The Load Influence on the Diagnosis of the Three-Phase Rectifier by Using the Analytical Model Method

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Abstract— **For the operation of the static power converters, the experience of an expert is absolutely necessary for competitive operation. Minor faults or defects of the elements of the static power converters can lead to ravaging effects both for the other components as well as other equipment from their operating system. The paper proposes a diagnosis method based on the analytic model which investigates the output waveforms of a three-phase rectifier supplying two types of loads: a passive RLC load and a variable DC drive. Two types of possible faults of the switches are considered: interrupted and short circuit. For identifying the defective components, the waveforms corresponding for different faults are stored in an information database in order to be compared with the ones corresponding to normal operation.. Another solved problem in this article refers to the influence's analysis of the defect propagation in the driving system. There are analyzed the waveforms corresponding of the different faults for different types of loads including a passive RLC load and a variable DC drive. For the both types of faults, important oscillations of the output voltage of the static power converter are noticed which can damage the load, but also, determine the additional stress to other healthy switches.**

I. Introduction

In industrial applications area, new techniques and methodologies lead to the development of the diagnosis systems. Because of the decreasing of the IT costs, during the last period, the monitoring and diagnosis systems became more frequently, with large applicability in areas as systems engineering, architecture, financial system, education etc.

Concerning the artificial intelligence, two directions can be mentioned: the first one in the field of expert systems, for diagnosis matters, robots command, intelligent use of the databases, development of intelligent programming media and the second one in the field of shape recognition, understanding and voice synthesis, image processing, knowledge representation and natural language learning.

The diagnosis of the systems can be defined as the assembly of the scientific exact and heuristic methods for investigating, diagnosis, modeling and design, applied for improving the quality of the decisions which determines the efficient control of a system. This aim is possible only if several stages, which determine the life cycle of the system, are fulfilled (Fig. 1).

The methods of faults detection and diagnosis can be classified: methods based on signals, methods based on knowledge and methods based on analytic models.

The methods based on signals select the signals which contain information and data specific to the fault operation from the multitude of the signals measured from the process. By analyzing the selected signals, the possible symptoms of the faults are defined, the faults are located, the moment of occurrence and possible causes are identified also [1].

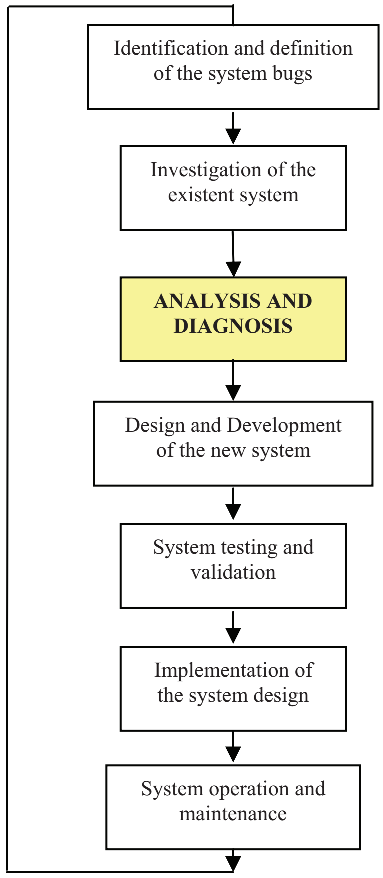

Fig. 1. The complete life cycle of a system.

The methods based on knowledge are used when the complex systems must be diagnosed. In these cases, the knowledge about process can be often insufficiently. The behavior of the system is quantitatively described by using knowledge about system which is grouped in rules and facts, as results of human empirical observations. For the complex systems, the qualitative models can be used for defining the relationship cause-fault-symptom by using the fault tree concept [3].

The methods based on analytic models consist in comparing the system behavior with the results of the mathematical model which reproduce the system in normal operation. If the analytic model is available, this method proves to be more efficient than the methods based on signals [2].

The evolution of the CAD methods has recently brought the diagnosis systems which contain artificial intelligence modules.

The static power converters are essential equipment for adapting the type and parameters of the electric energy, being placed between the power sources and loads. In designing of the static power converters, the experience of an expert is absolutely necessary in order to obtain a competitive solution. During the operation of the static power converters, the experience of an expert is also absolutely necessary for competitive operation. Minor faults or defects of this equipment can lead to ravaging effects [3]. The effects can be propagated in the power system if the protection system does not properly operate.

