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A strategy to Enhance Electric Vehicle Penetration Level in India

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Abstract

In wake of the very recent initiative by the Indian government under the Faster Adoption and Manufacturing of Hybrid and Electric Vehicle (FAME) scheme 2015, to provide subsidies for electric vehicle purchase, the cost difference between electric vehicle and conventional diesel vehicle is bridged to an extent. This paper attempts to provide strategies to increase the cost advantage of Electric vehicles by reducing its payback period by exploring possibility of vehicle to home(V2H) scheme and thus to increase the willingness to pay (WTP) of the customer. The biggest beneficiary of this scheme will be the Indian power grid. This scheme will enable capacity enhancement during peak load hours in the Indian scenario utilizing the stored energy available in the electric vehicle using V2H system. Electric vehicle can be used as a storage methodology i.e. when electric vehicles are parked and connected to a charger, it acts as a storage space for electrical energy. An Indian 11kV distribution network is used to conduct the case study, to illustrate the effectiveness of the developed concept for reducing peak demand. The hypothesis presented by the author is specific for a State, nevertheless these findings are heterogeneous enough across the country and this can significantly increase social benefits for the whole nation. Overall results indicate that implementation of V2H can go a long way in addressing two of the present major technological problems of cost disadvantage of electric vehicle and peak levelling of Indian power grid by identifying and exploring potential cost benefit avenues to reduce the payback period of EV's and thereby making them a technology of our everyday life rather than an idealistic plan of a distant future.

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Keywords: Vehicle to home(V2H); electric vehicles(EVs); Vehicle Mission Mobility Plan; Smart Home; T&D losses; Transformer Efficiency; Greenhouse emissions(GHEs); Distributed generation; Battery Electric vehicles(BEVs)

1. Introduction

There are several problems that the conventional petroleum vehicle pose such as dependency on foreign oil, degradation of air quality and carbon emissions that perpetuate climate change. India imports large amount of oil for

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automotive use. Nearly 80% of India's crude oil requirement is imported. The global oil price fluctuations directly affects the Indian economy. Indian transport sector is responsible for a good share of these imports. The 2008 oil price shocks are still fresh in the mind of government and consumer. Moreover India's petroleum demand is expected to increase at an annual rate of 2.5% until 2040.

Now, the petroleum based road transportation sector in India is responsible for a good share of country's greenhouse gas emissions (GHGs). 87% of India's CO_2 equivalent emissions of the transport sector comes from road transport. India has roughly 11 cars per 1000 people, compared to 403cars per 1000 people in the United States [1]. This number is expected to increase rapidly as the economy develops. The government has proposed 30,000 MW of new renewable sources. The national action plan on climate change (NAPC, 2008) [2] calls for launch of mission in Energy sector (including transportation) on climate change. Moreover, petroleum based transportation, primarily in the form of diesel in India is a major cause of air pollution [3]. Diesel exhaust contains pollutant that cause respiratory irritation, heart diseases, lung cancer, causing substantial health risk to those who frequently exposed to diesel exhaust. The only way to address these issues is to migrate from existing conventional diesel vehicles to pure electric vehicles or at least plugin hybrids. But then EVs and PHEVs are costlier than conventional diesel counterpart. Meanwhile, the country has seen an increase in infrastructure of renewable energy resources such as solar and wind on account of improved competitiveness of renewable energy technologies. Keeping these development in view, the Govt. of India launched the 2020 plan of the National Mission on Electrical Mobility [4] wherein government plans to create a potential demand for 5 to 7 million electric vehicles, including buses, light commercial vehicles, two-wheelers and three-wheelers, as well as electric cars [5]. The government plans to offer $2.5 billion as subsidy to the auto industry until 2020 would help the country save about $11 billion on fuel costs. Under the FAME 2015[6] initiative, this subsidy has become a reality. However even after the subsidy, the cost difference between conventional diesel vehicle and electric vehicle still remains high. The sales figures of car manufactures stand testament to this fact.

This paper attempts to explore a methodology to reduce the payback period of Electric vehicle by bringing in substantial capital and running cost advantage. The paper attempts to integrate electric vehicle to Electric supply terminal of home to power Indian urban homes. If implemented on a large scale it has a good potential to address the grid related problems of high peak demands, high T&D losses and low electricity penetration.

2. Input Data

2.1. Assumptions

This is a technology which is expected to mature from research level to commercial level in near future say next five years. Thus it realistically assumes certain economic and technological trends. The proposed system requires smart metering, with data of real time power cost. It also assumes that the global oil prices are going to increase.

