Uluslararası İleri Doğa Bilimleri ve Mühendislik Araştırmaları Dergisi
Sayı 8, S. 20-27, 3, 2024

Araştırma Makalesi

International Journal of Advanced Natural Sciences and Engineering Researches
Volume 8, pp. 20-27, 3, 2024

Research Article

https://as-proceeding.com/index.php/ijanser
ISSN: 2980-0811

Analysis of Two SRMs at the Same Power Density Per Volume using ANSYS/Maxwell

Bekir Gecer*, N. Fusun Oyman Serteller [2] and Alper Nabi Akpolat [3]

[1]*Mechatronic Programme, Atasehir Adiguzel Vocational School, Turkey*
[2]*Electrical and Electronic Engineering,, Marmara University, Turkey*
[3]*Electrical and Electronic Engineering,, Marmara University, Turkey*

Email of the corresponding author: bekirgecer@adiguzel.edu.tr

(Received: 20 April 2024, Accepted: 25 April 2024)

(2nd International Conference on Scientific and Innovative Studies ICSIS 2024, April 18-19, 2024)

ATIF/REFERENCE: Gecer, B., Serteller, N. F. O. & Akpolat, A. N. (2024). Analysis of Two SRMs at the Same Power Density Per Volume using ANSYS/Maxwell. *International Journal of Advanced Natural Sciences and Engineering Researches*, 8(3), 20-27.

Abstract **–** Switched Reluctance Motors (SRMs) are old member of the electric machine family. Nowadays, SRM is getting popular in academic fields and in industry, especially in electric vehicles, due to the advantages of the offer such as high torque at low speed, simple structure and development of semiconductor technologies such as Mosfet and Igbt companents. This paper proposes compare two different SRMs at same power density per volume that are SRM 1 and SRM 2 about efficiency and torque parameters using ANSYS/Maxwell software program. So we have focused on to give same or near input values the motors to analyze and they are designed at same power density to comparasion. Design parameters of motors are obtained from optimization studies. Analysis results are shown that the SRM 1 is %3.64 efficier than the SRM 2 and also, the SRM 1 can produce 8.42 Nm torque more than the SRM 2. But the torque ripple of the SRM 1 is more than the SRM 2 torque ripple. As a result, the SRM 1 is better than SRM 2 for the electric vehicle applications such as e-scooter, e-bicycles and e-drones. For the future studies, a torque control system can be apply to minimize torque ripples for better performances.

Keywords – Analysis, Ansys, Efficiency, Torque, SRM.

I. INTRODUCTION

This The Switched Reluctance Motors (SRMs) are old member of the electric machine family. They have gained popularity in last years due to its simple structure, controlability robustness, ruggedness, reliability, and high torque ratio[1-3]. Many software programs have helped development of the electrical machine design like ANSYS/Maxwell program that designs and analaysis 2-D and 3-D electromagnetic and electromechanical devices, including motors, actuators, transformers, sensors and coils using Maxwell's equations. The design and performance analysis of SRM have studied by engineers as simulation in Maxwell[4-6]. The ANSYS/Maxwell software is used studying electric machines and magnetic field effects in engineering departments[8]. Also the SRM applications are worked where especially in electric vehicle fields like in [2], [7]. Another study presents a technical overview for low-noise switched reluctance motor (SRM) drives in electric vehicle (EV) applications[9]. For high efficiency and high motor performance of the electric vehicle applications, Model Predictive Control(MPC) method is used to direct torque control. This method show better performance than the conventional techniques[10]. Another study of electric vehicle applications is about design and development of the SRM in[11]. The most important problem that is torque ripple minimizing of SRM has studied using magnetic equivalent circuit method as detailed in[12]. Different motor modeling methods of Switched Reluctance Machines are compared about dynamic performance of SRM[13]. A Series Hybrid Electric Vehicle's simulation and dynamic modeling presented using SRM in[14]. For high speed SRM in electric vehicle, the vector control method is prefered. Results shows high speed, high output power and minimum vibration performance[15]. Besides motor modeling, the drive system studies of SRM are important for the applications as discharge of DC link capacitor[16]. Lastly for ligh electric vehicle , SRM Drive System's commutating strategy for optimizing have been studied and here, an analytical method is implemented[17].

