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Design and Analysis of Bi-directional DC-DC Driver for Electric Vehicles

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ABSTRACT

The level of exhaust gases is rising with increasing usage of internal combustion engine vehicles. To reduce carbon emission, researchers and industry head up for improving electric vehicle technologies in all over the word. This paper deals with design and simulation of a bi-directional power converter of electric vehicle. The power electronics block is comprised by batteries, bi-directional dc-dc converter and dc machine. The initial state of battery charge is set around 90% where the discharge current is 44.5 A during motor mode. The nominal voltage of battery stack is 350 V and maximum capacity is 100 Ah. The rated power of dc machine is set to 250 HP with 500 V armature voltage and 300 V field voltage. The operating mode of power converter is determined according to the torque values of dc machine which is operated in motor and generator modes. The charge and discharge conditions of batteries have been controlled regarding to operating modes of dc machine. The bi-directional dc-dc converter is controlled with fuzzy logic controller in both modes. The proposed converter and controller are designed to meet charge control and motor drive requirements of an all-electric vehicle.

INTRODUCTION

Transportation sector occupies a fundamental place in the world. Fossil fuels used in conventional vehicles technology emit greenhouse gases such as carbon dioxide, carbon monoxide and methane. The excessive consumption of these gases causes air pollution, climate change and global warming. In order to reduce these effects, there is a tendency to electric vehicle (EV) technology. The EV has much lower fuel cost according to fossil fueled car since they are mainly composed of battery system, power electronic circuits and electric machine. The battery system in an EV is the most crucial component in charge control time and determining distance [1,2].

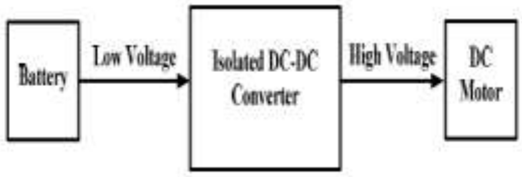

Fig 1 Conventional isolated DC-DC converter

The electric machines of an EV are operated in both motor and generator modes due to regenerative breaking feature that enables electric machine to be operated in generator mode which is impossible in conventional internal combustion engine (ICE) vehicles. Therefore, electric machine charges the battery by operating in generator mode during the regenerative braking and it ensures recharging the batteries [3,4]. EV are classified into two types as hybrid EVs (HEVs) and all-electric vehicles. The HEV technology is used in conjunction

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conventional vehicle technology. The main system in HEV technology includes fuel tank and ICE such as diesel or gasoline engine, and auxiliary system which is comprised by electric machine, power electronic circuits and battery. HEVs are classified as parallel and series hybrid vehicles [5] that the parallel HEV consists ICE and electrical machine together as shown in Fig.1. As the parallel electric vehicles operates at electric mode during the acceleration of electric machine, the motor operation is supplied from battery

PROPOSED SYSTEM

The designed EV motor driver is comprised by four sections such as battery, bi-directional dc-dc converter, FLC and dc machine as shown In this study, the starting voltage of battery is set to 378 V while the operating voltage of dc machine used in traction system is 500 V dc. The battery voltage is increased up to 500 V with bi-directional dc-dc converter in generator mode. The battery is discharged when dc machine is started acceleration. The motor mode simulation with various torque values are performed to observe battery parameters such as state of charge (SoC), current, voltage and voltage of the dc machine. The voltage of the dc machine is decreased to 500 V with bidirectional dc-dc converter which is controlled with FLC. The battery is charged during the generator mode operation of dc machine. The FLC determines duty cycle of S1 and S2 to ensure charge and discharge of battery. The dc machine is comprised by brushes, armature core and windings, commutator, field core and windings. Armature circuit is comprised by series structure with inductor, resistance and counter-electromotive source. Similarly, battery parameters such as SoC, current, voltage and voltage of the dc machine are observed in the generator mode simulation regarding to various torque values applied to dc machine.

