Review of Controlling of Switched Reluctance Motors (SRM) Drive Techniques in Micro-grid

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Abstract- There has been growing interest in the switching reluctance motor in both the academic and business communities. The minimal cost of construction and the fact that no rare materials are required are two of Micro-most grid's lauded qualities. Switched reluctance motors are more difficult to manipulate than conventional machines. The most researched issue in the subject is how to minimise torque ripple in the control system. The purpose of this work is to provide a review of the relevant literature and an understanding of the specifics involved in micro grid control of switching reluctance motors. There is a literature review on the effects of fundamental control approaches on the study of motor performance. Several other studies are offered for the reader to use as comparisons in this comparative study. Studies employing a non-linear switching reluctance motor model derived from an actual motor are the primary emphasis of the papers, which are based on the theory presented for literature review.

Keywords- Switched Reluctance Motors, Drive techniques, Micro-grid

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INTRODUCTION

When all the automobiles in a large city release their exhaust gases at once, the result might be dangerous levels of air pollution. People in large, polluted cities across the globe suffer from respiratory ailments and premature deaths, and a rising number of infants are born with birth defects. The volume of traffic noise inside urban centers has reached disturbing levels. The European Union's (EU) efforts to lower transportation emissions emphasize on improving the efficiency of current cars and creating new ones that use sustainable fuels and motor technologies, as well as electrifying automobiles. If you electrify your car, you'll have something that's more efficient, dependable, safe, and good to the environment. Electric propulsion systems for HEVs, PHEVs, and EVs are selected based on vehicle restrictions (such as motor size and weight, vehicle type, vehicle weight, payload, etc.), energy source (such as batteries, fuel cells, ultra capacitors, etc.), and, of course, driver preferences (acceleration, maximum speed, braking, range, etc.). The electric propulsion train must provide results that are competitive with those of existing road vehicles [1] given the constraints and opportunities.

A flawless, highly efficient VSD has always been out of reach from a design and functionality standpoint in the industrial sector. To far, only DC and Induction motors have been employed for this purpose, although both kinds have significant limitations. SRM is practical and appropriate for a wide variety of general purpose VSD applications because to its inherent simplicity, durability, and cheap cost. A thorough understanding of the dynamic behaviour of the motor is crucial for the design of any electric drive system. As power converters are needed to get the necessary torque and speed from the motor, understanding how an electrical motor interacts with them is also important [2].

In this study, we explore two separate control objectives for SRM: driving and generating. When using SRM for position control, a steady output torque with no ripple is required. Its primary function as a generator is to reliably provide the necessary DC bus voltage while operating at peak efficiency. Therefore, a flawless machine model is required to achieve desirable outcomes in every circumstance [3].

Unlike any other kind of electrical equipment, SRM construction is quite easy to understand and carry out. It's important to note that in SRM, windings are only present in the stator. What sets the SRM different is that the rotor has no wires or permanent magnets. Steel laminations are piled on top of a shaft to form the rotor. The promise of cheap cost associated with SRMs' straightforward mechanical construction is what has spurred so much study of this technology over the last decade. This ease of mechanical operation does, however, have certain practical consequences. For example, unlike traditional machines, SRMs need the assistance of electronic commutation switches in order to function, rather than using a direct DC bus or AC line. The machine's ability to generate the requisite reluctance torque is dependent on the double saliency of the stator and rotor, which also explains the machine's robust non-linear magnetic properties. This makes it harder to analyse and regulate SRM, which in turn confirms the well known fact that industrial adoption of SRM has been gradual [4].

The SRM industry has stalled due to a number of perceived challenges, chief among them a lack of electrical technology to control the machines and a glut of commercially accessible AC and DC devices. SRMs, on the other hand, provide industries with benefits such as low-cost and high-efficiency alternatives. The physical, magnetic, and electrical properties of each SRM phase are distinct from those of the others, making the machine as a whole exceedingly dependable. Its fast speed is achieved in part because the rotor does not have any magnets or conductors. Using an SRM has certain drawbacks, including the fact that it may be difficult to regulate and always needs rotor position reading through a shaft position sensor. As a result, they are often more loud, and their torque ripple is greater than that of other motors. With an improved knowledge of SRM, this can readily mitigated. [5]

One such device that may transform electrical energy into mechanical work is the switching reluctance motor (SRM). Like more traditional motors (such as induction motors and synchronous motors), this electric motor may function in all four directions simultaneously. That is to say, it has the ability to both speed up and slow down for both clockwise and counterclockwise rotor revolutions [6].