In this study; design, analysis and comparison of two diffirent SRM have been presented using Maxwell software. Further the efficiency, torque and other parameters of the motors have been analyzed and finally the results has been presented in order to decide which motors are more proper for electric vehicle applications such as e-scooters, e-bicycles and e-drone as comparison. The Chapter II is about SRM, the design of SRM is in chapter III and chapter IV presents the simulation and analysis results of SRMs using ANSYS/Maxwell with results. Finally the conclusion part is in Chapter V.

II. DESIGN PARAMETERS OF SRM

The SRM is a doubly or singly salient machine where torque is produced by the tendency of the rotor to move to aligned position. There is the inductance of the energised windings is maximum. The basic 8(stator poles number)/6(rotor poles number) SRM structure is given in Fig 1 a) and equivalent circuit of SRM is seen in Fig 1 b).

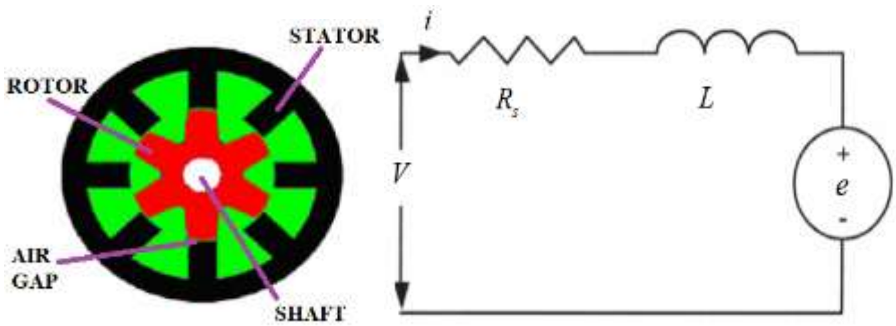

Fig. 1. a) 8/6 SRM Structure. b) Equivalent circuit of SRM.

The electrical equation is [1]:

$$V = R_s i + \frac{d(L(\theta,i)i)}{dt} = R_s i + L(\theta,i)\frac{di}{dt} + \frac{dL(\theta,i)}{d\theta} i\omega_m \tag{1}$$

$$e = \frac{dL(\theta,i)}{d\theta} i\omega_m = K_b i\omega_m \tag{2}$$

$V(V)$:Applied voltage, $R_s(\Omega)$: The resistance per phase , $i(A)$: Phase current, $L(H)$: Self-inductance, θ(rad): Rotor position, $\omega_m(rad/s)$: Angular velocity, K_b: Back-emf constant, $e(V)$:Induced emf.

The mechanical equation is [1]:

$$J\frac{d\omega_m}{dt} = T_e - T_L - b\omega_m \tag{3}$$

$J(kg.m^2)$: Inertia moment, $T_e(Nm)$: Induced Torque, T_L(Nm): Load Torque, b: Friction coefficient.

III. DESIGN OF SRM IN ANSYS/MAXWELL

The Switched Reluctance Motor (SRM) is an electric motor that works by reluctance torque. The energy is delivered to windings in the stator rather than the rotor. So its mechanical design is so simple, but there is a complex switching system of windings. The design of SRM depends on the geometry and number of the stator and rotor poles, the load characteristics and desired application[18]. In this study, we are focused in studying two different design of 8/6 SRM structures and they are designed to comparison at same power density as the SRM 1 and the SRM 2 in Maxwell.

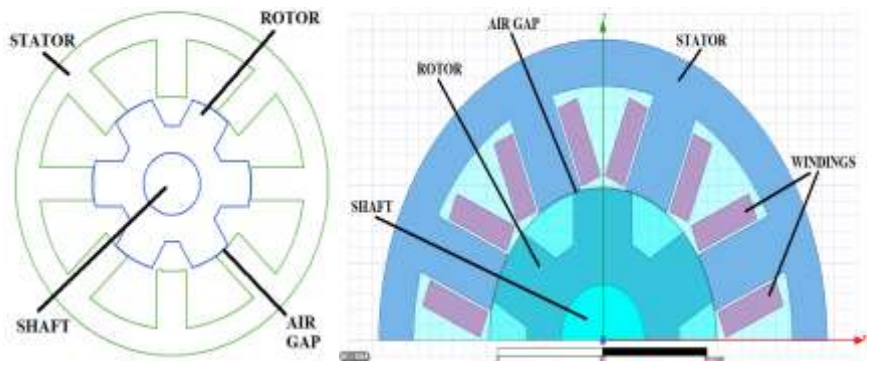

Fig. 2. a) SRM 1 RMxprt Model. b) SRM 1 Transient Model.

