

Energy balance in motor vehicles

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Abstract. This paper presents the concept of testing energy balance. The test was conducted on the test bench equipped with the alternator, battery and standard mounted current receivers. The course of measurements consisted in recording the indications of three ammeters and a tachometer. On the basis of the recorded current values, it was possible to determine: energy received from the battery, consumed by the receivers and the energy drawn from the alternator.

1. Introduction

Energy balance includes the analysis of energy consumed by the receivers, supplied by the alternator and received by the battery; on this basis it can be determined whether a given alternator has enough power to ensure the proper functioning of the receivers and the appropriate charging of the battery [1-3].

The way energy balance is tested is determined by the industry standard. It shows that the verification of balance consists in comparing battery capacity before a test drive with its capacity after the appropriate drive cycle has been carried out. This standard specifies that the battery capacity at 25 °C should not be less than 80% of the capacity at the beginning of the test. The method of checking balance consists in calculating the energy consumed by the receivers and calculating the energy returned by the alternator. This method, however, is a theoretical one; it does not take battery work into consideration, and it also takes into account a lot of correction factors, e.g. the time in which the alternator returns energy, in relation to the duration of the whole drive cycle.

The concept of testing balance presented in this paper eliminates the drawbacks of the method described in literature. The presented method is accurate and makes it possible to:

- prepare the accurate balance sheet,
- take into account changes in the current drawn by the battery,
- take into account and analyse transient states of receivers work,
- take into account additional receivers which are not the standard equipment of the car,
- take into account the actual power consumed by the receivers,
- control the charging process of the battery at any time; it can be determined how long it will take the alternator to charge the battery to its rated capacity.

The method of determining balance consists in mounting three ammeters and a tachometer in the car. The ammeters measure the following currents:

- ⌘ battery current
- ⌘ alternator current
- ⌘ current of the receivers



The essence of the method is based on the basic balance equation, which is determined by the following formula:

$$A_{alt} - A_{odb} - \frac{A_{ak}}{\eta_Q} = 0 \quad (1)$$

A_{alt} - energy returned by the alternator,

A_{odb} - energy consumed by the receivers,

A_{ak} - energy charging of the battery,

η_Q - battery charging efficiency.

Testing balance consists in registering, by means of ammeters, the three currents and the rotational speed at regular intervals.

On the basis of the obtained results, graphs of currents measured in time and the chart of alternator rotational speed (after taking ratio into consideration) can be drawn up. Then, the obtained results are multiplied by the mean value of the voltage in the system during the preparation of the balance sheet (approximately 13.5 V) according to the formula:

$$P(t) = U \cdot I(t) \quad (2)$$

and the graphs of power similar to the graphs of current are obtained. Then, the obtained graphs of power are integrated according to the following formula:

$$A(t) = \int_0^t N(t) dt \quad (3)$$

in time from $t = 0$ to the end of measurement duration, and what is obtained are the graphs of energy:

- ▲ consumed by the receivers.
- ▲ returned by the alternator,
- ▲ either returned or collected by the battery.

Analysing the charts the energy consumed by the receivers and returned by the alternator makes it possible to decide:

- ▲ whether the power consumed by the receivers will be fully covered directly by the alternator or partly by the battery,
- ▲ whether there are possibilities to install additional receivers in the car.

The analysis of energy collected or returned by the battery leads to some conclusions about the state of battery charge at any time of conducting the balance [4-6,12,13]. On the basis of the graph, it can be stated after how much time of the test duration the battery is charged to its rated capacity. On the grounds of the graph of the power returned or collected by the battery, the chart of energy stored in the battery can be drawn up.

The initial energy A_0 can be determined from the formula:

$$A_0 = I \cdot U_{sr} \cdot t = Q \cdot U_{sr} \quad (4)$$

A_0 - energy stored in the battery [Wh]

I - current discharge amperage [A]

U_{sr} - mean discharge voltage [V]

t - discharge time [h]

Q - battery capacity [Ah]

Energy stored in the battery as a percentage is calculated from the equation.

$$A\% = \frac{A_{Wh}}{A_{100\%}} 100\% \quad (5)$$

$A\%$ - energy expressed in [%]

A_{Wh} - energy expressed in [Wh]

$A_{100\%}$ - energy expressed in [Wh] equivalent to 100% .

