Design and Analyze Real Drive Cycles for Electric Vehicle Using MATLAB Simulink

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ABSTRACT

With the advancing technology, it has shifted in the automobile industry with the introduction of Electric Vehicles. Electric Vehicles provide humanity with a sustainable mode of transport, by not deteriorating the environment. modeling and simulation of Electric vehicles have attracted increasing attention from researchers. This paper describes the procedure for modeling an Electric Vehicle in MATLAB Simulink, by analyzing real Drive cycles (Driver behavior), Powertrain models (Battery, PMSM, Motor control), and Vehicle Dynamics models. Four Real drive cycles represented different road types such as Crowded, Urban, Rural, and Highway roads. Through Simulink, the designed Electric Vehicle is simulated and various factors are analyzed like; Vehicle Dynamics (Speed, Acceleration, Distance), Battery (current, voltage, power, power losses, state of charge, energy and capacity consumption), electric motor (speed, torque, and power). Motor cooling system (motor and coolant temperature). All simulation results were plotted and discussed. This study forms the foundation for further research and development.

Keywords: Design, Analysis, Drive Cycles, Electric Vehicle Modeling, MATLAB, Simulink.

1. INTRODUCTION

The usage of Electric Vehicles (EVs) has proportionally increased in recent years due to the positive impacts EVs. These positive impacts include their usage their non-dependency on the depleting reserves of conventional fuels and their environmentally friendly emissions as compared to the air pollution caused by the usage of conventional vehicles. Due to the recent developments in electrical sources such as Super Capacitors (SCs), Fuel Cells (FCs), and the advancements in conventional battery systems, the performance of the EVs has reached new heights. Due to their independence from the increasing fuel prices of conventional fuels and their non-emission of air pollutant characteristics the modeling and control of EVs have received a major focus in recent years. The modeling of the EV presents many challenges as it is the combination of the many complex sub-systems such as battery management systems, electrical motors, and power electronics interfaces [1].

EVs consist of an electric motor that is powered by a built-in battery unlike an internal combustion engine and fuel tank. The battery is charged with a plug-in charging unit during the vehicle is not in use [2]. for instance, they have provided favorable acceleration and efficient motor power. In addition, they enable further usage of renewable energy sources with charging batteries. Besides that, low-cost electricity can be used by charging overnight [3], [4], and [5]. Although EVs seem to be excellent for use in transportation, they have already some weaknesses. The main electric storage system, the battery, is still overpriced and the trade-off between the range of the vehicle and the time cost of the charging process is not fulfilling yet. The location of charging units is important and the cost of infrastructure for these units is expensive [6]. The most important circumstance that affects the design level of an EV is obtaining efficient fuel economy and being respectful to the environment. Besides that, the vehicle should satisfy performance requirements such as good acceleration [3].

The EV's performance is ensured by the maximum power of the engine and the capacity of the energy storage system. Acceleration, braking range, and maximum power of an electric motor are the main parameters for choosing an appropriate engine. Besides, vehicle features such as weight, type, etc. are the main constraints for the design. Another important component of EVs is the energy storage units or in other words battery. Energy storage should meet not only the power requirements of EVs but also driving range necessities. The battery should store sufficient power and also satisfy peak powers such that the electric motor needs instantaneous power throughout the acceleration [7].

The mathematical model of EV is represented by various researchers in the literature. Newton's laws of motion were used to model the electric drive vehicle. Besides that, a kinematic model of an electric drive vehicle on a planar and horizontal road was modeled considering longitudinal and lateral dynamics. In addition, multi-degree of freedom dynamics of an electric drive vehicle was proposed in [8]. In this manuscript, an analytical model and simulation of EV will be proposed using a MATLAB/Simulink environment. The components of EV will be explained in detail and also, and they will demonstrate by Simulink blocks. The proposed vehicle model will be simulated with four different drive cycles such as Crowded Road, Urban Road, Rural Road, and Highway Road however the Simulation results will be analyzed [8].

2. ELECTRIC VEHICLE MODELLING

For modeling purposes, the recommended EV drive train is shown in Figure 1. The drive train basically consists of six components; Drive Cycles, a Lithium-ion battery, an Electric motor, Motor Cooling System, a simple gearbox & differential, and vehicle Dynamic.

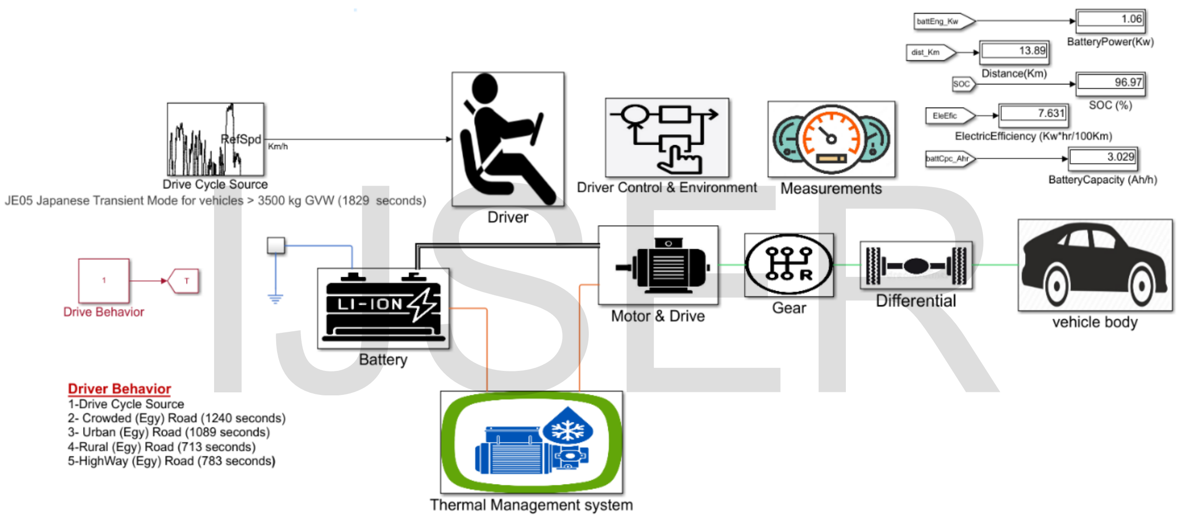

Figure 1 EVs simulink block Diagram.

The vehicle measurements model provides interface for sensors and controls which communicates with the motor controller, battery controller and unit conversation. The motor controller normally controls the power supplied to the motor, while the battery controller controls the power from the battery. The battery is for the energy storage, usually a Lithium Ion cells which provides more than 350 V and high current to the power electronics with internal resistance 0.002 Ω. The power electronics manipulates the voltage, current and frequency provided to suit the motor requirement.

2.1. DRIVE CYCLES

Driving patterns in developing countries differ markedly from those in developed countries or less-populated cities. However, the majority of vehicles driven in these areas are tested using driving cycles that do not correspond to those special driving characteristics. You can also use some of the legislative and non-legislative United States and European drive cycles from the drive cycles source block. The device responsible to record data for measured route location track from the GPS for the designed cycle. in Simulink signal builders and the drive cycle source is used as the drive input as in figure 2.

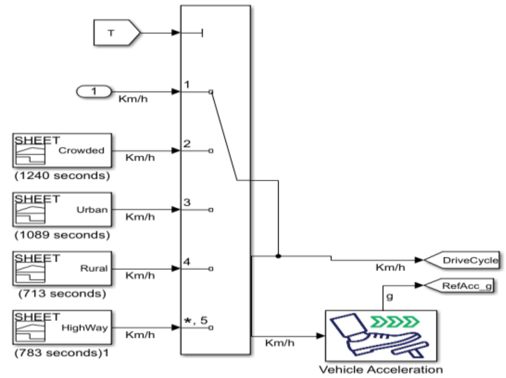

Figure 2. Block diagram of Drive Cycles

Figure 3. Photo of Egypt Crowded Road

2.3.1 crowded road Drive Cycle: Egypt is a metropolitan city with high-populated people, and some roads have a high density of traffic, this is led to many stoppings' times with repetitive patterns of acceleration and deceleration that have a significant effect on energy consumption and driving behavior, other reasons refer to the bad condition of the road surfaces. A road was chosen that fits a crowded road in slums in Egypt.

2.3.2 Urban Road Drive Cycle: An Urban Road is a road located within the boundaries of a built-up Cairo area. Most of the urban roads in Egypt have been developed since 2014, which led to an increase in the efficiency of the road surface and relative ease in the rate of movement and traffic density. Therefore, the rate of stopping at the speed of the car and the rate of acceleration and deceleration have decreased compared to the crowded roads and this is due to the overcrowding in urban areas.

