RIGA TECHNICAL UNIVERSITY
Faculty of Power and Electrical Engineering
Institute of Industrial Electronics and Electrical Engineering

Igors Uteshevs

DEVELOPMENT OF CONTROL ALGORITHMS OF EMBEDED WIRELESS BRAKING EQUIPMENT OF ELECTRIC RAIL TRANSPORT BY MEANS OF POZITIONING INFORMATION SYSTEMS USE

Abstract of the Thesis

Riga 2010

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OFICIAL REVIERS

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I acknowledge that the work I submitted to Riga Technical University for promotion of Doctor degree in engineering sciences is my own. No part of this work is submitted to other universities or other institutions for any degree obtaining.

Igors Uteshevs..(Signature)

Date: ………………………

The promotion paper is written in the Latvian language, it contains and introduction, 4 chapters, closing part or conclusions, list of references, 8 appendices, 45 figures and illustrations, on 139 pages. The list of references contains 193 titles.

CONTENTS

GENERAL INTRODUCTION INTO THE WORK

Topicality of the work

The objectives of the promotional work are connected with the development of a model of electric rail transport automatic control under the condition of emergency braking, models of insulation testing methods and development of an algorithm for testing of the condition of insulation of electric equipment at rail transport in the regime of emergency braking.

Aims and objectives of the paper

The aim of the work is to develop modern algorithms for the control and diagnostics of electric transport braking systems.

The following objectives are considered in the paper:

- to elaborate an approach for the improvement of train braking automatic control system, that allows defining of train location and realization of train stop in front of traffic light with inhibit signal.
- to elaborate an improved method for calculation of train braking parameters; the method will allow control of the train speed, mass, location and profile of the road.
- to elaborate an approach to electric insulation diagnostics, that in contrast to existing methods allows realizing of condition control of locomotive electric motor insulation in the emergency braking regime in real time without its disconnection from the supply.
- to develop a model of electrical equipment operation in the regime of locomotive braking, that in contrast to existing models allows comparison of different processes and algorithms for embedded intelligent systems.
- to elaborate an approach for the improvement of train braking automatic control system, that allows defining of train location and realization of train stop in front of traffic light with inhibit signal.
- to elaborate an improved method for calculation of train braking parameters; the method will allow control of the train speed, mass, location and profile of the road.

- to elaborate an approach to electric insulation diagnostics, that in contrast to existing methods allows realizing of condition control of locomotive electric motor insulation in real time without its disconnection from the supply.
- to develop a model of electric transport automatic control in emergency braking regime.
- to elaborate models of modern methods for electric transport insulation control and algorithms of control of electric transport equipment insulation condition in the regime of emergency braking with the use of artificial neural networks possibilities.

Methods and Tools of the Research

The following theoretical and practical methods have been applied in the study:

- computer modelling within the SIMULINK environment;
- method of multicriteria optimization;
- clusterization analysis;
- method of mathematical modelling;
- method of mathematical statistics.
- modern theory of decision making;
- neural networks;
- analysis of systems;

Scientific topicality of the research

- The research has resulted in the development of an improved electric transport automatic braking control system, that in contrast with those existing allows defining of the electric transport location and realization of the transport stopping in front of traffic light with the inhibit signal with the use of Positioning Information System.
- The research has resulted in the elaboration of an improved method for calculation of electric transport braking parameters; the method in contrast with the others existing allows control of the electric transport speed, mass, location and profile of the road with the use of Positioning Information System.
- The research has resulted in the elaboration of a new approach to electric insulation condition diagnostics that in contrast to existing methods allows realizing of condition control of locomotive electric motor insulation in real time in the regime of emergency braking after partly intensity loading without disconnection of the motor from the supply.
- The research has resulted in the development of a model of electrical equipment operation in the regime of electric transport braking that in contrast to existing models allows a comparison of different processes and algorithms for embedded intelligent systems.
- The suggested models and algorithms can meet the requirements of Latvian Railway.

Approbation of the research

The results of the research have been presented and approved at the following international scientific conferences:

1. The 18th International Conference on Multiple Criteria Decision Making. Chania, Greese, 19-24 June 2006.

2. ECAD/ECAE 2006 2nd International Conference on Electrical/Electromechanical Computer Aided Design & Engineering 12.-13. October 2006 Stuttgart, Germany.
3. EURNEX-Zel 2007 The 2th International Scientific Conference, Zilina, Slovakia, 30-31. May 2007. g.
4. The IEEE EUROCON 2007, Varšavā, Polijā, 9-13 September 2007.
5. The 48th International Scientific Conference of Riga Technical University 11.-13. October 2006 Riga, Lavia.
6. EURNEX-ZEL 2008 "Towards sustainable and competitive European rail system "International Scientific Conference, Žilina, Slovak Republic, 2008.
7. th International Symposium „Topical Problems in the field of Electrical and power Engineering", Kuressaare, Estonia, January 12-17 , 2009
8. „Intelligent Technologies in Logistics and Mechatronics Systems (ITELMS'2009)", June 4-5, Panevezys, Lithuanian, 2009
9. The 50th International Scientific Conference "Power and Electrical Engineering", Riga Technical University, Riga, Latvia, 2009.
10. th International Symposium „Topical Problems in the field of Electrical and power Engineering", Kuressaare, Estonia, January 11-16 , 2010
11. The practical workshop "Intelligent systems for electric vehicles" in the Virumaa College of Tallinn University of Technology, Estonia, 15-18 March 2010
12. The practical workshop "Intelligent systems for electric vehicles" in the Virumaa College of Tallinn University of Technology, Estonia, 07-08 April 2010

The author's publications

1. Uteševs I., Levčenkovs A., Kunicina N., Gorobecs M. „Modelling of group decision making for elektrical process control in mechatronic systems", MCDM 2006, book of abstract Chania, Greese, 2006, 209 p.
2. Uteševs I., Levčenkovs A., Kunicina N., Gorobecs M . "Intelligent Agents Networks for Power Processes Control in Mechatronics Systems", ECAD/ECAE 2006 Electrical/Electromechaical Computer Aided Design & Engineering, Stuttgart, Germany, 2006
3. Uteševs I., Levčenkovs A., Vinogradova B., Ziravetska A., „Intelligent Network of Substation for Safety Power Supply for Electrical Railway", EURNEX-Zel 2007 The 2th International Scientific Conference, Žilina, Slovak Republic, 2007
4. Uteševs I., Levčenkovs A., Kunicina N., Gorobecs M "Modelling of Intelligent Devises for Energy Distribution Control ", The IEEE EUROCON 2007, Warsaw, Poland, 2007.
5. Uteševs I., Levčenkovs A., "Intelligent electrical network for safety of electrical railway ", The 48th International Scientific Conference of Riga Technical University, 2007
6. Uteševs I., Levčenkovs A., Balckars P., Gorobecs M "Classification of the basic types of the electrical substations ", The 48th International Scientific Conference of Riga Technical University, 2007

