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Microgrid integration and control of SRM drive for EVS using Matlab

Ashwini Ambarish Deshpande[1], Dr Vijayalaxmi Biradar[2], Dr Manoj Ramesh Tarambale[3]
[1] PhD Scholar, Department of Electrical Engineering, Kalinga University Raipur, Chhattisgarh, India
[2] PhD Guide, Department of Electrical Engineering, Kalinga University Raipur, Chhattisgarh, India
[3] Associate Professor, Department of Electrical Engineering and I/C Principal of the Institute, PVG's COET & GKP(W) IOM, Pune, Maharashtra, India

Abstract

One potential option to create energy systems that are sustainable, efficient, and dependable is to combine microgrids with electric vehicle (EV) technology. With MATLAB/Simulink as the modeling and simulation platform, this study delves into the integration and control of a microgrid with a Switched Reluctance Motor (SRM) drive for electric vehicle applications. While SRM drives are ideal for electric vehicle propulsion because to their fault tolerance, high torque density, and resilience, they still necessitate sophisticated control systems to mitigate noise and torque ripple. To provide bidirectional power flow for both charging and vehicle-to-grid (V2G) operations, the proposed system design integrates EV SRM drives with a hybrid microgrid that includes renewable energy sources, energy storage systems, and grid interfaces. Load variations, renewable intermittency, and dynamic drive cycles are just a few of the operational situations that may be thoroughly studied with the use of MATLAB-based models. Power management algorithms make the most of the microgrid's resources, and an improved current profile and speed regulation system improve efficiency and reduce torque ripple. The findings of the simulation show that the energy efficiency, charging times, driving performance, and grid support capabilities can all be improved. Through smart SRM drive control in microgrids, this study helps to advance smart mobility solutions, promote renewable integration, and enable transportation systems that are robust and low carbon.

Keywords: Microgrid integration, control, srm drive, EVS Matlab

Introduction

An important step toward creating intelligent, efficient, and environmentally friendly transportation systems that are in sync with the use of renewable energy sources is the incorporation and regulation of Switched Reluctance Motor (SRM) drives for electric vehicles (EVs) inside a microgrid architecture. Due to their ability to dynamically interact with power networks, EVs provide new possibilities for energy optimization and are quickly becoming an integral part of the contemporary energy ecosystem, which is driven by the growing need for sustainable mobility options (Omekanda, A. M. 2007). Because of their dual operation as islanded or grid-connected systems, microgrids offer a versatile framework for incorporating DERs including solar photovoltaics, wind turbines, and energy storage devices. Microgrids and electric vehicles work together to improve charging efficiency and open the door for vehicle-to-grid (V2G) capabilities, which allow for the recirculation of energy from electric car batteries for grid-based tasks including frequency management, peak shaving, and load balancing (Emadi, A. 2005) [2]. The SRM stands out as an ideal electric vehicle (EV) propulsion system because to its fault tolerance, broad speed range, cheap production cost, and sturdy construction. By eliminating the need for permanent magnets and rotor windings, SRMs are able to improve thermal efficiency even when subjected to extreme operating conditions, while simultaneously decreasing their reliance on rare-earth minerals. Nevertheless, sophisticated management procedures are required for SRMs to operate smoothly due to torque ripple, acoustic noise, and non-linear magnetic properties. In situations like these, the robust modeling, simulation, and control design environment provided by MATLAB is priceless. Engineers may model SRM drives with great accuracy in MATLAB/Simulink, use sophisticated control algorithms like Direct Torque Control (DTC), hysteresis current control, or adaptive fuzzy-logic-based controllers, and test how well the system works under varying grid and load situations (Radun, A. V. 2001).

For the purpose of optimizing microgrid power flow and electric vehicle propulsion, MATLAB also allows for the smooth integration of renewable generating profiles, load needs, and battery management systems into a single modeling platform. In high renewable penetration scenarios, where power unpredictability is a concern, electric vehicles may run effectively and contribute to grid stability with the help of microgrid energy management and SRM drive control (Sepe, R. B. 2005). In this combined system, the electric vehicle serves as a load and a distributed energy storage unit, enhancing the reliability and efficiency of power grids in both urban and rural areas. Efforts to promote energy decentralization, lessen reliance on fossil fuels, and decrease emissions of greenhouse gases are all in line with the goals of the study and development of such systems (Liaw, C. M. 2006). So, it's a technical undertaking and a strategic contribution to the future of sustainable mobility and smart energy systems to explore microgrid integration and SRM drive control for EVs using MATLAB. Achieving realistic, scalable, and environmentally conscious transportation systems that seamlessly integrate with the changing smart grid environment is made possible by this method's meticulous modeling, optimization, and control (Fahimi, B. 2003).

Methodology

In this research, we build a converter and link it to a test bench to see how well Switched Reluctance Motors (SRMs) work as vehicle propulsion. A method for tuning a 6/4 pole-switched reluctance motor (SRM) drive's speed that doesn't rely on sensors is shown.

