Review on DC-DC Converter Fed Drive For Electric Vehicle System

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Abstract- *In this project batteries are the primary energy-storage devices in ground vehicles. Now days battery fed electric drives are commonly being used for electric vehicles applications, due to various advantages, such as: nearly zero emission, guaranteed load leveling, good transient operation and energy recovery during braking operation. To fulfill these requirements converters with bidirectional power flow capabilities are required to connect the accumulator (battery) to the dc link of the motor drive system. Battery fed electric vehicles (BFEVs) is required to function in three different modes namely: acceleration mode, normal (steady-state) mode and braking (regenerative) mode. During acceleration and normal modes the power flow is from battery to motor whereas during braking or regenerative mode the kinetic energy of the motor is converted into electrical energy and fed back to battery. The DC-DC converter is required to perform mainly two functions: first to match the battery voltage to the motor rated voltage and second to control the power flow under steady-state and transient conditions, so that the drive performance is as per the requirement. In the present work closed loop operation of bi-directional dc-dc converter feeding a dc motor and its energy recovery due to regenerative braking has been demonstrated. The characteristics of battery operated electric vehicle under different drive condition are also presented. The effectiveness of the system is verified through the simulations using Simulink/ MATLAB*

Keywords- DC-DC converter, dc motor, MATLAB

I. INTRODUCTION

This project deals with the formation of a bidirectional DC-DC converter for driving a Permanent Magnet DC (PMDC) motor for Hybrid Electric Vehicle (HEV) and Battery Fed Electric Bikes (BEV) application and Half Bridge non-isolated bidirectional DC-DC converter topology has been selected for this work because of the absence of the transformer which reduces the weight of the system and therefore the size and the cost of the system considerably reduces. Non isolated half bridge topology is the appropriate option for the systems requiring high power applications as well as systems having constraints on their size and weight or both such as spacecraft applications, HEVs and the electric bicycle. Conventionally the bidirectional DC-DC converters are designed with the voltage source on both the sides, but the present work proposes the converter power stage directly feeding the PMDC motor.

II. MOTIVATION

One of the main considerations for the HEV drive train is to improve the efficiency of the motor drive. This can bedone by increasing the voltage level of the ESS and thereby reducing the high currents and thus the associated losses. The increase in the voltage level of the ESS can be done by the addition of the more number of the cells in the battery back of the ESS of the HEV. Although it increases the voltage level but at the same time it also increases the weight, size and cost of the system which is obviously not a desirable option for a vehicular application which has constraints on its size and weight. The other option is to use a bidirectional DC-DC converter. Bidirectional DC-DC converters boost up the voltage level of the electrical storage system to the higher voltage level and thereby reducing the current level and hence the losses. Also Bidirectional DC-DC converter facilitates the provision for the reverse power flow back into the ESS during regenerative braking and hence further increasing the efficiency.

III. BIDIRECTIONAL DC-DC CONVERTER

Bidirectional DC-DC converters serves the purpose of stepping up or stepping down the voltage level between its input and output along with the capability of power flow in both the directions. Bidirectional DC-DC converters have attracted a great deal of applications in the area of the energy storage systems for Hybrid Vehicles, Renewable energy storage systems, Uninterruptable power supplies and Fuel cell storage systems. Traditionally they were used for the motor drives for the speed control and regenerative braking. Bidirectional DC-DC converters are employed when the DC bus voltage regulation has to be achieved along with the power flow capability in both the direction. One such example is the power generation by wind or solar power systems, where there is a large fluctuation in the generated power because of the large variation and uncertainty of the energy supply to the conversion unit (wind turbines & PV panels) by the primary source. These systems cannot serve as a standalone system for power supply because of these large fluctuations and therefore these systems are always backed up and supported by the auxiliary sources which are rechargeable such as battery units or super capacitors. This sources supplement the main system at the time of energy deficit to provide the power at regulated level and gets recharged through main system at the time of surplus power generation or at their lower threshold level of discharge. Therefore a bidirectional DC-DC converter is needed to be able to allow power flow in both the directions at the regulated level. Likewise in HEVs, bidirectional DC-DC converters are employed to link up the high voltage DC bus to the hybrid electrical storage system (usually a combination of the battery or a fuel cell with the super capacitor). Here they are needed to regulate the power supply to the motor drive to assist the ICE according to the traction power demanded. Therefore a bidirectional DC-DC converter is needed to be able to allow power flow in both the directions at the regulated level. Likewise in HEVs, bidirectional DC-DC converters are employed to link up the high voltage DC bus to the hybrid electrical storage system (usually a combination of the battery or a fuel cell with the super capacitor). Here they are needed to regulate the power supply to the motor drive to assist the ICE according to the traction power demanded. The need for a bidirectional DC-DC converter .