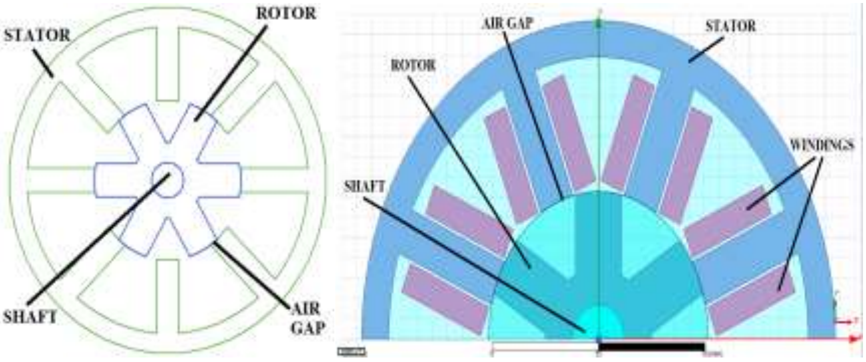

Fig. 3. a) SRM 2 RMxprt Model. b) SRM 2 Transient Model.

The Fig.2a and Fig.3a are the RMxprt model of the motors that designed to static analysis. Design parameters of the SRM 1 and SRM 2 are given in Table I. Although the motors size are different, the power density of motors are same because of different power values. Also reference speed, steel type and stacking factor values are given same for the both motors.

The Fig.2b and Fig.3b are the transient model of the motors that designed to dynamic analysis. They are called 2D motor model too in Maxwell. To do dynamic analysis, we need driver system for SRM as in Fig.4 that named asymmetric converter. Driver circuits of both SRMs are obtained from transient analysis section in Maxwell. Components values of these circuits are according to SRM input parameters to drive motors.

Table 1. Srm 1 and Srm 2 Motor Desıgn Parameters

Parameters	**Motors**	
	SRM 1	***SRM 2***
Power	2200 W	700 W
Voltage	220 V	300 V
Reference Speed	1500 RPM	1500 RPM
Stator outer diameter	194 mm	157 mm
Stator inner diameter	100 mm	73 mm
Rotor outer diameter	99 mm	72.60 mm
Rotor inner diameter	36 mm	17 mm
Stator Steel Type	M19_24G	M19_24G
Stacking Factor	0.95	0.95
Stator Length	92 mm	44.7 mm

Since the number of stator poles is 8, the drive systems have 4 phases as seen in Fig 4. The each phase is energized seperately by given input voltages. They are 220 V and 300 V for SRM 1 and SRM 2 driver circuits respectively.

