INTRINSIC FUNCTION OF CONVENTIONAL RAILWAY INTERLOCK AND FUTURE ASPECT OF INTERLOCK EQUIPMENT AT IOT ERA

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ABSTRACT

The interlock equipment has supported the safe train operations of today as a device for controlling the operation in the safe station premises. This paper surveys interlock device's transition from mechanical signals to today's electronic signaling devices and analyzes how security mechanisms have evolved. It shows that safety has been supported by the notion of fixed block system, in which only one train is allowed to travel in one route. In addition, this paper discusses the realization of moving block suitable for Communication Based Train Control era and proposes a new interlock table. Unified Train Control System (UTCS) is introduced as an implementation example, and it is shown that the UTCS is an IoT-era train control, which realizes simplification of the interlock function itself and flexible and safe control by exchanging information between the central processing unit and the point machine, the level crossing device and the train.

Keywords: CBTC, interlocking equipment, moving block, railway signaling, train control.

1 INTRODUCTION

The interlock equipment for ensuring safe operation in the station premises has incorporated a number of safety mechanisms including technological advances [1]. Today, the most advanced interlock equipment is computerized interlock equipment, but their logic follows relay interlock equipment. Electronic interlocking equipment was under development around 1985 [2]–[4]. In the early 2000s, studies on formal methods [5], [6] intended to improve software reliability and on verification [8]–[10] were invigorated. However, in many cases, interlocking logic remained unchanged from that incorporated in conventional relay interlock equipment. In that situation, a distributed interlocking system that fulfills the interlocking function by networking local signaling devices, each of which is equipped with a computer, was proposed in [11]. While being a novel system, it is designed to perform the conventional interlocking function. In Europe, development aiming at the idea of a new interlock equipment has been carried out. However, in order to summarize various developed interlock equipment into a common specification from the viewpoint of European integration [12], 'the idea of a new interlock equipment' has not been essentially researched. We are studying the ideal Communication-Based Train Control (CBTC) system of the next-generation [13]–[16]; we obtained the prospect that the simplification of the interlock can be realized by integrating it with the Automatic Train Protection (ATP) control of the CBTC. In addition, according to this method, the moving block can be realized even in the station premises. And, the interlock table, which realizes the function, was also developed. The new system architecture was exactly the same as the IoT architecture, in that the essential elements of the railway system, i.e. the point machine, the level crossing, and the train, could only exchange information with the central processing unit to ensure the same safety as the interlock function. The outline will be clarified below.

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2 HISTORY OF INTERLOCK TECHNOLOGY AND ITS GOAL

2.1 Check of the position of points for setting signals (Interlocking box)

There was a time when mechanical signals and points, which were responsible for route setting within stations, were operated manually. If relevant points are not in the correct position when a corresponding signal displays a proceed aspect, this would lead to a serious accident such as a train derailment. This means it was necessary to confirm that all relevant points were positioned correctly when a signal was set.

For this purpose, interlocking boxes were placed locally. Interlocking boxes enable signal levers to be pulled only when relevant points are positioned correctly by adjusting the position of notches on lateral and longitudinal rods. Pulling signal levers then makes all the points corresponding to the signals immovable. Using this mechanism, an interlocking operation between points and signals was achieved as shown in Fig. 1. However, there were faults that prevented the normal interlocking operation due to e.g. wear in notches; periodic inspections were thus required.

In addition, steel pipes, which expand and contract with thermal changes, were used to operate local equipment and, thus, preventive measures against the malfunction of the equipment due to their expansion and contraction were required. As a solution, a pipe compensator (Fig. 2) was installed on a pipe to compensate its expansion and contraction due to thermal changes. Such efforts to ensure safety, e.g. by overcoming such environmental conditions, have been persistently continued, backed by the technology of the time.