For achieving the diagnosis, the system model must be developed in order to analyze the fault propagation in different monitoring locations.

II. The Simulink Model of the Rectifier with Passive RLC Load

By using Simulink of Matlab® the model of a phase controlled three phase rectifier has been developed (Fig. 2) [4].

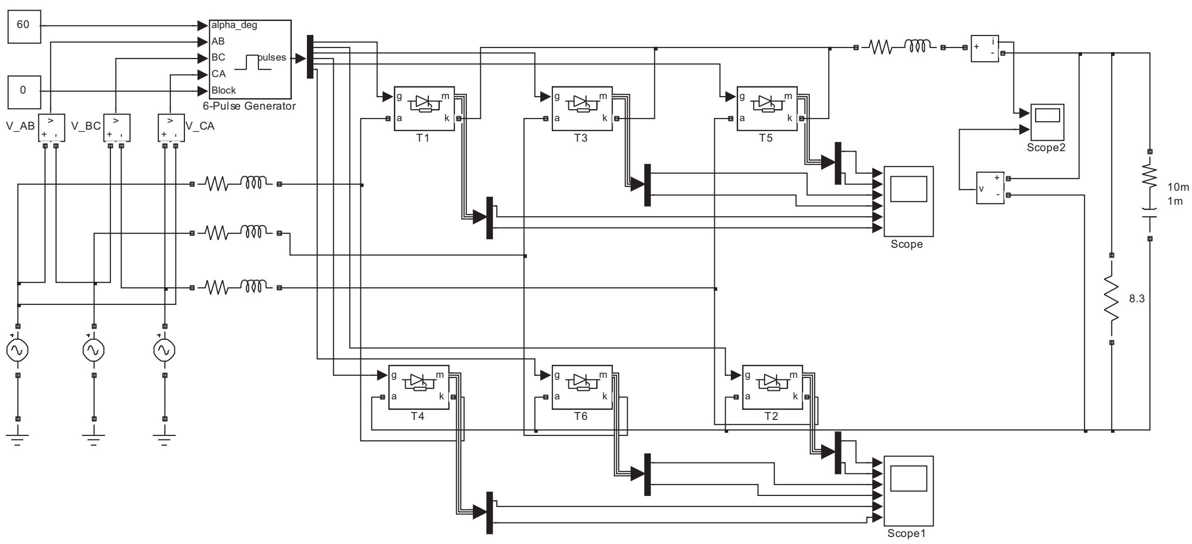

Fig. 2.The Simulink model of the phase controlled three phase rectifier.

The proposed diagnosis system based on the analytic model investigates the output waveforms of a rectifier for two types of possible faults of the switches: interrupted and short circuit.

For the beginning, the fault consisting in interruption of one device, for eg. T_4, is analyzed and the consequences of this fault on the other switches and on the rectifier operation are investigated.

By using the model from Fig. 2, in Fig. 3 are plotted the waveforms of the devices currents corresponding to the leg in fault (T_1 and T_4). The Fig. 3 plots the waveforms for normal operation in the interval (0-0.1s) and when the T_4 is interrupted at the instant 0.1 s. An increasing of the current in the health switch (T_1) is noticed.

Comparing with Fig. 3, which corresponds to the normal operation, after the fault occurrence (starting with the time 0.1s), the waveforms change significantly for the both switches. On one side the current in T_4 changes the waveform and on the other side, T_1 seems that doesn't conduct anymore. This is happens because of the fact that the firing pulses find T_1 reverse polarized due to the changes of the voltage applied. Practically, all the time, the switch T_1 stays reverse polarized.

