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Modular Multilevel Converter for Battery Electric Vehicles

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Abstract: *New advanced power conversion systems play an essential role in the extension of range and life of batteries. This project proposes a modular multilevel converter with embedded electrochemical cells that achieves very low cell unbalancing without traditional balancing circuits and a negligible harmonic content of the output currents. In this topology, the cells are connected in series by means of half-bridge converters, allowing high flexibility for the discharge and recharge of the battery. The converter features a cell balancing control that operates on each individual arm of the converter to equalize the state of charge of the cells. The project shows that the proposed control does not affect voltage output, even for significantly unbalanced cells. The viability of the proposed converter for battery electric vehicles and the effectiveness of the cell balancing control are confirmed by numerical simulations and experiments on prototype.*

Keywords: *Battery Electric Vehicles, Modular Multilevel Converters ,Battery Management System*

I. Introduction

The usage of vehicles is increasing day by day. As the vehicles are fed by fossil fuels such as petrol and diesel which cause air pollution leading to global warming and related issues. More over fossil fuels are no longer a reliable source of energy as they are fastly exhausting. So here comes the role of electric vehicles which use. Electrical vehicles (EVs) are attractive alternatives to conventional petrol and diesel internal combustion engine counterparts because they produce zero emissions at the exhaust pipe. The electric vehicle consists of a conventional internal combustion(IC) engine and an electric motor part. For the electric part we make use of a converter, electric motor and a battery. However, they are limited by the short range due to the limited amount of energy stored in the electrochemical batteries. Electric vehicles are a less mature technology with still large margins for improvements, especially in the area of energy storage devices and electric drives. The diffusion of EVs could be significantly improved with a better use of the available energy, and this could be achieved making the power conversion system more and more light, compact, flexible and reliable. This work tackles this problem by introducing a converter topology that enables a better exploitation of battery cells and improve the efficiency of the power conversion system. This project proposes a new modular multilevel converter (MMC) with embedded electrochemical cells that achieves very low cell unbalancing without traditional balancing circuits and a negligible harmonic content of the output currents. In this new topology, the cells are connected in series by means of half-bridge converters, allowing high flexibility for the discharge and recharge of the battery. The converter features a cell balancing control that operates on each individual arm of the converter to equalize the state of charge of the cells.[2]

Numerous industrial applications have begun to require higher power apparatus in recent years. Some medium voltage motor drives and utility applications require medium voltage and megawatt power level. For a medium voltage grid, it is troublesome to connect only one power semiconductor switch directly. As a result, a multilevel power converter structure has been introduced as an alternative in high power and medium voltage situations. A multilevel converter not only achieves high power ratings, but also enables the use of renewable energy sources. Renewable energy sources such as photovoltaic, wind, and fuel cells can be easily interfaced to a multilevel converter system for a high power application the elementary concept of a multilevel converter to achieve higher power is to use a series of power semiconductor switches with several lower voltage dc sources to perform the power conversion by synthesizing a staircase voltage waveform. Capacitors, batteries, and renewable energy voltage sources can be used as the multiple dc voltage sources. The commutation of the power switches aggregate these multiple dc sources in order to achieve high voltage at the output.

II. Converter Structure And Operation Principle

The layout of proposed modular multilevel converter is given in the Fig.1. In a single phase MMC, each of the phase units consists of two multi valve, and each multivalve consists of *n* submodule(SM) connected in series where the SMs consist of a single electrochemical cell with a half-bridge converter. Due to voltage level of SMs, low-voltage MOSFETs can be used as power switches to reduce conduction and switching losses of the converter. For this reason, fast switching antiparallel diodes are avoided and the body diodes of the MOSFETs conduct only during the dead-time between the commutations.[1]