When comparing SRM control to other motor controls, such as those for AC motors that are fed sinusoidal current waveforms or DC motors that are fed constant voltage, there is no comparison. In the simplest control, square current waveforms are used to magnetise and demagnetize each motor phase (winding) at the appropriate times, depending on the rotor's location. However, due to the extremely non-linear nature of the motor, the electromagnetic torque depends not only on the instantaneous current amount but also on a non-linear inductance profile, thus producing torque with just square current waveforms results in a significant ripple component [7].

The switched-reluctance machine (SRM) may be an unusual choice among the machines already in use, but it has considerable promise as a motor and generator. The following are its primary characteristics.“It has two distinct windings that are stimulated separately; (ii) the rotor lacks permanent magnets and conductors. Therefore, its sturdy construction makes it ideal for use in fast-moving vehicles. When it comes to manoeuvrability, its torque and acceleration are second to none. The used converter is of a fault-tolerant, basic topology design. While SRM has several advantages, its double salient construction also gives rise to a number of downsides, such as increased torque ripple, vibration, and acoustic noise. In addition, it is more challenging to accomplish dynamic modelling and high-performance control due to the nonlinear winding inductance and non-ideal winding current waveform. This means addressing a plethora of urgent matters. Common techniques include (i) rotor position sensing and commutation setting, (ii) power circuit design and switching control, (iii) dynamic modelling, (iv) current control, (v) speed control, (vii) commutation shift, (viii) voltage boosting, (ix) field weakening via commutation shifting, and (x) torque ripple and vibration reductions. To effectively enhance the torque producing capabilities of the SRM winding current waveforms at high speed and/or heavy load, commutation shift with similar field-weakening effects is the best solution.” To improve the current tracking responsiveness when the speed is raised, a voltage boosting strategy is required [8].

It is possible to use an SRM as a generator by allocating current correctly across the windings in the area of negative winding inductance slope. “SRM is well suited for use as a wind generator because of its robust mechanical construction and simple, torque-free start-up for cogging. However, numerous essential aspects, notably the impacts of back electromotive force (EMF), which is negative in generator mode to aid the current during the demagnetizing phase, have a significant impact on the generating behaviours of SRG. SRG's performance may be enhanced in a number of ways, but they include I the quality of the excitation source equipment, (ii) the setting and shifting of commutation, (iii) the control of switching current and voltage, (iv) the control of voltage, and (v) the control of power maximisation. Most often, the PWM hysteresis current control with hard freewheeling is used to efficiently mitigate the hazards of back-EMF.” This investigation has shown that immediate commutation adjustment is the most efficient method for enhancing the developed power and ripple characteristics of an SRG [9].

“For a switched-reluctance machine to produce a quasi-square winding current waveform, a suitable converter is required. By far the most adaptable winding current PWM switching control is available in the 2N-switch asymmetric bridge converter (where N is the number of phases). That's why it's so widely used, particularly the SRM drive that also has SRG [10] and regenerative braking capabilities.”The paper is divided into a Literature review of the SRM in Section 2, the Comparative study on recent methods in Sections 3, a research gap described in Section 4, conclusion described in Section 5

LITERATURE REVIEW

The degradation of photovoltaic (PV) modules in the Algerian Sahara was evaluated in [11] based on performance metrics and visual examination. In 11 years of operation, the modules' output power degraded anywhere from 33 percent to 7 percent owing to increases in series resistance and decreases in shunt resistance, with an average annual rate of roughly 1.5 percent. De-lamination, burn scars from hot areas, fractures, defective anti-reflective coatings, discolored covers, etc. are all examples of visible deterioration.

In [12] author described for analyzed the effect of 300% PV penetration on the distribution system. In the analysis it was established that very high PV penetration will result in reverse power flow. The design of distribution should consider the impact of bidirectional power flow on system components and protective devices.

In [13] author did a case study to analyze the impact of PV penetration on the low voltage distribution network. For this a large low voltage network of Newzealand had been considered. A power flow model was prepared using data from geographical information system and SCADA system. Different methods for increasing PV penetration limit were evaluated.

The effects of low PV penetration on a low voltage distribution system were examined in [14]. For the purpose of simulating the feeder, Open DSS was employed. To conduct the research, a live feeder from the Kerala State Electricity Board was monitored and analysed. The parameters of the model were approximations to increase its realism. It was calculated that if PV generation was situated near the linked load, distribution losses would be minimised. However, unbalanced load on feeders should be kept to a minimum before any linkages are made.

In [15] author evaluated comparative analysis of PV generation at different locations and for different capacity for a distribution network of Islamabad. The model was simulated on power world simulator software and tested for four different PV distributed generation cases. From the simulation results it was concluded that the voltage profile improves and losses in the feeder reduce with increasing penetration of PV generation. Also the location of distributed PV generation affected the voltage profile and distribution losses of the system.

