AMERICAN Journal of Engineering, Mechanics and Architecture
Volume 3, Issue 6, 2025 ISSN (E): 2993-2637

Investigation Of Load Current Ripples When Powered By A Controlled Rectifier

M.Sh. Shadmonxodjayev

D.M. Insapov

A.T. Ziyamukhamedov

Tashkent State Transport University (Tashkent, Uzbekistan)

Abstract. The article presents the results of a study of the pulsations of the output current of a source intended to power DC traction motors, which ensures the rotation of the moving parts of wheel-motor units of electric locomotives and electric trains, with a frequency regulated for the position of in-place diagnostics of bearings. The experiments were performed in the MatLab/Simulink simulation environment. Graphic methods are used to determine the current pulsation coefficient of traction motors of electric rolling stock. Energy indicators were determined in tabular and analytical forms, as well as converter control parameters that ensure the standard value of the power factor. Based on the assessment, a circuit design for the source was proposed, including a three-phase uncontrolled bridge rectifier and a pulse converter.

Keywords: power supply, electric rolling stock, traction electric motor, rectifier, adjustment parameters, current ripple, transformerless three-phase bridge controlled rectifier, pulse regulation.

Introduction

To ensure the normal functioning of traction electric motors, their current pulsation level should not exceed a certain level.

The level of current pulsations of traction electric motors is judged by the coefficient of pulsation (unevenness) of the K_p [1-8]:

$$К_{\boldsymbol{p}} = \frac{\boldsymbol{I}_{\max} - \boldsymbol{I}_{\boldsymbol{min}}}{\boldsymbol{I}_{\max} + \boldsymbol{I}_{\boldsymbol{min}}}$$

The essence of the ripple coefficient is explained in Figure 1.

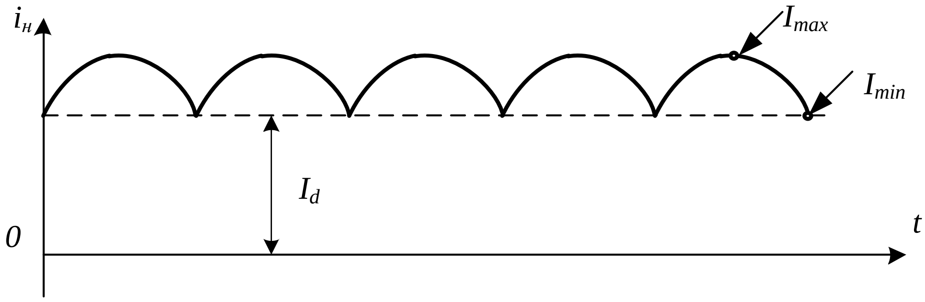


Figure 1. The instantaneous value of the load current in as a function of time t.
I_d is the constant component of the load current;
I_{max} is the maximum current value for the load;

I_{min} is the minimum value of the load current.

Methodology

As a rule, the acceptable value of the ripple coefficient is selected

The estimation of the load current ripple value allows us to formulate the requirements for the output filter of the rectifier.

To solve this problem, a mathematical model was developed in the Matlab/Simulink environment, which is described below.

A model has been developed in MATLAB with the Simulink package for a three-phase bridge transformer rectifier (Fig. 2). In it, the rotation frequency of the specified alpha traction motor is investigated [9].

The results of the study

The three–phase bridge rectification circuit on the Simulink package consists of a three-phase 380/220 V, 50 Hz depot power supply, a three-phase rectifier with a step-down transformer and its control system, an L-shaped filter, and a load (see Fig. 2) [12, 13].

The model determines the ripple coefficient with and without a filter of a three-phase rectifier at different speeds of the TED armature. The data obtained are summarized in Table 3 [10, 11].

We select inductors L type SOC-63/0.5U4 for rated rectifier current (Table 1), capacitor C type K50-90 for rated voltage (Table 2) [14, 15].

