non-conventional type of sources compared to the conventional sources such as coal, petroleum etc.

These all generations or distributions are connected to a single interconnected network called the Grid. The Grid connects the Generating stations, the transmission to the various users and the distribution. The electrical grids are usually placed or installed far from a city on an isolated place which should not affect the normal human life. Grids come in various sizes depending upon the need in that area. Since the grid is the vital part, they may be prone to attacks too for which many grids will have grid security. The figure represents the basic Grid technology [2].

Grid connects all the conventional and non-conventional source of energies. New invention in 20th century is smart grid which allows the generating stations to observe and control system parts including generation, transmission and distribution more accurately and efficiently. It builds a bridge between the two ends for more reliable communication and operation. Most of the generation is done from the conventional sources which contribute around the 70% of the total electricity generation in India. The remaining 30% constitutes of energy generation from the non-conventional i.e. renewable energy along with thermal and nuclear energy.

Generation of electricity through renewable energy is increasing day by day. People are now more opting for this as this produces less carbon emission and clean energy compared to the conventional form of energy which does not affect the environment. Renewable energies such as solar are being installed nowadays for the household purposes too which are fetching them great results.

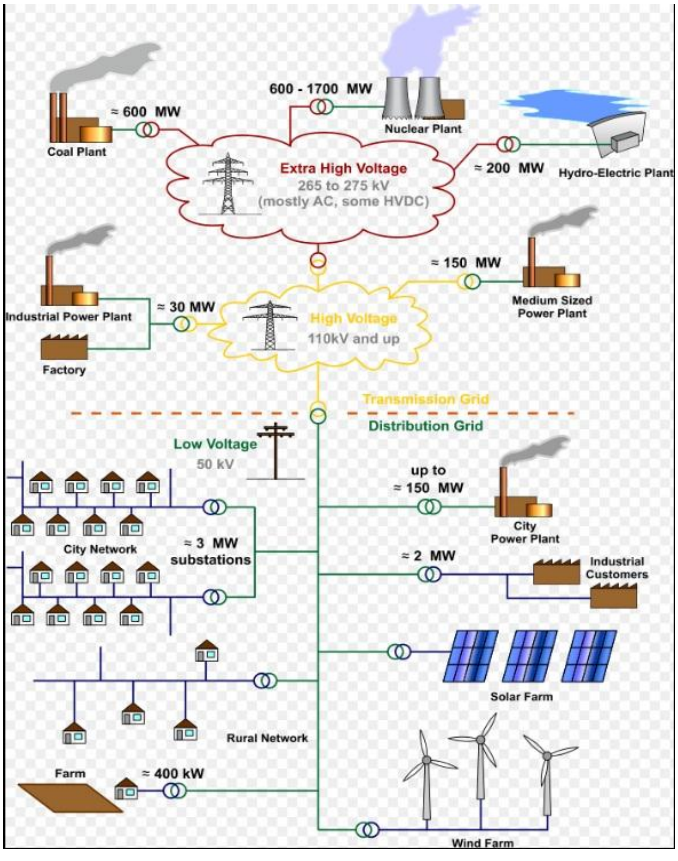

Figure 1. Representaion of Grid Technology

A new technology has emerged by giving the excess generated power through the renewable energy to the existing grid. The generated power can be contributed to the grid which can help the electricity generation and distribution. These are done using the renewable energies installed in industries or the houses which can be given back to grid, the excess energy, for which the electricity boards pay some amount for their contribution towards the electricity. This technology has a move towards the battery operated vehicle or the electric vehicle too, which is getting scope in supplying the excess energy to the grid called namely by Vehicle to Grid technology. This paper focuses on the study on the vehicle to grid (V2G) technology and its impact, advantage and necessity for the electricity.

II. V2G TECHNOLOGY

Many cities in America such as California, New York, Massachusetts, Vermont and Maine have taken up policies of developing the renewable energy through the electric drives which will result in less pollution and less use of conventional type motors by increasing the reliability and the efficiency of the electrical grid according to the report of 2001 by Willett Kempton [3]. The report represents the study of the V2G with respect to its size, availability and economic potential for the grid. It presented about how the V2G might the change the course of the electricity grid economically and reliably. The paper talks about the various parameters needed to be considered while designing or implementing an EV. The base load power (power taken from the power station, which can be supplied by EV in the same manner), spinning reserves (an auxiliary power sources which will work in reserve only if the main power system fails to works) and the regulations are much needed knowledge for designing an EV. When to take everything in account, the interface and infrastructure, resource size and analysis of vehicles is a must. The interface and the infrastructure covers the topic related to the connection between the grid/the power system to the EV and vice versa as shown in figure 2.