1. SRM Model

Despite its seemingly simplistic construction, the Switched Reluctance Motor (SRM) is able to withstand high temperatures, tolerate imperfections, and function well. The variable speed drive community holds it in high esteem. Because the rotor is devoid of windings and permanent magnets, the aforementioned issues arise. This explains the loudness, power fluctuations, vibrations, and difficulty in controlling the pace. Figure 2.1 shows the schematic architecture of the SRM drive system. The components include a DC voltage source, a capacitive filter, a power converter circuit, a single-phase synchronous rotor motor (SRM), a speed driver, a rotor position sensor, a gate pulse triggering device, and a schematic design. Most people agree that a position monitor is the most reliable tool for tracking the rotor's location during maintenance. Thanks to advancements in digital signal processing, it is now possible to automate system monitoring and management without resorting to antiquated mechanical monitors like position and speed sensors. The area of information technology has made great strides forward with this modification. This kind of control system is called sensorless speed control.

Further discussion of the sensorless HO algorithm-based speed control method will be provided in the sections that follow.

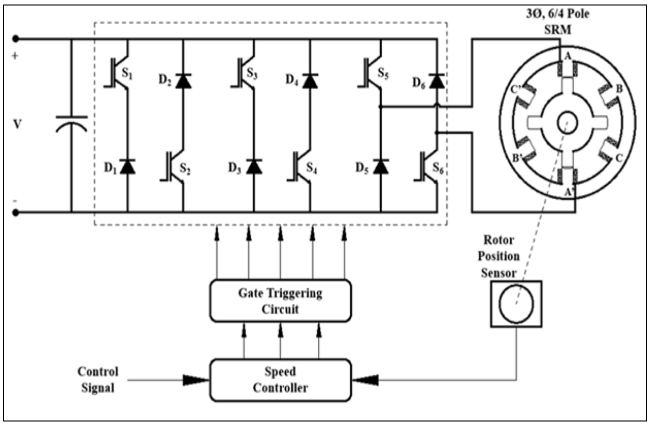


Fig 1: Electric Schematic Representation of SRM Drive

2. Non-Linear Model of SRM

The nonlinearity of the SRM drive component may be shown using differential equations as an approach. The voltage is defined by equation 2.2, whereas the magnetic flux of the switching reluctance motor (SRM) is specified by equation 2.1 for each phase.

$$\lambda_n = L_n\ (\ l_n\ ,\theta\ ),\ l_n \qquad 2.1$$

There are three possible choices for the phase number, n. Each phase's flux linkage (ψ) is directly proportional to the inductance (L) of the winding and the current (I) passing through it.

$$V_n = R_n l_n + \frac{d\lambda_n(l_n,\theta)}{dt} = R_n l_n + \frac{d\lambda_n}{dl_n} , \frac{dl_n}{dt} + \frac{d\lambda_n\square}{dt} , \frac{d\theta}{dt}$$

$$V_n = R_n l_n = L_n , \frac{dl_n}{dt} + \frac{\partial\lambda n}{\partial\theta} ,\omega \qquad 2.2$$

The equation $[(\partial\lambda_n/\partial\theta)/(\partial\lambda_n/\partial l_n)\omega]$ denotes the incremental inductance of the nth phase divided by the back electromotive force (BEM) of the motor. The co-energy (WC) may be expressed using equation 2.3.

$$W_c = \int_0^l \lambda(\theta, l)dl \qquad 2.3$$

To find the electromagnetic torque, one may use equation 2.5, and to describe the torque of the nth phase of the switching reluctance motor (SRM), one can use equation 2.4.

$$T_n=[\frac{\partial W_c(\theta,l_n)}{\partial\theta}]l_{n=constant} \qquad 2.4$$

$$T_e = \sum_{n=0}^{3} T_n \qquad 2.5$$

T_n represents the torque of the nth phase. Equation 2.6 describes the mathematical movement of the SRM caused by the electromagnetic torque T_e and the load *Tl.*

$$T_e - T_t = J\frac{d\omega}{dt} + B\omega \qquad 2.6$$

Formulation of the rotation equation is given by equation 3.7.

$$\frac{d\theta}{dt} = \omega \text{ or } \theta = \omega \qquad 2.7$$

Here is a list of the variables used in this specific situation: The rotor's moment of inertia and the input load on the motor are both represented by the symbol J. B is the coefficient of friction during contact. The parameter for angular velocity is represented by the symbol ϋ. A "t" indicates that time is passing.

3. Computation of Turn-On and Turn-Off Angle

Various control functions are activated when the Switched Reluctance Motor (SRM) is turned on and off at different angles. The motor's speed is altered in this way. Although the turn-off angles may alter significantly as the speed increases, the turn-on angles remain constant. Consequently, a negative force will be generated as a result of generating a tail current. Setting the switching settings so that they are proportional to speed will provide the maximum torque and optimal performance. We can get the angle at which the SRM is activated using equation 3.8, and the angle at which it is deactivated using equation 3.9.

