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# ВЫЧИСЛЕНИЕ ПОТРЕБЛЕМОЙ АВТОМОБИЛЕМ ЭНЕРГИИ НА ЕЗДНЫХ ЦИКЛАХ С ИСПОЛЬЗОВАНИЕМ ПРОГРАММНОГО ПРОДУКТА ADVISOR

# CALCULATION OF VEHICLE ENERGY CONSUMPTION ON DRIVING CYCLES USING ADVISOR TOOL

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*В работе представлен расчет энергопотребления электромобиля с использованием программы Advanced Vehicle Simulator (ADVISOR). Энергия, потребляемая компонентами электромобиля, расчитывается при движении в различных ездовых циклах, характерных для крупного мегаполиса. Объектом исследования является электромобиль Vinfast VF e34. Результаты компьютерного моделирования показывают, что электромобиль более энергоэффективен при движении в городских условиях. Кроме того, электромобили восстанавливают больше энергии за счет системы рекуперативного торможения в городских циклах, особенно в смешанных циклах с большим количеством переходных процессов, где поведение водителя весьма агрессивно.*

*This paper presents the electric vehicle's energy consumption calculation using Advanced Vehicle Simulator (ADVISOR). The energy consumed by EV's components is quantified when traveling in different me-*

*tropolis driving cycles (DCs). The test object in the study is Vinfast VF e34. The results show that the electric vehicle (EV) is more energy efficient when traveling in urban cycles. In addition, EVs recover more energy through regenerative braking system in urban cycles, especially in DCs where the driver behavior is aggressive.*

***Ключевые слова:*** *электромобиля, ADVISOR, энергопотребление электромобиля, ездовые городские циклы.*

***Keywords:*** *electric vehicle, ADVISOR, energy consumption, urban driving cycles.*

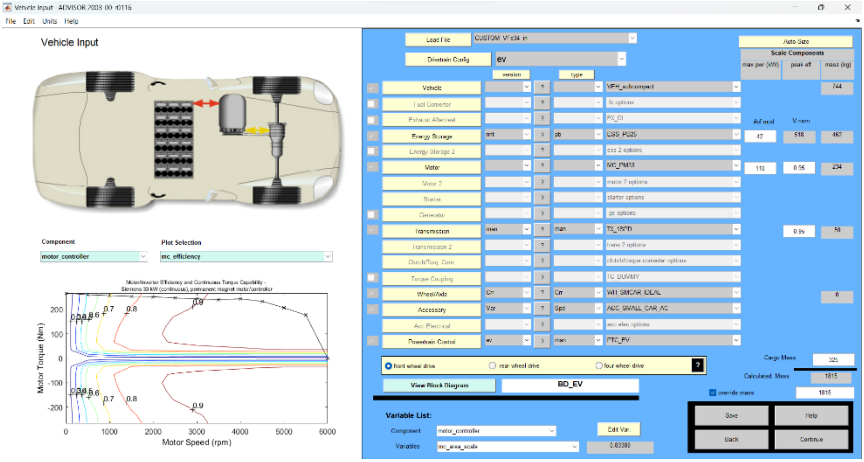
## INTRODUCTION

EVs are recognized as an efficient transportation mode with higher energy efficiency, especially in congested urban networks. Many studies have been conducted to reinforce this EVs' merit. Xinkai Wu et al. [1] claimed that the EV is more efficient when driving on in-city routes than on freeway routes. Mike Knowles et al. [2] claimed that EVs are much more efficient when driving on interrupted urban routes than uninterrupted freeways due to the regenerative braking system (RBS). The drivetrains of EVs can operate at over 80 % efficiency explain why EVs have great potential in reducing the transportation energy demand [3].

Measuring and calculating the EC of EVs is an essential requirement for the future improvement of the energy efficiency of the EV transportation system. Thus, this study aims to provide a quantitative estimation of EV's EC in the case of Hanoi. Advanced Vehicle Simulator (ADVISOR) is used to quickly estimate the EC in four different DCs in Hanoi, which provide significant evidence of EV's advantages in urban driving conditions.

