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Modeling and Simulation of Electric Vehicle to Optimize Its Cost and Range

Shivangi Kaushik

***Abstract:** In the present days, the vehicles are primarily operated for transportation applications. The conventional energy sources like oil and gas are used as fuel sources of various vehicles. Since the year 2000, electric vehicles are commonly used in various countries. Within the previous few years, the electric vehicle remains a constant topic for the research community. The drive train can be the main challenge for the researchers. In this paper, we developed an EV drive train configuration with the help of AC motors. The developed model contains a battery source, AC motors (Induction (squirrel cage) and Synchronous (PMSM), motor controller (DTC (Direct torque control) and FOC (field Oriented control), PI control, wheels configuration (Front and Rear) and vehicle body. The model developed on the Simulink tool of Matlab. A Metaheuristic optimization algorithm WOA (Whale Optimization Algorithm) used to optimize the gain parameters of PI control. WOA based optimized PI controllers can adjust their gains values (K_p and K_i) in correspondence to deviations of EV speed and torque and results in stable speed and torque conditions. The proposed optimization controllers possess advantages over conventional controllers in terms of its robustness, to achieve better EV stability, no speed overshoot and accurate speeds.*

***Index Terms:** Electric vehicles, Motors, Drive train, PI controllers, Whale optimization algorithm (WOA)*

I. INTRODUCTION

In the present scenario, the fuels demand is high, and their consumption increases. Due to the uses of these fuels in the vehicles Co2 gas dissipated in the large amount. The carbon dioxide gas effect the environment varies badly. The Co2 reduction is the main challenge, and it can be achieved by the Eco-friendly vehicle or car called Electric vehicle (EV). Due to the increasing cost of the fuels in the present days, the fuel cell vehicle is not economical. The EVs are very economical due to their driven process achieved by an electric motor. They do not pollute the environment. The cost of the batteries and motors are stable, so EV prefers than the fuel based vehicles.The Electric Vehicle developed by the motor, battery, controller, converters, and wheels. The motor connected to the differential of the wheels. Figure 1.1 shows the block diagram of the electric vehicle construction.

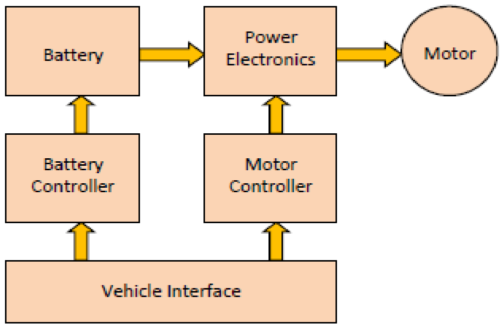

Figure 1.1 Electric Vehicle Drivetrain [2]

Figure 1.2 shows the schematic arrangement of the Electric vehicle drive train configuration. In this configuration, a battery pack is used to provide the dc energy to the circuit which is further connected to the inverter circuit

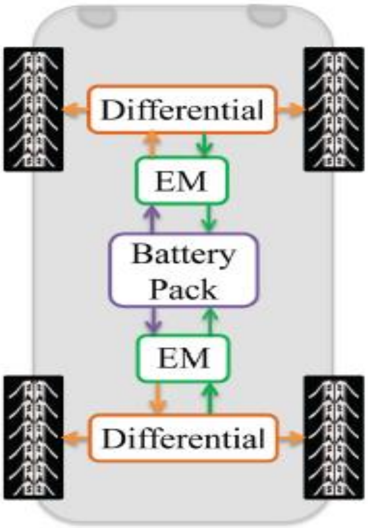

Figure 1.2 EV schematic arrangement [3]

In this basic configuration of EV, the four wheels are used. Two wheels are connected in the front portion called front wheel drive. Rest of two wheels connected at the rear portion of the drive, so it is called real wheel drive. Both the ends wheels are connected through the differential. The differential is provided the balancing to the rear and front wheel drive system. The differential portion represents a gear mechanism that allows the driven shaft to spin at different speeds. The fidelity of the gear model improved by specifying the parameters of the differential gear system like gear inertia, meshing, and viscous losses. A battery pack is used as the source of the electric vehicle model. A lithium-ion battery fixed in the modeling of Electric Vehicle (EV) which provides input supply both the motors connected across the front and rear end of the model.

