Connected Vehicle

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Contributor: NARESHKUMAR DARIMIREDDY

A connected vehicle is an electric vehicle connected with different communication systems that enable its connection to external devices, networks, applications, and services.

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1. Introduction

The global energy crisis and health hazards caused due to the traditional internal combustion engine (ICE)-based vehicles have led electric vehicles (EVs/automated vehicles) to become an attractive alternative solution for automotive industries/electronics. EVs outranked conventional ICE owing to non-consumption of fossil fuels and are useful to mitigate PM issues to a greater extent. The electric car is a cost-effective and electrically propelled motor-drive system which utilizes alternate energy sources on-board within the vehicle to meet zero-emission. Besides, an electric vehicle connected with different communication systems that enable its connection to external devices, networks, applications, and services is referred to as a connected vehicle. The term “connected vehicle” covers not only a variety of connections but also applications and services. This type of vehicle is not only connected to a network (vehicle to network, or V2N), they are also able to exchange information with other vehicles (V2V), with infrastructures (V2I), or even with pedestrians (V2P). Beyond their connectivity, some vehicles can integrate more or less significant levels of driving assistance. In extreme, autonomous vehicles are capable of driving without the driver’s intervention in specific configurations. These automated vehicles require a high-end communication aspect. Thus, this survey has been categorically split into two parts based on various technical viewpoints.

An EV is formed by the integration of a different set of technologies working together to develop a complete electric machine. The machine can compete for conventional vehicles in the future in the sense of driving range, wide operating speed, high power density (in terms of circuit volume inside EV), high-level communications, and least emission. The next level of EVs will also include automated vehicles, connected vehicles, hybrid electric vehicles, and autonomous vehicles. This vehicle is highly interlinked with exciting and high dimensional interdisciplinary engineering technologies. The PEC is a non-linear circuit topology with an advanced control function and is useful for controlling various subsystems within the vehicle. A special class of PEC is DC-to-DC converters that are used to transfer DC power from the battery to the motor-inverter section. The schematic diagram of bidirectional converters (BDCs) is technically a sub-category of DC-DC converters and is meant to transfer energy from the battery to the motor inverter section or feedback the regenerative power to the battery is shown in Figure 1.

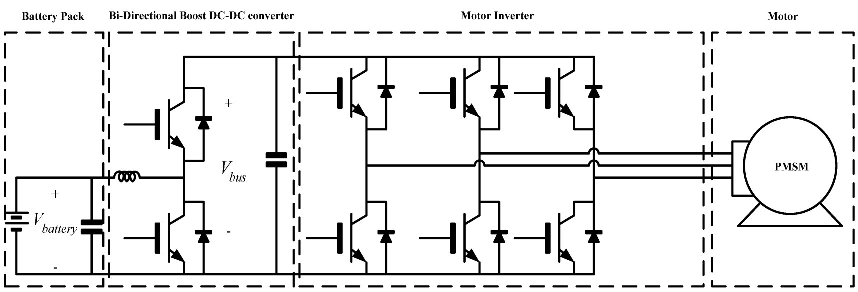

Figure 1. Typical Powertrain architecture highlighting conventional bidirectional boost converter.

EVs’ heart is utterly dependent on how power electronics technology plays a role in controlling the vehicle’s motor drive system. Simultaneously, optimally managing the on-board energy resources to propel, accelerate efficiently, and cruise may be done based on the driver needs. Advances in electric vehicles lead to various derivatives such as battery electric vehicles (BEVs), hybrid electric vehicles (HEVs), and fuel cell electric vehicles (FCEVs) [1][2][3][4]. All these derivatives have sub-categories as per the advances in EV technology. Moreover, there is a need to get acquainted with the term “vehicle-powertrain”. The powertrain of a vehicle consists of a motor-drive system and battery. In some cases, DC-DC (Bidirectional) converters are placed between the battery and motor drive system for the bidirectional power flow. Caricchi et al. [5] reported that motor drive efficiency is severely affected if the battery system is directly feeding power to the inverter motor drive system. The bidirectional converters and communication aspects used to facilitate electric power conversion and communication with the outer environment are critical components for an automated vehicle. The power electronic bidirectional converters play an active role in transferring DC power from the battery to the motor-inverter section. Similarly, antenna technology is essential for automotive radar applications in leading the vehicles to a fully automated and autonomous state.