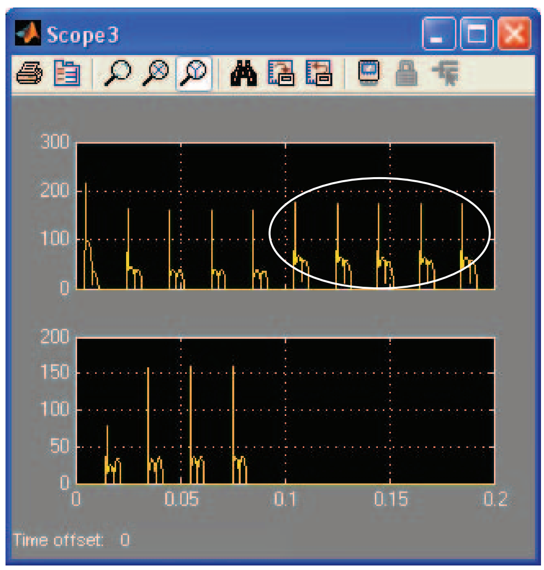

Fig. 3. The currents flowing in T_1 and T_4.

The Fig. 4 plots the output current and voltage waveforms: for normal operation in the interval (0-0.1s) and for fault operation (T_4 interrupted at 0.1s). Important oscillations occur, both in current and in voltage.

Following, the short circuit of the T_4 switch and its consequences on the other switches and on the rectifier will be analyzed.

The Fig. 5 plots the currents waveforms of the devices corresponding to the leg in fault (T_1 and T_4) when the T_4 is short circuited at the instant 0.1 s.

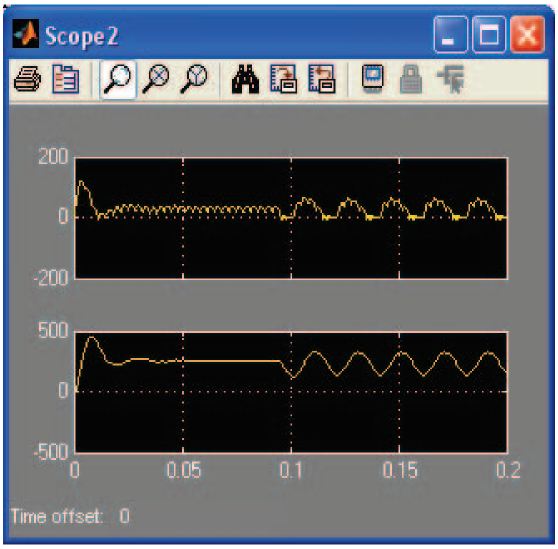

Fig. 4. Output current and voltage.

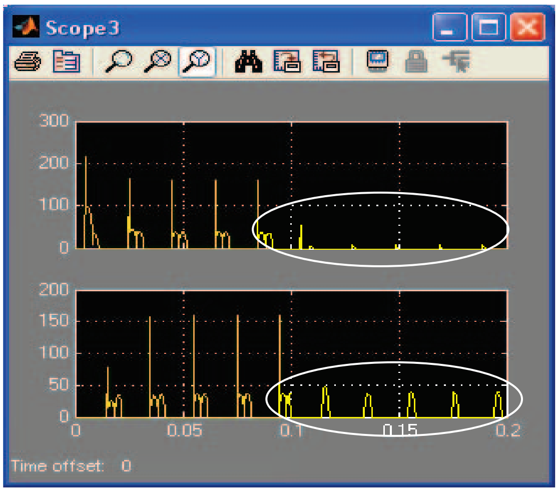

Fig. 5. Currents flowing in T_1 and T_4, with T_4 in short circuit.

The Fig. 6 plots the voltages and currents which flow in the switches on the same side of the bridge with the switch in fault (T_4, T_2 and T_6 respectively): for normal operation, in the interval (0-0.1s) and for fault operation (T_4 in short circuit at 0.1s).

A significant increasing of the current through the healthy switches (T_2, T_6) is noticed after the fault occurrence (T_4 in short circuit).

The Fig. 7 plots the voltages and currents which flow in the switches on the healthy side of the rectifier (T_5, T_3 and T_1 respectively). After the fault occurrence, the current through T_3 increases significantly.

