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Optimizing Electric Vehicle Performance, Range and Parameter Estimation through NEDC Urban and Suburban Analysis using MATLAB

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ABSTRACT: This research paper focuses on electric vehicle (EV) driving range and parameter estimation, with an emphasis on analyzing the New European Driving Cycle (NEDC) urban and suburban drive cycles. By examining these drive cycles, we obtain critical data on the moments when an electric vehicle transitions between constant velocity, acceleration, and deceleration phases, which significantly affect power consumption and driving range. We investigate various techniques for parameter estimation, including battery capacity, energy consumption rates, and powertrain efficiency, essential for improving EV performance and providing realistic range expectations. Empirical experiments in diverse driving conditions contribute valuable data to refine our understanding of EV driving range and performance in different scenarios. The research underscores the role of predictive modeling, data analytics, and advanced technologies in real-time parameter estimation, offering precise and convenient range predictions to enhance user confidence.

KEYWORDS: New European Driving Cycle (NEDC),Urban Driving Cycle, Suburban Driving Cycle, Power Demand, Battery Capacity, Energy Consumption, Driving Range

1. INTRODUCTION

The electrification of transportation is a pivotal response to the pressing environmental and economic challenges associated with fossil fuel-dependent vehicles[1]. As we strive to transition to more sustainable urban and suburban transportation systems, electric vehicles (EVs) have emerged as a promising solution. This research paper is dedicated to a comprehensive exploration of the optimization of electric vehicle performance, range estimation, and parameter estimation, with a specific emphasis on analyzing the New European Driving Cycle (NEDC) urban and suburban drive cycles.The New European Driving Cycle (NEDC) serves as a crucial test bed for evaluating EV performance in real-world urban and suburban driving conditions[2][3]. By meticulously scrutinizing these drive cycles, we gain vital insights into the precise moments when an electric vehicle transitions between different driving phases—uniform velocity, acceleration, and deceleration. It is in these transitions that power consumption fluctuates, significantly influencing the driving range and overall efficiency of EVs[4][5].One of the central themes of this research is the estimation of critical parameters essential for enhancing EV performance[6]. We delve into the intricacies of battery capacity, energy consumption rates, and powertrain efficiency. Accurate estimations of these parameters are pivotal in providing EV owners with realistic expectations regarding their vehicle's range capabilities and overall performance[7].To validate our findings and enhance their real-world applicability, we conduct a series of empirical experiments in diverse driving conditions. These experiments provide valuable data that refines our understanding of EV driving range and performance under varying scenarios, contributing to the reliability of our parameter estimation techniques.Furthermore, we highlight the role of predictive modeling, data analytics, and advanced technologies in the realm of real-time parameter estimation[8]. These tools hold the potential to offer precise and convenient range predictions for EV users, thereby enhancing user confidence and facilitating a smoother transition to electric mobility[9].As the global shift towards electric mobility continues to gain momentum, understanding the factors that optimize EV performance and range is paramount. This research aspires to contribute to these ongoing efforts, enabling more informed and confident electric vehicle communities and ultimately driving us closer to a greener and more sustainable future[10].

2 NEDC WORKING CONDITION

The standard driving distance of NEDC cycle is 11.022 km.The NEDC cycle for electric vehicles primarily encompasses three distinct driving conditions: uniform driving, acceleration phases, and deceleration phases.In Figure 1, the chart illustrates a sequence of four urban driving regions followed by one suburban driving region. The plot depicts the relationship between a vehicle's velocity and time.also the vehicle parameter is given in table 1

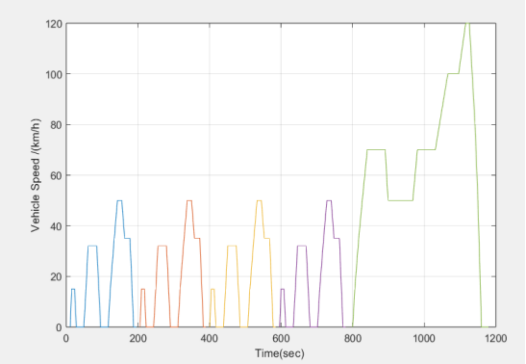

Figure 1. NEDC urban and suburban region velocity vs time of vehicle obtain from simulation