On the basis of the drawn up current-speed characteristics of the alternator, the value of current which the alternator can provide at a given rotational speed can be determined for the tested vehicle. For complete energy balance while driving in different conditions, one should adopt coefficients of the simultaneous use of particular receivers, taking their power into consideration [8-11].

2. The description of the test bench and the course of measurements

The test was conducted on the test bench , equipped with the alternator type A115-34B, 45 Ah battery, air conditioning system (figure 1), ESP system (figure 2) and standard mounted current receivers. On the experimental bench, the ammeters and a voltmeter were mounted. The course of measurements consisted in recording the indications of three ammeters and a tachometer every 5 seconds, for a randomly selected drive cycle which lasted 1800s. This cycle was simulated for a particular rotational speed of the alternator. During the cycle, engine rotational speed was changed and different current receivers were switched on.



Figure 1. Air conditioning test bench.



Figure 2. ESP test bench.

3. Test results

On the basis of the recorded measurement results, it was possible to determine: current drawn from the battery (Fig. 3), current in the circuit of the receivers (Fig. 4) and the current flowing from the

alternator (Fig.5). On the basis of the recorded current values, it was possible to determine: energy received from the battery (Fig. 6), consumed by the receivers (Fig. 7) and the energy drawn from the alternator (Fig. 8). Figure 9 shows the external characteristics of the alternator A115-34B.

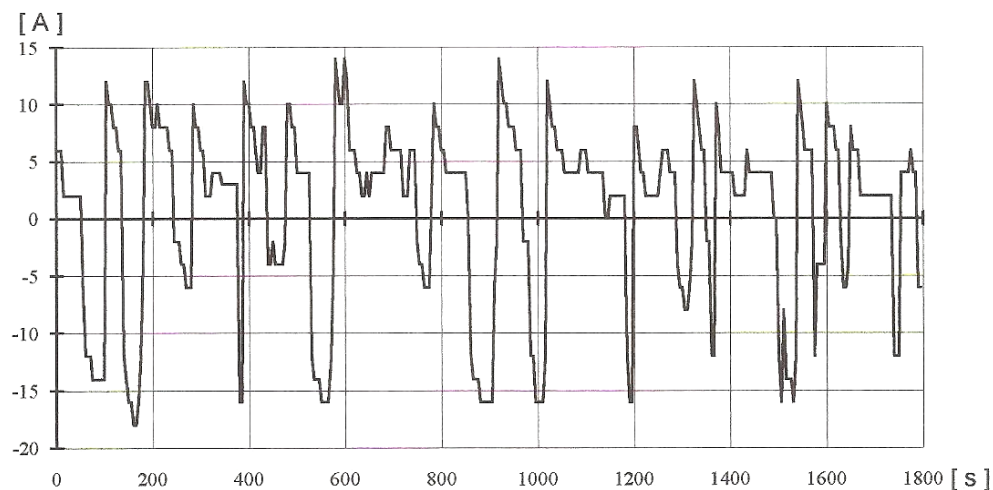


Figure 3. Current drawn from the battery.

