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Review

Developments in xEVs charging infrastructure and energy management system for smart microgrids including xEVs

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ABSTRACT

The swiftly growing structure of urbanization and smart cities facilitating the transportation era at peak. Thus, the rising pattern of conventional automobiles leading to the high contribution of greenhouse gas (GHG) emission. To mitigate the hazardous profile of GHG emissions, the electric vehicles (xEVs) as the part of smart cities, are gaining immense consideration. However, the unscheduled EVs connectivity with conventional grid system leading unreliable and interrupted power supply, which may lead to the grid failure. In such state of affairs (i.e. GHG emission and rising power demand), the smart microgrids including Renewable Energy Sources (RESs) based charging infrastructure are becoming the most viable paradigm. In this paper, two most emerging technologies belonging to smart cities i.e. xEVs and RESs based smart Microgrid has been covered. The xEVs part of the presented manuscript discusses the detailed study of rising advancement in xEVs charging infrastructure, enhancement in international standards for proper xEVs deployment, and state of art in the xEVs application such as the vehicle to grid (V2G) and vehicle to home (V2H). The second part of the presented work elaborates the state of art in research of smart microgrids energy management system (EMS) including xEVs to enhance the reliability of charging infrastructure.

1. Introduction

At the same time that the world population increases, urbanization processes intensify and economies grow, electricity supply is becoming ever more important, as energy is a key component to modern societies. The swiftly growing structure of urbanization and smart cities facilitating the transportation era at peak. Thus, the rising pattern of conventional automobiles leading to the high contribution of greenhouse gas (GHG) emission. To mitigate the hazardous profile of GHG emissions, the electric vehicles (xEVs) as the part of smart cities, are gaining immense consideration. However, the unscheduled EVs connectivity with conventional grid system leading unreliable and interrupted power supply, which may lead to the grid failure. In such state of affairs (i.e. GHG emission and rising power demand), the smart microgrids including Renewable Energy Sources (RESs) based charging infrastructure are becoming most viable paradigm (Boulanger, Chu, Maxx, Waltz, & Member, 2011; Graditi, Langella, Laterza, & Valenti, 2015; Hermance and Sasaki, 1998; Labak, Lu, Lai, Balamurali, & Esteban, 2013). Electric vehicles (EVs) and the sharing of EVs has the capability to provide a solution to many of these problems (Somayajula, Meintz, & Ferdowsi, 2009).

Two major issues that hurdle the commercialization of electric vehicles are the high cost associated with large battery packs and the estimation of the energy storage capacity. In Shankar and Marco (2013), authors propose an approach based on Neural Network to calculate per km energy consumption of the electric vehicle under different scenarios. Short cruising range and the limited infrastructural support are the two major reasons for restricting the development of EVs. Through navigation system and route planning approaches, the cruising range of EVs can be extended and these approaches provide the information of energy efficient routes and the recharging requirement to the driver. Nowadays the subject of eco-driving analysis is of great interest which focuses on how to drive in an economic and ecological way. According to eco-driving analysis, drivers try to maintain a steady state velocity and try to avoid unnecessary use of acceleration (deceleration).Vehicles, drivers, and infrastructure are all linked together through eco-driving. 10–15% of savings in energy is possible with the help of eco-driving. Principles of eco-driving suggest the driver variety of practices which help in the reduction of energy consumption. R. Zhang and E. Yao worked on the framework of eco-driving for signalized intersection which is designed in order to reduce the energy consumption of EVs (Zhang and Yao, 2015).

It is expected in future that the consumption of electric power would significantly increase in vehicles. There is a need of smart strategies on

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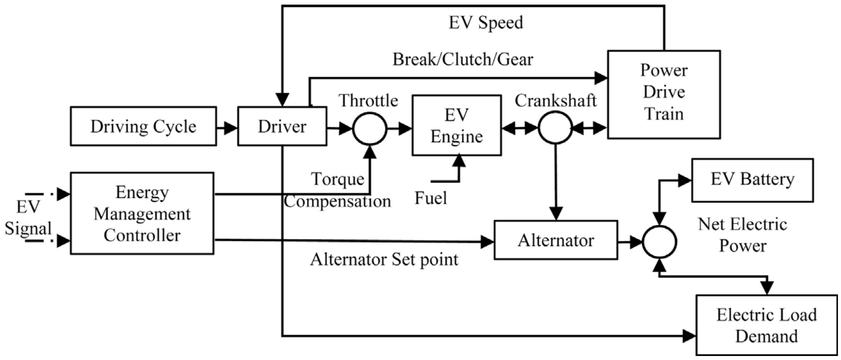

Fig. 1. Energy management controller in the vehicle.

electric power consumption, generation, distribution, and storage side which helps in the reduction of exhaust emissions and fuel consumptions. Different types of energy management strategies for the limitation of exhaust emission and fuel consumption are listed in (Nasar and Trutt, 2011) which is mainly based on the future prediction or the vehicles current state of information. Interaction of energy management controller and vehicle is shown in Fig. 1. Simulation results show that the 2% of fuel reduction can be achieved with the help of energy management strategies and largest part of fuel reduction is achieved through regenerative braking. A study by an Electric Power Research Institute (EPRI) clearly shows that the replacement of ICV by an electrically powered equivalent, not only reduce air pollution where EV is driven but also over the rest part of the map. This happens because of two main reasons: i) It is better to use electricity from hydroelectric plants and nuclear reactor which are the non-air polluting sources as compared to the transportation sector which is completely powered by petroleum products. ii) Much more efficiently and cleanly a fossil fuel can be burnt by electric utilities than internal combustion engines do (Riezenman, 1999).

