A Model of Remote Control of Railway Traffic Based on PLC Technique

Saša Krstanović[1], Gordan Stojić[1], Dragan Šešlija[1], Ilija Tanackov[1], Laslo Tarjan[1] and Jovan Tepić[1]

Abstract – **Shown in this paper is a model of railway traffic regulation, based on application of Programmable Logic Controller (PLC) technique which represents a pioneering attempt in recent modes of remote control and command of train traffic. The model has been tested on a simple example of a railway station.**

Keywords– **trains, remote control, safety, signalization, PLC.**

I. Introduction

Railway interlocking systems are apparatuses that prevent conflicting movements of trains through an arrangement of tracks. These systems are finite state machines that take into consideration the position of the switches (of the turnouts) and do not allow trains to be given clear signals if the routes to be used by the trains intersect or run a turnout set against and thus cause train derailment.

Computer applications to railway interlocking systems [1]are safety critical applications and must obey the rules and conditions or informal specifications of the already designed or implemented railway interlocking system [2], [3].

According to this model, any given proposed situation is safe **if and only if** a certain set of criteria (the position and type of trains and the movements allowed - the latter depend on the position of the switches and the color of the semaphores) is met [2], [3]. This model is independent from the topology of the station and the fact that trains could occupy more than one section is also considered.

II. Overview

In this section we shall discuss some preliminary notions on the matter which can be helpful for unacquainted readers.

Locomotives and railways rolling stocks do not have wheels with plain rims but **single flanged conical wheels** which are guided along the tracks. Therefore this is a guided transportation system.

A train can be guided from one track to another only at certain places, where a**turnout** is installed (US: railroad switch).It sends trains on direct track or diverted trackwhich is displayed via turnout indicator (US: switch indicator). The turnout hastwo directions: the facing direction and the trailing (opposite) direction.

If the train came from the trailing direction, it could find the switch in the wrong position, and the train would run a turnout set against (US: make a trailing point movement). If this would happen,a turnout could be seriously damaged and/or the train could derail.

The turnouts can be designed so that running a turnout set against is allowed at very low speed . They are called ***trailable turnouts***.

However, the design of the turnouts does not usually allow running a turnout set against.

The movements of the rolling stock are controlled by **signals and semaphores**. Formally speaking, semaphores are distinguished from signals (signals are mechanical devices, usually incorporating coloured lights too) and we shall consider possible states only for (main) semaphores.

There are also ***advanced semaphores***, coordinated with the corresponding main semaphore, that can indicate the train to prepare to stop at the next (main) semaphore (i.e., to proceed at restricted speed) and***complex semaphores*** at junctions and they are controlling each possible route.

There are two main safety devices related to railway traffic: automatic block systems (regarding traffic in railway lines) and railway interlocking systems (regarding coordination among turnouts and signals/semaphores within stations, junctions, etc.).

The purpose of an **automatic block system** is to avoid collisions between trains running on a line by dividing it into intervals (denoted blocks or sections). Fixed semaphores indicate whether or not a train may enter a block (this is based on automatic train detection).

On single-tracked railway lines it is necessary to space trains to avoid collisions by maintaining at least one whole section clear behind each train at every moment. It is also necessary to avoid collisions of trains moving in opposite directions. Therefore, before authorising a train to proceed, it has to be checked that the sections ahead (until the next passing loop) are clear too.

Railway interlocking systems are designed to prevent conflicting movements through an arrangement of tracks such as junctions or crossings.

Once remote controls of turnouts and signals were concentrated in signal boxes (in order to spare workers the task of having to walk to turnouts (respectively: signals) whenever the position of their switches (respectively: arms) has to be changed), it was possible to think of global coordination of all the turnouts and signals within a railway station or junction. The apparatus that takes care of this is the railway interlocking system.

Since 1990s, high-tech companies began to install ***computer-controlled railway interlocking systems***[4-7] with topology-independent railway interlocking systems [9].

Railway interlocking systems should comply to two safety requirements, namely that trains following signals):

[1]All authors are with the Faculty of Technical Sciences, Trg Dositeja Obradovića 6, Novi Sad, Serbia,e-mail: sasa.krstanovic@gmail.com, gordan@uns.ac.rs

- cannot collide, and
- cannot derail, i.e., trains should not be authorised to run a turnout set against (if the turnout is not a trailable one) and changes of switches under a train should not be authorised.