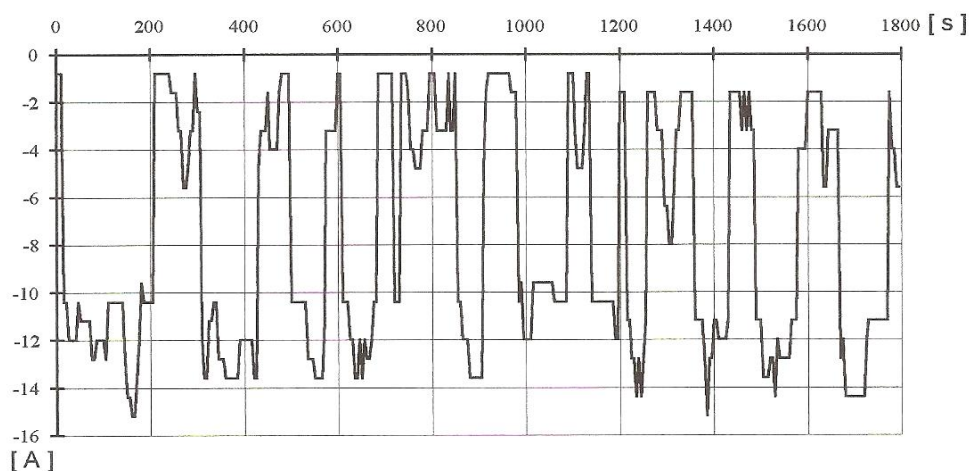


Figure 4. Current consumed by the receivers.

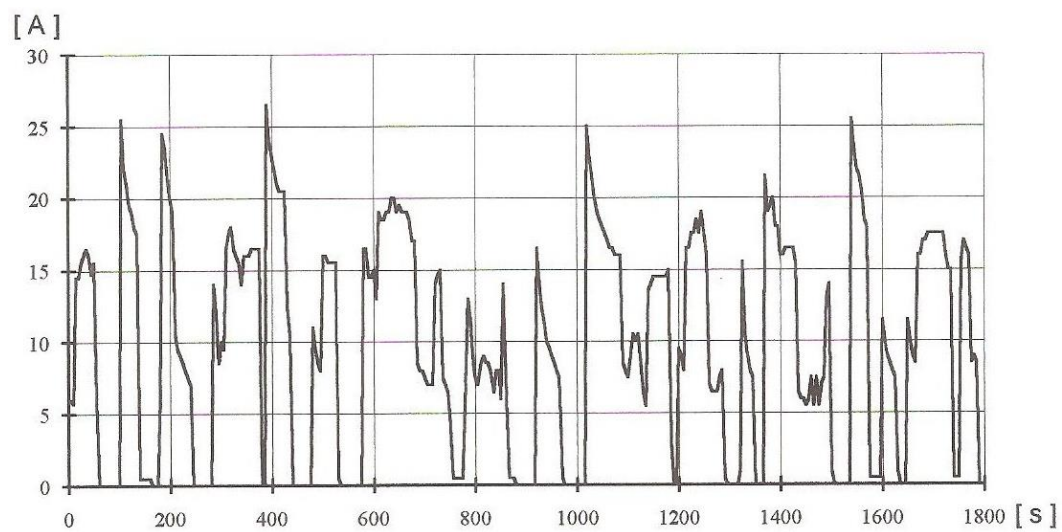


Figure 5. Current flowing from the alternator.

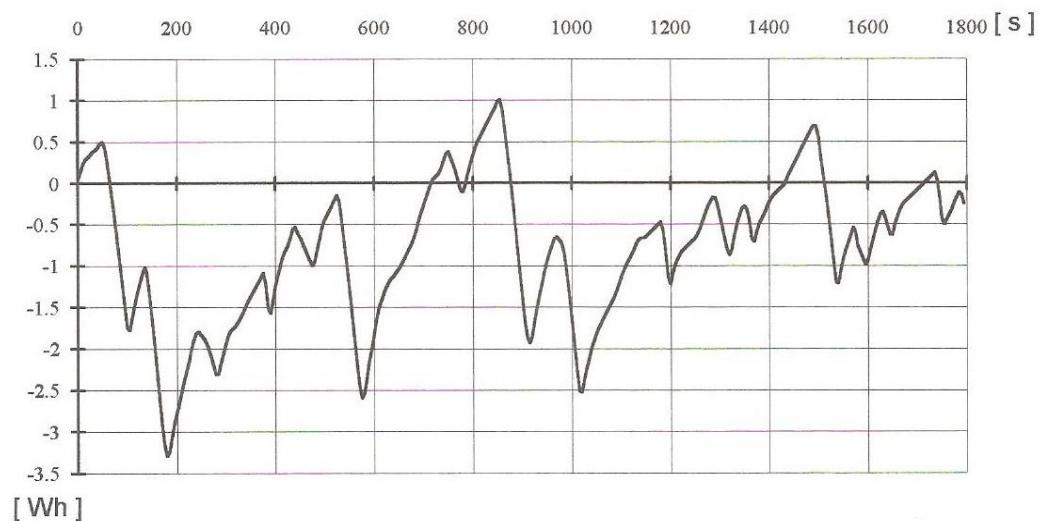


Figure 6. Energy delivered to the battery.