Turn on angle, $\alpha = \frac{\pi}{N_r}$ (degree) 2.8

Turn on angle, $\beta = \alpha + \frac{2\pi}{q*N_r}$ (degree) 2.9

Let Nr represent the number of rotor poles and q represent the number of phases.

Results

1. SRM Model using IHO Algorithm

The goal of this contribution is to create a model that can properly represent the machine's behavior under both transient and continuous load conditions while removing any unwanted approximations. In order to implement and evaluate different control mechanisms, this model will be utilized. Figure 3.1 shows the Enhanced SRM simulation model that uses the IHO method and is tied to the EV system. You can see the extra parts of this model in Figures 3.2 to 3.4.

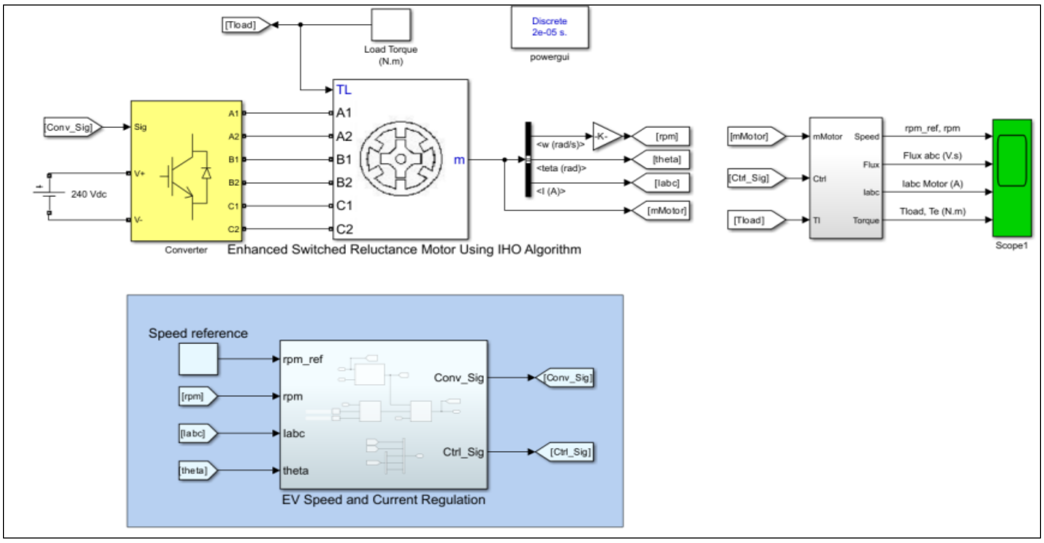


Fig 2: Simulation of SRM modeling using IHO algorithm

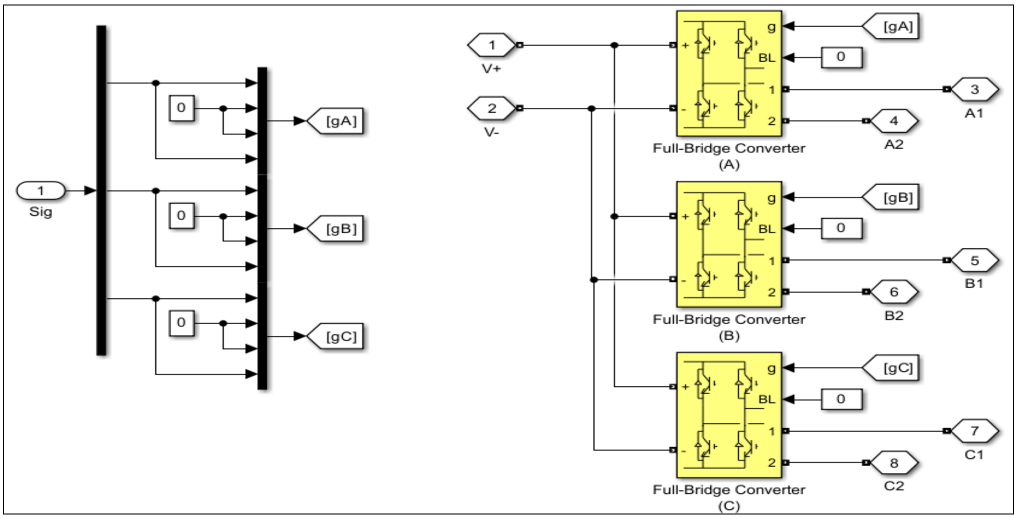
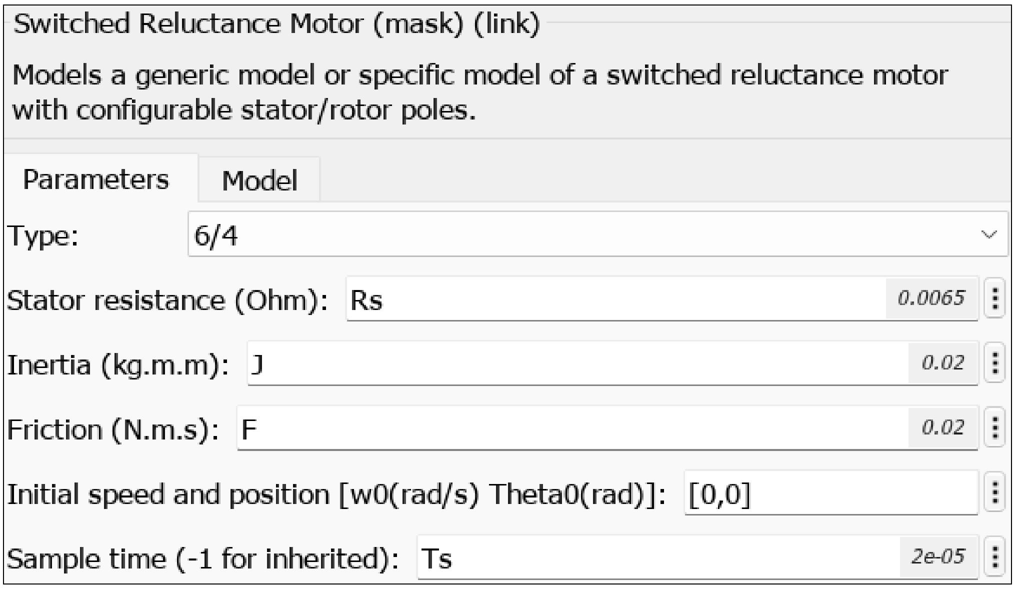


