Fuzzy Systems and Soft Computing
ISSN : 1819-4362

INTEGRATED SRM POWERTRAIN TOPOLOGY FOR PLUG-IN HYBRID ELECTRIC VEHICLES: ENHANCING EFFICIENCY AND PERFORMANCE

#1 Mr.DONTHULA SANTHOSH, Assistant Professor,
#2 KARRE UDAYKIRAN
#3 PITTALA AKHILA
#4 BANOTH DEEPTHI,
Department of Electrical and Electronics Engineering,
SREE CHAITANYA INSTITUTE OF TECHNOLOGICAL SCIENCES, KARIMNAGAR, TS.

ABSTRACT: Plug-in hybrid electric vehicles (PHEVs) are becoming increasingly popular due to their long driving range, low pollution, and good gas mileage. Compared to other powertrain topologies, the integrated switched reluctance motor (SRM) powertrain topology for plug-in hybrid electric vehicles (PHEVs) allows for longer driving and faster battery charging while using fewer electrical components. Motor driving mode allows you to select one of four different driving modes based on the road conditions. It is possible to complete the motoring and stopping procedures successfully. The battery mode has three charging modes, none of which require the use of additional battery chargers. The SRM windings and integrated converter circuit are used to charge the traction battery via the grid. This results in a three-channel, interleaved boost converter with power factor correction. The traction battery or generator includes a half-bridge isolation dc/dc converter that charges the backup battery. Researchers created a proof-of-concept prototype platform and tested it on a twelve-pole three-phase SRM to determine how well the proposed integrated drive topology and associated control schemes work.

KEYWORDS: Onboard Charging, Plug-In Hybrid Electric Vehicle (PHEV), Powertrain Topology, Switched Reluctance Motor (SRM).

1.INTRODUCTION

Electric vehicles (EVs), plug-in hybrid electric vehicles (PHEVs), and hybrid electric vehicles (HEVs) are becoming increasingly important to the environment and the economy because they consume less gas and emit less CO2. Plug-in hybrid electric vehicles, or PHEVs, are advanced hybrids that combine the best features of electric vehicles (EVs) and plug-in hybrid electric vehicles (HEVs). It has a longer driving range than HEVs because it consumes less gasoline.

A hybrid electric vehicle (HEV) can only charge its inverter using an ICE-powered generator. However, the power grid can also charge the PHEV's battery bank. With the way batteries are manufactured today, the PHEV is a better option because it can use a variety of fuels. . The interior permanent magnet synchronous motor (IPMSM) is the most common type of electric motor used in HEVs and PHEVs due to its high efficiency and power output.The electric drive system is an essential component of PHEVs.

In contrast, IPMSMs use NdFeB permanent magnets made of rare-earth materials. These magnets are known to make large-scale HEV production difficult [Switched reluctance motors (SRMs) are much more competitive in the transportation industry than rare earth motors This is due to their solid construction, high starting torque, wide speed range, ability to handle faults naturally, and efficient operation. contain ideas for design indicators and SRM structure optimization techniques for HEV and EV applications.

The SRM drive system for electric vehicles incorporates high-performance average torque control, adaptive variable angle control, and model predictive current control. These are used to improve driving efficiency, reduce torque ripple, and increase speed range flexibility, in that order . A common issue when designing plug-in hybrid electric vehicles (PHEVs) is limited space; simply increasing the motor power is insufficient. One good idea is to use integrated electrical drivetrains, which reuse the traction motor and power electronics while also charging batteries. . It is critical that the power converter for the electric drive system is well designed. When it comes to plug-in hybrid electric vehicles (PHEVs), various types of motors have been tested to see how they would interact with the onboard charger. Some of these include permanent magnet synchronous motors , induction motors , and SRMs In and the stator windings and power converter of traction motors are transformed into a boost battery charger.

An external power rectifier and an LC filter are also installed. In , a 3H-bridge topology is used to connect a dc/dc converter. This means that the motor wings must be rearranged so that the grid connects the center of the stator windings. Because the current in the second split-phase coil cancels out the effect of the first, the MMF decreases. and describe a three-phase integrated motor drive and charger based on a split-phase permanent magnet motor.

