Design of PI Controlled Non Isolated Bidirectional DC to DC Converter for Electric Vehicle Application

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Abstract: Non isolated Bidirectional DC-DC Converter (NIBDDC) is a good interface between DC source and inverter Fed induction motor drive. This paper deals with comparison between open loop and PI controlled Bidirectional DC to DC Converter Inverter System (BDDCIS). The modelling and control of BDDC is becomes an important issue. Open loop BDDCIS and closed loop PI controlled BDDCIS are designed, modelled and simulated using Matlab- simulink and their results are presented. The investigations indicate superior performance of PI controlled BDDCIS. The proposed BDDCIS has advantages like bidirectional power transfer ability, reduced hardware count and improved dynamic response.

1. Introduction

A Minimum Power-Processing-Stage Fuel-Cell Energy System Based on a Boost-Inverter With a Bidirectional Backup Battery Storage Conventionally, series of battery strings are provided to offer high voltage (HV) required for electric vehicle drives[1]. However, the variation in temperature gradient and charging imbalance between the strings leads to degradation in battery life span. Paralleling of battery string may overcome those problems but the significance of that reduces the output voltage [2].

Bidirectional DC-DC separated converters like half and full Bridge gives better voltage increase under venturing here and there and the voltage by changing the transformers turns apportion however the nearness of spillage reactance in the coupling transformer may prompts hazardous HV starts on the working switches at exchanging drifters, expansive copper misfortune and very little suited for extensive voltage variety applications [3, 4]. The development of soft switching techniques in converters paved way for the reduction in transient switching losses [5-7]. The improvement of delicate exchanging systems in converters cleared path for the lessening in transient exchanging misfortunes.
Switched capacitor (SC) power converter can have a reduced size of converter and improved power density however for large voltage gain is required; the size of the switched capacitor must also increase [8]. Consequently, DC-DC converter with high pick up in voltage has achieved numerous analysts intrigue. This work tries to distinguish a superior bidirectional topology for an enlistment engine based EV drive with high voltage pick up. It additionally manages the shut circle controller application to the better converter that prompts a change in the dynamic reaction of the framework.

2. Circuit Analysis

Fig 1 depicts the schematic circuit diagram of the proposed converter. Initially S1 and S2 switches are made on. In this mode, the inductors and capacitor get charged.

\[
\begin{align*}
V_{L1ind} &= V_{low} + V_{cap} \\
V_{L2ind} &= V_{low}
\end{align*}
\]

In the next mode, S3 and S4 switches are on whereas S1 and S2 are made off. Now the stored charges get discharged to the induction motor via 2level inverter. The voltages across L1 inductor and L2 inductor under this mode are as follows.

\[
\begin{align*}
V_{L1ind} &= V_{low} - V_{high} \\
V_{L2ind} &= V_{low} - V_{cap}
\end{align*}
\]

The design formula for calculating the inductors values are shown below

\[
\begin{align*}
L_{1ind} &= \frac{\alpha(2-\alpha)(1-\alpha)^2R_M}{2f_{sw}} \\
L_{2ind} &= \frac{(1-\alpha)^4R_M}{2f_{sw}}
\end{align*}
\]

Here \(V_{low}\) and \(V_{high}\) are the input and stepped up output voltage, \(V_{ind}\) and \(V_{2ind}\) are the inductor voltages, \(V_{cap}\) is the capacitor voltage, \(\alpha\) is the duty ratio and \(R_M\) is the load resistance. Voltage gain for step up mode is given by,

\[
\frac{V_{high}}{V_{low}} = \left(\frac{1}{1-\alpha}\right)^2
\]

3. Simulation Results

3.1 Open loop NIBDDI System

Open loop NIBDDCI system with change in load torque. The motor speed is shown in Fig 2 and its value is 1300 RPM. The speed decreases due to increase in load. The torque developed is shown in Fig 3 and its value is 1.2 N-m. The increase in torque is due to increase in load.
3.2 **NIBDDCI system with PI controller**

Closed loop NIBDDCI system with PI controller is shown in Fig 4. Actual speed is compared with the reference speed and the error is applied to the PI controller. The output of PI is given to the Pulse Generator (PG). The PG updates the width of pulses applied to NIBDDC.
The motor speed is shown in Fig 5. The torque developed is shown in Fig 6 and its value is 4 N-m. The comparison is given in table 1.

![Motor Speed Graph](image1)

**Fig 5 Motor speed**

| Type of Controller | $t_r$(sec) | $t_s$(sec) | $t_p$(sec) | $E_{ss}$(volt) |
|--------------------|------------|------------|------------|----------------|
| OPEN LOOP          | 0.75       | 1.7        | 0.75       | 6.2            |
| PI                 | 0.60       | 1.6        | 0.51       | 5.3            |

**Table 1**: Comparison of Time Domain Parameters

4. **Conclusion**

The BDDCIS is modelled and simulated. The results of BDDCIS are compared with those of bidirectional DC to DC converter inverter system. The performance of BDDCIS is found to be superior to Z BDDCIS. The BDDCIS is investigated with a step change in load torque. The closed loop BDDCIS system with PI is investigated. The settling time with PI is reduced to 0.60 sec and steady state error is reduced to 5.3 RPM. Therefore PI based BDDCIS is superior to open loop based BDDCI system.

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