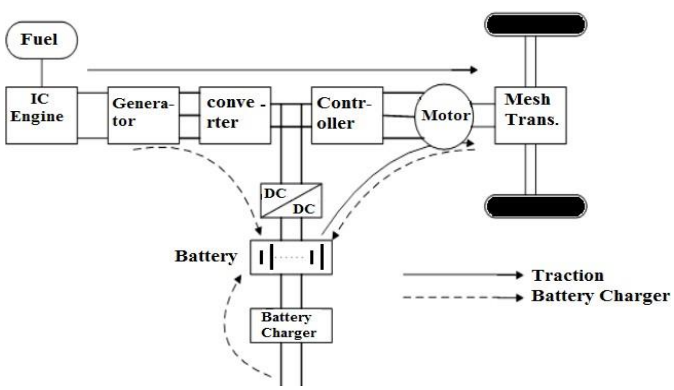

Figure 1: Series hybrid Drive Train employing a bidirectional DC-DC converter

There are some of the requirements for the Bidirectional DC-DC converters design for the HEV applications which are as follows:

- High efficiency.
- Light weight & compact size.
- Lower electromagnetic Interference.
- Lower input and output current ripple.
- Controlled power flow in spite of wide input voltage variation Classification of Bidirectional DC-DC converter

Basically, bidirectional DC-DC converters can be classified into two categories depending on the Galvanic isolation between the input and output side:

1. Isolated Bidirectional DC-DC converters
2. Non-Isolated Bidirectional DC-DC converters

IV. ISOLATED BIDIRECTIONAL DC-DC CONVERTERS

These converters can regulate a wide range of power from few watts to hundreds of kilowatts. Galvanic isolation is required in certain applications demanding Personnel safety, noise reduction as well as proper operation of protection systems. Also certain systems require voltage matching between the different stages for the proper design and the optimization of different stages. Generally Voltage matching and Galvanic isolation is achieved by the transformer in a power electronic circuitry. This necessitates the requirement of the ac link for the energy transfer. Thus the system complexity grows up with the incorporation of all this features. Basically most of the isolated bidirectional DC-DC converters have the structure as shown in the fig.2

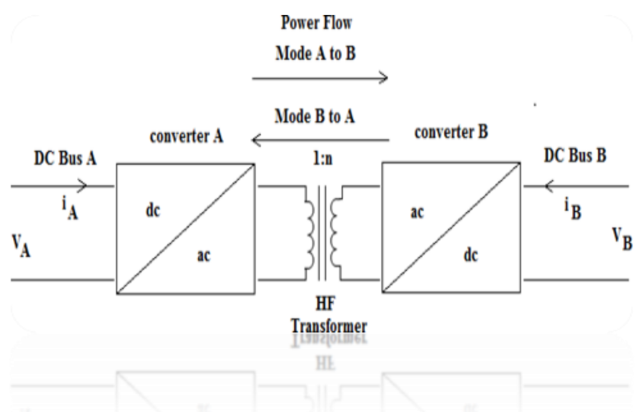

Figure 2: Basic Structure of an Isolated Bidirectional DC-DC Converter

V. CONTROL STRATEGY

The control circuit of the bidirectional converter is shown in Figure 4.To control the speed of the dc drive; one possible control option is to control the output voltage of the bidirectional converter. To control the output voltage of the bidirectional converter for driving the vehicle at desired speed and to provide fast response without oscillations to rapid speed changes a PI controller is used and it shows satisfactory result. In this control technique the motor speed ωm is sensed and compared with a reference speed ωref. The error signal is processed through the PI controller. The signal thus obtained is compared with a high frequency saw tooth signal equal to switching frequency to generate pulse width modulated (PWM) control signals.