The motor windings can function as a transformer to charge the battery. In any case, the motor's winding configuration must be changed between the charging and traction modes. The machine windings serve as mutually coupled inductors in and , which construct an integrated three-phase and single-phase OBC for fast and gradual charging, respectively, as well as a two-channel interleaved boost converter. For single-phase and three-phase chargers, an additional rectifier is required. In references -lan to cancel out torque is proposed for a three-phase integrated battery charger topology that is not isolated.

However, for this strategy to work, the machines must be designed with split three-phase or multiphase windings. Putting the OBC and the dc-dc converter together could be advantageous because it could result in a higher volumetric power density. describes an integrated bidirectional converter with a single-stage OBC. That being said, the additional four switches, one inductor, and one diode bridge should be included. proposes six working modes and a TriPort converter to improve the flexibility of energy flow control.

These modes allow the photovoltaic (PV) panel, battery, and SRM to work together. In any case, the suggested structure is only suitable for implementing pulse width modulation (PWM) control in SRM. [shows a modular multilevel converter (MMC)-based SRM drive for a HEV's powertrain, while shows a multiport bidirectional power converter. A rise in dc voltage can be used to rapidly demagnetize and excite the material. When an asymmetric bridge converter is combined with a bidirectional two-quadrant front-end dc/dc converter a multiple function converter is created that can handle G2V, V2H, and V2G. However, the V2H and V2G functions require additional inductors and capacitors. SRM can be difficult to use in PHEV applications due to its unique power converter design.

This article discusses a plug-in hybrid electric vehicle power converter with low-power devices built in. When the motor is running, the SRM's power source can switch between the generator and the traction battery, or both, depending on the road conditions. It is demonstrated that the proposed topology works effectively for both driving and stopping. The rectifier, SRM windings, and power converter combine to form a three-channel interleaved boost power factor correction (PFC) converter that supplies power to the traction battery while it is being charged.

The SRM windings can function as filter inductors and energy storage for the OBC without needing to be replaced. The proposed integrated converter topology supports three charging modes: grid to traction battery (G2T), generator to auxiliary battery (G2A), and traction battery to auxiliary battery (T2A). These are made possible by the stator windings and SRM's integrated power converter.

The proposed converter contains numerous components that can perform multiple functions under various operating conditions. These components include the capacitors C1 and C2, the rectifier, the SRM winding, and the power converter. Compared to the new topologies, the integrated powertrain under consideration has more operational modes and levels of integration. The electric drive system could also be made smaller and cheaper, allowing it to compete with SRM in PHEV applications. There are also suggestions for how to control the driving and charging modes so they work properly.

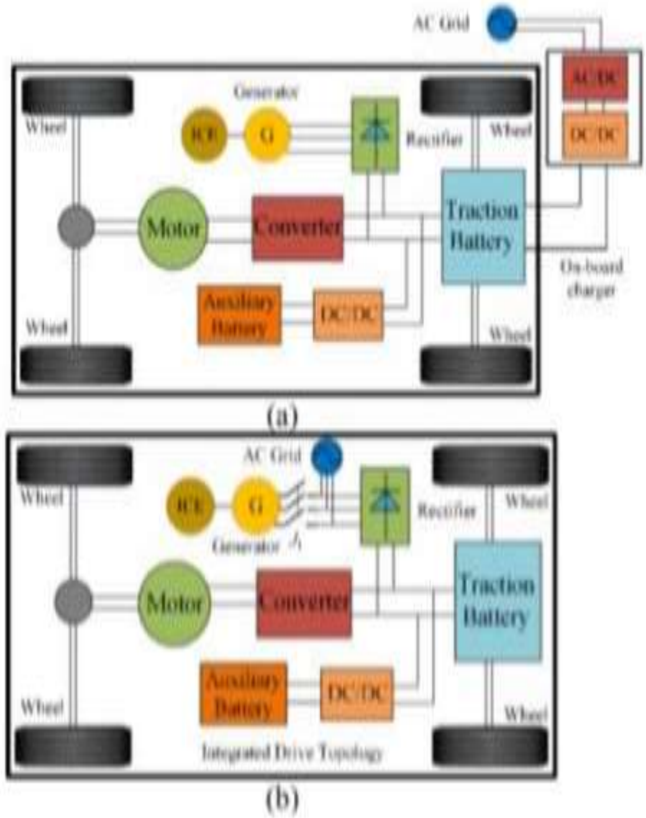

Fig. 1. Schematic of the PHEV powertrain. (a) Traditional powertrain. (b) Proposed powertrain.