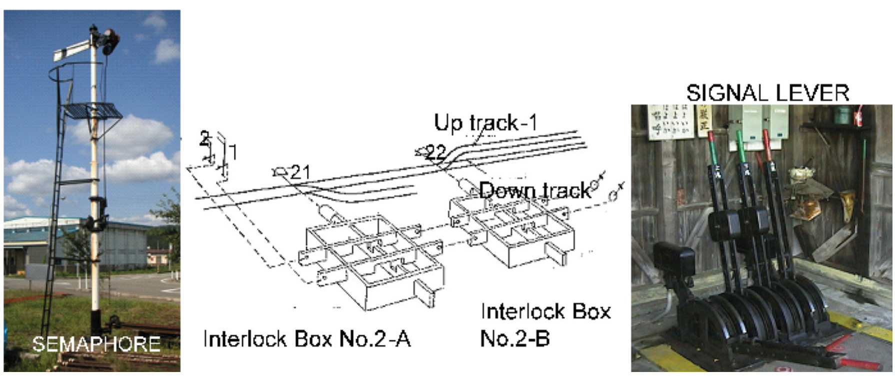


Figure 1: An interlocking box.

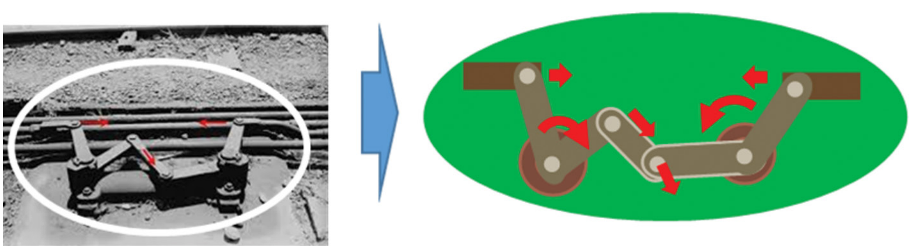


Figure 2: A pipe compensator and its mechanism.

Prevalence of electric signaling equipment and changes in how to fulfill the interlocking function.

The age of mechanical point operation that controlled local equipment using pipes and wires changed to the age of electric color light signals and electric point operation. Accordingly, mechanical verification was replaced by magnetic and electric verification; hence, a verification mechanism became able to be accommodated within an equipment room, which led to greater flexibility in design and construction.

2.2 Relay interlocking and locking

The method of using interlocking boxes placed locally developed into that of using train location information available from track circuits, and safety became able to be checked in abundant ways. For route setting, functions to ensure safety according to train location were provided, e.g. confirmation that another train is not occupying a target route, locking of points within a route set for a target train after the train enters the route and until it reaches the end of the route, etc. At the same time, the interlocking function was also improved.

The above functions were then specified as prerequisites for route setting, leading to the development of interlocking tables. If even one requirement for a target route shown in an interlocking table is not met, the route cannot be set. Consequently, the principle of only one train within a route, which is used today, was established.

3 INTRINSIC FUNCTION OF RAILWAY RELAY INTERLOCK [1]

3.1 Characteristics of relay interlocking

The ultimate purpose of relay interlocking is to ensure the safety of trains moving in stations. For this purpose, points and signals are interlocked by making the most of information from track circuits involved in a target route. Possible risks in train movement within stations include a collision between trains, a lateral collision with a running train, and a derailment of a running train due to an unintended movement of a relevant point. They are caused by a variety of factors: human handling errors, failures of sensors, element failures, faulty logic, etc.

One of the advantages of relay interlocking is that various types of logic are implemented to inhibit the occurrence of unsafe events caused by human faulty operation so that no human errors may result in an accident. Another advantage is its fail-safe feature; the occurrence of any failure in sensors or signal relays as logic elements always leads to the output of the fixed value of 0 (safety-oriented operation) in order to prevent such a failure from causing an accident. The subsequent sections describe intrinsic functions to ensure the safety of relay interlocking.

3.2 Prevention of accidents that may be caused by simultaneous operation by several operators

Human errors may occur due to wrong assumptions, distractions, etc. Since a variety of routes can be set within stations, it is difficult for operators to understand all conditions of routes being set and trains running along the set routes. Therefore, it is highly dangerous to rely only on human judgment of whether an action about to be taken has no possibility of compromising safety at all. What would be helpful for operators is the rejection of erroneous actions in order for such actions not to lead to an accident, even if they are serious mistakes.