Figure 4. Photo of Egypt Urban Road

Figure 5. Photo of Egypt Rural Road

2.3.3 Rural Road Drive Cycle: Rural roads are defined as low-traffic volume roads located in forested and rangeland settings that serve residential, recreational and resource management uses. They may have been constructed to relatively low standards with a limited budget. Cairo Alexandria Rural Road is one type the main Rural roads in Egypt, most of the road consists of two lanes, one to go and one to return, with each lane of only two cars. The road is entirely developed by the end of 2021.

2.3.4 Highway Road Drive Cycle: The New Administrative Capital City Road is considered the best highway in Egypt, as it was built inside Egypt because it provides all the individual's requirements of suitable housing with standard specifications, as well as commercial and investment services, with the presence of major investment projects in the city, and it is located in a privileged location linking many areas within Cairo.

Figure 6. Photo of Egypt Highway Road

2.2 Lithium-ion Battery

Figure 7 shows a very simple equivalent circuit model of an electrochemical battery, in which V_{OC} represents an ideal no-load battery voltage, R_{dis} and R_{ch} represent the internal resistances of the battery during discharge and charge by the current b, resulting in a load-dependent terminal voltage V_t.

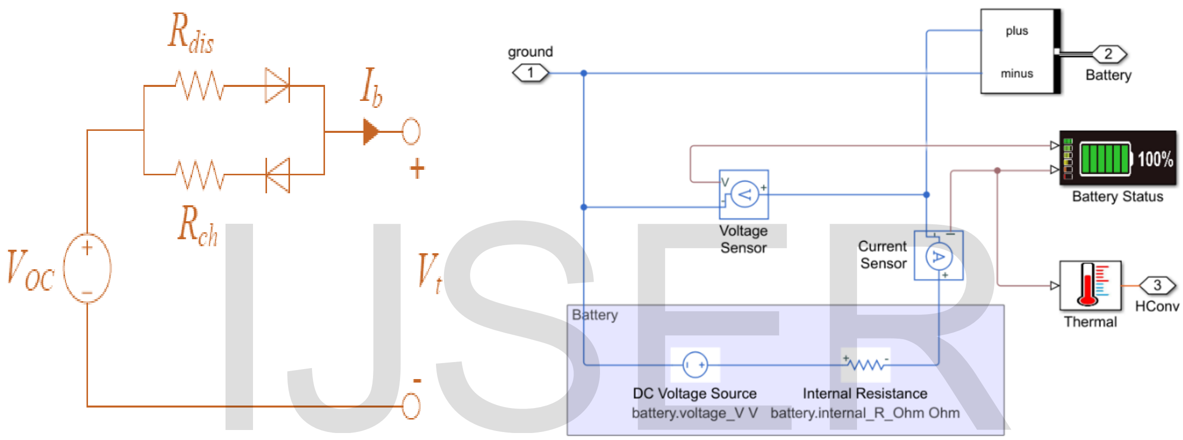

Figure 7. Simple battery model with separate internal resistance for discharge and the battery Simulink block.

The terminal voltage equation during discharge and the charge content in the battery is often described by the term state-of-charge (SOC) which changes with battery current over time. SOC_{init} is the initial SOC level, and Q_{tot} (Ah) is the total charge capacity of the battery. Normally a lithium-ion battery cell has a maximum and minimum allowed terminal voltage level, and a maximum and minimum allowed current, or C-rate, where a discharge rate of 1C means that the current is sufficient to discharge the battery in one hour. According to [9] the test to determine a battery's energy content is usually done for a constant current discharge at a C/3 discharge rate. The output power can also be limited by a minimum voltage, such as:

Table 1. Battery status Simulink block equation

N	Equation	Sy.	Description	Unit
(1)	$V_t = V_{OC} - (R_{dis} * I_b)$	V_t	terminal voltage	volte
		V_{OC}	Battery volt at no load	volte
(2)	$SOC(t) = SOC_{init} - \frac{\int_{T0}^{T} I_b(t)dt}{Q_{tot}}$	I_b	Battery current	Ah
		SOC	State of Charge	%
(3)	$P_{ideal} = P_{actual} + P_{losses}$	SOC_{init}	Initial state of charge	%
		P_{actual}	Actual power of battery	watt
(4)	$P_{ideal} = I_b * V_{OC}$	P_{losses}	Battery power losses	watt
				Ah

(5)	$P_{actual} = (I_b * V_{OC}) - (I_b^2 * R_{dis})$	Q_{tot}	total charge capacity of the battery	
		R_{dis}	internal resistances of the battery during discharge	Ω
		P_{ideal}	Theoretical power of battery	watt
(6)	$P_{max,Vmin} = V_{min} - \frac{V_{oc} - V_{min}}{R_{dis}}$	$P_{max,}$	maximum power of the battery	watt
(7)	$P_{losses} = I_b^2 * R_{dis}$	V_{min}	Lowest volte can get from battery	volte

2.3 Permanent Magnet Synchronous Motor PMSM

The operation of a PMSM is similar to a three-phase induction motor. The three-phase voltage source connected with the stator winding produces a rotating magnetic field (RMF). The RMF cause the rotor to turn. The power losses in the rotor side do not occur because the rotor of PMSM is a permanent magnet . Moreover, this machine can provide a constant torque. The structure and equivalent circuit of the PMSM are shown in Figure 8. Use this block to simulate a brushless motor and drive (such as a PMSM) or, more broadly, traction and actuation systems implemented with a variety of motor types

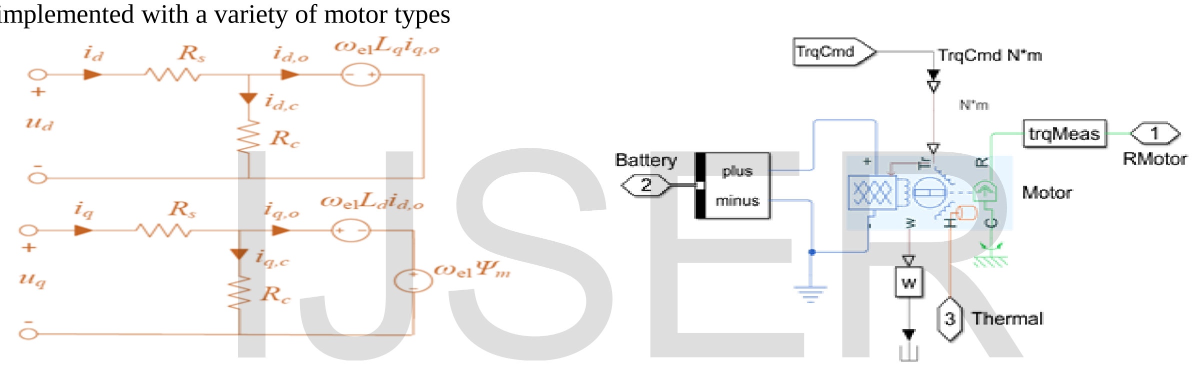

Figure 8. Steady state model of a PMSM and the Motor & Drive Simulink block

This block abstracts the motor, drive electronics, and control to allow for fast system-level simulation. The torque-speed envelope defines the range of torques and speeds that the block allows. This data is specified in the block dialogue box as a set of speed data points and corresponding maximum torque values in the default block configuration. [10]. Because core losses are difficult to estimate with high precision, an alternative method may be to introduce a core loss resistance, Rc as was done in [11] and [12], as shown below:

Table 2. Battery Simulink block equation

N	Equation	Sy.	Description	Unit
(8)	$u_d = R_s i_d - \omega_{el} L_q i_{q,o}$	u_d, u_q	individual phase voltages across the stator windings	volte
		R_s	equivalent resistance of each stator winding.	Ω
(9)	$u_q = R_s i_q + \omega_{el} L_d i_{d,o} + \omega_{el} \psi_m$	$\omega_{el} L_q i_{q,o}$	rates of change for the volte in each stator winding	volte
		i_d	currents flowing in d-axis stator windings	Ah
(10)	$T_m = \frac{3n_p}{2}(\psi_m i_{q,o} - (L_d - L_q) i_{d,o} i_{q,o})$	i_q	currents flowing in q-axis stator windings	Ah
		$\omega_{el}\psi_m$	total fluxes linking each stator winding	joule

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(11) $$\mathrm{P_{m\_in} = P_{m\_out} + P_{m\_loss}}$$

