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Research Article

V2G IN EV SCHOOL BUS SYSTEM: FEASIBILITY AS A SOLUTION FOR PEAK HOUR ENERGY NEEDS IN THE US

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Abstract

The demand for electricity has been growing exponentially due to increasing inclination of the Governments towards adoption of green electricity as the most preferred source of power and electric vehicles (EVs) as the most preferred choice of transportation. U.S., as a country, is plagued by the deficiency in the supply of powers and the situation becomes even worse during peak hours, let alone the inadequacies that become conspicuous in during the summers and winters when the demand for electricity is particularly higher. The rapid growth and expansion of industrial and manufacturing activities and of data centers along with the growing severity of weather conditions are already creating lot of pressure on electricity demand, while the retiring of coal-fired electricity at a rapid pace is reducing supply. The gap between the two is rapidly increasing raising alarm for severe power shortages. This gap needs to be bridged in a non-polluting way and the novel vehicle-2-grid technology provides a fantastic opportunity to achieve this target. Especially during peak hours when there is over load on the grid, the electric vehicles can be used to supplement as they are able to pump their unused power back to the grid. This literary piece of work highlights the dangers of an impending massive power shortfall unless steps are taken to replenish the power shortfall created by retiring of coal-fueled power while demand continues to remain robust. Each and every battery-operated electric vehicle cannot only act a power storage but can also play an important part during peak power demand when there is pressure on the grid. The electric school vehicles can be particularly helpful in this respect as they remain idle during most part of the day and are used just for picking-up and dropping-off school children. Rest of their times can be used to supply power grids by supplying the idle power, of course at a price which will also provide them with additional income making the entire system sustainable even during peak hours.

Keywords: Vehicle-to-grid, V2G, Vehicle-2-grid, School buses, Electric vehicles, EV, Power, Demand, Supply, Coal-fired, Coal.

INTRODUCTION

The world population is ever-growing which creates a lot of energy demand just to fulfil the daily activities of the masses. The demand for electricity has been growing rapidly and immensely. Until recently energy had been generated predominantly by using non-renewable resources as the feedstock. This has also been a key reason behind the rapid increase in the emission of green-house gases (GHG) leading to increase in the average global temperature and hence global warming. Clean energy sources have become a precedence area for a large number of organizations. Both the government and the regulators are providing incentives for these initiatives, which in turn would help to achieve sustainable development goals (SDGs) [1]. A key pillar for clean energy is the adoption of electric vehicles or EVs, which would help establish a sustainable transportation ecosystem in the United States [2]. While the demand for power, electricity to be precise, keeps growing with the recent push coming from wider adoption of electric vehicle (EV), the challenge is now to develop electricity for regular day to day use without adding to pollution. While countries around the world are concentrating on development of energy from renewable resources, it is becoming increasingly challenging to store the incremental energy production. The key consideration is the ways in which we can have adequate battery energy storage systems (BESS) for supporting the growing number of electric vehicles (EVs) and the developing smart grid [3]. But that is just one aspect of modern-day electricity demand. At a time when countries are walking the path of transition to green and clean energy and electric vehicles are rapidly getting amalgamated into daily lives of modern man [4], the suppliers of energy now have to face the dual challenge –a) the growing demand to harness sporadic energy sources, for instance wind and solar energies even when there is significant dearth of or absence of adequate storage capacity for the energy that is produced at a large scale [5]and b) the pressing need to ensure the consistency and endurance of the grid especially its ability to fulfill the instant gratification needs of the modern consumers. The U.S. Department of Energy (DOE) had carried out a study that exhibited that the growing demand for electricity from the wider and more intense use of plug-in Electric Vehicles along with a plethora of other technologies that require electricity consumption, have the capability to magnify, by as much as 38%, the pressure or the load on the power grids over the next 27 years [6]. Indeed, it is a challenging job. Not only the power companies but also the government agencies are applying significant effort to ensure that they have or at least develop the ability to handle and fulfill such stupendous growth in daily electricity demand. For the maximization of the advantages that can be drawn from renewable energy, it is necessary to apply those technologies that will have the capacity to make it possible for the EV batteries to store the energy being generated at times when they are freely available – and use the unused energy to feed it back into the grid when the demand for electricity is high and rising, especially during the peak hours of the day and also to cater to the seasonal upsurges [7]. This can be given effect to through the application of the Vehicle-to-grid (V2G) Technology. This new-age technology has made bi-directional charging possible, which in turn creates the opportunity for charging the EV batteries and then drawing the energy stored within those EV batteries that can then be thrusted back to the power grid. In very simple terms, the technology called vehicle to grid makes export of idle or

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unutilized battery capacity possible for the EVs. The battery capacity that remains unexploited can be used to send power back to the grid with the objective of making up for or dealing with the interruptions that were caused in the generation of renewable energy or in providing support during peak hours when the demand is at its highest [4].