7. Uteševs I., Levčenkovs A., Balckars P "Modelling of neural controller for railway extremal electrical braking", EURNEX-ZEL 2008 "Towards sustainable and competitive European rail system "International Scientific Conference, Žilina, Slovak Republic, 2008
8. Uteševs I., Levčenkovs A., Balckars P "Modelling of neural controller for railway traction substations", Шестая Международная научно-практическая конференция „Исследование, разработка и применение высоких технологий а промышленности", Санкт-Петербург, 2008.
9. Uteševs I., Levčenkovs A., Gorobecs M. "The clustering analysis for evaluating state of the insulation for intelligent electrical networks". Intelligent Technologies in logistics and mechatronics systems ITELMS 2008. Kauno Techologijos Universitetas , Lithuania, 2008 .
10. Uteševs I., Levčenkovs A., „ The analysis of the artificial neuron networks method for the modelling of the voltage network", 6th International Symposium „Topical Problems in the field of Electrical and power Engineering", Kuressaare, Estonia, January 12-17 , 2009
11. Uteševs I., Levčenkovs A., „Modelling of overheat process control of electric motor",. The 50th International Scientific Conference "Power and Electrical Engineering", Riga Technical University, Riga, Latvia, 2009.
12. „Target train braking system modelling", The 8th International Symposium "Topical Problems in the field of Electrical and power Engineering", Pjarnu, Estonia, January 11-16 , 2010, 99 -104p.
13. Patent Nr. LV 14187 B. Device for control of train's breaking way. Anatolijs Ļevcenkovs, Mihails Gorobecs, Jānis Greivulis, Igors Uteševs, Pēteris Balckars, Leonīds Ribickis, Iļja Korago , Vitalijs Stupins, Sergejs Holodovs. Rīgas Tehniskā universitāte, Latvijas Dzelzceļš. 26.05.2010.

Contents of the Thesis

Introduction

The task of the train movement safety providing system is an exclusion of emergency situation because of driver mistakes or train control system fault. As an emergency situation first of all can be considered a continued movement at an inhibit signal of a traffic light and overrunning. The operation of this system should be safe even in the case if it is also fault. The system could considerably simplify the work of driver and allow to drive the train not on the basis of the current situation subjective evaluation by the driver but on the making a precise decision for particular conditions.

The applied in railway transport automation provides safe movement of trains. Although during the last years at the railways of Latvia and other countries different considerable accidents took place having resulted in fatal casualties and significant economic losses.

The reasons of the accidents can be distributed as following:

- Lose of attention of the driving crew..30%
- Sleeping of the driving crew 15%
- False evaluation of the signals........ ....13%
- Delay engaging of braking system or its false control..12%
- Running from non-coded way...10%
- Driving with fault or switched off equipment...9%
- Disability of the driving crew to drive a train...6%
- Lack of brakes effectiveness...5%

Analysis of the data can result in the conclusions that 70% of the accident cases take place when the technical means are in good working condition but the mistakes are made by the driving crew. In other words the human factor is a governing in consideration of these situations.

The trains braking systems allow braking from the maximum speed for full stop or decreasing the speed up to necessary minimum, but the braking way can achieve some thousands meters. In addition the length of braking way can be influenced by different factors that can only worsen the situation.

The already mentioned human factor plays also not less role, when the limited possibilities of the drivers do not allow visually observe the situation on the way at the distance of some thousands meters as well as not proven losses of time, moving out of schedule and provoking emergency situations.

The movement out of the trains schedule has been accepted as one of most important reasons of the catastrophe that took place at Riga Central Station when the electric train arrived to the station and collided with passenger train going from depot.

To improve the safety of the transport communication the intelligent automation devices permanently controlling the trains speed and way are necessary for defining where and when the braking regime is demanded, its intensity and the train's location on the way, where the train should stop to avoid collision or other emergency situation.

Statement of the tasks of the electric transport braking systems control

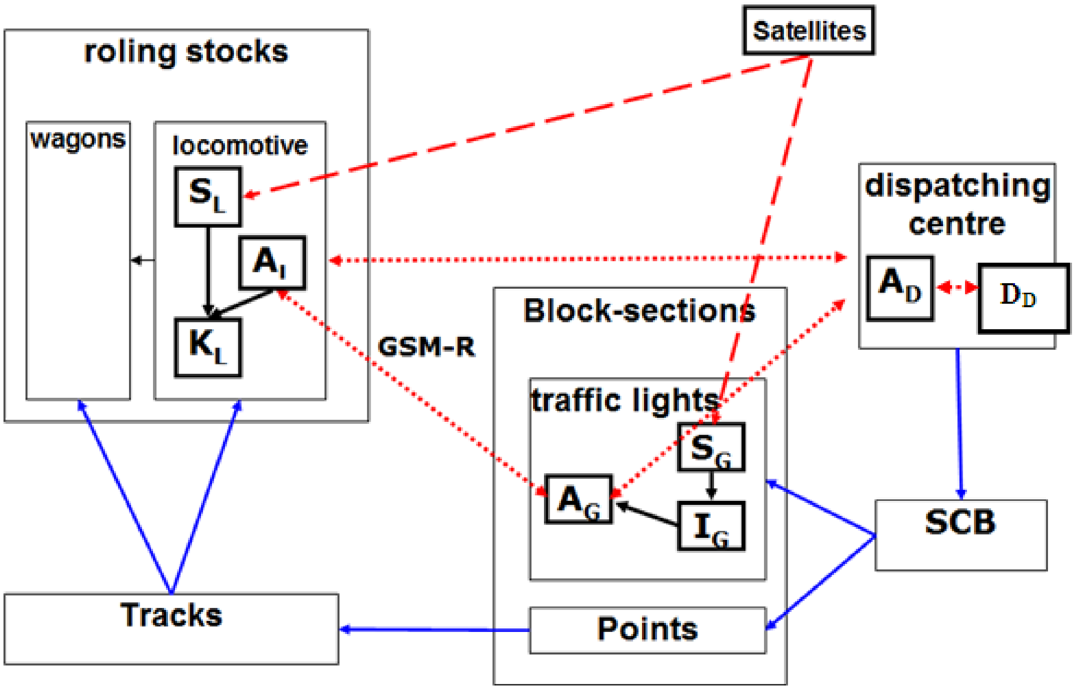
The first part observes main phases of the electric transport movement, the existing basic principles of the electric transport braking, basis of the necessity of automatic braking and the structure of the automatic braking system. The chapter contains the statement of the task of electric transport automatic braking for a new wireless control system with the use of Positioning Information System.

Following objects may be defined in railway system:
rail ways, points, stations, block-sections CP, signalisation, centralisation and interlocking system SCB, dispatching centre, traffic lights, rolling stocks, locomotives, wagons .

System elements:

- Satellite navigation recievers of traffic lights S_G and locomotives S_L ;
- Wireless signal transmitting antennas of traffic lights A_G , dispatching centre A_D and locomotives A_L;
- Device for signal generation of the traffic light I_G;

- Device of braking system control of the locomotive K_L.



1.fig. The scheme of the elements interoperation

This scheme fig.1 presents the interoperation of the elements for the new automatic braking control system of electric transport - the given coordinates at a given time moment with a given speed of electric transport it is necessary to define the starting point of the braking for its safe stop at a particular distance at the point with given coordinates in front of traffic light with inhibit signal without participating of a driver.

The satellite system controls the location of electric transport on way and its speed as well as location and signals of the traffic lights and transfer the information to the station of dispatcher post. . The train will be stopped in three cases: if there is a barrier on the way, if there is an inhibit traffic light signal, if the driver of the transport mean loses the control of the transport.