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* Correspondence Author
Shivangi Kaushik*, Bachelor of Technology degree from the Department of Electrical and Electronics Engineering, Raj Kumar Goel Institute of Technology, Ghaziabad

The induction motor and synchronous motor used for the driven portion of the electric vehicle due to their several advantages as studied earlier. On the rear wheel, a squirrel cage induction motor is connected due to high efficiency and high starting torque requirement. An induction motor has both characteristics efficiently. The high starting torque demand is complete by the induction motor which helps the electric vehicle in the initial stage. At the front wheel portion, the synchronous motor is connected due to their high power density and constant speed characteristics. The control operation performed by the inverter which provides three phase ac supply to the induction and synchronous motor.

II. PROPOSED WORK/SIMULINK MODEL

A. *Modeling of Electrical Vehicle (EV)*

We developed a four-wheel drive model of an electric vehicle. Two wheels place at the front portion and the other two placed at the rear portion. Both real and front wheels are controlled by an induction motor and synchronous motor with the help of the inverter controller circuit. The vehicle body placed on the four wheels of the drive with initial parameters of environments like wind, inclined and throttle. Before performing the modeling of the four-wheel electric vehicle drive train, we finalize the parameters and behavior of the vehicle body. On the front wheel side, we used a synchronous motor with a controller connected to the battery voltage source. Inverter circuit applied in the controller to provide a sufficient amount of electric supply to the motors.

B. *Vehicle Longitudinal Dynamics*

For the evaluation of longitudinal nature of electric vehicles some equations are used. The Electric vehicle model based on motion resistance forces like an aerodynamic drag, rolling and climbing resistance and vehicle velocity. The rolling resistance (R_x) is that term which related to the energy losses due to tire deformation and adhesion of contact area. For small speed, the rolling resistance calculated as

$$R_x = W(0.01 + 2.24 \times 10^{-4} V) \tag{1}$$

Wrepresents the weight of the function and V is the speed of the tire. The coefficients multiplied by the rolling resistance are the physical properties of the tire [3].

Other parameters aerodynamic drag (D_A) which is estimated as

$$D_A = \frac{1}{2}\rho V^2 C_D A \tag{2}$$

In equation 4.2, ρ is the air density which defined the resistance force,A reflects the vehicle frontal area and C_D represents the drag coefficients [24]. The electrical vehicle configuration consist of the electrical coupled differential system so the required torque calculated as

$$T_{req} = (Ma_x + (I_{dF}N_{dF}^2 + I_{dR}N_{dR}^2 + I_w)\frac{a_x}{r^2} + R_x + D_A)r \tag{3}$$

T_{req}reflects the requested torque or required torque, $I_d$and N_d are the differential inertia and transmission ratio for the front (F) and rear(R) wheel drive system [19].

The complete requested torque calculated by power management control (PMC) as per the configuration studied in chapter-1

$$T_{req} = T_F + T_R \qquad 4)$$

T_F and $T_R$represents the torque of the front and rear wheel propulsion system. The electrical vehicle speed is limited by the available driving power and restricted by tire traction. The weight transferred during the acceleration and tire ground peak coefficients of friction μ

$$T_{F(Max)} = \mu\left(\frac{Mgc}{2L} - \frac{Mha_x}{2L}\right) r \tag{5}$$

$$T_{R(Max)} = \mu\left(\frac{Mgb}{2L} - \frac{Mha_x}{2L}\right) \tag{6}$$

Lis the vehicle wheelbase, h represnts the vehicle gravity at centre height, g assume the gravitational acceleration, b is the longitudinal distance between the vehicle front axels and the gravity center and c also the longitudinal distance of vehicle across real wheel axels and gravity center.