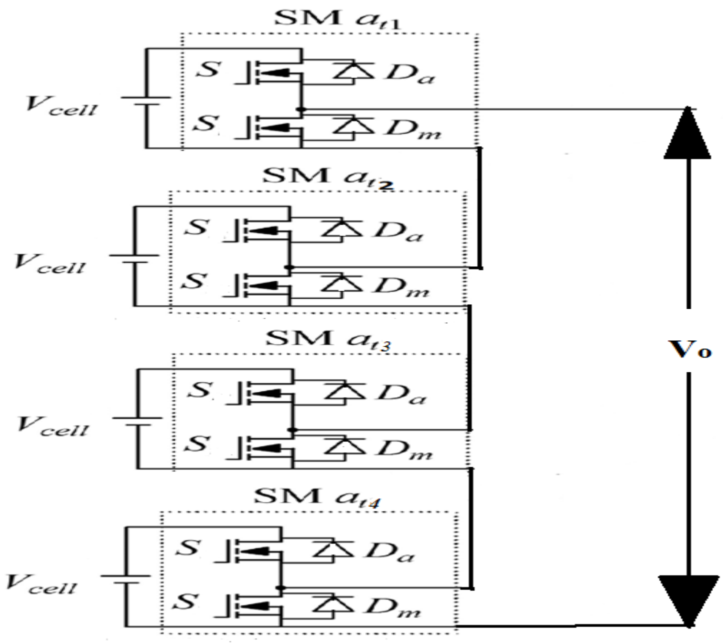

Fig.1 ,Layout of proposed MMC

The operation principle of the bidirectional half-bridge chopper cell can be explained with reference to Fig. 1. When the switch *Sa* is turned ON, the output voltage *Vo* is equal to the cell voltage *Vcell* . If the switch *Sm* is turned ON instead, *Vo* is equal to zero .The maximum voltage on each arm is *Varm,max* = *n Vcell* , being *Vcell* the nominal voltage of a single electrochemical cell and *n* the number of SMs for each arm. The two arms of each leg are controlled complementarily in order to keep constant the voltage between the positive and the negative busbars.

III. Simulation Results

The operating characteristics of the proposed MMC with embedded battery cells have been tested by means of numerical simulations. The simulation was based on by using MATLAB and Simulink. The converter has 4 cells, i.e., 2 cells for each arm, the nominal voltage of the single cell equals to 12V. In order to increase the efficiency of the conversion system, a larger number of cells should be used, allowing the connection of higher voltage loads. Moreover, a larger number of cells would improve further the voltage waveforms in terms of harmonic content.

Fig. 2 , Steady state voltage of single phase system

IV. Hardware Analysis

The MMC has been experimentally tested by using laboratory prototype. The prototype is a three level MMC with two submodules in each arm and has a total of four submodules. Each submodule is connected to dc voltage source.The prototype of three level MMC is shown in Fig .11

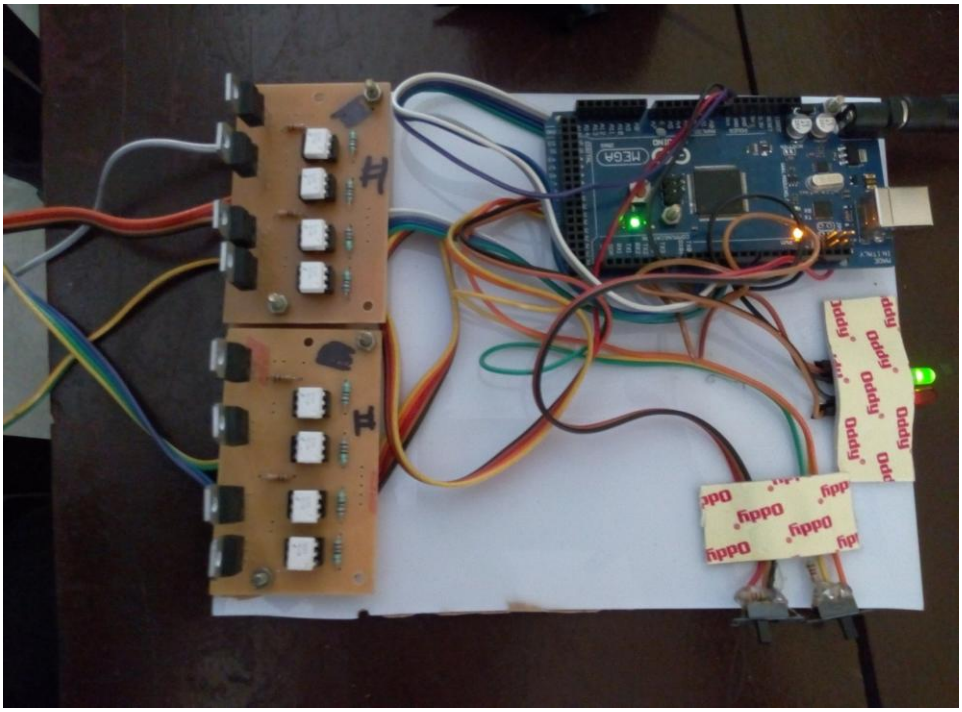

Fig. 3 , Prototype of single phase system

V. Conclusion

A modular multilevel topology with embedded electrochemical cells for BEVs has been presented in this paper. Modular structured multilevel inverter is very attractive in battery vehicle applications. The large number submodules increase the number of levels of the output voltages and it strongly reduces the THD of motor currents, reducing power losses of the motor. The MMC is therefore a suitable candidate to eliminate the balancing circuits of the battery pack of electric vehicles because in new concept the battery cells are directly embedded in the power converter.

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