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A MULTI PORT CONVERTER WITH FLEXIBLE ENERGY CONVERSION IN DIFFERENT DRIVING MODES APPLICATION IN SRM'S

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ABSTRACT
Cascaded multiport switched reluctance motor (SRM) drives are used in hybrid electric vehicle (HEV) applications because they allow for flexible energy conversion between the generator/ac grid, the battery bank, and the motor. They also perform battery management (BM) functions for state-of-charge (SOC) balance control and bus voltage regulation. AHB converter, the cascaded BM modules are intended to configure multilevel bus voltage and current capacity for SRM drive, which can accelerate the excitation and demagnetization processes during the commutation region, increase the speed range, lessen the voltage stress on the switches, increase the torque capability, and improve system effectiveness. The battery bank is used in generator operating mode to raise the phase voltage for quick stimulation and demagnetization. The capacitor is used as an extra charge capacitor and the converter is rebuilt as a four-level converter in battery operating mode to generate multiple voltage outputs, increasing the torque capacity. The suggested drive's working modes are described, and a thorough analysis of the phase current and voltage is done. By using the demagnetization current while driving and the regenerative current while stopping, the battery is automatically charged. Furthermore, when the car is at a complete stop, the suggested converter allows the battery to be charged by an exterior AC source or generator. By balancing the engine and battery power flows, the SRM-based PHEV can run at various rates. The efficacy of the suggested converter topology is confirmed by simulation in MATLAB/Simulink and tests on a three-phase 12/8 SRM.

INTRODUCTION
Over the decades, electrified vehicles (EVs) have drawn increasing attention due to the rapid depletion of fossil-fuel supplies and increasing exhaust gas emissions in urban contexts. Hybrid electric cars (HEVs) and plug-in hybrid electric vehicles (PHEVs) offer a lot of promise and more flexibility because they are a compromise between vehicles driven solely by batteries and those powered by internal combustion engines (ICE). Permanent-magnet synchronous motors, also known as PMSMs, are a popular choice for motor drive technology in hybrid electric vehicle (HEV) and plug-in hybrid electric vehicle (PHEV) applications.

However, the magnets in PMSMs typically make use of rare-earth materials, which limits their widespread application in the mass production market. As a direct consequence of this, alternative technologies for rare-earth-free or rare-earth-less solutions have been under intense demand. Switching reluctance motors (SRMs) are recognized to have a simpler and more durable structure without any rotor windings and permanent magnets. They can give a longer service time in severe settings and a more cost-effective motor drive choice than PMSMs. In addition, due to additional inherent benefits, such as high efficiency, high reliability, excellent fault-tolerance ability, and high starting torque in initial accelerations, SRMs are considered to be a competitive candidate for high-efficiency and plug-in hybrid electric vehicle (HEV) and plug-in hybrid electric vehicle (PHEV) electric propulsions.

In order to make the SRM system more reliable, techniques of control and fault tolerance schemes that do not require a position sensor have been developed for use in safety-critical applications. New direct torque control systems have been presented as a solution to this problem in order to lessen the ripple that the SRM torque causes. In addition, certain cutting-edge technological solutions have been presented as a means of enhancing the motor's overall efficiency and decreasing the amount of vibration that it causes in automobile settings. However, the integrated SRM converter topology for PHEV applications that would have many functionalities has not yet been established. In general, a compact and dependable inverter/converter is required for electric vehicle traction drives. SRMs have inspired the development of a few novel converter topologies in recent years. In the article, a revolutionary three-phase SRM drive with charging functions is given. These charging functions include charging an ICE as well as charging the grid. Nevertheless, the fast excitation and fast demagnetization cannot be performed, and this converter is derived from a C-dump converter, which has no fault-tolerance capabilities due to non- isolated phases in the converter circuit. In, the SRM drives are powered by a dc/dc converter, and a voltage-boost controller was developed to improve the winding current and speed dynamic responses of the SRM. The power density of dc/dc converters is typically decreased as a result of the presence of inductors and capacitors within the device.

