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Research Article

HYBRID AND ELECTRIC VEHICLES FOR ISTANBUL CYCLE AND DRIVETRAIN DESIGN

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ABSTRACT

In this study, selected Range Extender (REx) hybrid and electric vehicles were modeled and compared according to their performance on Istanbul drive cycle for the same operating conditions. The parametric drive train design and simulation of hybrid and electric vehicle were performed on the engineering software. The engineering analysis compared for power consumption calculation, maximum velocity calculation and acceleration time calculation over the selected hybrid and electric vehicle drive cycle of Istanbul. Also results can be evaluated for the conventional car which is equipped by internal combustion engine. Vehicle performance results were analyzed on the portion of power consumption in the internal combustion engine performance map. The study shows that the engine operates in a more efficient condition in the pure electric vehicle for the Istanbul drive cycle than that in the electric and conventional vehicles due to the stop-and-go situation. Thanks to the hybrid electric drive train system, both traction performance and fuel economy of the vehicle are enhanced in a big step. The results are widely and qualitatively in agreement with the previous experimental and computational studies in the literature.
Keywords: Hybrid vehicle, electric vehicle, engine performance, Istanbul cycle.

1. INTRODUCTION

Electric vehicles are becoming promising alternatives to be remedy for urban air pollution, greenhouse gases and depletion of the finite fossil fuel resources (the challenging triad) as they use centrally generated electricity as a power source. It is well known that power generation at centralized plants are much more efficient and their emissions can be controlled much easier than those emitted from internal combustion engines that scattered all over the world. All the benefits of electrical vehicles are starting to justify, a century later, attention of industry, academia and policy makers again as promising alternatives for urban transport. Nowadays, industry and academia are striving to overcome the challenging barriers that block widespread use of electric vehicles. Lifetime, energy density, power density, weight and cost of battery packs are major barriers to overcome. However, modeling and optimization of other components of electric vehicles are also as important as they have strong impacts on the efficiency, drivability and safety of the vehicles. In this sense there is growing demand for knowledge to model and optimize the electrical vehicles [1]. Environmental as well as economic issues provide a compelling impetus to develop clean, efficient and sustainable vehicles for urban transportation. Automobiles constitute

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an integral part of our everyday life, yet the exhaust emissions of conventional internal combustion (IC) engine vehicles are to blame for the major source of urban pollution that causes the greenhouse effect leading to global warming [2]. Electric vehicles paved their way into public use as early as the middle of the 19th century, even before the introduction of gasoline-powered vehicles [3]. Compared to conventional vehicles, there are more electrical components used in electric, hybrid, and fuel cell vehicles, such as electric machines, power electronics, electronic continuously variable transmissions (CVT), and embedded powertrain controllers [4-6]. Advanced energy storage devices and energy converters, figure 1, such as Li-Ion batteries, ultra capacitors, and fuel cells, are introduced in the next generation powertrains. In addition to these electrification components or subsystems, conventional internal combustion engines (ICE) and mechanical and hydraulic systems may still be present. The invention of improved battery technology, including efforts by Gaston Plante in France in 1865 [7] as well as his fellow countryman Camille Faure in 1881 [8], paved the way for electric cars to flourish in Europe. An electric-powered two-wheel cycle was put on display at the 1867 World Exposition in Paris by the Austrian inventor [9].

