Modeling And Simulation of An Electric Vehicle

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Abstract- *Electric vehicles (EVs) are likely to be an alternative energy mode of transportation for the future as it has shown a great ability to reduce the consumption of petroleum based and other high CO2 emitting transportations fuels. The switched reluctance motor is a strong candidate for electric/hybrid vehicle applications primarily because of its high power density, good efficiency and high-speed capability. The motor drive for an EV is desired to have a wide speed range capability to eliminate the gears. A 4:1speed range of the motor in the constant power region results in good performance of the system. The paper will report the design of an electric vehicle system using a switched reluctance motor drive. A system level simulation tool for electric vehicles using the Matlab-Simulink platform will also be presented. The paper will discuss the analytical and simulation models for each of the key system components of an EV, which are the motor, controller, battery and the drive train.*

Keywords- Electric vehicles, Automobile, Power System

I. INTRODUCTION

Environmental and economical issues are the major driving force in developing electric vehicles for urban transportation. The exhaust emissions of the conventional internal combustion engine (ICE) vehicles is the major source of urban pollution that causes the greenhouse effect leading to global warming. The pollution problem is only going to worsen with the increasing number of automobiles being introduced on the road every year.Statistics show that the number of automobiles in our planet will increase from half a billion to more than a billion from 1992 to year 2000. There is also an economic factor that is inherent in the poor energy conversion efficiency of the combustion engines. Although, when efficiency is evaluated on the basis of conversion from crude oil to tractive effort at the wheels, the numbers for electric vehicles are not significantly higher, it does make a difference. Moreover, efficient power generation at localized plants together with very high motor and controller efficiency and advancements in battery or power source technology within the vehicle, the electric vehicles show immense promise in further overall efficiency improvement. Electric vehicle is the only alternative for a clean, efficient, and environmentally friendly urban transportation system. The electric vehicles paved their way into the world asearly as in the middle of the 19th century, even before the introduction of gasoline powered vehicles. In 1900, 4200automobiles were sold out of which 40% were steam powered, 38% were electric powered and 22% were gasoline powered. However, the invention of starter motor, improvements in mass production technology of gas powered vehicles and inconvenience in battery charging led to the disappearance of electric vehicles in the early1900's. However, environmental issues and reducing the dependence on oil led to the resurgence of interest in EV's in the 1960's. The demand for investing in R&D for EV's is ever increasing in 1990's with the major automobile manufacturers embarking in plans for introducing their own electric or hybrid/electric vehicles. This paper presents a modeling and simulation tool based on Matlab/Simulink for electric vehicles with emphasis on the propulsion unit. The efficiency of the motor and controller unit of an electric vehicle can make a significant contribution in enhancing the overall efficiency of electric vehicles over ICE vehicles. A switched reluctance machine (SRM) has been selected as the propulsion unit in this project, because of its high power density and excellent motor-load torque-speed matching characteristics. The advantages of SRMs over other machines will be further discussed in the motor design section. The details of motor, controller and electric vehicle modeling will be presented in the modeling and simulation sections. The developed simulation program will serve as an evaluation tool for SRM based EV designs. Different designs can be analyzed fairly quickly using the methods presented in this paper. The objective of this paper is to present the fundamentals of electric vehicles so that one can easily understand the design criterion, procedure and principles of operation. This will serve the education aspects on electric vehicle, which is very important in arousing the interest among people for developing and using electric vehicles.

II. EV SYSTEM AND LOAD

The major components of an electric vehicle system are motor, controller, power source, charger and drive train. The block diagram of an electric vehicle system is shown in Fig. 1. Lead/acid batteries are typically used as the power source for electric vehicles, although other promising battery technologies are emerging in the horizon. A model for lead/acid batteries has been developed and added in the simulation program. A microprocessor-based controller is used for vehicle and motor control. Control complications are to be minimized as much as possible to avoid disastrous failures at this early stage of EV development. Insulated gate bipolar transistors with ratings as high as 600A and1200V are the power devices of choice for the power electronic converter.

