Basics of Railway Signaling

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1. Basics of Railway Signaling

Introduction

When trains run on railway tracks they follow rules of operations in which safety plays a very important role. The most important rule in respect of safety is ensuring that two trains do not occupy the same position on the track at the same time. To make this rule work operation of trains uses signaling to control movement of trains on tracks and divides tracks into several sections which are protected by the signals.

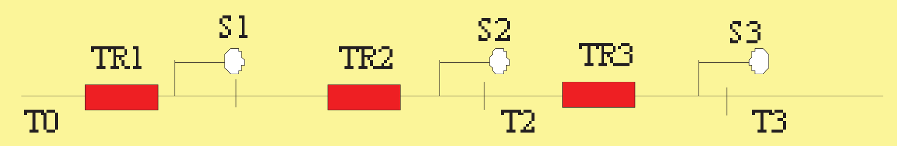


Fig 1.1

Fig 1.1 shows a representation of a railway signaling arrangement. The horizontal line represents the railway track, the signals are depicted by the symbol of the circle with a horizontal and vertical line to this circle and the red rectangles are the trains. This representation is however to explain how trains are run safely and the actual representation of various functions are explained later. The signals depicted are named S1, S2, and S3 etc. The railway track in the above example is divided into 4 sections called T0, T1, T2 and T3. Trains are referred to as TR1, TR2 etc.

Safety of train running is ensured by allowing only one train to enter any track section at a time. The entry to the track sections are controlled by signals placed short of the boundary of adjacent track sections.

In addition to straight sections as shown above when train movements take place on diversions safety of such movements are taken care of by signaling system.

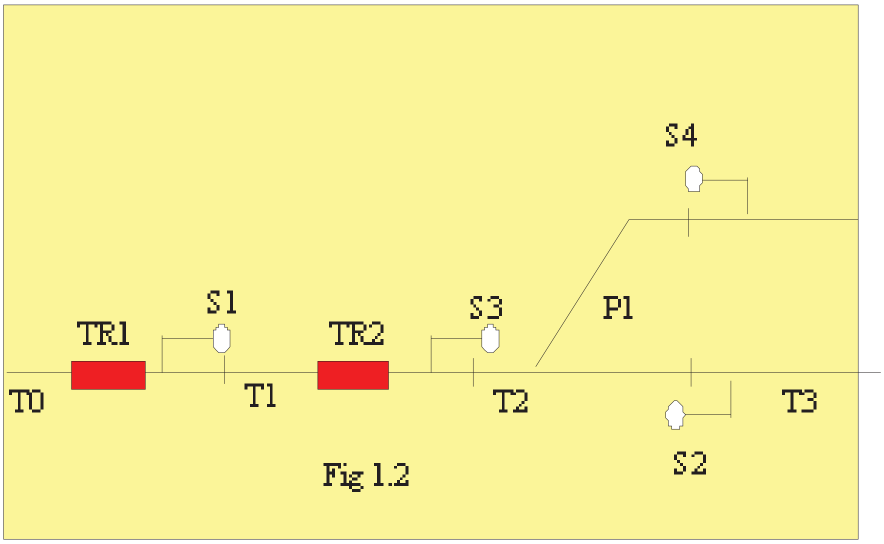


Fig 1.2

Fig 1.2 depicts the scenario around a diversion. The diversion is created on the track by what is referred to as point. P1 is a point on the track and allows a train approaching it to be diverted to the left or allowed to go straight. A point is a portion of the track which is a potential danger and can cause trains to be derailed if not properly controlled. The signaling system ensures that this is controlled properly. To ensure this, signals are provided controlling trains moving towards the point and unless the point is detected to be safe for

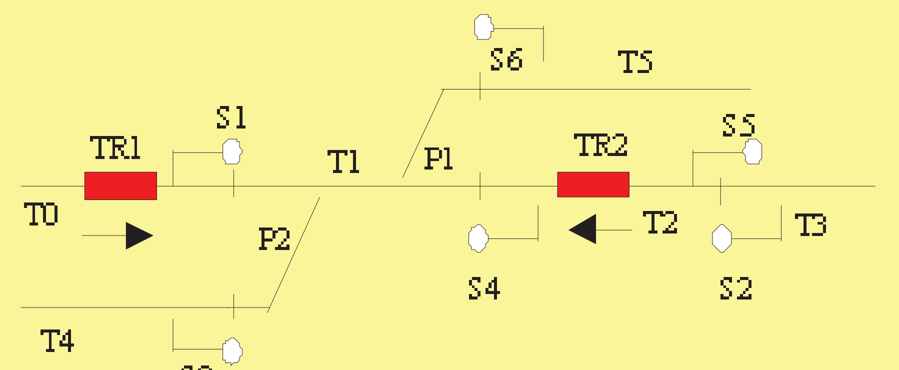


Fig 1.4

The importance approach locking is explained in Fig 1.4. Consider that two trains TR1 and TR2 approaching each other. Consider initially signal S1 had been cleared to allow train TR1 to move towards the track T1- T5 taking divergence at point P1, The train TR2 was to wait till train TR1 goes past the track T1 and onto track T5. Consider that due to change of mind the train controller decides to stop the train TR1 at signal S1 and move train TR2 to move onto track T1 and through diverging setting of point P2 onto track T4. To do this the signal S1 is put back to danger and then signal S4 is attempted to be cleared. Because of the delays involved in the carrying out the commands and the indication given by the signals at site it is possible that the train TR1 passes the signal S1 before it had turned red, lands on track T1 and starts to progress further not aware that the signal S1, it had passed was intended to be put back to red and it was supposed to have stopped at S1.