Reduction in air pollution by switching over to the EVs varies from pollutant to pollutant. For example, carbon monoxide would disappear completely while the reduction in sulphur dioxide, nitrogen oxide, and carbon dioxides depends on regional scenarios of generation and politics. Several factors that favor EVs over ICVs are that they are quieter, more reliable and require less maintenance. Electric motors are simpler than internal combustion engines because they are controlled by solid-state electronics whereas internal combustion engines are very complex because of the inclusion of various components like compressors, valves, fuel injectors and pumps. Other favorable factors of EVs are no hoses or belts to replace, no filters, no need to change oil, no need for water cooling system (Riezenman, 1999).

The question arises if EVs are so good then why did not the EVs come over long ago? The answer to this question mainly depends on three reasons: i) on a single charge, EVs cannot cover much distance as compared to ICVs which can go on a fuel tank. ii) EVs take much more time to charge a battery than ICVs to fill a gas tank. iii) Also, the cost of EVs is more than ICVs. G. Graditi et al. present a methodology, which includes environmental and economic indicators to evaluate an operating cost of EVs and ICVs (Graditi et al., 2015). Accurate and reliable estimation of the residual range is very important. The residual range can be defined as the distance that can be covered by the vehicle with the energy stored in the battery. The estimation of the residual range is a two stage process: first to estimate the remaining battery energy and then to combine it with the vehicle efficiency estimate, i.e., the distance covered per battery kW-hr. In Ceraolo and Pede (2001), authors have discussed in detail.

The intelligent and effective use of energy is possible through the smart grid by optimized integration of vehicle with the grid. Energy demand and environmental problems can be solved out with the help of Grid-enabled vehicles (GEV). But, before this, various challenges like EV range, infrastructure, cost, charging access and impact to the grid etc. must be addressed in order to achieve the potential of GEVs. A. G. Boulanger discusses these challenges in a detailed way (Boulanger et al., 2011).

Hybrid electric vehicles (HEVs) mostly use Energy Storage System (ESS) as a secondary power source, but if it is used as a primary power source than the size of the ESS would be the most important criteria in the design of HEVs. In addition to this, an intelligent strategy of energy management is required by HEVs in order to provide the best fuel efficiency in all the possible driving situations. The effect of the variation in the size of the ESS on the economy of fuel and the important design criteria of ESS is investigated by D. Somayajula et al. in reference (Somayajula et al., 2009).

Although electric vehicles have been the point of interest and focus for various stakeholders and industrialists since last two centuries. But, EVs started becoming popular from the beginning of 21 st century. Fig. 2 represents the evolution of electric vehicles.

The key contribution of the paper is as follows: Section 2 presents the state of art in the technical enhancement of charging infrastructure from charging level 1 to level 3 and fast DC charging framework. Further, this section deals with the internationally stabilized and under pipeline xEVs standard for proper deployment of xEVs. Section 3 evaluates the enhancement in the ESS for xEVs and microgrid backup power supply. Section 4 presents the state of art in research of xEVs application i.e. V2G, G2V, and V2V. Further, section 4 presents the state of art in EMS of smart microgrid including the xEVs and variable load as well as the backup power to meet the other critical load demand.

2. Enhancement in xEVs charging infrastructure

2.1. xEVs background and cataloging

In the transport sector, xEVs are very favorable in reducing environmental impact by reducing GHG emissions and other air polluting emissions. The fuel cost can be set to zero by using f RESs or charging purpose or with on-board electricity generating operations. xEVs can be categorized into various classes such as Electric Vehicles (EVs), Battery Electric Vehicles (BEVs), Fuel Cell Hybrid Vehicles (FCHVs), Hybrid Electric Vehicles (HEVs) and Plug-in Hybrid Electric Vehicles (PHEVs) (Maheshwari, Tambawala, Nunna Kumar, & Doolla, 2014).

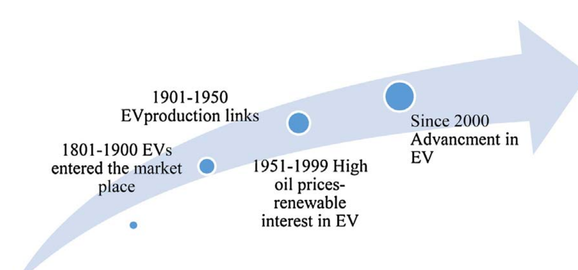

Fig. 2. The evolution of EVs.