France and Great Britain were the first nations to support the widespread development of electric vehicles [10]. Electric trains were also used to transport coal out of mines, as their motors did not use up precious oxygen. Before the pre-eminence of internal combustion engines, electric automobiles also held many speed and distance records [11, 12] . Among the most notable of these records was the breaking of the 100 km/h (62 mph) speed barrier, by Camille Jenatzy on 29 April 1899 in his 'rocket-shaped' vehicle Jamais Contente, which reached a top speed of 105.88 km/h (65.79 mph). Also notable was Ferdinand Porsche's design and construction of an all-wheel drive electric car, powered by a motor in each hub, which also set several records in the hands of its owner E.W. Hart. Electric trains were also used to transport coal out of mines, as their motors did not use up precious oxygen. In 1959, American Motors Corporation (AMC) and Sonotone Corporation announced a joint research effort to consider producing an electric car powered by a "self-charging" battery [13]. AMC had a reputation for innovation in economical cars while Sonotone had technology for making sintered plate nickel-cadmium batteries that could be recharged rapidly and weighed less than traditional lead-acid versions [14]. That same year, Nu-Way Industries showed an experimental electric car with a one-piece plastic body that was to begin production in early 1960 [13]. A nickel-cadmium battery supplied power to an all-electric 1969 Rambler American station wagon [15]. Other "plug-in" experimental AMC vehicles developed with Gulton included the Amitron (1967) and the similar Electron (1977). More battery-electric concept cars appeared over the years, such as the Scottish Aviation Scamp (1965) [16], the Enfield 8000 (1966) [17] and two electric versions of General Motors gasoline cars, such as the Electrovair (1966) and Electrovette (1976) [18].

Moreover, the case study that has done to express the system and characteristics of 1970s electrical vehicle is on the fallowing part. The electrical vehicle is a modified Chevy Chevette chassis and body. This electrical vehicle was used mainly as a test bed for Ni-Zn batteries. Over 35,500 miles of on-road testing proved that this EV was sufficiently road worthy. In 1980's the production of electrical vehicles and motors had a new trend. After years outside the limelight, the energy crises of the 1970s and 1980s brought about renewed interest in the perceived independence electric cars had from the fluctuations of the hydrocarbon energy market.

After years outside the limelight, the energy crises of the 1970s and 1980s brought about renewed interest in the perceived independence electric cars had from the fluctuations of the hydrocarbon energy market. At the 1990 Los Angeles Auto Show, General Motors President Roger Smith unveiled the GM Impact electric concept car, along with the announcement that GM would build electric cars for sale to the public. In the early 1990s, the California Air Resources Board (CARB), the government of California's "clean air agency", began a push for more fuel-efficient, lower-emissions vehicles, with the ultimate goal being a move to zero-emissions vehicles such as electric vehicles [19-20]. In response, automakers developed electric models, including the Chrysler TEVan, Ford Ranger EV pickup truck, GM EV1 and S10 EV pickup, Honda EV Plus hatchback, Nissan lithium-battery Altra EV mini wagon and Toyota RAV4 EV. The automakers were accused of pandering to the wishes of CARB in order to continue to be allowed to sell cars in the lucrative Californian market, while failing to adequately promote their electric vehicles in order to create the impression that the consumers were not interested in the cars, all the while joining oil industry lobbyists in vigorously protesting CARB's mandate [20]. GM's program came under particular scrutiny; in an unusual move, consumers were not allowed to purchase EV1s, but were i nstead asked to sign closed-end leases, meaning that the cars had to be returned to GM at the end of the lease period, with no option to purchase, despite lessor interest in continuing to own the cars [20]. Chrysler, Toyota, and a group of GM dealers sued CARB in Federal court, leading to the eventual neutering of CARB's ZEV (Zero Emission Vehicle) Mandate as shown in Table 1.

The trends in EV developments in recent years can be attributed to the following:

• High level of activity exists at the major automotive manufacturers.
• New independent manufacturers bring vigor.
• New prototypes are even better.
• High levels of activity overseas exist.
• There are high levels of hybrid vehicle activity.
• A boom in individual ICEV to EV conversions is ongoing.
• The fuel cell shows great promise in solving the battery range problem.

Table 1. The case studies of two GM EVs of the 1990s are given below [21-22].

Equipment	**Properties**	**Type**
Motor	137 hp, 12,000 rev/m	one three phase induction motor
Battery Pack	lead acid(26), 312V, 869 Lb	Lead acid batteries
Motor Drive	DC-to-AC inverter using bipolar transistors	Dc to Ac inverter using IGBTs
Top Speed	75 mph	75 mph
Range	90 miles on highway	95 miles highway, 70 miles in city
Acceleration	0 to 60 miles in 8.5s	0 to 60 miles in 8.5
Vehicle Weight	2900 lb	2700lb

The 2000s energy crisis brought renewed interest in hybrid and electric cars. In America, sales of the Toyota Prius (which had been on sale since 1999 in some markets) jumped, and a variety of automakers followed suit, releasing hybrid models of their own. Several began to produce new electric car prototypes, as consumers called for cars that would free them from the fluctuations of oil prices. In response to a lack of large-automaker participation in the electric car industry, a number of small companies cropped up in their place, designing and marketing electric cars for the public.