Fig 3: Converter design in contribution 1


Switched Reluctance Motor (mask) (link)

Models a generic model or specific model of a switched reluctance motor with configurable stator/rotor poles.

Type: 6/4

Stator resistance (Ohm): Rs 0.0065

Inertia (kg.m.m): J 0.02

Friction (N.m.s): F 0.02

Initial speed and position [w0(rad/s) Theta0(rad)]: [0,0]

Sample time (-1 for inherited): Ts 2e-05

Fig 4: 6/4 SRM model design parameters

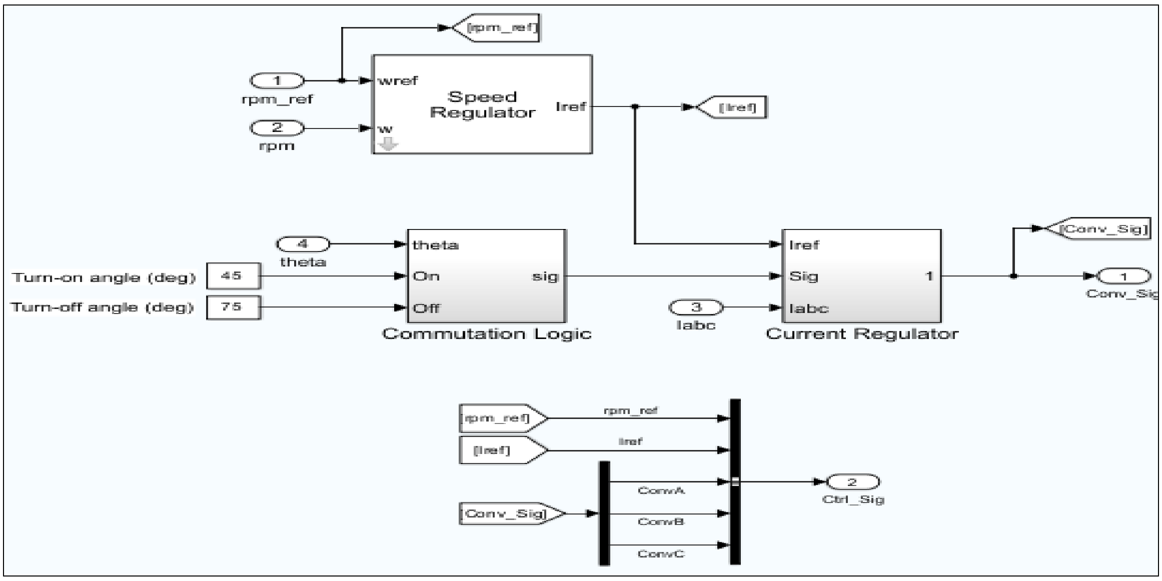


Fig 5: EV speed and current regularization model

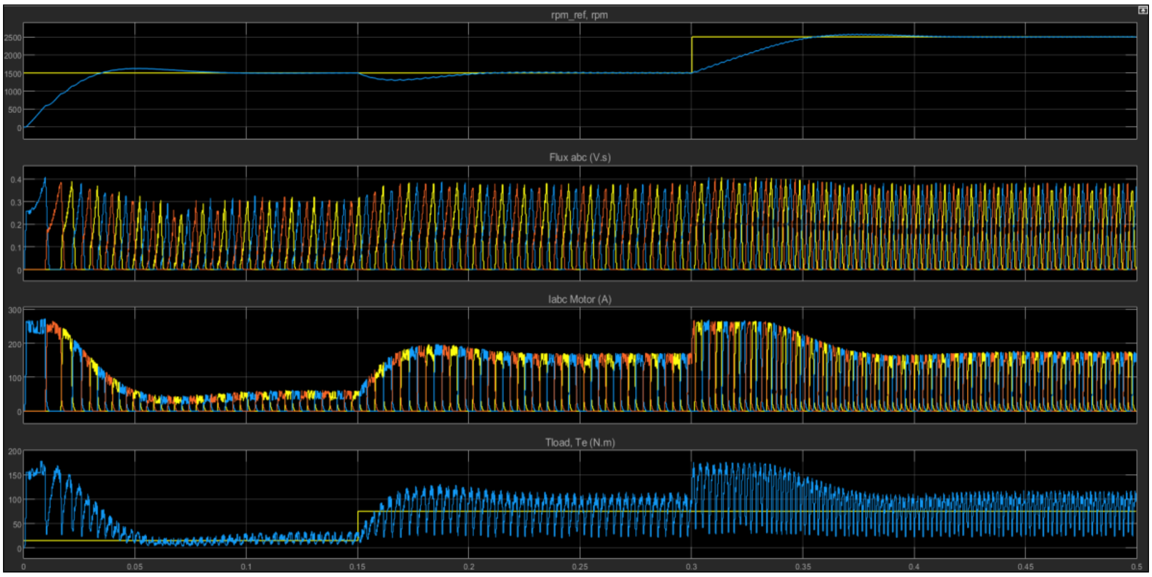
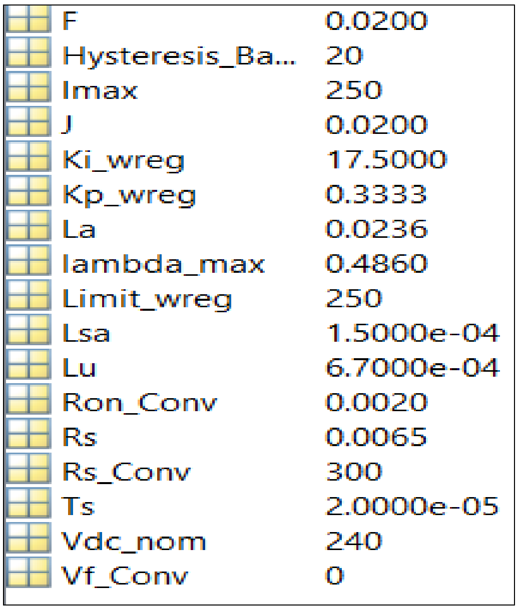


Fig 6: Simulated results for IHO-based SRM model of EV system



F	0.0200
Hysteresis_Ba...	20
Imax	250
J	0.0200
Ki_wreg	17.5000
Kp_wreg	0.3333
La	0.0236
lambda_max	0.4860
Limit_wreg	250
Lsa	1.5000e-04
Lu	6.7000e-04
Ron_Conv	0.0020
Rs	0.0065
Rs_Conv	300
Ts	2.0000e-05
Vdc_nom	240
Vf_Conv	0

Fig 7: Simulated outcomes for different measures

The results of the suggested model motor's RPM, flux, motor, and total load are displayed in Figures 3.5 and 3.6. You can see the remaining settings in Figure 4.6. By removing the unnecessary approximations, the suggested model appears to have enhanced the performances, according to the overall results.

2. SRM Model using Fuzzy-based Converter

The SRM model for EV systems that utilizes the fuzz-based converter and IHO-based SRM block is the second contribution of this work. Checking the machine's motor and generator operations is key to making sure it works in all four corners. Use of both average and instantaneous torque management schemes is required to keep performance at an acceptable level throughout a broad speed range. It is necessary to choose the optimal control method for each individual operating point. In order to test SRMs (Switched Reluctance Motors) for vehicle propulsion, a converter has to be built, assembled, and incorporated into a test bench. Using an IHO-based SRM drive and a fuzzy-based converter, the EV SRM model is shown in Figure 3.7.