2.PROPOSED INTEGRATED SRM POWER TRAIN TOPOLOGY

There is a primary energy storage medium, which could be a bank of traction batteries for propulsion, an auxiliary battery to power automotive electronics, an isolated dc/dc converter to connect the auxiliary battery to the dc-link bus, an ICE, a generator powered by the ICE to convert mechanical energy into electrical energy, a rectifier for rectification, and an auxiliary motor connected to a mechanical driveline. An OBC with an ac/dc converter, a dc/dc converter, and a few inductors and capacitors is typically required to charge traction batteries. Figure 1(b) depicts an integrated drive topology, which is proposed as a means of increasing integration.

The separate OBC is removed. The motor windings serve as filter inductors, and the generator and motor's existing ac/dc and dc/dc converters face the OBC. By adding relay J1, you can connect and disconnect the generator and rectifier. Compared to the typical electric powertrain for plug-in hybrid electric vehicles (PHEVs), this power converter topology would require fewer circuit components, such as power semiconductor devices, inductors, and capacitors. Figure 2a depicts how a three-phase, 12/8 pole SRM is assembled. Phase A consists of windings that are linked in series across four poles. Figure 2a depicts the phase

A winding as the letter LA. The connections for phase A's windings can also be applied to phases B and C. Figure 2(b) shows a complete diagram of the proposed integrated SRM drive topology. There is a mechanical connection between an ICE and a generator. The ICE delivers three-phase alternating current power to the generator. An ac-to-dc rectifier is installed after the generator to convert the power from alternating current to direct current. When the ICE and generator are not in use, the grid connector allows the battery bank to be charged from the power grid.

An EMI filter is installed in front of the rectifier to prevent electromagnetic interference (EMI) noise from reaching the battery side. The generator is equipped with a relay J1 that disconnects it from the power grid while charging the traction batteries. The SRM has three phase windings: LA, LB, and LC. The power converter for the SRM consists of four insulated gate bipolar transistors (IGBTs) labeled Q1-Q4, eight diodes D1-D8, an inductor L1, and a capacitor C3. A half-bridge isolation dc/dc converter was built using diodes D9, D10, D11, and D12, capacitor T, IGBTs Q5 and Q6, inductor L2, and capacitor C4.

This is what recharges the backup battery. The dc-link bus capacitors consist of two series-connected capacitors, C1 and C2. They are also included in the half-bridge isolation dc/dc converter, which charges the backup battery. Specifically, the traction batteries power the necessary electrical equipment as well as the propulsion motor. J2 and J3 relays allow for a wide range of operational modes.

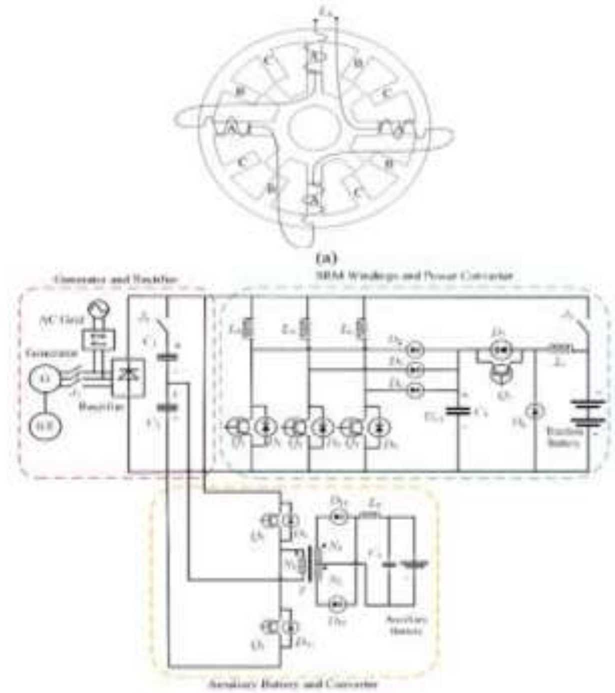

Fig. 2. Diagram of the SRM drive converter for PHEV. (a) Structure of the SRM. (b) Detailed diagram of the proposed integrated converter.