Most electric vehicles in the world roads are low-speed, low-range neighborhood electric vehicles (NEVs). Pike Research estimated there were almost 479,000 NEVs on the world roads in 2011 [23]. The top selling NEV is the Global Electric Motorcars (GEM) vehicles, with more than 46,000 units sold worldwide by April 2013 [24]. As of July 2006, there were between 60,000 and 76,000 low-speed battery-powered vehicles in use in the United States, up from about 56,000 in 2004 [25]. The two largest NEV markets in 2011 were the United States, with 14,737 units sold, and France, with 2,231 units [26]. Other micro electric cars sold in Europe were the Kewet, since 1991, and replaced by the Buddy, launched in 2008 [27].

All of the major automotive manufacturers have production EVs, many of which are available for sale or lease to the general public. The status of these vehicle programs changes rapidly, with manufacturers suspending production frequently due to the small existing market demand of such vehicles. Examples of production EVs which are or until recently have been available are GM EVl, BMW i8, i3, Ford Think City, Toyota RAV4, Nissan Hyper mini, and Peugeot 106 Electric. There are also many prototype and experimental EVs being developed by the major automotive manufacturers. Most of these vehicles use AC induction motors or PM synchronous motors. Also, interestingly, almost all of these vehicles use battery technology other than the lead-acid battery pack. The list of EVs in production and under development is extensive, and readers are referred to the literature [4] for the details of many of these vehicles.The manufacturers of EVs in the 1990s realized that their significant research and development efforts on ZEV technologies were hindered by unsuitable battery technologies. A number of auto industries started developing hybrid electric vehicles (HEVs) to overcome the battery and range problem of pure electric vehicles. The Japanese auto industries lead this trend with Toyota, Honda, and Nissan already marketing their Prius, Insight, and Tino model hybrids. The hybrid vehicles use an electric motor and an internal combustion engine and, thus, do not solve the pollution problem, although it does mitigate it. It is perceived by many that the hybrids, with their multiple propulsion units and control complexities, aren't economically viable in the long run, although currently a number of commercial, prototype, and experimental hybrid vehicle models are available from almost all of the major automotive industries around the world [4]. BMW, Toyota, Honda, and Nissan are marketing the hybrid vehicles well below the production cost, with significant subsidy and incentive from the government.

HEVs and EVs are expected to be high until production volume increases significantly. Fuel cell electric vehicles (FCEV) can be a viable alternative to battery electric vehicles, serving as zero-emission vehicles without the range problem. Toyota is leading the way with FCEV, announcing the availability of its FCEV in 2003. The Toyota FCEV is based on the Toyota RAV4 model.

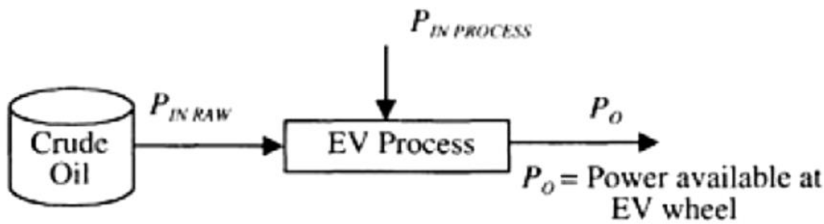

Figure 1. EV process from crude oil to power at the wheels.

The global economic recession in the late 2000s led to increased calls for automakers to abandon fuel-inefficient SUVs, which were seen as a symbol of the excess that caused the recession, in favor of small cars, hybrid cars, and electric cars. California electric car maker Tesla Motors began development in 2004 on the Tesla Roadster, which was first delivered to customers in 2008 [28]. The Roadster was the first highway-capable all-electric vehicle in serial production available in the world. Since 2008 Tesla has sold more than 2,100 Roadsters in 31 countries through December 2011. [29] The Roadster was also the first production automobile to use lithium-ion battery cells and the first production all-electric car to travel more than 200 miles (320 km) per charge [30]. Tesla expects to sell the Roadster until early 2012, when its supply of Lotus Elise gliders is expected to run out, as its contract with Lotus Cars for 2,500 gliders expired at the end of 2011 [31-32]. Tesla stopped taking orders for the Roadster in the U.S. market in August 2011, [33].

