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Auxiliary systems consumption in electric vehicle

***Abstract**. In battery powered electric vehicles (BEV) major portion of battery energy should be spent on traction. Only minor part of battery energy should be used for powering of auxiliary systems. This paper gives the analysis of auxiliary systems in BEV and their power consumption. Since all that energy comes from the power grid, there is a significant decrease in energy consumption if some measures are taken. Comparison of several measures are here presented.*

***Streszczenie.** W pojazdach elektrycznych zasilanych baterią główna część energii baterii wydatkowana jest na ruch pojazdu. Tylko mała część energii zużywana jest na zasilanie systemów wspomagających. W artykule wykonano analizę systemów wspomagania w pojazdach elektrycznych i ich zapotrzebowanie energetyczne, Ponieważ cała energia dostarczana jest z sieci, możliwość istotnej redukcji w konsumpcji energii poławia się, jeśli podejmie się pewne usprawnienia techniczne. Porównania różnych usprawnień jest zaprezentowane. (**Pobór energii w systemach wspomagania w pojazdach elektrycznych**).*

Keywords: electric vehicle, auxiliary system, energy consumption
Słowa kluczowe: polazdy elektryczne, system wspomagania, spożycie energii

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Introduction

Electric vehicles, especially cars, are now in focus due to different agendas and interests. But the major problem of electric car is its power supply. If one concentrates to battery powered vehicles then this problem becomes even greater. Since batteries have rather low energy density, that means they occupy significant volume and have significant weight. Unfortunately electric cars should be as lighter as possible and have limited space. Therefore major part of energy accumulated in batteries should be used to propel the vehicle. But in standard car there are lots of additional loads incorporated in different auxiliary systems. Since accumulated energy in batteries is determined and limited, auxiliary system power consumption should be optimized or even minimized in order to increase vehicle drive range [1].

Auxiliary systems

Since electric car, like all other cars, should participate in traffic, there are standards that car should meet. Some of auxiliary systems are directly related to those standards. They are all necessary lights, horn and heating. Other systems are in the "luxury" department such as: power steering, brake booster, air conditioner, sound system, satellite navigation etc. All of them use electrical energy from batteries thus reduce vehicle drive range. Some of those loads are not significant but usually considered as very important. All of them will be analysed in this paper together with their consumption according to assumed scenarios. Special attention will be given to lights.

One of the examples are blinkers or turn lights. On average, every passenger car in Europe drives 40 km per day. Most of those kilometres are travelled within cities. If one assumes that there is crossroad every 500 meters and those cars, on average, change direction every four crossroads, then it can be said that while driving a car there is a need to switch on turn signals every 2 km. Each time when a turn signal is switched on, it blinks for an average of 5 seconds. Calculating the above leads to an average 50 seconds per day and car that turn signals are on. An average car has 4 lights for turn signals but only two of them works while turning. Each of those lights has the power of 21 W, so for all four of them that is 42 W. Turn signals spend a total amount of 2100 Ws per day and car, or 0,583 Wh per day and car. In one year one car would spend 5110 Wh for turning signals.

In the case of the car with diesel internal combustion engine with fuel consumption of 7 l/km and its efficiency of 30% (with alternator efficiency of 85%), there are, annually, 2 litres of diesel fuel consumed for turn lights (there are 10 kWh of energy in 1 l of diesel fuel). If the savings with LED turn lights is 75%, then 1,5 litres of diesel fuel (2,1 EUR) can be saved annually. In kilometres, saving is 21,5 km. Since 4 LED lights can be bought for 0,5 EUR each (total 2 EUR). This "investment" is returned under one year (0,95 years). Of course, when average customer does not think about such little savings since he can save more just with "lighter" foot on accelerator pedal. But nevertheless, when calculating such saving for all cars, lots of fuel can be saved and thus emissions can be reduced. In case of the battery electric car that needs 150 Wh/km and have battery efficiency of 70% and charger efficiency of 92%, then 5,11 kWh becomes 7,94 kWh annually from the grid. With the price of 0,137 EUR/kWh [2] this gives 1,09 EUR. With LED lights 75% can be saved so savings is 0,82 EUR. Now the "investment" is returned within little under 2,5 years (2,46 years). Also this savings, represent in kilometres, is 26 km. In 2008 there were more than 250 million passenger cars in use in Europe [3]. With this factor, all numbers mentioned above become more relevant to society. For example, with LED turn lights in all cars, 375,7 million litres of fuel can be saved annually. But for the future of battery electric vehicles, if all cars in Europe are electric, then 1,48 TWh of electric energy can be saved. That represents one 210 MW power source. If this power source is thermo power plant than emissions are again reduced.

