FINNISH RAIL ADMINISTRATION

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LINE BLOCK SYSTEM – APPLICATION NOTE

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1 FOREWORD

The mysteries involved in the technical system boundaries and interfaces are turned to understandable solutions and applied technology by appropriate documentation. In the safety related systems the interpretations related to planning and implementation are essential. In practice there are multiple parties involved from different organisations and cultures.

This application note is based on the "Safety system interfaces" report by Finnish Rail Administration 2008.

2 IMPLEMENTING A SAFETY CRITICAL INTERFACE PROJECT

The interlocking projects containing interfaces to other systems contain also all the elements related to the implementation of safety critical systems.

Compared to the overall system scope the interface portion may be relatively small. However, the implementation of the interface must contain all the same requirements dealing with the implementation of a safety related system as the main project. These requirements are expressed in international standards EN50129, EN50128 and EN61508.

2.1 Basic requirements

The interlocking systems are made and will also be made in future in sections forming interfaces to each other based on the best available practise.

The purpose of the interface is to carry the train safely across the boundaries of the separate systems. From the point of view of the fast moving train there should not be any more any recognisable boundary. The elements taking care of stopping the train in demand are always clearly connected to either one responsible system in the boundary area.

The purpose of the interface is to form a solid "handshake" connection between the systems. The system sending the train towards the boundary area controls the train authority by the elements and signals. The receiving (of the train) system is delivering the necessary safety related information to support the moving authority of the sender. Based on this fact the sending system has to be considered as a "Slave" to the receiving "Master".

The Finnish Railway Administration (infrastructure manager) and the Finnish Rail Agency (authority) have published on their web pages the basic requirements to be followed also in the interface related projects.

2.2 Analysis phase

The sending system needs information from the system across the boundary:

– The intended train route is possible (basic conditions);

– The set route has caused the required elements to be locked (locking conditions);

– After the forming of the route all the necessary interlocking related conditions of the elements have to be maintained (monitoring conditions).

The receiving system needs information from the system across the boundary:

– In the single track installations the set direction of Line Block;

– The required initiation mechanisms to reserve the necessary elements in the boundary area for the detected or intended train movement;

– The necessary interlocking mechanisms to hold the element locked during the train movement;

– The controlling mechanisms to cause an alarm and to stop the train in the case of violation of the rules or malfunction in the system.

2.3 Realisation phase

It is possible to determine the essential safety related elements across the boundary area:

– The signals and overlap securing the boundary area;

– The track sections in the boundary area.

The safety related systems in the boundary area are:

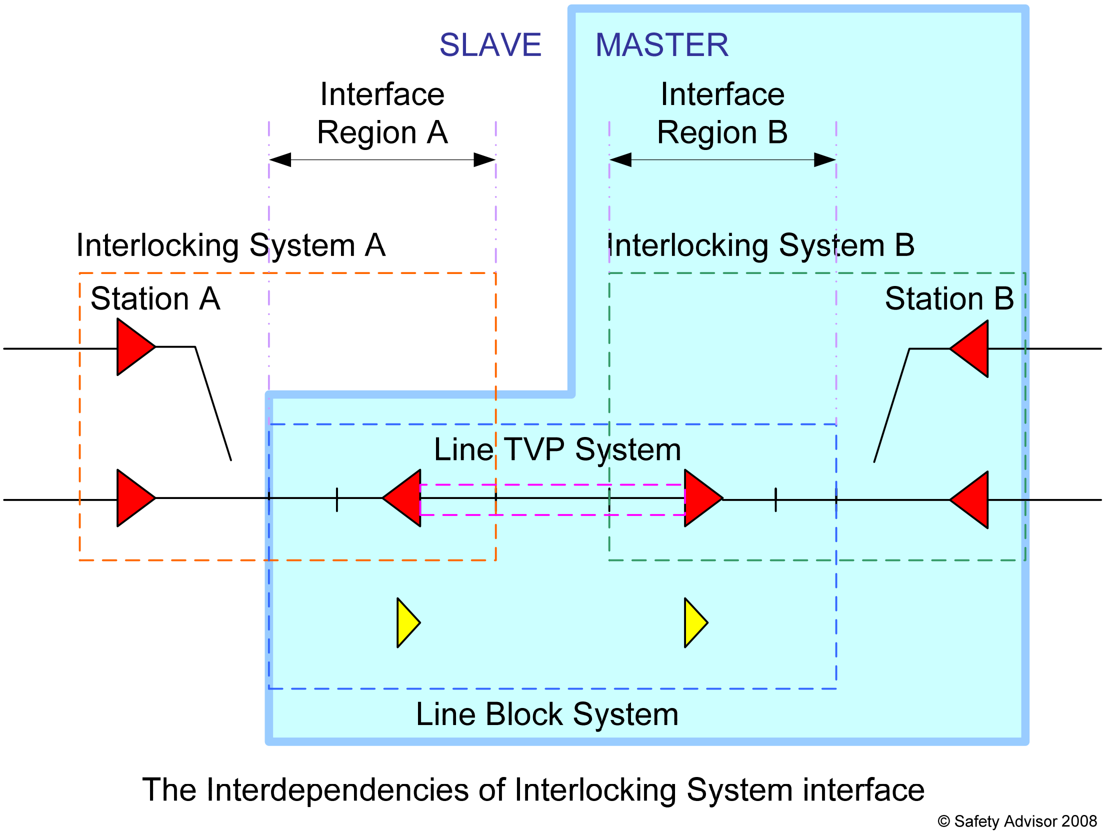
– The Interlocking Systems in both sides of the boundary;

