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Intelligent Control Based Cascaded Multiport Converter for SRM based Hybrid Electrical Vehicles

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Abstract: This article about a cascaded multiport switched reluctance motor (SRM) drive for hybrid electric vehicle (HEV), which gives two performances first thing flexible energy conversion among the generator/ac grid, the battery bank, solar panel and the motor, second achieves battery management (BM) function for state-of-charge (SOC) balance control and bus voltage regulation. SRM accelerate the excitation and demagnetization processes during the commutation region, extend the speed range, reduce the voltage stress on the switches, and improve the torque capability and system efficiency by integrating the battery packs into the AHB converter, the cascaded BM modules are designed to configure multilevel bus voltage and current capacity for SRM drive. It includes different operation requirements like the multiple driving modes, regenerative braking modes, and charging modes. The feasibility and effectiveness of the proposed cascaded multiport SRM drive are verified by the simulation experiment on a three-phase SRM.

Index Terms—**Fuzzy Logic Control (FLC), Cascaded multiport converter, battery management (BM), state-of-charge (SOC) balance, switched reluctance motor (SRM), hybrid electric vehicles (HEVs).**

1. INTRODUCTION

Need of suitable and reliable use of energy resources safer & pollution free options are being search out all time. Electric vehicles are a one of the technology for reducing air, sound pollution and CO_2, CH_4, NO_2emission. There are different types of electric motors that can be used for vehicle which via induction motor, dc series motor, brushless dc motors and switched reluctance motors. Comparisons of all the above motors are higher cost& have complex construction due to the presence of distributed winding except SRM. The capabilities of the SRM such as simple & rugged construction with concentrated winding on the stator and maintenance free rotor, four quadrant operation, fault tolerance, high efficiency & reliability.

Below could be a literature review of works distributed in previous few years for the Design and Performance Analysis of cascaded multiport converter for EV. S. Kimura in this DC to DC back connection makes down the size of magnetization and demagnetization .that control all components over high power density. D. Moon in that rolls of current source inverter at multilevel is important. The new configuration is adopted for drastically change in reduction in high current for output side for electrical vehicle motor. A. Kulvanitchaiyanunt in this gives best guidelines about control regional hybrid electrical vehicle station. The program supported to system run linearly follows. L. Herrera in that networked control and small signal modeling of charging facility for EV With the need to supply clean, renewable energies, integrations of Distributed Energy Resources (DERs) into Plug in Hybrid Electric Vehicle (PHEV) charging facilities are expected.

2. Proposed Converter Topology

To achieve the high-efficiency energy conversion among the generator/ac grid, the battery bank, solar panel and the SRM for HEV applications, a highly integrated multiport converter is proposed with BM function, as shown in Fig. 1.A relay *J* is used to connect the generator and the rectifier; a plug is used to connect the ac grid, and three BM modules. It looks like that the generator/ac plug, solar panels the ac/dc rectifier, the BM modules, and the AHB converter in series. Hence, the proposed converter can be containing as the combination of a front-end circuit and an AHB converter. The generator can act as a starter motor, as well as be used to charge the battery bank and power the SRM. The battery bank can also be charged by the SRM, solar PV power and the ac grid. The SRM can be powered by the battery bank orderly or overly. For separately managed and composed of a battery pack and three power switches with anti-parallel diode which help to improve the flexibility and reliability of the battery packs, more BM modules can be designed. By using the proposed topology, number of driving modes, regenerative braking modes, and charging modes are achieved to satisfy different operation conditions.

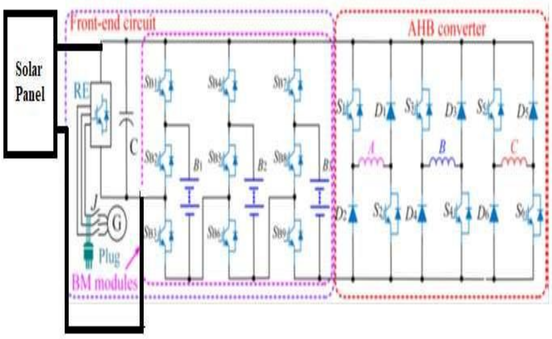

Fig 1 Proposed Converter Topology

3. Control Strategies of the Proposed Converter

(a) CONTROL STRATEGY UNDER DRIVING MODES

There are two control strategies are used in the SRM drive system via including current chopping control (CCC) and voltage- PWM control (VPC). Fig. 2 presents a block diagram of SRM control system. A position encode is helped to detect the rotor position for commutation control and speed calculation. A proportional integral (PI) controller is employed for speed closed- loop control. The control mode switch is used to select the control strategies according to speed reference. The driving mode is employed to driving the motor. Under driving mode, the CCC and VPC control strategies are chosen according to the motor speed.