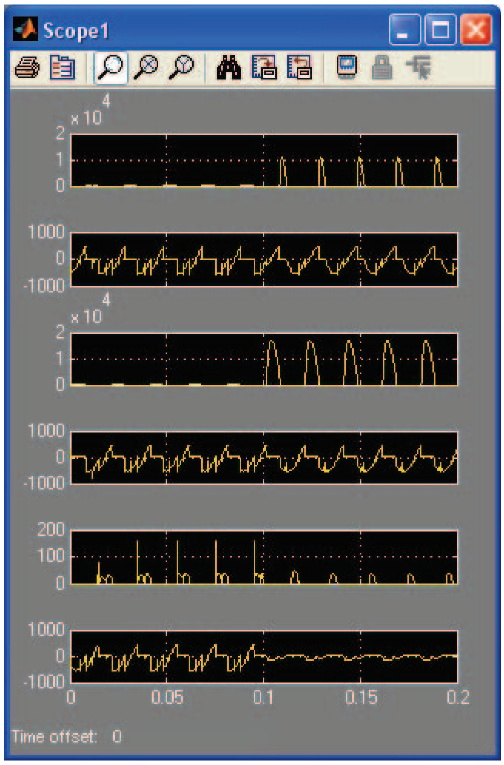

Fig. 6. Currents and voltages corresponding to T_2, T_6 and T_4 respectively.

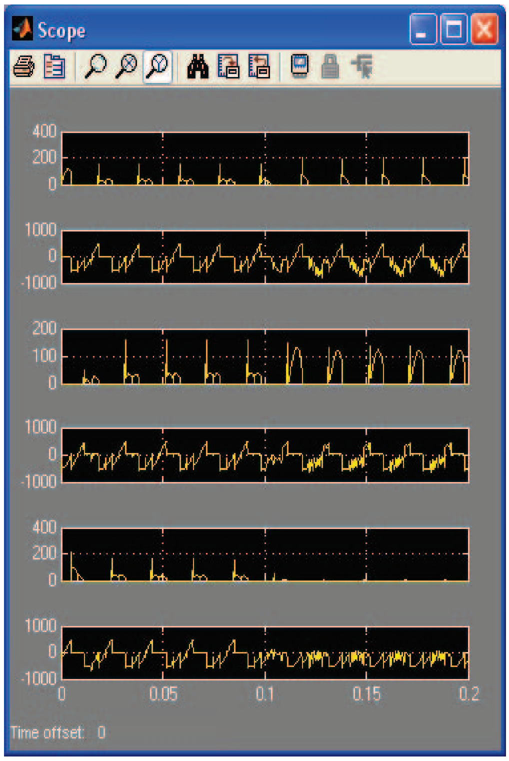

Fig. 7. Currents and voltages corresponding to T_5, T_3 and T_1 respectively

For this fault (T_4 shorted), Fig. 8 plots the output current and voltage after the fault occurrence. Important oscillations of the output voltage occur, which are dangerous for the load.

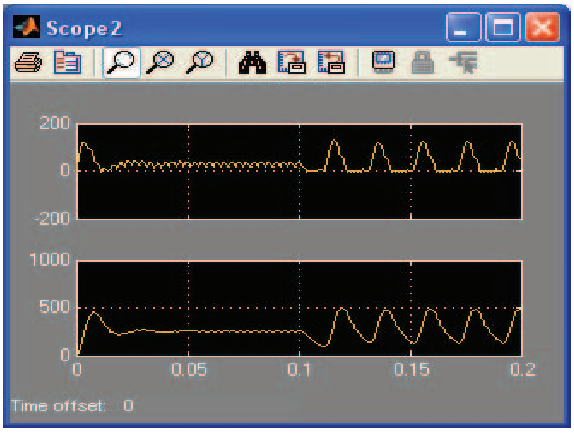

Fig. 8. Output current and voltage with T_4 shorted (0.1s).

III. The Simulink Model of a Rectifier Supplying a Variable DC Drive

The analyzed system consists of a three-phase rectifier supplying a variable DC drive.

The process of diagnosis process starts with the observation of the behavior in normal operation and continues with the analysis of the equipment behavior in faults conditions [8].

By using Simulink of Matlab® the model of a three-phase rectifier supplying a variable DC drive has been developed (Fig. 9) [4], [5]. The discrete components were used in order to simulate individual faults.

The proposed diagnosis method based on the analytic model investigates the output waveforms of a rectifier and the influence on DC machine operation for two types of possible faults of the switches: interrupted and short circuit [6], [7].

For the beginning, the fault consisting in interruption of a device, for instance T_4 and the consequences of this fault on the rectifier operation and on the DC machine operation, are also analyzed.

