



Matlab-Based Srm Drive Controlling for Evs and Microgrid Integration

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Abstract

The fault tolerance, high torque density, and robustness of a MATLAB-based control method for Switched Reluctance Motor (SRM) drives are starting to make a big splash in the electric vehicle (EV) and microgrid integration industries. This work introduces a thorough MATLAB/Simulink model for optimizing the control and analysis of SRM drives in EV applications, with the goal of improving performance, efficiency, and energy management; it also enables bidirectional power flow for microgrid support. To regulate the system so it runs smoothly under different loads and speeds, the suggested system uses smart controllers like fuzzy logic or model predictive control in conjunction with current profiling, speed regulation, and torque ripple reduction. Enhanced acceleration, efficient regenerative braking, and battery health preservation are the primary goals of the concept in the context of electric vehicle applications. Because of its dual role in microgrid integration, the SRM drive may charge from renewable sources during off-peak hours or feed stored energy back into the grid during peak demand. In spite of dynamic grid circumstances, the system was able to achieve steady operation, low torque ripple, and high efficiency, according to the simulation findings. By making use of MATLAB's simulation features for optimization and design, this study offers a cheap, efficient, and scalable solution for smart grid and environmentally friendly transportation applications.

Keywords: Matlab-based, SRM drive, EVS and microgrid, integration

Introduction

In densely populated urban areas, pollution from vehicle exhaust gasses is a particular concern. There is an annual increase in the number of kids born with complications, and the prevalence of lung ailments is higher in densely populated urban areas. The volume of traffic on city roadways has also increased to an alarming degree. Promoting electric cars, improving fuel efficiency, and making strides in utilizing sustainable fuels and power technologies are all ways the European Union plans to reduce transportation-related pollution (Kiran Kumar, M. 2019). More environmentally friendly, safe, reliable, and fuel-efficient vehicles may soon be on the horizon—all thanks to electric propulsion. How HEVs, PHEVs, and EVs choose their electric propulsion systems depends on a number of factors, including the vehicle's type, weight, payload, and the size and weight of the motor. Options for energy sources (batteries, fuel cells, ultra-capacitors, etc.) and the requirements of the driver (maximum speed, acceleration, braking, range, etc.) also play a role in the decision. The electric power system must outperform conventional automobiles when all factors are considered (Hegazy, O. 2021).

The design of SRM is quite straightforward and simple to comprehend when compared to other electrical devices [1]. Keep in mind that the rotor is the only part of a switched reluctance motor (SRM) that has windings. The SRM may be easily identified due to the absence of any permanent magnets or cables on its rotor. Steel laminations fastened to a shaft constitute the rotor. Over the last decade, SRMs have been the subject of extensive research because to their apparent low cost and ease of mechanical implementation. But being only a basic mechanical construction, the machine is limited in its capabilities. A DC bus or an AC line cannot

directly power an SRM, unlike a conventional machine (Sukumaran, S. 2019, Jul). Digital communication switches are substituted instead. Because the reluctance torque is produced by positioning the stator and rotor so closely to one another, the machine exhibits significant nonlinear magnetic characteristics. The gradual adoption of SRM by enterprises is something that everyone is already aware of, and this just confirms it. This complicates both studying and managing (Harley, R. G. 2019).

Too many AC and DC machines were already on the market, and there wasn't enough appropriate electrical technology for the SRM to establish a footing. Companies reap several benefits from SRMs. More efficient and less expensive options are two of them. Due to the separation of its physical, magnetic, and electrical components, SRM is an extremely stable machine. The rotor moves quicker than other kinds of specialized motors since there are no cables and magnets. The machine is difficult to manage and requires constant monitoring of the rotor's position using a shaft position indicator due to the operation of SRM. Because of this, they tend to make more noise and have bigger power wave than other types of motors. A better grasp of Supplier Relationship Management (SRM) could help reduce the frequency of this occurrence (Teja, M. S. 2020). Regular induction and DC motors have been the best choice for electric drives with varying speeds for a long time because they are reliable and flexible. The Switched Reluctance Motor (SRM) is a well-known and potential electric drive for variable-speed uses. Recent developments in powerful semiconductor devices and affordable microcomputers brought it about. A Switched Reluctance Motor is known for being simple and strong, able to work even when something goes wrong, very efficient, reliable

even at high speeds, and having power qualities that can be changed. A common recommendation is electric drives with speed changes. For SRM to work right, it needs to use position sensors and power circuit adapters (Ruan, Y. 2018).