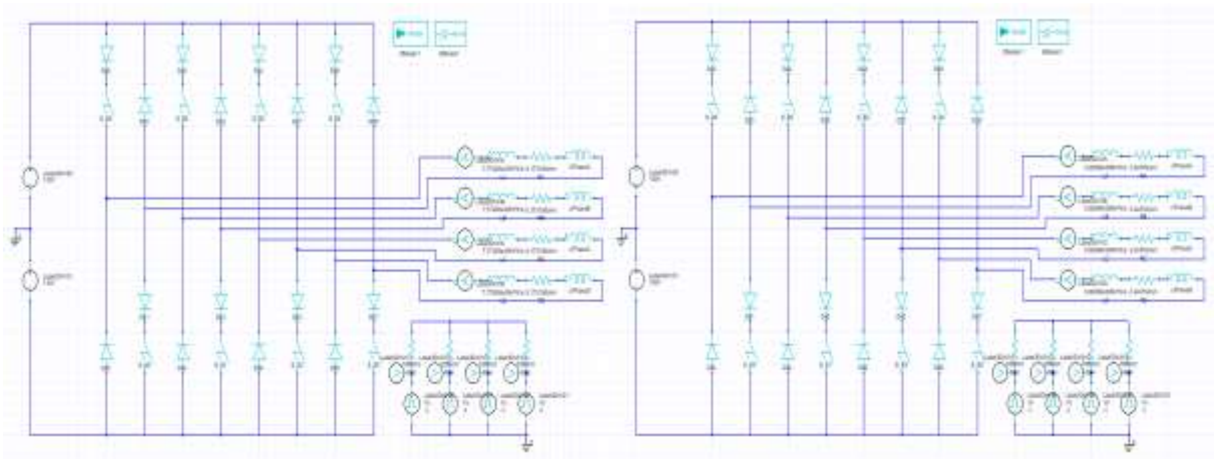

Fig. 4. a) SRM 1 Driver Circuit. b) SRM 2 Driver Circuit.

IV. ANSYS/MAXWELL ANALYSIS RESULTS

After design of the SRM motor models and driver circuits, the static and dynamic analysis of SRM 1 and SRM 2 were done according to input values seen in Table I. In this section the efficiency-speed, torque-time and torque-speed performances of both motors together are given as analysis results graphs in Fig. 5 , Fig. 6, Fig.7 and Fig. 8 comperatively.

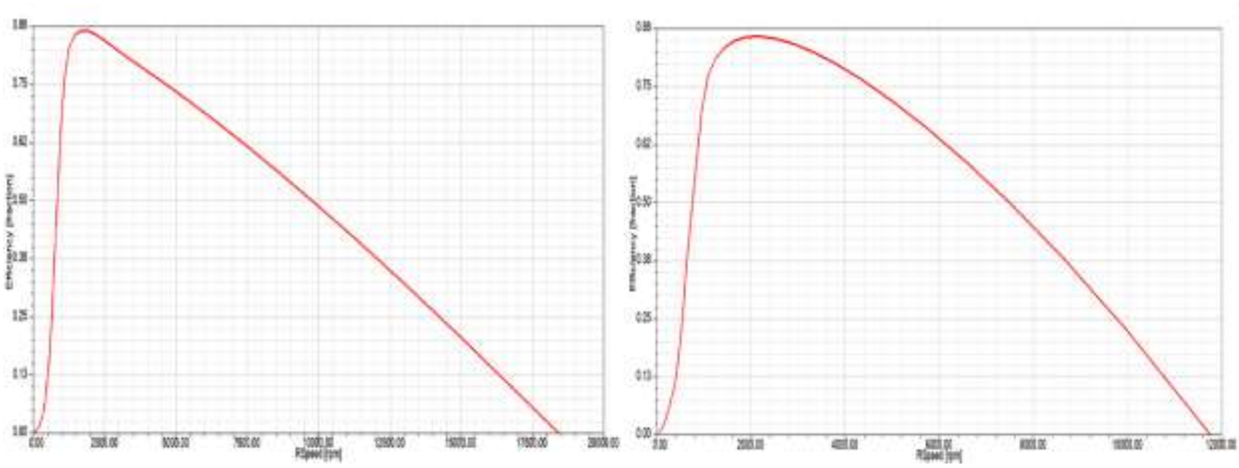

Fig. 5 a) SRM 1 Efficiency-Speed Graph. b) SRM 2 Efficiency-Speed Graph.

The efficiency of SRM 1 that is 86.21 % as in Fig 5 a) higher than efficiency of SRM 2 that is 82.57 % as in Fig 5 b).