2. METHODOLOGY and CASE STUDIES

In this study, pure electric car which is driven by only electric motor and range extender car which is kind of hybrid engine were modeled in improved engineering software. Hybrid and electric car properties were given in Table2. In engineering analysis, electrical and fuel consumptions were compared for hybrid and electric vehicles. Also for the same drive conditions, electrical motor torque, electrical power, mechanical power, car speeds, power lost and total efficiencies were simulated and analyzed.

Table 2. Values used in Modelling

Parameters	Electric Car	Range Extender Car
Curb Weight	1195,0 kg	1320,0 kg
Gross Weight	1620,0 kg	1750,0 kg
Frontal Area	1,89 m^2	1,89 m^2
Electric Motor Output (Kw)	76,99	76,99
Electric Motor- Max. Torque (Nm)	240	240
Capacity of NiMH Battery kWh	15.5	15.5
Range (km)	80	130
ICE Engine (Range Extender)	-	4 Cylinder, 1000 m^3 engine
Top Speed (km/h)	132,6	126
Charge time of high-voltage battery in h at 16 A	6-8 Hours	6-8 Hours

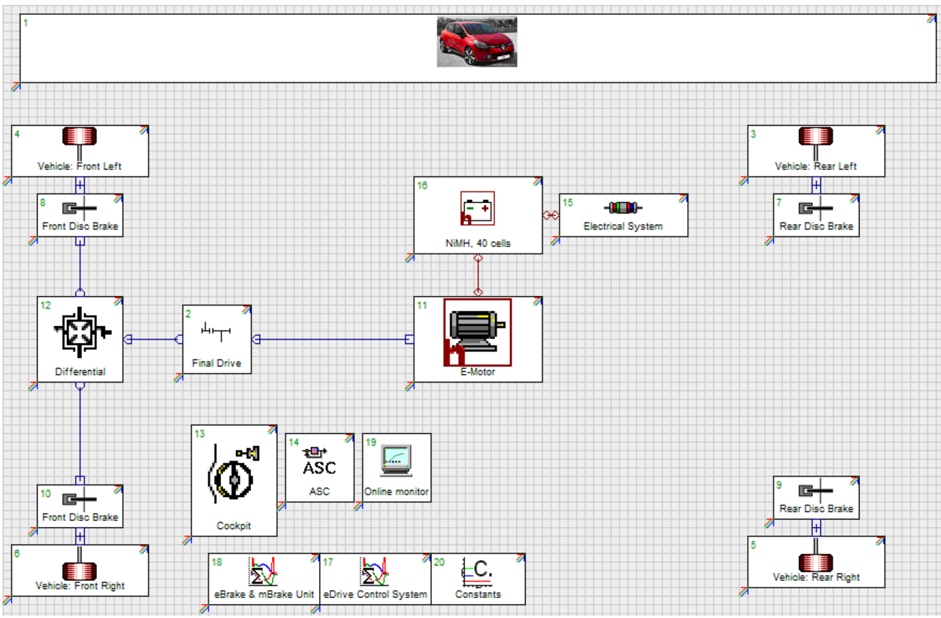

Figure 2. Electric CAR Modelling.

In case studies, by the electric and hybrid motor, engine controller, tires, disc brake, differential, drive system, rechargeable batteries, and electrical system were connected for both vehicles. Same operating conditions were defined to make comparison of electrical and hybrid vehicles. In hybrid vehicle, 3-cylinder 1 liter gasoline engine was used for the REx engine and light duty vehicles were investigated for the Istanbul Cycle. REx and electrical car modeling structure were given in figure 2, 3 and 4.