Relay interlocking is provided with logic that serves as a solution to the above issue. For example, the logic can reject a request to set a route that is not specified in specifications or that conflicts with another route having already been set; hence, such a request will not lead to unsafe operation. This indicates that safety can be maintained even if multiple operators manipulate a control panel simultaneously to set a route arbitrarily.

As to a large station, it is sometimes divided into areas where several operators share the responsibility for route setting and replacement accordingly. Regardless of how clear the division is, it is still important to confirm safety when an operator sets such a route that involves an area controlled by another operator. To cope with such a situation, relay interlocking has a function of route checking and locking that accepts or rejects a request of route setting depending on the condition of affected areas.

3.3 Prevention of accidents that may be caused by ambiguous interfaces between a driver and onboard equipment

Drivers follow signal aspects when driving. However, they may misidentify or miss a signal aspect at a certain rate. Especially misidentifying a signal within a station will lead to an accident immediately. For that reason, in addition to interlocking equipment, automatic train stop equipment (ATS) is provided to ensure safety, which stops a train automatically once the train is found to be running in spite of a signal at danger.

Nevertheless, an onboard driver cannot predict when a wayside signalman will start route setting. A proceed aspect having displayed may be canceled by an operational command. A train will possibly derail or overturn if a specified route for the train is changed in an unintended manner and the train then reaches a moving point.

One of the measures to prevent such an accident is to rely on the attentiveness of a signalman who is in charge of route setting. The signalman checks the location of a train and sets a route only when he/she finds there is no danger in doing so. However, it should be noted that this measure is not perfect in that it fully depends on human attentiveness. Another measure is to inhibit the movement of a point for a given period of time after changing a signal aspect when setting a route is confirmed to be dangerous based on the location of a target train. This measure is used in Japan and is called approach locking. When a signal is changed, and a new route is required to be set, relevant points still maintain the present state for a specified period of time, although a proceed aspect of the signal is changed to a stop aspect. 'A specified period of time' refers to the time from a brake application by the driver in response to the stop aspect until the train comes to a stop and is selectable depending on the speed of a target train, e.g. 120 seconds, 90 seconds, etc. If the train has not entered the area protected by a home signal after the specified period of time has elapsed, the request to set a new route will be accepted and relevant points be allowed to move.

Of course, a new route is set immediately without time delay when a train is not present in the vicinity of a signal. Relying on time delay to ensure safety instead of human attentiveness is effective to some extent from a safety point of view but leads to lower efficiency in train operation due to the unavailability of route setting for a certain period of time.

The ultimate cause of the above difficulties is that interlocking equipment, drivers and onboard equipment are interfaced via signal light units. If closed-loop communication is established between onboard equipment and interlocking equipment, unsafe conditions will be able to be prevented without ATS and availability, as well as safety will also be improved. Moreover, in approach locking systems, if interlocking equipment can make inquiries to

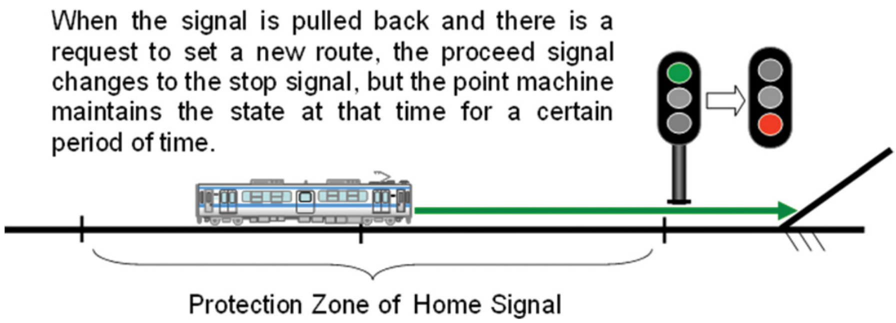


Figure 3: An illustration of approaching interlock.

onboard equipment of trains to obtain information about at which point they will stop by brake application and judge whether the new route setting is possible or not, safety will be fully ensured without relying on time delay and, consequently, efficiency in train operation be improved.

