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ELECTRICAL BRAKING IN SRM DRIVEN HYBRID ELECTRICAL VEHICLE

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Abstract*—Automobile industry is a developing sector. Many advanced technologies are implementing in this field. In the current situation for pollution control, conventional diesel vehicles are replacing with new echo friendly Green vehicles. Thus electric vehicles have their own importance in the current situation. Thus new and enhanced technologies are needed for improving the performance of conventional electric vehicles. The SRM driven electrical vehicle is a novel idea. In this paper electrical braking of SRM driven electrical vehicle is presented in this paper.

***Index Terms*—SRM motor, Electrical Braking, Electrical Vehicle, Partial Electrical Loading**

I. INTRODUCTION

In modern society, automobile plays a vital role. An automobile driven by an internal Combustion Engine(ICE) which runs on fossil fuel is a major achievement of the present technology. As fossil fuel being exhausting it has produced threats to the usage of internal combustion engine (ICE) vehicle. Therefore, the present research in the automobile industry is concentrated to design the electric transportation system for providing echo friendly and smart alternative.

Conventionally mechanical brakes are used in in vehicles. In this braking system, it has got disadvantages like loss of energy, wear and tear of mechanical parts and so on. These drawbacks of mechanical brakes can be overcome by using electric brakes. In SRM brakes firing angle control method is presented here. It provides more accurate and efficient braking torque as compared to mechanical brakes. Thus electric brakes improve the braking performances as well as overall efficiency of the vehicle.

II. SWITCHED RELUCTANCE MOTOR

The switched reluctance motor (SRM) works on the principle of reluctance torque. The SRM have wound field coils on the stator only. The rotor has neither magnets nor coils attached in it. In SRM torque is generated by the affinity of the rotor to move to a point where the inductance of the excited winding is extreme or reluctance is lowest. The magnetic reluctance of the rotor creates a force whenever the stator windings are energized, which helps to align the rotor pole with the nearest stator pole. To maintain the rotation a proper electronic control system is needed. It switches on the windings of stator poles in appropriate sequence in such a way that the magnetic field of the stator leads the rotor pole results in drawing it forward.

For driving the vehicle a 6/4 switched reluctance motor is used. The conventional switched reluctance motor model is used to drive the vehicle.

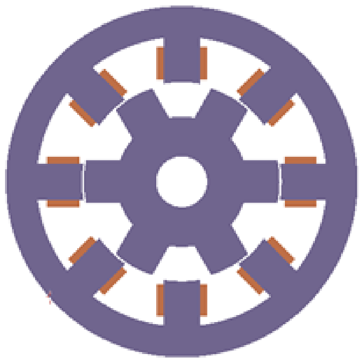

Fig. 1. Switched Reluctance Motor

III. ELECTRICAL VEHICLE MODELING

The mathematical model of electrical vehicle with two equally sized wheels, moving forward or backward along its longitudinal axis is developed. Assumed that vehicle is in the vertically stable state thus wheels are always perpendicular to the horizontal plane. For the dynamic modeling of the electrical vehicle partial loading scheme is used. In this scheme, the vehicle model is considered as a partial load. The vehicle model only takes the torque of the driver motor as input and it will produce the output.so this modeling technique is very useful to analyse the characteristics of different motors, their operation and their performance when used as a driving motor for electrical vehicle application. The vehicle modeling block is connected as a load to the driver motor.

For vehicle modeling following parameters are taken in to account:

'm is a mass of the vehicle in (kg) = 200
'a' is a horizontal distance of CG from front axis in (m) = 1.4
'b' is a horizontal distance of CG from rear axis in (m) = 1.6
'h' is a height of CG from the ground in (m) = 0.5
'A' is a front area in (m2) = 1.2
'Cd' is a drag co-efficient = 0.4
'A' is a front area in (m2) = 1.2
'Vx' is a longitudinal velocity of the vehicle in (m/s)
'ρ' is a mass density of air in (Kg/m3) = 1.2
'F_{XF}'is a longitudinal force applied at the front wheel in (N)
'F_{XR}'is a longitudinal force applied at the rear wheel in (N)
'r' is a radius of the wheel in (m) = .279