When a signal is cleared if there are points in the route then the points are kept locked in the position required for the route. As long as the signal is cleared this locking is maintained directly by the signal which has been cleared. However, if the signal is replaced

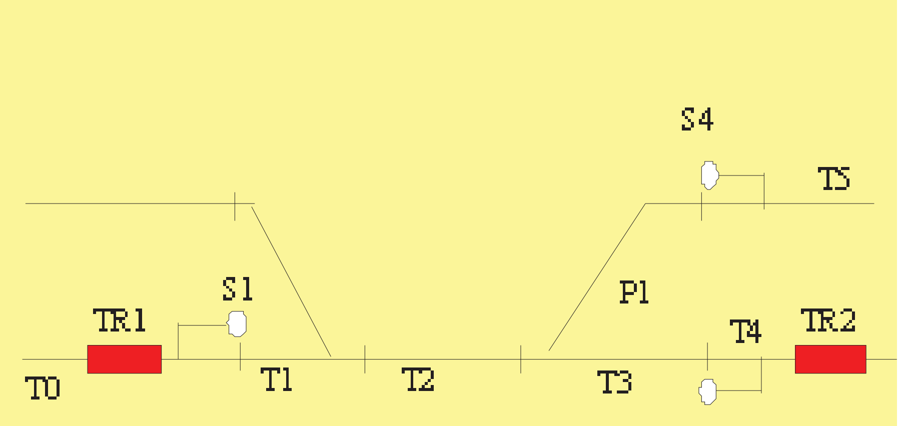


Fig 1.5

Fig 1.5 shows a condition when a train TR1 is planned to be sent to track T5 from track T0. When signal S1 is cleared it ensures that through direct locking and approach locking that point P1 cannot be moved. However once train TR1 goes past signal S1 onto track T1 the signal S1 is put back to red and these locking are lost. The train TR1 is however still approaching the point P1 and track T3. Until the train moves to track T5 it has to be ensured that point P1 is kept locked towards T5. It is also required to be ensured that the train TR2 is not at the same time approaching towards track T3. The locking of the point P1 and the train TR2 under this condition is ensured by route locking.

Flank protection and isolation

When a train is allowed to proceed by clearing a signal it is also necessary to ensure that no part of the train will be involved in a side collision.

Protection in the overlap

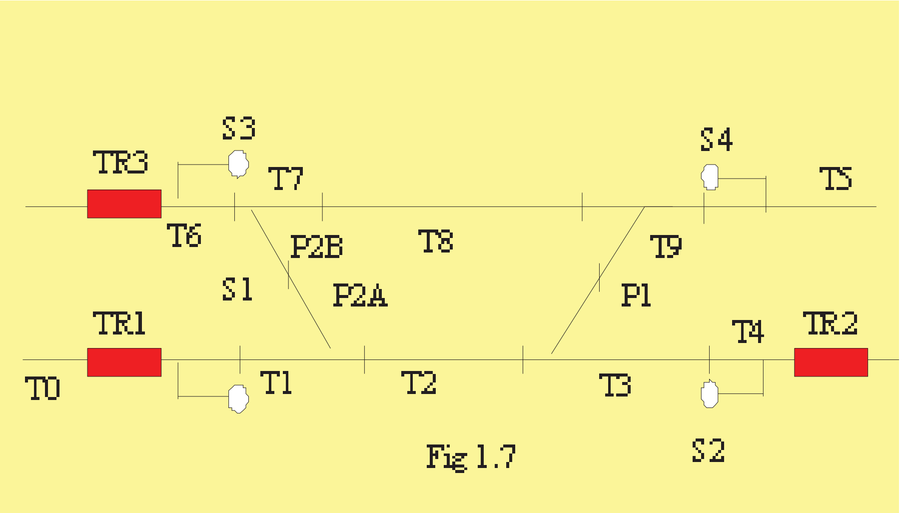


Fig 1.7

When a train is approaching a signal a possibility exists that the train may fail to stop at the signal where it is intended to stop due to mechanical failure or due to human failure. While there is no absolute arrangement to control against this eventuality a partial safety is ensured by providing a small part of the track beyond the signal at which the train is to stop free of any conflict or obstruction to the train if it fails to stop at the foot of the signal. Typically when train TR1 is approaching S1 it will normally be ensured that the track section T1 and T2 is free of any obstruction. This includes possibility of any train from the opposite direction reaching T2. Hence if TR1 is allowed to approach S1 it will be ensured that the train TR2 does not at the same time approach signal S2. Any point in this portion of the track also needs to be set and locked in the position allowing safe movement through it. If TR1 is approaching signal S1 it will mean point P2A must be set and locked for the straight route. The point P2A and track T2 is referred to be in the overlap for signal S1 and locks the signal

