Aspects Regarding Operation of Power Supply System of Cars

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Abstract **– In this paper there are presented a few aspects regarding the operation of the direct current power supply system of cars. The operation of the electronic voltage controller is specially approached. Theoretical aspects of the problem are presented. In the second part of the paper there are presented a series of experimental determinations carried out on a modern stand. The results have been confirmed by measurements with a car. In order to analyze the rectifier defects there have been viewed the output voltage waveforms for five situations of defect of the diodes. In order to analyze the voltage control, there have been obtained the waveforms of the excitation current for three particular situations. In the last part of the paper there are presented the conclusions obtained following the researches. It is emphasized that: damaging one or more diodes of the rectifier can be identified by viewing, by means of an oscilloscope, the waveform of the output voltage of the alternator; when one of all the diodes is functional, the waveform is symmetrical, waved and with small variations; for the same number of damaged diodes, the distortion degree of the voltage also depends on their position in the rectifying bridge (e. g. the distortion is higher when two positive diodes are damaged than in case when a positive diode and a negative one are damaged); an existing fault situation can be identified by viewing the output voltage of the alternator.**

Cuvinte cheie: *regulator automat de tensiune, generator sincron, redresor, alternator, autovehicule.*

Keywords: *automatic voltage controller, synchronous generator, rectifier, alternator, cars.*

I. INTRODUCTION

Along the time, three types of power supply systems have been used for cars:

-direct current systems;

-alternating current systems;

-combined system.

Among them, the most used system is the direct current one.

The essential advantage of this system consists in the fact that it allows accumulating energy, with the help of the accumulator battery.

For this reason, the car users can get electrical energy even when the heat engine does not operate.

The system contains, as a primary energy source, a generator.

Direct current generators were initially used.

From reasons related to commutator (sparks, low reliability, necessity to maintain it periodically etc.) this variant was quit.

Thus, nowadays synchronous generators of special construction are used [1], [2], their alternating voltage being rectified by means of some uncontrolled rectifiers.

At modifying the load of the power supply system or the drive speed of the generator, the voltage provided by the generator modifies, too.

In order to keep constant this voltage, an automatic voltage controller has become compulsory.

This controller oversees the output voltage.

If the voltage tends to decrease, the excitation current is commanded to increase.

Otherwise the excitation current of the generator is decreased.

II. ELECTRONIC VOLTAGE CONTROLLER

The issue regarding electronic voltage controllers is very common in scientific manifestations [3], [4], [5].

Problems regarding both modelling and simulation and experimental verifications are developed.

The block scheme of automatic voltage controllers is depicted in the following figure.

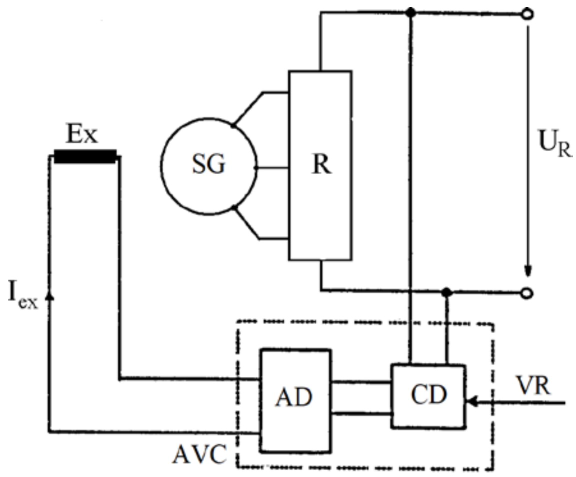


Fig. 1. Block scheme of automatic voltage controllers [6].

The notations used have the following meaning:

AVC – automatic voltage controller;

SG – synchronous generator;

R – rectifier;

CD – comparison device;

AD – adjusting device;

U_R – voltage provided by the alternator;

VR – voltage reference.

The automatic voltage controller compares, by means of the measuring device, the reference quantity to the generator voltage.

When a variation of the voltage U_R occurs in comparison with the reference quantity the measuring device transmits a command to the adjustment device, which will modify the relative conduction time, by increasing or decreasing it, until the difference between the reference quantity and the voltage U_R disappears.

Thus, if a constant value of the reference quantity is kept constant, the voltage U_R is automatically kept constant.

The higher the adjustment frequency is, the higher the adjustment quality is and the lower the pulsations of the excitation current are.