(12) $$\mathrm{P_{m\_out} = T_m * \omega_m}$$

(13) $$\mathrm{P_{m\_loss} = K_c\, T_m^2 + K_i \omega_m + K_w \omega_m^3 + c}$$

(14) $$\eta_{\mathrm{Propel}} \frac{\mathrm{T_m * \omega_m}}{\mathrm{T_m * \omega_m + P_{m\_loss}}}$$

(15) $$\eta_{\mathrm{Regen}} \frac{\mathrm{T_m * \omega_m + P_{m\_loss}}}{\mathrm{T_m * \omega_m}}$$

T_m	Torque flows from the motor case (block physical port C) to the motor rotor	Nm
n_p	number of rotor permanent magnet pole pairs	-
L_d	stator d-axis inductance	-
L_q	stator q-axis inductance	-
P_{m_out}	motor output power	Kw
ω_m	Mechanical rotational speed	rad/s
K_c	Motor loss constant from references motor	$^{s}/_{Kgm^2}$
K_i	Motor loss constant from references motor	joule
K_w	Motor loss constant from references motor	Kgm^2
c	Motor loss constant from references motor	watt
η_{Propel}	Efficiency of motor during propel	%
η_{Regen}	Efficiency of motor during regenerative braking	%

2.4 Motor Cooling System

A cooling system model consists of various component models. Each component was carefully modeled with different fidelity depending on its influence and sensitivity to the cooling performance. The components can be categorized by their function in the cooling system: heat source, heat sink, and media delivery components. Each component has several sub-models for heat transfer, pressure drop, flow rate, and heat generation.

In electric drive motors, and a power bus are the heat source components model in figure 9. Lumped thermal mass model is used for the temperature calculation of all heat source components. The model calculates the average temperature of the component by balancing heat generation by the component, heat transfer to the coolant, and heat transfer to the ambient. As a result, the component temperature change is calculated as follows [13] and [14]:

(16) $$\frac{dt_{comp}}{dt} = \frac{Q - q_{in} - q_{ext}}{\rho C_p}$$

(17) $$q_{ext} = (hA)_{int}(T_{comp} - T_{cool})$$

Heat transfer to the environment includes both natural convection and radiation.

(18) $$q_{ext} = (hA)_{int}\left(T_{comp} - T_{ext}\right) + \sigma A_{ext}(T_{comp}^4 - T_{cool}^4)$$

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Heat generations by the generator and motor are calculated based on their efficiency. The heat generation from the generator and motor is calculated with:

(19) $$Q_{gen} = t_{gen} * \omega_{gen}(1 - \eta_{gen})$$

The heat generated by the power bus is calculated based on the power delivered by the power bus and the efficiency of the power bus.

The power delivered by the power bus is determined by the power management mode, which will be discussed in the section on vehicle simulation. In normal mode, all power from power sources is supplied to motors, so the power consumed by motors is equal to the total power [14]:

(20) $$Q_{pb} = (1 - \eta_{pb})\left(\frac{t_{mot} * \omega_{mot}}{\eta_{mot}}\right)$$

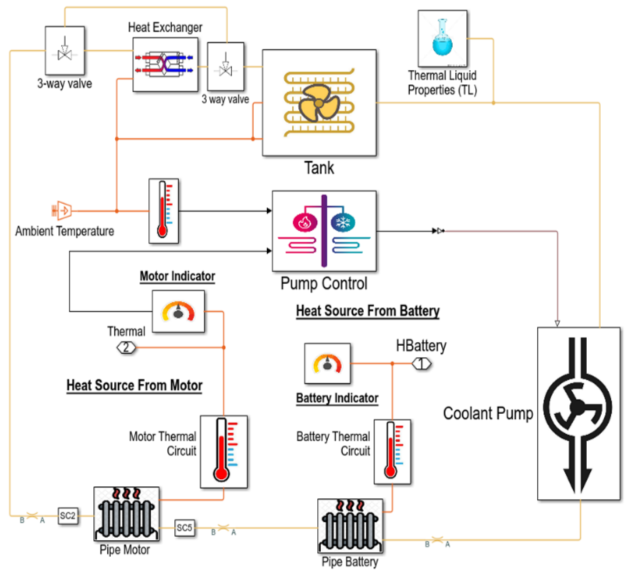


Figure 9. Motor cooling system Simulink block

2.5 Gear Box and Differential

The gear box is a Simple Gear block that constrains the connected driveline axes of the base gear, B, and the follower gear, F, to corotate with a fixed ratio that you specify at figure 10. You can specify whether the follower axis rotates in the same direction as the base axis or in the opposite direction. If they rotate in the same direction, the angular velocity of the follower, ω_f, and the angular velocity of the base, ωB, have the same sign. If they rotate in opposite directions, ω_f and $* \omega_B$ have opposite signs. Backlash, faults, and thermal effects can be easily added and removed. The Simple Gear block imposes the following kinematic constraint on the two connected axes: [15]:

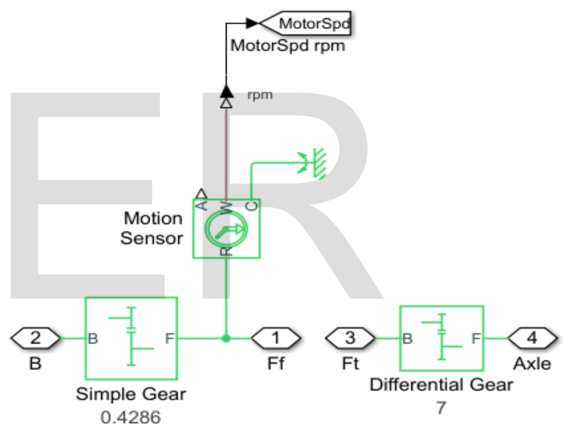


Figure 10. Gearbox & Differential Simulink block

Table 3. Gearbox and Differential Simulink block equation

N	Equation	Symp.	Description	Unit
(21)	$r_f * \omega_f = r_f * \omega_B$	r_f	is the radius of the follower gear.	mm
		r_b	is the radius of the base gear.	mm
(22)	$g_{fb} = \frac{r_f}{r_b} = \frac{N_f}{N_b}$	g_{fb}	base gear ratio = 0.4286	-
		N_b	is the number of teeth in the base gear.	-
(23)	$g_{fb}t_B + t_f - t_{loss} = 0$	N_f	is the number of teeth in the follower gear.	-
		t_B	is the input torque.	Nm
		t_f	is the output torque.	Nm
(24)	$t_{coul} = g_{fb}t_{ideal} + K_{tf}$	t_{loss}	is the torque loss due to friction. = 0 For the ideal case	Nm
		t_{coul}	is the Coulomb friction dependent torque.	Nm
(25)		K	is a proportionality constant.	-

Equation	Sy.	Description	Unit
$\eta = \frac{t_f}{g_{fb} t_{ideal} + (K+1)_{tf}}$	t_{ideal}	is the net torque acting on the input shaft in idle mode.	Nm
	η	Efficiency, is related to t_{ideal} in the standard, preceding form but becomes dependent on load	%

2.6 Vehicle Dynamics

The Vehicle Dynamic block represents a two-axle vehicle body in longitudinal motion in figure11. Each axle of the vehicle can have the same or a different number of wheels. For example, two front axle wheels and one rear axle wheel. The vehicle's wheels are assumed to be the same size. The vehicle's center of gravity (CG) can also be at or below the plane of travel.