PROPOSED SYSTEM CONFIGURATION

Hybrid electric vehicle (HEV) applications use cascaded multiport switched reluctance motor (SRM) drives, which not only enable flexible energy conversion between the generator/ac grid, the battery bank, and the motor but also accomplish battery management (BM) function for state-of-charge (SOC) balance control and bus voltage regulation. AHB converter, the cascaded BM modules are designed to configure multilevel bus voltage and current capacity for SRM drive, which can 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.

This chapter deals with the history, construction, working principle, operation, frequency variation of inductance, energization design and mathematical modeling of Switched Reluctance Motor (SRM). Besides, various converter topologies, rotor position sensor, control aspects of SRM,

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advantages, disadvantages and applications are also discussed. The detailed literature survey of the reference papers and the problems identified based on the literature survey are also presented in this chapter. Electrical drives play an important role in modern industries. In the last two decades, a new type of electrical drive named the SRM drive has been introduced and is closely monitored. The SRM drive has now reached a level of maturity that it allows to be used in industry as an efficient brushless drive with the cost advantages, a wide speed range and an inherent simplicity and ruggedness. However, the SRM is not a new concept because early inventors of electromagnetic engines understood the SRM principle, but were unsuccessful in their attempts to build a motor owing to its poor electromagnetic and mechanical designs and the unavailability of suitable switching devices. An interest in switched field machines was revived in the 1960's with the advent of the Thyristors. In the early 1980’s, the first SRM drive system using the new technology became commercially available as a result of work done by a group at Leeds and Nottingham Universities in the U.K. In recent years, this machine has shown a revival of interest for applications in 10 W and medium power drives. Such a machine is emerging 2 as an attractive solution for variable speed applications due to several advantages. Most prominent among these are, the simple structure of the motor with coils on the stator and no windings or brushes on the rotor.

An inverter is an electrical device that converts direct current (DC) to alternating current (AC); the converted AC can be at any required voltage and frequency with the use of appropriate transformers, switching, and control circuits. Static inverters have no moving parts and are used in a wide range of applications, from small switching power supplies in computers, to large electric utility high-voltage direct current applications that transport bulk power. Inverters are commonly used to supply AC power from DC sources such as solar panels or batteries.

The electrical inverter is a high-power electronic oscillator. It is so named because early mechanical AC to DC converters was made to work in reverse, and thus were "inverted", to convert DC to AC.

Multilevel cascaded inverters have been proposed for such applications as static var generation, an interface with renewable energy sources, and for battery-based applications. Three- phase cascaded inverters can be connected in wye, as shown in Figure, or in delta. Peng has demonstrated a prototype multilevel cascaded static var generator connected in parallel with the electrical system that could supply or draw reactive current from an electrical system.

The inverter could be controlled to either regulate the power factor of the current drawn from the source or the bus voltage of the electrical system where the inverter was connected. Peng and Joos have also shown that a cascade inverter can be directly connected in series with the electrical system for static var compensation. Cascaded inverters are ideal for connecting renewable energy sources with an ac grid, because of the need for separate dc sources, which is the case in applications such as photovoltaics’ or fuel cells. Cascaded inverters have also been proposed for use as the main traction drive in electric vehicles, where several batteries or ultra-capacitors are well suited to serve as SDCSs. The cascaded inverter could also serve as a rectifier/charger for the batteries of an electric vehicle while the vehicle was connected to an ac supply as shown in Figure. Additionally, the cascade inverter can act as a rectifier in a vehicle that uses regenerative braking.

The Chevrolet Volt is the world's top selling plug-in hybrid vehicle. Global combined volt/ampere family sales a Plug-in Hybrid Electrical Vehicle (PHEV) is a hybrid electric vehicle whose battery can be recharged by plugging it into an external source of an electric power as well by its on-board engine and generator. Most PHEV's are passenger cars, but there also PHEV versions of commercial vehicles and vans, utility trucks, busses, trains, motor cycles, scooters and military vehicles. Similarly, to all-electric vehicles, plug-in hybrids displace emissions from the car tailpipe to the generators powering the grid. These sources may be renewable or may have lower emission than an internal combustion engine. Charging the battery from the grid can be lower cost than using the on-board engine, helping to reduce operating cost.