Table 1.Vehicle Parameter of NEDC Cycle

parameter	value
Vehicle Mass(kg)	1300
Rolling Resistance Coefficient	0.013
Air Drag Coefficient	0.32
Frontal Area(m^2)	2.1
Tire Rolling Radius(m)	0.285
Rotational Mass Conversion Factor	1.002
Drive System Efficiency	0.95
Battery Discharge Efficiency	0.9
Transmission Ratio	5.3
Battery Pack Terminal Voltage	320

3. POWER CHARACTERISTICS

3.1 Motor Power under constant speed

The motor power required for an electric vehicle to travel uniformly on a flat road is given as

$$P_{m1} = \frac{V_x}{3600\eta}\left(mgf + \frac{C_D A_f V_x^2}{21.15}\right) \qquad (1)$$

where

Pm_1= motor power required for the vehicle to run uniformly

V_X = uniform speed of the vehicle, m = mass of the vehicle , η = drive system efficiency, f = rolling resistance coefficient, C_D = air drag coefficient , A_f = front area of the vehicle, δ = conversion factor of rotating masses, a_j = acceleration or declaration, t=time, V_{xf} =final velocity, V_{x0}=intial velocity

3.1.1 Simulation table for urban and suburban under constant speed

Table 2. Power Demand of Vehicle in URBAN Region

Constant speed(km/h)	Time(sec)	Range in NEDC(sec)	Power demand(KW)
15	8	15-23	0.7578
32	24	61-85	1.8541
35	15	163-178	2.0933
50	12	143-155	3.5826

Table 3. Power Demand of Vehicle in Suburban Region

Constant speed(km/h)	Time(sec)	Range in NEDC(sec)	Power demand(KW)
70	50	841-891	6.5765
50	69	899-968	3.5826
70	50	981-1031	6.5765
100	30	1066-1096	14.331
120	10	1116-1126	21.565

3.2 Motor Power Required for Acceleration and Deceleration

The motor power required for an electric vehicle to travel accelerating driving condition and declaration driving condition on a grad is given as

$$P_{m2} = \frac{V_x}{3600\eta}\left(mgf + \frac{C_D A_f V_x^2}{21.15} + \delta m a_j\right) \qquad (2)$$

$$V_{xf}(t) = V_{x0} + 3.6 a_j t \qquad (3)$$

where

Pm_2= motor power required for the vehicle to run uniformly

V_X = uniform speed of the vehicle

m = mass of the vehicle , η = drive system efficiency, f = rolling resistance coefficient, C_D = air drag coefficient ,A_f = front area of the vehicle, δ = conversion factor of rotating masses, a_j = acceleration or declaration, t=time, V_{xf} =final velocity, V_{x0}=intial velocity

3.2.1 Simulation table for urban and suburban under constant speed

Table 4. Power Demand of Vehicle in Urban Region for Acceleration

Acceleration (m/s^2)	Time(sec)	Range in NEDC(sec)	Power demand(KW)
1.04	4	11-15	6.8062
0.694	6	49-55	4.7707
0.787	6	55-61	11.6556
0.694	6	117-123	4.7707
0.505	11	123-134	9.0141
0.462	9	134-143	12.5002

Table 5. Power Demand of Vehicle in Urban Region for Deceleration

Deceleration (m/s^2)	Time(sec)	Range in NEDC(sec)	Power demand(KW)
-0.833	5	23-28	-4.0693
-0.808	11	85-96	-8.1956
-0.52	8	155-163	-6.4981
-0.972	10	177-178	-11.0698

Table 6. Power Demand of Vehicle in Suburban Region for Acceleration

Acceleration (m/s^2)	Time(sec)	Range in NEDC(sec)	Power demand(KW)
0.6944	6	800-806	4.707

0.5050	11	806-817	9.011
0.4166	10	817-827	11.7247
0.3968	14	827-841	17.4326
0.4273	13	968-981	18.2468
0.2380	35	1031-1066	23.4383
0.2777	20	1096-1116	34.8923

Table 7. Power Demand of Vehicle in Suburban Region for Acceleration

Deceleration (m/s^2)	Time(sec)	Range in NEDC(sec)	Power demand(KW)
-0.6944	8	891-899	-12.1504
-0.6944	16	1126-1142	-10.2382
-1.041	8	1142-1150	-23.6274
-1.388	10	1150-1160	-23.3639