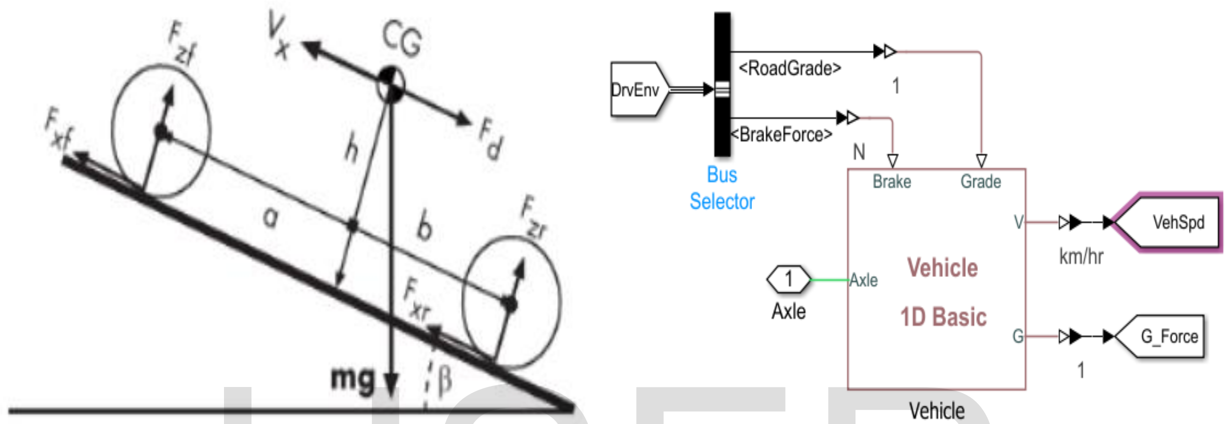


Figure 11. Vehicle Dynamics and Motion forces analysis and Gearbox & Differential Simulink block

The vehicle's motion is the sum of all the forces and torques acting on it. The vehicle is propelled forward or backward by the longitudinal tire forces. The vehicle's weight mg acts through its center of gravity (CG). The weight pulls the vehicle to the ground and either backwards or forwards depending on the incline angle. Aerodynamic drag slows the vehicle down whether it is moving forward or backward. The drag is assumed to act through the CG for simplicity. Pitch acceleration, on the other hand, is determined by three torque components and the vehicle's inertia [16]:

Table 4. Gearbox and Differential Simulink block equation

N	Equation	Sy.	Description	Unit
		g	Gravitational acceleration	m/s^2
(26)	$\mathbf{mV_x = f_x - f_d - mg\sin\beta}$	β	Incline angle	rad
		m	Mass of the vehicle	Kg
(27)	$\mathbf{f_x = n(f_{xf} + f_{xr})}$	h	Height of vehicle center of gravity above the ground	m
		a b	Distance of front and rear axles, respectively, from the normal projection point of vehicle CG onto the common axle	m
(28)	$\mathbf{f_d = \frac{1}{2} C_d * \rho_A (V_x + V_w)^2}$	V_x	Velocity of the vehicle. When $V_x > 0$, the vehicle moves forward. When $V_x < 0$, the vehicle moves backward.	m/s

(29)
$$f_{zf} = \frac{-h(f_d + mg\sin\beta + mV_x) + b\,mg\cos\beta}{n(a+b)}$$

(30)
$$f_{zr} = \frac{+h(f_d + mg\sin\beta + mV_x) + a\,mg\cos\beta}{n(a+b)}$$

The wheel normal forces satisfy

(31)
$$f_{zf} + f_{zr} = mg\frac{\cos\beta}{n}$$

(32)
$$\alpha = \frac{(f * h) + (f_{zf}a) - (f_{zr}b)}{j}$$

V_w	Wind speed. When $V_w > 0$, the wind is headwind. When $V_w < 0$, the wind is tailwind.	m/s
n	Number of wheels on each axle	-
f_{xf} f_{xr}	Longitudinal forces on each wheel at the front and rear ground contact points, respectively	N
f_{zf} f_{zr}	Normal load forces on each wheel at the front and rear ground contact points, respectively	N
A	Effective frontal vehicle cross-sectional area	m^2
C_d	Aerodynamic drag coefficient	-
ρ_A	Mass density of air	kg/m
f_d	Aerodynamic drag force	N
α	is the pitch acceleration	m/s^2
f	is the longitudinal force	N
j	is the inertia	kg/m^2

3. SIMULATION RESULTS AND DISCUSSION

The simulation for electric vehicles can be implemented for different real drive cycles and considering various conditions. In this section simulation results of Crowded, Urban, Rural, and highway road drive cycles are evaluated. In order to show the variance of the range covered by the EV, the power of the accessories was varied to the four different driving cycles.

3.1 Vehicle Speed.

The time series of vehicle speed for the real road drive cycles can be seen in Figure 12. The stopping vehicles time at the crowded roads about 20 times on another hand there is no stopping time on Rural and HighWay roads. Maximum speed reaches highway road, the vehicle can reach more than that but the Traffic law limits high speeds to preserve the safety and security of citizens. For urban road, the stopping times is lower than the crowded road but the vehicle speed is improved due to road specification.

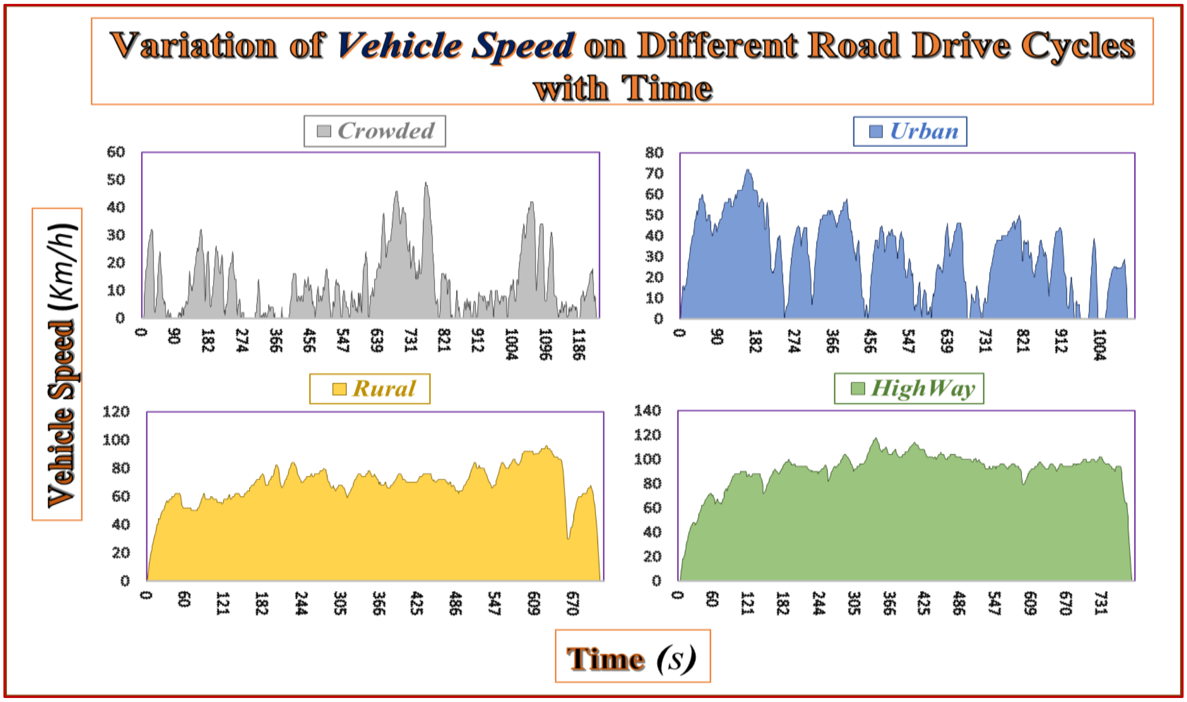


Figure 12. Vehicle Speeds analysis for the real roads drive cycle

3.2 Vehicle Acceleration

Vehicle acceleration is varying as vehicle speed varies. also و the vehicle also shifts from deceleration to acceleration and vice versa, as well as from stopping to accelerating and from deceleration to stopping. All these parameters affecting on vehicle acceleration. The acceleration and deceleration are repeated more for the crowded roads but it has the lowest value of the acceleration and deceleration as feen in figure 13. On the other hand, highway road has a high value of acceleration and deceleration and somehow is Temporarily fixed due to their high speeds.