Table 1 – Technical parameters of inductance L

Rated rectified current, I_n, A	Rated inductance, Gn	Dimensions, mm			Gross weight, kg
		H	L	B	
100	0.016	590	510	270	140

Table 2 – Technical parameters of capacitor C

U_n, V	C, mcF	Overall size (diameter x height), mm	Weight, kg
250	680	50 x 45	0,12

The three-phase controlled rectifier model has an output filter connected to a step-down transformer. This is a branch modeled using the RLC series block (Fig. 5).

The RLC Branch series is a block module that performs active and inductive maintenance. Paired, it simulates an L–shaped, inductive L and a consator with;

In Fig. 3 a DC machine is specified.

Table 3 – Results of calculations of the ripple coefficient with and without a filter for the transformer power supply model

α, degree	I_{min}	I_{max}	K_n	I_{min}	I_{max}	K_n
10	41,25	41,68	0,0052	41,46	41,47	0,0052
20	40,43	41,25	0,0100	40,93	40,95	0,0100
30	39,32	40,44	0,0140	40,02	40,05	0,0140
40	37,88	39,24	0,0176	38,72	38,75	0,0176
50	35,9	37,58	0,0229	36,97	37,01	0,0229
60	33,48	35,36	0,0273	34,69	34,73	0,0273
70	30,37	32,42	0,0326	31,69	31,74	0,0326
80	26,15	28,32	0,0398	27,57	27,62	0,0398

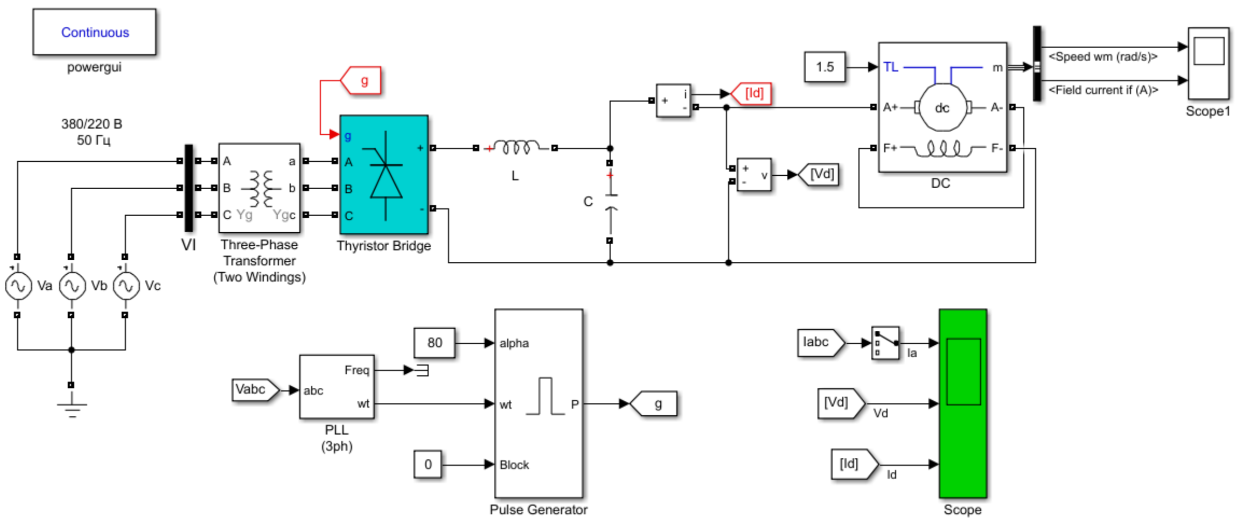


Figure 2. Three-phase network model for connecting to a Simulink computer

Permanent – this unit simulates a permanent installation, which is a means of transport management.;

A DC machine is a DC motor unit, complete with monitoring equipment.

We are now pursuing to study the methodology of parameters of a DC motor (DC machine) with sequential excitation. The program for converting DC machines in the MatLab environment, shown in Figure 3, is used as a library program for the Simulink/SimPower system/Block Library/Cars [10].