2.2. Specification of Vehicle

Technical specifications of vehicle is selected based on the specifications of popular EVs in the electric vehicle market. A Battery Electric Vehicle (BEV)is chosen for the study since it has a higher battery capacity when compared to Plug in Hybrid Electric Vehicles (PHEVs).A battery pack of 24kWh[7] is considered. Distance on full charge is around 117km[8].

2.3. Specification of travel route

The speed time graph of a typical urban route in south India is studied and an equivalent plot is selected as shown in Fig. 1. Distance between home and work is considered to be around 15 km. The road is assumed to have zero gradient.

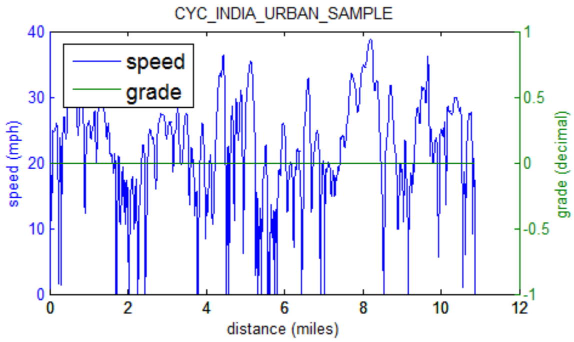

Fig. 1. Speed time graph (plotted using ADVISOR Software)

2.4. *Load curve of an urban housing complex in Kerala*

The typical load curve of a residential complex in Kerala is shown in Fig. 2. Since, this residential load curve, is taken in a sub-continental state like Kerala, we see that the load demand in summer is a bit higher in summer compared to winter season.

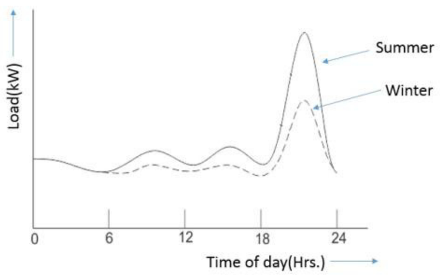

Fig. 2. Typical daily load curve of residential load(Kerala)

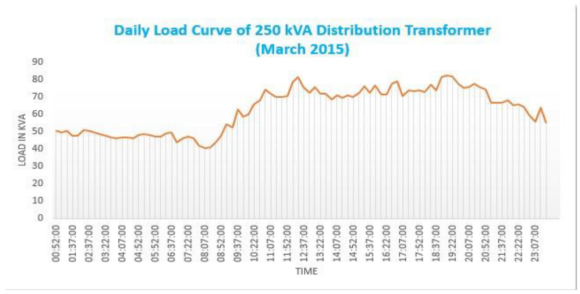

Fig. 3. Daily load curve of KSEB Distribution Transformer on a working day(March 2015)

In case of a residential load, as we can see from the Fig. 3, the minimum load is reached at about 2 to 3 hours at morning, when most people are asleep and during 12 noon, when most people are out at work. Whereas, the peak of the residential load demand starts at around 17 hrs and lasts up to 21 to 22 hrs. during night, after which again the load drops rapidly, as most people retire to bed. Kerala is largely dependent on hydropower, which is expected to diminish during summer, when the peak load demand increases, widening the supply demand curve.

2.5. *Loading pattern of urban housing complex in Kerala*

The proposed scheme is suitable for states which have huge demands during peak hours and thus borrow power from grid at a very high price. A study on Indian grid reveals that, Kerala is a state which relies heavily on power from outside that too at a high price during the peak hours. A survey on the loading pattern of Kerala reveals that its peak demand is very high. This is because around 78% consumers in Kerala are domestic consumers and 1.5 % industrial consumers[9]. A survey on the residential complexes in Kerala reveals that many of them are 15 storied buildings with 4 houses per floor. Thus a total of around 60 houses. A survey on a set of sample electricity bills of Kerala to understand the energy consumption in Kerala reveals that a typical Kerala urban home consumes around 7kWh of electrical energy per day. For 50 homes a combined maximum demand of 200kVA is considered. Thus an 11kV/415V, 250kVA distribution transformer needs to be used at the substation.

2.6. *Actual load curve of KSEB Distribution Transformer*

For the study, the actual load curve of a distribution transformer of exactly same specification (11kV/415V, 250kVA) used in an urban substation is used (Figure 3). The data is for a regular working day of March 2015. The data was so selected that the loading trend for the day is similar to other working days in that particular substation, thus a reliable representation of a typical working day for the area. Moreover on this day, 59% of energy consumed by the state came from imports, mostly during peak hours at a high cost.