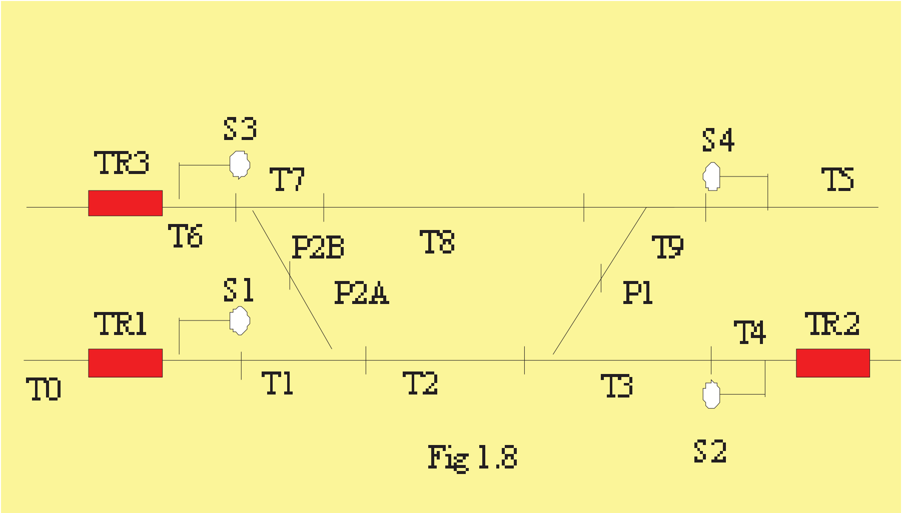


Fig 1.8

T0, T1, T2 etc are all such track circuits. Since train TR1 is occupying track T0 no other train will be signaled onto T0 till TR1 moves away from T0.

Track circuits are also provided in the tracks forming points and they are known as point zone track circuits. When a point zone track circuit is occupied points cannot be moved.

Track circuits to monitor track sections are implemented in many ways from mechanical means to electronic. Most of the methods are electrical/electronic using insulated joints marking the boundaries of the track sections monitored by the track circuits.

The most common way of implementing a track circuit is by setting up an electrical circuit using a source and a detector.

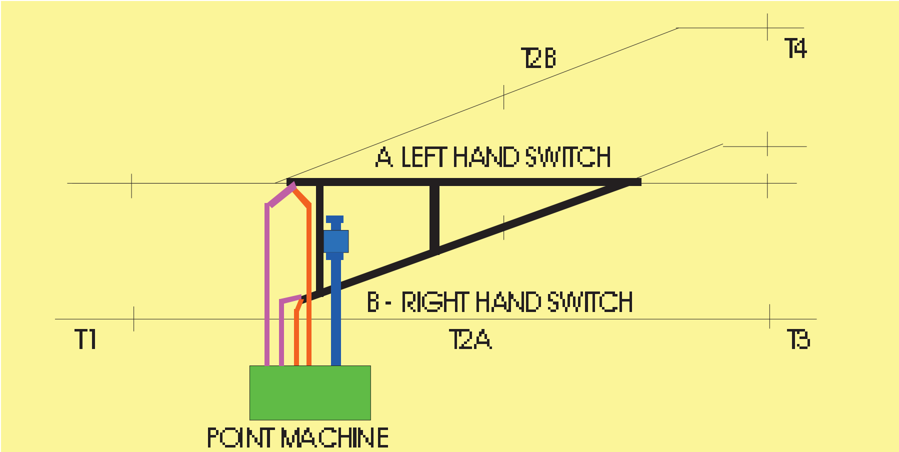


Fig 1.10

A typical arrangement is represented in Fig 1.10. The bold black line represents the two switches forming a point. The fixed rails on the point area are called the stock rails. The switches moves and flushes to the stock rail on one side or the other depending on the route the point is required to set across the point. The blue rod represents the drive rod which moves each of the switches. The red lines represent the detection rods.

When facing the point the moving rail on the left hand side which is marked A in the Fig 1.10 is referred to as the left hand switch and the moving rail on the right hand side marked B is referred to as the right hand switch. In the Fig 1.10 shown with the left hand switch closed the straight route T1 – T2A – T3 will be ensured for a train moving over the switch. When the right hand switch is closed then a divergent route T1 – T2A – T2B – T4 will be set for a train moving over the switch.

To move the switches the point machine rotates and through the red colored rods and fittings moves the two switches A and B towards left hand or right hand.

(e) and trains coming from 'A' goes towards 'B' when (a) touches (e), (b) is clear of (d) and trains coming from 'A' are directed to 'Cl. The condition is shown in Fig. 2.l(b).When the end touching fixed rail has a gap less than 5 mm and the other movable end is clear of the fixed rail the point is said to be set.

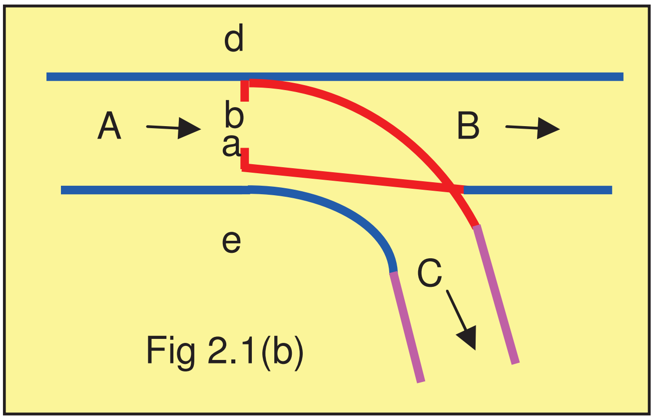


Fig 2.1(b)

Signaling arrangements ensures that when a train is allowed to follow a particular route the following are checked.

(i) The route through which the train is desired to move is not occupied by any other train.

