USAGE SIMULATION METHODS FOR EDUCATION

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The paper deals with usage of computer simulation methods for education at Department of Electrical and Electronic Engineering and Signaling in Transport, Jan Perner Transport Faculty, University of Pardubice. Current situation of railway technics is very complicated and sophisticated both from viewpoint of railway infrastructure and from viewpoint of transport means. The particular parts of system are necessary to be analyzed from viewpoint of their behaviour and from viewpoint of influence to surrounding parts of the whole system. Therefore students as future railway experts must be trained for ability of problem identification and suitable design of problem solution. This readiness of experts for real operation of these devices is one of the main goals of lecturers from the mentioned department.

Key words: simulation, harmonic, locomotive, catenary, interference, EMI

1 Introduction

The department educates students in field of electrotechnics, electronics and safety equipments for all transport modes. During study, students are acquainted with traction systems as well. The problems at these systems, which can occur during operation, are simulated by computers. The problems of parts are shown in the simulation. Students are trained for finding of reasons of the problems and for knowledge of fault effect in the system. After that they try to find the convenient solution.

The example of solving problem: An electric locomotive with diode or thyristor rectifier is in the section of track. This locomotive represents the source of harmonics which are propagated through the catenary [1], [2]. Creation of the physical model is not possible for this case. Accuracy and believability of simulations depend on input parameters and models of examined circuit parts.

2 Solution problem

Firstly, it is necessary to analyze the whole system. At the Czech Railways two systems AC and DC are used. AC 25 kV system consists of main parts:

- Feeding Line 110 kV
- Supply substation with FCD
- Catenary

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- Electric locomotive

And DC 3 kV system consists of main parts:

- Feeding Line 22 kV
- Supply substation with 12th pulse rectifiers
- Catenary
- Electric locomotive

For the computer simulation, AC system was chosen. The electric circuit consists of the main parts which are mentioned above at AC system. The locomotive presents a load but also a source of parasitic harmonic currents. The large number of electrical locomotives, which are used at the Czech Railways, has diode or thyristor rectifier representing a current harmonic source. Current harmonics pass through catenary, transformer of supply substation, feeding line 110 kV and then power system. Therefore it is necessary to use Filter-Compensation Devices (FCD) in supply substation to their elimination the highest add harmonic (i.e. 3th, 5th). FCD has two series LC branches of the 3rd and the 5th harmonic and a decompensation branch. The tuning of the LC branches is not adjusted to the number of the harmonic exactly but it is done for lower of value as n_3 = 2.90 - 2.95 and n_5 = 4.98 - 5.00. The device has to have sufficient total input impedance (Z_{input}= 500 - 900 Ω) for used control frequency ripple (216.7 Hz) which is used by supplier. This condition is realized by a suitable option of C_3 and C_5 values in the LC branches [3]. The decompensation branch contains: reducing transformer, thyristor phase controller and decompensation chokes. The control is made to inductive power factor DPF = 0.98 of input of electrical power. The models have to be made for each part of traction system which is used in simulation.

2.1 Problems of Short-circuits at AC system

The AC system as traction circuit consists of the same parts as were mentioned above except an electrical locomotive. The situation, when the catenary as lossy line is represented by one section, is on the Fig. 1. The short-circuits is made in traction voltage maximum at the end of the catenary.

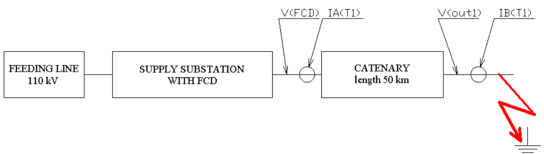

Fig. 1: The catenary is represented by one section.

The effects to FCD and behaviour of supply substation are demonstrated by simulation. The situation, where configuration of traction line is different, is demonstrated, see Fig.2.