Within a railway interlocking system **a route** denotes a path along the topology of the station or junction (for instance a path from an entrance of the station to a certain track where the train will stop). Establishing a route implies to adequately set the switches and signals/semaphores along the train route. Once an engine driver has been given a clear signal indicating a route, the route cannot be changed before the train has completely cleared it (then it is said that ***the route is locked***).

The standard approach to railway interlocking systems design is to predefine the admissible train routes and to manually study in advance their compatibility.

In this paper presented is a model of train traffic regulation based on the application of Programmable Logic Controller (PLC) and it presents a pioneering attempt in the recent ways of regulation train traffic in Serbia.

III. A Model of Remote Control of Railway Traffic

In the model presented in this paper the traffic flow on the railway is circular (Fig.1). In the model there is Station 1 and Station which are connected with interstational distances in areas A and B.

Circular connecting of train stations does not exist in practice, but in order to show a more realistic simulation of real situations with only 2 instead of 3 stations in laboratory conditions with 2 PLCs, H0 system model was made. However from the point of view of regulation manner and railway safety) the presented model truthfully presents the realistic situation in railroad traffic.

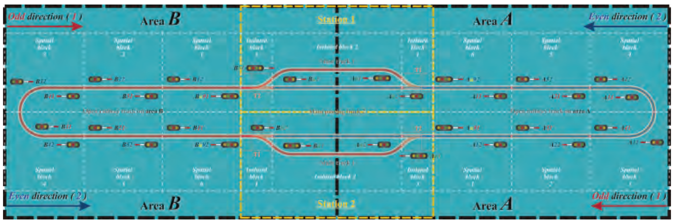


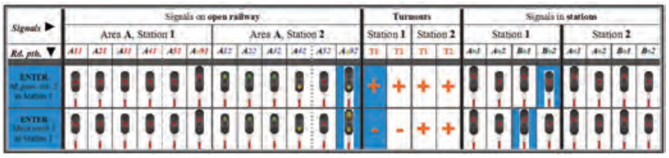
Fig.1. Situational Diagram

The model can work under two regimes: when it is governed by an operator (train dispatcher) and under the automatic regime, when the model forms train routes, based on the previously defined parameters from the timetable, dependency tables and train traffic monitoring

The whole system is meant to be modular and can be later upgraded with new modules or the existing can be changed/expanded.

In order to have safe and smooth train traffic, dependence tables have been done on the model (In total 19: 3 acceptances + 2 exits + 2 entrances + 2 combinations exit and entrance + 1 passing + 2 combinations exit, passing and entrance + 4 overreaches + 1 overtaking + 2 crossings). The dependence table represents the signal and turnout positions for all possible traffic situations on the presented model. In this paper presented is only one characteristic example of a constructed dependency table. (Table I).

TABLE I
DEPENDENCY TABLE



Space which is included in the station and open railway is defined by the number of their spatial blocks (SP) and isolated blocks (IB) which spread between isolated structures- places where the track is electrically separated into independently controlled and governed blocks.

In the model there are station tracks and tracks on the open railway (Fig.1).

Tracks in the station accept trains which after the performed manipulation (train entrance/exit, merchandize upload/unload, taking/leaving carts) and/or finished traffic reasons (crossing/ overtaking) continue their ride.

For every train ride (entrance, exit or pass trough the station) tracks and turnouts are positioned in the ride direction. A train ride on the track on the open railroad is possible only if the acceptance exists that is given by the neighboring station. The acceptance given for one path is valid for all consecutive trains until the path changes.

When the ride path is formed, the tracks in the station and on the open railroad get the color of the path in which the train is supposed to move.

Turnouts in the model have been labeled T1 and T2. Each turnout consists of the pair of linked tapering rails, known as *points*, lying between the diverging outer rails.For each turnout in the model, a position is defined based on intended ride. When the ride path is formed, the turnouts are automatically set in required position.After a finished ride over the turnout, the turnout automatically returns to its regular position (direction).

When forming the ride path or changing the direction of the acceptance in the model, all safety procedures used in practice were applied.

In this model three types of signals exist, entrance signals (Au91, Au92, Bu91 and Bu92), exit signals (Ao1, Ao2, Bo1 and Bo2) and spatial signals (A11~A51, A12~A52, B11~B51, B12~B52)(Fig.1). Entrance and exit signals that enable the ride with turning have four lanterns, while the rest have only three.