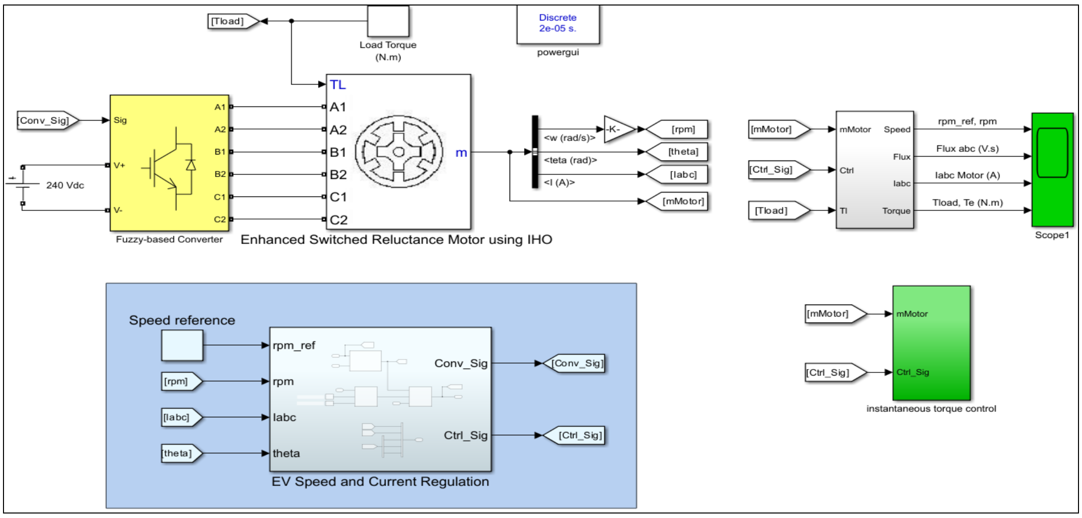
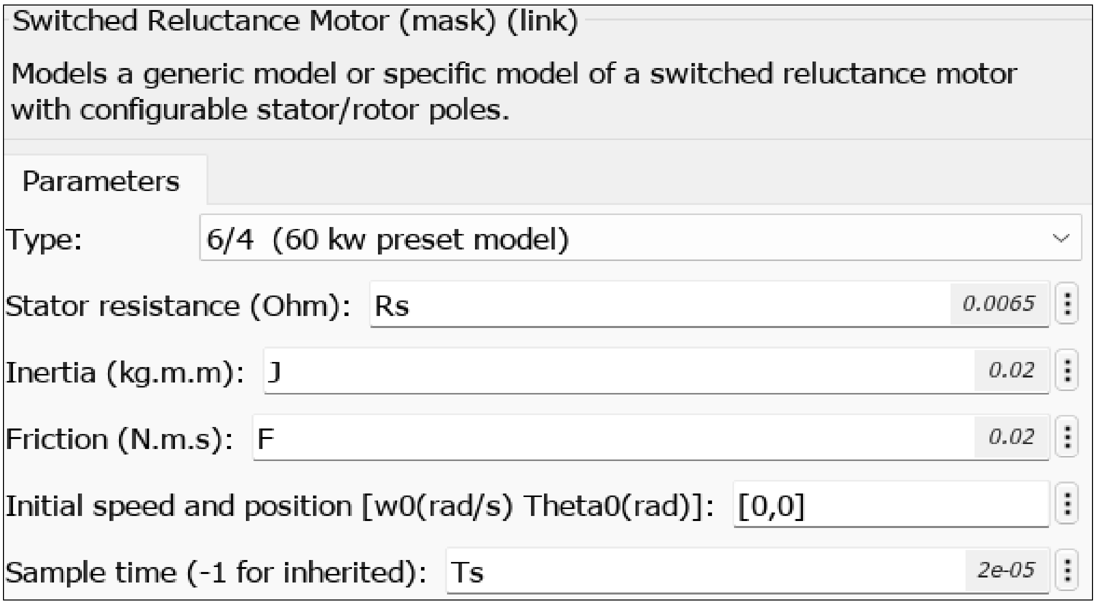


Fig 8: Simulation of SRM modeling using Fuzzy-based converter


Switched Reluctance Motor (mask) (link)

Models a generic model or specific model of a switched reluctance motor with configurable stator/rotor poles.

Type: 6/4 (60 kw preset model)

Stator resistance (Ohm): Rs 0.0065

Inertia (kg.m.m): J 0.02

Friction (N.m.s): F 0.02

Initial speed and position [w0(rad/s) Theta0(rad)]: [0,0]