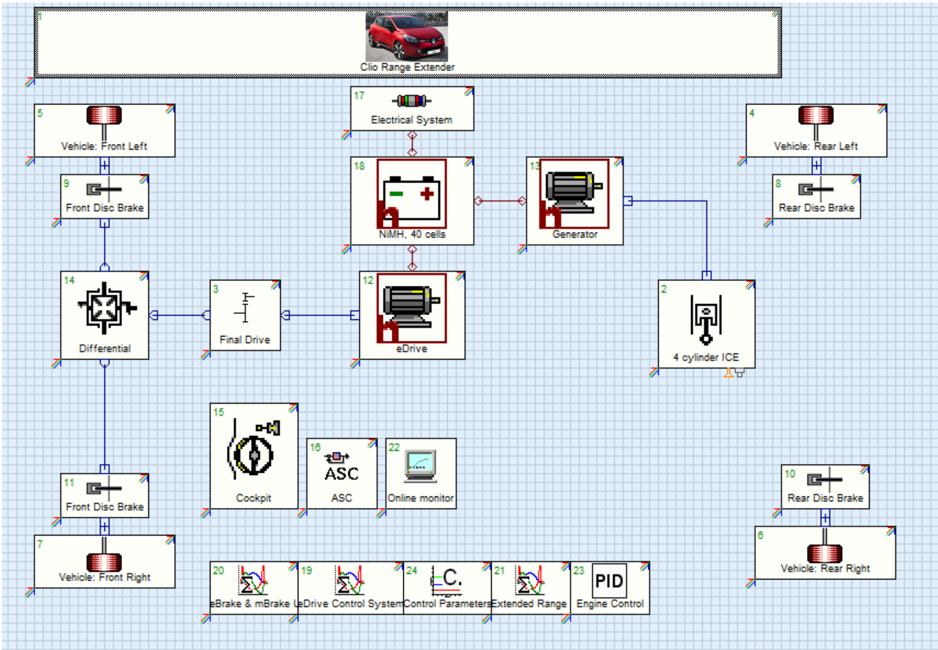

Figure 3. Range Extender Car Modelling.

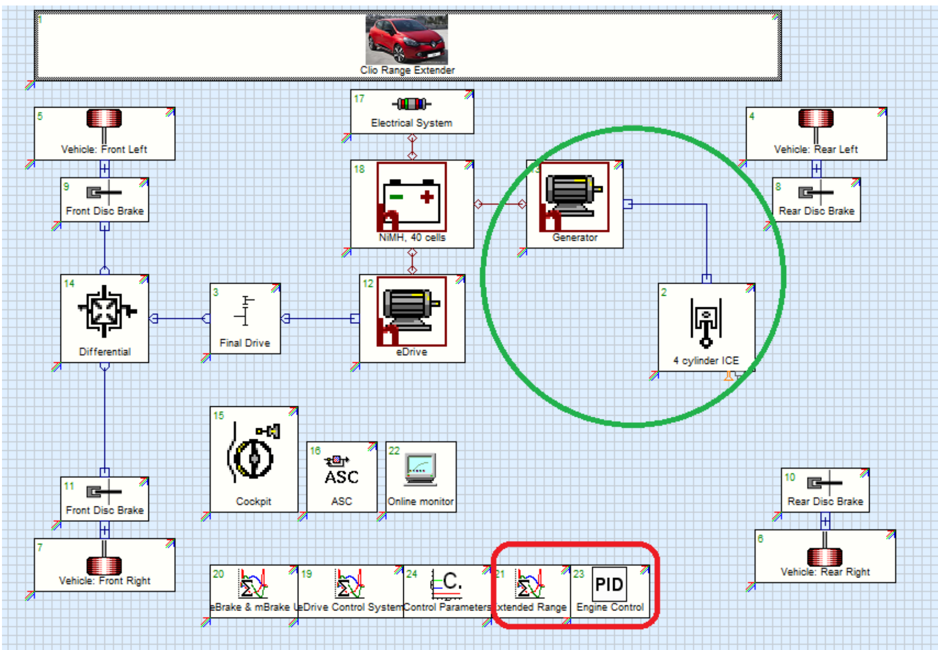

Figure 4. Range Extender Modelling.