Control of movement of electric transport

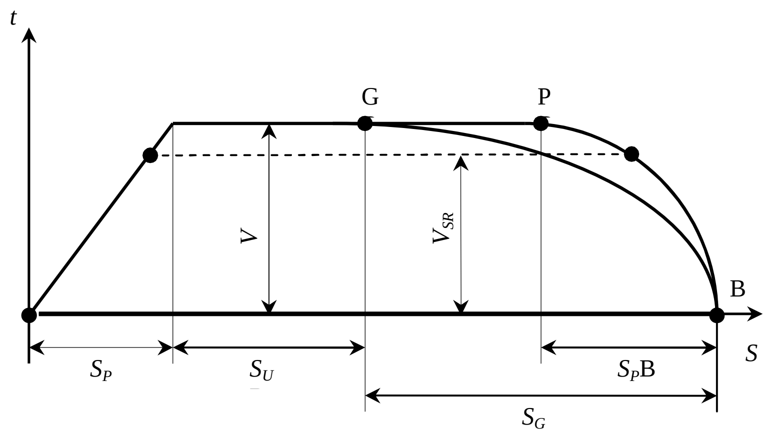
Controlling the train it is necessary to consider main motion phases on the parts of the way.

This scheme fig.2 the way that electric transport overcomes between points A and B can be divided into four main phases.

1. The section of the way S_R is an acceleration way of electric transport. The acceleration way depends on the power and mass of the train.

The way at the section S_U is stationary, as electric transport during

2. The section of the way S_R is an acceleration way of electric transport. The acceleration way depends on the power and mass of the train.



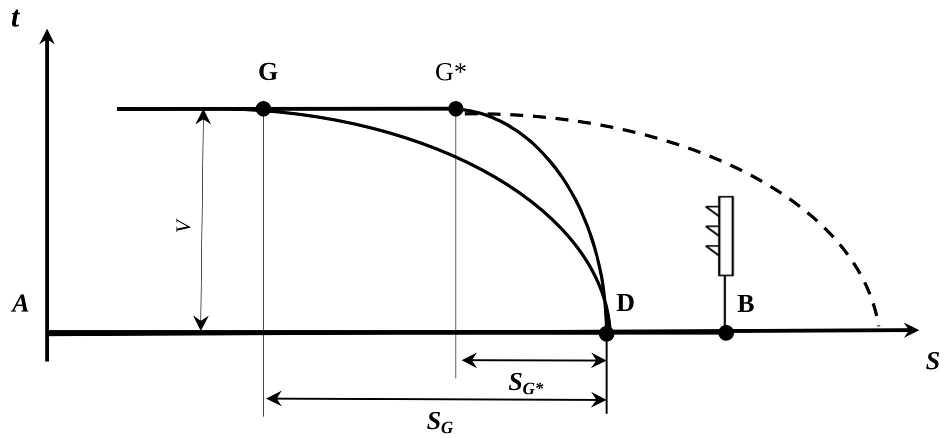
2.fig. Electric transport phases of motion at the parts of the way

3. The section of the way S_R is an acceleration way of electric transport. The acceleration way depends on the power and mass of the train.
4. The way at the section S_U is stationary, as electric transport during this section of the way goes with a particular speed, that depends on the power of electric transport, profile of the way and is defined with braking systems of electric transport to provide stop at point B or in front of inhibit signal of traffic lights.
5. The section of the way S_G is a braking way of cargo trains.
6. The section of the way S_P is a braking way for passenger trains.

The maximum speed of the motion is defined taking into account the maximum braking way. Thus with one and the same speed the braking system of cargo electric transport should be driven at point G earlier than the passenger electric transport at point P . The length of the braking way depends on the speed of the train, its mass, profile of the way and effectiveness of braking system operation. Therefore, with more effective braking system the braking process can be started later and technical speed at the way sector can be higher v_{SR}

This scheme fig.3 defining of the braking starting point of electric transport at the way section.

1. Point A - station of departure
2. Point B - location of traffic light with inhibit signal
3. Point D - point of electric transport stop in front of traffic light with inhibit signal.
4. Point G - starting point of braking of electric transport, when the braking system is driven by train's driver. Curve GD characterises braking way of electric transport after the moment, when the braking system is driven by train's driver.



3.fig. Defining of the braking starting point of electric transport at the way section.

5. Point G* - starting point of braking of electric transport, when the braking system is driven by braking emergency system.. Curve G*D characterises braking way of electric transport after the moment, when the braking system is driven by braking emergency system..
6. Dash line presents way of electric transport in the case when the control of the braking system is broken.

Functional dependences of electric drive

Voltage equation [19]: $U = f(E_a, I_a, \sum R)$; Current equation $I_a = f(U, E_a, \sum R)$; Power equation: $E_a I_a = f(p, N, a, \Phi, I_a \omega) = f(M, \omega) = P_{em}$; $UI_a = f(E_a, I_a, \sum R) = f(M, \omega, I_a, \sum R)$; ; EDS : $E = f(c_e, n, .\Phi, \omega, I_a, U_a, N, a)$;

Rotation frequency: $n = f(c_e, \Phi, U, I_a, \sum R)$; *Ia* depending on $I_a = f(M)$:Torque: $M = f(J, \omega, t)$; Inertia: $J = f(G, D)$;

Electrical braking modes of trains machines
Mode of dynamic braking

In the regime of dynamic braking the losses in the motor power circuit take place only transforming the electric energy : $P_M = \Delta P \ R_{br}$; The dynamic braking is used switching the armature from the supply and connecting it to special braking resistance R_{br} , but the excitation winding is left connected to supply. As the kinetic energy of rotating parts connected with the motor shaft continue its anchor rotation in the initial direction, the motor operates as generator with an independent excitation. The produced electric energy is consumed in the anchor circuit. The value of this current [19]: $I_a = -\frac{R_a + R_{pr}}{C_E C_M \Phi^2} M \quad R_{br}$; The motor with parallel excitation operates in the regime of dynamic braking with the resistance R_{br} ; $n = -\frac{R_a + R_{br}}{C_E C_M \Phi^2} M$; The motor in generator mode. The main feature of this mode is recuperative braking. Then the balance of power is the following: $P_M = P_E + \Delta P$;

Mode of recuperative braking

Transition from the motor regime to recuperative braking is possible when the speed of the motor exceeds the speed of idle running at M=0. . In the mode of recuperative braking the load of the network is equal to the energy returned to the network [147]: $U_{Sl} = U_{Tikl} = const$;

$\frac{dU}{dI} = 0$; then $\frac{dU}{dI} = 0$; and $\frac{dE}{di} < 0$; Voltage equation:

$e_{ier} = I_{ier}(r_{ier} + r_v) + (I_{en} + I_{ier})r_C$; Excitation current: $I_{ie} = \frac{e_{ie} - I_{en} r_s}{r_{ie} r_s r_v}$; EDS : $E_M = C\Phi V$;

; Anchor voltage equation : $U_C = E_M - I_{en} r_{en} - (I_{en} + I_{ier})r_C$;

Mode of rheostat braking $\begin{cases} V = \frac{I(r_E + r_R)}{C\Phi}; \\ B = \frac{C\Phi^2 V}{(r_E + r_R)\eta_F}; \end{cases}$

Mode of plugging braking

In this mode the motor consumes energy from the shaft and electric energy from the network.

The equation that defines the total energy: $P_M + P_E = \Delta P$;

The plugging mode can be realised in two ways:

- with the opposite connection the polarity of its voltage is changed and with it the direction of current and electromagnetic motor M is also changed;
- allowing the accumulated kinetic energy of the driven mechanism to rotate the anchor of the motor in its rotating direction in the motor operation mode.

Current of the anchor [19]: $I_a = \frac{-U - E_a}{R_a + R_p} = -\frac{U + E_a}{R_a + R_p}$; The direction is opposite to that initial, because of that the motor develops the negative electromagnetic torque.