Sample time (-1 for inherited): Ts 2e-05

Fig 9: SRM designing using 6/4 with 60 Kw preset

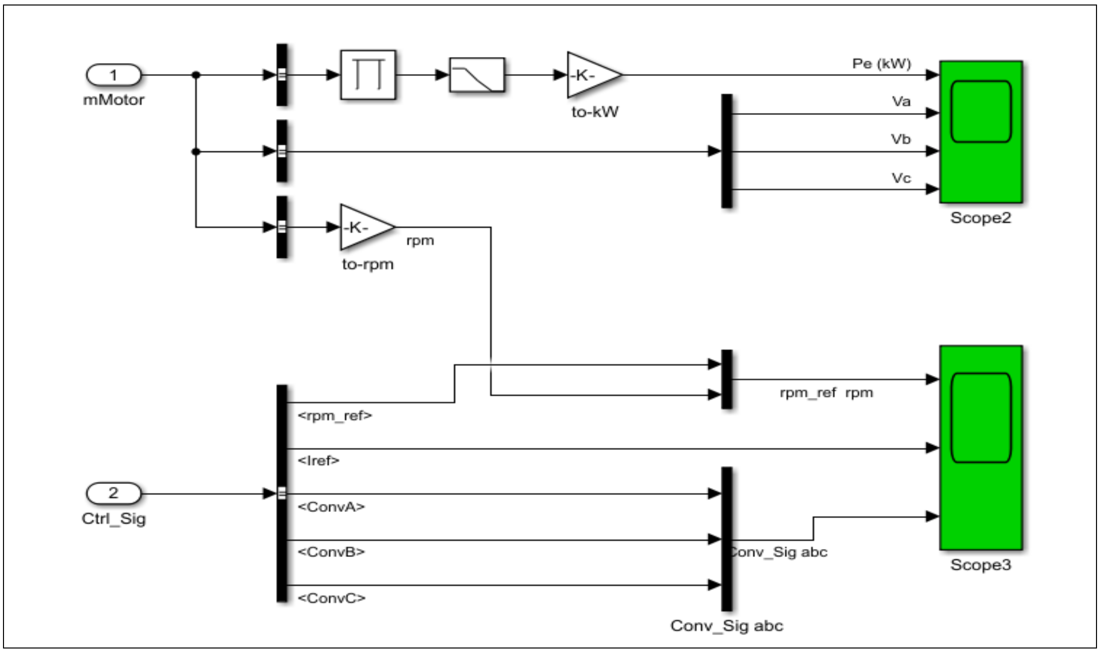


Fig 10: Designing of instantaneous torque control for second contribution

Viewed in Figures 3.8 and 3.9 are the additional parts of this model. Figures 3.10 and 3.13 show the estimated values for the motor's RPM, flux, motor, and total load, as well as the outcomes of the proposed model. As seen in Figure 3.11, the remaining parameters are also shown. Taken together, the results indicate that the proposed model was able to improve performance by doing away with superfluous approximations.

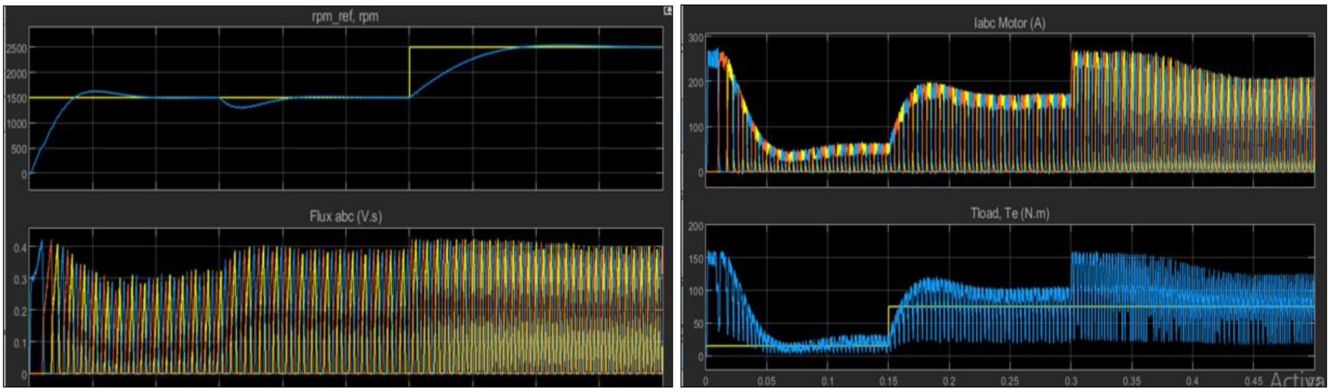
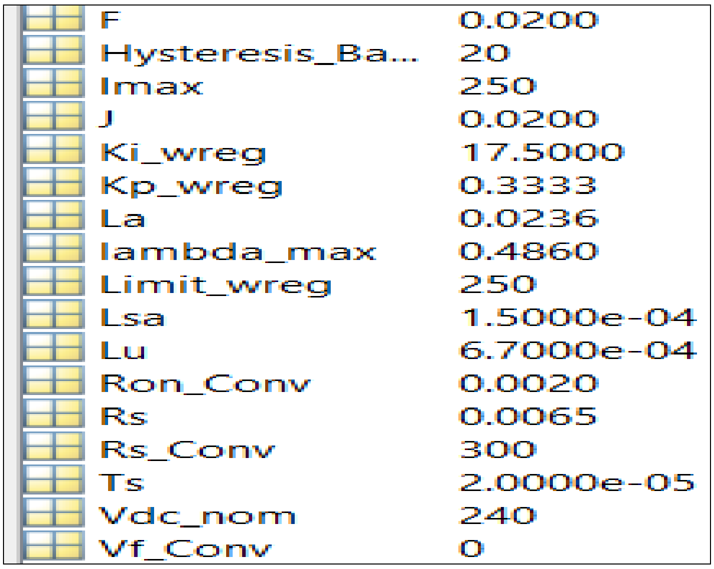