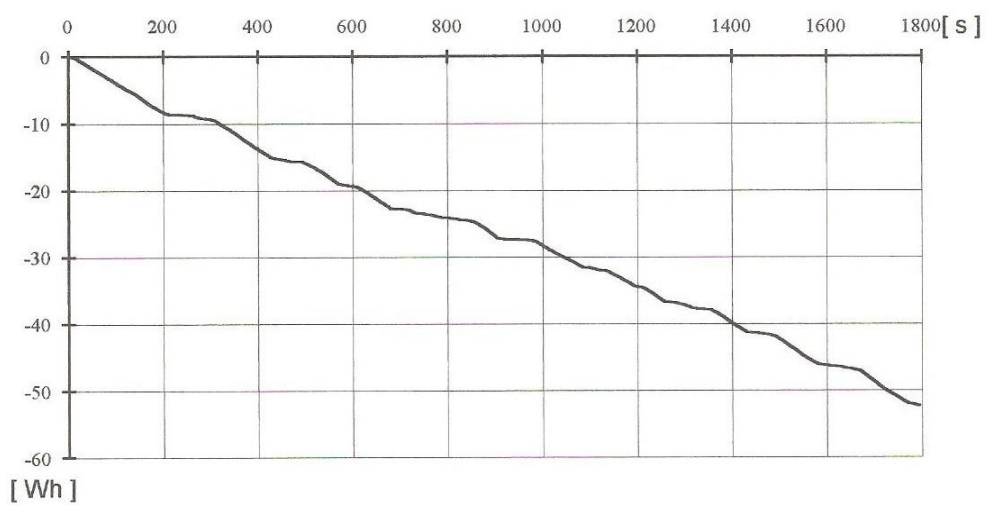


Figure 7. Energy consumed by the receivers.

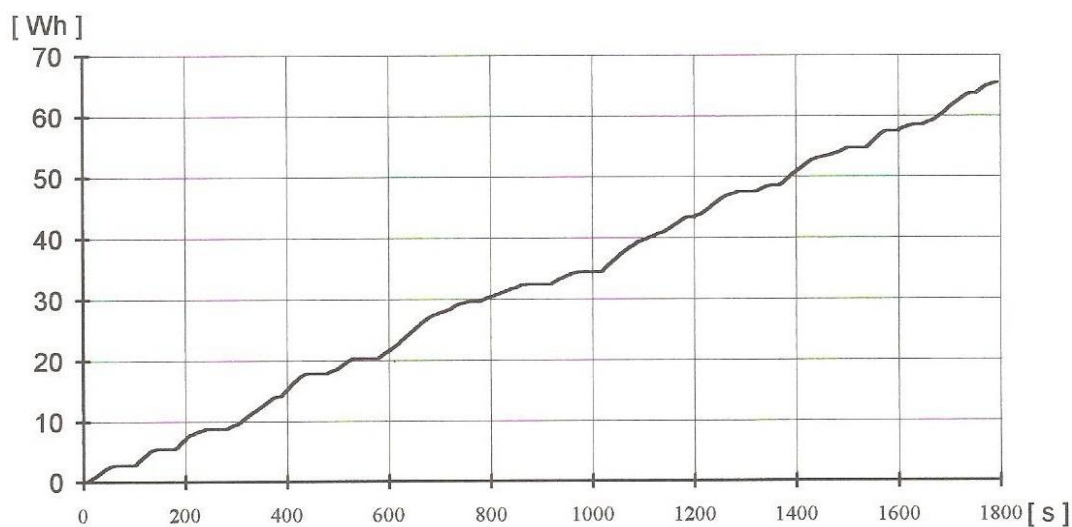


Figure 8. Energy returned by the alternator.