Thus, a critical survey has been conducted on converters and communication aspects, keeping because of the future automated vehicle technology. The present article, i.e., Part 1, discusses several useful bidirectional DC-DC power converters for electric vehicle applications. The details of which are as follows: conventional bidirectional converters [5][6][7][8][9][10]; isolated bidirectional converters [11][12][13][14][15][16][17]; soft-switching converters [18][19][20][21][22]; coupled inductor approaches [23][24][25]; fly-back converter [26][27]; three-level converter [28]; dual active bridge converter approaches [29][30][31][32][33]; and composite converter approaches [34][35]. From the state of the art, it has been observed that the composite converter is the most efficient power converter in which different sets of modules are connected in series or parallel to control the power flow. The conduction and switching losses are reduced by two to four times as compared to conventional topologies, which lower device stresses and hence, lowers the voltage rating of power devices. In addition, conditioning monitoring aspects for the PECs are emphasized as the concern of the life span of the power converter installed in the EV is a very crucial issue [36][37][38][39][40][41][42][43][44][45][46][47][48][49][50][51][52][53][54][55][56][57][58][59][60][61][62][63][64][65][66][67][68][69][70]. The aging effect of the electric vehicle's electronic components needs to be essentially monitored to maintain the drive system's health. Health index monitoring is an important liaison for the power electronics hardware installed within the EVs. In part 2 of this survey, 24 and 77 GHz low-profile (microstrip-based) antennas for automotive radar applications, types of antenna structures, feed mechanisms, dielectric material requirements, design techniques, and performance parameters have been critically surveyed and reported.

2. Future Aspects of EV Technology

Given the future aspects of electric vehicular technology, there are various domains, so discussing them in detail would overwhelm the purpose of the reading, and the additional references would be countless. Therefore, from a specific technological point of view, the goals of different technologies associated with electric vehicle advancement have been discussed here. Further, readers will have an overall intuitive idea about the role of power electronics together with other domains as per the recent updates in the technologies as follows:

- Semiconductor technology
- Power electronics and drive train technology
- Motor technology
- Battery and its management technology
- Control engineering technology
- Vehicle to grid (V2G) technology
- Home to grid (H2G) technology
- Wireless energy power transfer technology (WPT)
- Grid integration of EVs

Therefore, all these broad research areas have a different perspective on electrical engineering behind electric vehicles, as semiconductor devices are the heart of electric vehicles' power electronic systems. Further, it has a significant impact on the development of power electronics technology for an electric vehicle regarding reliability, cost, efficiency, and dynamics. Besides, various motor control and battery technologies need to be developed concerning the electric drive system, where batteries are critical and highly flammable at high temperatures. Various battery management systems (BMS) are in development for Li-ion cells as they are prone to hazard at high temperatures. Further, other alternatives are needed to be explored because of the batteries' electrochemical process, which may be reversed by using nanomaterials so that decomposing the battery after the end of the life cycle can be avoided. Because of motor technology, there are various motors available in the field for electric drive, i.e., brushless DC motors (BLDCs), switched reluctance motors (SRMs), permanent magnet synchronous motors (PMSMs), which are very popular among EVs. Several issues remained to be solved, such as cost, size, weight, control methods, fast dynamic response, and high efficiency.

Further, control engineering plays a vital role in sustaining all the systems within the vehicle in a highly stable state as the power electronic system requires control systems to maintain the vehicle's excellent dynamic performance in the presence of any disturbances. Therefore, challenges raised in this domain are very critical subject to the dynamical conditions of the vehicle. One has to control the battery system's temperature and decide when to operate in battery mode or internal combustion engine mode, control of bidirectional energy flow between the battery pack and the drivetrain, and control power electronic converters the proper operation of the drivetrain, etc. Potential mathematical modeling of power electronic converters is necessary because of controlling the issues mentioned above, i.e., small-signal modeling, steady-state modeling, controller design modeling, circuit averaging methods. Also, magnetics design modeling, filter designs, and advanced analog control techniques for power converters like voltage mode control (VMC), current programmed control/current mode control (CMC), Peak current mode control (PCMC), average current mode control (ACMC) may be emphasized. One may intermix the control methods for further technology advancement using digital control methods, neural networks, genetic algorithms, fuzzy logic, and other optimization methods for major controlling issues for their implementation.

Vehicular technology because of V2G, H2G, and WPT is again a new emerging domain for revising power systems. These technologies help our power system maintain power system stability since the power system's load curve throughout the day has to be constant. If the right time charging incentives are considered adequate but provided, customers have to understand electric vehicles' use as per the grid load dispatch laws. Further, Grid integration of these vehicles needs additional efforts for connecting EVs to the power grid as power electronic systems are prone to harmonic injection into the grid. This can lead to power quality issues where the phase-locked loop (PLLs) system's significant role plays a vital role in grid-tied converters. In addition to it, adequate care needs to be taken according to their life cycles as high circulation currents and over-voltages are subject to matter, which is required to be addressed. In the next section, condition monitoring aspects of these converters are highlighted, which is necessary to mitigate the life cycle mentioned above concerns of power electronic converters.

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