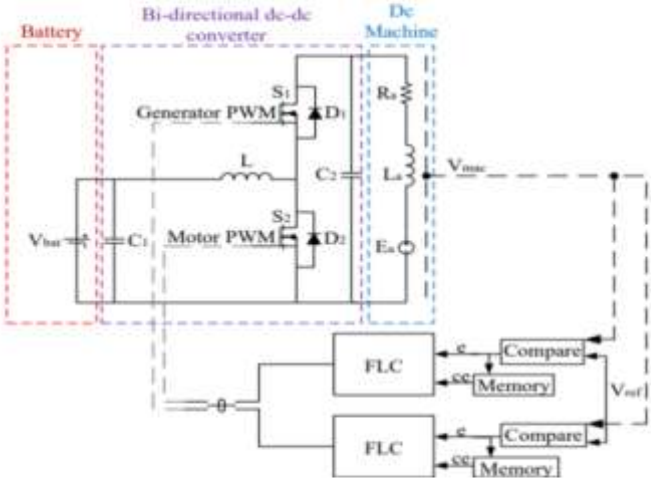

Fig 2 Proposed circuit configuration

The electrical energy is converted to mechanical energy or vice versa by dc machine that operates regarding to electromechanical energy conversion theory [7]. If a conductor is moved within the magnetic field, the voltage is induced on it which is known as generator operating mode. If alternating current passes through the conductor, magnetic field is created around it which explains the motor mode operation. When the dc machine is started acceleration, the resultant positive torque is achieved. On the other hand, negative torque is generated at the dc machine when it is operated in generator mode

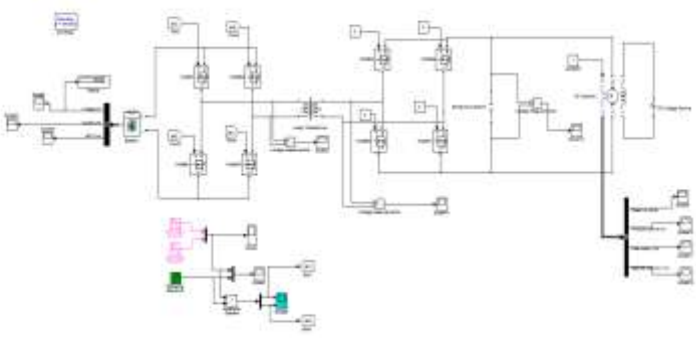

Fig 3 Conventional system

FLC is comprised by fuzzification, rule base, interface mechanism, defuzzification. Fuzzification is used to convert digital signals received through the system into linguistic variable. Rule base is comprised by the conditions to set for controlling the system at desired location. Interface mechanism makes inferences according to the rules of system by establishing a relationship between inputs. Defuzzification is used to convert linguistic variable received through the system into digital signals

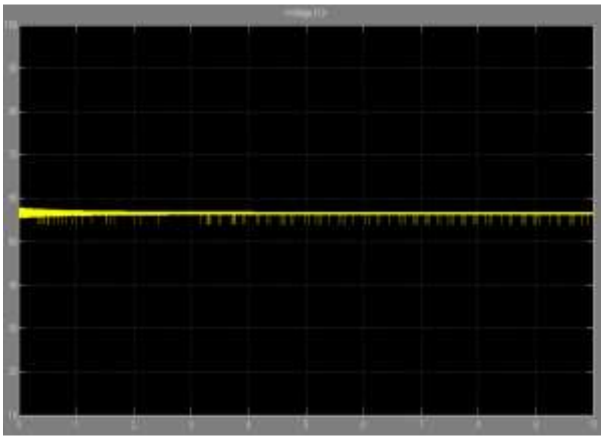

Fig 4 Battery voltage

The European new vehicle CO2 regulation (with a mandatory target value of 95 grams of CO2 per kilometer by 2021 for passenger cars) is currently in the process of being extended to 2025. In this context, one of the key questions is at what point a significant uptake of the electric vehicle market is to be expected. In order to help inform this debate about how electric vehicle technology could fit in a lower-carbon 2020–2030 new vehicle fleet in Europe, this paper focuses on collecting, analyzing, and aggregating the available research literature on the underlying technology costs and carbon emissions. In terms of technologies, this paper concentrates on the three electric propulsion systems: battery electric vehicles (BEVs), plug-in hybrid electric vehicles (PHEVs), and hydrogen fuel cell electric vehicles (HFCEVs). The collected cost data is used to estimate the technology cost for automotive lithium-ion (Li-ion) batteries and fuel cells.