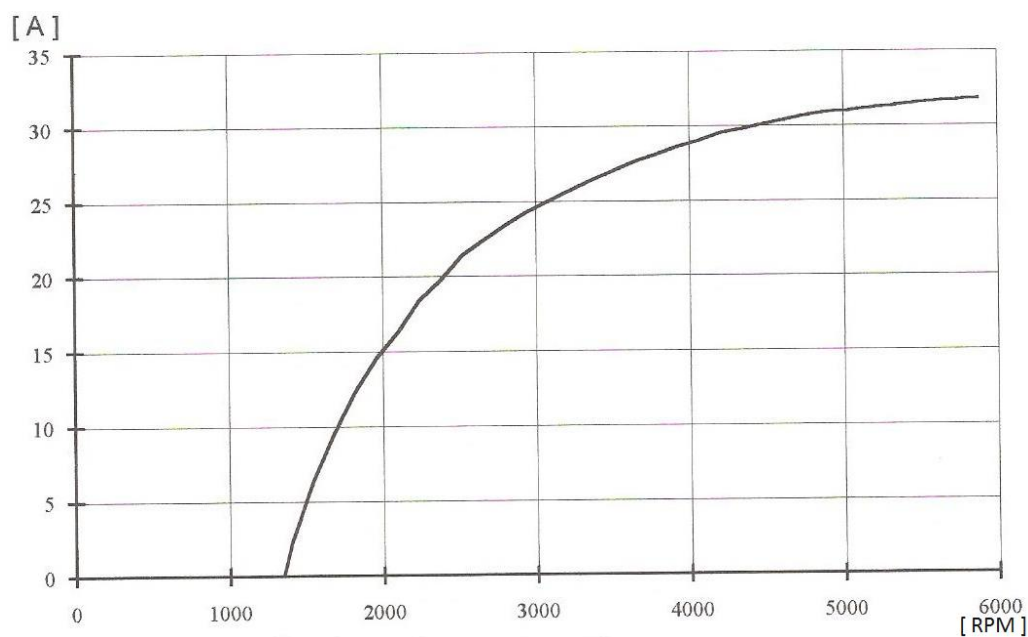


Figure 9. The characteristics of the alternator load.

Further in the study, the analysis of co-operation between the power supply system, the air-conditioning system (Fig. 10) and the ABS system (Fig. 13) was carried out. Measurements were conducted for four different air-conditioning fan speeds and variable rotational speed of the alternator. The measurement results have been shown in Fig. 11 and Fig.12.

Testing energy balance of the wiring system in co-operation with the ABS system was realized by changing the rotational speed of the alternator. The aim of the study was to determine the voltage value of the power supply system at which the ABS system works properly, and the voltage at which a failure will be recognized.

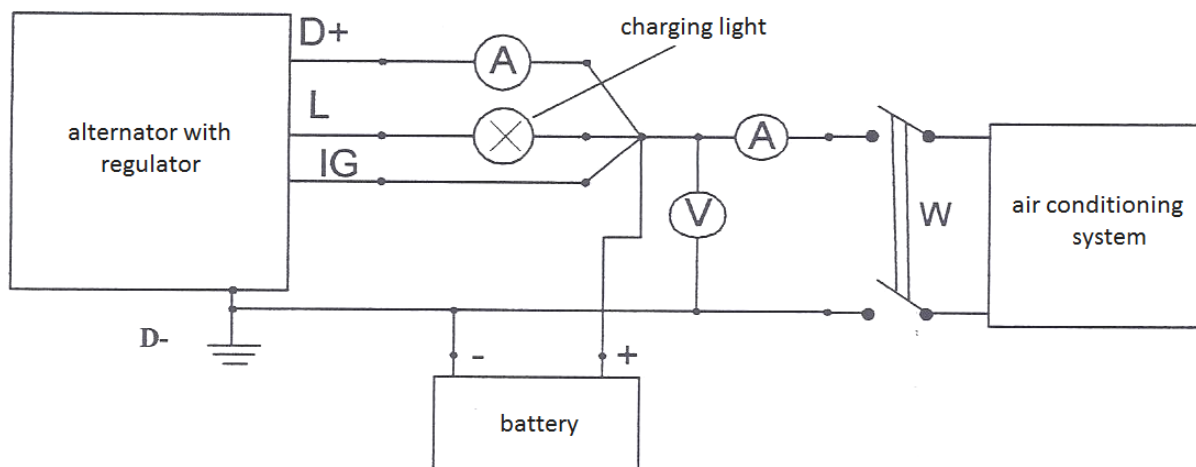


Figure 10. Scheme for examining the load imposed on the power supply system by air-conditioning.
 A - ammeter, V - voltmeter, W – switch.