(ii) All the points on the route are properly Set to the direction intended.

(iii) No part of the route will be followed by any other train before the train clears that part of the route for which signal is cleared.

All train signaling systems are based on giving a signal to a train after checking of these basic conditions. In addition other conditions are also satisfied as under :

(i) The route is clear to a specified distance beyond the point to which a train is signaled.

action for clearance of signal will be taken only if the route over which the train will move including overlap is clear from all obstruction.

The power involved to move a point is achieved by connecting the point through steel rods to a lever arrangement, which is under control of person operating the point (known as switchman). A typical arrangement is shown at Fig 2. 3.

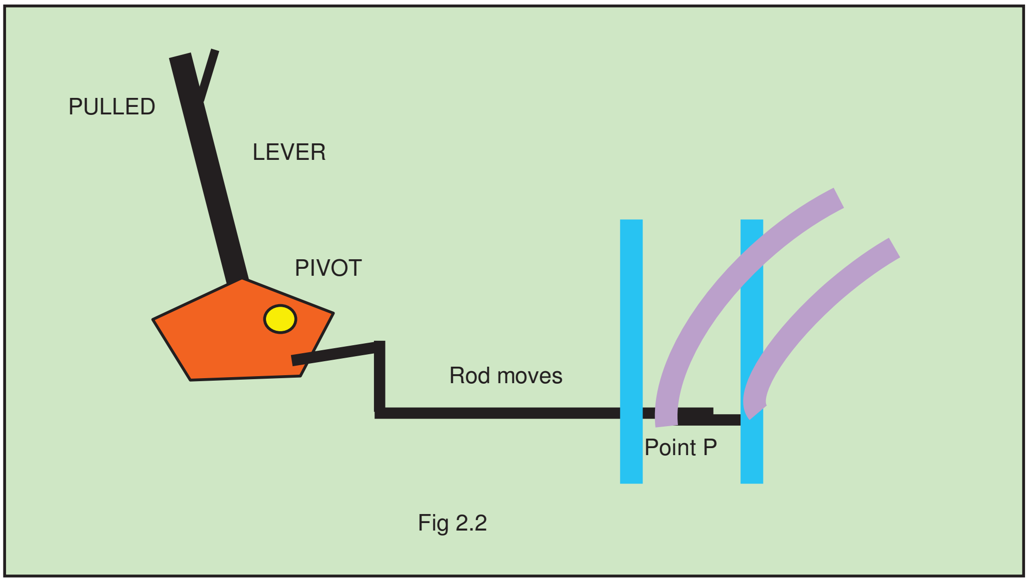


Fig 2.2

A picture showing a lever frame where several lever frames are made available is also shown.

The levers frame has slots firmly fixed to the floor of the cabin where the lever frame is fixed as shown in the picture.

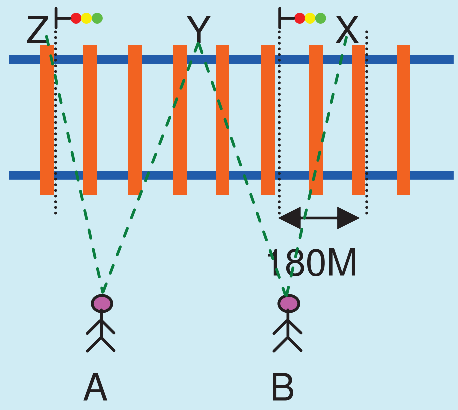


Fig 2.10

Before clearing signal 1 which allows train to go up to signal 'B' has to confirm that portion 'Y-Z is clear of obstruction.

Here for Signal (1) to be cleared for a train requires portion of track between 'X-Y' and 'Y-Z' to be clear of any obstruction. Let us consider that due to physical reasons visibility of switchman 'A' is limited beyond point 'Y' and another person 'B' has visibility over portion 'Y' & *'Z'.* 'B' can confirm the clearance of the portion 'Y-Z'. The confirmation can be given on telephone but verbal communication may be misunderstood and, therefore, an electrical control is used for safety. The arrangement is normally very simple and consists of a electric switch being given to 'B' which gives a feed

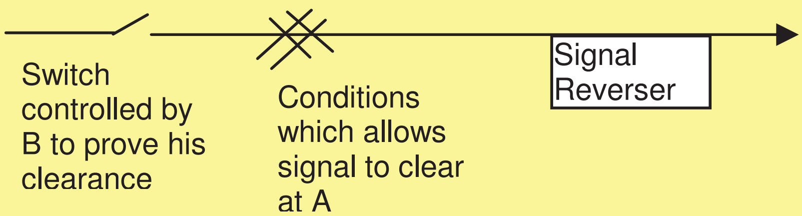


Fig 2.11

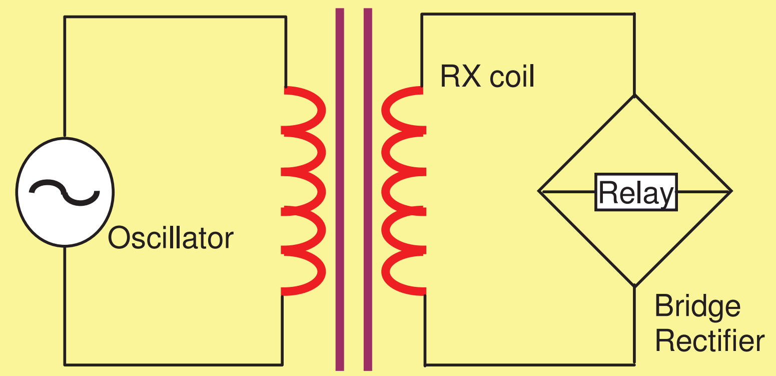


Fig 2.17

If the oscillator stops oscillating the relay will drop. The oscillator circuit has to be in proper operating condition to ensure oscillation is taking place and under as such a situation only the relay will pick up. Supervisory circuits are used to control the oscillator. On detection of any unsafe condition the supervisory circuit withdraws the feed and the relay drops.