MATERIALS AND METHODS

This research scans thoroughly through several published research articles published in renowned journals, business and other dailies and other periodicals and looks at various reports published by both Government and private agencies. The objective is to assess the electricity demand – supply scenario during those times of the day and the years when due primarily to weather conditions, power demand remains at its highest.

Power Demand-Supply Mismatch during peak hours

The COVID-19 was a one-off situation when people were forced to stay at home and the consumption of electricity went through the roof. But in the normal years as well, when people tend to stay at home for larger number of hours per day especially during extreme heat or extreme cold weather conditions, shortage of electricity supply turns into an actual problem. During summer months, when people stay home, electricity consumption scales up rapidly because these people would turn on their air conditioning, would do the laundry, run household chores like washing the dishes, and a host of other things that generate a significantly elevated peak energy demand in the evening –a time during which power production from renewable sources of energy, such as solar power, is extremely low [8]. In the continental US, the Peak hourly electricity demand reached 741,815 megawatt hours on July 27, 2023, which was a little below the highest ever peak of 742,704 MWh recorded on July 20, 2022, according to the Energy Information Administration` (EIA)[9]. By and large the hourly demand for electricity reaches its peak during the months of July or August when the demand for cooling reaches its highest level and is generally driven by the weather conditions [10]. However, it has the ability to conceal strains on the regional grid since electric grid in the continental U.S. functions as 3 separate electric systems – Texas, Western, and Eastern, with zero or extremely low interconnections [11, 12]. Any or all of those systems have the likelihood of being affected by distinct weather patterns or availability of different resource that result in the creation of variances in the intensity and timing of the peaking of electricity demand. [9, 10].

There are several indications that the United States is moving towards an electricity starvation which is a life-threatening energy crisis, a situation like Holodomor across several areas in the U.S. resulting from political decisions. The system is being set up to fail[13].The problem runs deeper than just temporary disruptions caused by events such as natural calamities. It has more to do with resources shortfall than with temporary disruptions. According to a report published in December 2023 by the North American Electric Reliability Corporation (NERC), a quasi-governmental agency tracking the strength and physical condition of the U.S. electric system, Texas, the Midwest, and New England are all face the threat of having severe shortage in supply of electricity [14]. The mechanism to cope with such a situation would in all probabilities be rotating blackouts and, as per NERC, the story remains equally somber for the rest of the country.

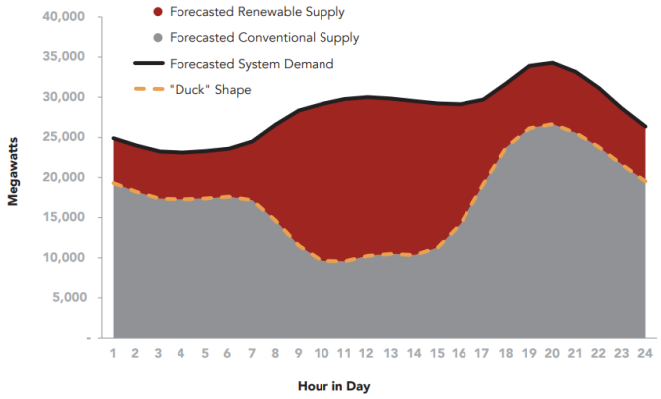

Figure 1. Power Demand & Supply Scenario Forecast [15]

