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Smart public transportation network expansion and its interaction with the grid

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ABSTRACT

This paper presents the smart public transportation network expansion and its interaction with the grid. Electric buses have been used to perform the mass transportation in the Guwahati city, Assam, India. Electric buses receive energy from the electric bus stops that are present through the ring road of the Guwahati city. A high capacity energy storage device and the solar plant have been connected to every bus stop, to achieve the smooth performance of the smart public transportation network. In this work, the capa-buses (supercapacitor based buses) and the electric vehicles have been used along with the electric buses to expand the electrified transportation network in the Guwahati city. Algorithm based controllers are responsible to control the energy flow between the high capacity energy storage device, the capa-buses and the electric vehicles. Fuzzy logic controller is present at every bus stop to control the energy flow between the grid, the energy storage device and the solar plant. The complete system response has been verified through Simulations: for different situations in all the seasons of a year and for the uncertain situations that exist in the system. This system is helpful to improve the air quality in city region and also improves the voltage profile of the grid.

1. Introduction

The petroleum based transportation system and the luxurious lifestyle of ever increasing population are the major sources of air pollution across the globe. Transforming the present transportation system from petroleum based to electric based is one of the possible solutions to curtail such issue [1,2]. The revolution in the electric based transportation system has been started with the introduction of trolley buses and tram systems (used for mass transportation in the city regions) [2–4]. However, the superiority of the internal combustion engine vehicles led the degraded demand towards these systems (the limited battery capacity, high cost and non-attractive models were the major hurdles for their popularity) [5]. Certainly, the rapid rise of air pollution level in city regions created the demand towards electrified transportation systems [6]. Therefore, the systematic enhancement in the clean energy based transportation system has been achieved and as a result the super-capacitor equipped tram networks have been introduced in Spain, Portugal and China [7]. Also, the supercapacitor based electric buses have been introduced for the public transportation in urban regions of China [8]. The on-board supercapacitor based transportation network reduces the electrical line infrastructure needed between the consecutive stoppages. However, in these systems, the supercapacitors receive energy from the grid periodically and act as a load to the grid for short durations. This may create transients in the grid. In [9], the on-line operation of electric vehicles (EVs) with the grid has been introduced. EVs charge from the grid via wireless-charging system installed under the road. This system is beneficial in the transportation system point of view, but from the grid point of view it creates an extra stress on the grid during the peak period. The current trend of research is the onboard solar energy based transportation system [10]. This system works very effectively during sunny days, but the electric vehicles may stop working in cloudy days. In such situation the electric vehicles need to receive energy from the grid. Therefore, the use of high capacity energy storage device (ESD) between the grid and the transportation system is one of the possible solutions for such difficulties [11–13].

As per [14], the interaction between the grid and the transportation system has been performed by using the energy storage systems. However, this system completely depends on the grid. Therefore, this system has the chances of failure if the grid is unable to support the transportation system. Solar energy utilization is one of the possible options to curtail this system dependence on the grid and to escape the failure situations. The proposed work focuses on these issues and achieves the smooth performance of the smart public transportation network by reducing the grid dependence. Therefore, objectives of the present work are as follows:

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Nomenclature

CBC	CB (Capa-bus) controller
EVC	EV (Electric vehicle) controller
E_{ESD}	ESD (High capacity energy storage device) energy status
E_{CBC}/E_{CBD}	Charge CBs from ESD or discharge CBs to ESD
E_{CBnet}	Net energy availability of CB
E_{EVnet}	A set of EVs net energy availability
E_{EVC}/E_{EVD}	Charge EVs from ESD or discharge EVs to ESD
E_{SP}	Solar plant energy status
FLC	Fuzzy logic controller
MEBS	Maligaav electric bus stop (EBS)
P±	Power from the grid to ESD in off-peak period or power from ESD to the grid in peak period
SP±	Power from solar plant to ESD in off-peak period or power from solar plant to the grid in peak period
Vpu	Per unit voltage of the grid

- The smart public transportation network response verification for all the seasons of a year.
- The smart public transportation network behavior for uncertain situations that exist in the system.