3. Vehicle Performance Study- Simulation Study using ADVISOR Software

3.1. Simulation Methodology.

This project uses the latest releases for canonical versions of the ADVISOR Software[10] and "Advanced Vehicle Simulator". ADVISOR is a MATLAB/ Simulink based simulation program for rapid analysis of the performance and fuel economy of light and heavy-duty vehicles with conventional (gasoline/diesel), hybrid-electric, full-electric, and fuel cell powertrains. This Speed time graph is fed to ADVISOR software, to understand the battery discharge pattern.

3.2. Simulation Results-Battery Discharge Characteristics

In order to supply this power, the charging cycle of the battery should have sufficient power. Matching vehicle speed time graph with the KSEB load curve. The battery discharge characteristics obtained from Fig. 4 is fed as an input to the Automatic V2H [11] battery management system (BMS) algorithm.

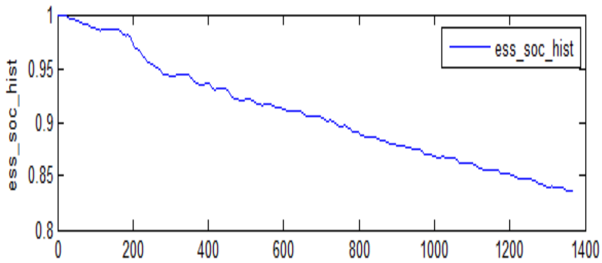

Fig. 4. Battery Discharge Characteristics (plotted using ADVISOR Software

4. Automated V2H Implementation

4.1. BMS Algorithm

A customized BMS algorithm for V2H automatic operation is developed. It takes the following parameters as inputs: the real time electricity cost from Smart meter, Vehicle Availability indicator, battery state of Charge (SOC), availability of grid power [12]and then makes a techno-economic optimal decision whether to charge or discharge the battery.

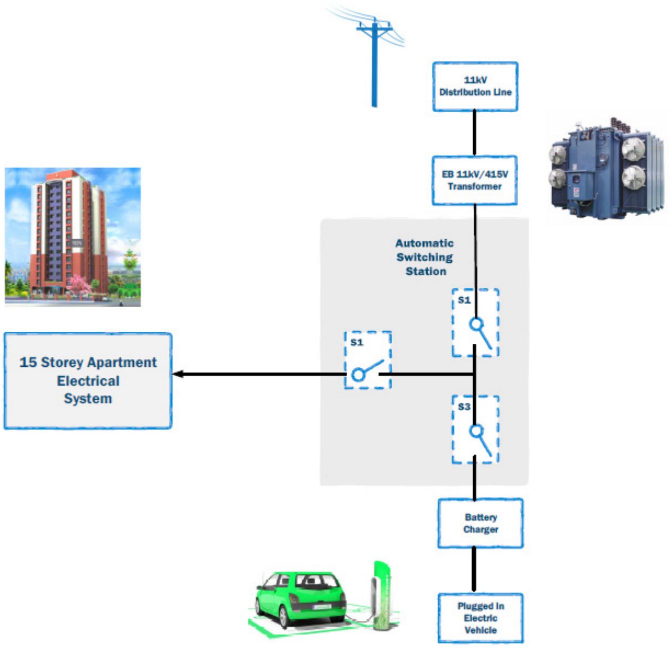

Fig. 5. Block diagram for Electrical System with V2G

This decision is based on peak shaving and valley filling concept of electrical grid. For example when the electricity cost is very low and the battery SOC is low then battery will be in charging mode. When the electricity cost is high @ night during peak load hours, and the battery SOC is high, then battery will discharge. The process of reducing the peak power demand on the system is called peak shaving. The process of reducing excess power in the grid is called as valley filling. This helps in maintaining the voltage and frequency constant. Fig. 5 shows the block diagram of the modification made in the electrical substation in order to integrate V2H system, and to implement peak shaving and valley filling concept. Table1 shows the main operating modes used in the BMS Algorithm.