This discussion was made for only turn lights. If all other lights are taken into consideration things are more radical. In [4] usage data were obtained in a field operational test, with 87 drivers using 11 instrumented vehicles. Each driver used one instrumented vehicle as a personal vehicle for between 13 and 27 days, with data collection occurring each time the vehicle was driven. Table 1 shows the summary data that were recorded (DRL - Daytime running lights; CHMSL - Centre high mount stop lamp).

If data from Table 1 are analysed and compared to previously stated assumptions (50 seconds of assumed daily usage of turn lights in Europe – 5 hours per year compared to 20 hours of turn light usage in USA) one can conclude that at least four times more pollution can be avoided. Since in USA daily millage per car is 30 miles (48 km) compared to Europe (40 km), this 20% difference gives factor of 3,2 between usage time in USA and Europe. All other values from table 1 can be reduced by that factor and applied to Europe. But never the less, usage ratio is still the same.

One can safely assume that turn lights represent only 5% of all car light power consumption. That means that all savings are at least 20 times greater than those previously mentioned (30 litres less of diesel per car per year, or 520 additional kilometres for electric car per year, or 4200 MW less of power source). Additional auxiliary system does not represent such great possibility for savings (of money and fuel) but can definitely be optimized. Nevertheless right now we are spending too much fuel (and polluting too much) just because our commotion. If we have ICE (internal combustion engine) car than we have lots of heat that we use during cold days for heating. In electric cars we have to use electric heaters, thus reducing drive range by additional electric energy consumption. Also air conditioners are now essential part of additional equipment in every car. They represent significant load (several kW) and are very rarely applicable in electric vehicles. Solution can be found in smaller air condition units powered from solar panels. We usually turn on air conditioners after car was for several hours exposed to sunlight and we want to cool the whole vehicle immediately. If smaller air conditioner runs continuously powered from solar panels (photovoltaic) than the difference between outer and inner car temperature would be substantially reduced, thus lowering the need for rapid air conditioning when we enter our car. Power steering, depending on car configuration, can consume up to 2 – 3 kW and is emphasised in cities where lots of steering is present. This load is significant for batteries (in electric car). In ICE cars it is also electrically driven but it is not so simple to reduce this load (reduce fuel consumption). There are ways to avoid power steering, but they are applicable when designing a new car. Brake booster uses air pressure lower that atmospheric air pressure to enhance braking force produced by driver's foot. In ICE cars brake booster uses ICE as constant supply of low air pressure. But if there is no ICE (or ICE is not used as low air pressure supply) than vacuum pump should be installed. Now there are electric systems for supplying low air pressure (it is not vacuum) that include vacuum pump, pressure switch and vacuum container. Their power consumption is around 100 W and can easily be satisfied with solar panel. This is also the case with sound system and navigation. But all together, loads that should be powered from solar panels reach combined power of around 2 kW. This implies that air conditioning is used while the car is parked and the other loads (systems) are used during driving. In best case, solar panel can produce 200 W per m^2 so there should be at least 10 m^2 of solar panels which is impossible for average car.