In the second case the braking regime takes place if the static torque of the driven mechanism M_{stat} is higher than the rotating torque of the motor M . Voltage equations in the traction motor mode: $U_C = C\Phi V + Ir$; Recuperation mode : $C\Phi V = U_C + Ir_D$;

Defining of the multicriteria braking target function: $S_T = \frac{v_0 t_n}{3{,}6} + \sum \frac{500(v_N^2 - v_K^2)}{\zeta(w_{ox} + b_m + i_C)} \to \max$; $t_m = t_p + \sum_{i=1}^{n} \frac{v_n - v_k}{3{,}6 \cdot \varepsilon_i} \to \max$;

$v = v_0 + \int_0^t a\partial t \to 0$; $0{,}6 \le \varepsilon_i = \dfrac{v_n^2 + v_k^2}{2 \cdot 3{,}6^2 \cdot \Delta S_p} \le 0{,}8$; Where: S_T - the total braking way; t_m - the total braking way of the train; v - speed of the train; ε_i - average weakening value;

Normalization functions

Maximum values of the target function: $S_{T_{MAX}}$, $t_{m_{MAX}}$, v_{MAX}, $\varepsilon_{i_{MAX}}$;
According to the normalization of the values:

$$S_{T_{MAX}} = \frac{S_{T_{MAX}} - S}{S_{T_{MAX}}};\ t_{m_{\max}} = \frac{t_{m_{MAX}} - t_m}{t_{m_{MAX}}};\ v_{MAX} = \frac{v_{MAX} - v}{v_{MAX}};\ \varepsilon_{i_{MAX}} = \frac{\varepsilon_{i_{MAX}} - \varepsilon_i}{\varepsilon_{i_{MAX}}};$$

The basics of the target function is to elaborate modern algorithms for the control and diagnostics of trains braking systems, using neural networks theory, analysis of clasterization and methods of mathematical modelling.

Algorithms of electric transport embedded wireless equipment

The second part contains the principles of electric transport braking parameters calculation with the use of Positioning Information System. The chapter suggests the mathematical models of braking taking into account the distribution of electric transport mass, analyses the influence of the transport mass on the braking process with the use of Positioning Information System. The chapter considers an elaboration of new model of control of electric transport braking regime with the use of Positioning Information System.

Algorithm for the train braking

Step 1. Initialization of braking way;
Step 2. Defining of the factor of the way gradient;
Step 3. Defining of the general braking factor;
Step 4. The procedure of defining of main resistance for the movement in idle running;
Step 5. Defining of the general braking factor;

The braking way consists of preparation and real segments: $S_T = S_P + S_D$;

Step 6. Go to Step 1.

The braking power of the train should be defined taking into account a real force of the braking chock influencing the train wheels. A real friction factor depends on the braking chock material.

The following factor characterises the braking chock made of cast iron [145]: $\varphi_K = 0{,}6 \dfrac{16K + 100}{80K + 100} \cdot \dfrac{v + 100}{5v + 100}$; The cast iron braking chocks containing phosphorus of 1,0-1,4% are characterised with the factor $\varphi_K = 0{,}5 \dfrac{16K + 100}{52K + 100} \cdot \dfrac{v + 100}{5v + 100}$; The mentioned above factor for braking chocks of composite materials can be defined with the following expression : $\varphi_K = 0{,}44 \dfrac{K + 20}{4K + 100} \cdot \dfrac{v + 100}{2v + 100}$;

The calculations of braking force of the chocks.

For the standard cast iron braking chocks : $K_P = 2{,}22K\frac{16K+100}{80K+100}$; The cast iron braking chocks containing phosphorus of 1,0-1,4% $K_P = 1{,}85K\frac{16K+100}{52K+100}$; For the braking chocks of composite materials : $K_P = 1{,}22K\frac{K+20}{4K+20}$; The total braking factor: $\vartheta_{PO} = \frac{\sum K_P}{Q+P_u}$; The main force resistive to the motion in idle running $W_{Ox} = W_{O1} + N \cdot W_{Oc}$; where N - quantity of the carriages.

Locomotive without the train: $W_{0l} = 24 + 0{,}11v + 0{,}0035v^2$; Cargo carriages: $w_{0c} = 7 + \frac{a+v+0{,}025v^2}{q_0}$; Passenger trains: $w_{0c} = 12 + 0{,}12v + 0{,}002v^2$; The total braking time of the train : $t_m = t_p + \sum_{i=1}^{n}\frac{v_n - v_k}{3{,}6\cdot\varepsilon_i}$; As within the time interval Δt the braking force and opposite self-resistive force ω_{Ox} to the motion of train are assumed as constant values then the increasing of the speed can be calculated according to : $\Delta v = \frac{\xi(b_T + \omega_{Ox} + i_c)\Delta t}{3600}$;

The speed of braking force distribution is braking wave : $V_t = \frac{L}{t_t}$; where: L- length of the train; t_t - time from the moment when the driver turns the handle of the hoist till the pressure exists in the braking cylinders; air wave : $v_v - 20\sqrt{T}$; where: $T = 273 + t^\circ C$ - absolute temperature of gas. The braking way consists of preparation and real segments [145]: $S_T = S_P + S_D$; where the segment of preparation $S_P = 0{,}278v_0t_p = \frac{v_0t_n}{3{,}6}$; Real segment $S_P = 0{,}278v_0t_p = \frac{v_0t_n}{3{,}6}$: $S_D = \sum\frac{500(v_N^2 - v_K^2)}{\zeta(w_{ox} + b_m + i_C)}$;

Thus the total braking way : $S_T = \frac{v_0t_n}{3{,}6} + \sum\frac{500(v_N^2 - v_K^2)}{\zeta(w_{ox} + b_m + i_C)}$;

Algorithm of defining of the distance between train and object

Step 1. Initialization of the distance between the objects;
Step 2. The transformation of distance value from degrees to meters;
Step 2. defining of the distance between the train and object taking into account the night of the object above the level of the Baltic Sea;
The distance between train and object can be calculated with the formula: `Dist = SQRT(Alt2+L2);`
Step 4. Go to Step 1.

Average weakening value [145] : $\varepsilon_i = \frac{v_n^2 + v_k^2}{2\cdot 3{,}6^2\cdot\Delta S_p}$;

Mass of the train.

If the train is simultaneously on the different profiles of way, then the equation of its motion will be [151]:

$$Q_v = \frac{-\zeta(B(t,v)+W(v))}{g\left(\frac{dv}{dt}+\frac{\zeta}{l_v}\left(s_0 i_1+\sum_{j=2}^{m-1} s_j i_j+(l_v-s_0-\sum_{j=2}^{m-1} s_j)i_m\right)\right)};$$

The procedures for defining of the train mass listing STL language programmable logic controller

/ / 1. Procedure of defining of the train mass:

```
1.1. LD SM0.0 // call in each cycle;
1.2. MOVR #F:LD28, AC0 // local variable of the braking force;
1.3. –R #Wo:LD32, AC0 // local variable, write in to accumulator;
1.4. MOVR AC0, #mass:LD8
1.5. /R AC3, #mass:LD8
1.6. MOVR AR< #mass:LD8, 0.0
1.7. 1E-013, #mass:LD8
```

The procedure of GPS block operation listing STL for the embedded device

/ / 1. Initialization of the GPS system parameters.