Heat is precisely the reason why the demand for electricity is so high during the summers and heat is also the reason why it is becoming increasingly difficult to meet the peak electricity demand in the summers. The transmission lines get heated up because of the hot weather which is the cause behind the operators being unable to push the same volume of current through hot wires as the volume that these operators can push through the cool wires [10]. According to NERC, extreme temperatures during the summer months put a lot of stress on a sizeable segment of the connection thereby reducing the availability of surplus supply for transfer as also bringing down the ability of the transmission network to transfer this excess. Wind, solar and other powers generated from clean resources are normally produced in areas that are far away from load. During the hours when the power is needed the most, during high temperatures when demand is pushed to its peak level, the grid is not able to transport the energy to places where it is required [13]. During the winter months as well, there remains the risk of a substantially large number of outages imposed by generator in extreme and extended cold temperatures continue to remain a threat to the reliability in places where the fuel supply infrastructure including the generators and are not retrofitted or designed for these conditions. The enlargement of the risk of reserve shortage compared to the previous winter is primarily on account of robust growth in load that equivalent growth in dispatch able resources is not able to meet [14].

Phasing Out of Coal

Electricity generated using coal as the feedstock is among the most important sources of greenhouse gases that trap heat thereby adding to global warming. In order to meet the target of arresting temperatures from increasing by 2°C over the pre-industrial levels, it has become essential to phaseout the coal power globally as there no options for carbon capture that are commercially viable [16]. At present almost 25 % of the 200568 MW of coal-fired capacity is operational in the US, which, according to the Government's plan, would be retired by the end of 2029 [17]. Irrespective of the alarms sounded by NERC repeatedly regarding the possibilities of electricity shortages, power generation fired by coal continues to phase outwit distressing rapidity. As per the announcements made by their owners, over 11,000 megawatts (MW) of coal generated power have been discontinued during the time between the latest winter assessments and its previous one. On top of this, nearly 5,300 MW of coal-fueled power generator are anticipated to go out of business next year. Consequently, it becomes essential that adequate measures be taken to make sure that retirement of coal does not outpace the supply of

those resources to power generators that have the same attributes as coal with regard to power generation. These attributes include but are not restricted to an elevated level of accredited capacity value that measures the degree of dependability of a resource at the times of peaking of the electricity demand, and fuel assurance, many other attributes [18].

Risk of Shortage of Electricity Supply

The risk of shortage of reserves that can lead to energy emergency alerts has gone up to "elevated" for the peak load hour, from "low". The demand for electricity for the winter this year is estimated to be at 70,451 megawatts which is higher by 6% in Texas compared to the previous year [19]. According to the data published using Federal Energy Regulatory Commission (FERC) Form 714, the grid planners anticipate the national power demand to increase by 4.7% year-on-year over the next 5 years, 2024-2028, as compared to 2.6% that was estimated previously indicating that the growth in load is significantly faster compared to the expectation of the grid planners [20].

Figure 2. Electricity Demand Forecast Raised [21]

There are a couple of impending bottlenecks –a) there is an attempt to squeeze a much higher volume of power into a grid that is inadequate, and b) power plants that are fired using coalare being retired at a pace that is significantly faster compared to the pace at which new plants, that generate power from renewable energy sources such as wind and solar, are being constructed to take their place [22]. The power grid appears to be unprepared for this significant load growth as mentioned in the to Federal Energy Regulatory Commission report which also concludes that the transfer capability being significantly low amongst regions, it becomes a key risk factor as long as reliability of load growth outstrips the deployment of new generation in more than one regions [20].

Emergence of V2G Technology

The rapid and significant growth the adoption and usage of electric vehicles across the US and the growth and expansion of smart grid has led to the development of the concept of and the construction of vehicle-to-grid (V2G) technology whose biggest positive is that it allows pulling unused power from the electric vehicle into the smart grid [23]. The vehicle-to-grid technology uses a charging device that can absorb electricity from the electric vehicle battery and then it just drives the power back to the grid, and then the power continues to move towards the location that is closest to where the electrical power is needed [24]. EVs have the ability to draw energy from the grid (during those times when the cost and demand are both low) and discharge energy back to the grid (during those times when demand and costs remain high) and this is made possible by the novel Vehicle to Grid or V2G Technology. V2G enabling technologies that are based on battery technology, such as vehicle-to-grid (V2G) work like a device for storing energy when theloads at peak hours put pressure on the grid [23]. A key advantage of V2G technology are that it reduces the total cost of power, brings down carbon emissions significantly, and leads to substantial curtailment in the usage of renewables. The potential benefits can be enhanced by scaling up the proportion of EVs that take part in the V2G program. V2G alters the respective shares of the wind and solar power generations that have been installed recently. The application of V2G technology makes electricity production shift from areas that are significantly more expensive to areas that are low-cost [25].Owing to the structure of the V2G system and the supplementary role that it plays for the grid, it is able to shape the power demand and supply curve at the same time. Needless to say, it depends on various factors including location, the driving patterns, preferences for times of charging and / or discharging, and the infrastructure of the system [26].