Background on electric mobility and microgrid integration

A route toward lowering carbon emissions, improving energy efficiency, and encouraging sustainable development is presented by two of the most notable innovations in contemporary energy and transportation systems: electric mobility and microgrid integration. Powered by batteries or hybrid energy storage systems, electric drivetrains are displacing internal combustion engines and revolutionizing the transportation sector. This trend is spearheaded by electric vehicles (EVs). In addition to lowering emissions of greenhouse gases and improving air quality in cities, switching to electric vehicles also allows for more control over energy usage and less reliance on fossil fuels. Microgrids, which are smaller-scale energy networks that may either function independently or in tandem with the larger grid, are being used more and more to connect decentralized renewable power sources such as tiny hydroelectric dams, wind turbines, and solar photovoltaic (PV) systems. Decentralized energy generation is encouraged, transmission losses are decreased, and grid resilience is increased by these technologies. Electric vehicles (EVs) may integrate with microgrids and serve as mobile energy storage units, enabling them to engage in vehicle-to-grid (V2G) and vehicle-to-home (V2H) operations, resulting in a potent synergy.

By integrating with the microgrid or main grid, electric vehicle batteries can provide load balancing and voltage stabilization by storing renewable energy surpluses during periods of high output and feeding them back at peak demand. Smart charging infrastructure also optimizes electric vehicle charging in response to changes in renewable energy sources, power prices, and grid conditions, which helps to alleviate strain on the power grid. Microgrid load needs, renewable generation patterns, and electric vehicle charging schedules may all be precisely coordinated with the use of sophisticated control systems built and tested in MATLAB/Simulink. When it comes to rural electrification and energy delivery in distant areas, this integration is very important. Off-grid microgrids that are supplied by renewable energy sources may run electric vehicle fleets without depending on the centralized grid infrastructure. The significance of this confluence is being recognized by policymakers and industry leaders, who are implementing regulatory frameworks, subsidies, and incentives to encourage the adoption of electric vehicles (EVs) in conjunction with microgrids powered by renewable energy sources. Problems still exist, though, and they include things like renewable energy sources' intermittency, electric vehicles' and charging infrastructure's high initial prices, the necessity of sophisticated battery management systems, and the creation of interoperability standards to ensure smooth integration. Improving energy management and predictive control in integrated systems is anticipated to be made possible by technological improvements in energy storage, power electronics, and artificial intelligence, which are anticipated to tackle a number of these obstacles. Electric mobility and microgrid integration work hand in hand to create an intelligent energy environment that is resilient, decentralized, and supports global decarbonization goals.

Power Converter with SRM Control

A power converter is essential for the switching reluctance motor's operation, since it is responsible for stimulating the phase windings in the right order in relation to the rotor's position. The asymmetric half-bridge converter will be the center of attention here, notwithstanding the many scholarly suggestions. The system's adaptable control capabilities and robust durability have contributed to its widespread use, which this work takes use of. An 8/6 SRM is the only use for it. The accurate activation and deactivation of the power converter's electrical switches is essential for the device's faultless operation. A controller, ranging from a simple analog or discrete digital integrated circuit controller to a high-speed digital signal processor or field-programmable gate array controller, is needed for this. It is the application's unique requirements that dictate the controller to be used. It is common practice for the controller to receive rotor position, speed, and current data. The power converter is subsequently given appropriate control signals based on this processed data. The rotor's location may be detected using a pulse pattern generated by an encoder. The central processing unit (CPU) usually uses the pulse train to determine the speed. If the predicted speed is different from the target speed, the current regulator, which supplies the signal, is adjusted accordingly. The SRM, together with its power converter and controller, is often shown as a mysterious black box that takes in a current signal and two angles for turning on and off as inputs and outputs torque. The black box probably has a current regulator that can make the right waveform of current.

There may be reliability concerns with using a mechanical sensor to operate the motor under extreme conditions like high pressure, high temperature, high humidity, and strong vibrations. For these kinds of uses, pinpoint accuracy in rotor positioning and reliability in operation are of the utmost importance. Minimizing the motor drive's overall size and weight is also essential. Further design complexity and maintenance cost increases result from physically attaching the rotor position transducer to the driving system. It also adds another possible weak spot in the SRM drive. When talking about automated control systems, "sensor less control" means doing away with mechanical position sensors. Reducing costs and improving the motor's reliability under difficult conditions are the main reasons to remove the position sensor.

- Control without the Use of Sensors
- Energized Phase Methods
- Unenergized Phase Methods

Energy Consumption in Various Sectors

Global warming poses a significant threat to all forms of life on Earth. It discusses the consequences of an abnormal increase in the average surface temperature of the Earth brought about by human activities. During the last century, the surface of the Earth has warmed an average of 0.08 degrees Celsius every year. Temperatures have been climbing at a pace of 0.18 degrees Celsius every decade for the past forty years, more than tripling in that time. The 10 warmest years on record, from 2005 to 2020, are shown in Figure 1. The hottest year is 2020. Seasonal cycles are impacted by the unusual increase in temperature because it has altered wind patterns, ocean currents, and daily temperature fluctuations.