III. RESULTS

The proposed EV prototype structure is shown in figure 1 that consists of independently controlled front and rear wheel drive systems to enhance the driving performance and to keep the anticipated torque and speed conditions in EV is verified in Matlab/Simulink environment. As formerly mentioned, to increase the steering ability in traffic congestion and the requirement of efficiently generated torque at the low-speed permanent-magnet synchronous motor (PMSM) is used in the front drive system. To maintain driving torque under high speed and overload conditions induction motor (IM) in the rear drive system is preferred. The rotor of these motors is straight coupled with a respective differential gear, and with the help of these gears, the generated motor driving torques are transmitted to the respective wheel sides. Furthermore, the wheel drive systems are controlled with the help of individual controller and PWM inverters. EV management controller throughout supervised the considered wheel drive systems. Moreover, it appropriate controls the front and rear wheels distributed torque rendering to running conditions and result in enhanced EV operating efficiency overall speed regions.

A. *Simulation*

To describe the behavior, speed and torque characteristics of the proposed EV wheel drive system, simulations are carried out using the model built in Matlab/Simulink which is shown in figure 6.

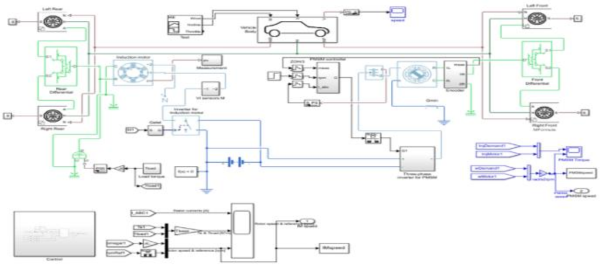

Figure 6: Proposed EV wheel drive system Simulink model

The simulation results of both controlling phases, i.e., with and without WOA optimization analyzed to show the feasibility of the proposed EV drive system model. The speed and torque control of EV is executed through the torque distribution in front and rear wheel drive by the following running modes. Figure 7 shows the WOA optimizer convergence curve

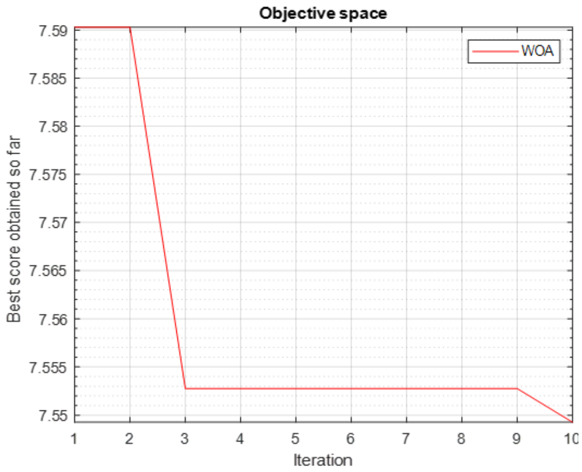

Figure 7: WOA optimizer convergence curve

B. Initial Starting mode

At starting this mode appears, when the key connected with the battery source is turned on the front, and rear wheel drive motors get the supply and start functioning. And EV starts accelerating and the generated reference torque from the accelerator distributed to rear wheel drive system. Instantaneously after sensing the rotor position, it shifts to normal mode operation, and that is favorably distributed to the front drive system. Figure 5.3shows the comparison of un-optimized and WOA optimized front wheel drive system speed. In this figure, it is seen that un-optimized speed is oscillating to its reference speed; this is because we conventional PI controllers are used in this phase. This can result in unstable steering and seed operations, and a lot of efforts are required to make EV stable. This oscillating speed also creates a safety issue for the passengers. Also, the un-optimized EV drive system requires almost 4 seconds to make the speed constant. On the other hand, by using an optimized controller, we can obtain stable speed which is almost equal to the front wheel drive reference speed. Also, to the reduced speed error, the controller takes the very small time of 0.25 seconds to attain its reference value. And also, by the help of WOA optimizer generated oscillation in EV speed is eliminated. In rear wheel drive, system speed curves are shown in Figure 9. This figure shows that this speed becomes stable in very less time and rear wheel drive speed also becomes synchronized with the front wheel speed of 1600 rpm.