Electronics circuits is also used for achieving advanced controls for train running. In these systems the signals for running of trains are given as indications to the train drivers in the locomotive on the basis of which train drivers control the trains. Thus on seeing a Green indication a driver runs train at full speed while on seeing a red signal drivers stops the train. Indications as yellow signal or double yellow signal is meant to indicate that train is to be stopped shortly and drivers control the speed. However, this means that a human element is involved in such a case and in case the driver fails to control the train on the basis of the indications provided to him there can be mishaps.

Such systems are important for railway services where time between two successive trains is are required to be kept very small to as much as one min or less. Even with such small interval between trains complete safety & punctuality can be attained using the continuous automatic train control and protection system.

Use of Electrical/Electronic Gadgets for ease of operation

Over and above train controls by the use of electrical/electronic gadgets is also made for ease of train operations and higher efficiencies.

Systems known as Route Relay Interlocking allow control of signals and points with higher efficiencies.

Such systems use color light signals for signaling and electrical point machine for operation of points.

Where route relay interlocking is not implemented a hybrid arrangement is also used where rods may operate the points and signals are color light or where some of the points which are far from the operating cabin are operated through point machines. Essentially the safety in such hybrid system continues to be ensured through mechanical means.

In some form of partial route relay Interlocking systems electrical switches are provided which allows electrical feeds to signals of appropriate colors and to points as desired. Through use of suitable relay logic the safety of the system for train running is ensured. In such systems electrical detection of point is used and track circuits are used for proving safety of train running. Each of these safety monitoring elements are

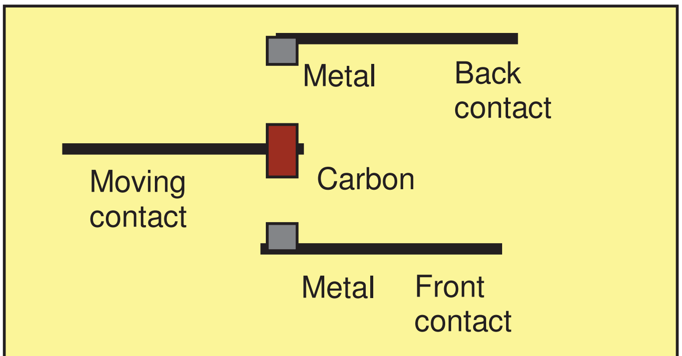


Fig 2.18

Circuits are designed such that when relays are un-operated no unsafe condition of train running occurs. It is, however, also possible to use metal to metal contact relays for realizing the logic circuits but such circuits have to be designed with care to ensure that even under failure condition train operations are safe. This is achieved by designing the circuits in a manner that for every clearance of a signal the relays that pick up to cause the signal to clear is also checked with respect to its back contact.

Use of Electronics :

The main advantage on such a system lies in the reduction on wiring material considerably both indoors & outdoors. Such systems also allow less effects due to failures because redundancies can be introduced easily so that failure of a single equipment causes only an alarm and standby units take over to carryout the operations. Such systems also require very little hardware changes in the physical layout on the yard changes. Therefore, introduction & support to changes can be more easily accommodated.

Such systems are based on microprocessors or full fledged computers which carries out the logical operation under software control. The Drives to external functions as signal lights, point machine etc. are typically given through suitable serial ports and decoder/controller drivers at site. Design on the system is made keeping in view the safety requirements.

In the case Solid State Interlocking safety is attained mainly through redundancies.

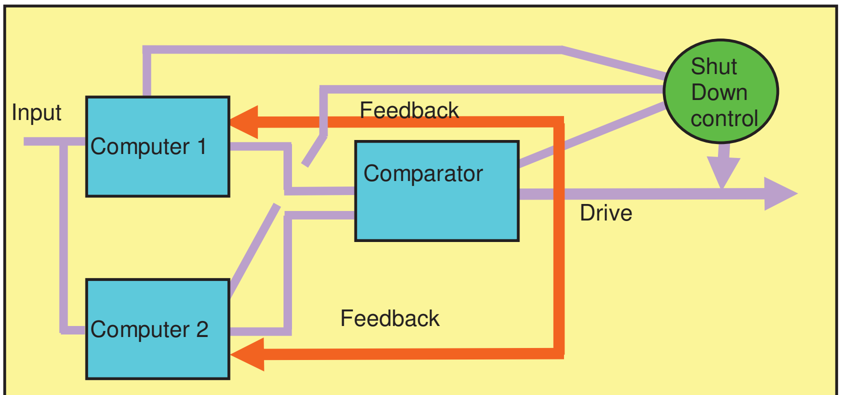


Fig 2.19

3. Signaling Plans

Signals are provided bearing in mind the following main considerations

a) Safety is ensured by the indications offered by the signals

b) Operational needs are satisfied.