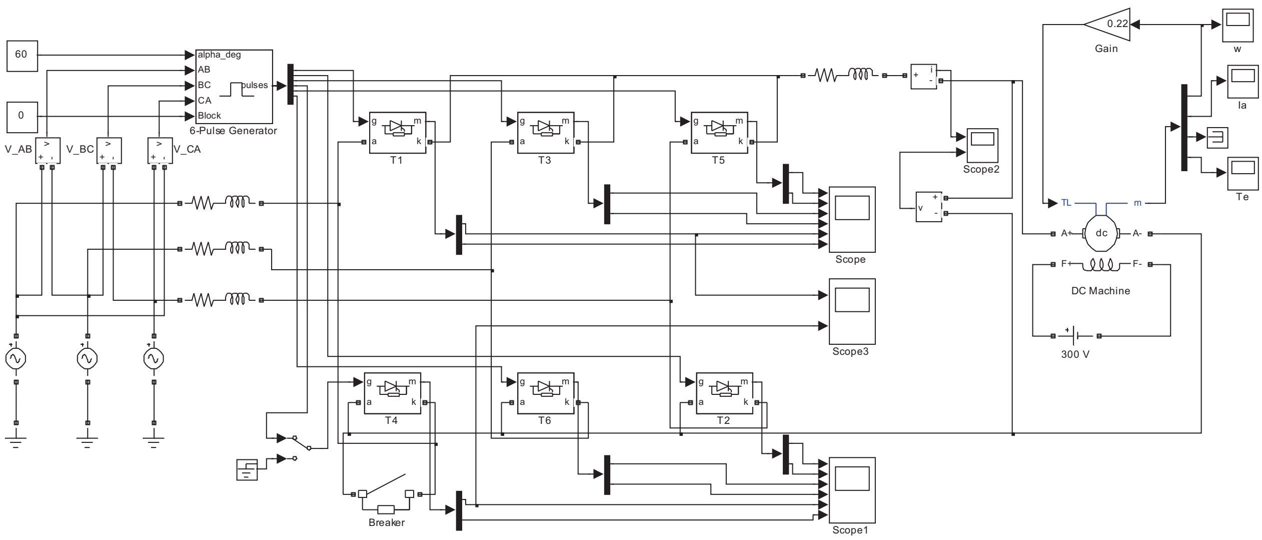

Fig. 9. The Simulink model of a three-phase rectifier supplying a variable DC drive.

IV. Simulation Results

By using the Simulink model in the Fig. 9, the evolution of the rectifier outputs can be plotted for the (0-6) s interval.

In the Fig. 10, the output current and voltage waveforms are plotted: T_4 is interrupted during the interval (2-4) s, otherwise, the normal operation is considered.

As can be seen, important oscillations occur, both in current and in voltage.

In the Fig. 11, the speed waveform for the considered fault, means the device T_4, is interrupted during the time interval (2-4) s, is plotted.

From Fig. 11, a severe fall of the speed is noticed near stop, and also the important ripple can be seen.

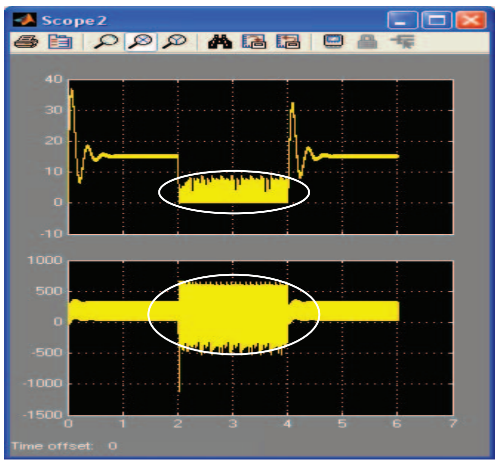

Fig. 10. Output current and voltage, with T_4 interrupted (2-4) s.