METHODOLOGY

This article is a qualitative research work, secondary in nature. It used literature that are publicly available on various domains including newspapers, scholarly articles published in renowned journals such as the International Journal of Supply Chain Management, research articles published by renowned research houses and data published by government agencies. The research does not use any primary source of data. All the data had been collected and published by others. Secondary analysis of qualitative data is helpful in addressing the questions and doubts that have hitherto remains unaddressed by researches that had been carried out previously or have evolved because of further research.

DISCUSSION

Relevance of V2G Technology

As has been explained in the report published by the Federal Energy Regulatory Commission, the peak electricity demand is forecasted to grow by 38 GW higher during the 5 years to come driven by significant growth in investment in new manufacturing facilities, industrial facilities and data center facilities [21]. This forecast being significantly higher compared to the earlier estimates published, the only logical conclusion is that the present electric grid does not have the capacity to handle this sudden surge in electricity demand. They are simply is not prepared for this significant growth in load. Muted transfer capability among regions is a one of the major risks in terms of reliability in case load growth outstrips distribution of newly generated power in a few of the regions [20]. The V2G System is capable of addressing the power crisis situation to quite an extent. In simple terms, V2G refers to that communication system which connects electrified carriages to the power grid. In case of traditional charging, vehicles pull energy and consume it and the flow of electricity is in one single direction only. In case of a V2G system, which

is bidirectional in nature, the battery of an EV can supply the electricity drawn from the grid, back to the grid itself once it is plugged to the charging device. The grid can experience spike in demand all of a sudden. When that happens, these electric vehicle battery energy storage systems(BESS) can be utilized for supplying energy back into the grid which will then help to balance this peak demand which is usually only temporary [3]. As is clear from the ongoing discussion, the vehicle-to-grid technology has to do with obtaining from the car the power that remains unused and pumping it back into the smart grid. Vehicle-grid integration (VGI) or what we popularly refer to as V2G, has the capacity to help the energy-grid provide electricity at hours when the demand is at its peak. It also has the capacity to build an extra source of power during those times when there is a scarcity in the availability of renewable sources of energy that are predominantly dependent on the weather for their adequate supply. For instance, any and every home that uses the sunlight and heat for power generation will not be able to generate electricity at night, but an electric vehicle that runs on battery would be able to provide an ancillary source of power should the need arise [27]. One of the key instruments that will help to achieve the ambitions of decarbonization of the US economy will be the transition from burning of fossil fuels to achieve the objectives of heating and transportation to the use of electricity generated from clean sources [28]. Using batteries for power generation, therefore, augurs well as it does not involve the combustion of such inputs as coal. So even is coal is being retired as the principal feedstock for power generation, the supply of power will not be drastically affected if there is a rapid shift towards sourcing of power that is generated from cleaner sources. Herein comes the importance of novel technologies such as vehicle-to-grid

Vehicle-2-grid is the kind of technology that has the potential to help achieve the clean energy targets set by the government such as reaching the target of zero-carbon emission by 2045. To consumers, V2G will be able to provide an additional benefit through the potential reduction in the cost of ownership of electric vehicle. It will be possible for the owner of an electric vehicle to sell the surplus power from their vehicle back to the grid for money. This will create an earning for these electric vehicle owners that will help them offset other costs[27].