The need to ensure safety is always the topmost consideration and under no circumstances the signaling arrangement can compromise with this primary requirement.

The operational needs is next to be satisfied. thus if a signal is provided which never shows a proceed aspect while safety is ensured nothing is achieved as no train can move on the signal. Hence the need to ensure that the signaling arrangement ensures that trains can be moved effectively.

Satisfying these two considerations require the definition of various types of signals and the location of these signals to result in the best signaling arrangement for a particular use.

Any Signaling arrangement requires to follow a set of rules which are normally ensured by the Railway for ensuring that the trains can be moved safely and in a manner which is desired for the optimization of the use of the facilities.

Any rules of operation of a Railway therefore defines a set of signals which can be generally categorized into the following types

a) Main Line signals

beyond which obstruction is expected. This modification to the statement brings into the concept of multiple aspect signaling by use of which it is possible to indicate a train where a possible obstruction is. It is sufficient for most signaling systems to indicate the location of obstruction two signals ahead of it as this will normally ensure at least 2 Km distance is available before another obstruction is likely to be encountered by a train. This means that as long as trains are not run at frequencies such that trains are spaced 2 Kms apart this arrangement is sufficient. This in turn means that with average speeds of 60 Kmph trains are running at interval of 2 minutes. This is a very good frequency of train operation and so covers most circumstances. This in turn means that the signals need to indicate the following conditions

a) No obstruction after second next signal

b) Track beyond the second next signal is obstructed

c) Track beyond the next signal is obstructed

Hence the signals need to indicate three conditions which is typically indicated by a Green for the condition a) Yellow for the condition b) and red for the condition c).

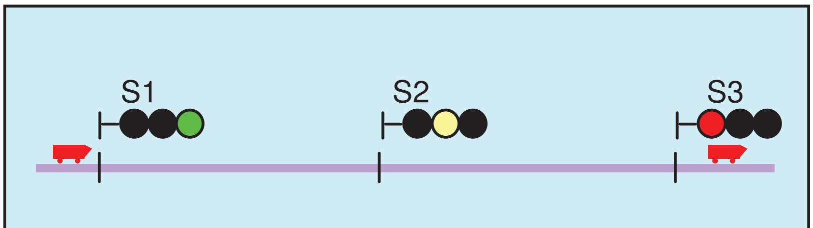


Fig 3.2

Referring to Fig 3. 2 with 2 trains one in rear of S1 and another in advance of S3, Signal S1 when cleared can be green but signal S2 can be yellow

Main Line Signals at a station can be classified into the following:

a) A signal which controls entry into and directs it to specified line of a station yard which is in many cases referred to as Home signal and can be generally called the first stop signal of a station Signal S5 is a Home Signal in Fig 3. 3.

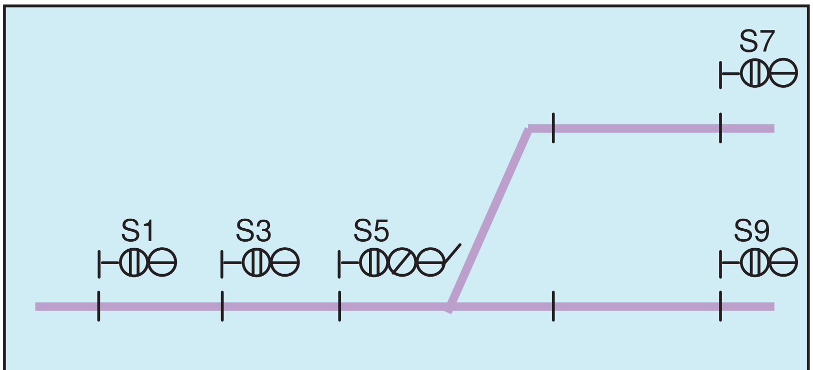


Fig 3.3

b) A signal which allows departure from specified lines of a station yard which is in many cases referred to as Starter Signal. In Fig 3. 3 Signals S7 and S9 are starter signals.

c) A signal which allows a train to leave a station yard which in many cases referred to as Advance Starter Signal and can be generally called the last stop signal of a station. Refer to Fig 3. 4 where Signal S11 is a Advance Starter Signal.

d) A signal which is at adequate braking distance from the from the first stop signal and often called the Distant Signal and is a approach repeater signal. In Fig 3. 3 Signal S3 is the distant signal.

The aspect which is normally displayed by a signal is indicated by drawing the line twice within the circle.

Using these symbols a typical signaling plan will look as below.

All functions are named and certain practices are loosely followed for allocating names. The signals are named using odd numbers for one direction and even for those in the opposite direction. Independent shunt signal numbering is started after providing a gap for adding more main signals if there is a modification carried out at a later date. The alphabets in front of main signal numbers and for shunt signal numbers are kept different. Sometimes different alphabets used in front main line signals depending on the direction of traffic to which the signal belongs.