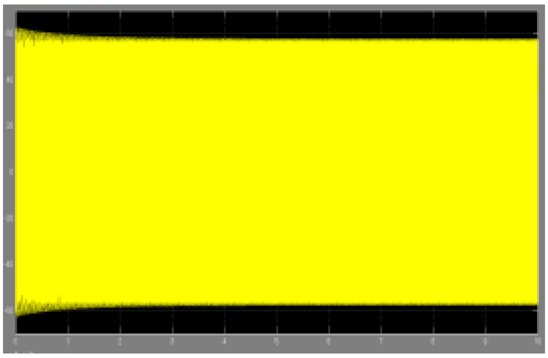

Fig 5 Transformer primary voltage

The cost of battery packs for BEVs declined to an estimated €250 per kWh for industry leaders in 2015. Further cost reductions down to as low as €130–€180 per kWh are anticipated in the 2020–25 time frame. The costs of fuel cell systems are also expected to decrease considerably, but cost estimates are highly uncertain. Furthermore, the application of fuel cells and batteries in HFCEVs, BEVs, and PHEVs is approximated using a bottom-up cost approach. Overall, the different power train costs largely depend on battery and fuel cell costs. This paper concludes that the costs of all power trains will decrease significantly between 2015 and 2030 (Figure S 1).

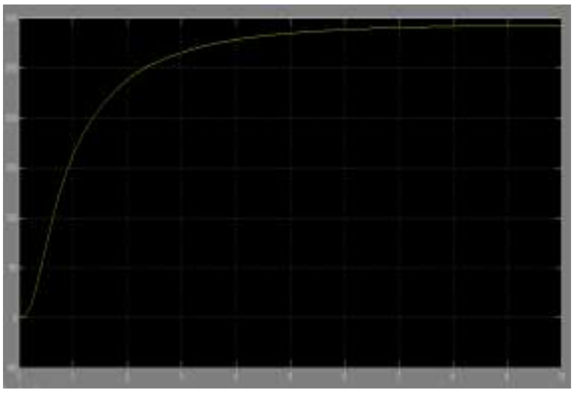

Fig 6 Dc Motor speed

As shown, power trains for PHEVs will achieve about a 50% cost reduction, compared with approximate cost reductions of 60% for BEVs and 70% for HFCEVs. Costs for hydrogen and electricity chargers are estimated separately. Greenhouse gas (GHG) emissions and energy demand for electric and conventional vehicles are presented on a well-to-wheel (WTW) basis, capturing all direct and indirect emissions of fuel and electricity production and vehicle operation. The results are based on former analyses, and are updated and refined with real-world fuel consumption levels. Real-world fuel consumption is

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commonly about 20%–40% higher than official typeapproval measurements. Finally, WTW estimates for electric and conventional vehicles are put in the context of the 2021 CO2 standard for European passenger vehicles. It is found that carbon emissions of BEVs using European grid-mix electricity are about half of average European vehicle emissions, whereas HFCEVs and PHEVs have a lower emissions reduction potential. In the 2020 context, electric vehicle WTW emissions are expected to continue offering greater carbon benefits due to more efficient power trains and increasing low-carbon electric power. A lower-carbon grid and higher power train efficiency by 2020 could cut average electric vehicle emissions by one-third again. However, the expected cost reductions and potential CO2 emission cuts will not be achieved without targeted policy intervention. More stringent CO2 standards, and fiscal and non-fiscal incentives for electric vehicles, can help the electric vehicle market to grow and costs to fall. Also, efforts need to be combined with activities to decarbonize the grid, or emission reductions will not be as great as they could be. Although the analysis is focused on the European context, similar dynamics with electric vehicle technology, policy, and market development are prevalent across major markets in North America and Asia.