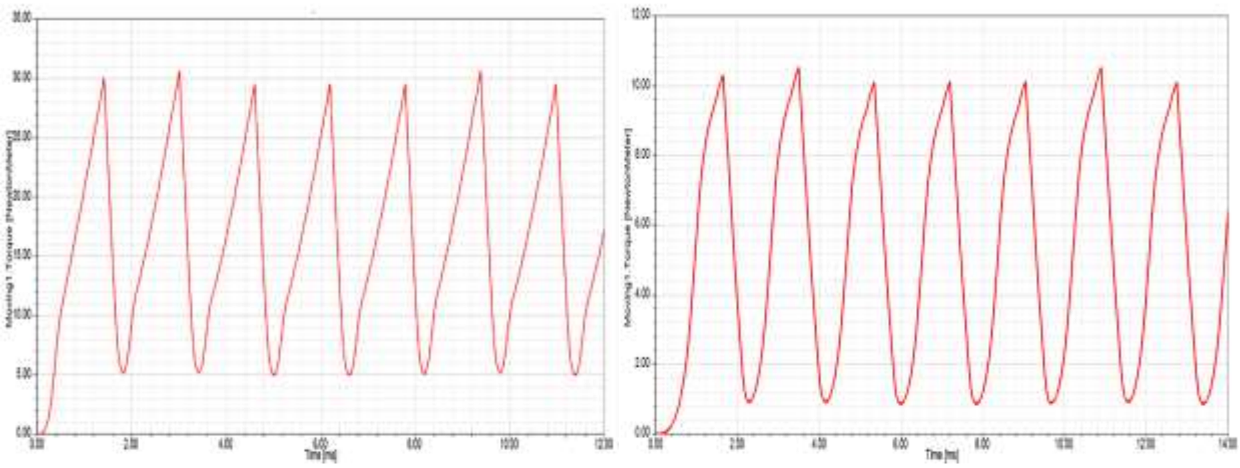

Fig. 6 a) SRM 1(air gap=1mm) Torque-Time Graph. b) SRM 2(air gap=0.4mm) Torque-Time Graph.

Torque-time graph of both motors are given in Fig 6. Because of different input power values, SRM 1 shows 8.42 Nm higher torque performance than SRM 2. But the torque ripple of SRM 1 is 15.4 Nm more than SRM 2, it is disadvantage of SRM 1 according to SRM2.

There was an another analysis to check torque ripples of both motors with different air gap values. We aimed to see effect of air gap on the torque ripple values. The results are shown in Fig 7.

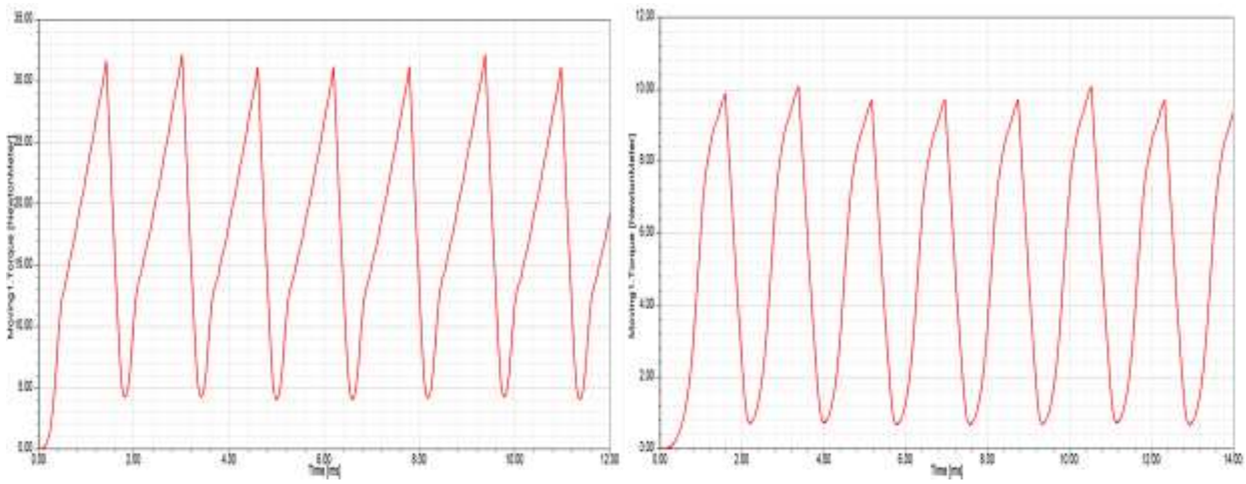

Fig. 7 a) SRM 1(air gap=0.5mm) Torque-Time Graph. b) SRM 2(air gap=0.2mm) Torque-Time Graph.