V2G School Bus System Can Be Helpful

It might appear surprising that a humble school bus is taking the center stage as the best candidate for achieving the net-zero target and for successfully driving the country toward a grid that is low-carbon. It all commences with the vision to bring down carbon emissions by switching over to electrified fleets from vehicles powered by diesel. The US EPA Clean School Bus Program which is currently in place In the United States, has kept a $5 billion fund aside for the upgradation of older school buses to their clean versions that are said to be their zero-emission models that will be in use over the coming5 years. According to the United States Public Interest Research Group or the US PIRG, as much as half a million of the school buses carry almost 50% of the children in America to their schools and back, but less than one in a hundred of this fleetof 489,000 school buses running in the USA is powered by electricity [29]. It must be kept in mind that diesel exhaust is full of over 40 substances that are identified to cause cancer which makes the health benefits of switching over to school bus fleets that are all-electric all the more obvious [3]. Across the whole of US, the number of school buses that are electric-powered and are on the road or on order has gone up by more than three times over the last couple of years [29]. Beyond a doubt we are in love with the idea of producing clean energy using renewable sources and generate electricity using solar panels and wind turbines to power up our houses, offices and streets. The fact, however, remains that the output generated from the exploitation of the renewable energy sources such as these is a lot unpredictable and a lot less reliable when compared with the power output generated from a conventional coal-fired power plant. The rapid adoption and broad-based use of renewable energy sources through the application of photovoltaic (PV) systems puts a lot of pressure on what is called the “duck curve” challenge. Power demand not only peaks during extreme temperatures during summers and winters but also touches a peak daily when the activity levels across the locations reach the zenith. During seasonal or everyday peak irradiation, the energy produced from the renewable source is much higher in volume compared to the required volume of energy which is symbolized by the duck’s belly, that has slumped over the years with the increase in the energy produced using PV systems. It may become necessary for the utility providers to pare down the PV energy production at times when the irradiation is at its peak, which will result in the reduction of the benefits, both environmental and economic, derived from it [30].

V2G makes it possible for the electric vehicle batteries to act as a storage system that can discharge energy to the grid and are able to provide the complete and impeccable storage solution for these sources of renewable energy. It is, therefore, clear that the EV batteries can also be utilized for the provision such grid services as regulation of frequency and demand response and also makes smart charging possible so that EVs can get charged at hours that are non-peak and then can discharge the energy that is stored during those hours of the day when the grid comes under a lot of pressure from the high peak demand for electricity [8]. The electric school buses can be particularly helpful in supporting the grid at peak hours as they remain idle during most part of the day, especially during the times when the day-to-day activities and hence power demand peak. EV school buses are used just for picking-up and dropping-off school children. Rest of their times when they remain parked, they can be used to supply power grids by supplying the idle power, of course at a price which will also provide them with additional income making the entire system sustainable even during peak hours [30].

Electric school buses are able to provide a prime storage solution using the V2G grid services since these vehicles have huge batteries which remain parked as well as connected to charging stations throughout the largest part of the day. These vehicles also have the potential to function like a virtual power plant (VPP) through the aggregation of vehicle batteries across a particular part of the country for providing the energy as and when required. Subsequently, these electric school buses can be deployed prior to the occurrence of a power outagein regions that are witnessing a surge in demand for power with little or inadequate power availability. In the near future, electric school buses will also be able to provide emergency services such as alternative power back-up that can cater to areas which have already lost power. These vehicles can be particularly helpful during vacation months and in case of one-off instances such as the pandemic. During events such as the pandemic, while a large many of the schools across the U.S.

remained closed for in-person learning, electric buses could continue to provide service in this unique way [8].

Conclusion

While coal is being considered to be a major source of carbon emission it is also true that the power generation industry had been heavily dependent on coal. The majority of power demand was being met by electricity generated using coal as the feedstock. But with the move of Government to gradually phase out non-renewable sources, fossil fuels, and shift towards renewable sources, it becomes difficult to cater to the ever-rising demand for power. Power demand is particularly high during peak working hours every-day as also during the summers (because of the heat) and winters (because the people need heat).The energy shortfall that is created can be taken care using V2G technology which uses batteries of EVs to generate and store power and push the excess power back to the grid thereby providing reinforcements to handle peak power demand. EV schools buses are of particular interest here as they remain idle for the most part of the day and can be effectively used for this purpose. V2G school buses will not only be able to increase grid resilience and support renewable energy sources but also address environmental concerns, be a bane for the community and at the same time provide and avenue for additional income that will help to bring down the cost of ownership of the EV. While these vehicles can aid the grid by supplying power at peak hours and months and as giant batteries storing power, they can also earn additional income by providing the excess power that they generate to the grid, making the system sustainable over the longer run.

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