Entrance signals allow or forbid trains to enter the station and exit signals allow or forbid the exit of trains from the station. Spatial signals allow or forbid the entrance into the next spatial block depending on the fact if the next SB is available or not.

The regular position of the entrance and exist signals is "STOP". Train dispatcher or the model under the automatic regime, set the signals in the position of the enabled ride by forming entrance/exit ride path.

The signals in the model have been marked in accordance to existing rues on Serbian railroads, and signal signs they emit correspond to the signals signs being emitted on railroads where such signals (for example tracks on Corridor X). Signal signs emitted by the signals in the model have a double meaning. They inform the locomotive driver how to drive in the SB he is in and what to expect in the next SB.

Station panel (SP) represents a command-control panel from which the train dispatcher regulates the train traffic. (Fig. 2). At the same time he has the option to control. In this model there are two SP one for each station.

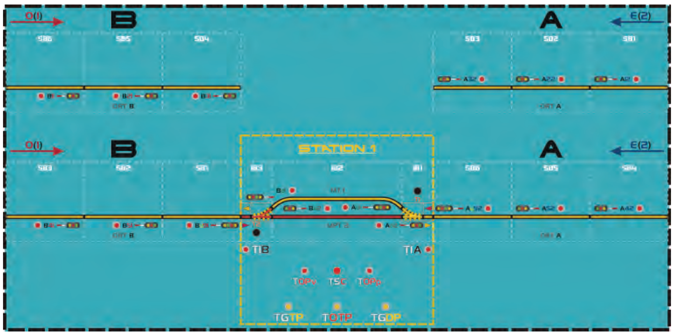


Fig.2. Station panel

From SP it is possible to allow and forbid entrance/exit of trains, to change the direction of the acceptance and to intervene in case of immanent danger. In that case the train dispatcher can put any signal to STOP position and to turn of the charge in the contact network on the electrified rails.

On SP exist the following switches: signal buttons, TGTP (combinatory button for acceptance demand), TOTP (combinatory button for denial of the demanded acceptance), TGDP (combinatory button for allowing acceptance), buttons TIA and TIB (for permitting the exit to areas A and B), TOPv (combinatory button for ride path recall), TSC (combinatory button for putting up the signal sign "STOP") and TOPp (combinatory button for the recall of overrun path) All buttons listed are used in combination with the corresponding signal button. The model executes the command only if the right combination is used.

With SP, based on the indicators, it is possible to control the position of the signal (type of signal sign), availability/ unavailability of the tracks and SB, position and availability of the turnouts and train location.

IV. PLC TECHNIQUE

A process control system is made up of a group of electronic devices that provide stability, accuracy and eliminate harmful transition statuses in production processes. As technology quickly progresses, many complex operational tasks have been solved by connecting programmable logic controllers (PLCs) and a central computer. Beside connections with devices (e.g., operating panels, motors, sensors, switches, valves, etc.) possibilities for communication among instruments are so great that they allow a high level of exploitation and process coordination. In addition, there is greater flexibility in realizing a process control system. Each component of a process control system plays an important role, regardless of its size (e.g. without a sensor, the PLC would not know what is going on during a process).

In an automated system, a PLC controller is usually the central part of a process control system. Unlike general-purpose computers, the PLC is designed for multiple inputs and output arrangements, extended temperature ranges, immunity to electrical noise, and resistance to vibration and impact. With the execution of a program stored in program memory (battery-backed or non-volatile), PLC continuously monitors status of the system through signals from input devices. Based on the logic implemented in the program, PLC determines which actions need to be executed with output instruments. A PLC is an example of a hard real time system since output results must be produced in response to input conditions within a bounded time, otherwise unintended operation will result. [8].

Advantages of control panel that is based on a PLC controller can be presented in few basic points:

- compared to a conventional process control system, number of wires needed for connections is reduced by 80%,
- consumption is greatly reduced because a PLC consumes less than a bunch of relays,
- diagnostic functions of a PLC controller allow for fast and easy error detection,
- change in operating sequence or application of a PLC controller to a different operating process can easily be accomplished by replacing a program through a console or using a PC software (not requiring changes in wiring, unless addition of some input or output device is required),
- needs fewer spare parts,
- it is much cheaper compared to a conventional system, especially in cases where a large number of I/O instruments are needed and when operational functions are complex,
- reliability of a PLC is greater than that of an electro-mechanical relay or a timer.