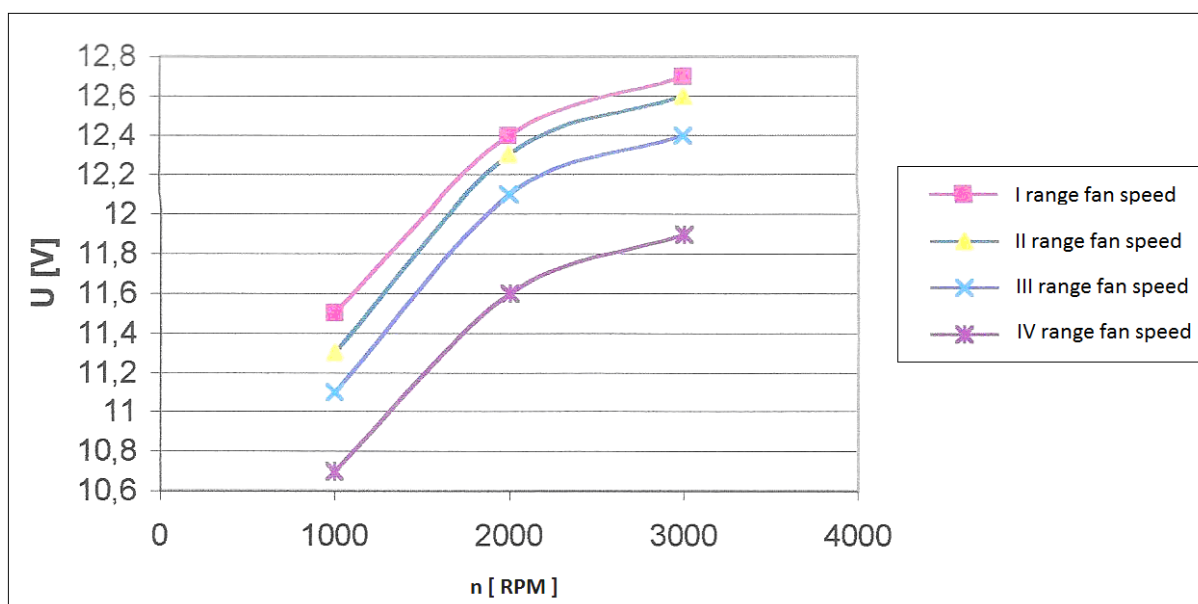


Figure 11. Voltage - speed characteristics of the alternator load.