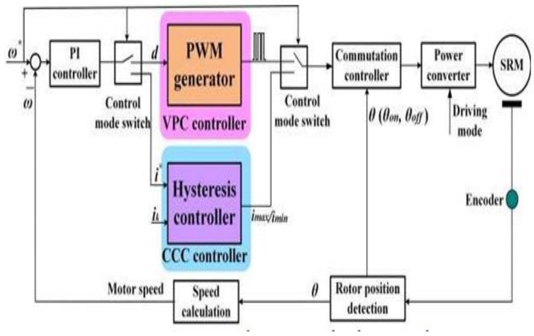

Fig 2 Control strategy under driving modes

(b) CONTROL STRATEGY UNDER REGENERATIVE BRAKING MODES

The SRM control system is analyzed by Fig. 3, when the motor is under the regenerative braking mode. To avoid the over current damage and implement the pulsed charging process, the CCC is employed to regulate the phase current. According to braking operation, the different braking current can be set for the inertial braking, slow braking, and quick braking. However, the energy stored in the phase windings can be used to charge the battery packs.

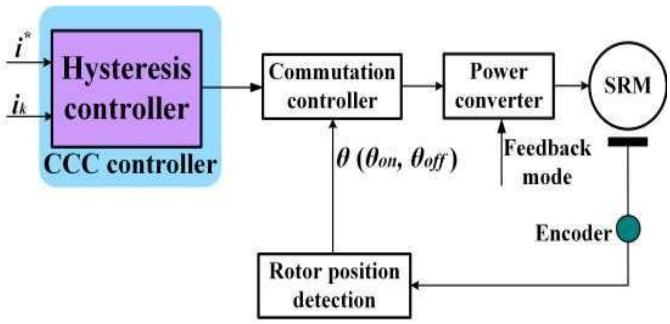

Fig 3 Control strategy under regenerative braking modes

(c) CONTROL STRATEGY UNDER CHARGING MODES

The proposed converter can act as a charger to charge the batteries. The charging process can be arranged into three steps according to the SOC, as shown in Fig. 4.

In step 1-(0<SOC<SOC1) which means that the battery pack is under extreme energy loss condition. To protect the battery from vital damage, the pre-charge stage is necessary and a lower constant-current (i.e. i_{ref1}) charging mode is

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employed to protect the battery packs.

In step 2-(SOC1<SOC<SOC2) a standard constant-current (i.e. *i*ref2) charging mode is employed. In step3- (SOC2< SOC < 100%) to assurance the battery pack are fully charged, a constant-voltage charging mode is adopted.

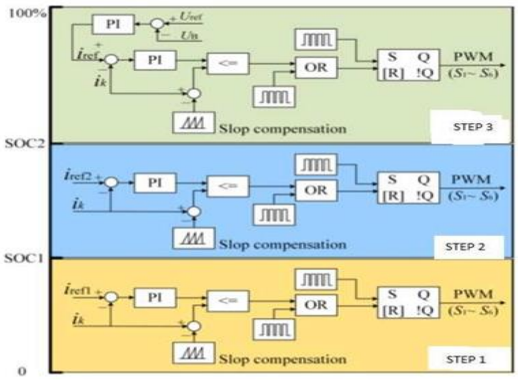

Fig 4 Control strategy under charging modes

4. SOC BALANCE CONTROL

Hence, the SOC difference among the three battery packs may be caused for the proposed converter topology, according to the operation conditions, the optimal voltage level will be achieved to power the motor. To protecting the battery packs from over discharge issue, the SOC balance control is important under driving modes as well as to protect the battery packs from the overcharge issue. The SOC balance control is also necessary under regenerative braking and standstill charging modes.

