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# Railway Fail-Safe Signalization and Interlocking Design Based On Automation Petri Net

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***Abstract*— Safe transportation on the railways can be achieved by the use of a reliable interlocking and signalization systems in order to provide safety on the railways so as to avoid fatal accidents. Presently, the relay based interlocking systems are being replaced by the programmable interlocking systems. It has both hardware and software aspects. Looking at the designing aspect a formal method can be used to fulfill the need of an efficient interlocking system so as to avoid the accidents caused due to manual operations. In this paper Automation Petri-Nets (APNs) which is an extension of Petri-Nets are being used to model a railway track interlocking and signalization operation systems. The obtained model can be converted into PLC ladder logic program easily so as to verify the accuracy for the chosen railway yard.**

***Keywords- APNs, Railway Signaliztion, interlocking systems, Switches, PLC, Automation.***

## I. INTRODUCTION

The main decision mechanism in a railway signalization is the interlocking system. In railway signalling, interlocking means "An arrangements of signal, points, field equipments and other signal apparatus that prevents conflicting movements operated whether from a panel or level frame, so interconnected by mechanical, electrical locking or both that their operation must take place in proper sequence to ensure the safety." Railway systems have characteristics of Discrete Event Systems (DES) [1] [2] such as lack of event synchronization, inherent uncertainties and complexities and therefore they can be considered as DES. Automation Petri Nets (APNs) [3] [4] [5] is a suitable formal method among several other methods that can be used for modelling this type of systems which is an extension of ordinary PNs and it also includes both sensors and actuators. The main advantages of APNs are easy graphical illustration, easiness in modelling and implementing on PLC [7] [8], easy tracking of error and modification. In addition to this, not only APNs can be used for modelling purposes they can also be used for design of supervisory control of interlocking and signalization and for different railway operations.

In this paper, a sample railway yard is chosen and the modelling is done by using APNs. Furthermore, the simulation of the obtained model is done on a PLC to check the accuracy.

The advantage of using a PLC for interlocking and signaling is to automate the system so as to reduce the human intervention and to improve the reliability of the system by reducing the chances of errors.

This paper is structured as follows: after introduction in section I, section II gives a brief description of APNs. The various components in railway signalization and interlocking are discussed in section III. Design and model of a sample railway yard by APN with the Token passing logic (TPL) is presented in section IV.

Lastly, some conclusion and discussion are given in section V.

## II. AUTOMATION PETRI NETS

Petri Net (PNs) is a weighted bipartite directed graph which mainly consists of places, transitions, directed arcs and tokens. APN can be obtained by adding four terms to ordinary PNs. An APN is defined as follows and is shown in fig. 1.

APN = (P, T, Pre, Post, In, En, $\chi$, Q, Mo)

P: {p1, p2… pn}, finite set of places.

T: {t1, t2… tn}, finite set of transitions.

Pre: (PxT) → N, directed ordinary arcs from places to transitions (N is a set of nonnegative integers).

Post: (TxP) → N, directed ordinary arcs from transitions to places.

M0: P → N, initial marking

In: (PxT) → N, inhibitor arcs from places to transitions.

En: (PxT) → N, enabling arcs from places to transitions.

$\chi$: {$\chi$1, $\chi$2,…, $\chi$m}, firing conditions associated with the transitions.

Q: {q1, q2… qn}, finite set of actions that might be assigned to the places.

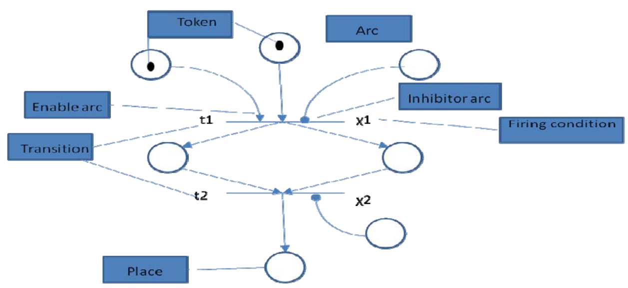


Fig. 1 Automation Petri Nets

In addition to ordinary directed arcs (→) defined in PNs, inhibitor arcs and enabling arcs are added to APNs structure. These newly added arcs are ineffective on the number of tokens in places but enable or inhibit transitions.

