7.1 INTRODUCTION

The purpose of this research is to analyse the performance of both NBDC and IBDC with low output ripple using suitable control techniques. The implementation of a bidirectional converter fed drive system in HEV application should be designed in such a way to regulate both motoring and regenerative braking operations. This contributes to a substantial increase in the overall efficiency of the drive system. Therefore, the focus of this research is to identify the suitable module for HEV applications among the three proposed converters.

7.2 SUMMARY

The performance of three proposed modules suitable for HEV applications were studied in this research work. The performance of proposed modules is also reviewed with different types of filters, controllers and hysteresis control strategy. The modeling and control of the DC-DC converter is an important issue. Hence, the detail literature survey is accessible to review the closed loop control techniques which are applicable to the modules suggested in this research. The proposed modules are simulated using conventional and SCT based controllers and their performances are compared. This present research is organized into three different modules.
Performance Analysis of NBDC

In order to reduce the switching loss, NBDC is designed using a few passive elements along with the conventional converter. In order to reduce the switching loss, NBDC is designed using a few passive elements along with the conventional converter. The supplementary circuit comprises of a resonant inductor and resonant capacitors. This auxiliary circuit affords ZVS function and it cancels the ripple component present in the main inductor current irrespective of the power flow direction.

Thus there is no additional switch provided for soft switching of the main switch in NBDC. This soft switching is done by using resonant circuit and thus achieves ZVS in the switches $S_1$ and $S_2$. The performance of proposed NBDC was presented in both boost and buck mode with various filters and quad filter is chosen as best among the other two filters used. The NBDC using quad filter produces peak to peak output ripple voltage in boost mode is reduced from 0.09V to 0.0013V whereas in buck mode, the ripple voltage value gets reduced from 0.08V to 0.002V.

The feasibility of the proposed converter is analysed under the control of both open loop and closed loop. Thus, the choice of optimal control for the proposed converter is chosen with neural controller which provides faster response with virtually no overshoots and low steady state error value of 0.10V in boost mode and 0.8V in buck mode when compared to other controllers.

The NBDC with hysteresis controller proposes reduced ripple current of 0.02A in boost mode and 0.35A in buck mode. Thus the performance analysis of NBDC confirms low ripple at its output, better
efficiency and shows good regulation comparatively than the conventional converters. An experimental prototype is implemented for the proposed converter to confirm its stability.

❖ Performance Analysis of NBDCCI

The configuration of the NBDCCI consists of two switches namely $S_1$ and $S_2$ and has a coupled inductor whose winding turns remains the same in both primary and secondary side. Switch $S_3$ acts as synchronous rectifier. The PWM technique is implemented to control the gating signals of the switches.

The performance of proposed NBDCCI was presented with various filters. Comparative analysis was done for both boost and buck mode. Among the three filters used, quad filter is chosen as the best which greatly reduces peak to peak ripple voltage. Using quad filter, the ripple output voltage is reduced to 0.001V in boost mode and in buck mode, it gets reduced to 0.0015V. From the results, it can be seen that the ripple cancellation is better when compared C-filter and Pi-filter.

The performance of proposed NBDCCI is also analysed under open loop and closed loop control. The converter is analysed with step change in input of 15V to 20V in boost mode whereas in buck mode, it is incremented to 30V to 30.3V and their corresponding results are presented. The choice of optimal control for proposed NBDCCI is identified with neural controller which provides improved performance when compared to fuzzy and other classical controllers.

The proposed NBDCCI was also simulated with suitable control strategy like hysteresis controller in order to improve the dynamic response of
the converter. The NBDC with hysteresis controller proposes reduced ripple current to 0.051A and 0.38A in boost and buck mode respectively.

Simulation results were analyzed and compared with the results obtained using hardware circuits and the simulation model is validated. The proposed topology achieves high efficiency by reducing high-voltage spike and output current oscillations.

❖ Performance Analysis of IBDC

In this proposed module, the first stage of a Dual active bridge (DAB) converter is connected to a single-phase rectifier. This rectifier is used to convert the AC voltage of grid to a fixed DC voltage. The output of the DAB converter is connected to inverter which in turn drives the load. The switches present in this converter design are subjected to lower value of the switch current than the switches present in the conventional bidirectional converter.

The performance of proposed IBDC was presented with the help of C, Pi and Quad filters. Comparative analysis was presented for both boost and buck mode. From the ripple voltage output, it is concluded that quad filter is more suitable for the proposed converter. The efficiency of the designed converter is verified by implementing various controllers. From the performance measures, neural network based controller is proven to be more suitable which provides faster response with no overshoots and low steady state error value of 0.002Volts in boost mode and 0.002Volts in buck mode when compared to other controllers.
The dynamic performance is further improved by designing the proposed module with HC. The IBDC with hysteresis controller proposes reduced ripple current to 0.047A and 0.003A in boost and buck mode respectively. The experimental results are also verified with the simulation results so as to validate the converter.

Apart from the performance analysis of the converter with all the controllers, the efficiency of the three proposed modules is verified with both RLE and BLDCM load through inverter unit. The presented calculations and measurements affirm a comparable efficiency of the proposed NBDC, NBDCCI and IBDC.

Thus, the dynamic performance of these three modules over the classical converter is clearly demonstrated by both simulation and experiment. From the results, it is clearly proven that the performance of NBDCCI with both the loads is good when compared with other two modules. The THD of the system is very low and at the same time, the torque of 15.21Nm and mechanical output power of 586.3Watts are high. This in turn increases the life time of the components present in the system.

The motor drive should have high performance while designing for HEV applications. This can be achieved by implementing a BDC. The tasks have been completed in this work are listed as follows,

✓ Three different types of bidirectional DC-DC converters (NBDC, NBDCCI and IBDC) have been analysed.
✓ Incorporated ZVS-PWM technique to reduce the ripple losses in the converter.
✓ Developed MATLAB simulink models for SCT based FLC and Neural controlled systems.
✓ Developed MATLAB simulink models for FPID controlled systems.
✓ Proposed NBDCCI for BLDCM drive.
✓ Proposed HC in the converter to reduce output current ripple.

Therefore from the analysis, it is observed that NBDCCI is identified as the most attractive concept of the investigated converters. Hence, it is concluded that the proposed NBDCCI converter is more suitable for HEV applications when compared to other two proposed modules.

7.3 SCOPE FOR FUTURE WORK

✓ The proposed techniques discussed can be implemented in Microgrid systems.
✓ The investigations can be expanded by introducing advanced SCT based controllers for BLDC fed drive systems.
✓ Research on the Power management strategy will be incorporated.