Table 1 Recorded usage time of different lights

Function	Average usage rate	
	Minutes per 100 km	Hours per year
DRL	116,5*	382,0
Low beam	97,6[+]	97,3
High beam	9,8[+]	9,8
Parking/position	107,4[+]	107,1
Turn signal, left	5,8	24,9
Turn signal, right	4,6	19,5
Side markers	107,4[+]	107,1
Stop	18,9	80,7
Tail	107,4[+]	107,1
CHMSL	18,9	80,7
Backup/reverse	0,9	3,8
License plate	107,4[+]	107,1

*Daytime driving only
[+]Night time driving only

Measurements

Some of, above mentioned, numbers are checked with measurements (Fig. 1) on actual electric car [5], [6]. The idea was to measure changes made in turn lights system. Three cases are measured:

- Old system with classic light bulbs (Bulb1 in diagrams)
- New system with classic light bulbs (Bulb2 in diagrams)
- New system with LED lights (Led in diagrams)

a) b)

Fig. 1 Electric car (a) with LabVIEW based measurement system (b)

All cases are measured while all four lights were turned on. Old system means that bimetal is used as switching device for turn lights. In this case additional energy is used for heating bimetal which can be seen on Fig. 3 and Fig. 5. Combined with classic light bulbs (21 W, 12 V) this system has greatest power and energy consumption. New system (Fig. 2) is IC (integrated circuit) based and combined with classic light bulbs has somewhat lower power and energy consumption. But new system (IC based) combined with LED lights has exceptionally low power and energy consumption (Table 2). Energy consumption is also dependable on time frame. Old bimetal system has slightly greater switching frequency, but what is more important light bulb comparison was made on the same system with the same switching frequency.

Table 2 Measurement overview

	Bulb 1	Bulb 2	Led
Current (A)	6	5,5	0,26
Voltage drop (V)	0,36	0,55	0,04
Power (W)	67	56	3
Energy (Ws)	193	159	8,3