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It is shown in figure 1 that if a place is connected to a transition with an enabling arc that transition can be fired, if, and only if, the token number of that place is equal to or greater than the number of enabling arcs. Likewise if a place is connected to a transition with an inhibitor arc that transition can be fired, if, and only if, the token number of that place is less than the number of inhibitor arc.

More than one action can be assigned to places, and by putting enough number of tokens on a place, the assigned actions are activated. However, a transition can be fired under two conditions: firstly, the number of tokens on a place must be greater than or equal to the number of ordinary directed arcs, and secondly transition firing condition $\chi$ (information coming from sensors that is associated with transition *t*) must be satisfied. When these two conditions are satisfied, tokens can be passed from one place to the other through transition *t* and the number of tokens on both places decrease and increase.

In Figure 2 (a) the number of tokens on *P1* is equal to the number of ordinary arcs between *P1 - t1* therefore *t1* is enabled. If firing condition $\chi 1$ is satisfied then transition *t1* is fired and the number of tokens on *P1* are decreased (by the number of ordinary arcs from *P1* to *t1*) and the number of tokens on places connected to *t1* are increased (by the number of ordinary arcs from *t1* to *P2* and *t1* to *P3*) as can be seen in Figure 2 (b).

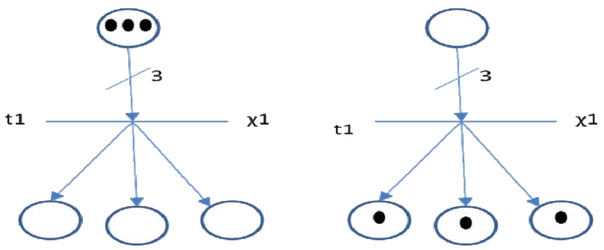


Fig. 2 Token Passings

APNs which is one of the suitable formal method and is discussed in this section. The various components in railway signalization and interlocking system are described in the next section.

## III. Components of Railway Interlocking and Signalization System

### A. *Railway switches:*

Switches are mechanical devices through which train changes their direction or route from one track to another due to the absence of steering mechanism in railway vehicles. Switches are controlled over switch motors and generally have two states normal and reverse.

With the help of sensors particular data related to the condition of a switch are transmitted to the interlocking systems. An example of crossover switch is shown in fig. 3.

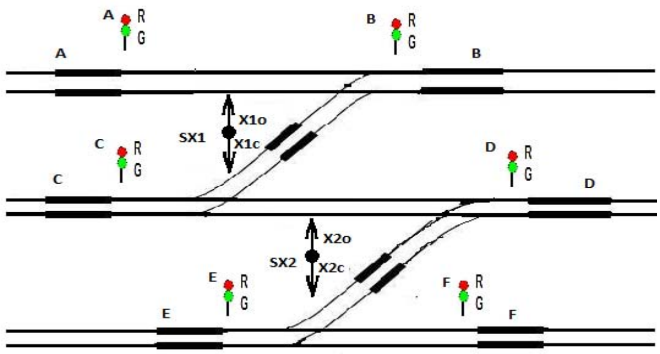


Fig.3 A sample railway yard with two crossover switches

### B. *Track circuits and signal lights:*

Track circuits are electronic components that detect the presence or absence of a train on a railway. They are used to inform signalers and other control equipment. It can be of two types AC or DC track circuits. A logical '1' is sent to the interlocking system when no train is present on track otherwise a logical '0' is sent if a train is present on a track. Signals are the lights that are placed in front of the switches on railway yards to inform the train driver if the railway yard is occupied or not via the interlocking system.