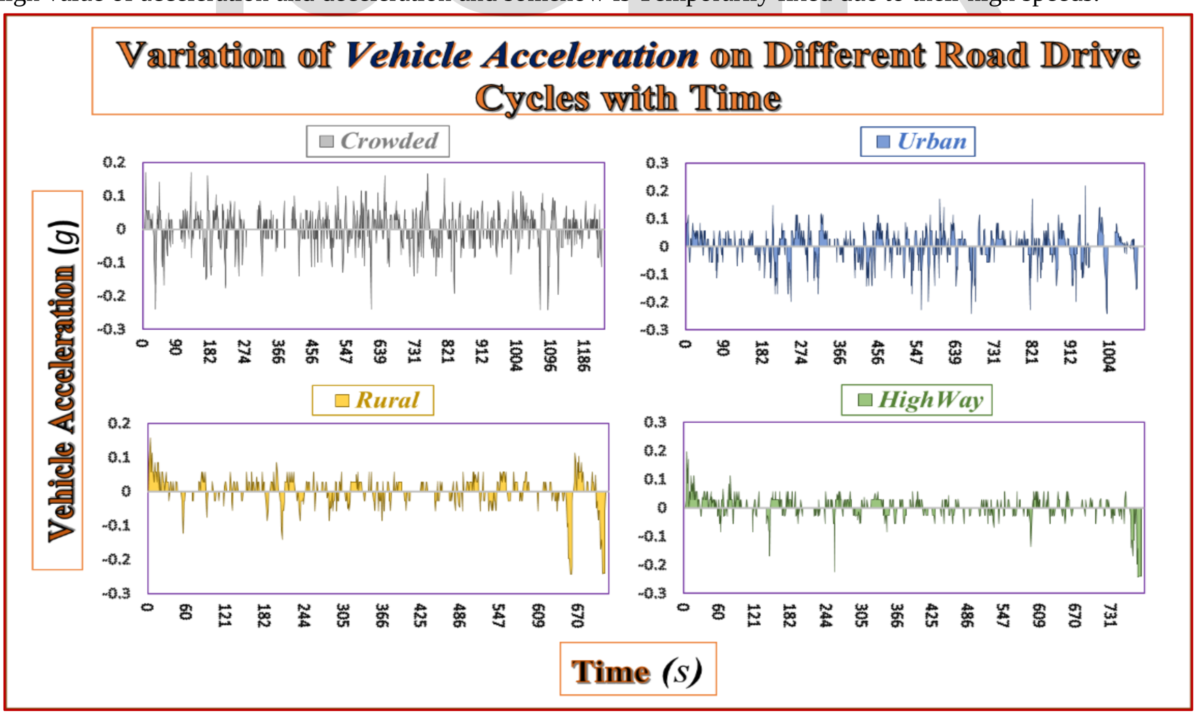
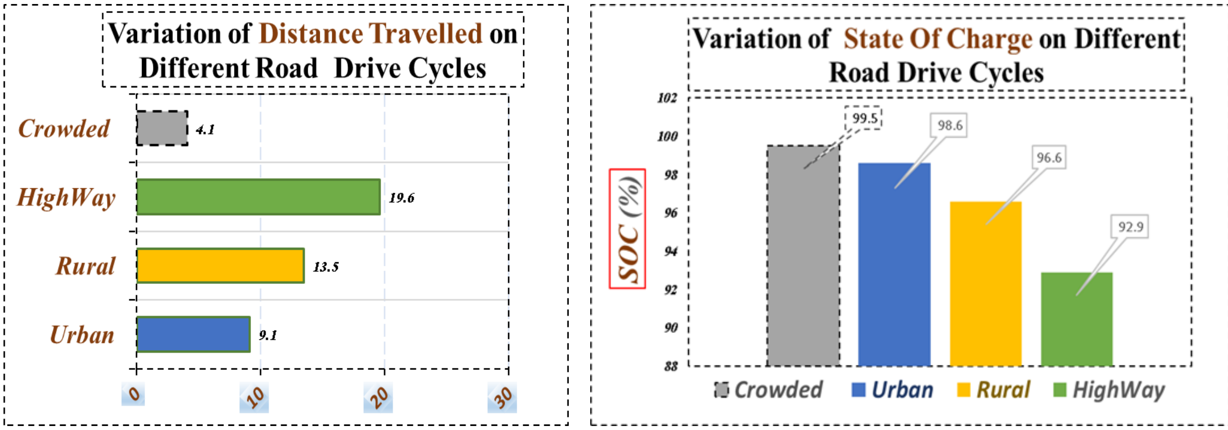


Figure 13. Vehicle acceleration analysis for the real roads drive cycle.

3.3 Travelled Distance and Battery SOC

The value of the SOC varies between 0% and 100%. If the SOC is 100%, then the cell is said to be fully charged, whereas a SOC of 0% indicates that the cell is completely discharged. SOC is affected by vehicle traveled distance, the vehicle at different roads is traveled (4.1, 9.1, 13.5, and 19.6 Km respectively) and the battery is drained about (0.5, 1.4, 3.4, and 7.1%) as shown in figure 14.



Figures 14. Vehicle acceleration analysis for the real roads drive cycle.

3.4 Battery Volte

Battery packs for all EVs can contain several hundred individual cells. Each cell has a nominal voltage of 3-4 volts, depending on its chemical composition, voltage determines how strongly electrons are pushed through a circuit. in figure 15, the voltage of the battery is changed in a small range (± 0.4 volt), the changes are depending on the changes in the deceleration, acceleration, and range of SOC.

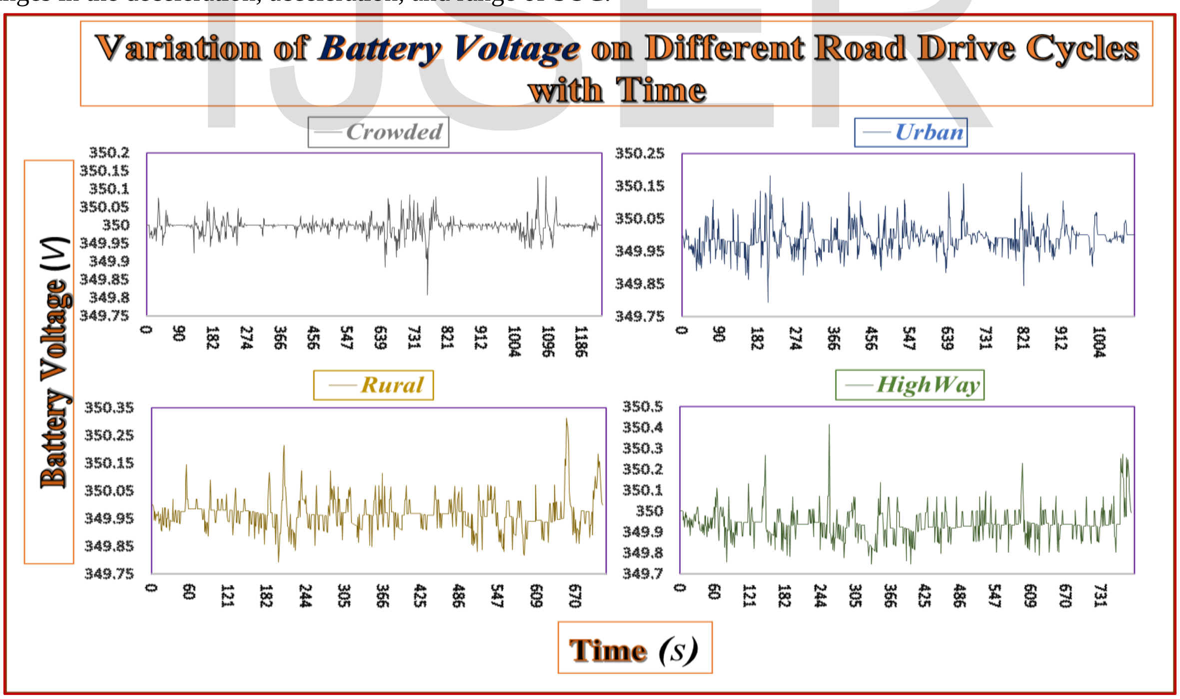


Figure 15. Battery voltage analysis for the real roads drive cycle.

3.5 Battery Current.

As known, Current is the rate at which electric charge passes through a circuit. In EV batteries, the current is changed from positive to the negative and vice versa due to charge and discharge cycles which is depends on vehicle acceleration and deceleration, and regenerative braking as well. In figure 16, it is noticed that the amount of drained current is high on highway roads due to the high speed and no stopping distance, and almost the speed is stable. And also, the drained current is affecting on drained current.