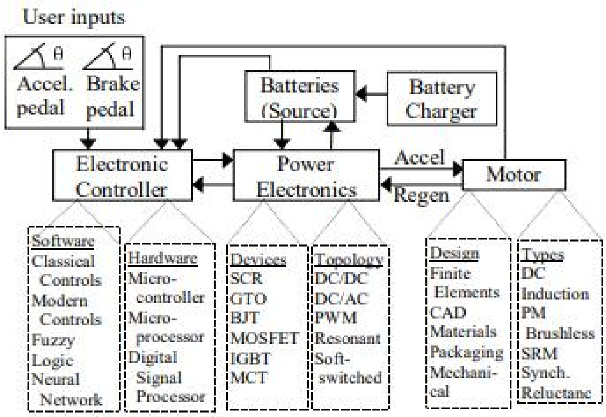

Figure 1. Major electrical components of an electric vehicle system.

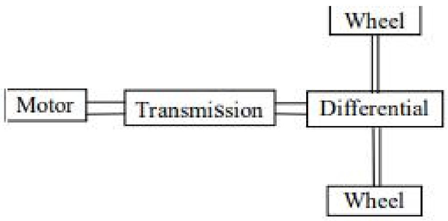

Figure 2. Drivetrain of an electric vehicle.

III. MOTOR DESIGN

The electric motor of the vehicle must overcome the road load, which is established by the vehicle mass, roadway gradient, rolling resistance and aerodynamic drag coefficients and vehicle velocity and acceleration. The motor is desired to have a high starting torque for initial acceleration, high power density and high efficiency to extend the battery range and a wide operating speed range to facilitate single gear transmission. The torque-speed profile of an electric motor has three regions; constant torque, constant power and natural characteristics regions. The constant torque region extends up to the rated or base speed of the motor when the rated power condition of the motor is reached. The constant power region is the field-weakening region that helps extend the operating speed of the motor beyond its rated speed. The motor fails to maintain the rated power beyond this region and the speed drops according to the natural characteristics of the motor. It has also been shown in [2] that the motor power and size is minimized for an electric vehicle application when the constant power region of the motor is extended. Ideally, eliminating the constant torque region would provide the minimum power rating of the motor, but this is not physically realizable. Therefore, the design objective would be to minimize the constant torque region and extending the constant power region. A good efficiency in the field weakening region is of extreme importance in electric vehicles.

The motor rated power reduces drastically if the constant power range is extended from 1:1 to 1:4. The power continues to decrease beyond 1:4 range, but not significantly, and the increase in transmission gear size and cost would outweigh the reduction in motor size. 1:4 constant power range is a good choice for a typical passenger vehicle with a maximum motor speed of 10,000 r/min and maximum vehicle speed of 44.7 m/s (100mph), although the optimum ratio would depend on the system variables and constants.

The type of motors that enable field weakening would be ideally suitable for traction applications. DC motor torque-speed characteristics and their field weakening capability matches the electric vehicle load characteristics very well. However, the size penalty and the brush and commutator problems render the dc machines unsuitable for such applications. The current trend is to use induction machines or brushless PM machines as the propulsion unit of EVs. The rapidly decaying linear region of the torque speed profile of induction machines beyond the breakdown torque limits the constant power region to 1.

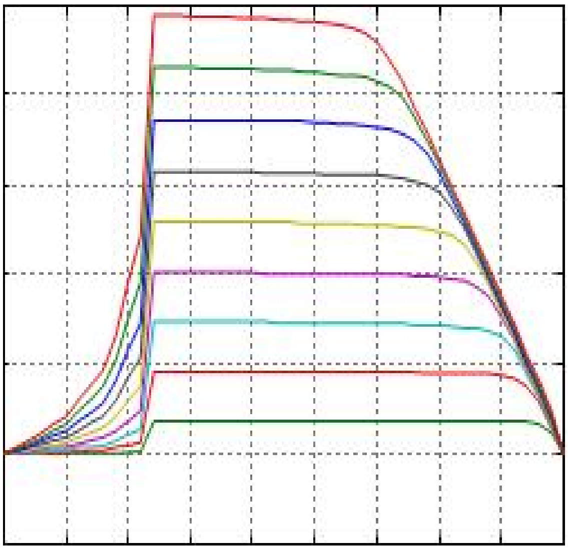

Figure: Torque-angle-current characteristics of the designed SRM.