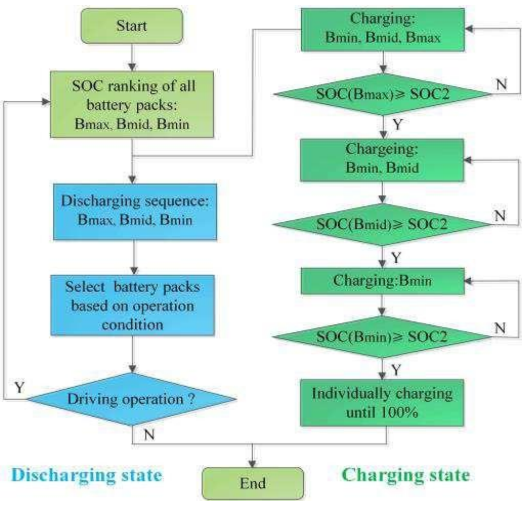

Fig 5 SOC balance control strategy

5. FUZZY LOGIC CONTROL

L. A. Zadeh presented the first paper on fuzzy set theory in 1965. Since then, a new language was developed to describe the fuzzy properties of reality, which are very difficult and sometime even impossible to be described using conventional methods. Fuzzy set theory has been widely used in the control area with some application to power system [5]. A simple fuzzy logic control is built up by a group of rules based on the human knowledge of system behavior. Matlab/Simulink simulation model is built to study the dynamic behavior of converter. Furthermore, design of fuzzy logic controller can provide desirable both small signal and large signal dynamic performance at same time, which is not possible with linear control technique. Thus, fuzzy logic controller has been potential ability to improve the robustness of compensator. The basic scheme of a fuzzy logic controller is shown in Fig.3 and consists of four principal components such as: a fuzzy fication interface, which converts input data into suitable linguistic values; a knowledge base, which consists of a data base with the necessary linguistic definitions and the control rule set; a decision-making logic which, simulating a human decision process, infer the fuzzy control action from the knowledge of the control rules and linguistic variable definitions; a de-fuzzification interface which yields non fuzzy control action from an inferred fuzzy control action [10].

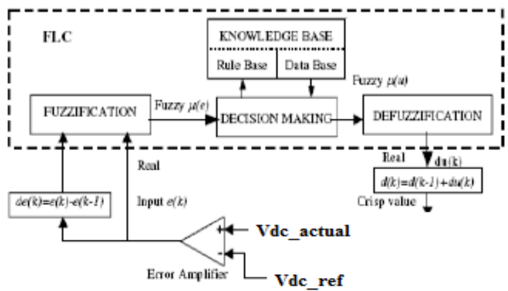

Fig.6. Block diagram of the Fuzzy Logic Controller (FLC).

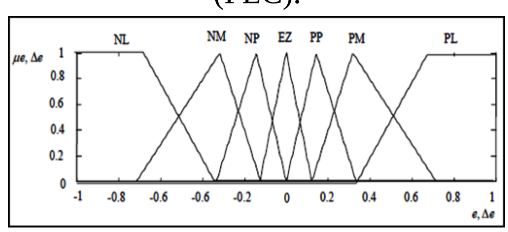

Fig.7 Membership functions for Input, Change in input, Output.

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Rule Base: the elements of this rule base table are determined based on the theory that in the transient state, large errors need coarse control, which requires coarse in-put/output variables; in the steady state, small errors need fine control, which requires fine input/output variables. Based on this the elements of the rule table are obtained as shown in Table 1, with „V_{dc}" and$V_{dc\text{-}ref}$ as inputs.

This section presents a flexible control strategy to improve the performance of DSTATCOM in presence of the external inductor *L*ext. First, a dynamic reference load voltage based on the coordinated control of the load fundamental current, PCC voltage, and voltage across the external inductor is computed. Then, a proportional-integral (PI) controller is used to control the load angle, which helps in regulating the dc bus voltage at a reference value. Finally, three-phase reference load voltages are generated. The block diagram of the control strategy is shown in Fig. 6.