3.4 Ensuring safety by means of time delay

As described above, approach locking systems prevent unsafe events caused by the ambiguity of interfaces from occurring by means of time delay. Another time-based method of improving safety is also applied by interlocking equipment. Existing interlocking equipment determines the location of trains using track circuits. Track circuits are based on the mechanism of short-circuiting rails in which a track circuit current is flowing by means of wheels and axles. However, rusting or fouling of rails often inhibits rails from short-circuiting, and this may consequently cause a delay in train detection. There are even extreme cases where trains occupying their own route sometimes remain undetected for a short time. Track circuits have a fail-safe configuration, and an occurrence of a failure leads to the output of 0, which represents the de-energization of track relay, i.e. the presence of a train on the track section in question. In contrast, in the event that a train occupying a track section cannot be detected, it results in an unsafe condition (i.e. the track relay is energized, which is represented by the output of 1), and countermeasures will thus be required. As a countermeasure that is taken under current practice, when the value 0 changes to 1, the subsequent action is taken not immediately but after a specified period of time (2 seconds later). It is physically impossible for a large-sized vehicle that has been traveling on the route to disappear suddenly; following a principle of keeping an eye on a train to track its movement will be able to suppress the unsafe operation of track circuits. While electronic interlocking can be provided with train tracking logic to improve safety, relay interlocking has to rely on the time-based safety improvement method because it is not easy to incorporate the same logic in relay interlocking.

4 CONCEPT OF NEW INTERLOCK AT IOT ERA

Today, new IoT innovations such as Industry 4.0 are spotlighted by industries. In the railway industry, CBTC has attracted attention as an advanced train control system and has already been incorporated in many projects. Restructuring the current architecture of CBTC from an IoT point of view is expected as an approach to achieving an ideal train control system. The authors propose a new type of train control system for the IoT era, called the Unified

Train Control System (UTCS), in which system components exchange information with each other to ensure safety. In the IoT era, the UTCS will be a successor to CBTC. The UTCS, which the authors propose herein, is a new ideal train control system that was developed by restructuring, from an IoT viewpoint, the CBTC system architecture represented by ETCS Level 3 and the radio-based train control system of East Japan Railway Company called 'ATACS', which is in operation in Japan. As a new train control system for the IoT era, the UTCS ensures safety by allowing system components to exchange information with each other, thereby being able to simplify itself. The UTCS can thus be said to be a new-generation CBTC system with high reliability, availability, maintainability and safety, as explained below in more detail. The UTCS does not require interlocking equipment to be deployed in each station, and interlocking logic is centralized at the central processing unit. Various types of locking operation performed by conventional interlocking equipment are reduced, and interlocking logic is also simplified because the control logic in the central processing unit is capable of eliminating any conflicts between routes for individual trains, etc., at the time of generation of moving authority limit information (a row of block IDs and position in a block) given to each train. Local equipment can significantly be reduced as the authors emphasize in this paper, the central processing unit and onboard equipment are interfaced directly with each other and 'a new interlocking function for IoT era' that makes 'moving block system' within stations possible is realized. The subsequent sections describe the interlocking operation performed by UTCS in relation to train separation control executed by CBTC.

4.1 The control logic for train separation provided by CBTC

CBTC controls the separation of trains running between stations by informing onboard equipment of a train of its movement authority limit determined based on the position of the rear end of a preceding train allowing for a certain safety margin. This makes possible the moving block system in which a moving authority limit moves forward according to the movement of a preceding train. Most CBTC systems consider a railway line as a group of blocks and control train movement based on block IDs and train position within a block, Onboard equipment of a train is informed of a relevant block ID (or a row of block IDs, if several blocks are involved) and its position within a block as a movement authority information.

In Japan, a type of CBTC, called ATACS, has been in operation and West Japan Railway Company and Tokyo Metro Co., Ltd. are also making an effort to put CBTC into service. What is common to these systems is that they use the moving block system between stations but rely on conventional interlocking equipment for train protection within stations. Using conventional interlocking equipment means that only one train is allowed to exist in a route and, if there is a train running in a route, another train following it has to wait behind the route until the preceding train leaves the route. It should be noted that movement authority information given to onboard equipment within stations consists of a block ID (or a row of block IDs) and the position within a block instead of the name of the route, hence the processing to be done by onboard equipment within stations is not different from that to be done by onboard equipment between stations.