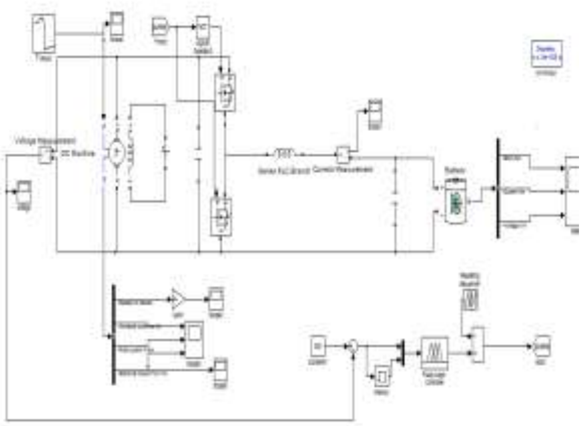

Fig 7 Proposed circuit configuration

The first EVs were introduced as early as 1838—or 52 years before internal combustion engine vehicles (ICEVs) entered the market. Despite recent growing interest, EVs have remained a relatively small market until today (IEA, 2015). However, the global share of EVs is expected to increase significantly, driven by substantial battery technology improvements and a variety of policies that are accelerating the development of the electric vehicle market. Overall, the market has grown from just hundreds of EV sales in 2010 to more than 500,000 sales worldwide in 2015 (EV Sales, 2016). The early development of markets for electric vehicles is seen predominantly in parts of China, Europe, and the United States, where electric vehicle support policies are helping promote the technology, while costs are still relatively high compared with conventional vehicles. Table 1 shows the global and regional estimated stock of BEV and PHEV passenger cars as of 2015, and electric vehicle supply equipment (EVSE) as of 2014. EVSE includes semipublic or public charging points or outlets, but not private charging points. Most of the electric vehicles on the road today are registered in the United States, with about half of those in the state of California. The United States also has the largest number of electric vehicle charging points. The Netherlands is the European country with the highest electric vehicle passenger car and charging-plug stock in terms of absolute sales. The following countries have achieved relatively high market sales shares of passenger electric vehicles, as a percentage of all 2014 passenger vehicle sales: Norway (13.7%), the Netherlands (3.9%), Sweden (1.5%) (Mock, 2015), and the United States (1.5%) (Lutsey, 2015b). Most other major automobile markets have EV sales shares at or below 1%.

