

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 to ensure 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.

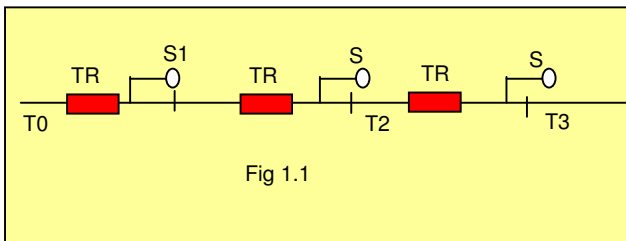


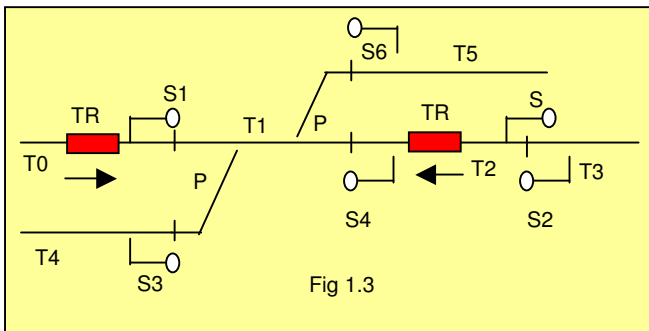
Fig 1 shows a representation of a railway signaling arrangement. The horizontal line represents the railway track, the signals are depicted by the symbol of the circle with a horizontal and vertical line to this circle and the red rectangles are the trains. This representation is however to explain how trains are run safely and the actual representation of various

Locking

There are three types of locking

- a) Direct
- b) Approach
- c) Route

Direct locking is available as long as a signal is clear or track is occupied or a point is set. This is the most fundamental level of locking.



When signal S1 is cleared the cleared condition of the signal locks other signals which can cause trains to run on any part of the route over which S1 allows a train to run. Thus with S1 cleared allowing trains to move to track T1 signal S4 cannot be cleared and will

be locked as the latter also allows trains to occupy track T1.

Other form of direct locking is the locking of the point in the route for which signal S1 is cleared. If S1 is cleared to the straight route T0 – T1 – T2 then the point P1 will be set and locked to allow a train to move on the straight route over Point P1. Attempts to move point P1 from this position will not be allowed and hence will be locked. Conversely if the point P1 is not set for straight the signal S1 will be locked.

The occupation of a track also locks signals if T1 is occupied then signal S1 cannot be cleared. Signal S1 is therefore directly locked to the cleared status of the track.

Points are directly locked to track circuits over the point zones. If the track circuit over a point zone is occupied then it is locked so that it cannot move. This is the direct locking of the point.

Approach Locking

While ensuring safety for train running it is not only

necessary to ensure that safety is ensured over all portions of track for which signals have been given but also over portions over track which can get occupied due to trains approaching a signal which protects these portions of track failing to stop at this signal. Such protection is required under two conditions

- a) When the signal protecting had not been cleared.

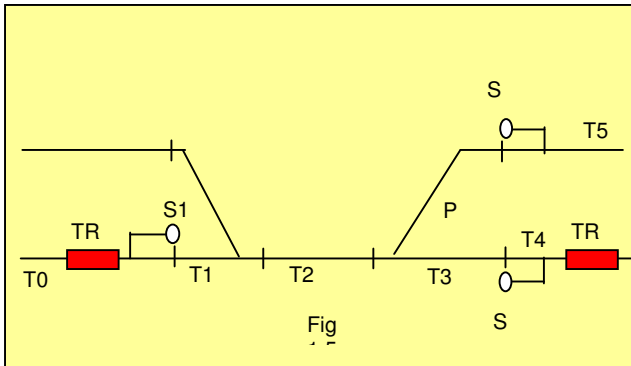
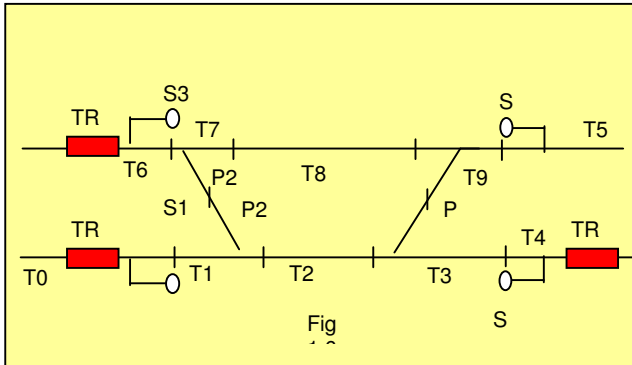