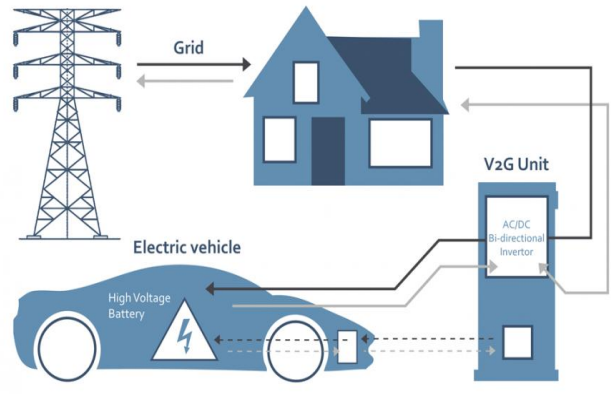

Figure 2. V2G Technology

An energy meter and a connection unit or an efficient converter is needed to work as an interface between the two. Resource size divides itself in three parts, first being simple projected sales of EV; second the number of vehicles, approx., that would fleet on road at a time contributing to the V2G technology i.e. back to the grid and the third one being the number of vehicles needed to develop base load power, spinning reserve and peak power. The electric vehicles used three types of source which were battery, hybrid and fuel cell. The paper [10] talks about the local environment between the grid and the user shown below in figure 3.

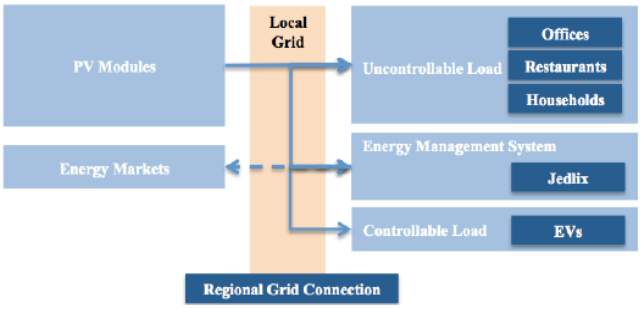

Figure 3. Local environment grids

As shown the local environment grid will have 6 main components namely PV modules, Energy meters, uncontrollable loads such as offices, houses etc., energy management systems and the EV which are controllable loads. The demand in the day time can be generated more from the PV modules as the grid must be worked at the time as there will be no use of solar. The uncontrollable loads must be kept supplying demand in the peak time, at night the grid will not have that pressure as it will be non-peak hours. The EV from the report is said that can be charged in non-peak hours i.e. from 6pm to 6am as it would decrease the pressure on the grid.

In the paper [4], the author talks about the V2G technology from which the electricity can be generated from the parked vehicles to the grid. It talks about the potential of the V2G technology using a comprehensive energy system model. His paper presents about the electric drive vehicles which will have great impact once it sets off in the field compared to conventional type by using the Energy Research and Investment strategies (ERIS) an energy optimization model that includes detailed research and investment of technologies and their dynamics. He presents about the graph representing the global automobile transport demand projection all over the world using the ERIS shown in figure 4.

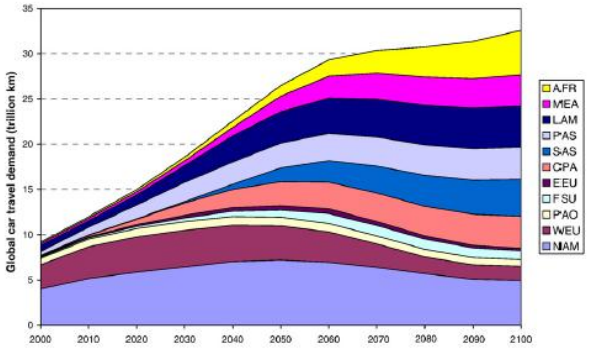

Figure 4. V2G demand projection globally

He presented about the methodology of ERIS to calculate the analysis and the impact of the V2G on global world. He talks about the current scenario and the cost effective models which can be implemented. Figure 5 represents the discussed result in his paper about the technology and the global deployment of V2G infrastructure and its impact.