In [16], the author developed an optimization strategy that used active damping and smart power management with fuzzy logic supervisor to reduce MG component size. It analysed developing an active damping technique based on a voltage source convertor mathematical model without additional sensors, reducing the size of the output LC filter by shifting the frequency and adjusting the active damping coefficient, and building a strong fuzzy logic supervisor for smart power management. The research system consisted of a PVA, Voltage Source Converter, gas generator, dc water pump, and electric vehicle.

In [17], the author presented a control approach for grid-connected and islanded hybrid PV-battery systems. In such configuration, a DC/DC boost converter connected the PV array to the DC bus, while a bidirectional DC/DC converter controlled battery charging and discharging. The AC bus had AC loads. CAPMS delivers a dependable power supply to the system when PV power varies owing to unpredictable irradiance or when the PV array has problems.

In [18], the author developed a voltage imbalance reduction strategy using generation-side inverters and demand-side control. PV grid-tied inverters and thermostatically regulated loads mitigate voltage imbalance on the generation-side and demand-side, respectively.

[19] presented a fuzzy logic controller (FLC) for islanded AC MG power management. “Their suggested controller integrated FLC with bus-signaling to regulate energy flow. By adjusting the AC bus frequency and using local droop controllers, the controller was achieved without MG unit communications. Fuzzy controllers lack dimensionality and tuning.”

In [20], the author examined the effect of low PV penetration on a low voltage distribution network. For the purpose of simulating the feeder, Open DSS was employed. “To conduct the research, a live feeder from the Kerala State Electricity Board was monitored and analyzed. The parameters of the model were approximations to increase its realism. It was calculated that if PV generation was situated near the linked load, distribution losses would be minimized.” However, unbalanced load on feeders should be kept to a minimum before any linkages are made.

New switching reluctance machine topologies are detailed in [21], expanding the author's previous review of electric machines (EMs) beyond the traditional PMSM, induction machine, synchronous reluctance machine (SynRel), and PM-assisted SynRel. Power density, efficiency, torque ripple, vibration and noise levels, and fault tolerance are all used as metrics in this work.

The author of [22] describes and illustrates the design procedure for a 60-kilowatt switching reluctance motor used in a hybrid electric vehicle's traction application. “Both the stator and rotor of the motor have 24 poles each. The optimal conduction angles have been determined for both key operating points and the complete operating range using a multi objective optimization approach. Output torque maximisation and torque ripple reduction are employed as optimization targets.”

The author of [23] noted that the interest in EVs is increasing. New, less expensive motors like Switched Reluctance Machines have been the primary focus of R&D funding (SRM). Comparing the controllability, cost, fault tolerance, and complexity of several SRM converter topologies for EV use is the focus of this paper.

For use in plug-in hybrid electric vehicles (PHEVs), author [24] describes a converter that uses switching reluctance motors (SRMs) supplied by a modular front-end circuit. “Changing the front-end switches from "on" to "off" may provide a number of distinct operating modes. When running on generator power, the battery bank is used to boost phase voltage for quick excitation and demagnetization. When the vehicle is being powered by a battery, the converter is switched to a four-level configuration, and the capacitor is employed as an extra charge capacitor to provide multiple voltage outputs; this increases the vehicle's torque capacity.” Phase current and voltage are investigated in depth, and the suggested drive's many working modes are described.

This is what the author of [25] outlined. “This innovative idea lessens the burden on the converter, maximizes the usefulness of energy stored in batteries and other devices, and gives the dc bus voltage an extra boost. As a result, the motor drive may function across a wider amperage range while maintaining peak torque. The simulation tests how well the HESS and IPM drive work in an electric car.” The usefulness of the system is shown experimentally using data from a prototype.

For electric vehicles (EVs) powered by a brushless DC (BLDC) motor, the author of [26] proposes a novel regenerative braking system (RBS). “The BLDC functions as a generator during regenerative braking. Therefore, the energy is transferred to the super capacitor or the battery via the inverter by increasing the dc-link voltage using an appropriate switching strategy. When going uphill, the vehicle's battery pack may be protected from deep discharge by using the gathered energy to boost acceleration.” With the help of an artificial neural network, the distribution of braking force is brought to fruition, making for a dependable and well-functioning brake.

