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ASSESSMENT OF VEHICLE PARAMETERS EFFECT ON MOTOR-GENERATOR PERFORMANCE FOR HYBRID ELECTRIC VEHICLES

BY

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Abstract. The proposed paper introduces a new integrated analysis method with the scope of assessing the impact of vehicle parameters on the motor-generator performance in hybrid electric vehicles. This method takes into consideration some vehicle body parameters together with headwind speed and the road inclination angle, which influence the energy efficiency and assesses their level of impact on the motor and generator performance. The study is based on Matlab modelling and simulation. The efficiency of the method is demonstrated through a series of simulation results obtained after analysis of the data generated from a set of 216 case studies. The motivation of the research is given by the fact that the energy efficiency topic still represents one of the biggest technical challenges in the field of hybrid electric vehicles. The advantage of this method is that the systems performance in terms of motor-generator behaviour can be validated from an early concept stage. The added value is given by the accuracy of the simulation results and the comparative overview obtained as a result of the presented performance analysis methods. The results can contribute to the practical need of improving the energy efficiency and the development time for future hybrid electric drives.

Key words: HEV; energy efficiency; simulation; motor-generator.

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1. Introduction

Energy efficiency is an important topic in the domain of Hybrid Electric Vehicles (HEV). The research activities are currently focusing on improving the performance of the battery and the fuel efficiency. Some of the current industry challenges are the driving range in case of full electric drives and the level of fuel consumption together with the level of emission in case of hybrid drives. Better energy efficiency can be obtained through a very good parameter selection and better control strategies. Precise simulations and accurate analysis techniques can contribute to a better understanding of the systems and can generate comparative overviews that will help in a better parameterization. Lately system simulation techniques became actual design tools due to their flexibility and the possibility of assessing the system level effect from the early concept phase. Electrical machine is one of the most important components in hybrid electric vehicles. A good performance of the motor and generator can increase the energy efficiency.

This paper presents a set of case studies based on simulations and a new method of performance analysis. Section **2** presents the results of 216 case studies together with simulation results and data analysis. Section **3** presents a set of conclusions together with the direction of further research. The goal is to improve the energy efficiency of hybrid and electric vehicles.

2. Case Study (Motor-Generator Performance) – Analysis

The block diagram of the model used in the performance analysis method is presented in Fig. 1.

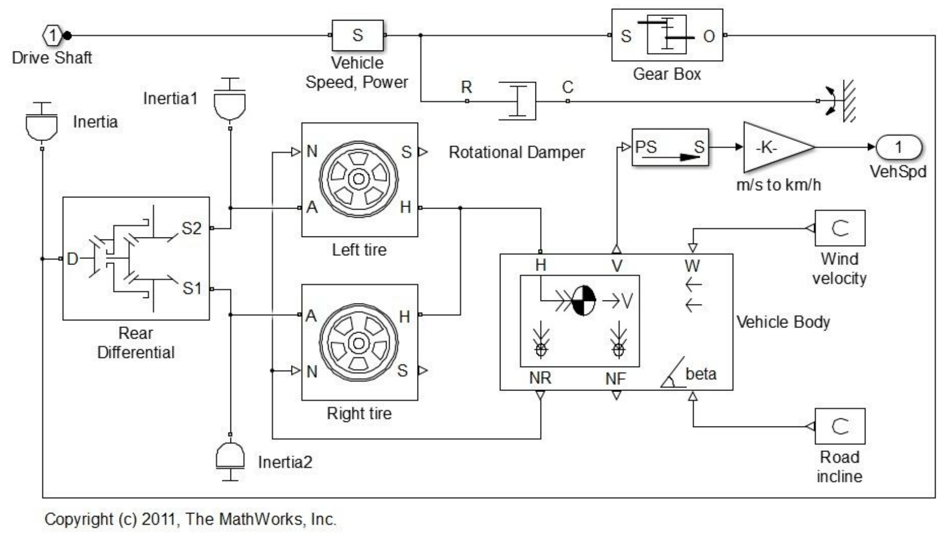

Fig. 1 – Model Block Diagram.

The block diagram represents the simulation of the vehicles dynamics. It is designed based on validated generic blocks available in the Matlab library. The vehicle dynamics block is integrated in hybrid electric vehicle architecture in order to assess the system effect and impact on motor-generator behavior. The parameters under study are: tire radius, drag coefficient (dimensionless aerodynamic drag coefficient, for the purpose of computing the aerodynamic drag force on the vehicle), frontal area (effective cross-sectional area presented by the vehicle in longitudinal motion, to compute the aerodynamic drag force on the vehicle), headwind speed and the road inclination angle. The first three parameters depend on vehicle type, and the last two depend on the driving conditions. Through a set of 216 case studies the proposed analysis method assesses the impact of the vehicle dynamics parameters on the motor and generator behavior. Through all the 216 case studies the tire radius is varied between 0.3 and 0.4 m, the drag coefficient between 0.25 and 4, the frontal area between 2 and 3 m^2, headwind speed between 0 and 4 m/s, inclination angle between 0 and 3 deg. A minimized overview of the case studies is presented in Table 1.