Table 1. Modes of operation of BMS Algorithm

State of Electrical System	Mode of BMS Algorithm	Power Transfer Direction		Switch Condition		
		From	To	Switch S1	Switch S2	Switch S3
Peak Demand	Mode_1	Vehicle	Home	Open	Close	Close
Grid Failure	Mode_1	Vehicle	home	Open	Close	Close
Vehicle charging	Mode_2	Grid	Vehicle, home	Close	Close	Close
Vehicle in use/ Unplugged	Mode_3	Grid	home	Close	Close	Open

4.2. Practical Capability of peak shaving and valley filling by EVs

Electric vehicle with its V2H and V2G methodologies may seem insufficient to make an impact on the load curve of the power grid. But case-studies reveal otherwise. A study in US states that five percent of California's passenger vehicle fleet could provide 10 percent of the state's peak power requirement. India is a country having a peak demand deficit of 12.1%.[13]Moreover the renewable energy source will not be able to meet the peak demand[14].In this case study, a practical feasibility study was conducted. It is established that a battery of capacity 24kWh is capable of feeding peak power to 45- 50 urban homes of Kerala for a duration of 1-1.5 hours. Thus, this system is very much suitable for urban apartment complexes where one vehicle is sufficient to meet the peak load requirement.

5. V2H Integration Results

5.1. Load Curve

Now if this battery charging scheme is employed in the KSEB urban distribution transformer, transformer loading is increased in off peak hours when the vehicle battery is charging and the peak loading decreased during the peak hours. The load profile is improved or levelled using the battery management algorithm as shown in Fig. 6.

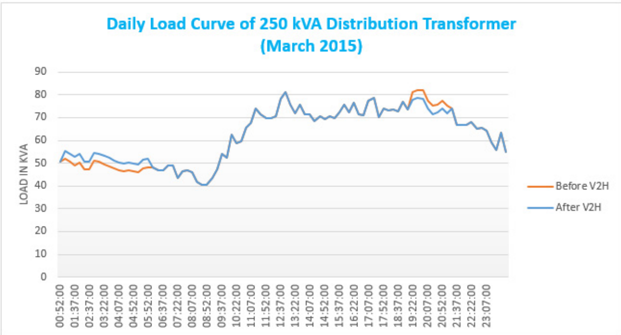

Fig. 6. Transformer daily Load curve

The performance parameters of the housing complex substation transformer with V2H and without V2H are tabulated in Table 2.

Table 2 Transformer Parameters before and after implementation

Parameter	Units	Before Implementation	After Implementation
Average Load	kVA	62.14783	62.14783
Maximum Demand at night peak hour	kVA	82.1	78.6
Daily Energy	kWh	1491.548	1491.548
Transformer	kVA	250	100
Loading % of Transformer	kVA	24.85913	62.14783
Load Factor		0.756977	0.79

The average load remains unchanged. The results show that the maximum demand of the transformer has decreased from 82.1 to 78.6 kW. The load factor increased from 0.75 to 0.79. The installed capacity can be reduced from 250 to 100 kVA. The percentage loading of the transformer is increased from 24.86% to 62.14%.

5.2. Tailpipe Emissions Results

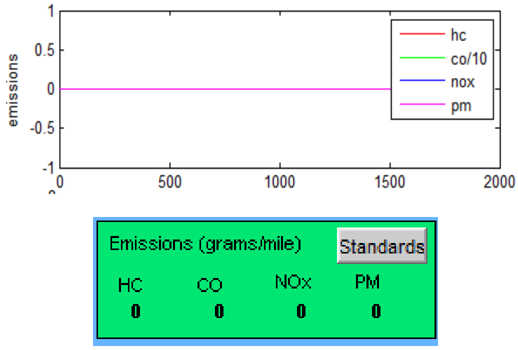

Fig. 7. Emissions Results (plotted using ADVISOR Software)

Emissions results obtained from ADVISOR is shown in Fig. 7. From Fig. 7 it is observed that the emissions of HC, CO, NO_x and PM are significantly reduced to zero in EVs when compared to a conventional diesel vehicle, which has allowable emissions of 0.56g/km of HC+NO_x, 0.64g/km of CO and 0.05g/km as per Bharat Stage Emissions Standards.

6. Benefits from the proposed system

6.1. Cost Savings from V2H transactions for KSEB.

The study results reveal an annual savings on employing peak shaving by V2H power transactions. If similar system is employed in industry, the cost benefit will go to the consumer also since the consumer is paying for MD charges and also there are very less probability that the consumer will incur MD penalty. This algorithm acts as automatic maximum demand controller maintaining the MD well below the contract maximum demand.

6.2. Reduced investment Cost of transformer.

The study results show a one time saving in investment cost of transformer on downsizing the transformer capacity from 250kVA to 100kVA. Although the downsizing may seem very high, but then the demand factor of 250kVA transformer is estimated to be 0.3284. With load support from V2H system it is suggested that KSEB can operate a 100kVA transformer to meet the peak load demand. This method can be employed for future urban installations having possibility of V2H integration. Whereas for existing installations, the EB can go for replacement of higher capacity transformer with a lower rated device. This suggestion is practically feasible, as KSEB in the past have taken many initiatives of relocating transformers to reduce distribution losses.