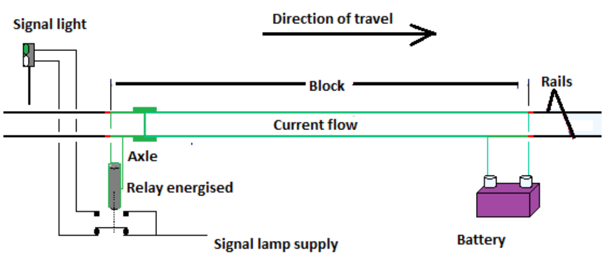


Fig.4. Track circuit and signaling

### C. *Interlocking:*

Interlocking is the part of the signaling system and is the main decision mechanism in a railway signalization. For a complex network with heavy traffic it is important that the signal is taken off only after the ensuring the traffic is clear, points are set, locked and secured for the particular route on which the train is to traverse, interlocked level crossing gate falling in the route of the train including the overlap, are closed and locked against the traffic so as to ensure safety. For a particular track the interlocking enables reservation by changing the conditions of the field equipments to an appropriate position so that no other train can occupy the same track and it assures safety such that no collision could occur.

The prohibited railway track becomes enabled for new route reservation only, after the train completes the route reserved for it.

All these components play a major role in the railway interlocking and signaling system. The APN model of the

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chosen railway yard with the TPL is presented in the next section.

## IV. Interlocking, Signalization and TPL

In this paper railway yard given in Figure 3 is used. The entrance of any train on this railway yard can be sensed via track circuits which are established in regions A, B, C, D, E and F. After entering the section the train follows the route which is reserved by TCC. In the Fig.3 Railway yard there are two crossover switches in the section X1o X1c and X2o X2c which shows the position of the switch. When switch SX1 is in X1o position, crossing from the upper track to lower track is enabled, otherwise crossing is disabled and this condition is similar to the other switches also. For the chosen sample railway yard in Figure 3, the APN model [9] [10] can be seen in Figure 5. Since only one train can exist on a railway track, so for every track circuit M (bit) memories are used by the PLC. Incoming signals are the inputs of the PLC (ascending (↑) and descending (↓) edges) from track circuits and reserved route information provided by CTC are compared with each other by PLC, then lights on the reserved routes are turned to green and all the others are kept on red.

While a train is moving on its route all lights which are passed by turn back to red immediately for new reservations. Note that all lights are red and switch is on T1c position when there is no train on the railway yard.

APN of railway yard consists of 39 transitions with 15 places. Firing conditions associated with the transitions are ascending and descending edges of the input signals incoming from track circuits. If all conditions are satisfied then related transitions is fired and token (train) passes from that place (track circuit) to another place (track circuit). For example, in order to fire transition t35, four conditions has to be satisfied which are as follows: There have to be a train on TC-E, TC-F must be reserved and there mustn't be any train between TC-F and TC-E, TC-X2 mustn't be reserved and if the descending edge signal of TC-F is received afterwards t35 will be fired and train (token) can pass from one place to another.

While the train is moving along its route related lights and switch (if necessary) change their position. At the beginning, it is assumed that all lights are on red and all the switches are in there c position i.e. X1c and X2c. When a track circuit is reserved by CTC then the related light turns green while the others remain red. This is provided by enabling arcs, for example in order to turn light E into green TC-E must be reserved that is provided by putting a token into place PEm.

The APN model obtained in fig. 5 can easily be converted into ladder logic and implemented on a PLC via Token Passing Logic [11] -[14].