Table 1
Parameter Definition

Case study	Vehicle dynamics parameters variation				
	Tire radius m	Drag coefficient	Frontal area m^2	Headwind speed m/s	Inclination angle deg
1	0.35	0.25	2.5	0	0
2	0.35	0.25	2.5	0	3
3	0.35	0.25	2.5	2	0
4	0.35	0.25	2.5	2	3
…					
145	0.4	0.25	2.5	0	0
…					
168	0.4	0.35	2.5	4	3
…					
216	0.4	0.4	3	4	3

For all 216 performed simulations it is analyzed the generator power, motor power, generator current, motor current and DC-DC bus voltage. On each figure all results are overlapped in order to have an overview of the impact on the analyzed parameters for the motor-generator behavior. In this way, it can be assessed how wide the values range is. Based on the generator power an energy efficiency chart was created in order to identify the most efficient combination of parameters together with the least efficient one.

The generator power values are plotted in Fig. 2. All signal values are overlapped in the same plot and it is visible how wide the generator power distribution is over all case studies. It can be observed that the bandwidth of generator power is around 1 kW at a certain moment in time for a specific sample. It is visible that the generator power is not that much affected by the vehicle dynamics. A higher impact is visible on the motor power.

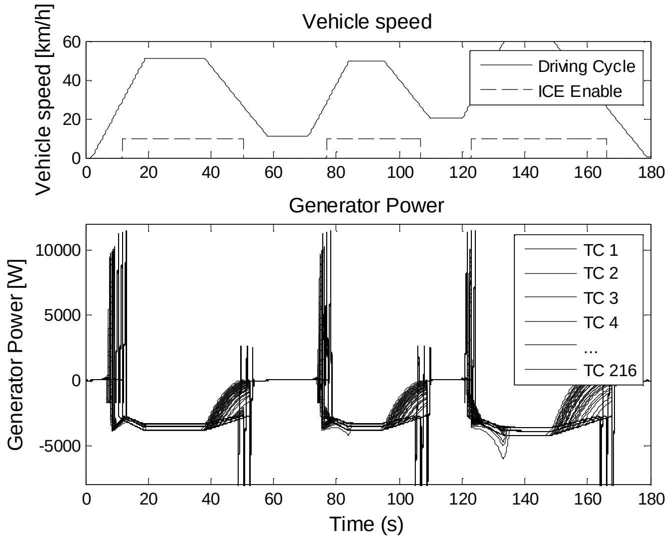

Fig. 2 – Generator power distribution.

The motor power values are plotted in Fig. 3. All signal values are overlapped and it can be observed that the bandwidth of motor power distribution is around 10,...,15 kW at a certain moment in time.

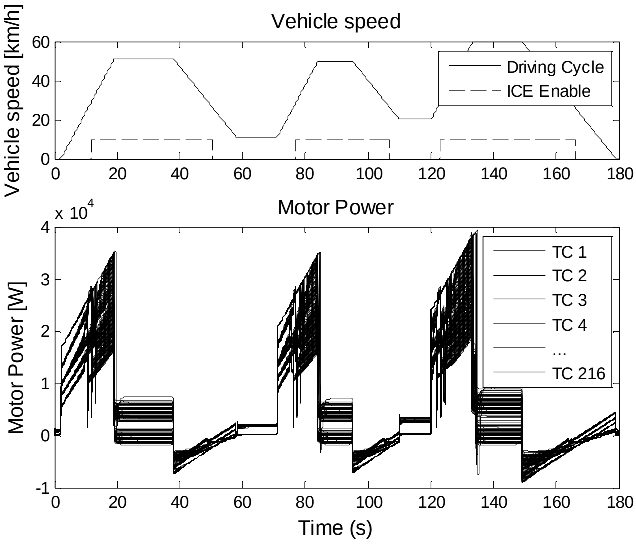

Fig. 3 – Motor power distribution.

It is visible that the vehicle body parameters together with headwind speed and the road inclination angle have a higher impact on the motor mode than on the generator mode. The DcDc bus voltage values are plotted in Fig. 4. Spikes up to 30 V are visible when switching between motor and generator mode.