Temperature shifts brought on by climate change have been responsible for the extinction of many plant and animal

species. Surprisingly, various forms of commercial energy consumption account over 80% of global warming pollution. Burning fossil fuels releases greenhouse gasses into the atmosphere, including carbon dioxide. That is where much of this energy is coming from. The International Panel on Climate Change has concluded that emissions from fossil fuels are the primary driver of climate

change. In 2018, 89% of the world's CO₂ emissions was caused by industrial processes and the combustion of fossil fuels. Coal is often cited as one of the most environmentally damaging natural fuels. Scientists have connected it to about a third of the one-degree Celsius increase in average global temperatures. That is why burning coal is the primary driver of the climate crisis.

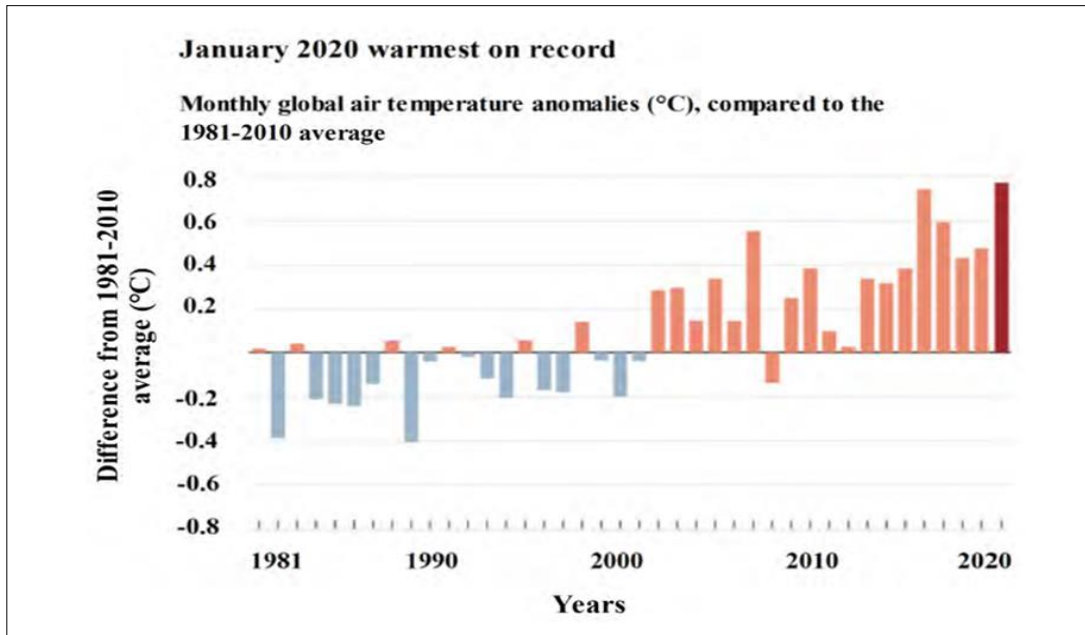


Fig 1: Monthly global air temperature anomalies(c) compared to 1981-2010 average

More heat is being generated. A third of the world's carbon pollution is caused by excessive oil consumption. The environmental impact of natural gas compared to fossil fuels is lower, according to many. Despite contributing 20% of global carbon emissions, it is nevertheless regarded as a stable fuel. Over the next several decades, human activity will exacerbate climate change depending on the amount of carbon dioxide and other greenhouse gases released into the atmosphere. We must discover a clean, safe energy source to supplement or replace traditional energy sources if we are to avert the impending catastrophe caused by climate change. The transition from fossil fuels to renewable energy won't happen overnight. It will be necessary to eliminate

them one by one. The transient nature of green energy is another way in which it differs from conventional energy sources. To make green energy more reliable and beneficial, further research is required.

Two major sources of carbon gas emissions are vehicles and electricity plants. Figure 2 shows that transportation accounts for almost 21% of global greenhouse gas emissions. Annually, the typical private vehicle emits 4.6 metric tons of carbon dioxide. This figure might have several meanings depending on the fuel type, gas mileage, and efficiency of the vehicle. On a typical day, a single vehicle spews 404 grams of air pollution.