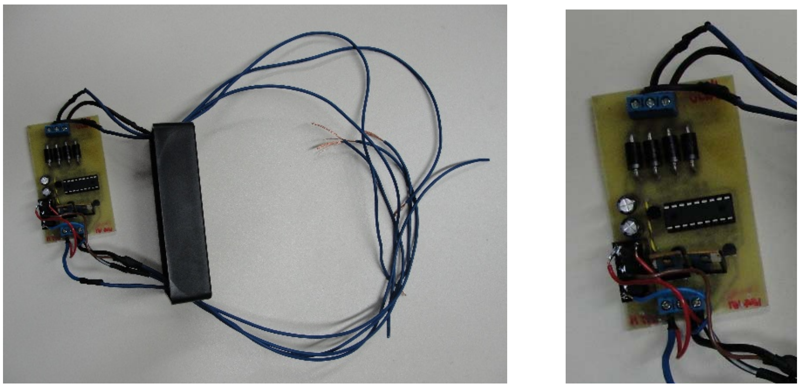

Fig. 2 New IC based light switching system

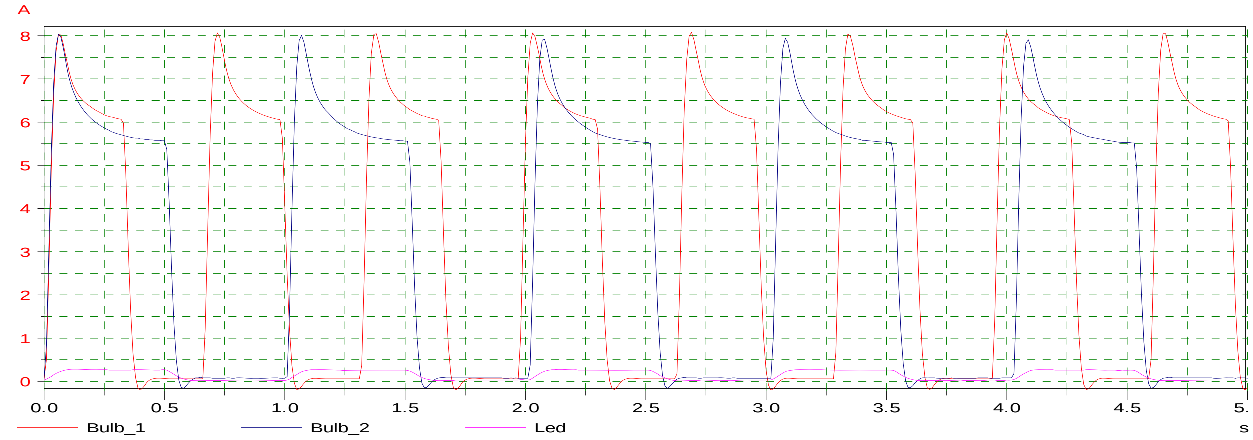

Fig. 3 Current comparison

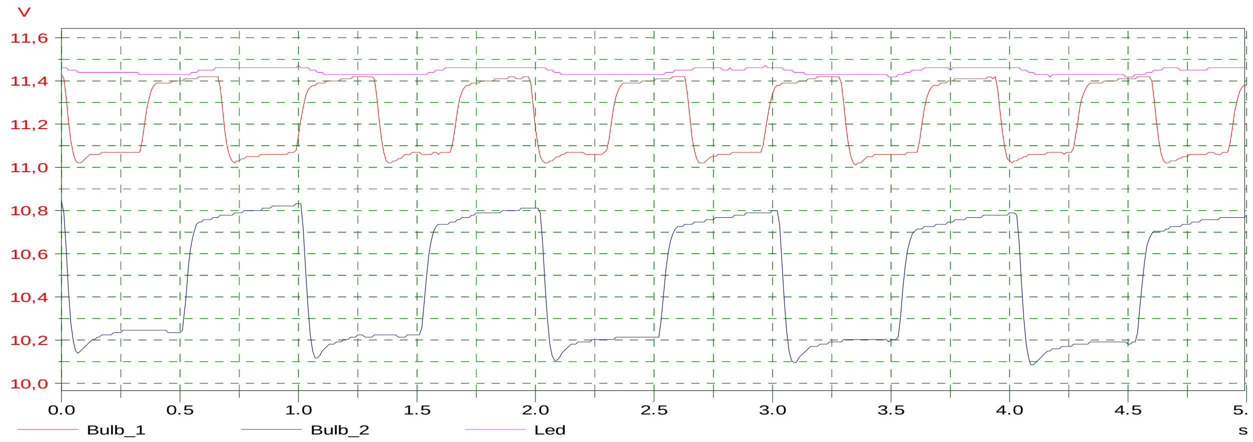

Fig. 4 Voltage drop comparison

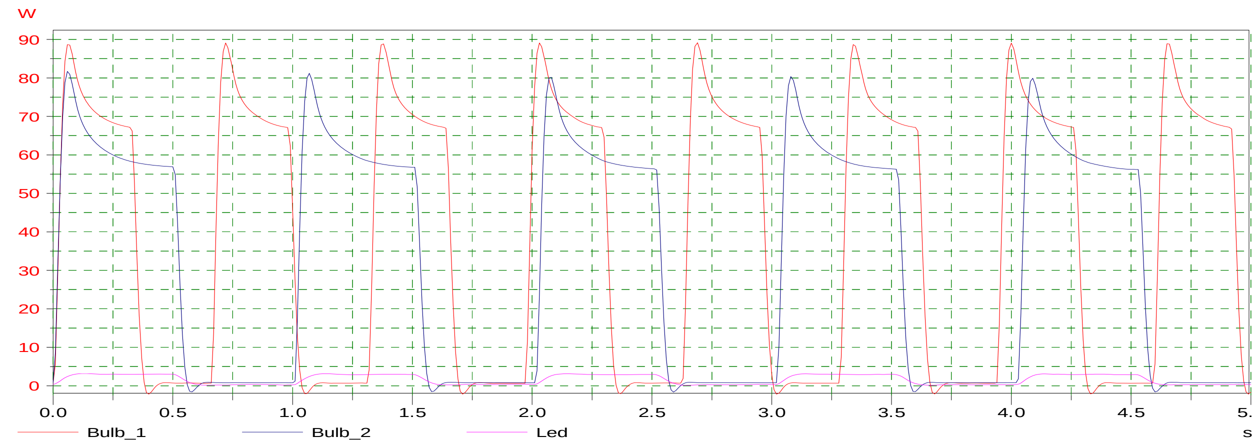

Fig. 5 Power consumption comparison

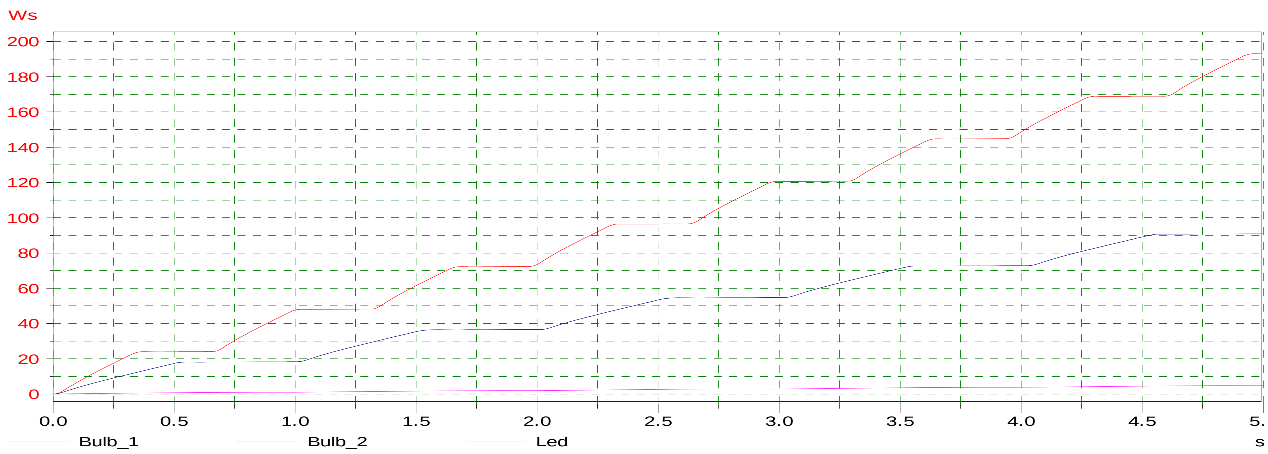

Fig. 6 Energy comparison

As it can be seen on measured diagrams, current that LED lights draw from batteries are significantly lower than the current for classic light bulb (over 20 times). That means that standard old bimetals cannot be used for switching because LED light current cannot produce enough heat to ensure bimetal operation. That is the reason for IC based switching device installation.

Conclusion

Auxiliary systems in modern cars represent substantial part in energy consumption. Sometimes even more than 15%. Since cars are essentially luxury, people tend to treat themselves with more additional equipment that consume more energy. In ICE cars that means that more fuel will be used and more pollution will be greater. In electric cars (BEVs) that means that driving range reduces thus presents BEVs as less attractive. For example, in electric busses, during summer, energy consumption of auxiliary systems (especially air conditioning) represent around 50% of total consumed energy. Nevertheless, there are some measures that can secure less auxiliary systems energy consumption. Of course, total picture should be considered. That means that some measures are justified according to