C. Normal Running mode

In this phase, the generated reference torque is mainly distributed to the front wheel drives and results to attain the steering stability on poor road conditions. Also, the distribution of torque in the rear wheels is done in such a way, that rear wheels are always in agreement to the speed of the front wheel drive systems. In figure 8 and 9 we can observe that during normal running conditions the speed of both front and rear wheels are becoming stable having a value of 1600 rpm. And we can easily saw the synchronization between these wheel drive systems.

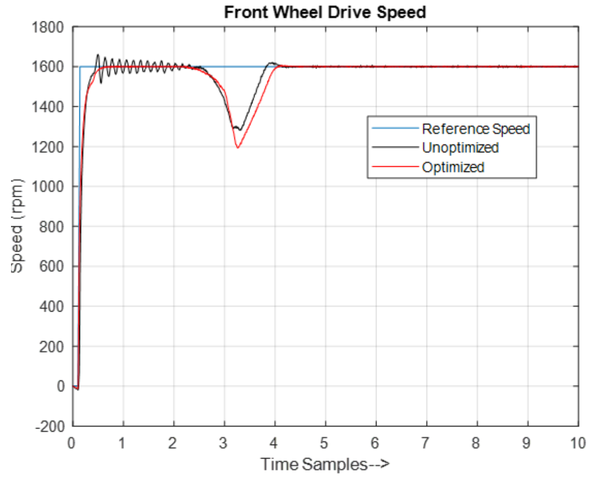

Figure 8: Front wheel drive speed

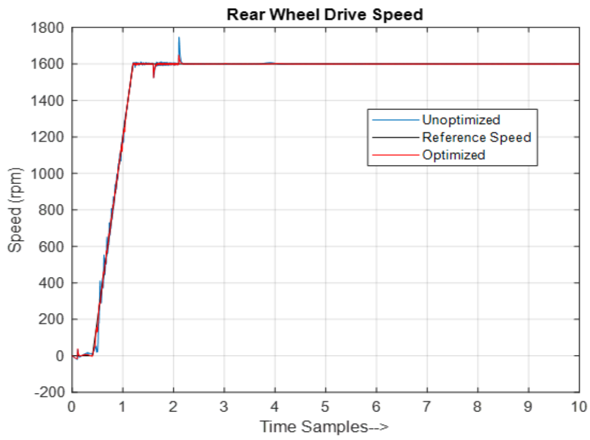

Figure 9: Rear wheel drive speed

Figure. 10 shows the optimized total EV speed, in this figure from 0to 4 seconds, i.e. in initial starting and acceleration mode the speed of the EV is increasing. After a time of 4 seconds, the speed of the EV becomes almost stable, i.e. EV is running in normal mode.

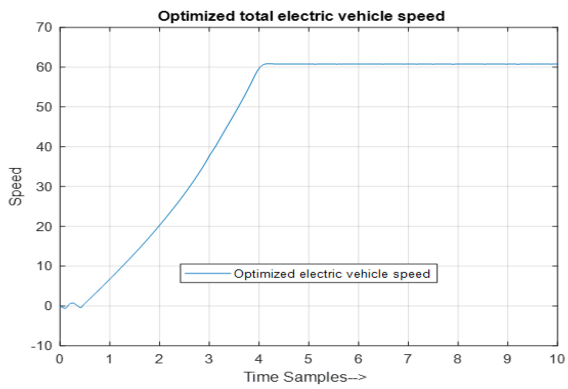

Figure 10: Optimized total electric vehicle speed

Figure 11 and 12 shows the optimized generated rear wheel driving torque and front wheel driving torque respectively.