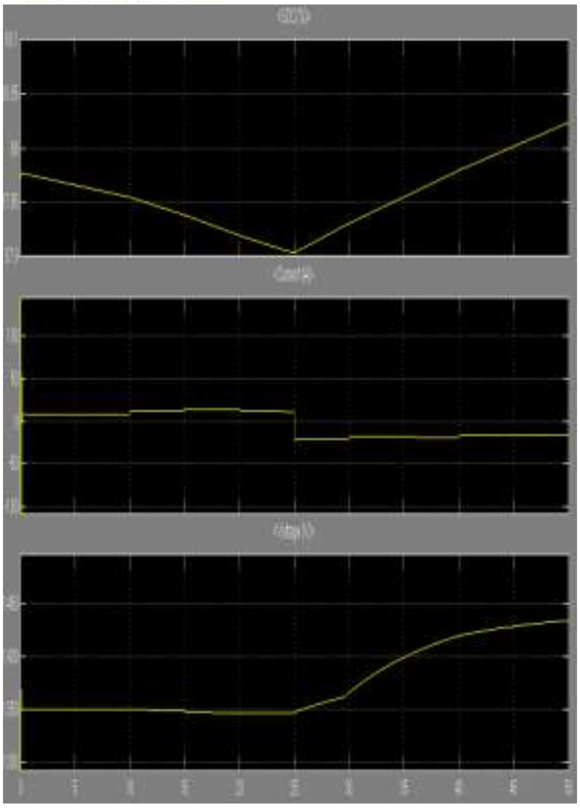

Fig 8 Proposed system Battery SOC, current, voltage

Pure battery electric vehicles (BEVs) are also referred to as battery-only electric vehicles (BOEVs). BEVs have no engine and are propelled by electricity that comes from one or several onboard high-energy batteries. Modern models use a regenerative braking system to save energy. Examples include the Renault Zoe and the Nissan Leaf. The Zoe has a 22 kWh Li-ion battery, and an energy consumption of 14.6 kWh per 100 km, which yields a range of about 140 km to 210 km per battery charge on the New European Driving Cycle (NEDC). The 2015 Leaf comes with a 24 kWh battery (plus a 30 KWh option for the 2016 model), and an official consumption of 15 kWh per 100 km. 3.2. PHEVs Plug-in hybrid electric vehicles (PHEVs) allow electric driving on batteries (in charge-depleting mode), but also conventional combustionfueled driving (in charge-sustaining mode). Usually, they are equipped with an electric motor and a highenergy battery, which can be charged from the power grid. Modern PHEVs can be driven in electric mode over varying distances before the combustion engine is required. In electric-driving mode, the energy efficiency of the propulsion system is much higher, and is comparable to that of a BEV. Available models include the Chevrolet Volt in U.S. markets (which is the Opel Ampera in EU markets), and the Toyota Prius Plug-in Hybrid. The 2015 Opel Ampera uses a 16 kWh Li-ion battery and consumes 16.9 kWh per 100 km in electric mode on the NEDC. The 2015 Chevrolet Volt has a 16.5 kWh battery, and the 2016 model has an 18.4 kWh battery.

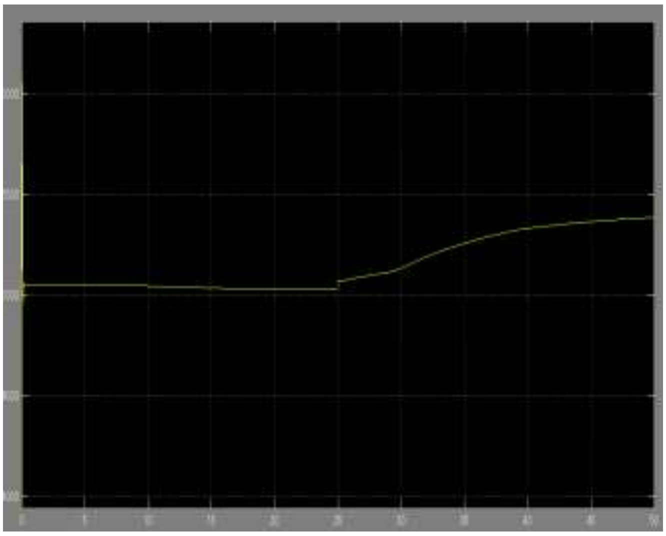

Fig 9 Proposed system Speed of the dc machine

PHEVs and BEVs use similar batteries, with Li-ion being the most common chemistry. There are two primary ways to extract the lithium used in batteries: mining spodumene and petalite ore using evaporation ponds on salt lakes. The majority of lithium is obtained from brine operation (USGS, 2015). The battery system is the key technology of electric vehicles and defines their range and performance characteristics. The battery works like a transducer by turning chemical energy into electrical energy. Li-ion is expected to be the dominant chemistry for BEVs and PHEVs for the foreseeable future, as most research is done in the field of Li-ion batteries.

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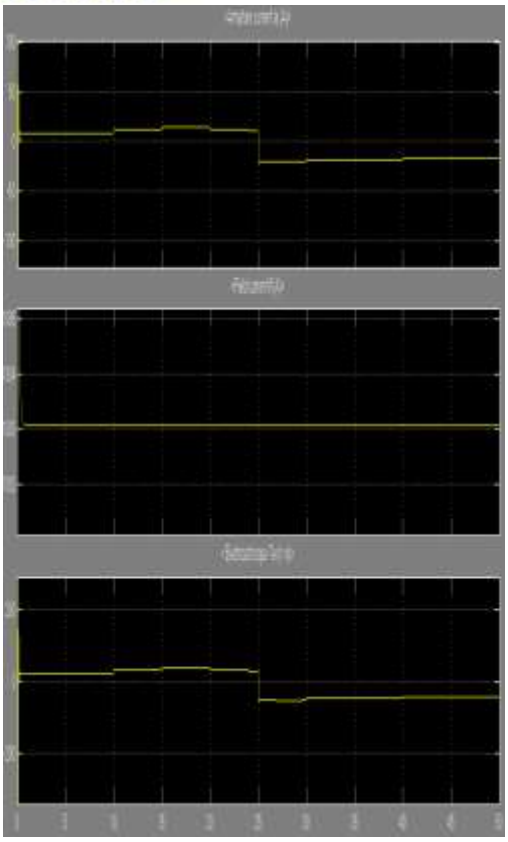