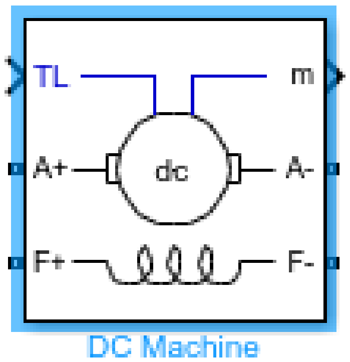
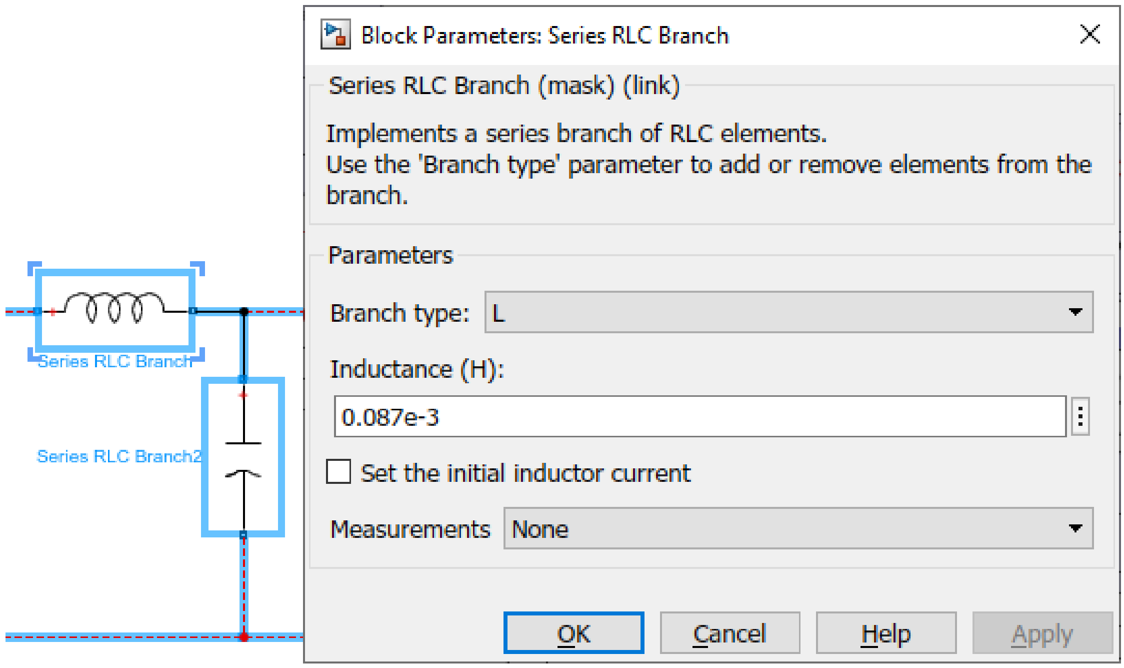