Mass-produced plug-in hybrids were available to the public in China and the United States in 2010. By the end of 2016, there were over 30 models of series-production highway legal plug-in hybrids for retail sales. Plug-in hybrid cars are available mainly in the United States, Canada, Western Europe, Japan, and China. Top-selling models were the Chevrolet Volt family, the Mitsubishi Outlander P-HEV, and the Toyota Prius PHV.

PHEVs typically require deeper battery charging and discharging cycles than conventional hybrids. Because the number of full cycles influences battery life, this may be less than in traditional HEVs which do not deplete their batteries as fully. However, some authors argue that PHEVs will soon become standard in the automobile industry. Design issues and trade-offs against battery life, capacity, heat dissipation, weight, costs, and safety need to be solved. Advanced battery technology is under development, promising greater energy densities by both mass and volume, and battery life expectancy is expected to increase.

The cathodes of some early 2007 lithium-ion batteries are made from lithium-cobalt metal oxide. This material is expensive, and cells made with it can release oxygen if overcharged. If the cobalt is replaced with iron phosphates, the cells will not burn or release oxygen under any charge. At early 2007 gasoline and electricity prices, the a break-even point is reached after six to ten years of operation. The payback period may be longer for plug-in hybrids, because of their larger, more expensive batteries.

Nickel–metal hydride and lithium-ion batteries can be recycled; Toyota, for example, has a recycling program in place under which dealers are paid a US$200 credit for each battery returned. However, plug-in hybrids typically use larger battery packs than comparable conventional hybrids, and thus require more resources. Pacific Gas and Electric Company(PG&E) has suggested that utilities could purchase used batteries for

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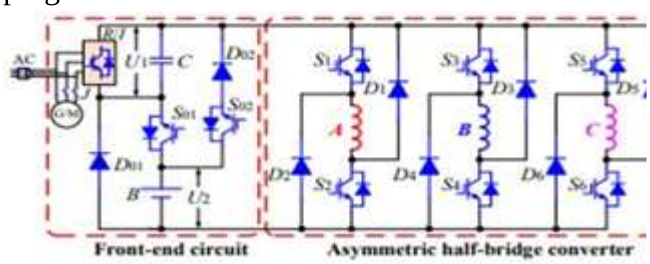
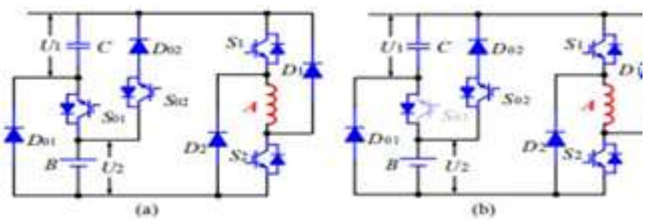
backup and load leveling purposes. They state that while these used batteries may be no longer usable in vehicles, their residual capacity still has significant value. More recently, General Motors (GM) has said it has been "approached by utilities interested in using recycled Volt batteries as a power storage system, a secondary market that could bring down the cost of the Volt and other plug-in vehicles for consumers."