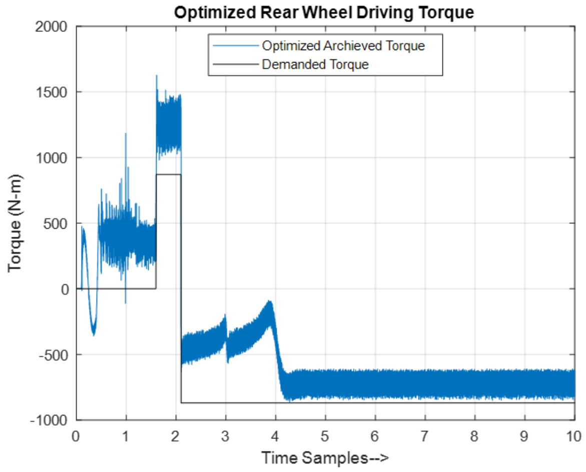

Figure 11: Optimized rear wheel driving torque

During initial starting mode and acceleration mode as large torque is required, in this acceleration period both wheel drive system act simultaneously and supports each other at every instant of time and provides large torque as shown in figures. EV optimized management controller throughout supervised the considered wheel drive systems. Moreover, it appropriate controls the front and rear wheels distributed torque rendering to running conditions and result in enhanced EV operating efficiency overall speed regions.

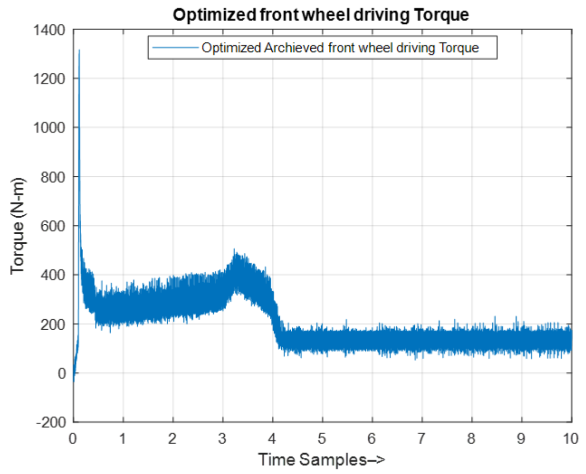

Figure 12: Optimized front wheel driving torque

IV. CONCLUSION

Proposed EV wheel drive system which is having individual front and rear control, improves the EV performance such as torque and speed stability, steer ability, drivability, and safety at low speed and high-speed operations. Also, the wheel drive systems were founded in such a way that above stated EV performance requirements attained more efficiently. The drive systems are also successfully synchronized in such a way that, if in some adverse conditions torque generated from the front wheel drive is found insufficient to drive the EV at desired speeds at the same time rear wheel drive system provides the adequate torque to the EV. In this work, firstly this synchronization and controlling of the drive system are achieved by conventional un-optimized PI controllers. Then later on the performance of drive controllers are further increased by the help of WOA along with DTC.

The simulation results also show the effectiveness of used optimization over PI controllers. Optimized EV system model achieves stable speed and torque in starting and normal running mode operations very quickly. Also, the results with WOA optimization are very accurate as compare to un-optimized controls. Thus the implementation of WOA in EV wheel drive control system is found successful.