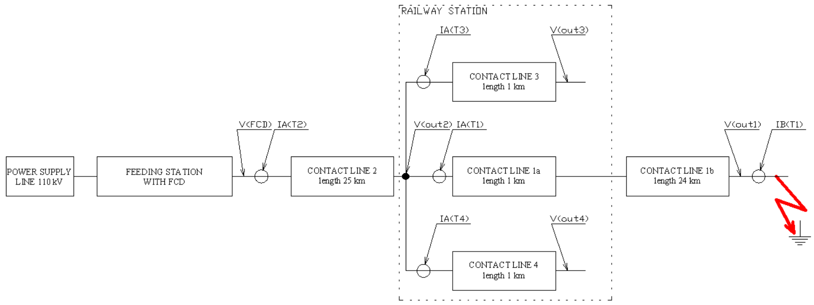

Fig. 2: The catenary is represented by sections with railway station.

The differences at propagation of voltage surges are marked in particular points of traction circuit, see Fig. 3 and Fig. 4. The curves of currents for the mentioned cases are shown on Fig. 5 and Fig. 6.

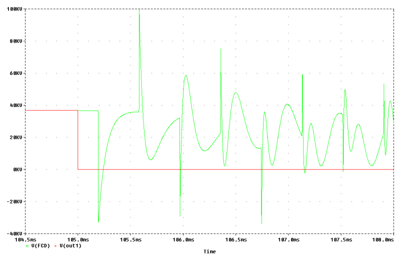

Fig. 3: Voltage surge for one section of catenary.

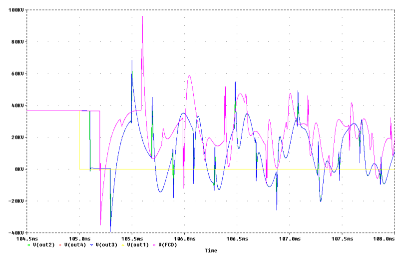

Fig. 4: Voltage surge for sections of catenary with railway station.

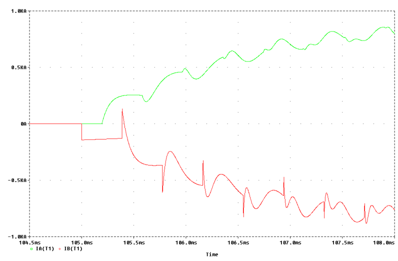

Fig. 5: Current for one section of catenary.

Fig. 6: Current for sections of catenary with railway station.

For example: The voltage surge can get triple of peak value of traction voltage theoretically at catenary represented by sections with railway station. The problem occurs at separate voltage surges to station sections. Overvoltage does not depend on number of station tracks. It depends on length of station tracks. The other details you can find in [4], [5].

The other example at study of the traction circuit is effect of position of locomotive to spectra in catenary.

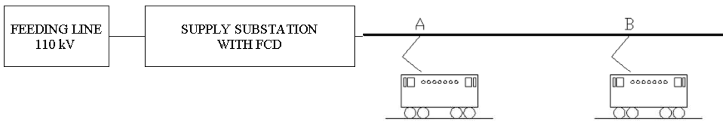

Fig. 7: The situation for position effect of locomotive.

The main problem of solution of this example are changing parameters of electrical locomotive during running which are dependent on the ways of driving (i.e. used speed ratio), locomotive load and track gradients. These parameters have also effect to waveform of generated current harmonics by locomotive. The situation is still more complicated at the operation railways when in this section it is not only a locomotive but more locomotives. Excitation of current harmonics in catenary is caused by electrical locomotives. These harmonic waves passed thought the catenary. They have different effect in the various positions of track. A harmonic spectra is result of simulation of single-track which are fed from supply substation at the beginning of section of track. When the locomotive will be in the section in nearness of the supply substation (i.e. point A) and at the end of catenary (i.e. point B), for this case we receive the different spectra under the same parameters of locomotive, see Fig. 8, (note: The fundamental harmonic is cut).

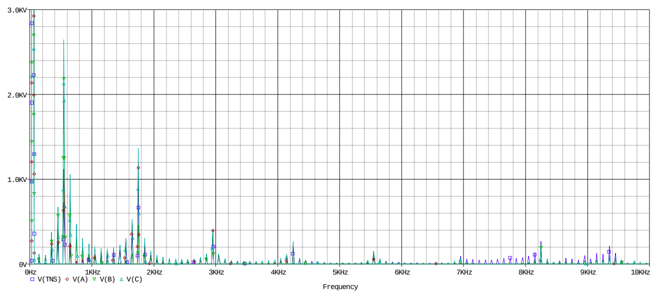

Fig. 8: Spectra excited by locomotive in position A.

