Algorithm for Public Electric Transport Schedule Control for Intelligent Embedded Devices

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***Abstract*. In this paper authors present heuristics algorithm for precise schedule fulfilment in city traffic conditions taking in account traffic lights. The algorithm is proposed for programmable controller. PLC is proposed to be installed in electric vehicle to control its motion speed and signals of traffic lights. Algorithm is tested using real controller connected to virtual devices and real functional models of real tram devices. Results of experiments show high precision of public transport schedule fulfilment using proposed algorithm.**

***Keywords:* public electric transport, algorithm for intelligent controller, traffic lights control**

I. Introduction

Nowadys in cities number of vehicles is increasing day by day. Traffic jams are the main reason for a lot of problems for public transport like delays, inefficient usage of energy etc. Fulfilment of the schedule in such conditions is unforeseen. And service level of public transport is going down.

Therefore some solutions to fulfil the schedule are necessary. There are some different ways to reach the goal.

The first possible solution is to change to schedule of the transport on-the-fly and show new schedule on the electronic tables of the passenger stops [1]

Another solution is to improve service level is to increase number of electric transport units. But this solution increases expenses of public transport companies in times [6].

In previous papers authors proposed two solutions such as optimal speed and schedule control [2] and "green wave" [4], which allows the tram to switch the traffic light to green for the time that is necessary to cross the road. The tram is moving from one passenger stop to another without any additional braking on the traffic lights.

In this paper new improved algorithm of uninterrupted motion of public electric transport and schedule completion is proposed and adopted to for industrial controller to create coordinated traffic lights working to public electric transport's good and to fulfil the schedule to provide better service.

II. Problem Formulation

To organize uninterrupted moving on the route is very important for standby time decreasing and consider the schedule in public transport. Currently in the Riga city traffic lights and public transport units are working separate from each other. They have not shared control system and have not coordinated along public transport routes.

If transport units moving on the route and traffic lights will work coordinated, this could decrease electric transport standby time, eliminate often breaking and acceleration, finally save electricity.

The purpose of this research is to create algorithm for electric transport moving control on the route according predefined schedule to put into practice the controller. Object of research is public electric transport system.

Main tasks of research are the following:

- to define structure of public electric transport with intelligent controllers;
- to develop algorithm of schedule fulfilment of public electric transport for programmable controller;
- to create computer model of proposed embedded control system;
- to create a functional model with real and virtual devices with realization of control algorithm in PLC.

Electric transport control system consists of vehicle moving control scheme, programmable controller and DC drive model as shown in Fig.1. Electric transport units receive GPS signal about current location, controller according received signal and predefined schedule calculate and send through transmitters signal for DC drive control and in same time relevant signal to traffic lights.
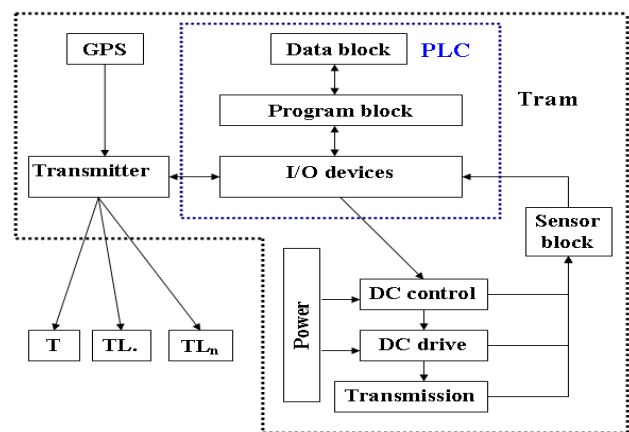

Fig. 1. Structure of control system of electric transport and traffic lights.