IV. EV MODELING

The component models of the EV system were integrated in a Matlab-Simulink system simulation program. The Simulink program maintains the modular structure of the composite system, which makes it convenient for expansion and dissemination.The modeling approach and the simulation results are given in the following.

- **A. MOTOR MODEL –**A switched reluctance motor can be conveniently described by its flux-angle-current and torque-angle-current characteristics.
- **B. EV LOAD MODEL –**The EV load model is given by the equation of motion.
- **C. CONTROLLER MODEL –** The controller model consists of a PI speed regulator, commutation scheduler, and a current/voltage controller. The vehicle speed is converted to motor rpm using the gear ratio and wheel radius.
- **D. DIAGNOSTICS BLOCK –** The diagnostics block is included to calculate the losses, efficiency and power factor of the switched reluctance motor. The information is valuable during the design process of a drive for an application. The losses in an SRM include the stator copper losses, core losses and friction and windage losses. The electrical input to the motor can be easily computed from the bus voltage and the rms input current. The rms input current is also used to calculate the stator copper losses.

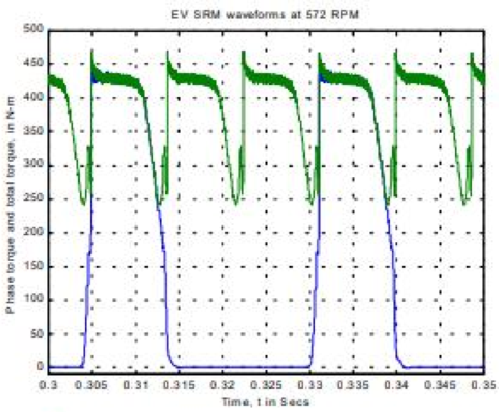

Figure [illegible]. Phase torque and total torque waveforms of the 60kW EV SRM at 572 rpm.

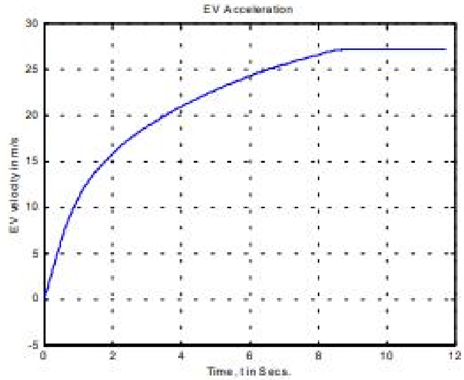

Figure [illegible]. Acceleration of the EV with a 60kW SRM.

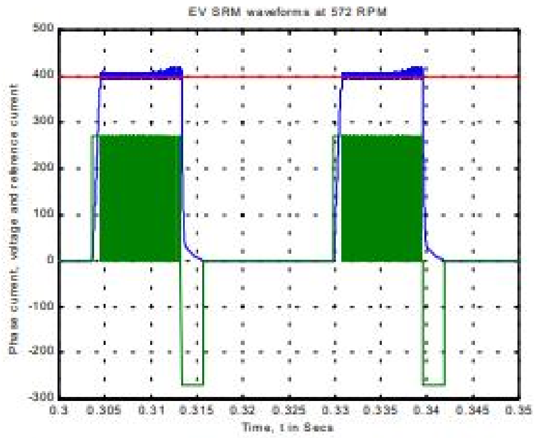

Figure [illegible]. Phase current, voltage and reference current waveforms of the 60kW EV SRM at 572 rpm.

V. CONCLUSION

The paper presents a design methodology and performance simulation of an electric vehicle system. The paper is focused on the design of the electric propulsion unit and evaluation of the drive in meeting the vehicle performance requirements. The paper demonstrates the effective use of computer tools in the preliminary design stage of an electric vehicle. The results presented demonstrated the capability of SRMs in operating over a wide speed range in the constant power region. This feature along with other positive attributes of SRMs make it ideally suitable for electric vehicle applications

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