Fig 1.5 shows a condition when a train TR1 is planned to be sent to track T4 from track T0. When signal S3 is cleared it ensures that the point P1 cannot be moved. However once train TR1 goes past signal S1 onto track T1 the signal S1 is put back to red train TR1 is approaching the point P1 and track 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 move by 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



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 onto 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 allowing approach of a train to signal S1 if not found free. Conversely if signal S1 is cleared any condition which can lead to the overlap from failing to remain in the condition to maintain safety for train TR1 approaching S1 will be locked.

Release of locking

Signals indicate when a route which it checks is safe for a train to travel. The safety is checked from different angles as explained above. After a signal has been cleared for a train it is required to be put back to danger as the train moves past it. There are two reasons for doing this

- a) To ensure the safety of the train which has moved past.
- b) To allow clearance of other signals which has been locked by it.

The release of locking is done automatically as a train moves along the route a signal had cleared for it. The locking is released in stages

- a) As the train moves past the signal the approach locking is brought back to normal.
- b) As the train clears the first track after the signal the direct locking gets released.

- c) As the train moves the route locking , flank or isolation protection for the portions of the route cleared by the train is removed.
- d) After the train has come to a stop at the next signal for sufficient time to prove that it is not moving the overlap is released.

This is the normal release with the passage of train. There can however be occasions when it is required to cancel a signal which has been cleared and yet to be passed by the train. When this is required the signal is canceled. When the signal is canceled it is necessary to ensure that the locking it had enabled also get canceled. Here again the cancellation starts from release of the approach locking followed by release of the route locking, locking of flank and isolation and finally the overlap. The release is done only after it is established that a train which had been approaching the train has come to a stopped at the signal before the locking to other signals are released.

Detection of trains

Signals control movement of trains. For it to effectively control movement of signals there is a need to know the location of trains on the track.

The railway tracks are divided into short sections normally referred to as track sections. At any time only one train can occupy one such a section. Track circuits or axle counters are used for the detection of trains in these sections. Only one train can occupy a track section at any time.

Normally the detector is fed with the signal from the source through the rails and as long the detector receives a signal it concludes that the track section is not occupied. If a train occupies the track section being monitored it short circuits the track cutting off the signal from the source to the detector. When the detector finds loss of signal from the source it concludes that the section is occupied by a train.

Principles of fail safety is also very well demonstrated in this arrangement. In case of a failure like a broken wire, rail fracture, power supply failure, failure of the source the detector will lose the signal and conclude the section is occupied by a train. This will allow the detection to maintain safety even under failure condition and satisfy requirements of fail safety.

Control and drive to points

Points are driven by electrical motors. The motors are known as point motors and moves point using a mechanism which including the motor is referred to as point machine. A point machine mechanism moves switches of a point through a mechanical arrangement of rods and gears.

Signals

Signals indicate to the train drivers whether the route till the next signals is reached is safe or not. Before a signal is cleared the signal control logic verifies that everything is safe for a train which follows it. This will mean

- a) All track sections over which the train will be routed is unoccupied. This is checked by checking the status of the track circuit relays. Track proving relays of all track sections which are clear will be picked up. By checking the status of these relays which are referred as track relays the signaling control logic can determine that the route is clear.
- b) Routes of any signals which conflict with the signal is not cleared and that none of the signals have been approach locked.
- c) There is not route set over a track section conflicting with the route of the desired signal. This is proved by checking that all track circuits over which the signal reads is clear of route locking.

Implementation of Signaling Systems –

Train running and signaling the drivers of the trains depends to a significant extent on mechanized equipment. The technologies used for this application ranges from very rudimentary systems to highly sophisticated equipment. The technologies are based to a great degree on mechanical arrangement at large number of installations. Advanced technologies are in use on sections where train densities are high and specially where Railway Electrification has already been done. Technologies used for this application are for two reasons :-

- 1) To ensure safety of train running
- 2) To improve operational efficiency

Basic Principles :

Safety of train running in practice means ensuring that two trains do not occupy the same location at the same time. Since trains are bound onto Railway tracks it means ensuring two trains do not occupy same location of the track at the same time. This is ensured in two stages.