3.3 Based on table 2-7 the power characteristics obtained from simulation

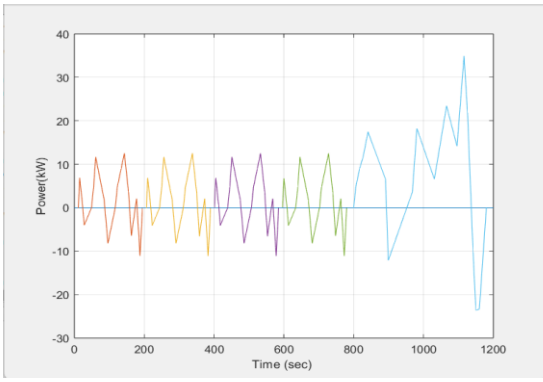

Fig. 2. Power Demand vs Time

This figure was drawn according to the information from the table and equation of Pm_1 and Pm_2 .it can be seen that at the end of acceleration of 100-200km/h in the NEDC cycle, the maximum power of the electric vehicle is 34.8923 kw, and the peak power of the motor is chosen to be equals to p_{emax} = 35 kW.

4. MOTOR POWER RATING

4.1 The relationship between the peak power of the motor and the rated power of the motor :

$$P_{emax} = \lambda P_e \qquad (4)$$

Where Pemax is the peak power of the motor, P. is the rated power of the motor, λ is the overload factor. the motor overload factor is chosen to be equal to 2.2, by using the previous formula, we can calculate the rated power and that is 16 kW(35/2.2).

When the electric vehicle runs at the highest speed, the driving motor works in the constant power region. The relationship between the speed of the electric vehicle and the rotation of the driving motor can be obtained from:

$$\eta_{max} = \frac{V_{xmax} i}{0.377r} \qquad (5)$$

•Where η_{max} is the maximum speed of the motor in rpm, Vxmax is the maximum speed of the electric vehicle, i is the transmission ratio of the transmission system (including the final drive ratio),r is the tire rolling radius

4.2 Maximum speed of the motor

- The maximum speed of the motor i.e n_{max} is 5919rpm (Vxmax =120km/h)and we will take it approximately equal to 6000 rpm

.•The rated speed of the motor is calculated as:

$$n_e = \frac{n_{max}}{\beta} \qquad (6)$$

- Where n_e is the rated speed of the motor, β is the coefficient of the extended constant power region of the motor
- The bigger the value of β, the lower the speed, the higher the torque, and the better the acceleration and climbing performance of the electric vehicle. but the size of the power converter will also increase.so β should not be too high. β usually takes a value of 2 to 4 .take β=3 then from the last formula the rated speed of the motor is 2000 rpm.

5 TORQUE CALCULATION

- An electric vehicle has different output requirements for the driving motor under different working conditions. At high speed, the main driving motor output requirement is the output power, and the main torque is the output when starting or accelerating the vehicle.according to the relationship between torque, power and speed, the rated torque of the motor is given by:

$$T_e = \frac{9550 P_e}{n_e} \qquad (7)$$

- Where T_e is the rated power of the motor,P_e is the peak power and n_e is the rated speed
- The peak torque of the motor is given by :

$$T_{emax} = \frac{9550 P_{emax}}{n_e} \qquad (8)$$

- From the previous equations, the rated torque is T_e=76 N.m and the peak torque is T_{emax} =167 N.m

Storage Capacity of the Power Battery

The power required for an electric vehicle at a constant speed on a flat road is shown for P_{m1}, the storage capacity that is required to meet the requirement of the power battery for a uniform driving condition as follows

$$C_{m1} = \frac{P_{m1} t_{m1}}{3.6 V_{batt}} \qquad (9)$$

Where Cm_1 is the storage capacity of the power battery required for uniform driving, t_{m1} is the uniform driving time of the electric vehicle, V_{batt} is the power battery terminal voltage

The power required for an electric vehicle accelerates is shown for P_{m2} , the storage capacity that is required to meet the requirement of the power battery for acceleration driving condition as follows

$$C_{m2} = \frac{P_{m2} t_{m2}}{3.6 V_{batt}} \qquad (10)$$

Where Cm_2 is the storage capacity of the power battery required for acceleration driving condition, t_{m1} is the acceleration travel time of the electric vehicle

6.1 URBAN REGION ANALYSIS

6.1.1 urban driving constant speed part

Table 8. Capacity Demand of Urban Driving Constant Speed

Constant speed (km/h)	Time(sec)	Range in NEDC(sec)	capacity demand(A.h)
15	8	15-23	0.0072
32	24	61-85	0.0386
35	15	163-178	0.0273
50	12	143-155	0.0373