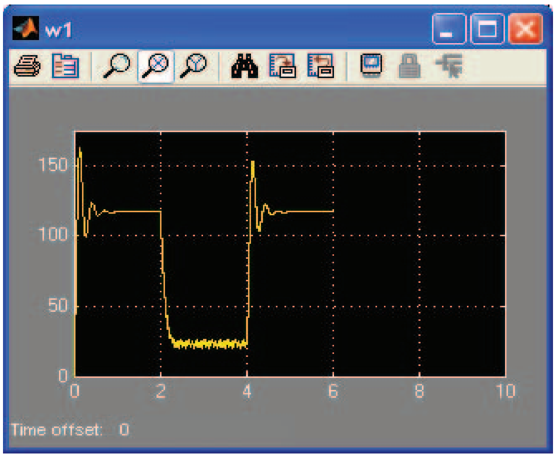

Fig. 11. DC motor speed with T_4 interrupted (2-4) s.

This symptom is caused by the severe reduction of the average armature current (Fig. 12) and by the increasing of its ripple.

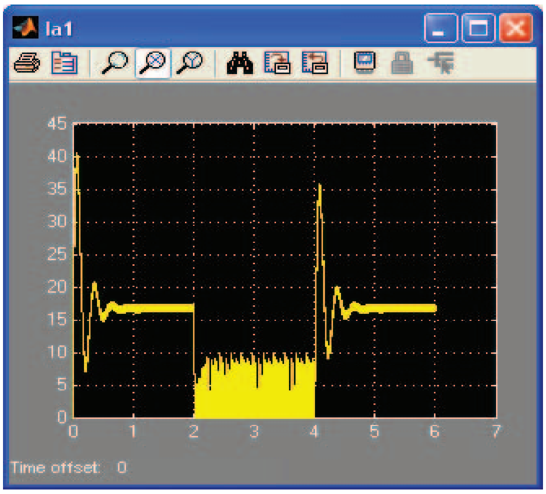

Fig. 12. DC motor armature current with T4 interrupted (2-4) s.

Following, the short circuit of the T_4 switch and its consequences on the rectifier and on the DC motor will be analyzed.

The output current and voltage of rectifier waveforms with T_4 in short circuit during the interval (2-4) s are shown in the Fig. 13.

As can be noticed from this figure the significant oscillations of the output voltage occur, dangerous for the DC motor.

The Fig. 14 shows how this fault (T_4 in short circuit) influences the motor speed. This parameter slightly decreases, but the oscillations occur, due to the significant ripple of the armature current (Fig. 15).

During this fault (T_4 in short circuit), a significant increasing of the current flowing in the health switches on the same side (T_2, T_6) is noticed (Fig.16).

It is interesting to note that the short circuit of a device of the rectifier determines less severe effects on the system drive behavior than the interruption of a switch.

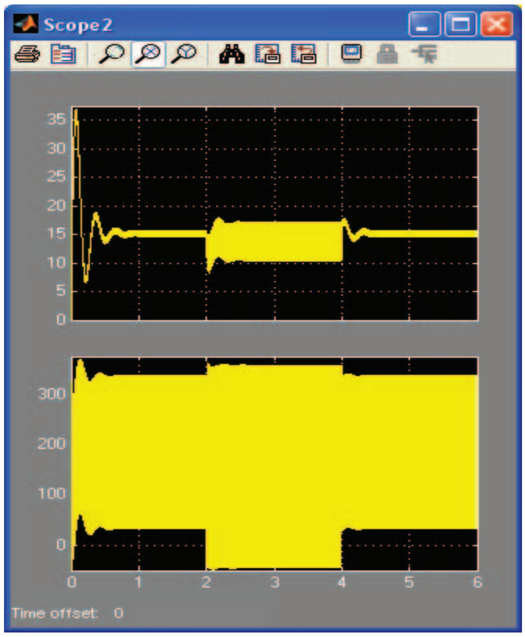

Fig. 13. Output current and voltage with T_4 in short circuit (2-4) s.

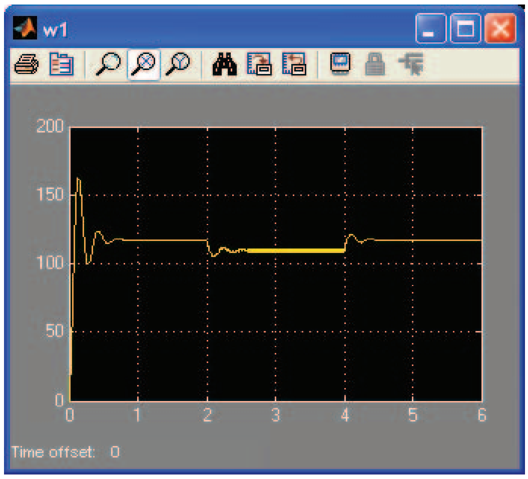

Fig. 14. DC motor speed with T4 in short circuit (2-4) s.