Fig 10 Proposed system Armature current, Field current, Electro magnetic torque

They provide relatively high power and energy for a given weight or size, and can significantly reduce costs compared with other battery concepts. Energy density of the battery pack is estimated to roughly double, up to about 300 Wh per kg, between 2007 and 2030 (Kromer & Heywood, 2007; Ricardo-AEA, 2015; NAS, 2013). Also, they have a relatively long life cycle and low selfdischarging losses. One of their few drawbacks is their sensitivity to overcharging, which is why they require a battery management system. Other automotive battery concepts include nickel-metal hydride (Ni-MH), sodium-nickel chloride (Na/NiCl2), and non-electrochemical alternatives such as supercapacitors, which allow fast charging but provide low energy density. As a result, batteries with higher energy and power densities are being developed, such as lithiumair (Li-air), lithium-metal or lithiumsulphur (Li-S), but these are far from commercialization (Cookson, 2015; Hacker, Harthan, Matthes & Zimmer, 2009). Li-air batteries may reach energy densities of up to 11,680 Wh per kg (Imanishi & Yamamoto, 2014), which approximates the energetic content of gasoline.

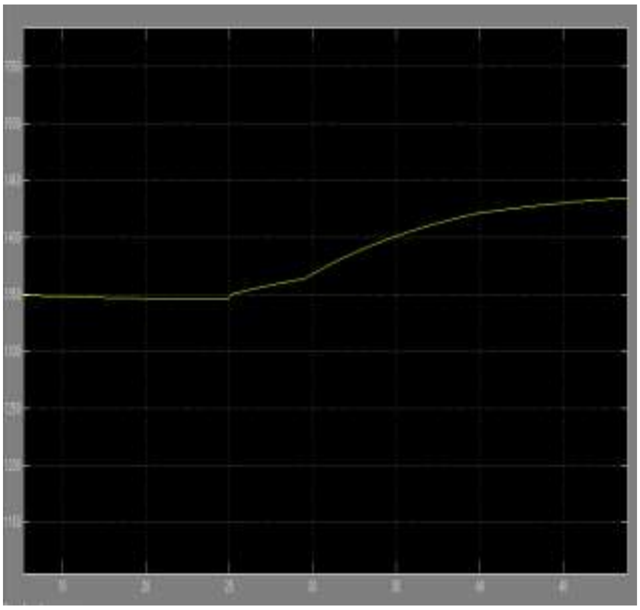

Fig 11 Proposed Dc machine across voltage

CONCLUSION

This project presents design and control bi-directional dcdc converter for all-electric vehicle. The bi-directional dc-dc converter is controlled with FLC according to rules. When the battery is discharged, the dc machine is operated in motor mode and bi-directional dc-dc converter is operated in boost mode. Variable positive torque values are applied to the dc machine and condition of the battery is observed. According to simulation result, the battery SoC is reduced from %88 to %87.337 and voltage of the dc machine is constant at 500 V. When the battery is charged, the dc machine is operated generator mode and bi-directional dc-dc converter is operated in buck mode. Variable negative torque values are applied to the dc machine and effect on the battery is observed. According to simulation result, the battery SoC is increased from %87.337 to %87.445. In all-electric vehicle, regenerative breaking is occurred in this state. Charge and discharge states of the battery are the most essential for distance to determining.

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