– The Track Vacancy Providing (TVP) system of the limited interface track;

– The Line Block System taking care of the safety measures across the boundary.

In practical implementations it is common that the functionality of the interface has been part of one of the Interlocking Systems.

Picture 1 shows a model of the structure of the interface system. This is between two similar Interlocking Systems. The interface functionality has been implemented as a part of the Interlocking System B.



Picture 1. The modelling of the interface between Interlocking Systems

The information produced and required to secure the safe movement of the train can be easily found in the model.

In order to send the train to the line and control the route conditions the Interlocking System requires following information:

– Track vacancy information from the TVP-system;
– Safety information related to Line Block System.

The Line Block System taking care of the safety conditions across the boundary has interfaces to both Interlocking Systems and to the TVP-system.

2.4 Operational phase

The safety related changes to the inspected and commissioned Line Block System has to be conducted according to a documented and assessed way in line with the appropriate standards and requirements (common safety methods).

3 LINE BLOCK REQUIREMENTS

The majority of the interfaces between two interlocking systems have been implemented as an interconnection through the Line Block.

The Finnish Rail Administration documents related to the line block and indications are available in web (www.rhk.fi):

- RATO 6 Turvalaitteet / Safety Devices , 3.9.2007/7.4.2008
- Asetinlaiteilmaisut – Interlocking, indications (RHK 2700/043/2008), 15.12.2008

The attachments in the tendering documentation: the Functional requirements package contains a set of documents describing the essential functionality of the line block and the interlocking. Examples of the topics covered (at the time of writing):

- Interlocking System, Functional Requirements, V1.3 FR 2.Interdependence 1781/732/2003, 2006-07
- ROUTE GENERAL V2.0 RHK, UIC-EUROINTERLOCKING, 20.12.2006
- ROUTE INITIATION-COMPLETION, UIC-EUROINTERLOCKING, 20.12.2006
- LINE BLOCK V2.0 RHK. UIC-EUROINTERLOCKING, 20.12.2006
- FUNCTIONAL REQUIREMENTS DOMAIN KNOWLEDGE V1.0 RHK, UIC-EUROINTERLOCKING, 20.12.2006
- MONITORING V2.0 RHK, UIC-EUROINTERLOCKING, 20.12.2006
- TVP SECTION V2.0, UIC-EUROINTERLOCKING, 20.12.2006

3.1 The Definition of the Block according to RATO 6

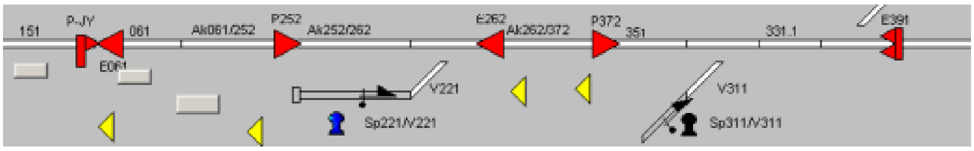
A **block** is an entity containing a number of functions that ensure the block conditions for the line in respect to the interlocking route conditions. A block can be implemented with a separate line block system or an equivalent operation can be implemented by the route conditions of the signals controlled by an interlocking system.

A **block system** is a separate system from an interlocking system that controls the running of units. The system does not function on the principle of route conditions as the interlocking system does, but it is based on block conditions that allow only one unit on a block section at any given time. Conditions are considered equal with route conditions as applicable.

A **block section** is a section between the route entry and exit points on a blocked track. A block section may include several track sections.

A **block entry signal** is a block signal that is situated in the interface of the interlocking system and the line equipped with a block system and has the first block section in advance of that signal. A block entry signal cannot be a route exit signal.