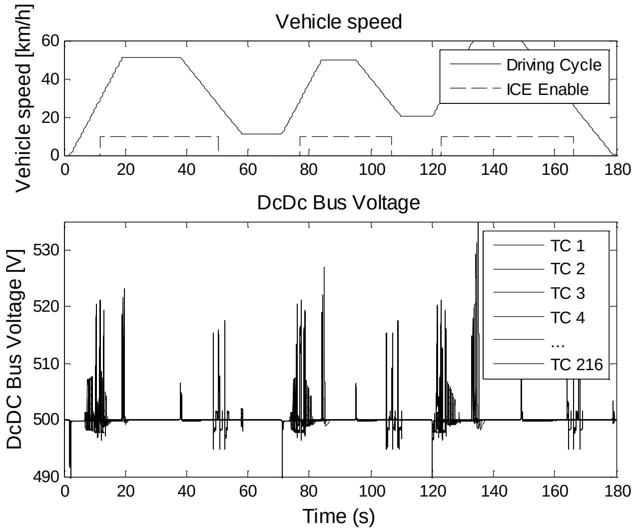

Fig. 4 – DC-DC bus voltage distribution.

The generator current distribution is plotted in Fig. 5. It can be observed that the bandwidth of the generator current is not very wide. In line with the generator power the generator current is not highly affected by the vehicle dynamics.

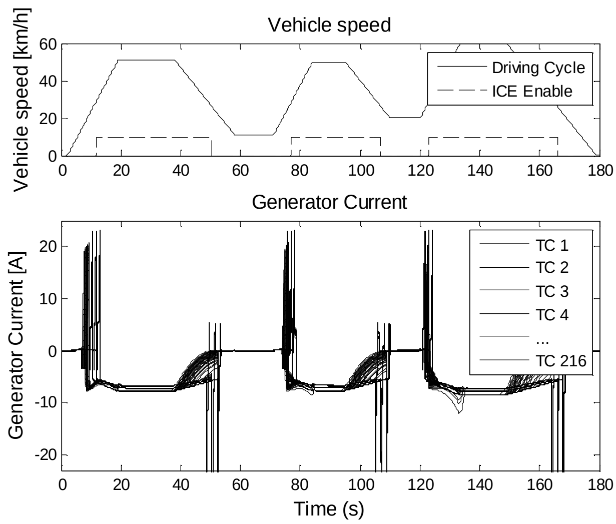

Fig. 5. Generator current distribution.

The generator current distribution is plotted in Fig. 6. The motor current is affected by vehicle dynamics mainly during the acceleration phase. In comparison to the generator current where the vehicle dynamics impact is lower, for the motor current the impact is significantly higher. From the data analysis it is visible that the bandwidth of the motor current is up to 30 A at a certain moment in time.

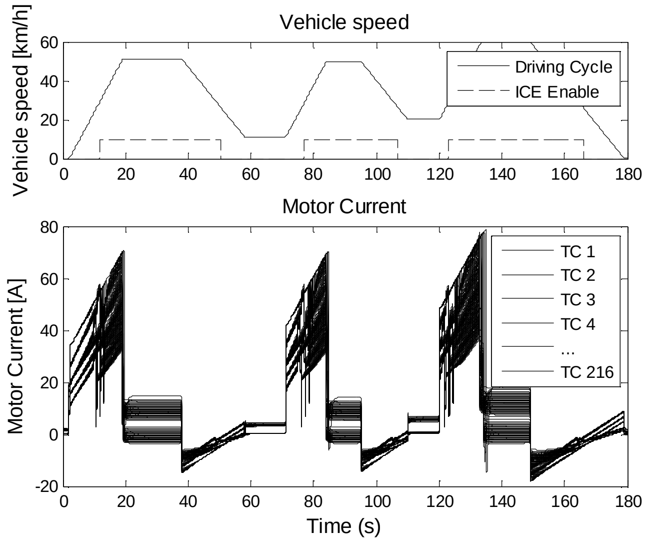

Fig. 6 – Motor current distribution.

The simulation data generated from all case studies is analyzed in order to create a profile of the generator behavior for each combination of the proposed vehicle dynamics parameters. The outcome of the data processing is presented in Fig. 7. For each case study is calculated the percentage while the generator mode is on. The best contribution to the energy efficiency was obtained in the case study 145, and the poorest contribution to the energy efficiency was obtained in the case study 168. Details of the vehicle dynamics parameter values are available in Table 1. The time percentage through the entire simulation set, when the generator is ON is situated between 32.3799% and 37.9923%, while the time when the generator is OFF is situated between 62.0077% and 67.6201%. In order to improve the energy efficiency in hybrid electric vehicles it is recommended to improve the efficiency of the motor mode. The control strategy needs to be adjusted in a way that the motor takes a lower amount of energy from the battery. There is more room to improve the energy management of the motor mode than the energy management of the generator mode. A good parameterization of the control strategy in line with the vehicle body parameters can bring some added value to the overall system behavior. The motor mode efficiency can be increased by adjusting the acceleration factor. The generator mode efficiency can be increased by adjusting the deceleration factor.