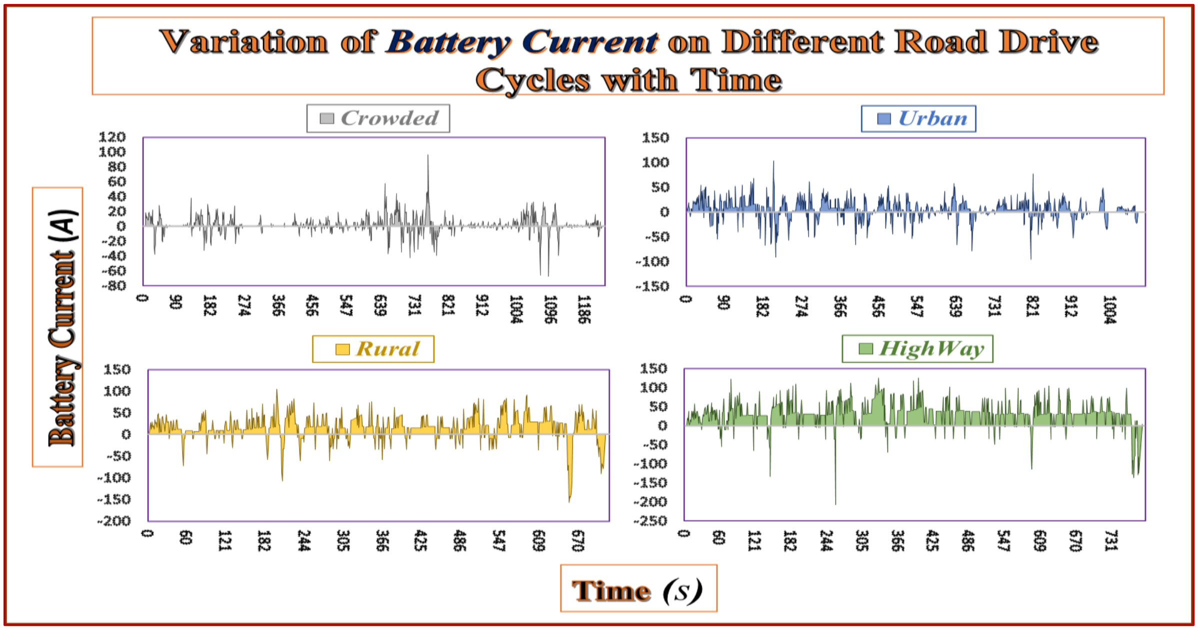


Figure 16. Battery current analysis for the real roads drive cycle.

3.6 Battery Power.

In Simple, Power = voltage x current. The higher the power, the quicker the rate at which a battery can do work this relationship shows how voltage and current are both important for working out what a battery is suitable for. In figure 17, the shape of the power consumption is the same shape as the battery current, it is due to the voltage being almost constant value which is lead to the same reason as the battery current

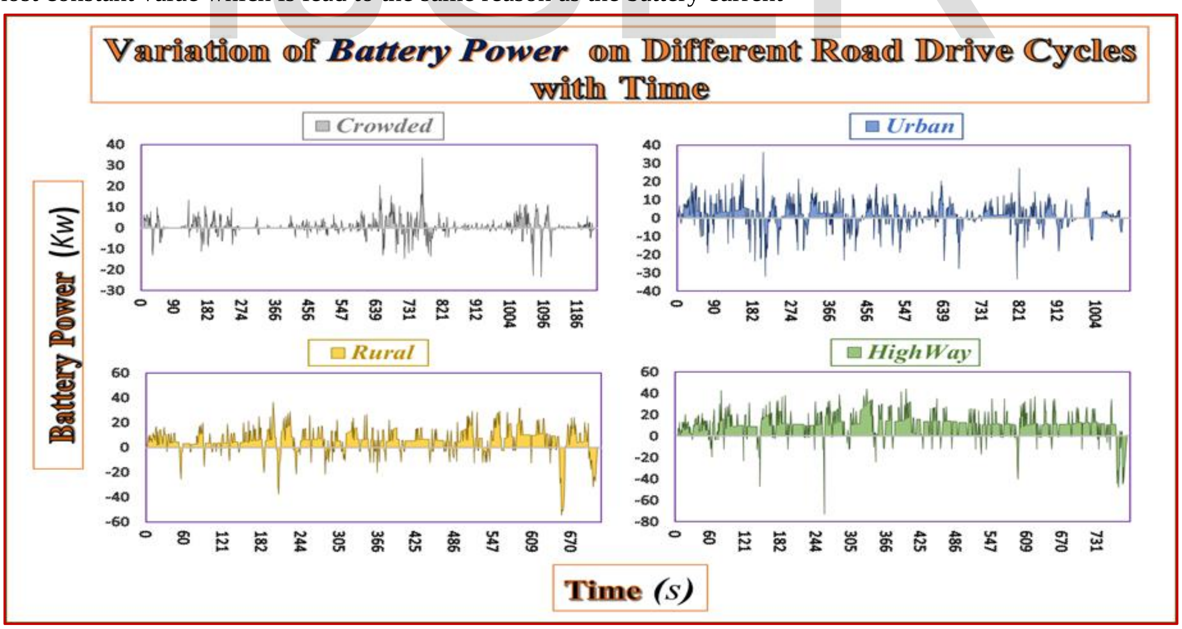


Figure 17. Battery power analysis for the real roads drive cycle.

3.7 Battery Power Losses.

battery power losses are very important for its operation in safe conditions. Determining the power losses will be important for choosing the cooling system of the battery and so, keeping the accumulator in the optimal range of temperatures, increasing also the lifetime, which reflects itself in price reduction. When the battery power consumption is increased the battery power losses are increasing too. However, the power losses are depending on vehicle load and speed. In confirmation of the above, we note in figure 18, that the crowded road has the lowest power losses, and it Increasing in order of road drive cycle

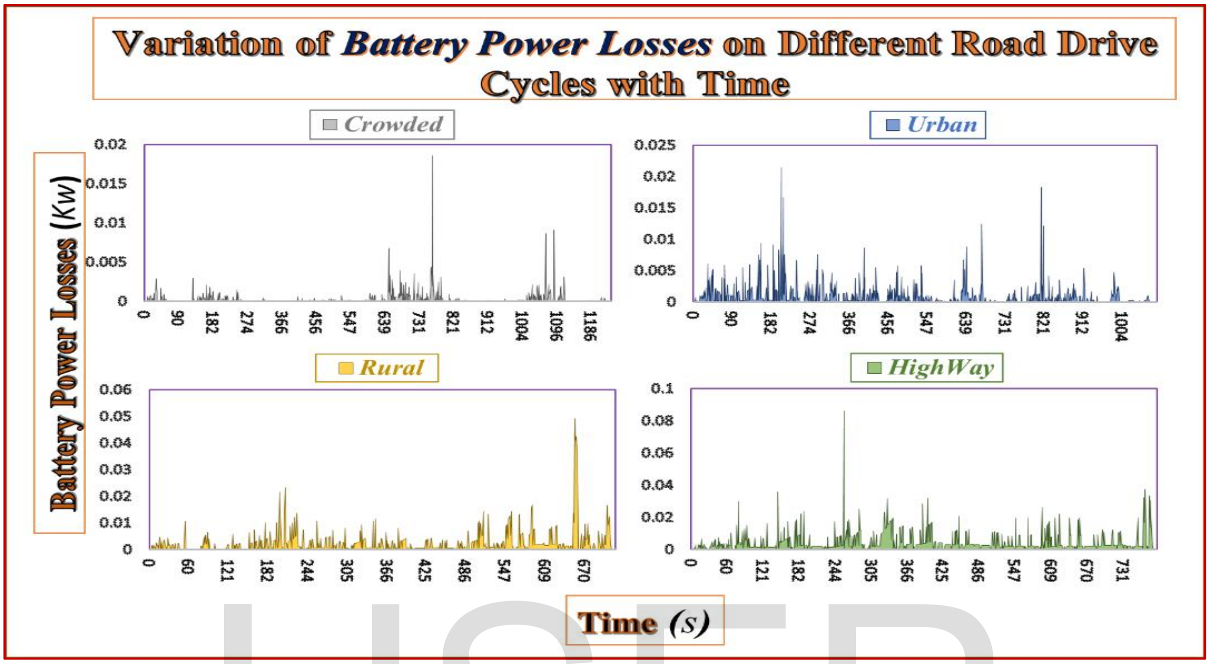
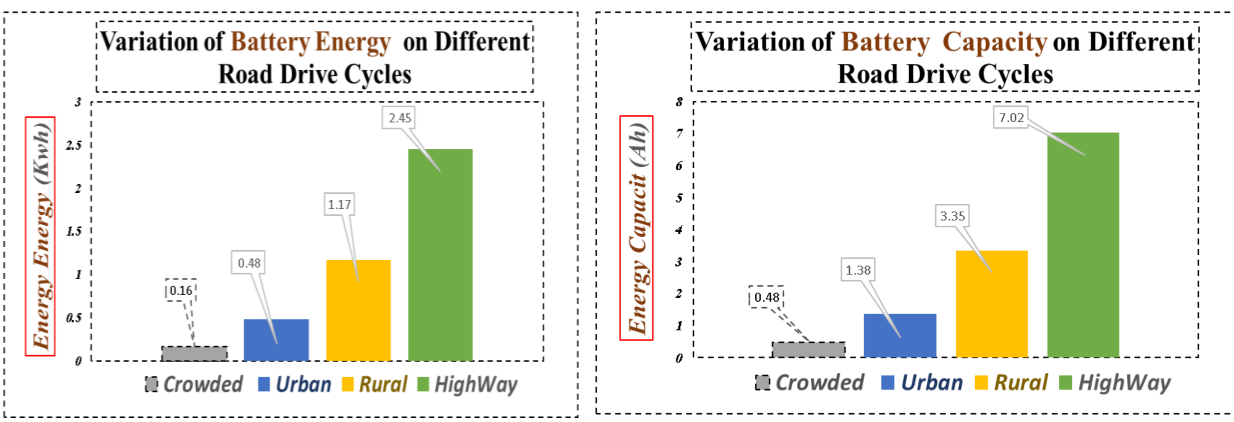


Figure 18. Battery power losses analysis for the real roads drive cycle.