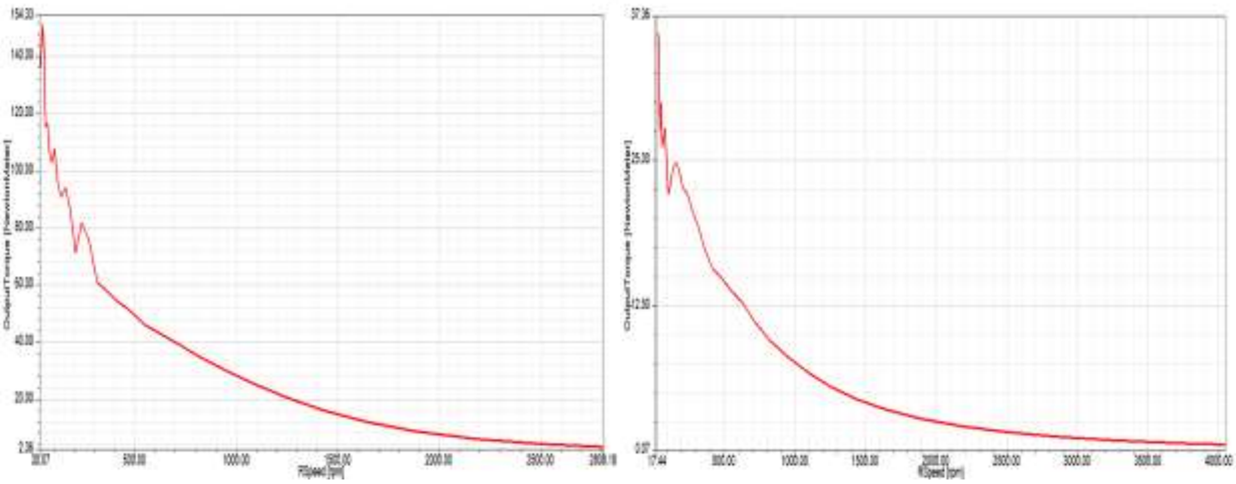

Fig. 8 a) SRM 1 Torque-Speed Graph. b) SRM 2 Torque-Speed Graph.

SRM 1 and SRM 2 show high torque performance even low speed values. It is on of the most important advantage of SRMs. The both motor's bevaiours are similar. SRM 1 torque value is higher than SRM 2 due to high input power value. They are seen in Fig 8. Motors can perform high torque behavior longer time using the torque control methods.

In addition, the static and dynamic analysis of SRM 1 and SRM 2 were redone according to different air gap values shown in Table II, and the analysis results are also given here.

V. CONCLUSION

The SRMs has been preferred in many applications in last years. One of the these applications is the electric vehicles. Because, the characteristics of the SRM such as high torque at low speed and other properties are proper for electric vehicles . In this paper, two different SRMs have been designed and they compared about efficiency, torque and torque ripple range at same power density. The SRM 1 %3.64 efficier and has 8.42 Nm higher torque than SRM 2. They are desired properties for electric vehicles. However torque ripple range value of SRM 1 is 15.4 Nm bigger than SRM 2. It is a undesirable feature and a disadvantage for SRM 1. Considering all results, the SRM 1 is better than SRM 2 for electric vehicles such as e-scooters, e-bicycles and e-drones.

Table 2. Srm 1 and Srm 2 Analysıs Results

Parameters	**Motors**			
	SRM 1 (air gap=1 mm)	***SRM 2 (air gap=0.4 mm)***	***SRM 1 (air gap=0.5 mm)***	***SRM 2 (air gap=0.2 mm)***
Power Density	635.83 W/cm3	635.83 W/cm3	635.83 W/cm3	635.83 W/cm3
Torque	13.36 Nm	4.94 Nm	13.26 Nm	4.22 Nm
Efficiency	86.21 %	82.57%	87.04 %	83.15 %
Torque Ripple Range	25 Nm	9.6 Nm	28 Nm	9.2 Nm

The analysis results of the SRM 1 and SRM 2 are given as in Table II. to decide which motor performance is better for applications especially such as e-scooters, e-bicycles and e-drones. Althoug they have same power density, their torque, efficiency and torque ripple ranges values are different.