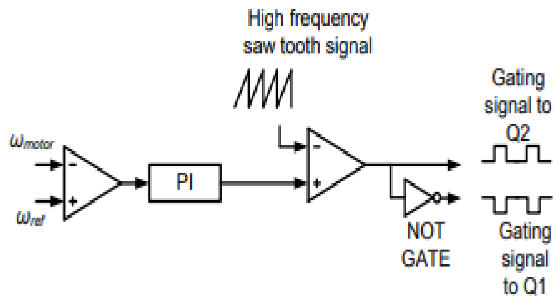

Figure3: Control of the bidirectional dc-dc converter.

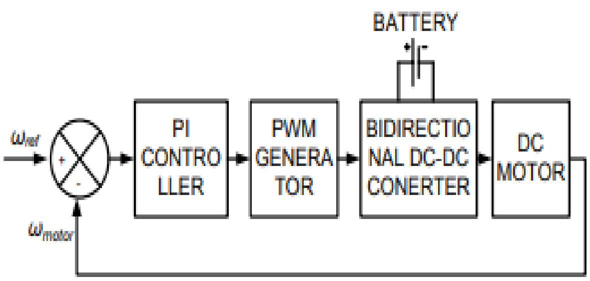

Figure 4. Closed loop operation of the drive.

The block diagram of feedback speed control system for DC motor drive is shown in Figure 5; the control objective is to make the motor speed follow the reference input speed change by designing an appropriate controller. The proportional-integral(PI) controller is used to reduce or eliminate the steady state error between the measured motor speed (ωmotor) and the reference speed (ωref) to be tracked. The transfer function of PI controller is given by –

$$G_c(s) = K_p + \frac{K_i}{s}$$

Where, KP and Ki are the proportional and integral gains. The value of KP and Ki are obtained by using Zeigler Nichols tuning method. Simulink model of the overall system is shown in figure 5.

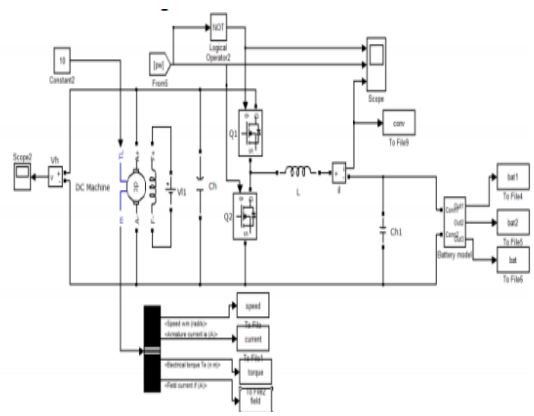

Figure 5. Simulink Model of the Drive system.

VI. BATTERY REQUIREMENT FOR AUTOMOTIVE APPLICATION

Mainly Nickel-Metal hydride (NiMH) and Lithium-ion batteries are used in vehicular application due to their characteristics in terms of high energy density, compact size and reliability. The battery is being recharged by the regenerative capabilities of the electric motors which are providing resistance during braking helping to slow down the vehicle. The lithium-ion battery has been proven to have excellent performance in portable electronics and medical devices .The lithiumion battery has high energy density, has good high temperature performance, and is recyclable. The promising aspects of the Li-ion batteries include low memory effect, high specific power of 300 W/kg, high specific energy of 100 Wh/kg, and long battery life of 1000 cycles. These excellent characteristics give the lithium-ion battery a high possibility of replacing NiMH as next-generation batteries for vehicles. Equation (25) is used to estimate the state of charge (SOC) of the battery.

$$V_{SOC}(t) = V_{SOC}(0) - \frac{1}{C_{CAP}}\int_0^{\tau} i(t)\,d\tau.$$

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