These controllers are lately of electronic type.

Electronic controllers have the following advantages:

a) they admit higher currents, so they can be used in higher power generators;

b) they do not have mechanical attrition and the electrical attrition is very low. Consequently, they have a longer lifespan and no need of maintenance;

c) they have a higher precision, better constant and repeatability;

d) they ensure an operation frequency with an order of magnitude higher (round 5kHz), improving the form factor of the voltage controlled (so a smoother voltage) and the adjustment precision. Consequently they are single-step built.

e) they have a smaller volume but can ensure several functions (for example, beside adjusting voltage, also ensure signals of faults, auto-test etc.);

f) having a small volume, they can be assembled even inside the generator; this way, connection conductors, possible wrong connections, wiring faults being removed;

g) they have a compensation characteristic with optimum temperature and are less sensitive to aggressive environmental factors (gases, humidity, vibrations etc.);

h) they have a good reliability and no need of adjustments;

i) cost price comparable in this moment, but the evolution tendency is towards electronic voltage controllers.

A disadvantage of electronic voltage controllers can also be admitted, a relative one, namely a higher sensitivity to exceeding maximum admitted values.

In Fig. 2 there is depicted the principle scheme of an automatic voltage controller which allows adjusting the excitation current i_{ex} [6].

In this situation, the excitation current is modified in steps, by impulses.

The excitation winding of the generator having the resistance R_{ex} and the inductance L_{ex}, is supplied with the voltage U_R according to the previous scheme by means of two switches k_1 and k_2.

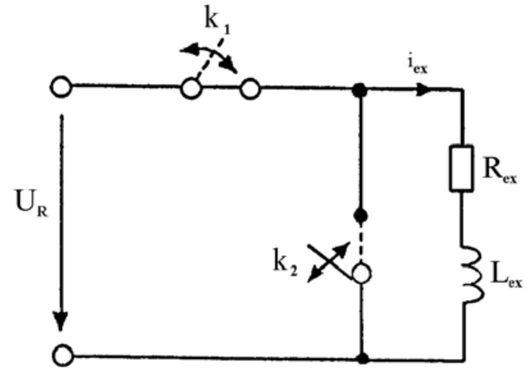


Fig. 2. Principle scheme of an automatic electronic voltage controller.

The current variation in the excitation winding is depicted in Fig. 3 [6].

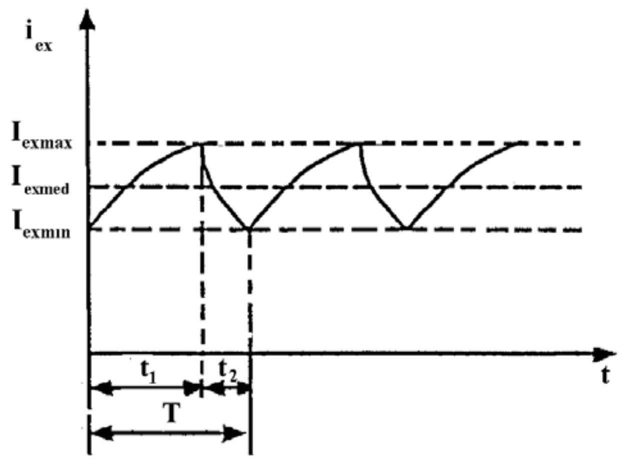


Fig. 3. Excitation current variation.

It is assumed that the generator excitation winding which has the resistance R_{ex} and inductance L_{ex}, is supplied with a voltage U_R as in Fig. 2, by means of the switches k_1 and k_2.

These switches are made with thyristors.

The following notations are introduced:

$T = \frac{1}{f}$ - period corresponding to closing and opening switches;

t_1 - time when k_1 is closed and k_2 is open;

t_2 - time when k_2 is closed and k_1 open;

Times t_1 and t_2 can be changed by commanding the two thyristors.

For $t \in [0, t_1]$ we can write:

$$U_R = i_{ex} R_{ex} + L_{ex} \frac{di_{ex}}{dt} \quad (1)$$

With these relation the average value of the excitation current and the current pulsations to this value can be established [4]:

$$I_{exmed} = \frac{U_R \cdot \gamma}{R_{ex}} \quad (2)$$

$$\gamma = \frac{t_1}{T} \quad (3)$$

From the relation which establishes I_{exmed} we can notice that the excitation current value can be modified adequately by modifying γ.