## METHODOLOGY

ADVISOR, which was developed by the U. S. Department of Energy's (DOE), is a validated simulation tool for evaluating EV performance and energy efficiency with high accuracy [4]. The ADVISOR interface and calculation diagram are shown in Fig. 1 and 2 respectively. In this paper, Vinfast VF e34, the widely used EV in Hanoi traffic, whose specification is shown in Table 1, is simulated in ADVISOR to calculate EC.



Component: motor_controller
Plot Selection: mc_efficiency

Load File: CUSTOM_VFe34_in
Drivetrain Config: ev

Vehicle: VEH_subcompact, mass (kg) 744
Energy Storage: rint, pb, ESS_PB25, # of mod 42, V nom 518, mass (kg) 462
Motor: MC_PM33, max pwr (kW) 110, peak eff 0.95, mass (kg) 234
Transmission: man, man, TX_1SPD, peak eff 0.95, mass (kg) 50
Wheel/Axle: Crr, Crr, WH_SMCAR_IDEAL, mass (kg) 0
Accessory: Var, Spd, ACC_SMALL_CAR_AC
Powertrain Control: ev, man, PTC_EV

● front wheel drive ○ rear wheel drive ○ four wheel drive

BD_EV

Cargo Mass: 325
Calculated Mass: 1815
☑ override mass: 1815

Variable List:
Component: motor_controller
Variables: mc_area_scale 0.83389

Figure 1 – ADVISOR interface

Table 1 – Vinfast VF e34 specs

| Parameter | Value | Unit | Parameter | Value | Unit |
|---|---|---|---|---|---|
| Curb weight | 1490 | kg | Wheel friction of coefficient | 0., | |
| Wheelbase | 2,611 | m | Rolling resistance coefficient | 0,008 | |
| Mass center height | 0,58 | m | Frontal area | 2,424 | $m^2$ |
| Tire radius | 0,32535 | m | Motor power | 110 | kW |
| Wheel's rotational inertia | 0,815 | $kg{\cdot}m^2$ | Motor efficiency | 95 | % |
| Transmission efficiency | 95 | % | Battery energy | 44,5 | kWh |
| Charger efficiency | 86 | % | Battery efficiency | 95 | % |

The vehicle and its components are then simulated through four microscopic speed-versus-time DCs. The DCs' speed profiles are shown in Fig. 3.

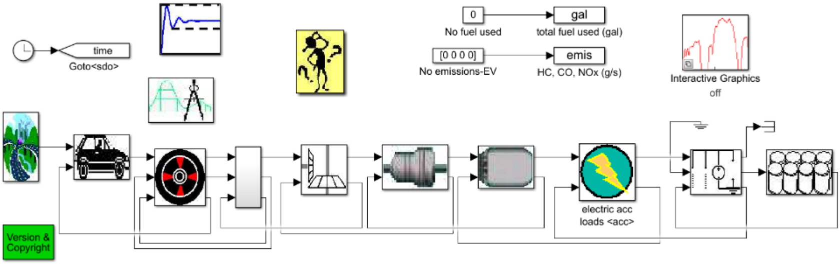


Figure 2 – Basic ADVISOR Block Diagram

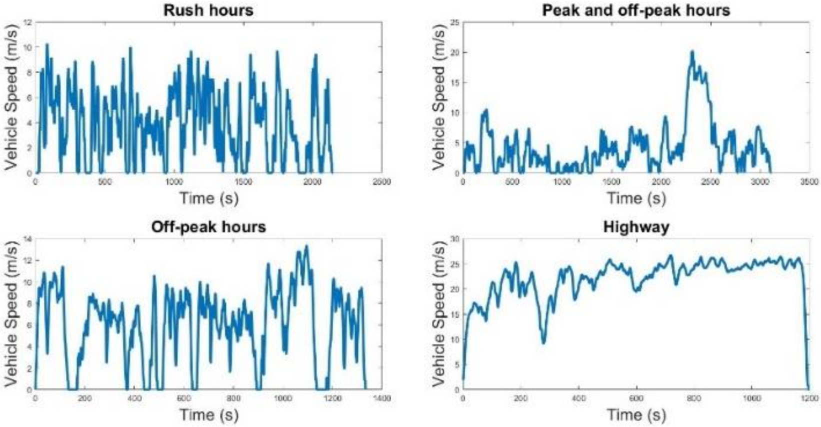


Figure 3 – Hanoi DCs speed profile

According to the fundamental theory of vehicle dynamics, the resistance power can be calculated as the sum of aerodynamic and rolling resistance power:

$$P_{res} = P_{roll} + P_{air} \tag{1}$$

The total input power is the sum of components' power, calculated as:

$$P_{input} = P_{res} + P_{mot-loss} + P_{trans-loss} + P_{regen} \tag{2}$$

where: $P_{regen}$ is the regenerative power by RBS, $P_{mot}$ is the motor power, $P_{trans-loss}$ is the transmission power loss.