financial criterion and some according to ecological criterion. Sometimes those two criterions are compliant but most of the times are not. Usage of LED lights instead classic light bulbs definitely meets both criterions and, as discussed earlier, easy applicable and very profitable.

REFERENCES

[1] Goia C., Popa L., Popescu C., Popescu M.O., Supercapacitors used as an energy source to drive the short urban electric vehicles, *7th International Symposium on Advanced Topics in Electrical Engineering (ATEE)*, 2011, pp. 1 – 6.

[2] Eurostat, March 2014, Electricity prices for household consumers, http://epp.eurostat.ec.europa.eu/tgm/table.do?tab=table&init=1&language=en&pcode=ten00115&plugin=1

[3] UNECE, February 2012, Transport Statistics for Europe and North America, http://www.unece.org/trans/main/wp6/publications/stats_annual_2012.html

[4] Schoettle B., Sivak M., Fujiyama Y., LEDs and power consumption of exterior automotive lighting: implications for gasoline and electric vehicles, Report No. UMTRI-2008-48, *The University of Michigan Transportation Research Institute*, Ann Arbor, Michigan 48109-2150, U.S.A., October 2008

[5] Vražić M., Kovačić M., Džapo H., Ilić D., Concept of mobile lab for electric vehicle systems research and testing, *Acta IMEKO*, August 2013, Volume 2, Number 1, pp 27–31

[6] Vražić M.,Vuljaj D.,Pavasović A., Pauković H., Study of a Vehicle Conversion from Internal Combustion Engine to Electric Drive, *Energycon 2014*, Dubrovnik, 2014., pp 1622-1626

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