Pulse width adjustment technique for DC drives is proposed. PLC changes the pulse width depending on the received signals and pre-set data. As a result is DC drives rotational speed changes. Limit to the maximum rotational speed of 20 m / s is given for this task. Mechanical load during simulation is constant. Electrical scheme for DC drives with PLC control is presented in Fig.2.
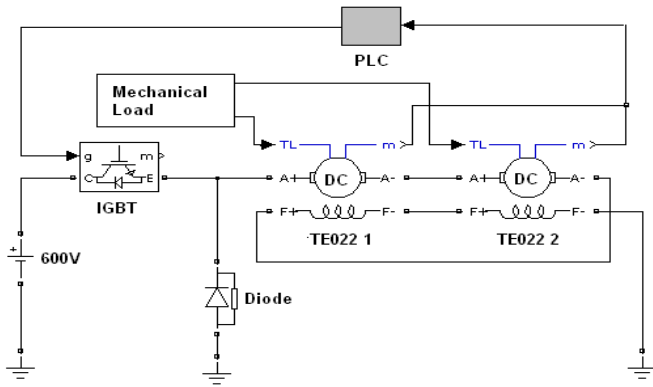
Fig. 2. Electrical scheme for DC drives control.

The following input data are necessary for the controller of the tram:

- Coordinates of passenger stops
- Coordinates of traffic lights
- Tram arrival time for passenger stops
- Tram waiting time on stops

Motion controller of the tram continuously receives data about the current transport spatial position and current time. The required speed for electric vehicle is calculated in accordance to the distance to the next stop.

Optimal time point to switch a next traffic light signal to green is calculated depending on the instant location and time. It provides a continuous movement of vehicles without stopping.

III. MATHEMATICAL MODEL FOR ALGORITHM

A. Nomenclature

Following definitions are proposed for mathematical model of algorithm:

1) A set of processors P – stops and traffic lights, where P = {P1, P2}, P∈N while Stops:

$$P^1 = \{p_1^1, p_2^1, ..., p_s^1\} \subset P$$

Traffic lights:

$$P^2 = \{p_1^2, p_2^2, ..., p_c^2\} \subset P$$

2) A set of jobs T – vehicles, where T={=t1,t2,..., tm}
Each vehicle has the schedule:

$$\forall t \in T, \quad \sigma_u : P^1 \rightarrow \{t_{u1}, t_{u2}, ..., t_{us}\} \subset \Re$$

Each passenger stop has the schedule:

$$\forall p \in P^1, \quad \sigma_p : T \rightarrow \{t_{p1}, t_{p2}, ..., t_{pm}\} \subset \Re$$

B. Parameters for DC drive

Each vehicle U DC drive E has following electrical and mechanical parameters:

I_{ie} – field current;
I_e – armature current;
c_f – magnetic flux;
$c_m = cf/2\pi$ – rotation torque constant;
n – rotation speed (apgr./s);
ω – rotation speed (rad/s);
U_m – DC engine voltage
L_e – armature inductance
R_e – armature resistance
L_{ie} – field inductance
R_{ie} – field resistance
L_{eie} – field-armature mutual inductance
g – duty ratio of pulse regulation
E_v – used vagon energy
J – inertia
B_m – viscous friction coefficient
T_L – torque
T_{ie} – Coulomb friction torque

In this investigation the centre of attention is ω – rotation speed (rad/s);Following parameters of the electric transport vehicle are controlled and calculated:

V_T – vehicle speed
S_T - vehicle made by way
$t_{current}$ – current time
S_{TP} – distance between vehicle and object
S_{br} – stopping distance
t_{br} - required braking time
V_{req} – required vehicle speed
t_{stop} – vehicle motion time till next stop
t_{tl} – vehicle motion time till next traffic light

C. Formulas that will be used in the calculation algorithm:
V_T tram speed (km / h):

$$V_T = \frac{\omega \cdot 2\pi \cdot R}{R_p} \tag{1}$$

where
- R - tram wheel radius (m);
- R_p - reduction gear ratio $R_p = 7,36$.