6.3. Reduced running Cost of transformer.

KSEB is putting efforts to reduce the T&D losses. Presently the gross loss is near 22%.[16]. As the transformer loading percentage is increased, the efficiency is improved. Thus the losses are reduced and thereby the running cost is reduced.

6.4. Improved ambient air quality in urban roads

As per CPCB, 50% of the Indian cities are having high levels of PM_{10}, 11% of the cities have high NO_2levels[17]. As shown in Figure 7, since tail pipe emissions of EVs reduces air pollution in the urban roads.

6.5. Near zero power outage at homes.

Historically, Kerala is a state where power supply is heavily dependent on hydro power which is unpredictable, resulting in occasional scheduled power cuts during peak hours. This can be minimized if V2H system is used for load levelling. Since V2H will provide power to critical load during short power outages, an uninterrupted power availability can be maintained in the houses supported by V2H.The provision for the same has been provided in the algorithm. However, when power outage happens at a time during the absence of vehicle at home, the power cannot be reinstated.

7. Future scope

V2H can be converted to V2G (Vehicle to Grid) if suitable grid regulations related to V2G are to be put in place. Vehicle-to-Home (V2H) electric vehicles allow owners to sell their battery capacity to electric grid operators during times the vehicle is not being driven, and thus have the potential of making EVs more economical. In future a large number of vehicles will represent significant storage or generating capacity. This geographically-dispersed capacity could be controlled remotely in order to provide power when and where it was needed. Green House Emissions can be also reduced if this system is integrated with renewable energy sources such as solar or wind. If the proposed scheme of renewable based distributed generation is employed, distribution loss can be eliminated.

8. Conclusion

In the near future, as the battery technology becomes cheaper, fossil fuels becomes costlier, electric vehicle technology becomes cost effectives, government subsidies for PHEVS, Tax Benefits for V2H, charging stations becomes widespread, and GHG emission law more stringent, it is a natural expectation that the vehicle to home (V2H) methodology will becomes popular and economically viable. This can happen by bridging the cost margin between the existing Diesel vehicles and the PHEVs. The authors in this paper have attempted to identify and quantify the avenues to the research fraternity and also to improve the willingness to pay (WTP)[18] of the customer by identifying potential qualitative advantages of V2H system, and thus making the vehicle mission mobility plan of India, a reality.

References

[1] https://en.wikipedia.org/wiki/List_of_countries_by_vehicles_per_capita
[2] http://envfor.nic.in/ccd-napcc
[3] http://www.moef.nic.in/
[4] http://dhi.nic.in/
[5] National Mission on Electrical Mobility
[6] http://dhi.nic.in/UserView/index?mid=2418
[7] https://www.nissanusa.com/ev/media/pdf/specs/FeaturesAndSpecs.pdf
[8] http://www.fueleconomy.gov/feg/Find.do?action=sbs&id=34918
[9] www.keralaenergy.gov.in
[10] http://www.nrel.gov/docs/fy99osti/25928.pdf
[11] Noel, L. & McCormack R. 2014. A cost benefit analysis of a V2G-capable electric school bus compared to a traditional diesel school bus. Applied Energy, 126: p.246-265.
[12] L. Jian et al./ A scenario of vehicle-to-grid implementation and its double-layer optimal charging strategy for minimizing load variance within regional smart grids / Energy Conversion and Management 78 (2014) ,p.508–517
[13] Mukesh Singh, Praveen Kumar, IndraniKar. Analysis of Vehicle to Grid Concept in Indian Scenario, 14th International Power Electronics and Motion Control Conference, EPE-PEMC 2010 T6 149-156.
[14] S. Singh, B.Singh, and J.Ostergaard, "Renewable energy generation in india: Present scenario and future prospects,," in *Energy Society General Meeting, 2009. PES '09*, July 2009, p. 1–8.
[15] www.keralaenergy.gov.in
[16] Identification of technical loss reduction and rationalisation of secondary distribution system at selected typical 3 distribution transformers of KSEB – BEE, EMC Kerala
[17] http://aqicn.org/map/india/#@g/21.0038/80.4772/5z
[18] G.R. Parsons et al./ Willingness to pay for vehicle-to-grid (V2G) electric vehicles and their contract terms / Energy Economics 42 (2014), p.313–324.