3.8 Battery Energy & Capacity.

The battery energy is measured in kilowatt-hours and provides an estimate of the amount of energy that can be stored. Battery capacity is measured in Ampere-hours it provides the maximum output of a current stored in the battery. Figures 19, shows both battery energy and capacity consumption for each real road drive cycle. Depending on vehicle distance traveled, the energy and capacity are changed as exhibited.



Figures 19. Battery power losses analysis for the real roads drive cycle.

3.10 PMSM Speed.

speed relates to the rate of rotation which can be calculated by examining the revolutions per minute RPMs. In a synchronous motor, the rotor uses a permanent magnet to rotate at the calculated speed. The motor speed shall be the same shape behavior of vehicle speed but a change in value. In figure 20 and figure 12, the shapes are matching. the comparison of the shape between the two figures shows the model calibration.

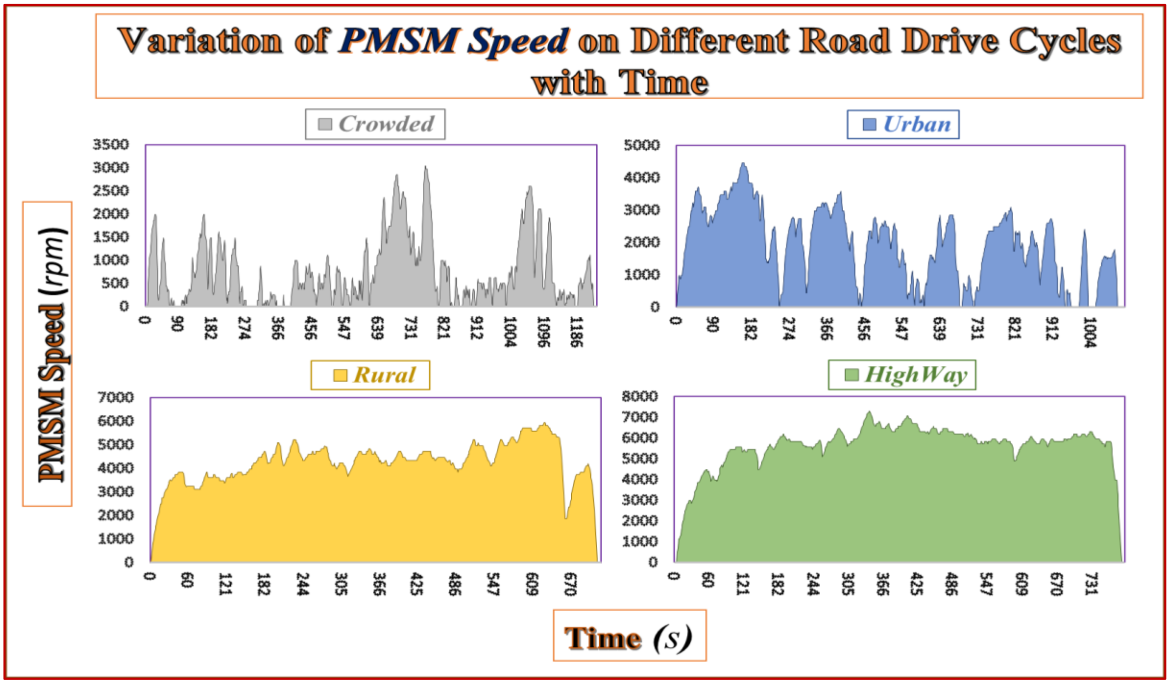


Figure 20. PMSM speed analysis for the real roads drive cycle.

3.11 PMSM Torque.

Torque relates to the rotational force of an electric motor while speed refers to the rate at that the motor can rotate. This means that torque is associated with rotational force, it is a rotating force produced by a motor's rotor. The more torque the motor produces, the greater its ability to perform work. Torque is commonly measured in Nm or pound-feet because it is a vector acting in one direction. In figure 21, the PMSM torque changes due to the vehicle behavior on the roads.

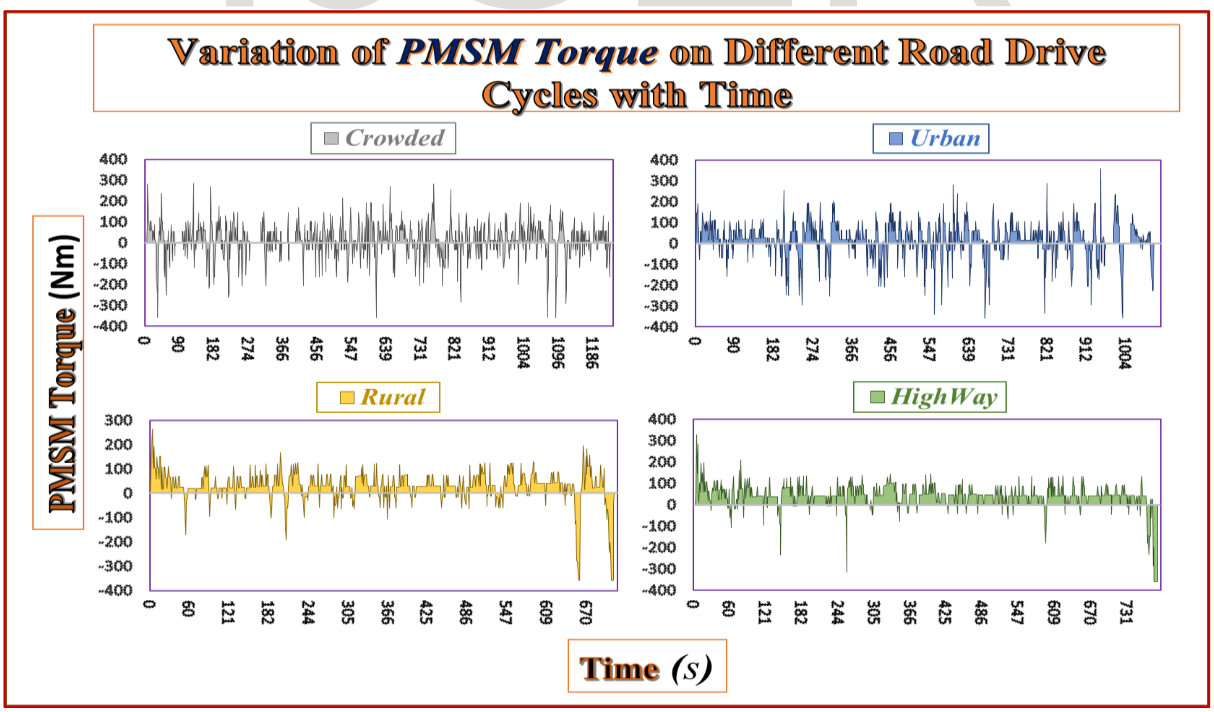


Figure 21. PMSM torque analysis for the real roads drive cycle.

3.12 PMSM Power.

Power is the rate at which work is completed in a given amount of time. Power is quantified in watts (J/s). the power of the PMSM depends on Vehicle operating condition requirements.