Tram braking distance (m):

$$S_{br} = \frac{V_T^{\,2}}{2 \cdot a} \tag{2}$$

The distance between current position of the tram X_T and the position of the stop X_P (m):

$$S_{TP} = X_P - X_T \tag{3}$$

Braking time (s):

$$t_{br} = \frac{V_T}{a} \qquad (4)$$

Time to stop the motion at constant speed V_T (s):

$$t_{motion} = \frac{S_{TP}}{V_T} \qquad (5)$$

Braking distance and the distance to the stop the comparison:

$$S_{br} \le S_{TP} \qquad (6)$$

The remaining travel time to the next stop t_{rem} (s):

$$t_{rem} = t_P - t_{current} \qquad (7)$$

Required speed $V_{required}$ (m/s):

$$V_{required} = \frac{S_{TP}}{t_{rem}} \qquad (8)$$

Formulas for obtaining the required parameters of the tram

Engine speed ω (min^{-1}):

$$\omega = (g - 40) \cdot 70 \qquad (9)$$

Simplified the calculation it is assumed that at 40% pulse width of the engine speed is already equal to zero, but at 100% of the voltage pulse width speed is 4200 min-1.

Tram speed V_T (m/s):

$$V_{Tms} = V_{Tkm/h} \cdot k \qquad (11)$$

where k - the calculated ratio $k = 0,27777$

IV. ALGORITHM FOR INTELLIGENT CONTROLLER FOR TASK SOLUTION

The public electric transport system object location scheme that will be used in the calculation algorithm is presented in Fig.3
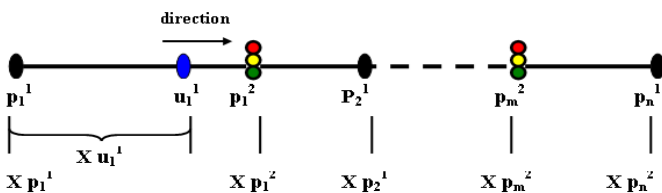
Fig. 3. The public electric transport system object location scheme.

The steps of algorithm are described below:

Sep1. Number of stops, distance between stops and arriving times are defined:
  Stops $Xp = \{1,2,...n\}$
  Traffic lights $Xl = \{1,2,...m\}$
  Speed increasing $Const_V$
  Time increasing $Const_t$
  Start point location: S_{curr}
  Start time: t_{curr}
Tram arriving time cchedule in stops:
  $t_p = \{2,3,...n\}$
Step2. START ; Start simulation
Step3. GET S_{curr} ; Get tram current location, equal to distance between starting point and tram current lication
Step4. GET t_{curr} ; Get current time
Step5. $V_{curr} = S_{curr}/t_{curr}$; Calculate tram current velocity
Step6. $S_{rem} = X_{pnext}-S_{curr}$; Calculate remaining distance up to next stop
Step7. $t_{req} = S_{rem}/V_{curr}$; Calculate requesting time to go remaining distance up to next stop
Step8. IF $t_{req} + t_{curr} < t_{pnext}$; Compare requesting time to go and schedule provided arrived time in next stop
  YES
Step9. $V_{curr} +Const_V$; $t_{curr} + Const_t$; Increase current time and speed
Go to Step3.
  NO
Step10. $S_{br(req)} = V_{curr}$ ^2/3.6 ; Calculate tram required braking distance up to next speed with current speed
Step11. IF $S_{br(req)} > X_{pnext} - S_{curr}$; Compare tram required braking distance with distance between tram and next stop
  YES
Step12. $V_{curr} - Const_V$; $t_{curr} + Const_t$; Decrease current speed and increase current time
Go to Sep3.
  NO
Step13. $S_{rem(lnext)} = Xl_{next}-S_{curr}$; Calculate remaining distance up to next traffic light
Step14. $t_{req(lnext)} = S_{rem(lnext)}/V_{curr}$; Calculate requesting time to go from current location up to next traffic light
Step15. IF $t_{req(lnext)} <= 10$
  YES
Step16. Set Signal R+Y
  NO
Go to Step3.
Step17. IF $t_{req(lnext)} <= 4$;
  YES
Step18. Set Signal G
  NO
Go to Step3.
Step19. IF $S_{curr} > S_{last}$
  YES
Step20. END
  NO
Go to Step3.