6.1.2 urban driving acceleration part

Table 9. Capacity Demand of Urban Driving Acceleration

Acceleration(m/s^2)	Time(sec)	Range in NEDC(sec)	Capacity demand(A.h)
1.04	4	11-15	0.0236
0.694	6	49-55	0.0248
0.787	6	55-61	0.0607
0.694	6	117-123	0.0248
0.505	11	123-134	0.0861
0.462	9	134-143	0.0977

6.1.3 Urban Driving Deceleration part

Table 10. Capacity Demand of Urban Driving Deceleration

Deceleration (m/s^2)	Time(sec)	Range in NEDC(sec)	Capacity demand(A.h)
-0.833	5	23-28	-0.0117
-0.808	11	85-96	-0.0783
-0.52	8	155-163	-0.0451
-0.972	10	177-178	-0.0961

6.2 Suburban Region Analysis

6.2.1 suburban driving constant speed part

Table 11. Capacity Demand of Suburban Driving Constant Speed

Constant speed (km/h)	Time(sec)	Range in NEDC(sec)	capacity demand(A.h)
70	50	841-891	0.2854
50	69	899-968	0.2145
70	50	981-1031	0.2854
100	30	1066-1096	0.3680
120	10	1116-1126	0.1898

6.2.2 Suburban Driving Acceleration part

Table 12. Capacity Demand of Suburban Driving Acceleration

Acceleration (m/s^2)	Time(sec)	Range in NEDC(sec)	Capacity demand(A.h)
0.6944	6	800-806	0.0248
0.5050	11	806-817	0.08607
0.4166	10	817-827	0.10177
0.3968	14	827-841	0.21185
0.4273	13	968-981	0.20591
0.2380	35	1031-1066	0.71210
0.2777	20	1096-1116	0.60576

6.2.3 Suburban Driving Deceleration part

Table 13. Capacity Demand of Suburban Driving Deceleration

Deceleration (m/s^2)	Time(sec)	Range in NEDC(sec)	Capacity Demand(KW)
-0.6944	8	891-899	-0.08437
-0.6944	16	1126-1142	-0.14219
-1.041	8	1142-1150	-0.16407
-1.388	10	1150-1160	-0.20281

6.3 Battery Capacity Characteristics

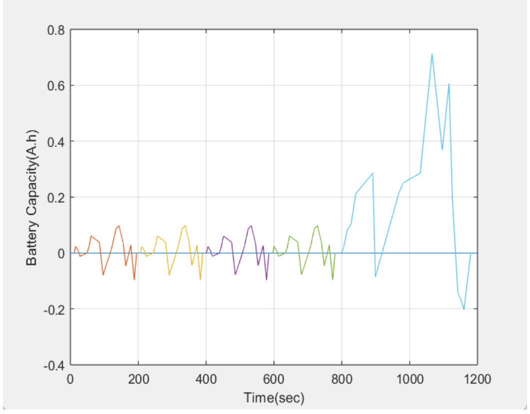

Fig. 3. Battery Capacity vs Time Obtained from Simulation

6.3.1 Urban cycle Capacity Demand

According to the figure 3 In the basic urban cycle, the power battery output capacity of 0.4281 A.h is needed for maintaining uniform and accelerating speeds. During braking, 20% brake energy recovery results in an additional 0.04624 A.h. Therefore, the overall power battery capacity required for a standard urban cycle is approximately 0.38186 A.h. For four urban cycles, the cumulative capacity demand amounts to 1.52744 A.h.

6.3.2 Suburban Cycle Capacity Demand

According to the figure 3 In the basic suburban cycle, the power battery output capacity required is 3.29136 A.h, accounting for constant velocity and acceleration. During braking, an additional 0.59344 A.h is utilized. With a 20% brake energy recovery rate (0.2 × 0.59344 = 0.118688 A.h), the power battery needs to supply approximately 3.17267 A.h to complete a standard suburban cycle.

6.4 Determination of Battery Capacity

For the entire cycle, the power battery must provide a capacity of 4.70011 A.h (1.52744 + 3.17267 = 4.70011 A.h). With a standard driving distance of 11.022 km in the NEDC cycle, ensuring a range of 300 km requires a power battery capacity of at least 128 A.h (approximated by (4.70011 × 300) / 11.022 = 127.92 ≈ 128 A.h).