Author [27] describes and exposes modern dc micro-grid technologies, including ac interfaces, designs, feasible grounding techniques, power quality challenges, and communication systems. “Benefiting from dc grids' strengths may boost efficiency and dependability in a wide variety of uses. The report also addresses the pros and cons of dc grid systems' use in various settings.” Recent developments in dc micro-grid technology are presented, together with a discussion of the pressing need for standardised protocols in this field.

“Author [28] described in detail The system is ready to produce up to 240 kW of 208-Y/120-VAC three-phase (3) electricity and can be set up in less than 20 minutes, making it ideal for a rapid deployment military station. Vehicle hotel loads (i.e., electrification of no propulsion and auxiliary loads) and off-board loads (tents/shelters, communications centres, or other electrical loads) are supplied with electricity by the system's 600-VDC generators, which are incorporated into the vehicles' transmissions.”

“Taking into consideration renewable energy sources, energy storage systems, and nonlinear loads, the author of [29] gives a summary of the key problems with hosting capacity and harmonic disturbances induced by the penetration of electric vehicles (EVs) in a smart grid. In order to govern the charging of electric vehicles, a novel hybrid deterministic and probabilistic approach based on algorithms and new control techniques is provided.”

An developing solution to exhaust gas emissions in urban transportation is the hybrid electric bus (HEB), as detailed by the author in [30]. “In order to boost the motoring performance and accomplish the flexible charging tasks, this study offers a multiport bidirectional switching reluctance motor (SRM) drive for solar-assisted HEB (SHEB) power train. Photovoltaic (PV) panels are mounted on the bus to reduce the need for gasoline batteries and charging stations, hence increasing the operating range and allowing the bus to charge itself.”

An off-board three-port integrated topology (TPIT) is defined and analysed in [31] for interfacing electric vehicles (EVs) and renewable energy sources like solar photovoltaic panels with the electrical power grid. “The TPIT is made up of three power converters all connected by a single dc connection, and it has four alternative modes of operation suitable for smart grids of the future.”

As the author explains in [32], Solar photovoltaic panel charging stations provide a sustainable future for the transportation sector. “In this study, we show the design and implementation of a 10 kW EV charger that can draw energy from either a PV array or the standard three-phase ac power grid. Objectives include conformance to Caedmon and combined charging standard/Combo EV charging standards, as well as the realisation of a high power density and high efficiency three-port power converter that combines the EV, PV, and grid.”

Rapid electrification of transportation, as outlined by the author in [33], highlights the growing need of a thorough grasp of the parameters utilised in motor selection. “For the purpose of electric vehicles (EVs) and hybrid electric vehicles (HEVs), this study details the design of an internal permanent magnet synchronous motor (IPMSM) with dispersed winding and concentrated winding, an induction motor (IM), and a switching reluctance motor (SRM).”

“In [34], the author explains how they are using cutting-edge methods to create a 45-kilowatt high-speed switching reluctance drive that may be used as a starter-generator in future aircraft engines. The machine required a large continuous power-speed range so it could carry out such a task.”

In [35], the author presented a PBC scheme for the switching reluctance generator (SRG) in dc micro-grid applications powered by small-scale wind energy conversion devices. “If the system provides constant power loads (CPLs) and runs on maximum power point tracking, then stabilising the output voltage is the primary concern (MPPT)."