4.2 How to introduce moving block system within stations and traveling path

This section describes how to introduce the moving block system in order to control train separation within stations. First of all, the concept of the route is used in conventional interlocking equipment as the basis for the fixed block system; hence, it is considered to be unsuitable for the moving block system. In the moving block system, a train is basically allowed to travel to a point determined based on the position of the rear end of a preceding train with a safety margin allowed for. However, only one train is allowed to exist within a turnout section according to the idea of detector locking. For the purpose of introducing the moving block system within stations based on the above conditions, the concept of traveling path associated with movement authority is to be adopted. Traveling paths are related to movement authority given to trains and determined based on the location of the preceding train and the position of points, as illustrated in Fig. 4. In this figure, Train B is running toward Point P on Track No. 2, following the preceding train A running toward Point Q on Track No. 1.

1. A traveling path (consisting of Block k, Block m and Lq in Block n) is given to Train A.
2. A traveling path given to Train B is Lp in Block k, which has been determined based on the position of the rear end on Train A with a safety margin allowed for.
3. After Train A leaves Block k and then enters Block m, only Lo, ended at the boundary of Block k is given to Train B as movement authority because Block m contains a turnout.
4. After Train A enters Block n, Block m becomes clear and Train B is given access to Block r that is incompatible with Block m. Subsequently, once a point no. 51 is moved to the reverse position and locked, Train B obtains movement authority to travel through Block r to the end of Lr in Block s.

4.3 Transition from exclusive control

As described above, onboard equipment can perform processing for the moving block system within stations in the same manner as the processing between stations. UTCS is a type of CBTC. Most of the existing CBTC systems distribute local equipment along the line, and the distributed equipment locally controls each train in each zone. On the other hand, UTCS features central processing equipment that centralizes the distributed wayside processing equipment, and the central equipment assumes the responsibility for tracking trains and providing each train with movement authority. Moreover, functions of looking for traveling paths within stations and validating requests for traveling paths are also centralized. Therefore, various locking functions that have played an important role in conventional interlocking equipment by assuming exclusive control over several requests are integrated into the algorithm for the search for traveling paths and thus become unnecessary. Only detector locking is still used, which does not allow a point to move when a train exists in the area containing the point. Detector locking in UTCS performs two types of processing: allowing only one train to enter an area containing a point and rejecting any request to control a point when a train exists in the area containing the point.

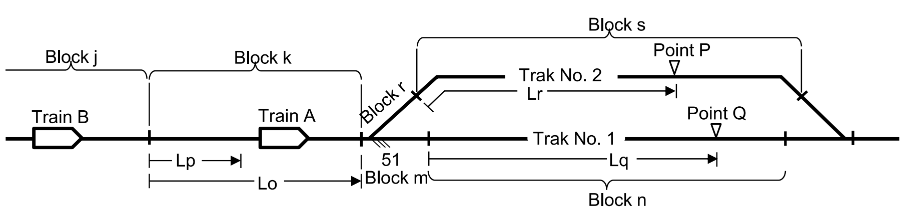


Figure 4: An example of how to look for traveling paths.