A specified number of electric bus stops (EBSs) are present through the ring road of the Guwahati city, Assam, India. The electric buses receive energy from each of the EBS to perform the mass transportation through the city [15]. The ring road circuit is considered as a case study in this work and the structure of the distribution system in the smart public transportation network is based on the real time load data (collected from state electricity board, Assam, India) [16,17]. Super-capacitors are the prime energy storage in electric buses due to their significant features [18–20]. At every EBS, the solar plant as well as ESD have been connected to perform the smooth functioning of the smart public transportation network and also, to improve the voltage profile of the gird (the voltage profile of the grid should vary within the permissible voltage limit [21,22]). The real time solar data is used to calculate the solar irradiance availability and accordingly the size of the solar plant has been decided [23–29]. The solar energy generation is proportional to the solar irradiance availability in all the seasons of a year. A specified EBS (Maligaav EBS (MEBS)) of the smart public transportation network has been considered to charge the capa-buses (CBs) and electric vehicles (EVs) along with the electric buses. The super-capacitors are used in CBs and Li-ion batteries in EVs due to their individual benefits. The use of CBs and EVs in the smart public transportation network shows the possibility to expand the electrified transportation network in the Guwahati city. Also, CBs and EVs usage along with ESD creates the possibility to perform more improvement in the voltage profile of the grid. Algorithm based controllers have been developed for controlling the energy flow between ESD and CBs and also, between ESD and EVs. CB controller (CBC) takes care of charging and discharging of CBs [30,31]. EV controller (EVC) takes care of charging and discharging of EVs. Every EBS in the smart public transportation network consists of a fuzzy logic controller (FLC) to control the energy flow between the grid, ESD and the solar plant [32–36]. The simulations have been performed, to verify the smart public transportation network response for three seasons of a year and for the uncertain situations that exist in the system.

The remainder of this paper is organized as follows. The structure of the smart public transportation network is given in Section 2. Section 3, explains the problem definition. The results and discussions are given in Section 4 and the conclusion is given in Section 5.

2. Structure of the smart public transportation network

This section explains the structure of the smart public transportation network including the structures of both, the distribution network and EBS-5. Fig. 1a shows, the structure of the smart public transportation network in the Guwahati city. A total of 32 EBSs are present through the ring road circuit. Each EBS has been connected to a separate distribution node (11/0.415 kV) along with the solar plant as shown in

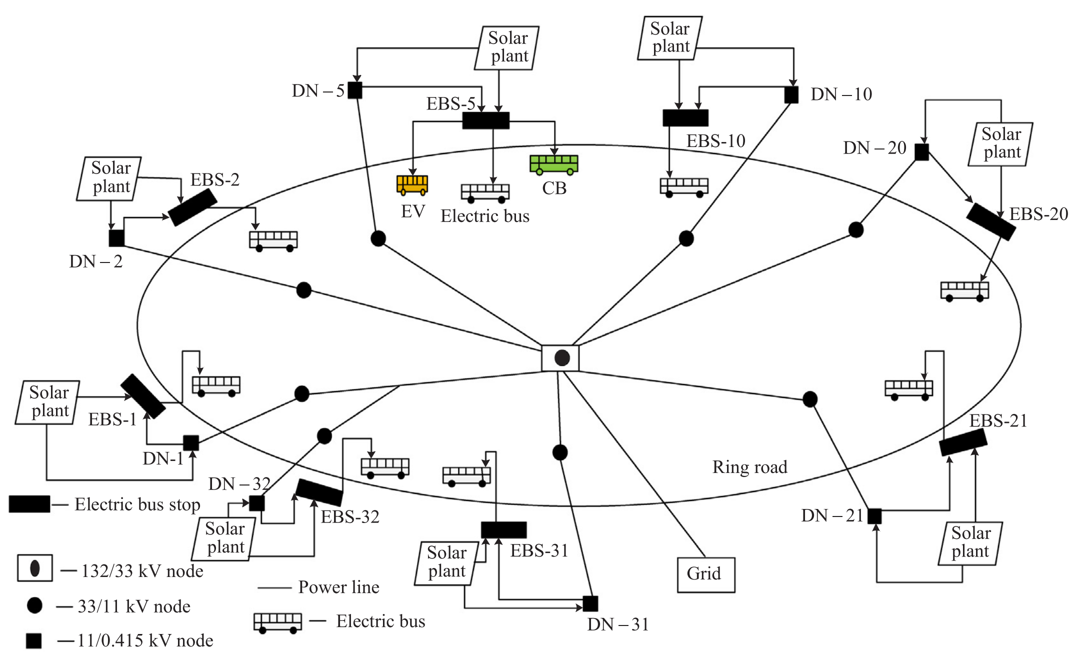

Fig. 1a. Structure of the smart public transportation network.