Fig 11: Simulation results for the contribution two



F	0.0200
Hysteresis_Ba...	20
Imax	250
J	0.0200
Ki_wreg	17.5000
Kp_wreg	0.3333
La	0.0236
lambda_max	0.4860
Limit_wreg	250
Lsa	1.5000e-04
Lu	6.7000e-04
Ron_Conv	0.0020
Rs	0.0065
Rs_Conv	300
Ts	2.0000e-05
Vdc_nom	240
Vf_Conv	0

Fig 12: Simulation readings for contribution 2

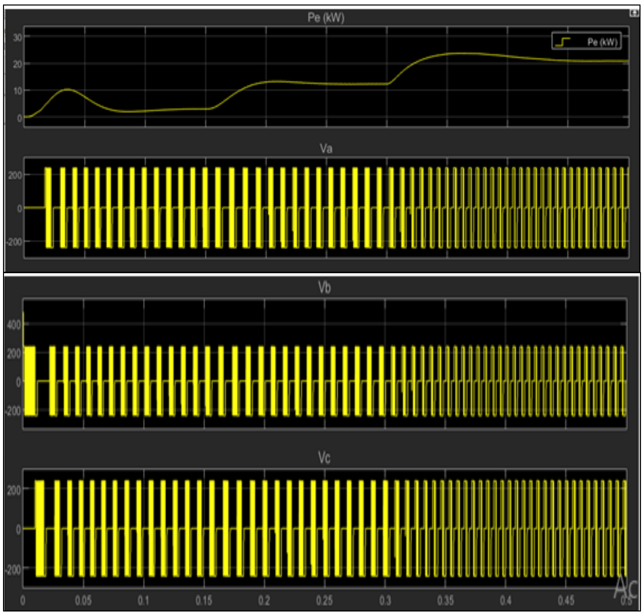


Fig 13: Voltage control outcomes for a, b, and c lines

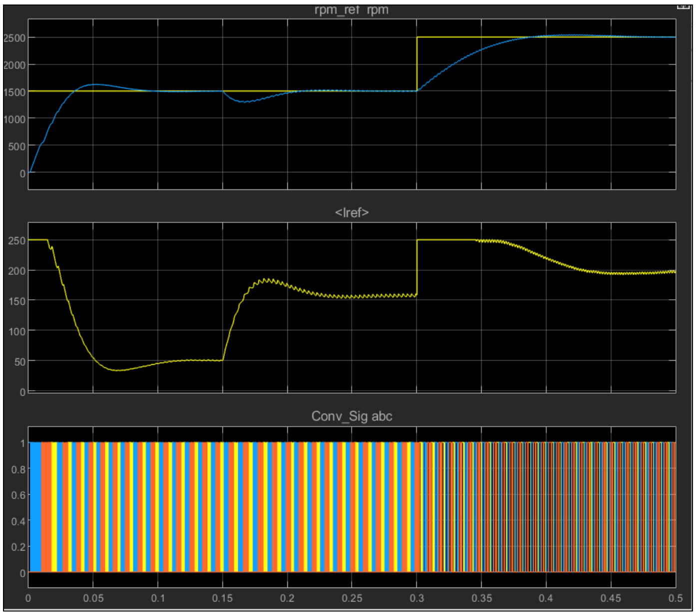


Fig 14: SRM motor RPM and converter abc signal values analysis

Conclusion

One potential way to achieve intelligent, efficient, and environmentally friendly transportation systems is to integrate and operate a Switched Reluctance Motor (SRM) drive for electric vehicles (EVs) inside a microgrid environment. This may be done utilizing control and simulation methodologies based on MATLAB. SRM drives are a good fit for electric vehicle operations because of their fault tolerance, high torque-to-weight ratio, and ruggedness. They provide bidirectional power flow for vehicle-to-grid (V2G) operations and enable renewable energy consumption when incorporated into a microgrid, and they offer increased energy management capabilities when used alone. SRM dynamics may be modelled, complex controllers can be designed, and performance under different grid conditions can be evaluated using MATLAB's simulation environment. Adaptive current profiling and torque ripple reduction are two examples of optimal control systems that greatly enhance efficiency, drivability, and power quality, according to the results. And by helping with things like voltage stability, frequency control, and load balancing, EVs linked to microgrids may make the grid more resilient. In addition to improving the performance of electric vehicle propulsion, the suggested solution would help achieve the larger goal of incorporating dispersed storage and renewable energy into contemporary power grids. The combination of SRM technology, electric vehicle mobility, and microgrid infrastructure can hasten the shift to smarter grids and greener energy, providing a long-term solution for transportation networks in both urban and rural areas.

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