/ / Using S7--200 data memory blocks to define GPS system space parameters variables:

```
1.1. #loc_LatDeg:LW16 // local variable of length LD, in degrees, Long
     Word;
1.2. LatDir_RS:VB2006 // Local variable width LD, in min, byte type
     address;
1.4. #loc_LongDeg:LW22
1.5. #loc_LongMin:LD24
1.6. LongDir_RS:VB2007
1.7. #loc_AltUnit:LB29
1.8. #loc_Speed:LD30
```

/ / 2. Defining of the speed of the object:

2.1. If the sped of the object is $V \neq 0$, then: local variable of speed SP, double type address;

2.2. If the speed of the object is $V = 0$, then go to 3.

/ / 3. Obtaining of data from GPS receiver.

/ / Variables of the GPS system time parameters will be defined.

```
3.1. Year:VB2000 // year global variable the satellite globālais
     mainīgais YR, byte type address;
3.2. Month:VB2001 // month global variable the satellite , byte type
     address;
3.3. Day:VB2002
3.4. Hour:VB2003
3.5. Minute:VB2004
3.6. Second:VB2005
```

/ / 4. Defining of number of satellites and quality of the signal.

/ / Variables of the GPS system satellites number and signal quality parameters will be defined:

```
4.1. SinView:VB2020 // global variable the satellite SAT, byte type
     address;
4.2. HDoP:VD2030 // global variable of the dopler frequency DOP,
     double type address;
4.3. GPS_FIX:VB2034
```

```
4.4. PSRec_Warnig:V2021.0
```

/ / 4. Converting of dispatcher station width and length from degrees to its tens and hundreds:

```
5.1. #loc_LatDeg:LW16 // local variable of length LD, in degrees, Long
     Word;
5.2. #loc_LatMin:LD18 //local variable of length LD, in degrees, Long
     Word;
5.3. LatDir_RS:VB2006
5.4. #loc_LongDeg:LW22
5.5. #loc_LongMin:LD24
5.6. LongDir_RS:VB2007
5.7. AC0
5.8. AC1
5.9. V2035.1
5.10.V2035.2
```

/ / 6. Converting of the object (train) speed into m/s:

6.1.# local variable of speed SP, m/s, byte type address;

/ / 7. Development of data buffer:

/ / If the data obtained from GPS receiver contain no error - go to subprogram:

```
7.1. LDN V2035.1 // Register of global variables;
7.2. AN V2035.2 // Register of global variables;
7.3. MOVR AC0, VD2280
7.4. MOVR VD2280, #Lat:LD0
7.5. MOVR AC1, VD2284
7.6. MOVR VD2284, #Long:LD4
7.7. MOVR AC3, VD2288
7.8. MOVR VD2288, #Alt:LD8
```

/ / If the data obtained from GPS receiver contain no error - go to 9.

/ / 8. Development of data buffer:

/ / If the data obtained from GPS receiver contain errors - taking the data from the buffer:

```
8.1. LD V2035.1 // local variable, double Word type address;
8.2. O V2935.2 // Register of global variables;
8.3. MOVR VD2280, #Lat:LD0 // platuma globālais mainīgais, double Word
     tipa adrese;
8.4. MOVR VD2284, #Long:LD4
8.5. MOVR VD2288, #Alt:LD8
```

/ / 9. Go to 1.

Algorithm of train control system operation in braking regime

Preset: L_1 $V(t_0)$ - locomotive; t_0 - speed of the locomotive L_1; $A(X_2, Y_2, Z_2, t_A)$ - initial moment at the given locomotive coordinates L_1; $B(X_3, Y_3, Z_3, t_B)$ - the preset stop point of the train; C - coordinates of the barrier; X_5, Y_5, Z_5, t_C ($V(t_0)$,) - traffic light ; G*- point of the beginning of the train braking;

Step 1. Initialization - defining of the system objects. L_1 - locomotive; A - the preset stop point of the train; B - coordinates of the barrier; C - traffic light ; G*- point of the beginning of the train braking;

Step 2. Defining of the system objects coordinates within the space: $L_1(X_2, Y_2, Z_2, t_A)$ - defining of the locomotive coordinates with IPS system, including real time and data moment; $V(t_0)$ - locomotive L_1 defining of speed with IPS system; t_0 - initial moment at the given locomotive coordinates L_1; $A(X_2, Y_2, Z_2, t_A)$ - the preset stop point of the train; $B(X_3,Y_3,Z_3,t_B)$ - coordinates of the barrier; C (X_5,Y_5,Z_5,t_C,) - traffic light ; G*- point of the beginning of the train braking;

Step 3. Defining of the system object parameters – $V(t_0)$ - locomotive L_1 defining of speed with IPS system; defining of traffic light signals: Az - prohibiting: Z - allowing; Existing of the functioning automatic signalling system of the locomotive.

Step 4. Evaluation of braking necessity :

$$S_T = \frac{v_0 t_n}{3{,}6} + \sum \frac{500\left(v_N^2 - v_K^2\right)}{\zeta\left(w_{ox} + b_m + i_C\right)} \to \max ; \qquad t_m = t_p + \sum_{i=1}^{n} \frac{v_n - v_k}{3{,}6 \cdot \varepsilon_i} \to \max ; \qquad v = v_0 + \int_0^t a \partial t \to 0 ;$$

$$0{,}6 \le \varepsilon_i = \frac{v_n^2 + v_k^2}{2 \cdot 3{,}6^2 \cdot \Delta S_p} \le 0{,}8$$

; If - C signal of traffic light is Az - prohibiting: go to step 5; No - go to step 2;

Step 5. Evaluation of driver controlling impact onto the train braking system: Yes - go to step 2; No - realizing of braking automatic regime with the use of wireless communication system IPS ;

Step 6. Go to Step 2.

The procedure for the control of train braking regime listing STL language programmable logic controller

/ / 1. Input of the parameters into controller.

```
1.1. LD SM0.1 // call in each cycle;
1.2. CALL Initial:SBR18 //  call of initialization subprogram;
```

/ / 2. Initialization of Ethernet block subprogram.

```
2.1. LD SM0.0 // call in each cycle;
2.2. CALL ETH1_CTRL:SBR14 // Ethernet connection subprogram;
2.3.M2.0
2.4.VW2200
2.5.VW2202
```

/ / 3. Initialization of GPS receiver calling subprogram.

```
3.1. LD SM0.0 // call in each cycle;
3.2. Lat_RS:VD2008 // global variable;
3.3.Long_RS:VD2012 3.4.Alt_RS:VD2016
3.4.Alt_RS:VD2016
3.5.Speed_RS:VD2250
```

/ / 4. Initialization of the distance between the objects subprogram in testing regime.

```
4.1. LD SM0.0 // call in each cycle;
4.2. Lat_RS:VD2008 // global variable of width, double Word type
     address;
4.3. Long_RS:VD2012
4.4. Alt_RS:VD2016
4.5. Lat_ML:VD2210
4.6. Long_ML:VD2214
4.7. Alt_ML:VD2218
4.8. mass:VD2230
4.9. Speed_ML:VD2254
4.10.Speed_RS:VD2250
4.11.Distance_:VD2238
4.12.Brake Distance:VD2258
```

/ / 5. Initialization of control bits subprogram.

```
5.1. LD SM0.0// call in each cycle;
5.2. CALL Control_bits:SBR23 // Initialization of control bits
     subprogram.
```

/ / 6. Initialization of mass factor subprogram.

```
6.1. Definition_mode:V1990.1 // call in each cycle;
6.2. Alt_ML:VD2218 // object width global variable, ML, in degrees,
     Double Word;
6.3. Speed_ML:VD2254
6.4. mass:VD2230
```

/ / 7. Initialization of braking control subprogram.

```
7.1. SM0.0 // call in each cycle;
7.2. Distance_:VD2238 // global variable;
7.3.Brace D_VD2234
7.4.BRAKE:V1991.1
```