REFERENCES

[1] A. E. , Fitzgerald, Kingsley C., Umans S.D., (1992), Electric Machinery, Mc. Graw Hill.

[2] K, Vijayakumar, R. Karthikeyan, S. Paramasivam, Arumugam, K.N. Srinivas, “Switched reluctance motor modeling, design, simulation and analysis: a comprehensive”, IEEE Trans Magn.,Vol.44(12), 2008, pp.4605-4617.

[3] Ali Emadi, B. Fahimi, R. B. Sepe, “A Switched Reluctance Machine BasedStarter/Alternator for More Electric Cars”, IEEE Transactions on energy conversion, vol. 19, no. 1, march 2004,pp.116-124.

[4] Ashwin R., Sreekanth P, (2007), “Design of a Switched Reluctance Motor in Ansys Maxwell”, International Journal of Innovative Research in Science, Engineering and Technology(IJIRSET), Vol. 6, Issue 2.

[5] Dr. S. Allirani, Ms. H. Vidhya, (2018), “Design and Performance Analysis of Switched Reluctance Motor using ANSYS Maxwell”, ICOEI , Sri Ramakrishna Engineering College Coimbatore, India.

[6] B. Gecer, N. F. Oyman Serteller, “Investigation of Effect of Pole Number Change on Opereating Parameters in Switched Reluctance Motors”, MSc Thesis of Marmara University Electrical and Electronic Engineering, 2019.

[7] Z. Yang, F. Shang, I. P. Brown and M. Krishnamurthy, "Comparative Study of Interior Permanent Magnet, Induction, and Switched Reluctance Motor Drives for EV and HEV Applications," in IEEE Transactions on Transportation Electrification, vol. 1, no. 3, pp. 245-254, Oct. 2015.

[8] N. F. Oyman Serteller, G.Karri, “Understanding the Foundations of Electromagnetic Field Theory with Computer Software” Education Engineering (EDUCON), IEEE,2019.pp.755-760.

[9] CHUN GAN , WUBIN KONG , “A Review on Machine Topologies and Control Techniques for Low-Noise Switched Reluctance Motors in Electric Vehicle Applications” , IEEE Access.

[10] R. A. Fadil, L. Sizamel, “Predictive Direct Torque Control of Switched Reluctance Motor for Electric Vehicles Drives” , Periodica Polytechnica Electrical Engineering and Computer Science, pp. 264-273, 2020.

[11] S. R. Patel, N. Gandhi, “ Design and Development of Switched Reluctance Motor for Electric Vehicle Application”, 2016 IEEE International Conference on Power Electronics, Drives and Energy Systems(PEDES).

[12] V. Naeini, “A detailed magnetic equivalent circuit modeling for torque ripples minimizing of a switched reluctance motor”, Electrical Energy Systems, 2019.

[13] S. Song, W. Liu, “A Comparative Study on Modeling Methods for Switched Reluctance Machines”, Computer and Information Science, Vol.3, No. 2, 2010.

[14] S. Sadeghi, J. Milimonfared, “ Dynamic Modeling and Simulation of a Series Hybrid Electric Vehicle Using a Switched Reluctance Motor”, Proceeding of International Conference on Electrical Machines and Systems, 2007.

[15] K. Aiso, M. Takahashi, “Study of High Speed SRM Using Vector Control for Electric Vehicle ”, 10^{th} International Conference on Power Electronics, 2019.

[16] G. Deepak, C. Das, “Active Discharge of DC Link Capacitor in SRM Drive for Electric Vehicle Application”, International Journal of Engineering Applied Sciences and Technology, 2020, Vol. 5, Issue 3, ISSN No. 2455-2143, Pages 568-571.

[17] G. Singh, B. Singh, “An Analytical Approach for Optimizing Commutation Strategy of Switched Reluctance Motor Drive for Light Electric Vehicle”, IEEE International Conference on Power Electronics, Smart Grid and Renewable Energy (PESGRE2020).

[18] B. Gecer, N. F. Oyman Serteller, “Understanding a Switched Reluctance Motor Control and Analysis Methods Using Matlab/simulink”, IEEE World Conference on Engineering Education, Guatemala, Doi : 10.1109/edunine51952.2021.9429155, 2021.