The factor γ may change as shown in Fig. 4.

The excitation voltage is shown in this figure.

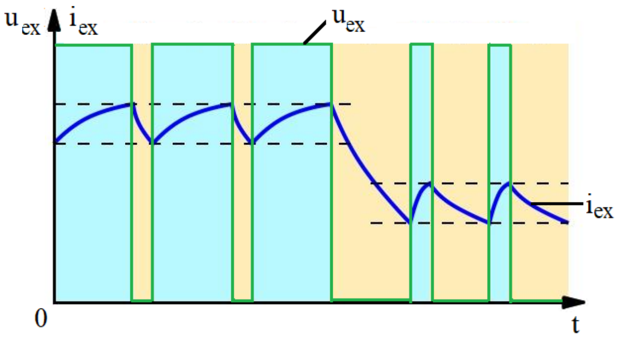


Fig. 4. Excitation voltage variation.

This voltage u_{ex} was determined experimentally in this paper.

III. TEST STAND

In order to carry out the tests of this paper, the stand depicted in Figs. 5 and 6 has been used [7].

The stand is made with real elements of cars which are nowadays in production.

This stand allows the study of electric and electronic equipments which are parts of the power supply system.

The tests have been then validated with a car Ford B-Max (Fig. 7).

The data acquisition has been carried out with the help of a monitoring system (Fig. 8) made with a data acquisition board (sampling frequency of 100 kHz, maximum 16 outputs) [9].

This system also includes a colour oscilloscope with possibilities of harmonic analysis of the viewed signal and a three-phase harmonic analyzer.

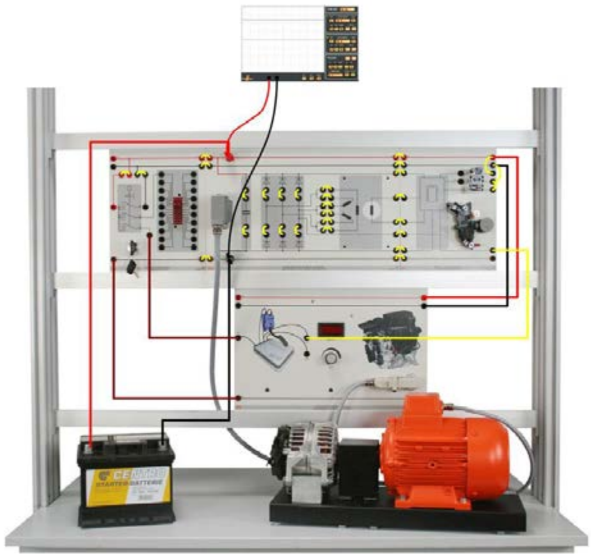


Fig. 5. Assembly for the rectifier study [8].

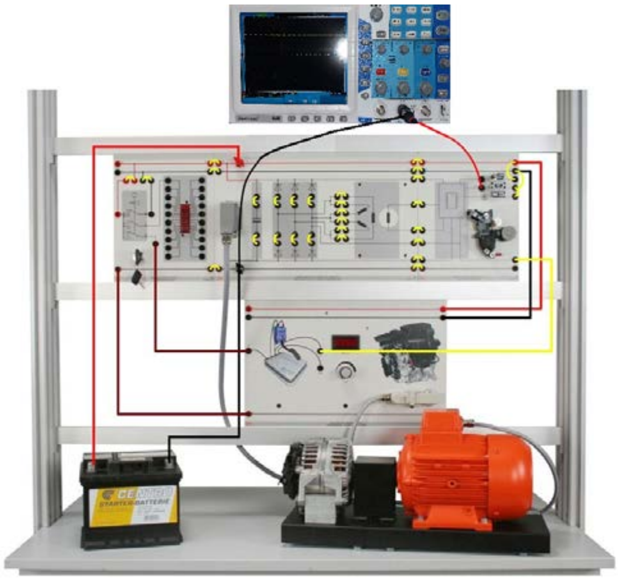


Fig. 6. Assembly for studying excitation voltage.


Fig. 7. Ford B-MAX.

Fig. 8. Data acquisition system [10].

IV. Experimental Results

There have been carried out a series of experimental tests which aimed at:

-obtaining some possibilities of diagnosing the rectifier faults;

-emphasizing the operation of an electronic speed controller in function of the drive speed of the alternator.