7. DRIVING RANGE CALCULATION

The energy consumed by the power battery under constant speed driving:

$$E_d = \frac{P_d S_d}{V_x \eta_e} \qquad (11)$$

Where E_d is the energy consumed by the power battery in constant speed driving condition, S_d is the constant speed distance of the electric vehicle, η_e is the battery discharge efficiency

- Electric vehicle constant speed distance is given by :

$$S_d = \frac{V_x t}{3600} \qquad (12)$$

Where t is the constant speed travelling time.

7.1 The energy consumed by the power battery under the acceleration-driving condition :

$$E_j = \frac{P_j S_j}{V_x(t) \eta_e} \qquad (13)$$

- Where E_j is the energy consumed by the power battery for the acceleration-driving condition, η_e is the power battery discharge efficiency.
- S_j is the electric vehicle acceleration distance and is given by:

$$S_j = \frac{V_{xj}^2 - V_{x0}^2}{25920 a_j} \qquad (14)$$

7.2 The total energy carried by the battery is given by

$$E = \frac{Q_m V_{batt}}{1000} \qquad (15)$$

Where E is the total energy carried by the battery, Qm is the rated capacity of the vehicle, Vbatt is the terminal voltage of the power battery, the mileage of the NEDC cycle is :

$$S_1 = \sum_{i=1}^{k} S_i \qquad (16)$$

Where S_1 is the mileage of an NEDC cycle, S_i is the distance travelled for each state for the constant speed and acceleration driving conditions, k is the total number of states that can be completed by electric vehicle.

7.3 The energy consumption of the power battery in the NEDC cycle is given by :

$$E_1 = \sum_{i=1}^{k} E_i \qquad (17)$$

Where E_1 is the energy consumed by the power battery in an NEDC cycle. E_i is the energy consumed by the power battery for each state.

The driving range of the electric vehicle is given by:

$$S = \frac{S_1 E}{E_1} \qquad (18)$$

Where S is the driving range of the electric vehicle in the NEDC cycle condition

When running the MATLAB code according to the NEDC, it can be seen that the Driving Range of the Electric vehicle is S=308.07km. so this meets our requirements.

8. RESULT

Table 14. Result of Vehicle Parameter

Parameter Name	Value
Rated Power(kw)	16
Peak Power(kw)	35
Rated Torque(N.m)	76
Peak Torque(N.m)	167
Rated Speed(rpm)	2000
Maximum Speed(rpm)	6000
Battery Capacity(A.h)	128
Driving Range(km)	308.07

9. CONCLUSION

Integrated Approach to EV Efficiency: The research paper presents an integrated approach to enhancing electric vehicle (EV) efficiency and performance. By combining comprehensive analysis of NEDC drive cycles, innovative parameter estimation techniques, and empirical validation through experiments, the study offers a holistic understanding of EV dynamics and range estimation.

Real-Time Predictive Modeling: A novel aspect highlighted in the conclusion is the emphasis on real-time predictive modeling and data analytics for parameter estimation. By leveraging advanced technologies, such as predictive modeling and data analytics, the research aims to provide precise and convenient range predictions to EV users, thereby enhancing user confidence and facilitating a smoother transition to electric mobility.

Validation through Empirical Experiments: The conclusion underscores the significance of empirical experiments in validating and refining estimation techniques. By conducting empirical experiments in diverse driving conditions, the research ensures the reliability and real-world applicability of its findings, contributing to a deeper understanding of EV driving range and performance.

Contribution to Sustainable Transportation Initiatives: Importantly, the conclusion emphasizes the broader contribution of the research to sustainable transportation initiatives. As the world continues to transition towards electric mobility, the insights provided by the study aid in optimizing EV efficiency and promoting a greener and more sustainable future of transportation.

Enhanced User Confidence: By providing realistic range expectations and optimizing EV performance, the research aims to enhance user confidence in electric mobility. This aspect is crucial for accelerating the adoption of EVs and achieving broader sustainability goals in the transportation sector.

In summary, the conclusion of the research paper offers novel insights into enhancing EV efficiency, validating estimation techniques through empirical experiments, leveraging advanced technologies for real-time predictive modeling, and contributing to sustainable transportation initiatives, ultimately aiming to foster a greener and more sustainable future.

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