Program block diagram is presented in Fig.4-5.
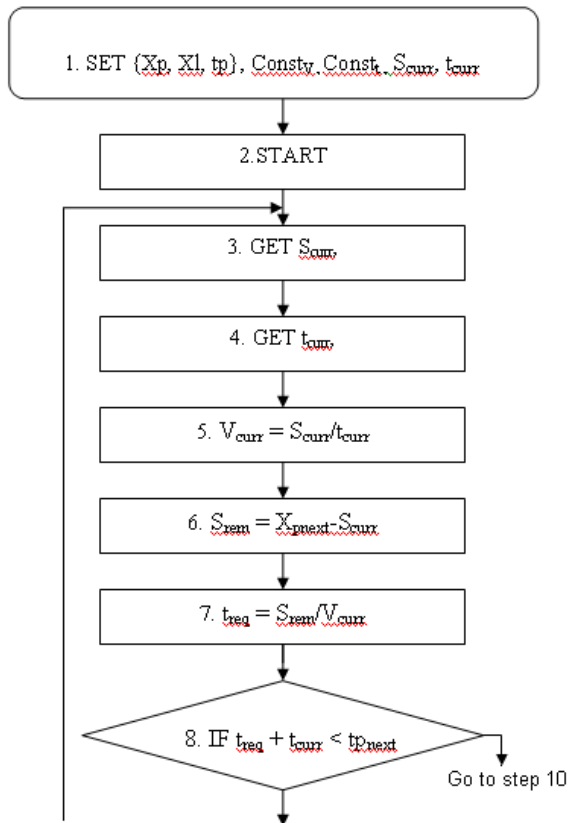
Fig. 4.   Algorithm block diagram.

V.   COMPUTER EXPERIMENT IN DEVELOPING OF INTELLIGENT CONTROLLER ALGORITHM

A part of public electric transport route was chosen as an example for computer experiment. It consists of four stops and three traffic lights. For algorithm programming industrial controller SIEMENS SIMATIC S7-200 was used.

Corresponding distance between stops and arriving in stops schedule is shown in tab.1.

TABLE 1.

STOPS LOCATION AND ARRIVING SCHEDULE

	Stop 0	Stop 1	Stop 2	Stop 3
Distance (m)	0	1000	1900	3200
Arr. time (s)	0	100	200	350

Corresponding distance between start and traffic lights is shown in tab.2.

TABLE 2.

TRAFFIC LIGHTS LOCATION

	Traff.light 1	Traff.light 2	Traff.light 3
Distance (m)	600	1500	2700
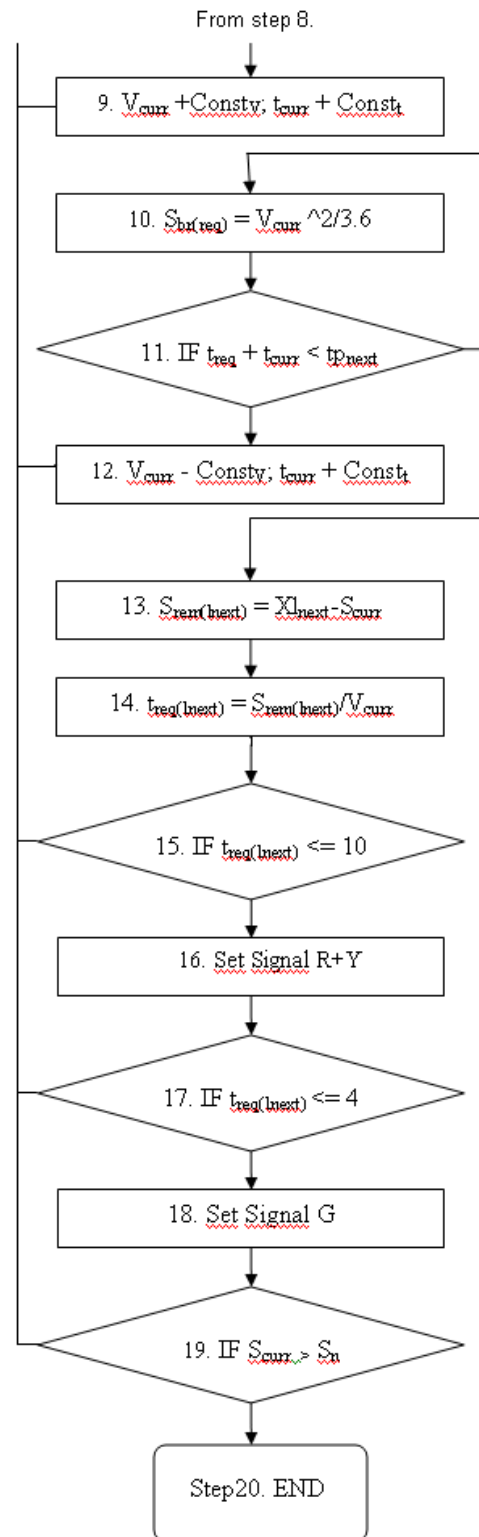
Fig. 5.   Algorithm block diagram (continuation).