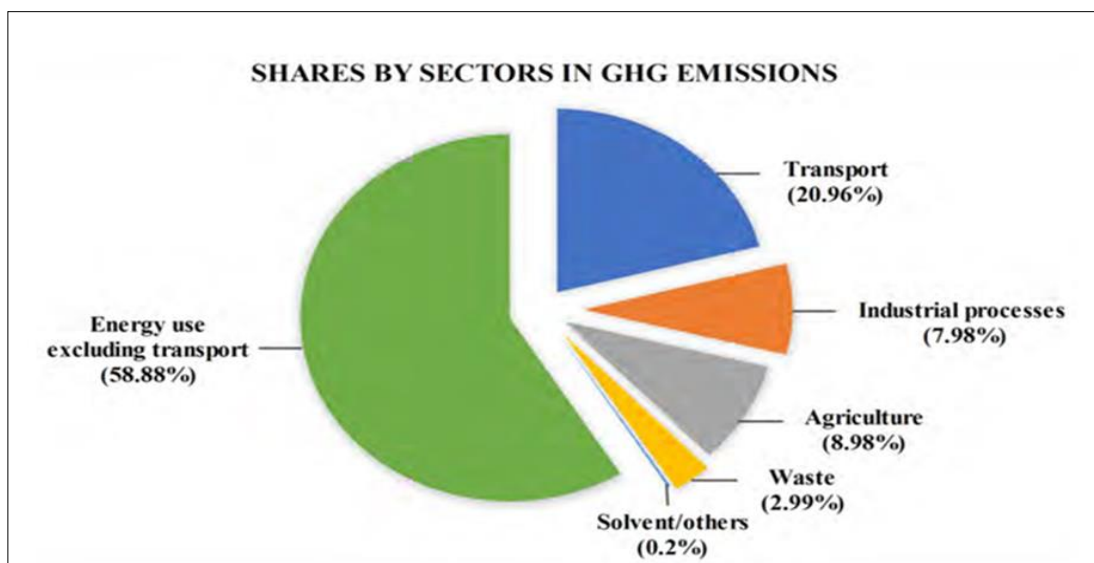


Fig 2: Major contributors of GHG emissions

On every mile it travels, it emits 10 units of carbon dioxide. Over the last quarter of a century, four percent of all travel time has been accounted for by automobiles and vans. For the other 73% of the time, the vehicle is idling at the owner's residence; for the other 23%, it's someplace else, like the office. Electric vehicles have the advantage of being able to be charged even while we're not using them.

Smart EVs and Renewable Energy Sources

The combination of state-of-the-art technology, environmental awareness, and sophisticated energy management techniques in Smart Electric Vehicles (EVs) powered by Renewable Energy Sources (RES) is a game-changer in the fight against climate change, fossil fuel exhaustion, and air pollution. Improved operational efficiency, dynamic power grid interaction, and participation in emerging concepts like vehicle-to-grid (V2G) and vehicle-to-home (V2H) are all made possible by smart electric vehicles' intelligent control systems, real-time monitoring, advanced connectivity, and data analytics. Electric vehicles may significantly reduce their lifecycle emissions of greenhouse gases when their charging infrastructure incorporates renewable energy sources like solar, wind, and small-scale hydropower. Electric vehicles may help improve grid stability and demand-side management by charging during times of excess renewable production and transferring stored energy back into the grid during peak demand, all with the help of smart charging systems. Recent developments in battery technology, energy storage systems, and predictive algorithms have further enhanced the synergy between smart EVs and RES. These algorithms optimize charging schedules, estimate renewable generation, and regulate energy flows to reduce costs and increase efficiency. Also, microgrid applications benefit greatly from decentralized energy systems, transmission losses are reduced, and energy resilience is improved by the integration of smart EVs with distributed renewable power.

Energy independence may be fostered in rural and distant locations through off-grid solar or wind-powered electric vehicle charging systems, while urban areas that have solar-powered charging stations can greatly reduce emissions from the transportation sector. Incentives, subsidies, and investments in infrastructure are propelling broad adoption as policymakers and industry players see the potential of this integration. By transforming EVs from mere consumers into contributors to the energy ecosystem, the integrated system enables auxiliary grid functions such as frequency management, voltage support, and emergency backup power in the event of power outages. Smart EV and RES networks that use AI, the Internet of Things (IoT), and blockchain technology enable safe energy transactions, autonomous charging choices, and real-time data exchange among drivers, stations, and grid controllers. In line with worldwide sustainable development and net-zero carbon emission goals, this astute coordination increases the utilization of renewable resources while decreasing operational costs and improving user convenience. Initial infrastructure costs, renewable energy fluctuation, interoperability standards, and battery recycling are some of the difficulties that need to be solved through legislative assistance, innovation, and coordinated research.