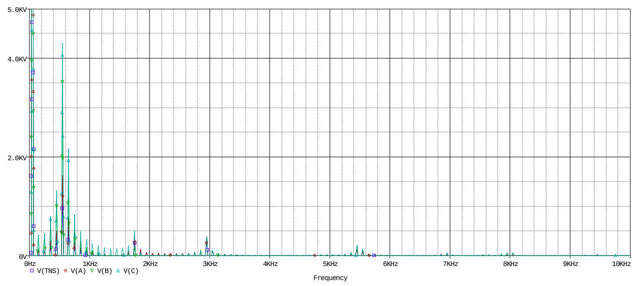

Fig. 9: Spectra excited by locomotive in position B.

The difference of amplitudes excited by resonance frequency of catenary is shown in figures. In the case of two locomotives with the same parameters, which are located in mentioned traction circuit, is the spectra shown in Fig.10. This spectra is different then before. More information can be found in [6], [7].

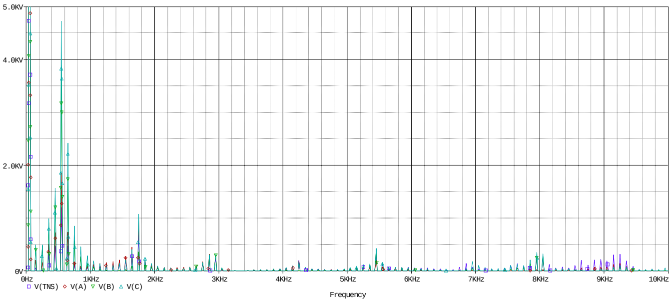

Fig. 10. Spectra excited by locomotives in positions A and B.

3 Conclusion

The paper demonstrates only a small part of problem of traction system solved by computer simulations which are used during study at Department of Electrical and Electronic Engineering and Signaling in Transport. Computer simulations are very useful and illustrative not only for study of some student examples but also at simulations of real states of devices when it is not possible to create physical model of the devices (e.g. higher financial costs). And also when it is not possible to do real fault states of the devices repeatedly (e.g at traction system the catenary or short-circuits at the catenary).

All problems, which can occur in real operation, cannot be solved during lessons but future railway experts should be able to decide possible cause of problem based on acquired knowledge. This better readiness enables them quicker and more appropriate problem solution.

Reference literature

1. J. Lettl, S. Flígl: "Electromagnetic Compatibility of Matrix Converter System", Journal: Radioengineering, vol. 15, no. 4, 2006.
2. J. Šimánek, R. Doleček, O. Černý, V. Schejbal: "Processor TI 2812 as Control Base of Permanent Magnet Synchronous Motor". Proceedings: Radioelektronika 2009, pp. 69-72, April 2009, Bratislava, Slovak Republic, ISBN 978-1-4244-3536-4.
3. K. Hlava: "Restriction of FCE effect to centralized ripple control of electric energy contractor - part 1-2", Report no. D2374026, Prague, 1996, (in Czech).
4. R. Doleček, O. Černý: "Short-circuits simulation at 25 kV, 50 Hz contact line system", Proceedings: ICREPQ 07, pp. 322-327, March 2007, Sevilla Spain, ISBN 978-84-611-4707-9.
5. R. Doleček: "Simulation of transient effects at traction line", Proceedings: ČD, no.27, pp. (15), 2009, ISSN 1211-232.1, (in Czech).
6. R. Doleček, O. Černý, J. Šimánek: "EMC of traction system AC 25 kV", Proceedings: EPE 2009, CD (6), June 2009, Pilsner, ISBN 978-80-02021513, (in Czech).
7. O. Černý, R. Doleček: "EMC of traction system AC 25 kV and effects to communication systems", Proceedings: EURO-Žel 2009 (part 2), pp. 117 - 122, June 2009, University of Žilina, Slovak Republic, ISBN 978-80-554-0024-2, (in Czech).