/ / 8. Initialization of Sinaut Micro SC with GPRS modems of data exchange subprogram.

```
8.1. LD SM0.0 // call in each cycle;
8.2. CALL GPRS_blocks:SBR1 // Initialization of data transmission
     subprogram;
```

/ / 9. Initialization of display TD 400 control subprogram.

```
9.1. LD SM0.0 // call in each cycle;
9.2. CALL TD400Ń:SBR17 // Initialization of display TD 400 control
     subprogram;
```

The procedure for the control of braking STL language programmable logic controller

/ / 1. Procedure of braking control:

```
1.1. LD SM0.0 // call in each cycle;
1.2. Test_mode:V1990.2 // testing regime, register of global
     variables;
1.3.BrakeDistance:VD2258
1.4. +R 50.0, AC0
1.5. AR<= #Dist:LD0, AC0
1.6. S #Brake_ON:L8.0, 1
1.7. LPP
1.8. AR= Speed_ML:VD2254, 0.0
1.9. R #Brake_ON:L8.0,1
1.10. R Test_mode:V1990.2,1
1.11. S Normal_mode:V1990.0, 1
```

Neural networks for electrical insulation diagnostic tasks

Neural networks for electrical insulation diagnostic tasks become necessary to maintain towed by an electric motor operating conditions, to provide traction and braking modes. To this research and develop the neural network model for electrical diagnostics. Neural network training algorithms are defined in electrical insulation diagnosis for the problem. In order to solve the traction motor insulation diagnostic task will use neural network, which consists of a single perseptron layer. Each neuron is calculated input signal and the amount of floating cells was the way out, which is similar to +1 or -1, the threshold function applications. If the output values shall decide:

- +1 - output belongs to class A, and the traction motor insulation condition is good;
- -1 - output belongs to a class B, and the traction motor insulation requires repair;

Neural network terms:

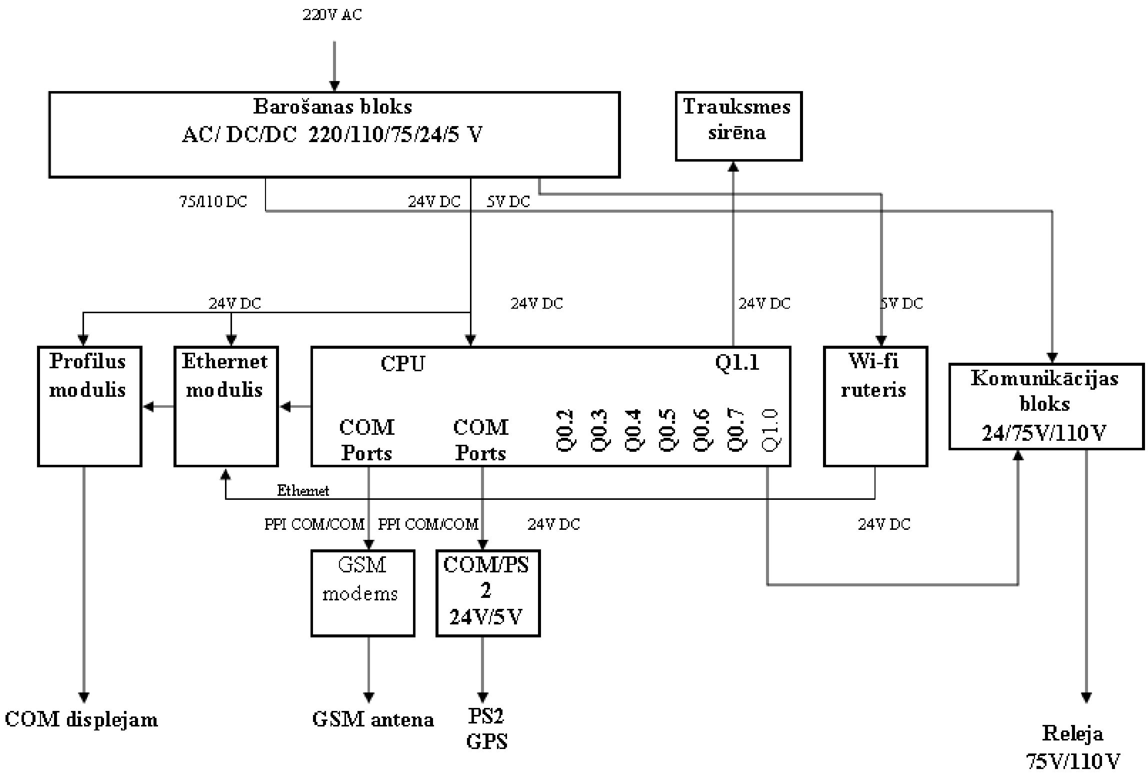
t - time moment;
i, j, k - the neural network code.
n - iteration, which corresponds to the nth training image;
X (t) - m-dimensional input signal at time t;
xi (n) - input vector X (n) the ith element of the n-th iteration;
C (t) - neural network output at time t;
wji (n) - the weight between the i-th and j-th layer neurons;
bj -shift of the neurons

The general mathematical model of the neural network
Neural network mathematical model:

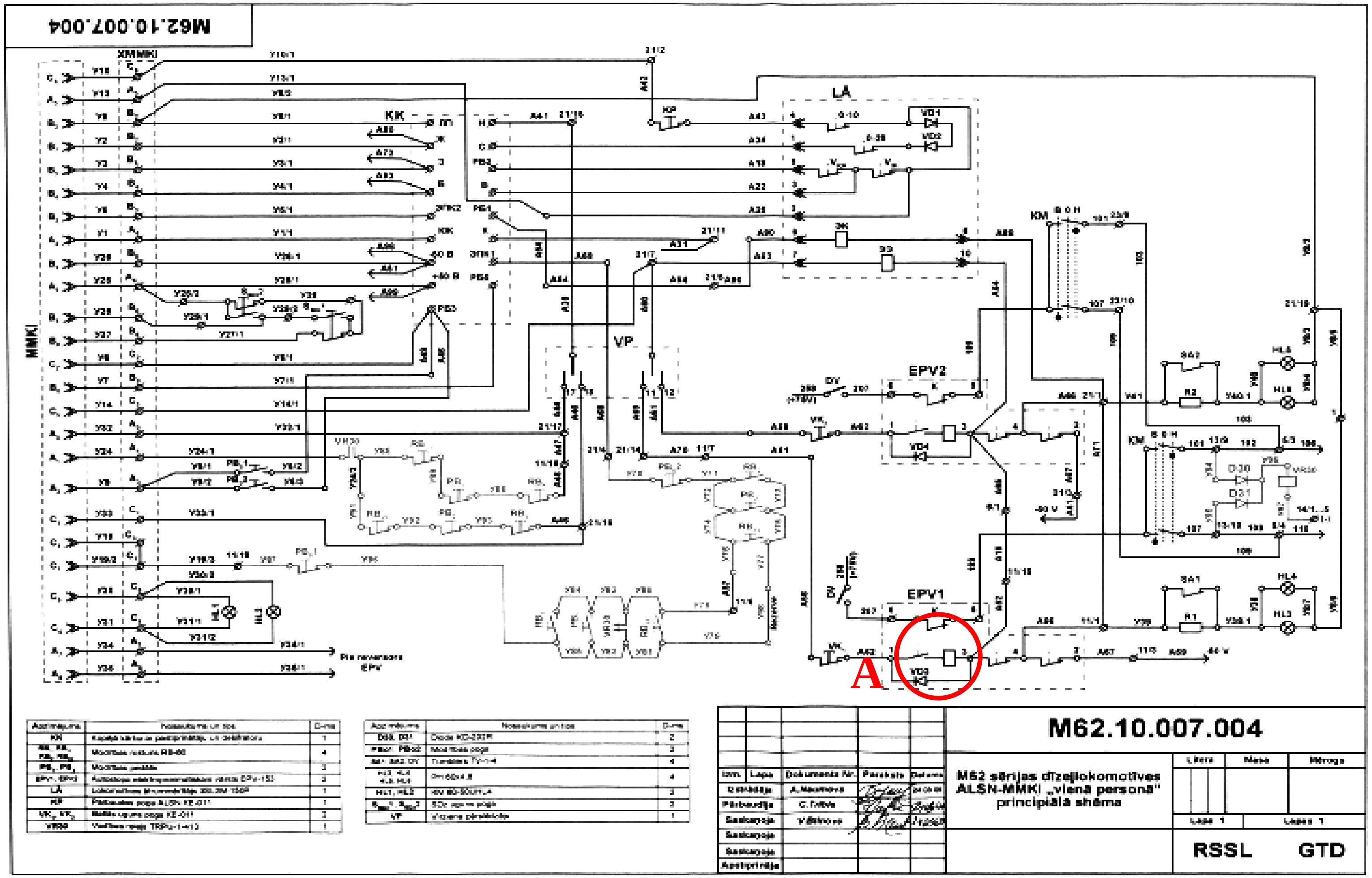
- neural network input vector: $X = \{x_1, x_2, \ldots, x_n\}$;
- Neural network output vector: $C = \{c_1, c_2, \ldots, c_m\}$;
- Weight vector for each set of j-ta-ta i-layer neuron inputs: $W_i^j = \{w_{i1}, w_{i2}, \ldots, w_{in}, w_{in}\}$;
- Offset for each j-th layer of the i-th neuron b_i^j;
- summation function for each j-th layer, the i-th neuron: $Y_i^j = \sum (w_i^j \cdot X) + b_i^j$;
- Activation function of all the j-th layer neurons: $Y^j(Y^j)$;