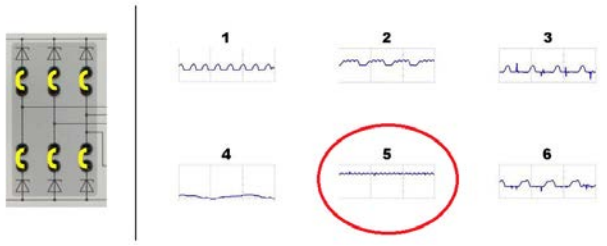
For the first case the tests have been carried out with the stand depicted in Fig. 5, the results being then verified with the car depicted in Fig. 7.

The second case has been analyzed with the help of the acquisition system (mobile variant with colour oscilloscope), presented in Fig. 8, with the same car.

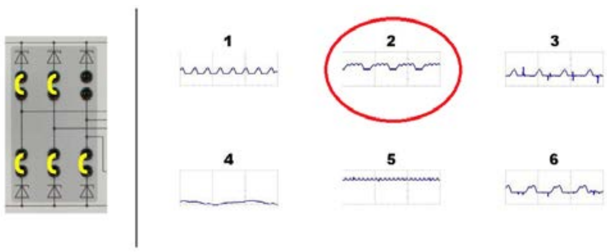
In order to study the rectifier, there have been simulated several fault situations (indicated in Fig. 9).

The tests have been carried out for the case of driving the alternator with a speed of 1300 r.p.m.

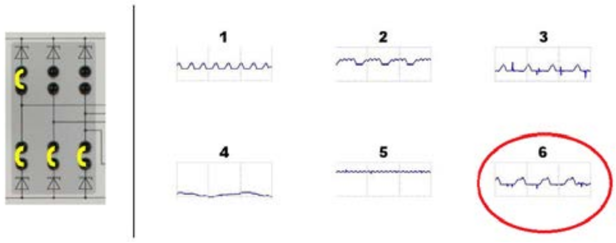
The voltage waveforms have been viewed with the help of an oscilloscope.



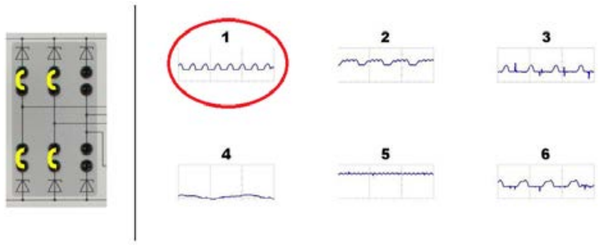
a)



b)



c)



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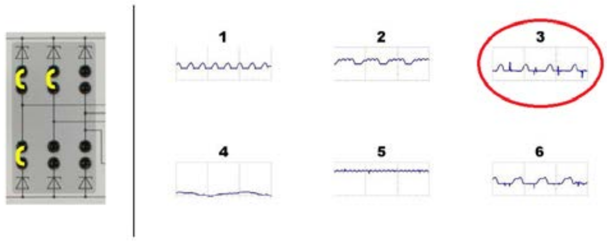


e)

Fig. 9. Simulation of some fault situations of the rectifier diodes.

From the analysis of this figure we get the following conclusions:

-damaging one or more diodes of the rectifier can be identified by viewing, by means of an oscilloscope, the waveform of the output voltage of the alternator;

-when one of all the diodes is functional, the waveform is symmetrical, waved and with small variations;

-when one, two or three diodes are damaged, the voltage waveforms are not symmetrical;

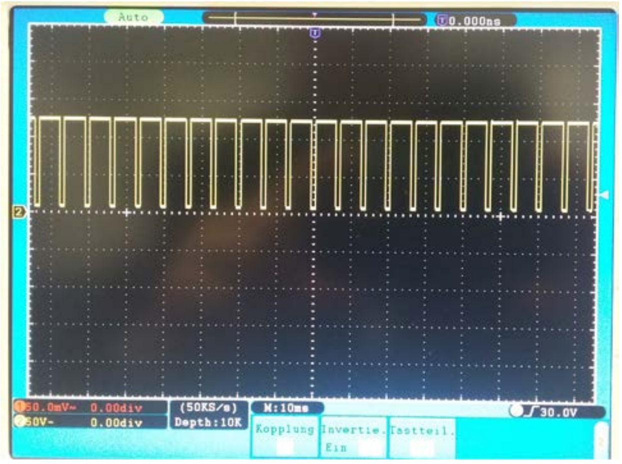
-the more diodes are damaged, the more unsymmetrical the voltage waveform is;