In REx engine which contains a small internal combustion engine with a generator that supplies energy for electric propulsion for the battery, PID system was controlled power unit. It is defined as a controller for the battery charging condition. Simulations were performed in order to investigate the performances of the vehicles take based on Istanbul driving cycles. Istanbul driving cycles contains too much slopes and is very different from European's cycles. It should be taking into consideration while selecting public transport vehicles for the sustainable city.

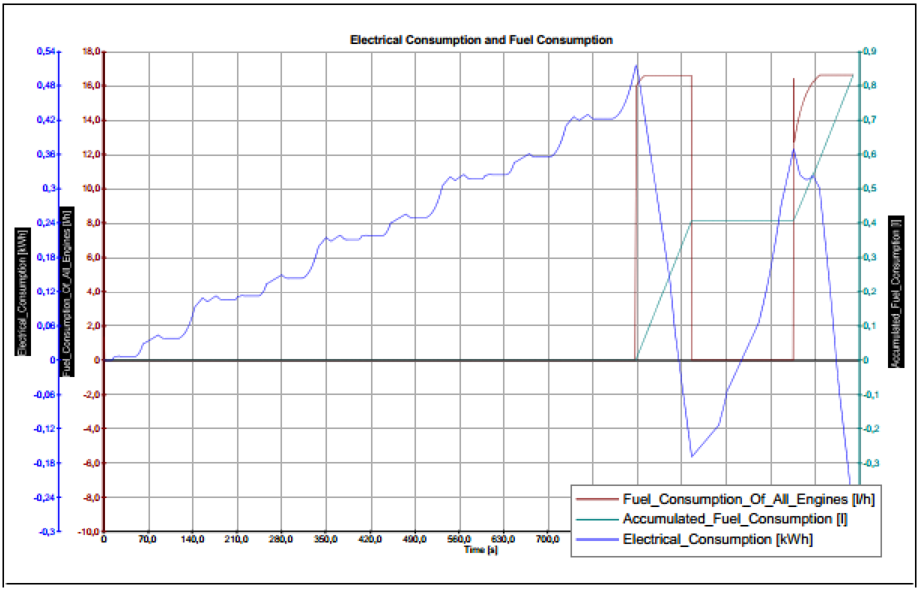

Figure 5. Electrical and Fuel Consumption of Range-Extender Car

In this paper, the range extender electrical car and pure electrical car were compared in 3 aspects;

- Acceleration, Velocity and Distance Values
- Electrical and Fuel Consumption
- Electrical Motor Torque, Speed and Mechanical Power

In Figure 5, fuel and electrical consumption of the vehicles were given. The consumption is too little in electrical car. On the other hand, the range extender car consumes electrical energy and fuel for the same drive cycle.