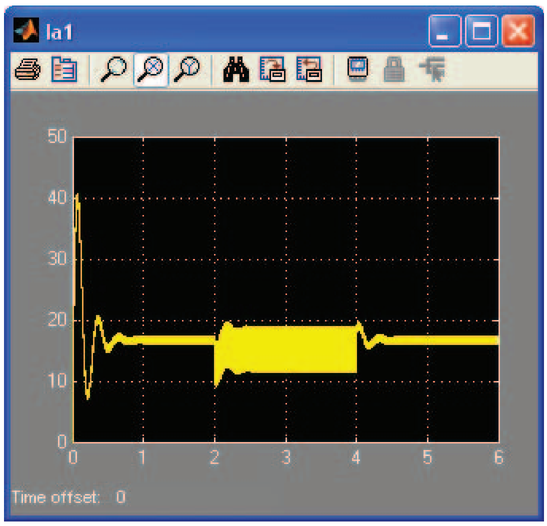

Fig. 15. DC motor armature current with T_4 in short circuit (2-4) s.

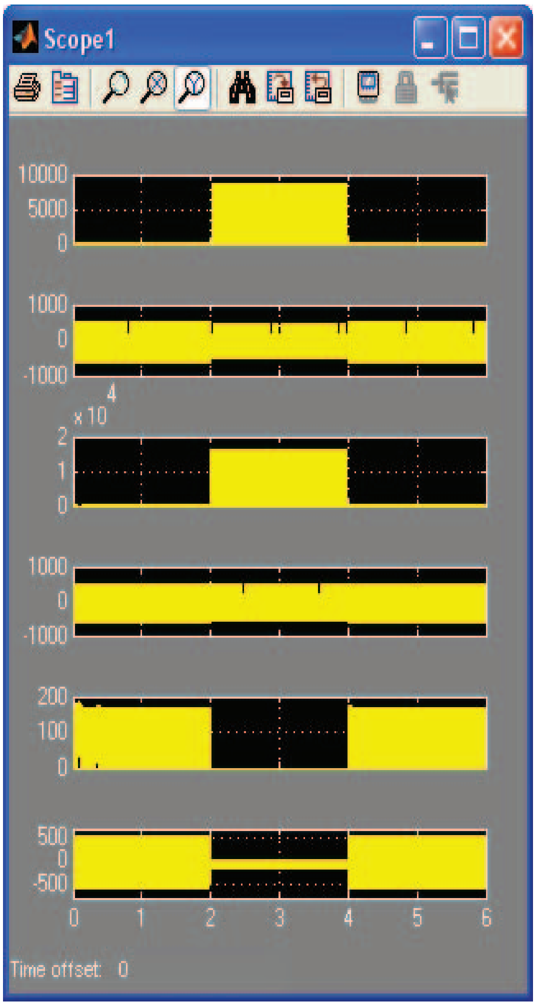

Fig. 16. Currents and voltages corresponding to T_2, T_6 and T_4 respectively.

V. Conclusions

The paper proposes a diagnosis method of the controlled three phase rectifiers supplying two types of loads: a passive RLC load and a variable DC drive, based on the analytic model.

The developed Simulink model was used for analyzing the influences and consequences of one device fault on the system drive operation.

Two types of fault were considered: interrupted and short circuit. If abnormal operation of the drive is signaled, based on the presented and analyzed waveforms, the fault type can be identified and following, the failed component can be located. The model can be used for different system drives, thanks to the easy parameterization.

For the both types of faults, important oscillations of the output voltage are noticed which can damage the load, but also can determine additional stress of the healthy switches.

The influence of the type of the load on the overall behavior was also highlighted.

For identifying the elements in fault, the waveforms corresponding to different faults can be stored in an information database and compared with the ones corresponding to normal operation.

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