The required speed is limited to the motor's maximum speed. The required torque is limited to the difference between the motor's maximum torque at the limited speed and the torque required to overcome the rotor inertia. The limited torque and speed are then used to interpolate in the motor/controller's input power map. Finally, the motor controller's maximum current limit limits the interpolated input power. This behavior is described in the following equations [5]:

$$P_{mot} = \min\left(P_{mot,in,map}, I_{con,max} V_{bus,prev}\right) \tag{3}$$

$$P_{mot,in,map} = f\left(\tau_{mot,\lim,req}, \omega_{mot,\lim,req}\right) \tag{4}$$

$$\omega_{mot,\lim,req} = \min\left(\omega_{mot,req}, \omega_{mot,\max}\right) \tag{5}$$

$$\tau_{mot,\lim,req} = \min\left(f_1\left(\omega_{mot,\lim,req}\right), \tau_{mot,req} + J_{mot}\left(\frac{\Delta\omega_{mot,\lim,req}}{\Delta t}\right)\right) \tag{6}$$

where: $P_{mot}$ is the power that the motor/controller requires, which must be provided by the batteries and/or the generator. $P_{mot,in,map}$ is the motor power from the motor performance map; f in equation (4) is the functional relationship described by the motor map; $\tau_{mot,req}$ is the torque required into gear reduction, $\tau_{mot,\lim,req}$ subject to motor torque limit.

## RESULTS

The results show that on the highway, EV generates more power to overcome the resistance force; however, RBS captures and stores the least energy in the battery, shown by the lowest percentage of regenerative energy. The EC rate during the simulation differs from the announced Vinfast VFe34 (0,148 kWh/km) [6]; however, the difference is not substantial. As a result, the ADVISOR results are applicable.

Fig. 3 and Table 2 show that the electric motor (EM) operates at the efficient area in the performance map in the highway, shown by the lowest motor power loss. However, in a cycle that requires harsher acceleration and deceleration, such as urban DC, RBS presents better efficiency.

Table 2 – EV component's EC and regenerative energy percentage

| **Parameter** | **Driving cycle** | | | |
|---|---|---|---|---|
| | Peak and off-peak hours | Rush hours | Off-peak hours | Highway |
| Input power (W) | 2398.46 | 2776.69 | 3707.21 | 11852.38 |
| Motor power loss (W) | 923.52 | 990.21 | 872.37 | 163.47 |
| Transmission power loss (W) | 139.78 | 151.52 | 260.51 | 1241.03 |
| Resistance power (W) | 862.47 | 681.59 | 1148.65 | 8808.17 |
| Regenerative power (W) | 472.69 | 952.91 | 1424.17 | 1641.37 |
| Energy consumtion (kWh/km) | 0.16 | 0.20 | 0.16 | 0.15 |
| Regenerative energy percentage (%) | 19.71% | 34.32% | 38.42% | 13.85% |

## CONCLUSION

This study uses ADVISOR to introduce the EC calculation for a widely used EV in Hanoi. The results show the power value from each EV component during operation in different DCs. The electric motor achieves better efficiency in high-speed DC, while RBS recuperates more energy in urban cycles. This research provides potential insights into EV energy use and should be expanded to include many different EV models and driving conditions to indicate the feasibility of EV in Vietnam traffic conditions.

The results of this study demonstrate the potential advantages of using ADVISOR software to optimize vehicle energy use. ADVISOR can promote more efficient driving practices and minimize energy consumption by delivering real-time feedback to drivers. The ability to analyze different driving scenarios and assess the influence of various car components on energy usage increases the software's utility.

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