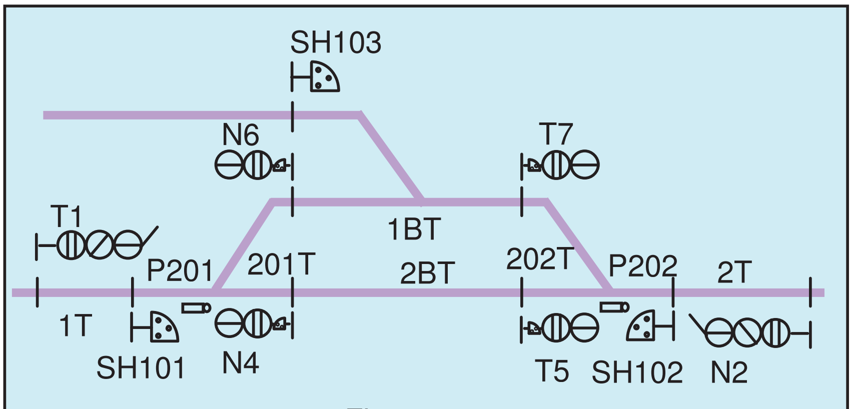


Fig 3.8

Points are numbered starting from a number large enough to accommodate all signal numbers with provision of adding additional signals at a later date. If a point is driven by a point machine a symbol of a point machine is added to the point machine. The number provided to track circuits are in simple layouts kept related to the signals and points to which they

Signal control relay	HR/DR/HHR

These relays would normally represent a safe condition when they are not set.

Where separate operation of points and signals are used the UCR relay is used to indicate steady state condition and in these circuits US/NLR relays (see below) are not used and UCR alone is used to prove the status of

Relays indicating the state of the Interlocking

There are several relays which indicate the steady state achieved by the signaling functions. The status of these relays are proved in the command progress relays and the command progress relays are picked up if the steady state of the signaling function is proper to maintain safety. These relays are normally picked up or for combinations as NLR/RLR at least one of them is always up. These relays are very vital for maintenance of safety and indicate if a signaling function is in the process of being set to less restrictive state.

Signal Approach Lock Stick Relay	ALSR
Route stick relay	USR
Point Normal / Reverse Relay	NLR / RLR
Point Free Relay	NWZ/RWZ
Route checking relays (in some cases)	UCR
Signal Normal Relay	NLR
Track Stick Relay	TSR

5. Axle Counter

Axle counters and track circuits

Track circuits are used to identify the presence of a train in particular section of a track and protect against accidents occurring on account of two trains moving to the same section of the railway track. Track circuits use various techniques and axle counting is one of them.

Axle counter counts axles. It counts axles in and out of section

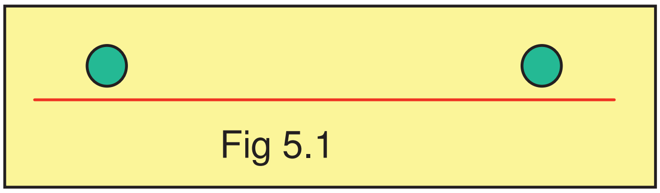


Fig 5.1

If axles in not equal to axles out then section occupied.

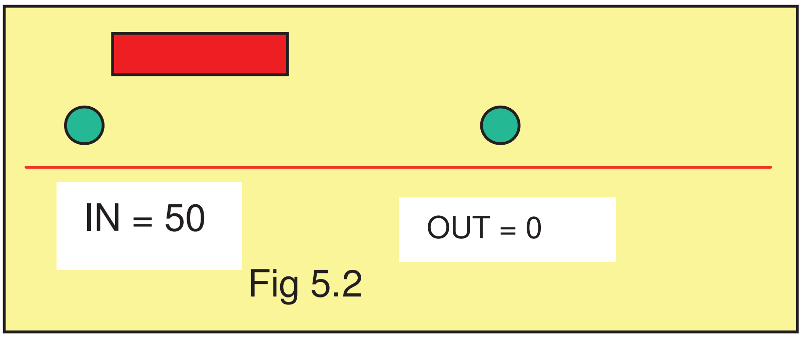


Fig 5.2

Section is occupied

When a train goes past the entry end detector in counts are recorded and at that moment as the train has not got past the exit end detector there is a IN

The Resultant signal is smaller and phase also changes

Signal can increase with wheels. Track devices do not necessarily have reduced coupling of magnetic field in the receiver coils when wheels traverse over it. In some axle counter track device the signal strength in the receiver coils increase when the wheels traverse over it.

The main requirement is that the signal changes as the wheel traverses over the track devices and its detection.

Earlier Axle counters only monitored the amplitude of the signal from detectors.

Present versions monitor both amplitude and phase. This gives additional discrimination between presence and absence of wheels.

Detection Of Direction Detection of direction of movement is important and it is done by having two detectors adjacent to each other. •Depending on the direction of movement the sequence of dips of the two detectors changes.

The Railway signaling follows simple logic to ensure safety is ensured. The computer system ensures that the logic required for ensuring safety is maintained when a train is signaled to move proceed beyond a signal.

The logic required for signaling is quite simple

a) Ensure that the portion after the signal being cleared and till the next signal is clear of any obstruction. The clearance of obstruction is proved by suitable means as track circuits or axle counters generally or it can even be manually done by switches etc.

b) Ensure that if any diversion is required then the portion of track which allows diversion (normally referred as switch) is properly mechanically set and locked in the required direction of the movement of the train. The setting locking and detection of route is done by point machines.

c) Ensure that a adequate distance beyond the next signal is also set properly and is clear of any obstruction. This in effect means that the checks as in a) and b) above is required to be carried out for a adequate distance beyond the signal at which the train is supposed to stop after it is allowed to proceed beyond the signal being cleared.

d) See that if trains are running at high speed then there are no connected tracks from where rail vehicles can roll and collide with the train being signaled to move.