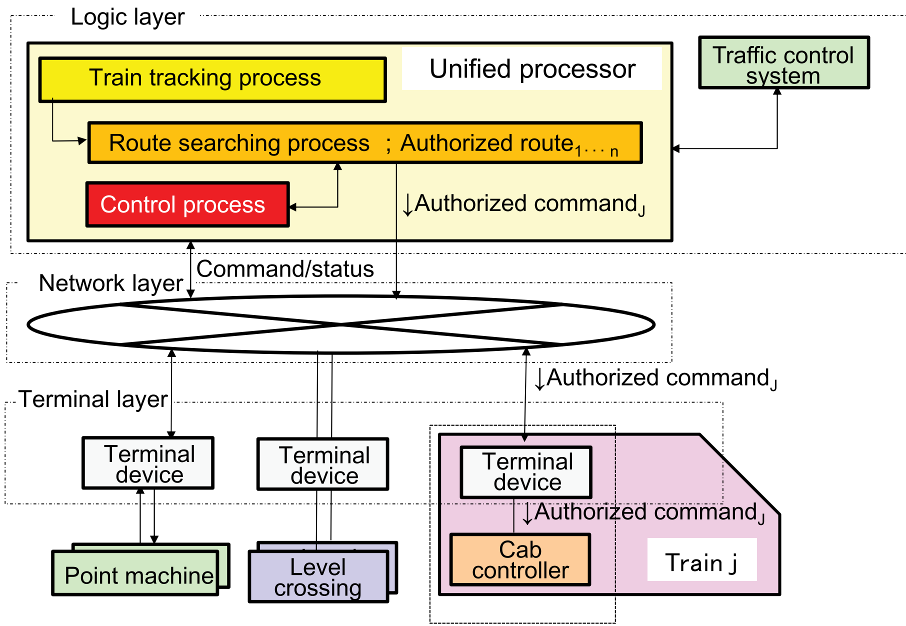


Figure 5: A concept of the UTCS.

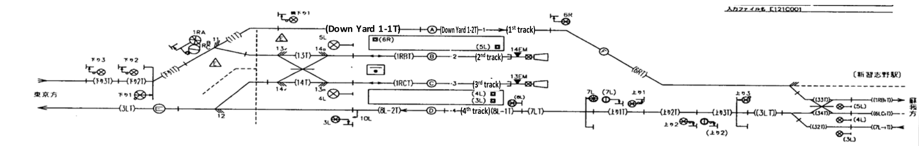
4.4 Design of an interlocking table for moving block operation within stations

Figure 6 illustrates a conventional interlocking table. An interlocking table can be considered as a set of specifications of interlocking equipment in a target station. Each row of the illustrated interlocking table shows requirements for route setting. For example, according to the table, the home signal 1RA on the route to the first track from Tokyo locks point 11 in the normal position and also displays a proceed aspect when requirements such as vacancy of 11T and Down Yard 1-1T are satisfied. A route cannot be set if those requirements for route setting are not met. The conventional interlocking table is based on the precondition to set routes for target trains that no other train exists in the route, i.e. relevant track relays are all energized, hence it also serves as the basis for imposing constraints on fixed block systems in which only one train can exist in a route.

In order to realize moving block systems within a station yard, it is essential to develop a new interlocking table that can support the control of moving block systems.

To meet this challenge, we developed a new interlocking table that is comprised of block data and traveling path data. A traveling path consists of a sequence of blocks. There are two types of blocks; the first one is a block that allows several trains to exist in it and the second one is that allows only one train to exist in it, i.e. a block containing a point (a point-containing block). Based on the above conditions, a new interlocking table is devised that specifies the order of blocks forming a traveling path and arranges rows of information on individual blocks. A path where a target train can run is searched according to the sequence shown in the traveling path data and an authorized command that informs the train of an available route consisting of a sequence of blocks that will not hinder its travel is generated and sent to the onboard cab controller.

Block information listed in a new interlocking table includes the length of a block, a block with or without a point and connection with adjacent blocks (for connection with a



(1st Class Computerized Interlock)