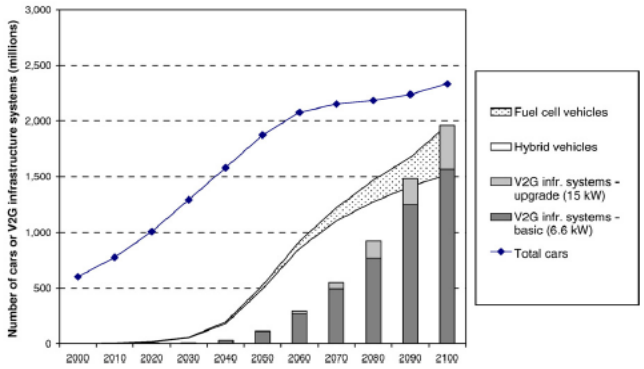

Figure 5. Global deployment of V2G technology

Paper [4] also represents a diagram which shows the use of energy during peak and non-peak hours. The vehicle can be charged and discharged according to the representation which would easily help user and the power system as it becomes a routine which would increase efficiency and the reliability.

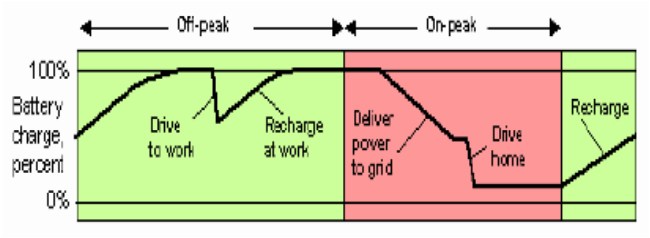

Figure 6. Representation of charging and discharging of battery by EV user

In paper [5], it presents about the V2G technology, its uses and applications and impacts. As all the papers do, it too presents about the economic analysis and the renewable energies system which can help curb the use of conventional type of energy sources. As seen from the figure 2, a bidirectional converter is fixed between the source and load which will allow the electricity to either charge the battery present in the car or transfer the power from the car to grid through it. This paper presents overall about the EV and its implementation issues such as scalability- setting up of lines for charging and discharging purposes between grid and EV, uncertainty of charging- this would trouble the user of EV if he fully discharge the vehicle and could not charge back as there are only ;less number of user for EV, reduced battery life which depends on the charging and discharging capability of the battery and finally the thermal issues related to the battery as shown by the author in figure 7 which represents about the battery life and its capacity at different temperatures. These problems might lead to the immature design of the EV as these arrive at nearly stages of the design.

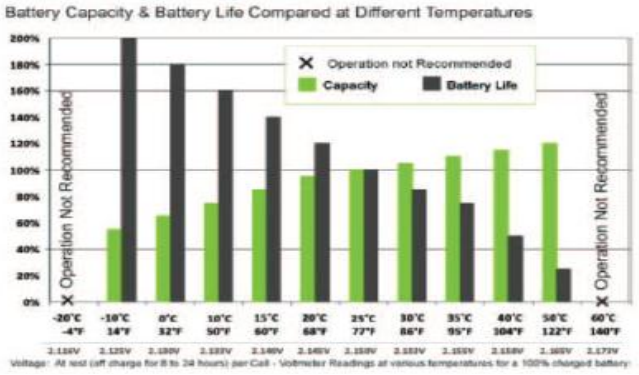

Figure 7. Charging and discharging capacity of Battery

In paper [6] the author talks about the new bidirectional converter which has three main functions namely, EV battery charging, grid connection and the reactive compensation of power. The paper presents about the controller system on the grid side and battery side, this forms a connection for the supply from grid to battery and vice versa. The framework shown in the paper is shown in figure 8 which shows a detailed representation of the V2G technology.