In the model the output of the vehicle is with the longitudinal velocity of the vehicle with the input longitudinal force applied to the front and rear wheels. Assuming that the rear wheel drives require longitudinal force at the rear wheel to accelerate the vehicle with the velocity Vx is, where

$$F_x = m\frac{dVx}{dt} - F_d + mg\sin(\beta) \qquad (1)$$

$$m\frac{dVx}{dt} = F_x + F_d - mg\sin(\beta) \qquad (2)$$

Aerodynamic drag force,

$$F_d = -\frac{1}{2} C_d \rho V_x^2 \,\mathrm{sgn}(V_x) \qquad (3)$$

From the (2) and (3) dynamic model of the vehicle system is simulated in the MATLAB Simulink environment as shown in Fig. 2 and Fig. 3

Fig. 2 Shows the MATLAB model of SRM –Hub driven electrical vehicle. In the electrical vehicle block vehicle modeling is inserted. Conventional SRM model is used to realize the driver motor. A position sensor is used to detect the position of the rotor. A rotor position feedback is essential in the operation of SRM. A hysteresis controller is used to limit the current flow in the field coils. It is used to protect the poles from saturation. During acceleration period the SRM takes large amount of current to overcome stationary inertia of the vehicle.

Fig. 3 shows the electrical vehicle modeling block. This block takes the torque developed by the switched reluctance motor as input and gives the output vehicle speed. From this speed all parameters like wheel RPM, Distance traveled, linear speed etc. are calculated. 6/4 switched reluctance motor generic model is used for simulation.so the step angle is 30 degree

.

The main disadvantage of switched reluctance motor is the torque ripple. It is reduced by using hysteresis current controller.

IV. DRIVER CIRCUIT

Two switch asymmetrical converters are used to drive the switched reluctance motor. The phase windings are connected to the DC source through this converter.

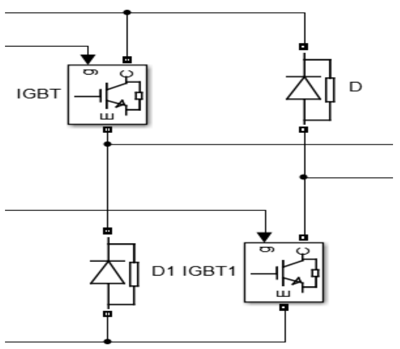

Fig 4. Asymmetric converter

Depending on the position of the rotor of switched reluctance motor, which is detected by the position sensor and fed back through a feedback circuit, the appropriate phase windings are excited by turning ON the static switches in the phases.