Name		No.		Lock	Signal Control or Detector Lock	Route Lock	Approach Lock or Stick Lock	Automatic Cont. or Route Cont.
Home Signal	From Tokyo to 1st track	1R	Ⓐ	11	11T Down Yard 1-1T	(11T)	Down 2T, Down 1T ((90sec.))	Down 3T
	Same above(alarm signal)				11T			
Home Signal	From Tokyo to 3rd track	1	Ⓑ	⑪ 13 14	11T 13T 1RBT 13EM	(11T)(13T)		
	From Tokyo to 2nd track	2	Ⓒ	⑪ ⑬ 14	11T 13T 14T 1RCT 14EM	(11T)(13T 14T)		
	–						1st Home signal to 8LT	
Starting Signal	From 4th Track to Tokyo	3L	Ⓔ	12	12T 3LT	(12T)	(上り2T 上り1T 7LT 但⑧L)8L-1T 8L-2T ((90秒))	((7L-1T但③L))又は(34T)又は(33T)又は8L-1T又は8L-2T
Starting Signal	From 3rd Track to Tokyo	4L	Ⓔ	13 14 ⑫	14T 12T 3LT	(14T)(12T)	1RCT ((30秒))	1RCT
Starting Signal	From 2nd Track to Tokyo	5L	Ⓔ	⑭ 13 ⑫	13T 14T 12T 3LT	(13T 14T)(12T)	1RBT ((30秒))	1RBT
Starting Signal	From 1st Track to Tokyo	6L	Ⓕ		6RT			下り3T又は構下り1−1T又は構下り1−2T
1st Home Signal	Soga to 2nd Home signal	7L	Ⓓ		7LT 8L-1T		上り2T 上り1T ((90秒))	((7L-1T但 ③L))又は(34T)又は(33T)
	Same above(alarm signal)				7LT			
2nd Home Signal	1st Home signal to 8LT	(8L)	Ⓓ	⑩L	8L-1T 8L-2T ⑩L ⑦L	(⑩L 但20秒)	(上り2T 上り1T 但⑦L)7LT ((90秒))	
	Same above(alarm signal)				8L-1T 8L-2T ⑦L			
Route clear lever		10L		12	③L			
Point machine		11		11T				
Point machine		12		12T				
Point machine	Double	13		13T 14T				
Point machine	Double	14		14T 13T				
解放てこ	集中	80	N					
	駅扱		R					
駅扱てこ	保守用	81R		1R [11]				
同 上	同上	82R		1RB 1RC 4L 5L [13 14]				
同 上	同上	83R		3L 4L 5L 10L [12]				
自動てこ	下り線用	85R						1R 6R
同 上	上り線用	86R						3L 4L 5L 7L 10L

Figure 6: An example of a conventional interlocking table.

point-containing block, both normal and reverse positions of the point need to be taken into account). Any exclusive relationship such as the position of a point (normal or reverse) is also included in the table. Figure 7 illustrates a new interlocking table.

4.5 Point control and automatic train protection using a new interlocking table

A block status table and a point status table are derived from a new interlocking table. As shown in Fig. 8. These two tables are undeletable working tables and updated with the status of points controlled and moving trains. In addition to these tables, a paths table containing sequences of blocks for respective traveling paths is also generated and referred to for the search for traveling paths.

(1) Automatic train protection; ATP

Automatic train protection to be performed by CBTC consists of train tracking and train separation control. Train tracking involves continuous updates of a train status table with the current location of a moving train according to the information obtained from its onboard equipment. Train separation control involves looking for and renewing movement authority limits for a train with reference to its current location.

Renewing a movement authority limit pertains to the extension of a limit to a farther point on a traveling path for a train on the basis of a movement authority limit already given to the train. The farther point is either of the following four options:

1. A point behind the rear end of a preceding train, determined by allowing for a safety margin,
2. A point behind the entrance to a point-containing block that a train running on the traveling path is not allowed to enter, determined by allowing for a safety margin,
3. A point behind the entrance to a level crossing through which a train running on the traveling path is not allowed to pass, determined by allowing for a safety margin, and
4. A point at which a train on the traveling path is supposed to stop.

New Interlock Table ;(** Station)

Block Data								Traveling Path Data				
				Front End Adjacent Block		Rear End Adjacent Block		Block Sequence for Rout				
Block Name	Point Machine	Competitive Block	Block Length	Normal Position	Reverse Position	Normal Position	Reverse Position	1LA	1LB	2RC	3RC	
1001			196			1002		6		1		
1002			77	1001		1003	1006	5		2		
1003	11ロN	1006	45	1002		1004				3		
1004			46	1003		1005				4		
1005	12イN	1007	45	1004		1101				5		
1006	11ロR	1003	61	1002		1057		4				
1007	12イR	1005	60	1056		1101					4	
1101			178	1005	1007	1102				6	5	
1102			120	1101		1103				7	6	
1103			55	1102						8	7	
1051			195			1052			7		1	
1052			74	1051		1053	1056		6		2	
1053	12ロN	1056	43	1052		1054			5			
1054			44	1053		1055			4			
1055	11イN	1057	153	1054		1058			3			
1056	12ロR	1053	30	1052		1007					3	
1057	11イR	1055	32	1006		1058		3				
1058			50	1057		1151		2	2			
1151			27	1058				1	1			

Figure 7: An example of a proposed new interlocking table.