Direct propagation algorithm
Monolayer perseptron learning algorithm:

1. Step 1. Weight and leakage initialization:
   Value $Wi(0)$ $(0 \leq i \leq (N-1))$ and neuron b leakage when installed Similarly, some small number of cases.
2. Step 2. New input and desired output signal to the network installation:
   The input signal $X = (x_0, x_1, \ldots x_{N-1})$ is set in a neuronal together with the desired output signal C.
3. Step 3. Neuron output to estimate:
$$y(t) = \left(\sum_{i=0}^{N-1} W_i(t) X_i(t) - b \right);$$
4. Step 4. Weight value adjustment:
$$W_i(t+1) = W_i(t) + r[C(t) - y(t)]x_i(t);$$
$$0 \leq i \leq N-1; \qquad ;$$
$$d(t) = \begin{cases} +1, vai \ \ klase \ A \\ -1, vai \ \ klase \ B \end{cases}$$
   Where r - the training step,
   (t) - desired output signal.
5. Step 5. Moving to pitch the second 2.

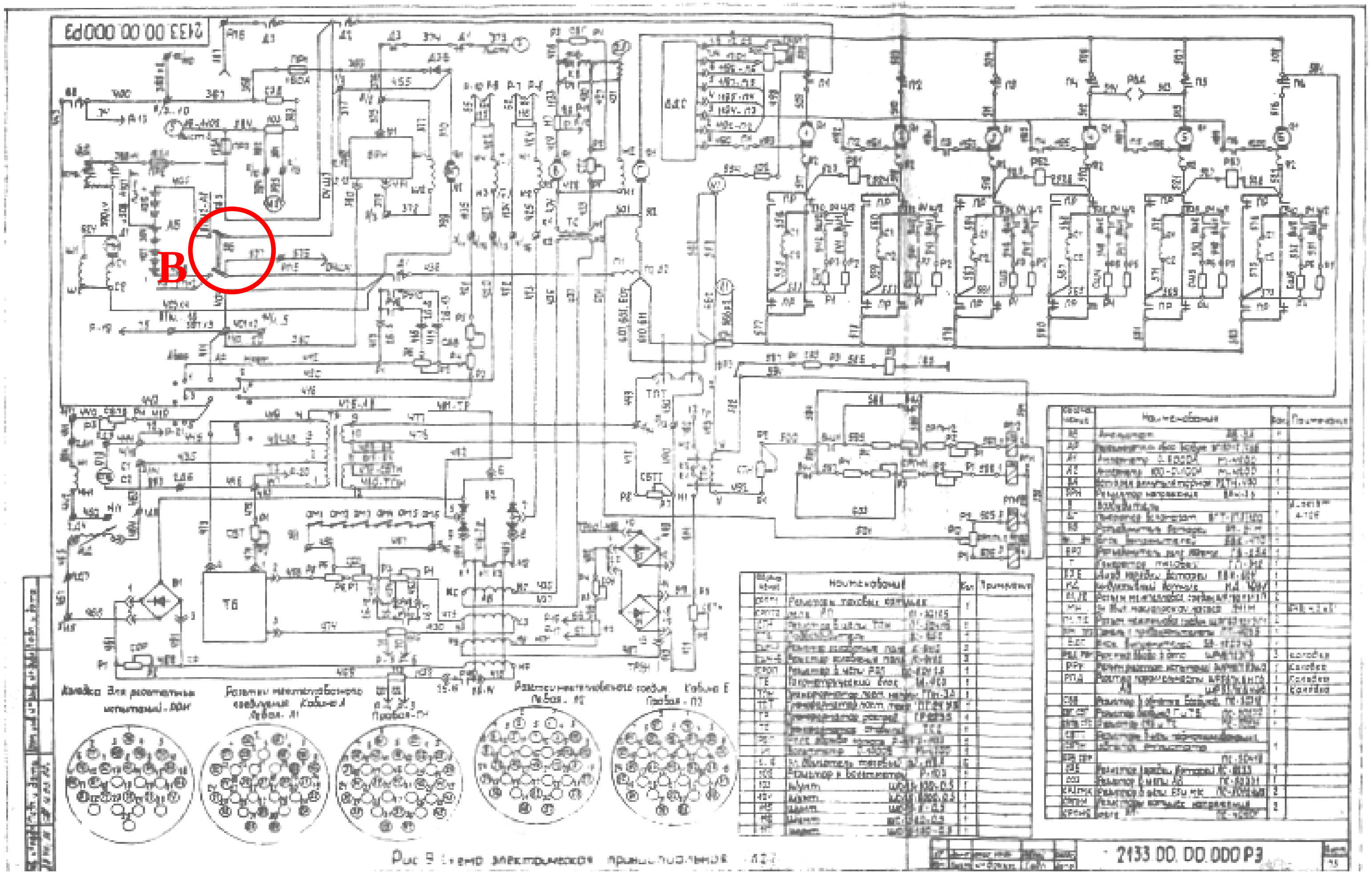


4.fig. Experimental embedded equipment block scheme.



5.fig. Locomotives M62.10 eclectic scheme, to which were made in a series of experiments

(With a red circle A appears excluded relay coil).