Steps in systematic approach in designing a process control system:

1. Select an instrument or a system you want to control;
2. Specify all input and output instruments that will be connected to a PLC controller and following an identification of all input and output instruments, corresponding designations are assigned to input and output lines of a PLC controller;
3. Make a ladder diagram for a program by following the sequence of operations that was determined in the first step;
4. Program is entered into the PLC controller memory and when finished with programming, checkups are done and, if possible, an entire operation issimulated.

Before this system is started, you need to check once again whether all input and output instruments are connected tocorrect inputs or outputs. By bringing supply in, system starts working [8].

PLCs are programmed using application software on personal computers. The computer is connected to the PLC through Ethernet, RS-232, RS-485 or RS-422 cabling. The programming software allows entry and editing of the ladder-style logic. Generally the software provides functions for debugging and troubleshooting the PLC software, for example, by highlighting portions of the logic to show current status during operation or via simulation. The software will upload and download the PLC program, for backup and restoration purposes.

For the model described in this paper, PLC has to be capable of having complete control under the automatic work regime or partial under the manual work regime. In Fig.3 presented is the algorithm based on which the PLC program instructions are performed.

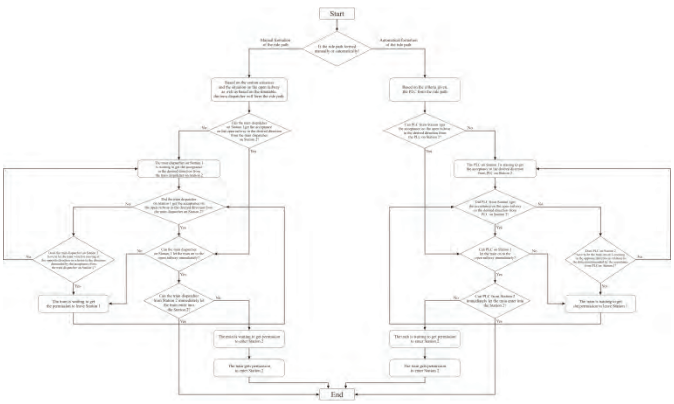


Fig.3.*Algorithm based on which the PLC instructions are performed.*

V. CONCLUSION

On railroad infrastructure in Serbia and surrounding countries, the existing system of railroad traffic is based on relay technique which has been integrated near the end of 1960s. This technique of traffic regulation, because of its age and overuse, is exposed to regular system failures. This endangers the safety and causes difficulties in traffic regulation causing significant train delays.

In the Serbian railroad system important prioritized are investments aimed at revitalizing and modernizing the infrastructure and adding more modern transport vehicles. The new techniques of traffic regulations, electronic station panels, are very expensive and are mostly a product of big industrial giants [1].

This paper represents a pioneering attempt of the application of PLC technique in regulating railway traffic in Serbia which is aimed at demonstrating the existence of domestic personnel resources and techniques that can provide contemporary and less costly solutions.

ACKNOWLEDGEMENT

This paper is a contribution to the Ministry of Science and Technological Development of Serbia funded project TR 36012.

REFERENCES

[1] Siemens, Thalis, Bombardier… promotional material
[2] Železnice Srbije,Saobraćajni Pravilnik, 1998.
[3] Železnice Srbije, Signalni Pravilnik, 2000.
[4] Siemens, Proyecto y obra del enclavamiento electronico de la estacion de Madrid-Atocha, Proyecto Tecnico, Madrid, 1988.
[5] Siemens, Microcomputer Interlocking Hilversum, Siemens, Munich, 1986.
[6] Siemens, Microcomputer Interlocking Rotterdam, Siemens, Munich, 1989.
[7] Siemens, Puesto de enclavamiento con microcomputadoras de la estacion de Chiasso de los SBB, Munich, 1989.
[8] Nebojša Matić,Introduction to PLC controllers on-line,Mikroelektronika, 2003.
[9] L. Villamandos, Sistema informatico concebido por Renfe para dise nar los enclavamientos, Vfa Libre 348 (1993) 65.
[10] Eugenio Roanes-Lozano, Antonio Hernando, A logic approach to decision taking in a railway interlocking system using Maple, Mathematics and Computers in Simulation, Article in Press, 2011.