3.PHEV DRIVING MODES

When a plug-in hybrid electric vehicle (PHEV) is moving, relay J2 activates. If there is a heavy load, the PHEV may draw power from either the generator or the traction battery. The three modes we just discussed have three different states: winding excitation, winding demagnetization, and demagnetization energy recovery. A detailed analysis of each mode is provided below. 1) Traction powered only by a battery:

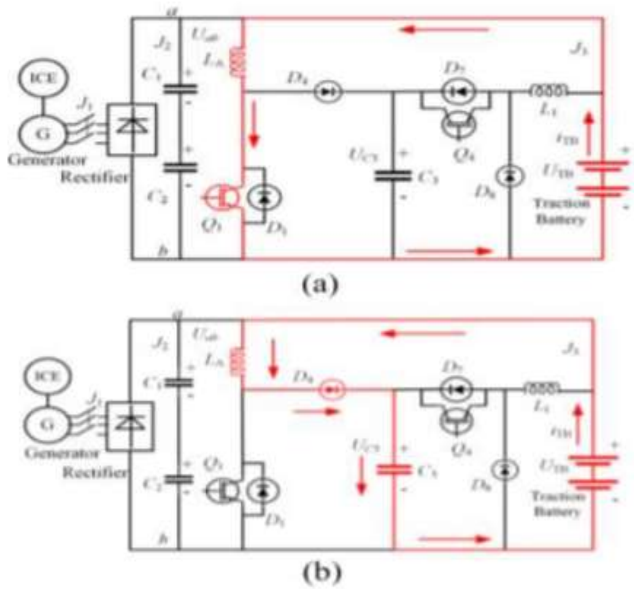

Fig. 3 illustrates the winding excitation and demagnetization states under light and moderate loads.

In the winding excitation state, as shown in Figure 3a, the PHEV is powered solely by the traction battery, with the generator switched off. Figure 3 and relay J1 are both switched off. It only moves with the help of its wheels and battery. (a) The state of circulation when excited. (b) The status of the reels' demagnetization.

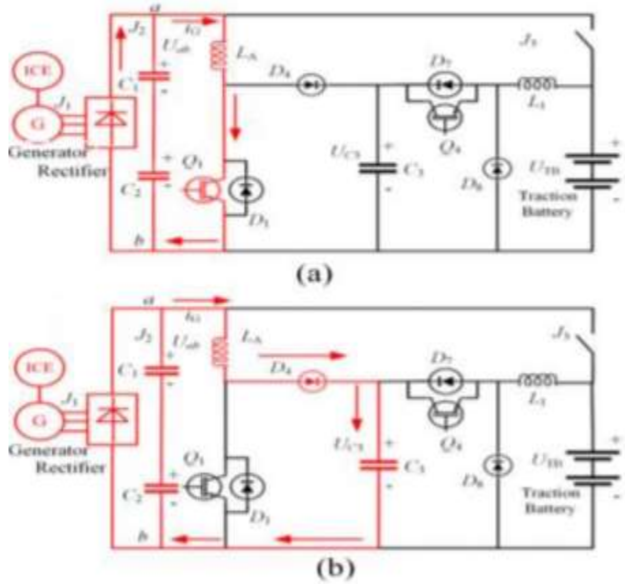

Fig. 4. Driven by generator-alone. (a) Winding excitation state. (b) Winding demagnetization state.

All three relays, J2, and J3, are "ON." When IGBT Q1 is enabled, only energy from the traction battery can be transferred to the wingding LA. The Q1 ceases to function when the winding loses its magnetic properties. After switching the current phase, the phase current flows through the capacitor C3, diode D4, and phase winging LA. The current paths are shown in Figure 3(b). 2) Self-Sustenance of Energy:

Figure 4(a) shows that if the traction battery's system-on-a-chip (SOC) runs out of power, the generator will be the only source of power for the plug-in hybrid electric vehicle. Relay J3 does not work, but relays J1 and J2 do. The ICE instructs the generator how to generate three-phase alternating current (ac) power. The rectifier converts AC power to direct current (DC power). When Q1 is turned on, the generator transfers all of its energy to the winding LA. When the winding demagnetization is turned on, phase current flows through capacitors C1 and C2, the phase winding LA, the diode D4, and capacitor C3. We are unable to run Q1 right now.