-for the same number of damaged diodes, the distortion degree of the voltage also depends on their position in the rectifying bridge (e. g. the distortion is higher when two positive diodes are damaged than in case when a positive diode and a negative one are damaged);

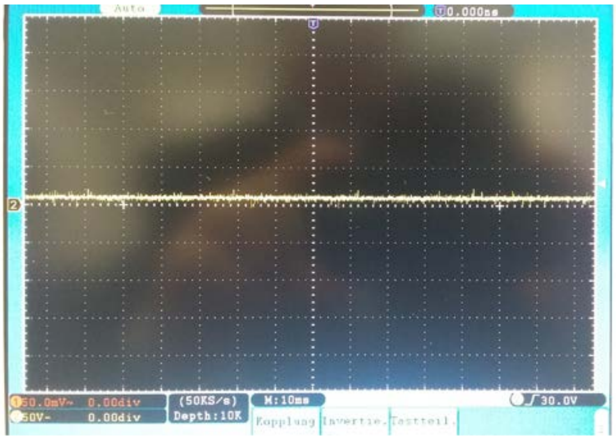
-an existing fault situation can be identified by viewing the output voltage of the alternator.

In order to analyze the voltage control, there have been carried out the experimental tests from Fig. 10.

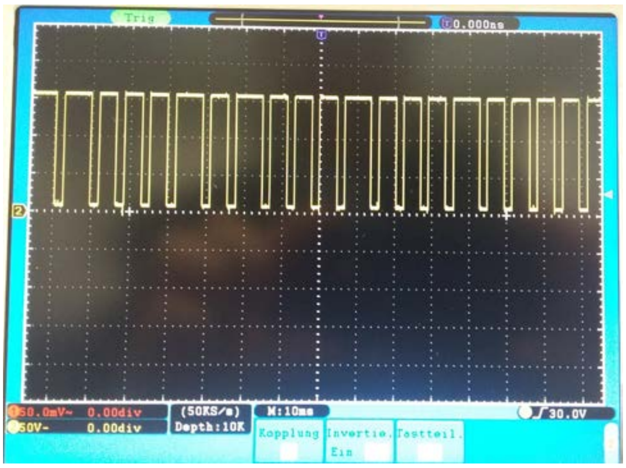
There have been acquired the waveforms of the excitation voltage for three particular values of the drive speed.



a) in resting state



b) 1250 r.p.m.



c) 3000 r.p.m.

Fig. 10. Oscillograms of the excitation voltage u_{ex} for different values of the speed.

The conclusions of the analysis of this figure are detailed below.

V. Conclusions

In this paper there have been made researches which have aimed at two objectives:

-obtaining some possibilities of diagnosing the rectifier faults;

-emphasizing the operation of an electronic speed controller in function of the drive speed of the generator.

As regards the first objective, the following conclusions have been obtained (Fig. 9):

-damaging one or more diodes of the rectifier can be identified by viewing, by means of an oscilloscope, the waveform of the output voltage of the alternator;

-when one of all the diodes is functional, the waveform is symmetrical, waved and with small variations;

-when one, two or three diodes are damaged, the voltage waveforms are not symmetrical;

-the more diodes are damaged, the more unsymmetrical the voltage waveform is;

-for the same number of damaged diodes, the distortion degree of the voltage also depends on their position in the rectifying bridge (e. g. the distortion is higher when two positive diodes are damaged than in case when a positive diode and a negative one are damaged);

-an existing fault situation can be identified by viewing the output voltage of the alternator.

In the future, a model will be built to take into account the fault conditions of the rectifier.

As regards the second objective (voltage control) the following conclusions have resulted (Fig. 10):

-at rest: the controller provides the complete excitation voltage for ensuring a sufficient level of charging of the battery in resting state;

-at 1250 r.p.m.: in this case, because the voltage is too high, the excitation is supplied intermittently in order to avoid a too high voltage of the generator;

-at 3000 r.p.m.: the modelling process limits the excitation curent when the speed increases.

For the future we aim at concentrating in a printed material all the data we have obtained, regarding the ways of diagnosing the faults of cars (few of them have been presented in this paper).

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Second coauthor – 20 %;
Third coauthor – 20 %.

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