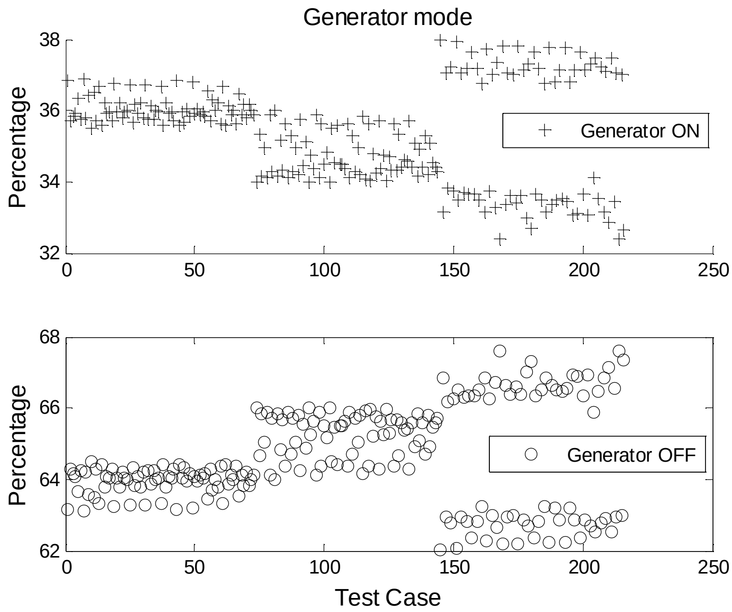

Fig. 7 – Energy efficiency overview.

3. Conclusions

Energy efficiency in hybrid electric vehicles still remains one of the major technical challenges of the industry. This challenge needs to be tackled from different perspectives in order to make a step further towards more efficient hybrid electric drives. Any minor improvement on a certain set of parameters can have a significant system level effect with regards to the efficiency aspect.

The present paper focused on motor-generator performance influenced by the vehicle body parameters together with headwind speed and road inclination. All these varied parameters are generically called vehicle dynamics.

A set of 216 case studies were performed in order to generate a consistent set of data. Data analysis underlined the impact of vehicle dynamics on generator power, generator current, motor power, motor current and DC-DC bus voltage. It was demonstrated that the impact of the vehicle dynamics can be more significant in motor mode. Based on the proposed analysis method an efficiency chart (Fig. 7) with regards to the generator power was created. From all 216 performed case studies the most efficient and the least efficient cases were identified. The proposed analysis method allows a high degree of flexibility and offers a wide overview on the analyzed parameters. Together with the study outcome, this method contributes to the practical need of improving the energy efficiency in hybrid electric vehicles.

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EVALUAREA IMPACTULUI PARAMETRILOR VEHICULULUI ASUPRA PERFORMANȚEI MOTOR-GENERATOR ÎN AUTOVEHICULE ELECTRICE ŞI HIBRIDE

(Rezumat)

Se prezintă o nouă metodă de analiză integrată cu scopul de a evalua impactul parametrilor vehiculului cu privire la performanța motor-generator în vehiculele electrice şi hibride. Această metodă ia în considerare unii parametri de caroserie a vehiculului, împreună cu viteza vântului şi unghiul de înclinare al rampei, care influențează eficiența energetică. Analiza evaluează nivelul de impact asupra performanței motorului şi generatorului. Studiul se bazează pe modelarea Matlab şi simulare. Eficiența metodei este demonstrată printr-o serie de rezultate obținute în urma simulării şi analizei datelor generate dintr-un set de 216 de studii de caz. Motivația cercetării este dată de faptul că tema eficienței energetice reprezintă încă una dintre cele mai mari provocări tehnice în domeniul vehiculelor electrice şi hibride. Avantajul acestei metode este acela că performanțele sistemelor din punct de vedere al comportamentului motor-generator poate fi validată într-un stadiu incipient. Valoarea adăugată este dată de acuratețea rezultatelor simulării şi privirea de ansamblu comparativă obținută ca urmare a metodelor de analiză prezentate. Rezultatele pot contribui la nevoia practică de a îmbunătăți eficiența energetică şi timpul de dezvoltare pentru viitoarele maşini electrice şi hibride.