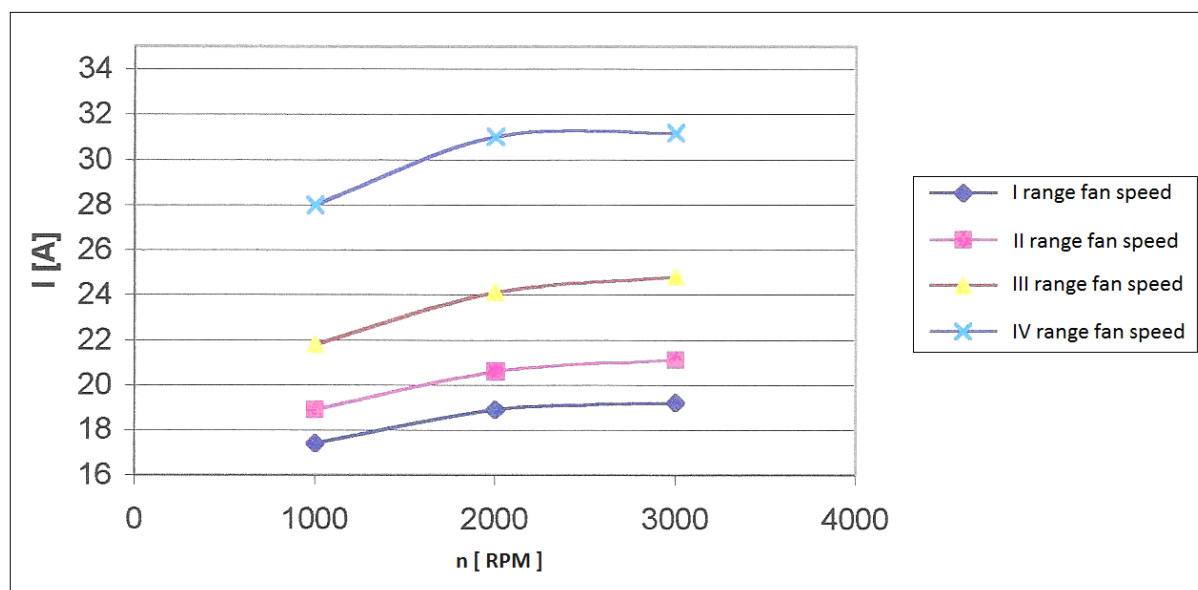


Figure 12. Current - speed characteristics of the alternator load.

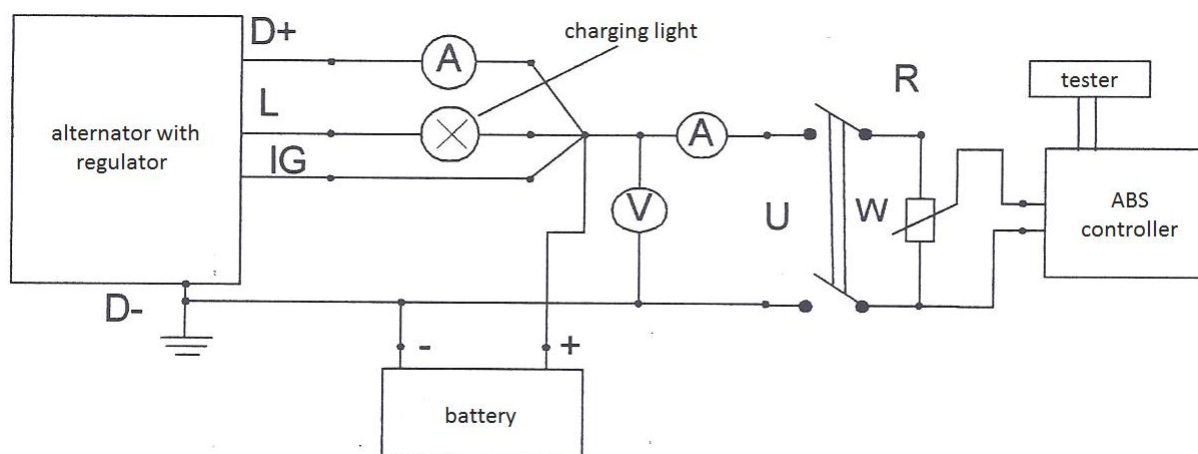


Figure 13. Diagram of supplying the system for testing the ABS controller
D-, D +, L, IG – alternator connectors, A - ammeter, V - voltmeter, R -resistor, W – switch.

4. Conclusions

The continuous improvement in safety and driving comfort led to the increase in the demand for alternator power. As a result of excessive load in the system, the supply voltage decreases, which leads to the malfunction of electronic devices and is indicated by control lights.

The measurement results of three characteristic currents: drawn from the alternator, consumed by the receivers and the current in the battery circuit are used in the method of drawing up energy balance of the car wiring. The balance method provides valuable information about the process of charging or discharging the battery. The indicator lamp indicated charging status in the supply system does not provide information about the distribution of currents in the battery circuit.

The carried out tests of power balance, in which the alternator and air-conditioning co-operated, confirmed the increase in values of current drawn from the alternator and voltage decrease in the wiring system for particular ranges of fan rotational speeds.

As the supply system and the ABS system cooperated, signalling a failure in the ABS circuit by lighting the ABS warning lamp in the case of voltage decrease was confirmed.

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