Once this logic is understood as required for a yard the implementation using a computer based system becomes quite simple. The critical item however is the

A Generalized look at Solid State Interlocking

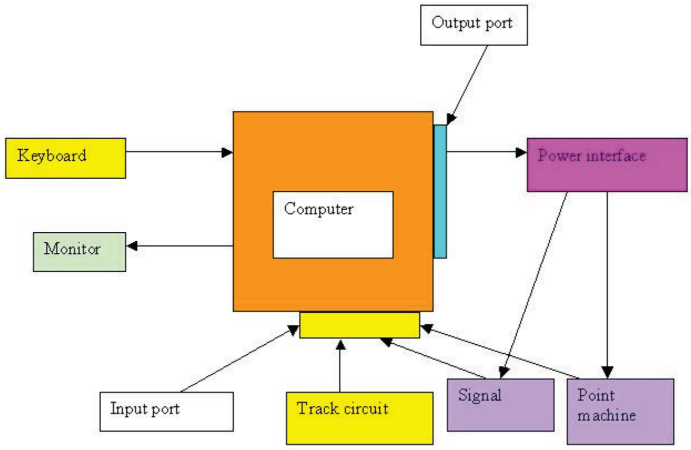
Solid State interlocking equipments and methods lack the ingredients of any computer based equipments this denying it the opportunity of taking advantage of the large scale developments that take place in the computer industry. The reasons for this exists in the very important area of its application being in the area which has impact on large mass of people. It is further aggravated due to the lack of economic support available even though it involves large number of people.

The computer industries remarkable growth and constant improvement is primarily due to the large scale support it receives involving a very segment of the human race. In this respect the Railway industry is no different as it is patronized by such large number of users considering specially that it is used much more in the developing countries and in metros where the population densities are the highest. Yet the same development as is seen by the computer industry is not existing in the Railway signaling industry and the sue of electronics in general and computer based equipments in particular has not been very encouraging and continues to lag behind the latest technologies specially in the area of computer based equipments by about a decade.

One of the major hurdles exist in the form of Railways failure to accept the use of Computer hardware in the same form as is used elsewhere in the industry. The hardware used for Railway signaling industry is always special and so cannot take advantage of new improvements in computer hardware directly and separate improvements become necessary.

Based on the above the simplest Railway Signaling system based on Computers should look like as below:

This is a pretty simple arrangement and can be realized by any computer suitably programmed to do



the job. We only have to ensure that the equipment is constructed out of hardware which is reliable enough to work satisfactorily. Signaling gears are pretty simple electrical devices like a signal is simply a group of lamps, a point machine a motor , a track circuit as far as the computer is concerned will only be a potential free contact which is to be monitored whether its made or closed. The position of point as well as signals in its simplest form again can be simply fed to the computer as potential free contacts.

The next part is obviously the requirement of safety which is a logical analysis of the state of the points, track circuits and signals. The result of the analysis is to generate commands to operate points, signals as required. The logic of signal operation is also simple remembering that it can be implemented by relay logic or even mechanical logic so it’s a pretty simple job for the modern computers.

system only feeds the information to the printer driver. The same will apply here. How it can simplify the situation is this that a reference to Home Signal is enough to ensure conditions of operations a home signal to be carried safely by the hardware.

The question is however how much we need to tell to the operating system from the application software. It is like a difference between a computer programmed to generate a single print statement and one which can print a page as chosen from among a set of pages or a case where one prints anything what is typed by the user of the computer. A computer required to print a single print statement need not have any control from the application program and everything can be in the operating system. While flexibility requires that a part resides in the application program.

It is this business of identifying how much we leave to operating system and how much to application in the case of signaling that is yet to be rationalized. At one end we have like the logic input equipments which makes the operating system concept irrelevant on the other end of the spectrum we have systems which puts in so much of rules inbuilt in the operating system that even a layout of the yard is sufficient to make the system work. In the latter system if the rules of operating the trains are different the interlocking system will not be operationally applicable for the case.

The problem therefore boils down to identifying how much is fundamental and how much can be left free. No track shall be occupied by two trains is a fundamental requirement but how do we bring a train for shunting purposes? Hence some rules which is very fundamental has some conditions under which it has to be changed. Similarly is how much overlap is

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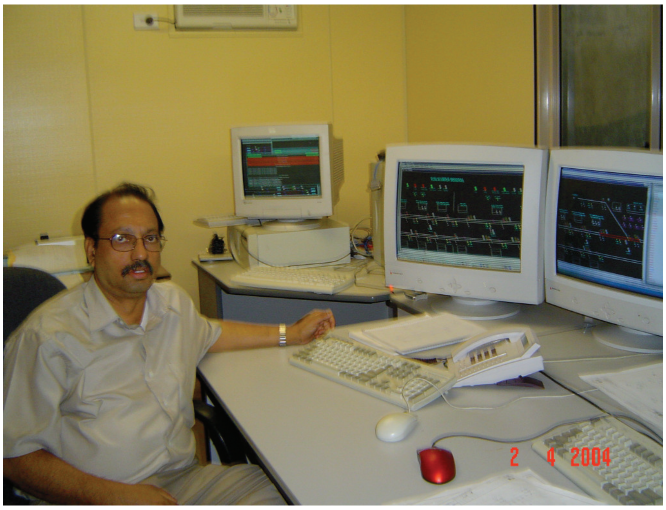

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