Fig. 3. Pictogram of the DPT image in the Simulink environment



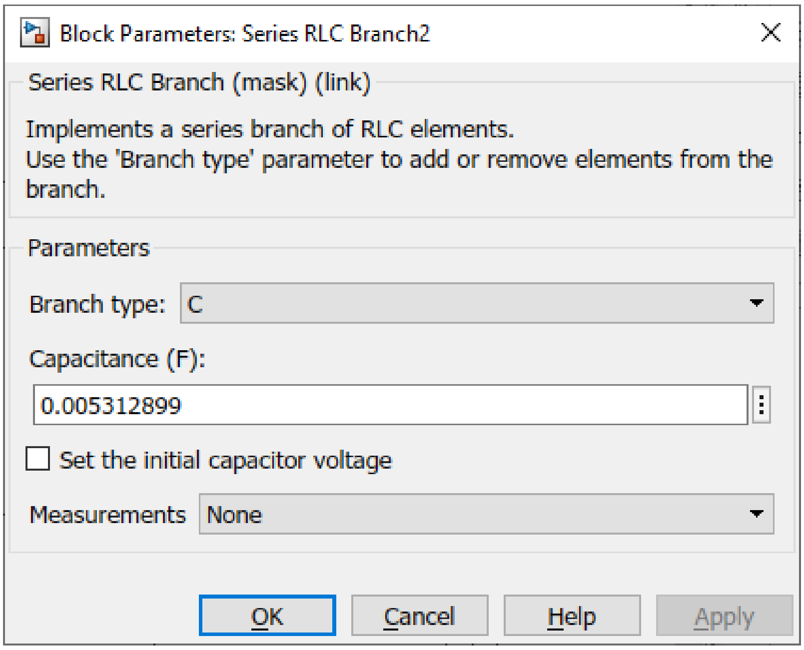


Figure 5. The filter and its parameters window in the Simulink environment

The ports of the model A+ and A are the terminals of the armature winding of the machine, and the ports F+ and F are the terminals of the excitation winding. The TL port is designed to provide a moment of resistance to movement. A vector signal consisting of four elements is generated at the output port m: speed, armature current, excitation current and electromagnetic moment of the machine.

The three-phase controlled rectifier model has an output filter connected to a step-down transformer. This is formulated using the Series RLC Branch block (Fig. 5).

The Series RLC Branch block simulates active and inductive resistance. There are two filters in the circuit, it simulates an L–shaped filter, an inductive L and a capacitor with.

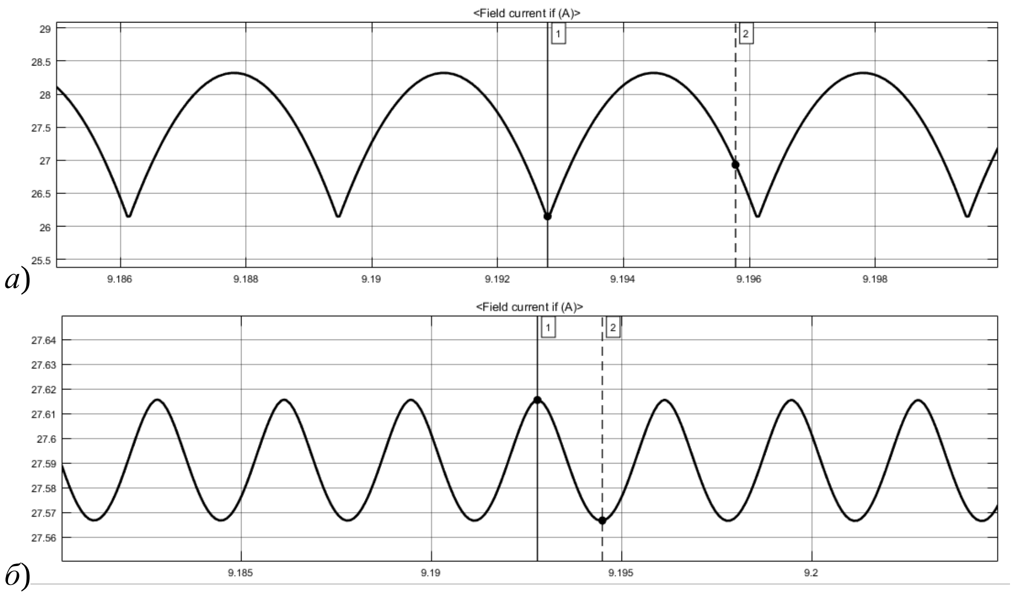


Figure 6. Determination of the minimum and maximum load current values without a filter (a) and with a filter (b) of a three-phase rectifier in a Simulink oscilloscope

It is proved that the simulation results of current pulsation do not exceed the standard values.

Conclusions

1. Mathematical models of power supply and load elements have been developed to analyze electromagnetic processes.

2. The levels of current pulsation in the elements of the power source have been determined, which makes it possible to formulate requirements for smoothing devices.