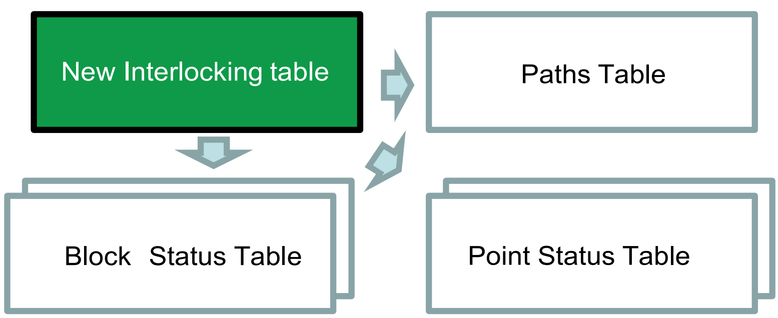


Figure 8: Tables for train control generated from new interlocking table.

In the search of a new movement authority limit, the nearest point is selected among the above four points, registered on a train status table as a new movement authority limit and reflected in a message to be sent to onboard equipment.

5 EFFICIENCY ESTIMATION FOR NEW INTERLOCKING AT IOT ERA

UTCS can reduce local facilities to a great extent, provide an interface between the central processing equipment and onboard equipment and realize ‘a new interlocking function for IoT era’ that makes moving block systems within stations possible. This new interlocking control method for the IoT era is expected to bring about various benefits:

1. ATP function within stations can be fulfilled without wayside equipment.
2. Train operation becomes more efficient and flexible by introducing moving block systems within stations.
3. A new interlocking system can work in conjunction with onboard equipment to ensure safety and also to prevent operational efficiency from decreasing, e.g. in changing the platform to be used by an arriving train upon request of the train.
4. The conventional time-based method of ensuring safety can be replaced with an intrinsic method.
5. Any changes in the interlocking function can easily be made by the central processing equipment.
6. Potential loss of safety to be caused by ambiguous interfaces between sensors and local equipment can be reduced.
7. Direct communication between the central processing equipment and onboard equipment can cope properly with any unexpected risk.
8. Conventional complicated interlocking logic can be simplified.

Since the proposed UTCS was developed by restructuring a highly safe system with the aim to consolidate and centralize essential functions for intrinsic control to meet the needs of the IoT era, the authors do not assume that the frequency of train traffic will be extremely increased. However, the authors also recognize that whether the UTCS, once adopted, is expected to bring about ‘an effect of reducing the headway’ or not is an important issue. With regard to this issue, it is generally known that ‘moving block system’ is more effective in improving train density than ‘fixed block system’ and this has already been proven by ‘ATACS’, a radio-based train control system of East Japan Railway Company, which has already been successfully used in Japan.

6 CONCLUSION

Interlocking equipment that ensures the safety of trains moving within stations has been evolving; starting with mechanical interlocking, through the emergence of electromechanical and relay interlocking, it developed into electronic interlocking. Various locking functions are of great significance in interlocking equipment for ensuring safety. This paper analyses the roles played by those locking functions and consequently reveals that many of the functions will become unnecessary by centralizing the processing of requests for route setting and replacement. Furthermore, this paper concludes that, in spite of the conventional restriction on the occupancy of a route by only one train, it will be possible to introduce moving block systems within a station yard by using the same processing as the train separation control between stations performed by CBTC. This paper also considers what kind of interlocking table will be suitable for the above purpose and consequently propose a new interlocking table. The new interlocking table specifies the order of blocks forming a traveling path and arranges rows of information on individual blocks. The new interlocking system proposed herein will be ideal as a next-generation interlocking and suitable for UTCS, in which those indispensable elements, such as points, onboard equipment and level crossings, are networked with the central processing unit for the purpose of train control. Consequently, in UTCS, the train separation control can be realized using the same ATP logic both within a station yard and between stations. With regard to in-depth safety evaluation, the basic CBTC system of Japan (ATACS by East Japan Railway Company) upon which the UTCS is based has already undergone safety evaluation.

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