REFERENCES

1. Y Mastanamma, Dr M ArunaBharathi, “Electric Vehicle Mathematical Modelling and Simulation Using MATLAB-Simulink” IOSR Journal of Electrical and Electronics Engineering (IOSR-JEEE), Volume 12, Issue 4 Ver. I (Jul. – Aug. 2017), PP 47-53.
2. J. J. Eckert, L. C. A. Silva, E. S. Costa, F. M. Santiciolli, F. G. Dedini and F. C. Corrêa, "Electric vehicle drivetrain optimisation," in IET Electrical Systems in Transportation, vol. 7, no. 1, pp. 32-40, 3 2017.
3. Wang, Y., Lü, E., Lu, H., Zhang, N., & Zhou, X., “Comprehensive design and optimization of an electric vehicle powertrain equipped with a two-speed dual-clutch transmission” Advances in Mechanical Engineering, vol-9, no.-1, 2017, pp 1-13.
4. M. W. Salehen, P &Su'ait, Mohd&Razali, H &Sopian, Kamaruzzaman, “ Battery management systems (BMS) optimization for electric vehicles (EVs) in Malaysia” AIP Conference Proceedings, 2017, pp 1-7.
5. TengkuMohd, TengkuAzman& Hassan, MohdKhair&a Aziz, Wmk, “mathematical modelling and simulation of electric vehicle using matlab-simulink”research gate, 2014, pp 1-10.
6. A. Bhatt, "Planning and application of Electric Vehicle with MATLAB®/Simulink®," IEEE International Conference on Power Electronics, Drives and Energy Systems (PEDES), Trivandrum, 2016, pp. 1-6.
7. David McDonald, “Electric Vehicle Drive Simulation with MATLAB/Simulink” Proceedings of North-Central Section Conference Copyright © American Society for Engineering Education, 2012, pp. 1-24.
8. N. Mutoh, Y. Miyamoto, T. Horigome and K. Takita, "Driving characteristics of an electric vehicle system with independently driven front and rear wheels," IECON'03.29th Annual Conference of the IEEE Industrial Electronics Society (IEEE Cat.No.03CH37468), Roanoke, VA, USA, 2003, pp. 931-938 vol.1.
9. J. Kang, J. Yoo and K. Yi, "Driving Control Algorithm for Maneuverability, Lateral Stability, and Rollover Prevention of 4WD Electric Vehicles With Independently Driven Front and Rear Wheels," in IEEE Transactions on Vehicular Technology, vol. 60, no. 7, pp. 2987-3001, Sept. 2011.
10. X. Yuan and J. Wang, "Torque Distribution Strategy for a Front- and Rear-Wheel-Driven Electric Vehicle," in IEEE Transactions on Vehicular Technology, vol. 61, no. 8, pp. 3365-3374, Oct. 2012.
11. T. Hofman and C. H. Dai, "Energy efficiency analysis and comparison of transmission technologies for an electric vehicle," 2010 IEEE Vehicle Power and Propulsion Conference, Lille, 2010, pp. 1-6.
12. JiankunPeng, HongwenHeandNenglianFeng, “Simulation Research on an Electric Vehicle Chassis System Based on a Collaborative Control System” Energies 2013, 6, 312-328.
13. R. Das, K. Thirugnanam, P. Kumar, R. Lavudiya and M. Singh, "Mathematical Modeling for Economic Evaluation of Electric Vehicle to Smart Grid Interaction," in IEEE Transactions on Smart Grid, vol. 5, no. 2, pp. 712-721, March 2014.
14. L. Pieltain Fernandez, T. Gomez San Roman, R. Cossent, C. Mateo Domingo and P. Frias, "Assessment of the Impact of Plug-in Electric Vehicles on Distribution Networks," in IEEE Transactions on Power Systems, vol. 26, no. 1, pp. 206-213, Feb. 2011.
15. Michael A. Roscher, Jens Vetter, Dirk UweSauer, Characterisation of charge and discharge behaviour of lithium ion batteries with olivine based cathode active material, Journal of Power Sources, Volume 191, Issue 2, 2009, Pages 582-590.

16. A. Wicaksono and A. S. Prihatmanto, "Optimal control system design for electric vehicle," 2015 4th International Conference on Interactive Digital Media (ICIDM), Bandung, 2015, pp. 1-6.
17. Jian Zhou, XiangmingShen and Dong Liu, "Modeling and simulation for electric vehicle powertrain controls," 2014 IEEE Conference and Expo Transportation Electrification Asia-Pacific (ITEC Asia-Pacific), Beijing, 2014, pp. 1-4.
18. Mirjalili, Seyedali& Lewis, Andrew, "The Whale Optimization Algorithm," Advances in Engineering Software, no-95, pp-51-67, 2016.
19. Gillespie, T.D.: 'Fundamentals of vehicle dynamics' (Society of Automotive Engineers – SAE, Warrendale, PA, USA, 1992

AUTHOR'S PROFILE

Shivangi Kaushik received Bachelor of Technology degree from the Department of Electrical and Electronics Engineering, Raj Kumar Goel Institute of Technology, Ghaziabad affiliated to Dr. A.P.J. Abdul Kalam Technical University, Lucknow in 2017. Currently she is in the final year of the Master of Technology course at Ajay Kumar Garg Engineering College, Ghaziabad.
She has published one research paper named "Electric Vehicles: Review on current trends, potential and challenges" so far.
E-MAIL ID- umeetshiva@gmail.com