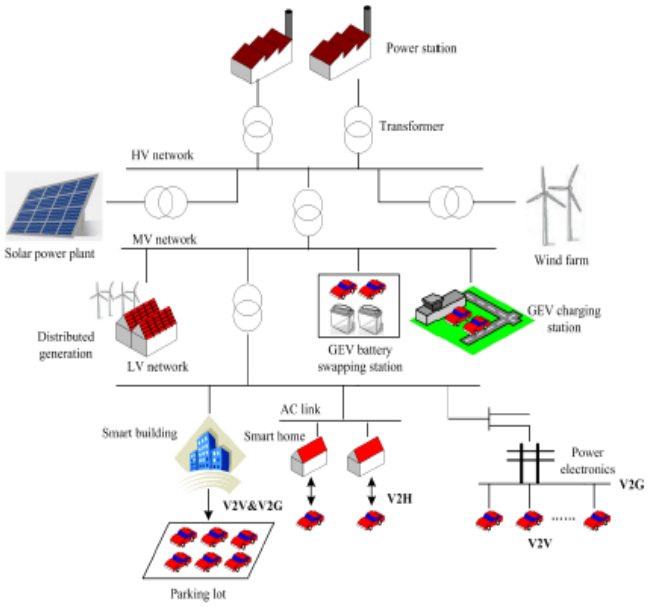

Figure 8. Framework of V2G Technology

Paper talks about the bidirectional converter consisting of an inverter, rectifier and buck boost converter all embedded in a single unit with controller attached to it. The control system has been implemented to both battery side converter and the grid side converter so as to make it controllable and to make a link between the two. The thesis [7] on V2G technology describes about the two main objectives out of which first one is setting up of fast charging stations and developing a platform where EV can support both active and reactive power to the grid. The other one being smart charging ability based on optimization technique which would benefit both EV and the grid. In this paper a Simulink model of f=grid side

converter and the local controller was designed and was shown in form of algorithm. It talks about the utility and the user functions which they need to follow with the results and discussion which would benefit both the EV user and the grid. The figure 9 represents the battery size, efficiency, charging capability of the selected EV models. This list includes model of some known manufacturers who have represented the fuel economy and the miles range an EV can travel before recharging the battery again.

Table 1: Charging Times, Range, Battery Size, and Efficiency of Selected EV Models.

Manufacturer	Model	Charging Time		Electric-only Driving Range	Battery Size (kWh)	Fuel Economy[1]
		120 volt AC	240 volt AC			
		Hours	Hours	Miles	kWh	MPGe
BYD	e6[2]	20	8-9[3]	186	61	97
Chevrolet	Volt (PHEV)[4]	10-16	4	38	17	94[5]
Chevrolet	Spark[6]	20+	7	82	20	119
Fiat	500e[7]	23	4	80 (est.)	24	108
Ford	C-MAX Energi (PHEV)[8]	7	2.5	21	8	100
Ford	Focus Electric[9]	20	4	76	23	105
Ford	Fusion Energi (PHEV)[10]	7	2.5	21	8	100
Honda	Fit EV[11]	20+	4	82	20	118
Mia[12]	mia	--	3 or 5	50 or 78	8 or 12	
Mitsubishi / Citroën / Peugeot	i-miEV / C-Zero / iON[13]	22.5	7	62	16	112[14]
Nissan	LEAF[15]	--	7	75	24	116
Opel	Ampera (PHEV)[16]		4	46	16	235
Renault	Zoe[17]	--	3.5[18]	130	22	--
Renault	Fluence[19]	--	6-9	115	22	--
Tesla	Model S[20]	30+	4-6	265	85	95
Toyota	Prius Plug-In (PHEV)[21]	3	1.5	11-15	4.4	95 est.
Toyota	RAV4 SUV[22]	44-52	6.5-8	103	41.8	76

Figure 9. Various EV models and their characteristics

Figure 9 also represents the charging time required by a battery in EV when fed from either 120V or 240V Ac supply.

Paper [9] represents the road map of the EV grid technology, which is a method consisting of time usage in connection with dimension gathering for strategy structure. Once a basic structure has been built, a detailed structure can be designed which would represent the relationships between the market, product and EV-Grid.

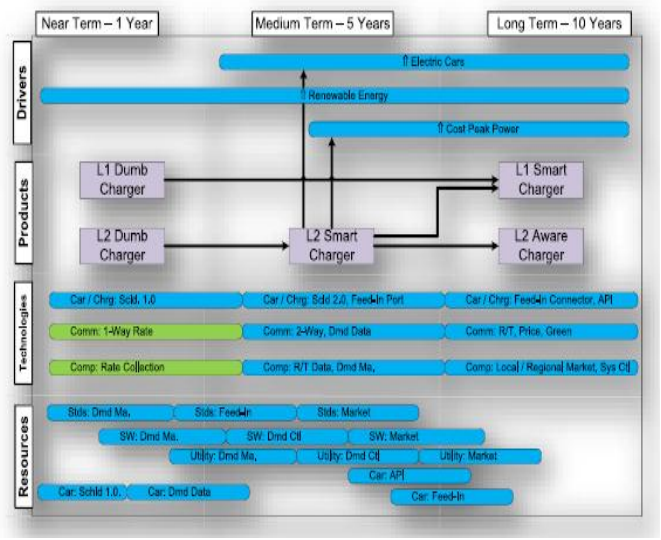

Figure 10. Strategy structure of the system

Resources, products, technologies and drivers are represented in the diagram over the period of 1 year, 5year and 10 years. The drivers include renewable energies, EV and the cost for peak power.