Figure 22 shows the output power of the PMSM during roads drive cycles, in crowded roads the speed is low which is need little value, moreover as the speed increases, the power output from the motor increases

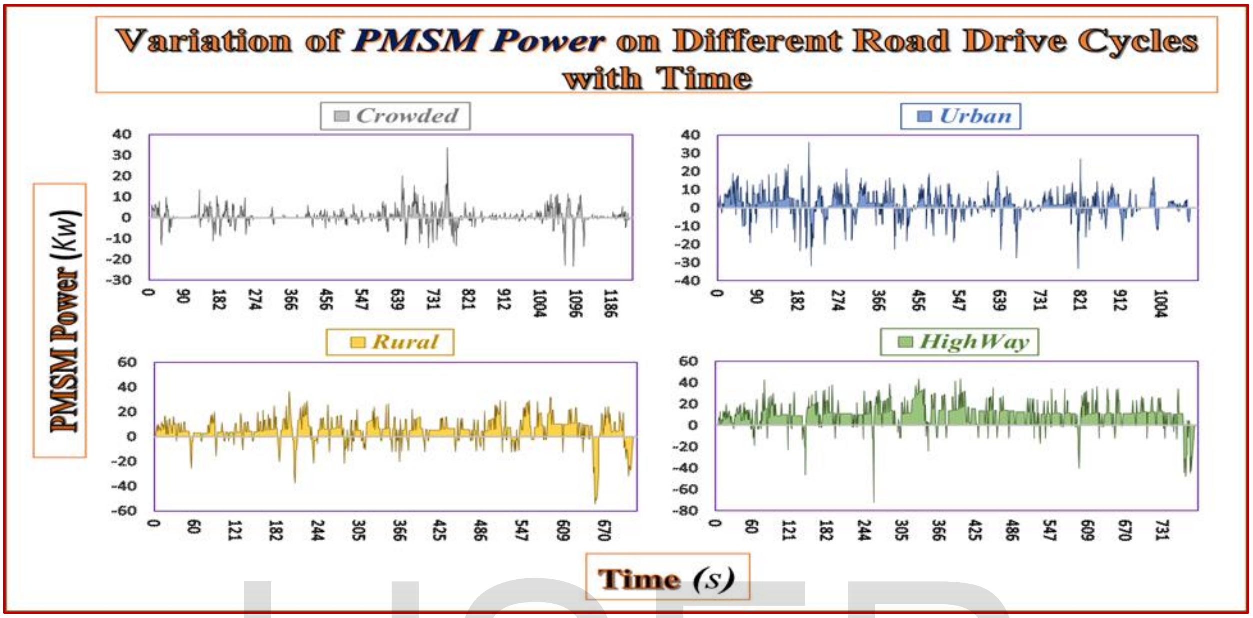


Figure 22. PMSM power analysis for the real roads drive cycle.

3.13 Coolant Temperature.

Antifreeze, or motor coolant, is a colored liquid that is mixed with water to help regulate your motor during extreme temperatures. The coolant temperature for the electric motor and the power electronics is maintained at below 60°C inside a separate circuit (inner, mid-blue circuit) using a low-temperature radiator. As the temperature outside changes from hot to the cold coolant is pumped throughout the engine block to maintain an even operating temperature. The coolant temperature is exhibited in figure 23. On a crowded road, the temperature of the coolant shape is not like other reads, due to the change in the acceleration and deceleration of the vehicle. Take into account that the ambient temperature is 27 C^{o}.

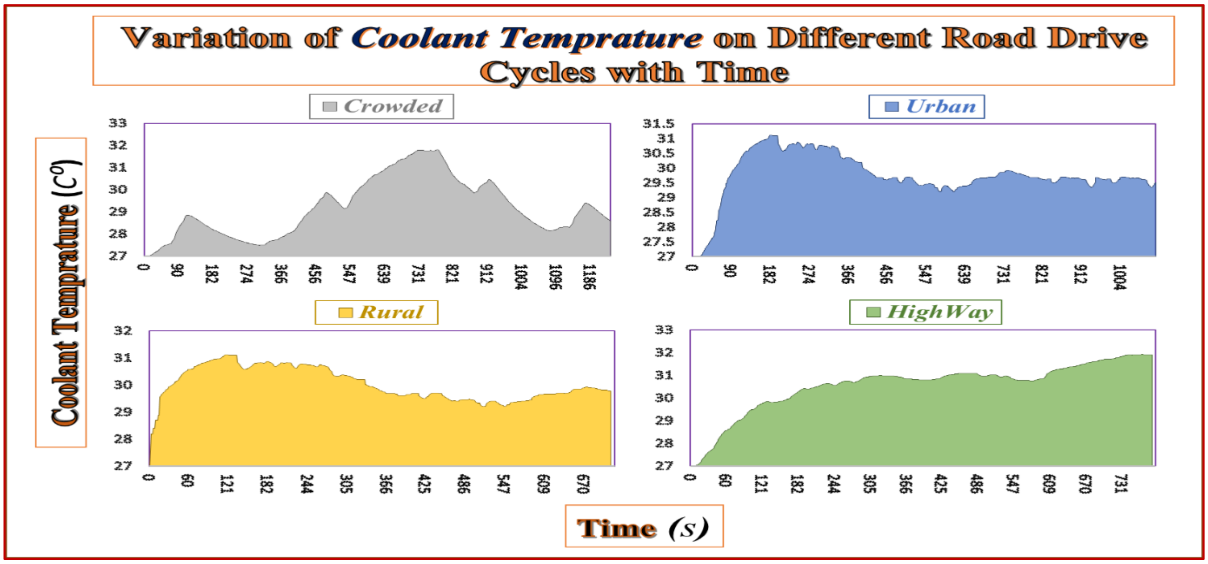


Figure 23. Motor coolant temperature analysis for the real roads drive cycle.

3.14 Motor Temperature.

Most electric vehicles use a cooling loop. This loop is typically cooled with ethylene glycol. Using an electric pump, coolant is circulated through the batteries and some of the electronics. This loop contains a radiator to release heat to the outside air. Figure 24 shows how the cooling system is maintaining the heat from the motor. Increasing motor output power led to increase in motor heat. Cooling system model is keeping the motor temperature in the operation condition. To let the motor work in good condition at any operation.

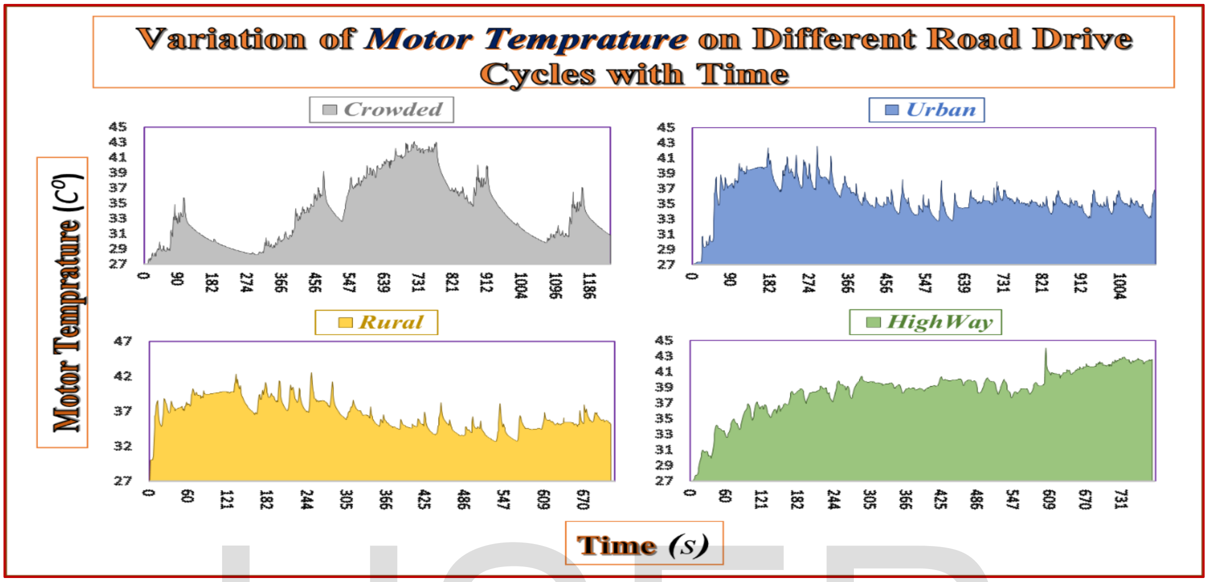


Figure 24. Motor temperature analysis for the real roads drive cycle.

4. CONCLUSION

Electric vehicles design had been simulated using local and standard test drive cycles. Most of literature stated that the simulation of electric vehicle without using thermal management of battery and electric motor using MATLAB Simulink. The design has including; vehicle dynamic, electric power train and thermal management. It can be notice that the designed local test drive cycle exhibited good performance with the other standard cycles which can use it to analyze fuel or energy consumption, emissions and engine or motor performance.

5. CONFLICT OF INTERESTS

The authors declare that there is no conflict of interests regarding the published results of this article.

6. ACKNOWLEDGMENTS

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