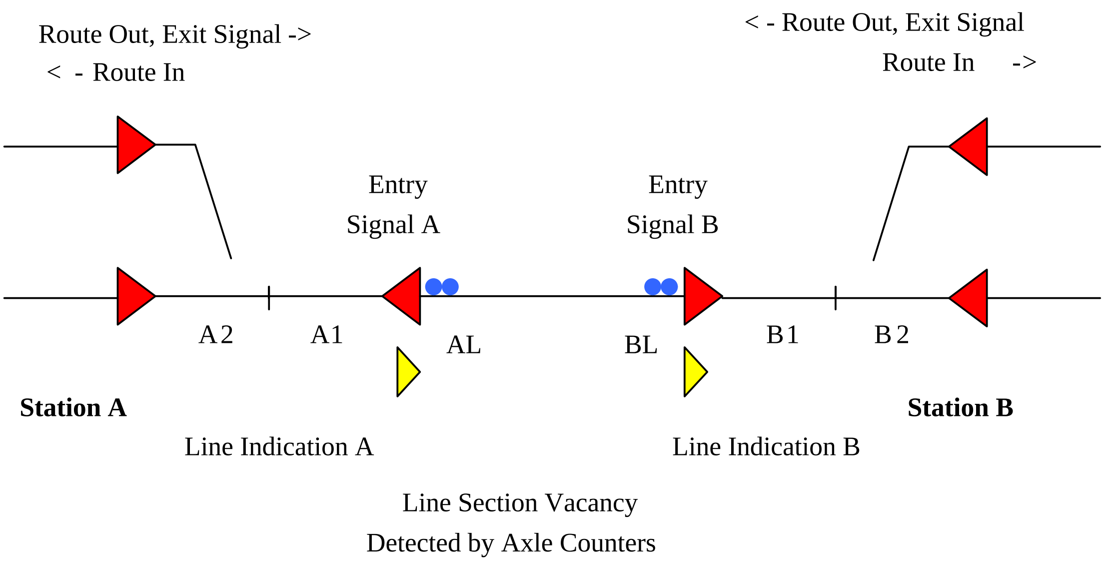
Picture 2 shows an implemented Line Block system. There are two subsequent blocks having a set of line points in between.



Picture 2. Line Block system.

4 GENERIC LINE BLOCK REQUIREMENTS

These requirements contain the essential properties of a Line Block System between two interlocking systems. The requirements also include some safety improvements.



Picture 3. The elements in the Generic Line Block System

4.1 Definitions

The Line Block has always a defined direction. This is presented as a safety related signal to both interconnecting systems. When the Line Block System is initiated the direction has to be defined by an administrative command/method (LHP; line emergency release).

4.1.1 Changing of the direction

Changing of the Line Block direction is possible when:

- Block is not in a failed state
- Block is vacant
- External locking requests do not exist
- Optional overlap is vacant
- Direction is not locked.

The change of the direction is initiated by a user command or a set route.

4.1.2 Monitoring of the signal

The lost monitoring of the receiving signal prevents the “proceed” aspect of the exit signal. The malfunction of the receiving signal is presented as a warning. The change of the direction shall be possible.

4.1.3 Monitoring of the line points

The monitoring signal of the line points is used to secure (lock) the Line Block. If a train leaves a line in the line points the Line Block will be locked until the line section becomes again vacant and the line points monitoring becomes secured.

4.1.4 Monitoring of the Line Block locking

The block shall be monitored the case when the line becomes vacant. The Line Block System shall follow up the signal and the TVP sections. The signal in rear of the occupied track shall be in “proceed” just before the line becomes vacant and the train shall not vanish without occupying subsequent track sections. Unexpected action of the line shall cause a fault state of the line.

4.1.5 Monitoring of a hostile train movement

Monitoring of the hostile train movement causes a fault state of the line and a separate alarm indication. This can be used by CTC system or by dispatcher to stop the trains. Hostile train movement shall be detected by proper devices (axle counter, subsequent track sections …).

4.1.6 Monitoring of a trailing train

Monitoring of a trailing train causes a warning when a following unit is detected.

4.1.7 Monitoring of a track blocking

Monitoring of set track blocking causes a warning in the case of a train enters the line with track blocking.

4.1.8 Monitoring of an overlap

Monitoring of overlap is a configurable feature. The track section in advance of the block exit signal (entry signal to the next block or area) is monitored. The Line Block remains locked until the section is vacant.

4.1.9 Locking of the direction

The direction shall be possible to set locked. This means that the direction cannot be changed neither by user command nor by the route setting.

4.1.10 Monitoring of the communication

The monitoring of the communication shall detect the disturbed or malfunctioning communication channel between the systems across the boundary by applying proper methods (static and dynamic signals …) and enter into the fault state.