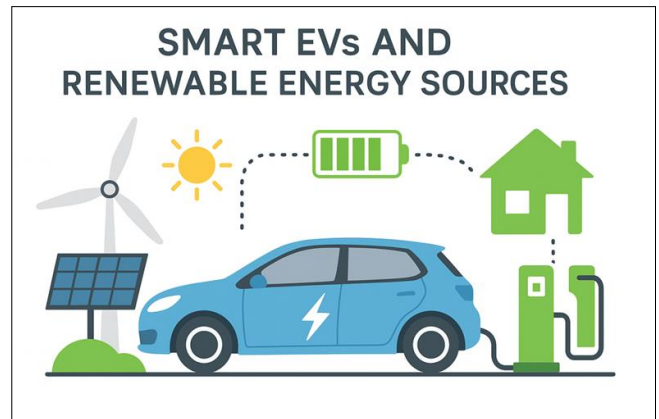


Fig 3: Integration of Smart Electric Vehicles with Renewable Energy Sources

Integration of Renewable Energy

Achieving a sustainable, low-carbon future—and meeting the growing worldwide demand for energy—requires the incorporation of renewable energy sources into contemporary power and transportation networks. Greenhouse gas emissions, air pollution, and climate change may all be greatly reduced with the help of renewable energy sources (RES) including solar, wind, hydro, and biomass, which are clean and never-ending substitutes for fossil fuels. By integrating renewable energy sources with energy storage, EVs, and smart grid technology, we can create an energy ecosystem that is both more stable and efficient. Distributed customers, such as residences, businesses, and EV charging stations, receive their power from the grid and renewable generating units, such as wind turbines and solar photovoltaic panels, in this integrated manner. Through Vehicle-to-Grid (V2G) technology, excess renewable energy may be stored in sophisticated battery systems or even in electric vehicle (EV) batteries. This energy can then be discharged back into the grid, helping with grid stability and managing peak loads. In a two-way energy exchange, as shown in the image above, renewable energy sources like solar panels and wind turbines may power smart electric vehicles, which can then power residential loads. By anticipating demand patterns, projecting renewable generation, and using energy when it is most abundant and inexpensive, smart control systems—powered by AI and IoT platforms—optimize energy flows. In microgrid applications, where renewable power distributes may keep essential loads running even when the main grid goes down, this integration helps decentralize energy systems by lowering transmission losses and increasing resilience. Solar charging centers in urban areas may help with energy independence and economic growth, while off-grid renewable solutions can help rural communities become more self-sufficient. The electrification of transportation, made possible by combining renewable energy with electric vehicle infrastructure, is critical in the fight against pollution and the over-reliance on fossil fuels. The use of transportation networks powered by renewable energy sources is further encouraged by government policies, subsidies, and carbon laws. But problems like high upfront capital costs, charging infrastructure standardization, renewable generation's intermittency, and the requirement for large-scale energy storage may be solved with research, innovation, and supporting legislative frameworks. To facilitate the smooth incorporation of RES with EVs, utilize blockchain for safe

energy transactions, and implement AI algorithms for autonomous energy management—digital technologies will play an increasingly important role in the energy landscape of the future. In the end, a carbon-neutral society can be advanced, energy security can be improved, innovation can be fostered, and economic growth can be driven by integrating renewable energy with sophisticated mobility solutions like smart EVs. In order to achieve global sustainability goals, make the environment cleaner, and build an intelligent energy system that can withstand challenges, this comprehensive strategy is crucial.

Conclusion

Sustainable energy and transportation systems of the future can benefit greatly from the MATLAB-based control of EV and microgrid-integrated Switched Reluctance Motor (SRM) drives. By accurately modeling and controlling SRM drives in MATLAB/Simulink, one can accurately simulate their dynamic behavior under different operating situations. These drives are renowned for their broad speed range, high fault tolerance, and simple and sturdy design. Electric vehicles (EVs) benefit from increased performance and longer ranges because to the MATLAB-based control's optimized torque output, less torque ripple, and better energy efficiency. When combined with regenerative braking and vehicle-to-grid (V2G) operations, the controlled SRM drive can assist grid stability, peak load management, and renewable energy integration in microgrids. It can also operate as a distributed generator. Researchers and engineers rely on MATLAB for quick prototyping, controller tuning, and fault analysis due to its versatility. All things considered, SRM drive control based on MATLAB improves EV operating dependability and energy efficiency, allows for smooth integration into smart microgrids, and aids in the worldwide shift toward greener transportation and decentralized energy systems. By working together, we can solve energy and environmental problems and advance sustainable development goals.

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