References

1. Shadmonkhojaev M.Sh. Position of vibroacoustic diagnostics of rolling bearings of electric rolling stock / M.Sh. Shadmonkhojaev, A.P. Zelenchenko // Traction rolling stock. - 2019. - № 210 - p. 80-81.
2. Shadmonokhodjaev M. Sh. Power source for the position of non-disassembled bearing diagnostics / A. P. Zelenchenko, A. A. Bogdan, M. Shadmonokhodjaev / Proceedings of St. Petersburg University of Railway Transport. SPb: PGUPS, 2021.-T. 18.-Issue. 4.-C. 554-560.DOI: 10.20295/1815-588X-2021-4-554-560.
3. Shadmonkhojaev M. Sh. Development of power source for vibroacoustic diagnostics position of locomotive depot bearings / A.P. Zelenchenko, M.Sh. Shadmonkhojaev / Bulletin of Scientific Research Results. - 2022. - Issue. 2. - p. 43-49. DOI: 10.20295/2223-9987-2022-2-43-49
4. Shadmonxodjayev M. Regulation of feeding part of complex of vibroacoustic diagnostics of rotary units of rolling stock / Shadmonxodjayev M., D. Insapov // E3S Web of Conferences. Vol. 401, July 2023. pp. 1-15. DOI: https://doi.org/10.1051/e3sconf/202340105007.
5. Basics of Rolling Bearings Diagnostics for Electrical Rolling Stock: Textbook / A.P. Zelenchenko, N.V. Orekhova, D.V. Fedorov. - SPb.: PGUPS, 2001. - 28 p.
6. Shadmonxodjayev M. Regulation of feeding part of complex of vibroacoustic diagnostics of rotary units of rolling stock / Shadmonxodjayev M., D. Insapov // E3S Web of Conferences. Vol. 401, July 2023. pp. 1-15. DOI: https://doi.org/10.1051/e3sconf/202340105007
7. Shadmonxodjayev M.Sh. The position of vibroacoustic diagnostics of rolling bearings of electric rolling stock // M.Sh. Shadmonkhodjaev // The scientific journal vehicles and roads 2023.: T.: TSTU, 2023. – Issue 1. – 13-16p.
8. Shadmonxodjayev M.Sh. Analysis of rectifier control during diagnostics of dc traction motors of electric rolling stock // M. Shadmonkhodjaev A. Lesov, T. Nazirkhonov, A. Miryakubov // The scientific journal vehicles and roads 2023.: T.: TSTU, 2024. – Issue 1. – 107-118p.
9. Plaks A.V. Electric rolling stock control systems. Textbook for universities railway. transport. - M.: Route, 2005. - 360 p.
10. Chernykh I. V. Modeling of electrical devices in MATLAB, SimPowerSystems and Simulink. — M.: DMK Press; St. Petersburg: Peter, 2008. — 288 p.: ill.
11. Herman Galkin S. MATLAB SCHOOL Virtual laboratories of power electronics devices in the MATLAB-Simulink environment Lesson 14. Analysis, calculation and research of the power factor corrector / S. Herman Galkin // Power Electronics. – 2011. – vol. 4. – No. 32. – pp. 90-96.
12. Kulik V.D., Korolev V.I. Abnormal modes of operation of semiconductor rectifiers and their diagnostics: textbook / SPbGTURP. - St. Petersburg, 2012. - 114 p.: ill. 109.
13. Smirnov B.C. Problems of stability analysis of pulsed distributed power supply systems. // Proceedings of educational institutions of communication. / SPbGUT. St. Petersburg, 2004. No.170.
14. Daibova L. A., Uskov A. E., Dedyulya K. A., Kravchenko N. A. To the calculation of the main criteria for the effectiveness of static power converters. Scientific Journal of KubGAU, No 124(10), 2016.

15. Stefan Linder Power semiconductor devices. Part one: basic information and applications. ABR Switzerland I td. Semiconductors Lenzburg. Switzerland stefan.Iinder@ch.abb.com.
16. T. M. Nazirkhonov, D. O. Radjibaev; Evaluation of the efficiency of a 4q-S converter of an alternating current electric locomotive of the "O’Z-ELR" series using a computer simulation model. AIP Conf. Proc. 16 May 2023; 2476 (1): 020055. https://doi.org/10.1063/5.0103507.
17. Khromova G., Kamalov I., Makhamadalieva M. Vibration simulation of the spring element of the locomotive swing link //E3S Web of Conferences. – EDP Sciences, 2023. – T. 401. – C. 05033.