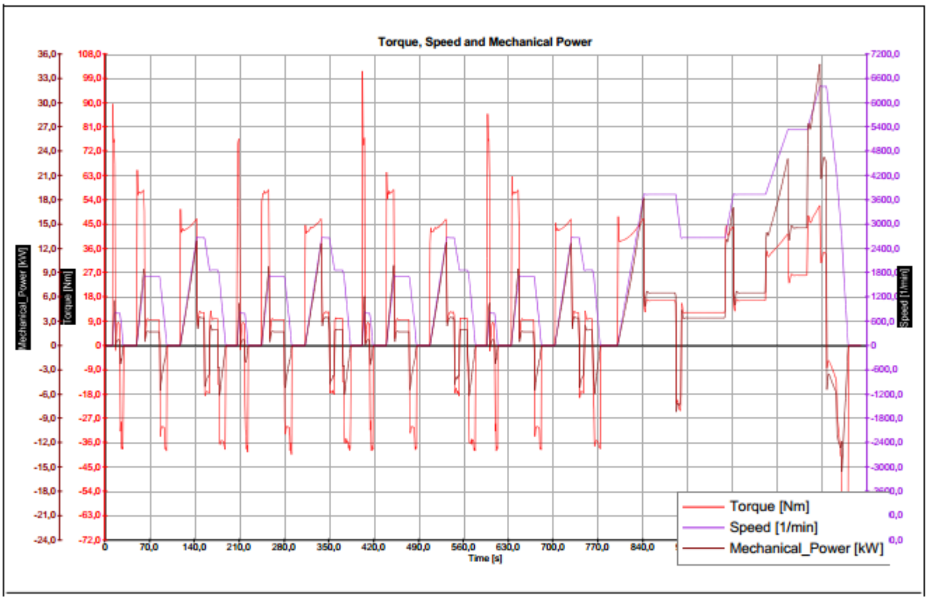

Figure 6. Electrical Motor Torque, Speed and Mechanical Power

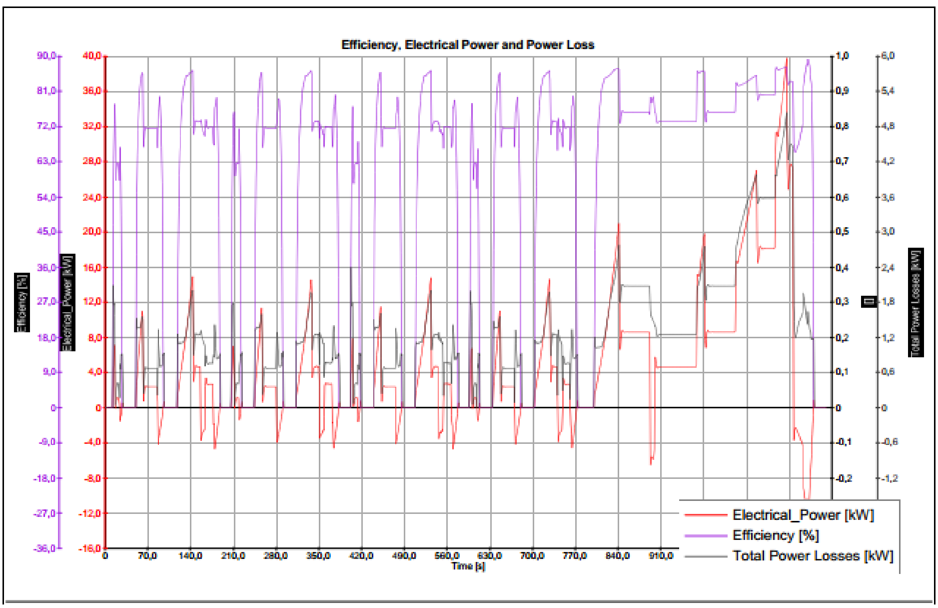

Figure 7. Electrical Power, Total Power Lost and efficiency

The electrical power, power lost, efficiency and also dynamic performances of the engines are close due to the same conditions for both vehicles. Electrical Motor Torque, Speed, Mechanical Power, Electrical Power, Total Power Lost and efficiency were shown in figure 6 and 7. REx engine speed is slightly slower than electric motor due to the vehicle weight and acceleration time.

Results show that, in Istanbul driving cycle, pure electrical vehicle is more efficient than hybrid vehicle due to the stop-and-go situation and traffic jam. However, intercity transport with Istanbul driving cycle, hybrid vehicle is more efficient in terms of fuel and power consumption.

3. CONCLUSION

REx and electric vehicles were modeled and compared for their performance on Istanbul drive cycle in the same operating conditions. Hybrid and electric vehicle modelling and drive train design were performed on the special software. Power consumption calculation, maximum velocity calculation and acceleration time calculation over the selected hybrid and electric vehicle drive cycle of Istanbul were compared both vehicles. Results show that the engine operates in a more efficient condition in the pure electric vehicle for the Istanbul drive cycle than the hybrid electric and conventional vehicles. Thanks to the electric drive train system, both traction performance and fuel economy of the vehicle are enhanced in a big step. The electrical power, power lost, efficiency and also dynamic performances of the engines represent close results due to the same conditions for both vehicles. Electrical Motor Torque, Speed, Mechanical Power, Electrical Power, Total Power Lost and efficiency were also analyzed graphically. REx engine speed is slightly slower than electric motor due to acceleration time and the vehicle weight. Also, pure electrical vehicle is more efficient than hybrid vehicle due to the stop-and-go situation and traffic jam in Istanbul driving cycle. However, intercity transport with Istanbul driving cycle, hybrid vehicle is more efficient in terms of fuel and power consumption.

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