4.CONCLUSION

This article proposes an integrated SRM drive converter topology for plug-in hybrid electric vehicles (PHEVs) that allows them to drive and charge themselves without requiring additional power. The main ideas of this article are summarized in the points below. Plug-in hybrid electric vehicles use fewer circuit elements in their integrated power converter topology than standard electric powertrains. With just three relays, you can set up different charging and driving modes. 2) Depending on the load, the driving mode selects one of four operation modes: regenerative braking, generator-traction battery hybrid driving, battery driving, or generator driving. When traveling at high speeds, the proposed electric driving system performs better. 3) When the charging mode is enabled, the traction battery is charged by a three-channel interleaved boost PFC converter that includes the rectifier, SRM windings, and power converter. This could improve the charging power and reduce the ripple in input current. The PHEV is easier to charge due to its three charging modes: G2T, G2A, and T2A. 4) The rectifier, SRM windings, power converter, and capacitors C1 and C2 are examples of integrated converter components that perform multiple functions in different operating modes. As a result, the electric drive system's level of integration improves while its volume and cost decrease. Furthermore, numerous experiments support the control schemes proposed to carry out the functions of charging the batteries, controlling the flexible power, and operating the motors.

REFERENCES

1. H. Chen, W. Yan, J. J. Gu and M. Sun, “Multiobjective Optimization Design of a Switched Reluctance Motor for Low-Speed Electric VehiclesWith a Taguchi–CSO Algorithm,” IEEE/ASME Trans. Mechatron., vol. 23, no. 4, pp. 1762–1774, Aug. 2018.
2. J. Ye, B. Bilgin and A. Emadi, “An Extended-Speed Low-Ripple Torque Control of Switched Reluctance
3. Motor Drives,” IEEE Trans. Power Electron., Vol. 30, No. 3, pp.1457-1470, Mar. 2015.
4. X. Li and P. Shamsi, “Model predictive current control of switched reluctance motors with inductance auto-calibration,” IEEE Trans. Ind. Electron, Vol. 63, No. 6, pp. 3934-3941, Jun. 2016.
5. J. H. Kim and R. Y. Kim, “Sensorless Direct Torque Control Using the Inductance Inflection Point for a Switched Reluctance Motor,” IEEE Trans. Ind. Electron, Vol. 65, No. 12, pp. 9336-9345, Dec. 2018.
6. S. K. Sahoo, S. Dasgupta, S. K. Panda, J. X. Xu, “A Lyapunov Function-Based Robust Direct Torque Controller for a Switched Reluctance Motor Drive System,” IEEE Trans. Power Electron., Vol. 27,No. 2, pp.555-564, Feb. 2012.
7. S.-K. Sul and S.-J. Lee, “An integral battery charger for four-wheel driveelectric vehicle,” IEEE Trans. Ind. Appl., vol. 31, no. 5, pp. 1096–1099, Sep./Oct. 1995.
8. L. Tang andG. J. Su, “A low-cost, digitally-controlled charger for plug-inhybrid electric vehicles,” in Proc. IEEE Energy Convers. Congr. Expo., Sep. 2009, pp. 3923–3929.
9. D. G. Woo, G. Y. Choe, J. S. Kim, B. K. Lee, J. Hur, and G. B. Kang, “Comparison of integrated battery chargers for plug-in electric vehicles: Topology and control,” in Proc. Electric Mach. Drives Conf., 2011, pp. 1294–1299.
10. L. Solero, “Nonconventional on-board charger for electric vehicle propulsion batteries,” IEEE Trans. Veh. Technol., vol. 50, no. 1, pp. 144–149, Jan. 2001.
11. G. Pellegrino, E. Armando, and P.Guglielmi, “An integral battery charger with power factor correction for electric scooter,” IEEE Trans. Power Electron., vol. 25, no. 3, pp. 751–759, Mar. 2010.
12. F. J. Perez-Pinal and I. Cervantes, “Multi-reconfigurable power system for EV applications,” in Proc. Int. Conf. EPE Power Electron. Motion Control, 2006, pp. 491–495.
13. S. Haghbin, K. Khan, S. Lundmark, M. Alak¨ula, O. Carlson, M. Leksell, and O. Wallmark, “Integrated chargers for EV’s and PHEV’s: Examplesand new solutions,” in Proc. Int. Conf. Electrical Machines, 2010, pp. 1–6.