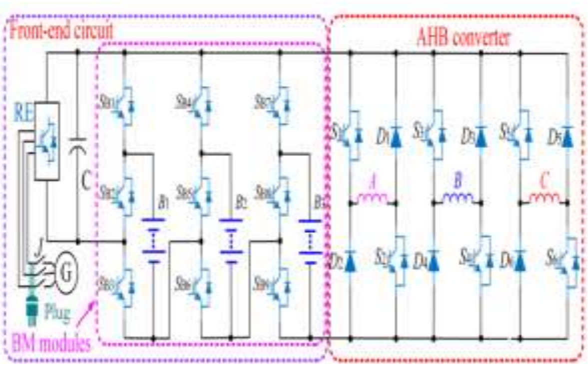
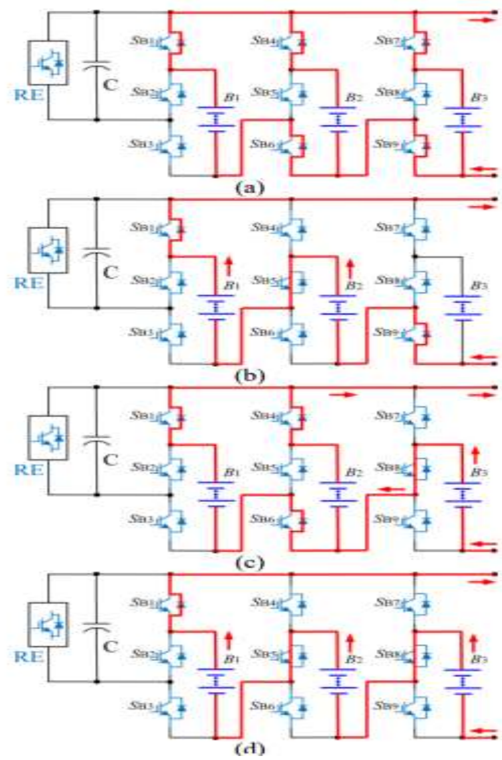


Fig1 Proposed multiport converter



Working conditions of the front-end circuit by the battery packs. (a) Mode 1. (b) Mode 2. (c) Mode 3. (d) Mode 4.Operation Principle of Driving Modes for SRM, Driving Modes by the Generator, Driving Modes by the Battery Packs, Driving Modes by the Generator and Battery Packs.

In order to validate the effectiveness of the proposed converter topology, a 750-W SRM is prototyped using the same parameters in simulation. The photograph of the experimental setup is shown in Fig 8.2. The motor is driven by the proposed converter with the front-end circuit. The IGBT module (IKW75N60T) with a fast recovery anti-parallel diode inside is used to construct the proposed converter topology. An adjustable dc power supply with 80 V is utilized to simulate the power source from the generator. A 48 V lead-acid battery bank is employed as

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the energy storage equipment. The rotor position is identified by using a 2500-line incremental encoder. A dsPACEDS1006 platform is employed as the main controller with peripheral high-speed logic circuits in the setup. A magnetic brake is used to give the load to SRM. The phase currents are detected from the Hall-effect current sensors (LA-55P) and simultaneously sampled by 14-bit A/D converters to implement the current control scheme.