COMPARATIVE STUDY

S. No	Title	Year	Method
36	"Design of computational experiment for performance optimization of a switched reluctance generator in wind system"	2018	"This work makes a novel contribution by presenting a strategy for improving the efficiency of a switching reluctance generator (SRG) in a wind energy conversion system with variable input. The ideal firing angles and dc link voltage that ensure the best system behaviour for each rotor speed are determined using a method based on the design of computational experiments."
37	"A reversible position sensor less controlled switched-reluctance motor drive with adaptive and intuitive commutation tuning"	2015	"In this study, an adaptable and user-friendly commutation instant tunings system for a reversible position sensor-less switching reluctance motor (SRM) drive is introduced. In the PWM channel, the tiny voltage pulses are fed into a de-energized phase winding." The Hall signal is obtained by sensing the resulting amplitude-modulated winding currents and applying signal processing.
38	"A current control scheme with back-EMF cancellation and tracking error adapted commutation shift for switched-reluctance motor drive"	2016	"In this study, we provide the design, implementation, and assessment of a revised winding current management method for switched-reluctance motor driving."
39	"An approach for switched reluctance generator in a wind generation system with a wide range of operation speed"	2017	"This study provides a comprehensive method for using a switching reluctance generator (SRG) in wind energy conversion systems with variable output. There are two suggested methods of direct power control (DPC) and a commutative system that would enable SRG performance over a broad range of speeds." This means that wind power may make use of a greater quantity of mechanical energy.
40	"Maximum power point tracking in grid connected wind plant by using intelligent controller and switched reluctance generator"	2017	"This work proposes intelligent controllers as a maximum power point tracking system for a variable speed wind turbine-driven switching reluctance generator (SRG). The intelligent controllers are ANN and FL."
41	"SRM converter topologies for EV application: State of the technology"	2017	"Electric cars are gaining popularity. R&D has concentrated on developing cheaper motors like SRMs (SRM). This article compares SRM converter topologies for EV controllability, prices, fault tolerance, and complexity."
42	"Analysis and design of a speed controller for switched reluctance motor drive"	2019	"An accurate method of regulating the speed of a reluctance machine is described here, with potential uses in electric drive systems. To achieve precise velocity regulation, a cascade control method using linear control theory was devised." The controller has been developed using the Root Locus Methodology and deployed on a platform for numerical simulation.
43	"A wind switched-reluctance generator based grid-connected micro-grid"	2017	"In this piece, we take a look at a wind-powered, plug-in, energy-supporting microgrid (MG) that uses switched-reluctance generators (SRGs). We'll start with the fact that the wind SRG has been expertly crafted and managed. The produced voltage has quick tracking and regulation responses under varied driven speed and load thanks to the use of dynamic commutation shift and robust voltage control."
44	"A batter/super capacitor powered EV SRM drive with bidirectional isolated charger"	2017	"In this research, we provide a micro-grid integrated operation control for a switched-reluctance motor (SRM) drive for a battery/super-capacitor (SC) powered electric vehicle (EV). An H-bridge converter couples the battery to the motor drive DC-link, while a one-leg boost-buck converter couples the SC to the DC-link."
45	Converters for switched reluctance motor - topology comparison	2019	"This research compares and contrasts several SRM converter topologies with an emphasis on the quantity and size of semiconductor components used in medium-power engines."

RESEARCH GAP ANALYSIS

Existence of commentators and brushes in DC machines reduces their dependability, lowers their maximum speed, and necessitates frequent maintenance, according to the available literature. "Electromagnetic interference is produced during the commutation process. The DC motor was unsuitable for use in electric vehicle propulsion due to its poor efficiency, low power density, and therefore high bulk and weight. In order to achieve the necessary performance, induction machine control is more complex and requires the use of power electronics. Nevertheless, IMs have a poor efficiency at mild loads and a narrow speed working range. Also, the rotor's tremendous heating has been causing issues. PMSM are considered to be the most effective generators because of the high power density and efficiency they provide out of the box. The great sensitivity of PMs to high temperatures and the complexity of the PMSM's structure contribute to their production costs. Researches are under pressure to find replacements for the PMSM because to the already high and rising price of the PMs and the lack of rare earths." Switched reluctance motors (SRMs) are becoming a serious alternative to more conventional types of electric motors. SRMs are well-liked because to their inexpensive manufacturing and maintenance costs, as well as their reliability, simplicity of design, and inherent fault tolerance.

"Switched reluctance machines (SRMs) have a decent shot at becoming a mainstream vehicle propulsion option because to its high efficiency, cheap cost, high dependability, and fault-tolerance. Since there are no permanent magnets (PMs) or rotor windings, the SRM may be made for less money while yet being capable of operating at high speeds. However, it is well-known that the SRM has downsides, including higher torque ripple, acoustic noise generation, and extremely nonlinear behavior. However, the machine's primary obstacles are all surmountable with good control tactics.The rotor in an SRM consists only of steel laminations, with no conductors or permanent magnets present at all. Its minimal design allows for significant savings via avoidance, and efficient heat loss. The kinetic energy of SRM is generated by the varying resistance of the air gap between the rotor and the stator." The propensity of the rotor to rotate to its minimal reluctance position when a single stator winding is ignited to create a magnetic field results in reluctance torque [46-57].

CONCLUSION

In this study, we present the design and analysis of an electric vehicle (EV) SRM drive powered by a battery/SC hybrid source. Schematic established, control schemes developed to achieve satisfactory driving and regenerative braking operating performances, including I a current feedback controller supplemented with an observed back-EMF CFFC and a simple RCECC, (ii) a direct current transmission scheme to conduct the commutation advanced shift, and (iii) the robust speed controller. Additionally, the suggested battery-followed H-bridge converter may boost motor efficiency at lower speeds. Experimental evidence supports the claim that the suggested variable vdc technique is successful in reducing energy use. The results demonstrate that the reduced/increased DC-link voltage may reduce battery energy consumption due to decreased switching loss at the slower speed. In the next step, a SC power source with a bidirectional interface converter is installed.

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