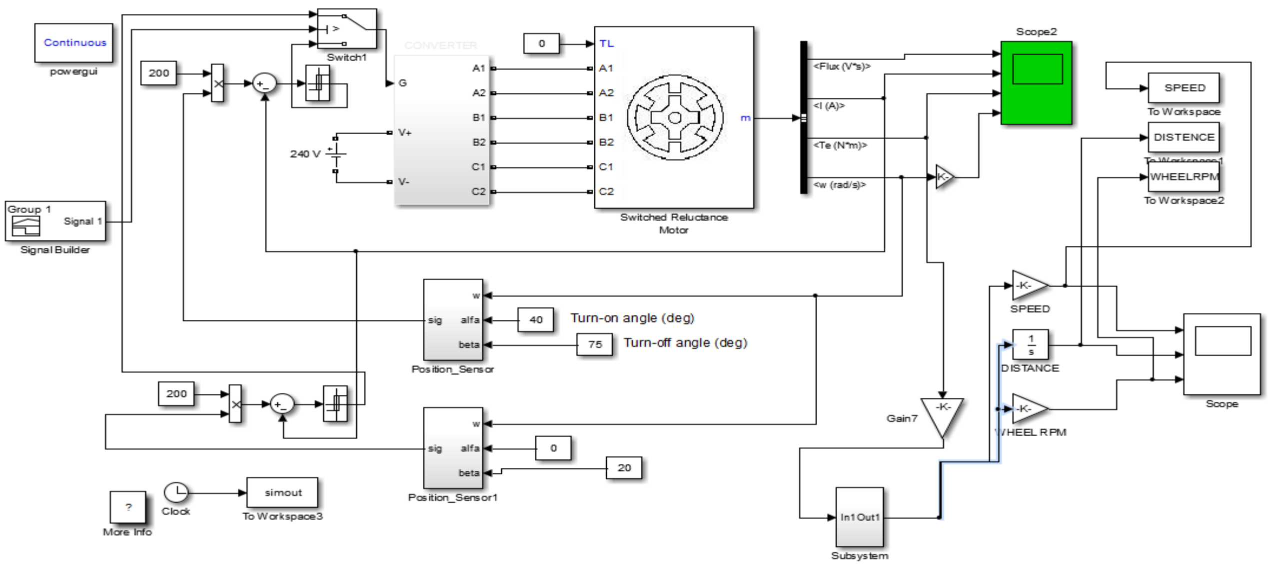

Fig. 2. Switched Reluctance motor driven electrical vehicle model

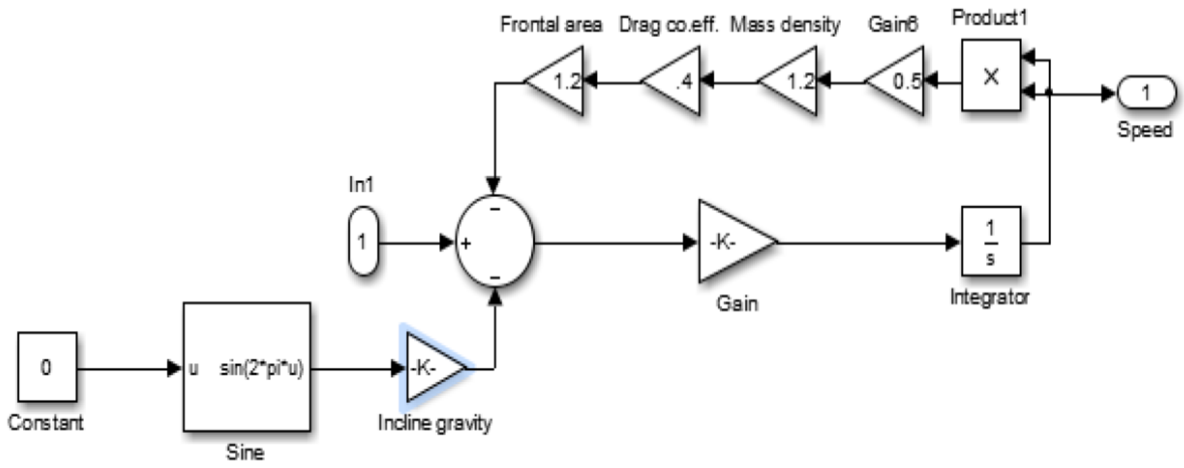

Fig. 3. Electrical vehicle model

I. ELECTRICAL BRAKING

In the SRM the EMF induced is given by

$$e = -\frac{d\Psi(i,\theta)}{dt}$$

Where, Ψ(I,θ) is the flux linkage which is a function of current and rotor angle.

$$\frac{d\Psi(i,\theta)}{dt} = L\frac{di}{dt} + i\frac{dL}{d\theta}\cdot\frac{d\theta}{dt}$$

$$= L\frac{di}{dt} + \omega i\frac{dL}{d\theta}$$

Where $\frac{d\theta}{dL} = \omega$ is the angular velocity.

L is the incremental inductance (slope of magnetization curve)

Power developed is given by

$$P = Li\frac{di}{dt} + \omega i^2\frac{dL}{dt}$$

Energy stored in the magnetic field

$$W_E = \frac{1}{2}Li^2$$

Power due to variation of magnetic field

$$\frac{dW_E}{dt} = Li\frac{di}{dt} + \frac{1}{2}\omega i^2\frac{dL}{d\theta}$$

Mechanical power =Power from supply – power due to change in magnetic field

$$P_M = \left(Li\frac{di}{dt} + \omega i^2\frac{dL}{dt}\right) - \left(Li\frac{di}{dt} + \frac{1}{2}\omega i^2\frac{dL}{d\theta}\right)$$

$$= \frac{1}{2}\omega i^2\frac{dL}{d\theta}$$

Torque is given by $T = P_M/\omega$

$$= \frac{1}{2}i^2\frac{dL}{d\theta}$$

Positive value of $\frac{dL}{d\theta}$ corresponds to motoring action and negative value of $\frac{dL}{d\theta}$ corresponds to generating action.