SIMULATION RESULT

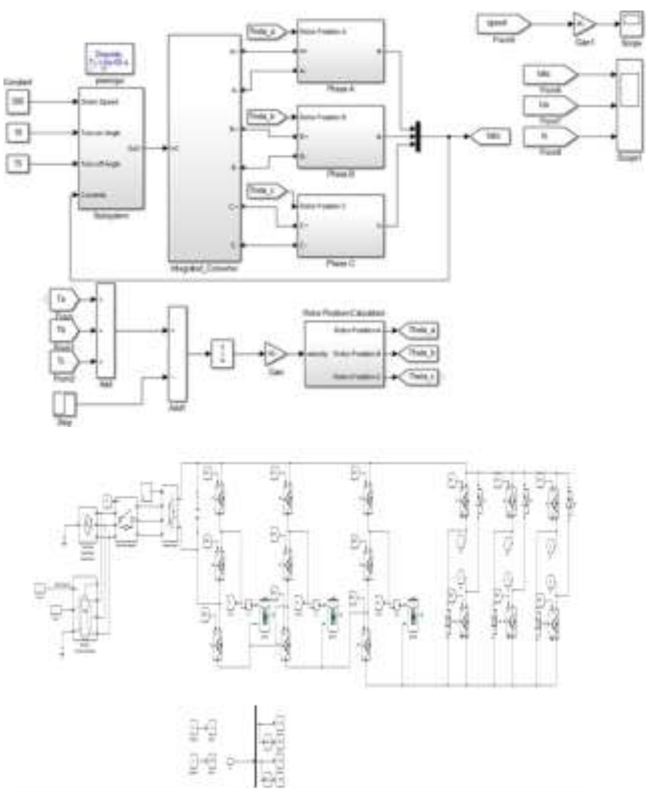

Fig 1 simulation circuit

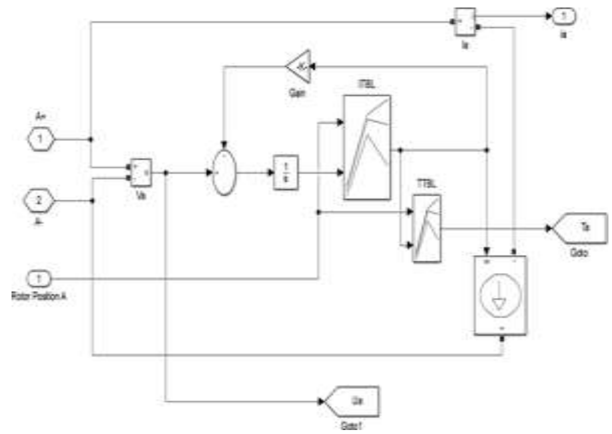

Fig2. Srm equivalent circuit of each phase

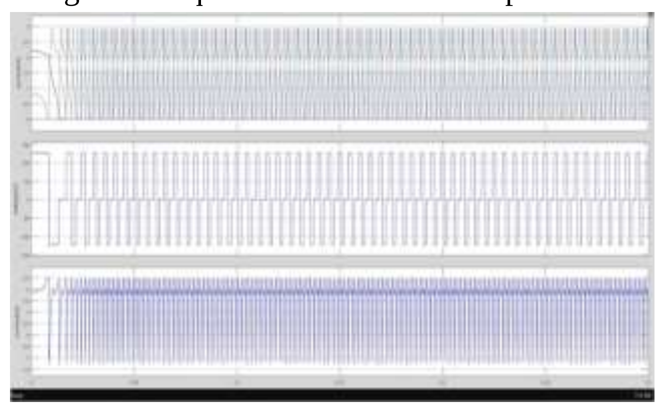

Fig 3. Output voltage current and converter voltage

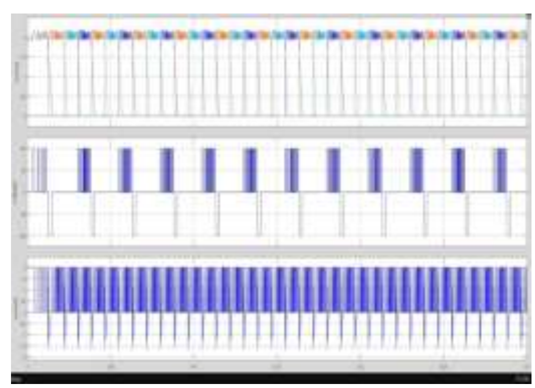

Fig4. Zoom in three phase srm voltages and currents

CONCLUSION

In this paper, a new SRM drive fed by a modular front-end circuit is proposed for

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PHEV applications. Multimode and multilevel voltages are achieved by controlling the on-off state of the switches in the front-end circuit. The excitation modes and demagnetization modes of the proposed converter are presented, and the voltage and current in different working states are analyzed in details. Compared to the existing schemes, an improved front-end circuit is employed for multilevel voltage and multimode operations using less power devices and simpler control algorithm. The proposed topology is easy to manufacture and replace due to its modularized structure. The proposed converter integrates the generator and battery bank in the drive system with only two IGBTs and two diodes without adding extra capacitors and inductors. Therefore, the proposed converter is more compact with a better power density. It can be expanded for higher power applications and multi-phase SRMs. The excitation and demagnetization are accelerated compared to conventional converters. The torque capability is improved by 30 % because of multilevel voltages, without increasing any torque ripples. The motor system efficiency is improved by 2 %~4 %. Moreover, the battery can be flexibly charged in standstill, motoring and braking conditions, without recourse to off-board charging facilities. The simulation and experimental tests are carried out to confirm the effectiveness of the proposed converter topology. It should be noted that this is a proof-of-concept work and the power rating is relatively low. However, the proposed SRM drive shows good scalability to build up to high-voltage and high power systems if required.

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