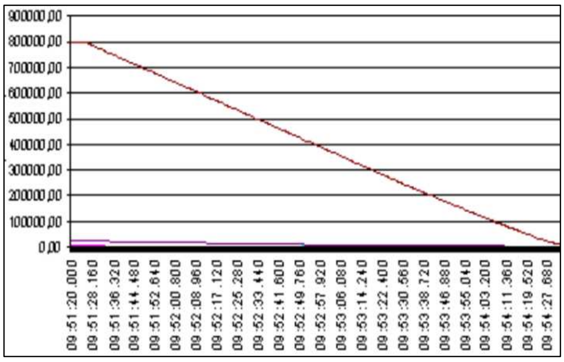
6.fig. Locomotives M62.10 eclectic scheme, to which were made in a series of experiments
(With a red circle B shown in SAFE -3R power connection)

Develop models and algorithms study results

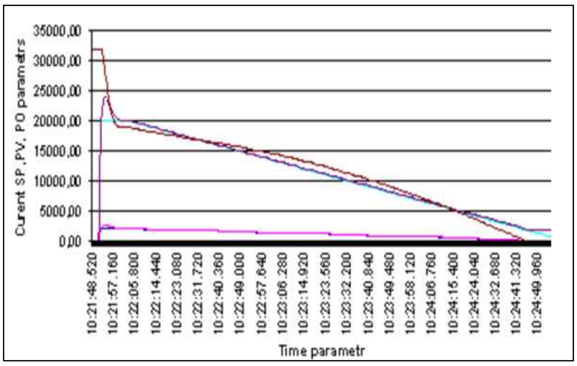
Developed and tested in practical advanced electric brake automatic control system, which, unlike the ones, enabling the location of electric and electric realize the suspension before the traffic lights to signal the Prohibition of the positioning systems that are used.

Experiments are carried out, the results, which allow you to control electric speed, mass, location, and alignment with the positioning system is applied.

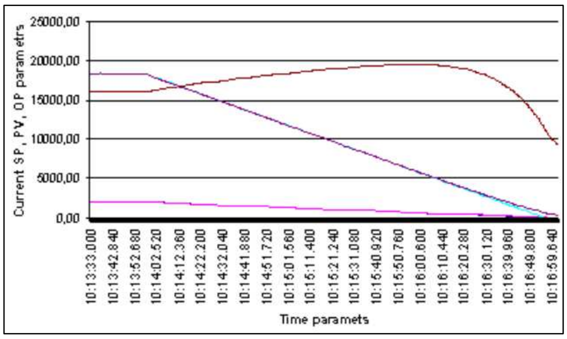
For example, 7-10 images represent the system under study braking test curve after exposure to leading-board controller on the locomotive brake system.



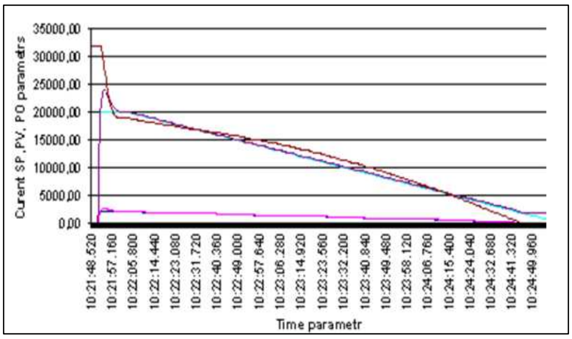
7.fig. Test results. Brake test Nr 1.



8.fig. Test results. Brake test Nr 2.



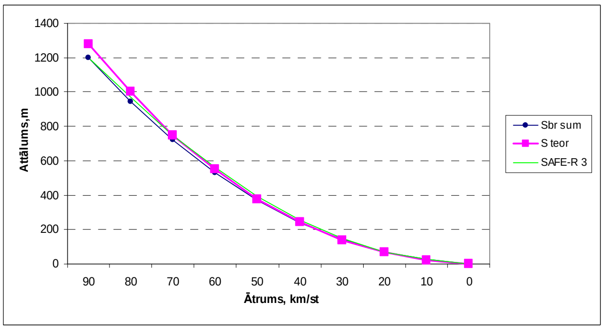
9 fig.Test results. Brake test Nr 3.



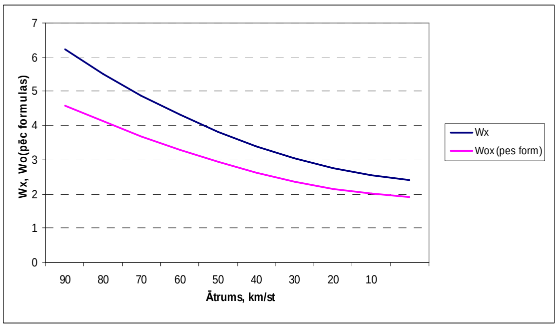
10 fig . Test results. Brake test Nr 4.

Since the test No. 1. with a red line appears desirable (in theory) the braking trajectory, test No. 2., 3., 4. is reflected in the actual braking path, built-in controller lead-effect of braking systems and the controlled system response to achieve the answer to stopping the trajectory.

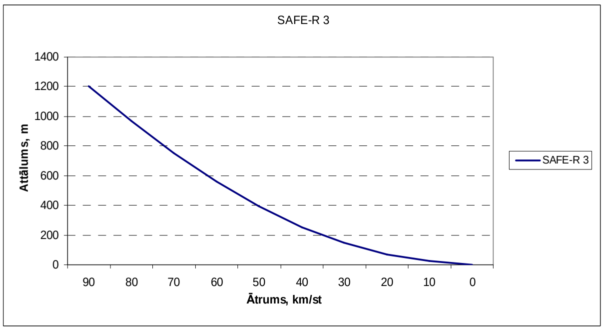
11-14 images below shows the stopping distance dependence of the locomotive speed and the comparison with the developed by the braking SAFE-R3 assistance.



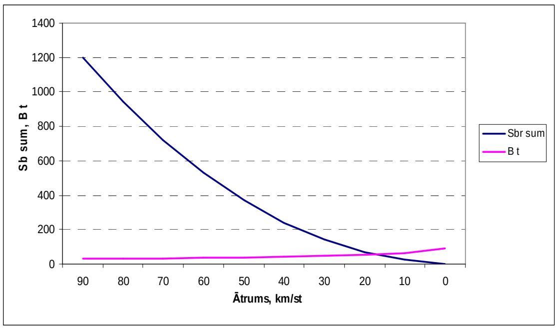
11 fig.Test results.T est Nr.1



12 fig. Test results. Test Nr.2



13 fig.Test results. Test Nr 3.



14 fig. Test results. Tests Nr 4.

Conclusions of research

- The task for modeling of electrical equipment operation in the regime of locomotive braking is formulated, that in contrast to existing models allows comparison of different processes and algorithms for embedded intelligent systems with the application of neural networks.
- The general algorithms of locomotive braking system control is developed and the structure of the algorithm is described, that in contrast with the existing systems allow sending of the control signal to the braking system of electric transport for its stop in front of traffic light with inhibit signal without control from the driver's side applying the embedded electronic programming devices with Positioning Information System.
- A new method for defining of braking way parameters is developed and described, the method applies embedded electronic programming devices on the basis of Positioning Information System.
- A new method of defining of electric transport speed is developed and described, that in contrast with the existing allow stop of the electric transport at a particular point with the given coordinates in front of traffic lights with inhibit signal, applying embedded electronic programming devices on the basis of Positioning Information System.

- A model of electrical equipment operation in the regime of locomotive braking, that in contrast to existing models allows comparison of different processes and algorithms for embedded intelligent systems is developed and experimentally tested.
- An improved method for calculation of electric transport braking parameters; the method in contrast with the others existing allows control of the electric transport speed, location and profile of the road is developed and experimentally tested.

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