Electrical braking is realized by achieving a negative rate of change of inductance with respect to the change in rotor position.

II. SIMULATION RESULTS

For obtaining the output simulate the model in driving mode up to a speed of 40km/hr and then apply the brake. The standard braking distance for a vehicle moving at a velocity of 40 km/hr is 12.2 m. In this simulation, the braking distance is less than 12m so the braking is efficient

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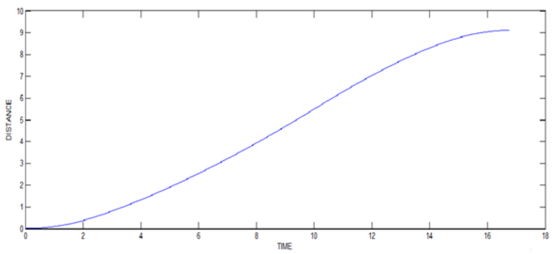

Fig. 5.Distance Vs. Time graph

Wheel rpm Vs. Time graph shows a good braking characteristic because the braking is not sudden so it is equivalent to an anti-lock braking system. After application of brake, the driver can control the vehicle direction. It is a superior character of this type of braking.

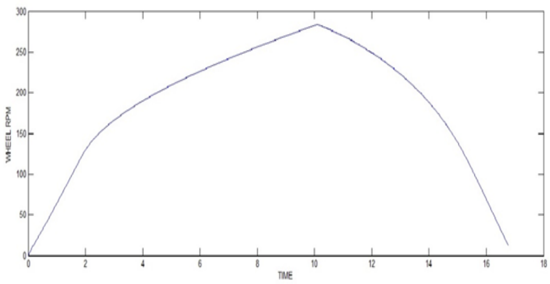

Fig. 6.Wheel rpm-Time graph

A hysteresis controller is used in the simulation to avoid the saturation of stator poles. So the current Vs. Time graph oscillates within the upper and lower limits. By using this technique overheating and damage rate is reduced

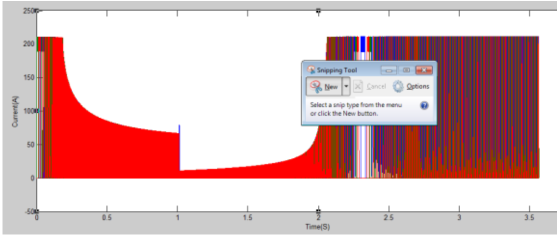

Fig. 7.Current Vs. Time graph

It is clear from the Torque vs. Time graph after the application of brake torque is negative that means the vehicle speed is reducing. Negative torque reduces the driving momentum so the speed of the vehicle reduces.

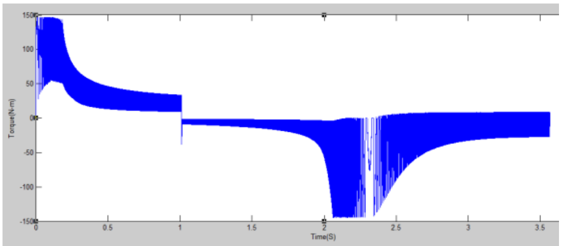

Fig. 8. Torque Vs. Time graph

III. CONCLUSION

Braking system used in electric vehicles are conventional hydraulic brakes which actuates the brake by using the braking fluid. It has got many drawbacks like huge energy is wasted in the form of heat, Expensive replacement, large maintenance cost and large wear and tear of brake parts. To improve the energy saving and braking performance electrical braking were suggested in this paper. For this firing angle control is used here.

From the output graph it is very clear that the electrical brake has superior characteristics than the mechanical brakes. Partial loading scheme is very useful to analyses the performance of electrical vehicle driving motors

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