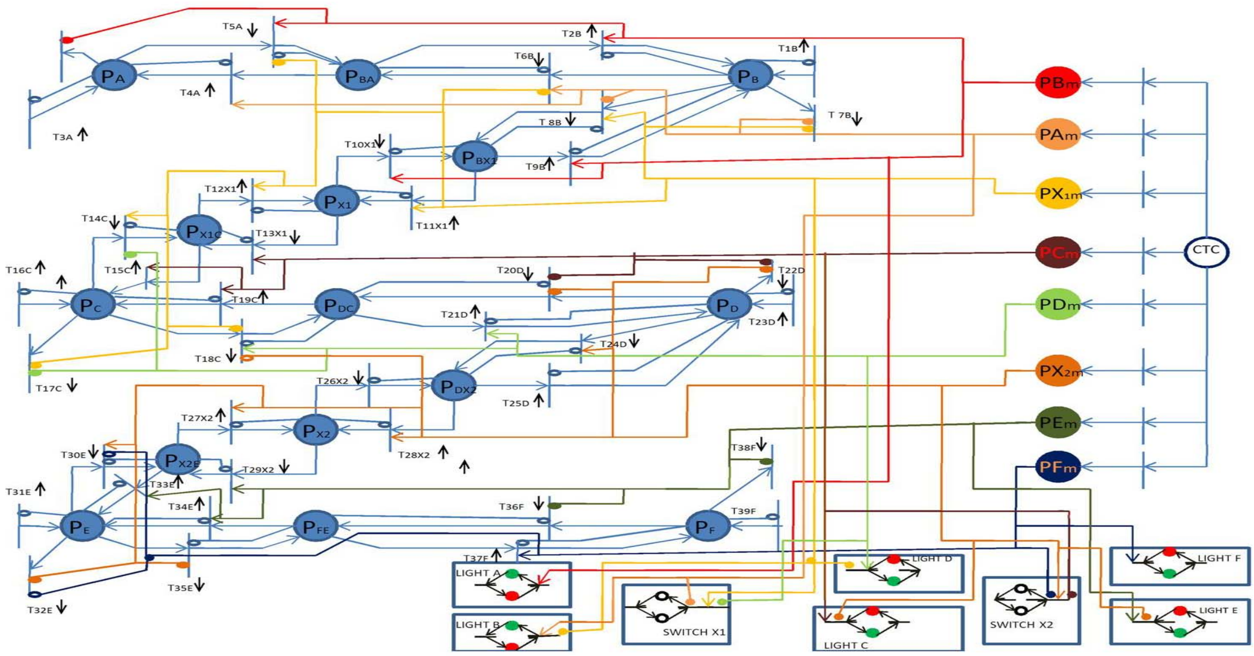


Fig. 5 APN Model for Railway Yard

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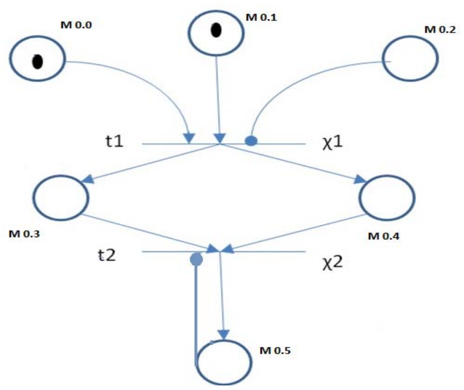


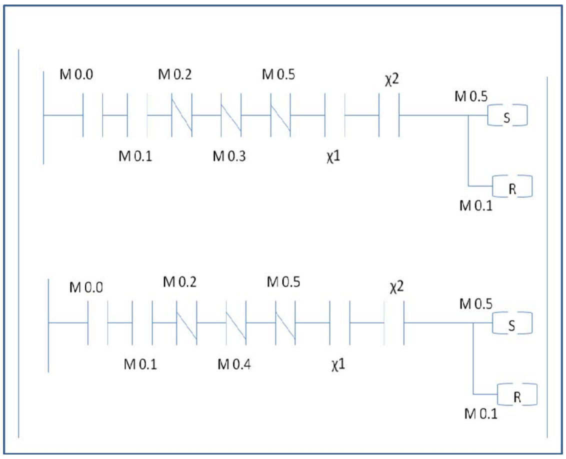


Fig. 6 Token Passing Logic

## V. Conclusion and Discussion

In this paper, APNs is used to design railway interlocking and signalization system for a sample railway yard. APNs are one of the most effective method in designing such kind of Discrete event Control Systems. With the help of Token passing logic the obtained APN model can be easily implemented on a PLC by converting it into ladder diagrams.

The main advantage of using APN is that it includes both actuator and sensors, also with a less effort we can trace the errors easily as the graphical illustrations are simple.

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