- 1) By dividing the Railway track into sections
- 2) Entry into each of these sections are controlled by suitable signaling system which ensures through various means that when a train is signaled to

(iii) The drivers controlling the train are signaled sufficiently in advance so that they can stop the train before signals which are not cleared. Since trains typically move at a speed of around 100 Km./Hr. it requires a braking distance of 1 Km before a signal at which it is required to stop. Hence signaling system ensures that signals are conveyed to the Drivers sufficiently in advance to bring the train to stop safely.

(iv) It should not be possible to move a point when a train is over the point or is very near to the point having picked up signal allowing the train to move over the point likely to be moved.

In addition to above various other rules are applied to make a signaling system safe. These rules are results of experiences gained after accidents. Thus one rule says that if a passenger train has to run through a line then this run through line should be isolated from other connected lines in the station by suitable means. This rule has been introduced to ensure that if there is a train standing on a connected line and it starts rolling it cannot result in a devastating collision as it is kept isolated from run through line on which high speed train has been signaled to go through.

Basic Rules .

The basic rules of safety in connection with train running is implemented through various methods. The Railway Engineering is very old and, therefore, implementation methods also are old. Availability of modern electrical & electronic technology is gradually changing the implementation of Railway signaling systems.

The technologies used in Railway signaling system depended on human element initially. Gradually mechanical systems were introduced followed by electrical/electromechanical and now electronics/electrical/electromechanical systems. The human element in Railway signaling is getting reduced more & more for improving safety and efficiency of train operations.

The human element :

Signaling Systems exist where setting of the point and locking of the same is entirely manual. The locking of the point is achieved through key and lock system. The signals are all hand Signals.

A more mechanized arrangement is where switches turning points are connected to levers and signals are given by mechanical arms known as semaphore signals.

In both the systems the human element ensure that the routes a train will take is not obstructed. The person who is clearing the signals for passage of the trains achieves this entirely visually.

The oldest signaling Systems are entirely manual where even the checking that a route has been set properly is manual. In more developed systems the checking of route is taken over by a mechanical detection system and mechanical levers are used for controlling signals.

The latter system is existing on the signaling system in a very big way. In this basic requirements of safety of signaling is mechanical means with some element of human element is involved in two areas :~

impulses regularly. Because of thig voltages it helps in rupturing resistance offered by train axles when they are standing on the track circuit section. Such track circuits are known as Jeumont track circuit. But these are very rarely used nowadays.

The 50 Hz & 83&113 Hz signal source is used in a manner similar to D.C. voltage and requires no special mention as the detector is simply a relay. In case of 83&1/3 Hz system normally 3 phase system is used and two phases are used on any section. The feed end gives one phase and a second phase is always fed to the detecting relay. When the track circuited section is free the two phases create a rotary force as in a AC electric motor. Absence of one of the phase via the rails due to presence of a train removes the rotating force dropping the relay. The 83&1/3 Hz track circuits is a popular track circuiting arrangement.

Electronics in Railway Signaling for improved safety

The audio frequency track circuit is the latest entrant in the field. This arrangement feeds an Audio frequency signal which causes pick up of Relay via the detector. A simple Audio frequency generator is used and at the detecting end a L.C. resonant circuit is used for picking up the desired Audio frequency picking up the desired Audio frequency signal & rejecting others. Due to the use of high frequency it is possible to use the Railway track as a transmission line and use of physical insulating pieces electrically isolating one section as "R' from 'A-B" is not required. By using resonant L.C. circuits at suitable points the AF signal can be made to stop beyond any particular point without the need of any insulating joint. This feature is a big advantage for this type of track circuit as there is no need to cut Rails & insert insulating pieces.

Indian Railways but considerable difficulties, faced on account of loss of track side equipment due to theft has rendered the system ineffective.

As a corollary to this simple arrangement, systems of continuous automatic control of trains are also available. Such systems continuously control speed of trains through transfer of signals from the track side to the engine. The system is quite elaborate consisting of a receiver located in the engine and suitable transmitter coils located on the sleepers between the track. A computer computes the required speed of trains running on the track for ensuring safety as well as for ensuring that trains run on time speeding as necessary or slowing when needed. Such a system is being implemented on Metro Railway Calcutta in India for the first time. Such systems are important for Metro 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 allowing higher levels of safety by using sophisticated controls the use of electrical/electronic gadgets for Railway Signaling is also made for ease of train operations and higher efficiencies.