Figure 11 represents the relative availability of the EV during a day [10]. The charging points the paper has been described as the residential charging, workplace charging, and company fleet charging and commercial charging.

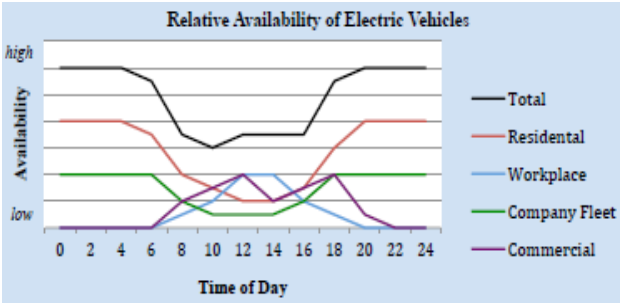

Figure 11. Availability of EV

The charging points at residential would allow user to charge his vehicle whenever its necessary, usually at the time between 6pm to 6am. There would be no waiting for this and would also good charge. The workplace charging would allow user to charge its EV at lesser rate of charging compared to the residential as it is meant only for charge required to go back home. This type of charging is at the convenience of the user and the company holds no responsibilities for this. Next comes the charging points at company fleet. This is encouraged by the companies at the workplaces which would benefit the company when it comes to tariffs. This would encourage many users and the workplace to implement and design more new technologies to reduce their tariffs. This would increase the profit and decrease the use of the EV as the charges tends to increase more and would benefit the company. The commercial charging points would allow user to charge at the convenient time, a necessary charging at the malls, theaters, restaurants etc. This may be used by the general public for the charging and discharging of the EV.

III. ECONOMIC IMPACT OF V2G TECHNOLOGY

Any new product or the development will have a factor called Economic impact analysis (EIA) which examines the effect of the new thing on the economy in an area which may range from a specific area to the global world. The report [3] begins with the study of the electric vehicles and its uses to the applications to the grid to the policy discussion. It talks about the necessity of electric vehicles which will result in less emission and need for installing charging and discharging points for the vehicles all over the globe. The figure 12 shows the table shown in the paper regarding the economic potential of the EV by using the three types of battery sources for base load, spinning reserve, peak hour and up/down regulations.

EDV Type	Interconnection	Potential electricity markets			
		Base-load	Peak	Spinning reserves	Regulation up/down
Battery	Two-way electrical (low cost logic modification to conductive charger)	×	√	√	√
Hybrid using storage	Two-way electrical	×	?	?	√
Hybrid using motor-generator	Electric from vehicle to grid; possible natural gas to vehicle	×	?	?	?
Fuel cell	Electric from vehicle; natural gas/H_2 to vehicle	×	√	√	√

Figure 12. Economic potential of EV on global market

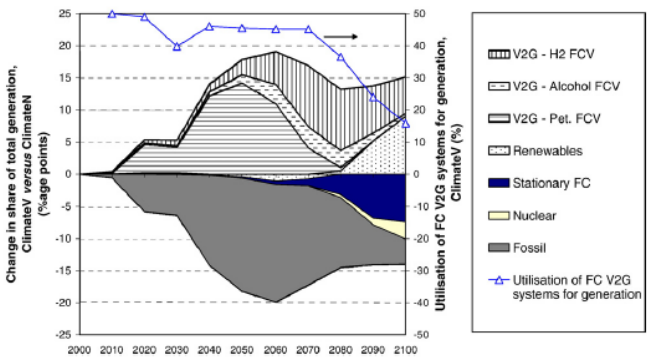

Figure 14. Increase and decrease of Energy sources

It also represents the estimation of the electric vehicles and the electricity market in America. It also encourages many users to adopt this as this might become the future. The study overall concludes with the type of electric vehicles used and their application and contribution to the electricity markets which would benefit the electricity companies as well as the users as the V2G technology is going to be the more beneficial and less pollution for all when compared to the conventional type of vehicles which use oil. Author [4] in his paper describes about the economic analysis on global level. Paper describes about the long term plans and technologies using a comprehensive energy system model where the electricity can be implemented to the hybrid electric and fuel cell drive trains too which will help supply many number of electricity markets. Investment factor and return factor too come in terms when a technology is invented. Growing of these will give scope to much renewable energy as seen from the report. The figure 13 represents the V2G technology impact on market shares and its availability and comparison with the non EV transports.