Table .1

Δe \ e	NL	NM	NS	EZ	PS	PM	PL
NL	NL	NL	NL	NL	NM	NS	EZ
NM	NL	NL	NL	NM	NS	EZ	PS
NS	NL	NL	NM	NS	EZ	PS	PM
EZ	NL	NM	NS	EZ	PS	PM	PL
PS	NM	NS	EZ	PS	PM	PL	PL
PM	NS	EZ	PS	PM	PL	PL	PL
PL	NL	NM	NS	EZ	PS	PM	PL

6. MATLAB Simulink Results

Most power full tool for analysis of converter topology MATLAB 2011a is employed. It takes time while compile because of lots of switching operation done through software its demerits of simulation.

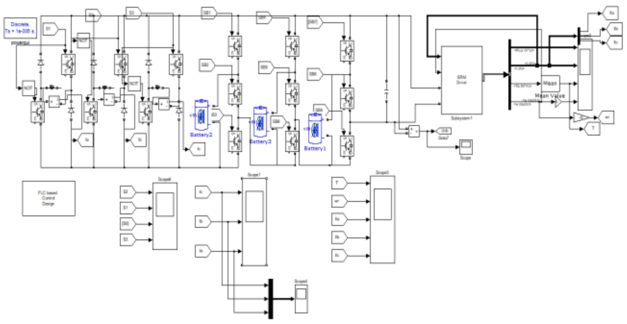

Fig 8 MATLAB simulation diagram

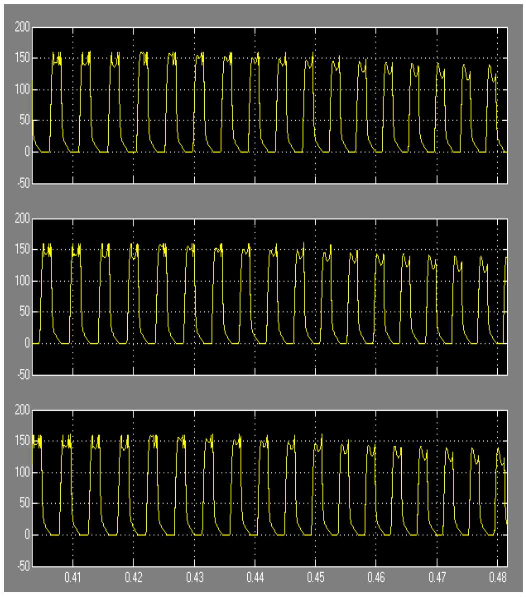

Fig 9 Simulation waveforms of the line currents

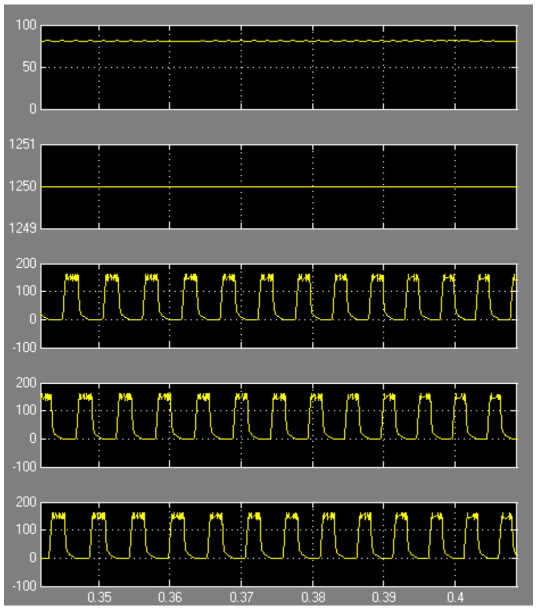

Fig 10 Simulation waveforms of the proposed method torque (Te),Speed (Wr), Load Currents (Ilabc)

Vabc 13, Vabc7, Vabc3 SOC charging discharging curve SOC>80 then discharge n <80 charging mode select as one battery fully charged then other will start too charged. Charged battery will go in discharge mode. Scopen rpm will show motor speed.

Conclusion

In this study, a cascaded multiport converter is proposed for the SRM-based HEV. By adopting the battery packs into the AHB converter, the reliable energy conversion is achieved among the generator/ac grid, solar panel, the battery packs, and the motor. Number of driving modes, regenerative braking modes, and charging modes can be flexibly selected in the proposed integrated converter topology. The converter has the capability of providing the demanded power by load in absence of one or two resources. The promising performance of the converter and employed control method offer a high reliability for utilizing the converter in industrial and domestic applications

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