Systems known as Panel Interlocking and its sophisticated variety known a Route Relay Interlocking are for control of signals and points with higher efficiencies.

Design of Signaling Circuits

Introduction

The design of signaling circuits is based on simple principles. Railway Signaling being one of the oldest control engineering is based on very simple methods and principles. One of the main reasons of its simplicity lies in the fact that technological aids for design were not very high till late 21st century and complicated design principles and methods could not be supported. as a result of this the circuits are drawn using very simple symbols and names are kept short. If looked in the context of the fact that the circuits had to be hand drawn in times where duplicating facilities were very primitive the reason why they are so simple can easily be understood.

Signaling circuits are based on defining relays of the following types

- a) Those signifying states in progress of a command
- b) Those indicating steady state of the signaling functions
- c) The last operation has been completed properly

All circuits of Railway Signaling has to ensure safety. Hence both the type of relays defined above also always ensure safety. This fundamentally means that in absence of any voltage to the circuit the relays shall assume safe state which is the drop state for all neutral relays and can be dropped or one of the latched state for relays which are latched electrically or mechanically

Steady state Indicating Relays

There are several relays which prove 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 NWKR /RWKR or NLR/RLR at least one of them is always up

Track circuit repeater relays-----TPR

Point detection relays -----NWKR/RWKR

Signal Approach Lock Stick Relay-----ALSR

Point Normal / Reverse Relay-----NLR / RLR

Point Free Relay----- NWZ/RWZ

Route Checking relay----- UCR

Signal Normal Relay-----NLR

Track Stick Relay-----TSR

Point Lock relay-----WLR

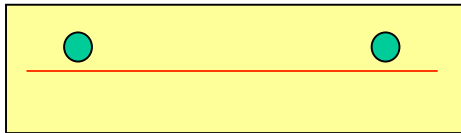
If these relays are up it proves that the signaling system has returned to safe state after its last operation

Axle Counter

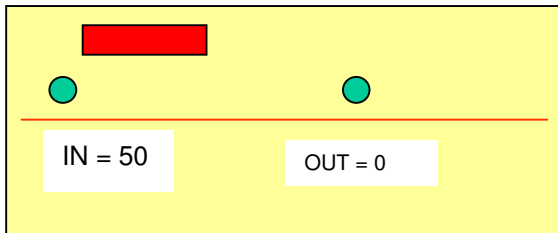
Axle counters and track circuits

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



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



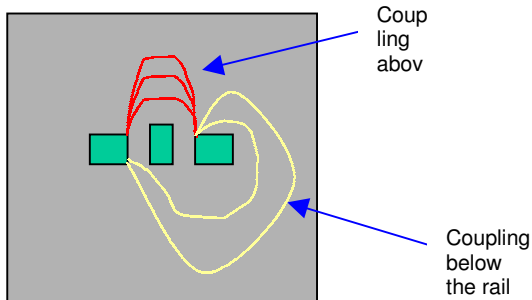
Section is occupied

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

- Can offer cost effective solution in monitoring yards with shared processor and multiple detectors

Working of Axle counter

Coupling of signal from transmitter to receiver•Audio frequency signal from transmitter coupled electro magnetically to receiver coil is interrupted by passage of wheels causing dips which are counted



There is therefore the need to ensure that at start up it takes a safe state and that is it assumes that the section is occupied. The first train run and detected successfully is then used to allow the monitoring of the section by the axle counter. The signaling circuits are to be designed implementing this principle.

Instead of running a validation train another method adopted is resetting of the axle counter by manual means to start the monitoring of the section. This can be safety risk and so normally procedure for resetting ensures more than one person will be required to enable a reset.

Resetting causes the counts recorded by the axle counter to be brought back to zero if there are any residual counts. So even if not used for validation is required to take care of counts registered due to unknown reasons.

Track devices require maintenance as the relative position of the transmitter coil, receiver coil and the rail on which it is fixed requires to be ensured for reliable detection of wheels of trains as it traverses the track devices.

For proper adjustments dummy wheels are used which are moved across the track devices and the dip in the signal from the receiver coil ensured to meet the specifications.

Solid State Interlocking

Safety of Railway operations in areas where several lines meet or diverge is maintained by signals which ensure that when any train is allowed go into a area it protected by at least one signal at its rear. Trains are