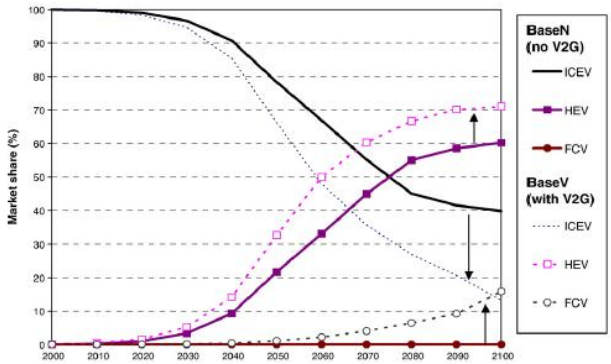

Figure 13. V2G impact on market shares

In paper [4], the author also represents about the impact of the V2G on the global level, which will decrease the consumption of non-renewable energies such as coal etc. less and will increase the use renewable energies such as solar, wind, V2G more.

The market analysis by [10] shows that the EV production all over the world would increase drastically by 2030 which will be able to transfer power from grid to EV and vice versa using new trending bidirectional converters used at the charging and discharging station.

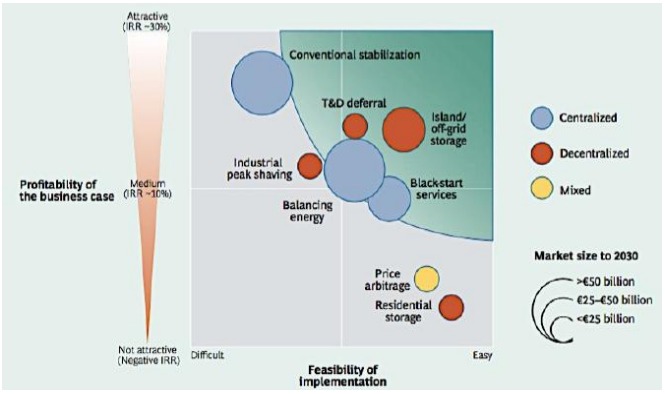

Figure 15. Market strategy of EV by 2030

IV. SCOPE FOR V2G

In this world, this is being shifted from the conventional to non-conventional source of energy, V2G technology will have greater impact when it comes to use of more Electric Vehicles (EV) rather than non EV. V2G holds many advantages and the good economic analysis as it may contribute back to the grid which would help establish good relationships between the users and the grid. The vehicle can be charged during the low demand and can be travelled when high demand of electricity. This type of EV's can also be used for powering small houses or offices as a form of Uninterrupted supply as these can power them with great capacity. Using many trending technologies a V2G technology can be designed and implemented which will benefit many users and the electricity market. According to the report [8], the experts in this field agree upon the following market trends regarding the EV:-

- The market impact of the EV is increasing due to availability and implementation of new models

- The HEV models are being replaced to the pluggable PHEV models which would provide integration between the grid and the EV
- Autonomy of the EV is increasing as the integration between the EV and the grid can be made easy
- EV manufacturers can provide one stop shopping offer which can fetch users' benefits like battery renting, wall box installation, electricity supply point etc.
- The EV and the grid integration is in premature state as the charging points are less because of less EV production
- Some of the installed charging points can be controlled remotely by making it ON/OFF. But due to the low EV economy these are not being done.
- Programmable charging is available in some places which can start automatically taking into electricity tariffs while charging or discharging
- Governments are providing support for the use of EV
- The Grid technology capacity might be improving little but most of the sectors are now focusing on the EV grid technology as this would ease the use of grid and would improve mobility of consumption

V. ADVANTAGES OF V2G

- The charging stations for EV can act as grid connection points through which the power can be given back
- EV can provide electricity to houses and offices during the demand peaks of electricity using automatic generation control (Grid regulation)
- Can increase efficiency and reliability of the grid system and the EV, most of the peak load demands can be met through this without needed to install one more power station
- Investment and the implementation of the EV compared to non EV is rather cheap and is an form of renewable energy
- Emissions from the grid can be reduced by use of EV which produces fewer emissions

VI. CONCLUSION

Electricity has become important and has great impact on human life without which the survival has become difficult. World moving now from conventional type i.e. coal to non-conventional i.e. renewable energies such as solar, wind etc. is becoming a positive mark as these reduces global emissions and helps improve the stability of the grid. This paper describes about the study of the Vehicle to Grid (V2G) technology in brief way and presents the scope and the advantages with which this can be implemented in India. Study describes about the technology, its necessity, its economic impact factor and its advantages.

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