Basic data was entered in SIEMENS SIMATIC S7-200 computer program Step7-Micro/Win. Part of programming code in Step7-Micro/Win environment is present in Fig.6.

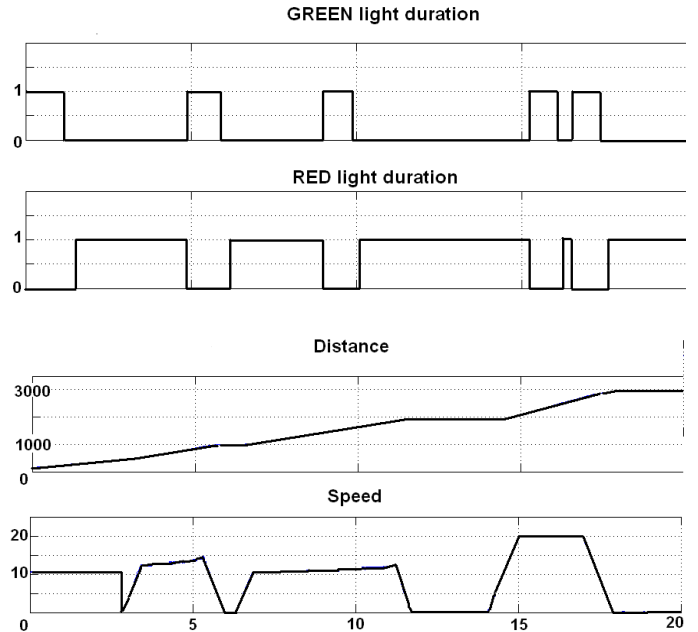Fig. 6. Part of programming code in Step7-Micro/Win environment.

Fig. 7. Tram completed distance, speed on route and traffic lights operating modes.

This part of program show calculation of several parameters:

Network 1. Required speed dependent of distance up to next stop

Network 2. Required braking distance up to full stop

Network 3. Required braking distance up to full stop at the current speed depending on the current location

Network 6. Braking simulation i.e. decrease pulse width depending on the distance up to next stop, required braking distance and tram current speed

Network 9. Acceleration simulation i.e. increase pulse width depending on tram current and required speed

The tram motion and to approach to traffic light was simulated and result of computer experiment was read in computer program Matlab Simulink environment. Tram completed distance, speed on route and traffic lights operating modes are shown in Fig.7.

VI. CONCLUSIONS

To analyzed in computer program Matlab Simulink fixed diagrams the conclusions are:

- traffic light mode RED and GREEN are switched corresponds the tram location on the route and task conditions about distance from vehicle up to next traffic light;
- the tram motion speed is control entire whole route with purpose consider predefined schedule;
- algorithm for intelligent controller can be used to solve public electric transport flow organization tasks ;
- industrial controller can be used for intelligent public electric transport schedule control.

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Using the "green wave" method is given the privileges for electric transport comparing to others; cars, trucks, pedestrians, etc. Advantages are:
− the uninterrupted motion of electric transport units decrease amount of braking-accelerating cycle on the route and therefore decrease total electric energy consumption;
− as less is electric energy consumption as cheaper passenger traffic could be provided;
− interrupted motion of electric transport units gives opportunity for optimal speed control and for considering predefined schedule.

On the other hand privilege for one type of vehicle traffic could bring about inconvenient for other types of vehicles and pedestrians. Proposed method possible imperfections are:
− staying time on crossroads for other types of vehicles is increased
− increased staying time on crossroads could step up volume and dimension of traffic jam.

To define saving up electricity and project influence on possible traffic jams it is necessary to implement additional researches.

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