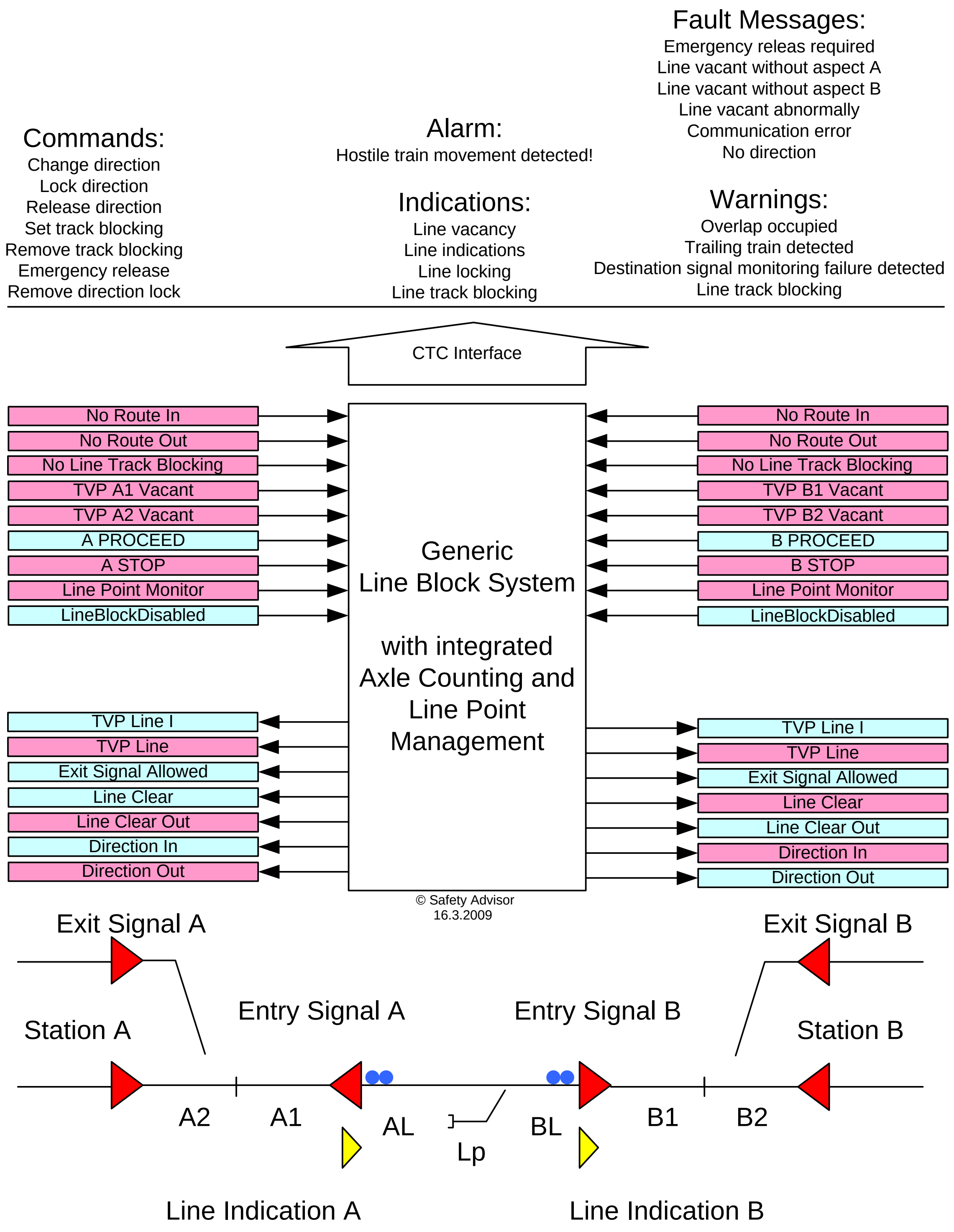
4.1.11 By-passing the Line Block rules

The by-passing shall be possible for commissioning and maintenance reasons on both ends of the line. In the non by-passed end of the line setting a train route to the line shall not be allowed. When the by-pass is removed the line shall enter to a failed state.

Interface signal	Normal Status	Signal direction	Source	Notes
No Route In	TRUE	output	Interlocking	The entry route of the station has not been set.
No Route Out	TRUE	output	Interlocking	The exit route of the station has not been set
No Line Track Blocking	TRUE	output	Interlocking	Track blocking has not been set.
TVP 1	TRUE	output	Interlocking	Vacancy monitoring of the first section after the station entry signal.
TVP 2	TRUE	output	Interlocking	Vacancy monitoring of the second section after the station entry signal.
PROCEED	FALSE	output	Interlocking	Monitoring the "PROCEED" aspect of the entry signal.
STOP	TRUE	output	Interlocking	Monitoring the "STOP" aspect of the entry signal.
Line Points Monitor[1]	TRUE	output	Interlocking	Line points monitoring
Line Block Disabled	FALSE	output	Parameter	Line Block by-pass
TVP Line	TRUE	input/output	Line Block/ Interlocking	Track Vacancy Proving of the line. The signal direction is related to the TVP-strategy used.
Exit Signal Allowed	FALSE	input	Line Block	TRUE-signal is set to enable the station exit signal "PROCEED" aspect when the Line Block is set to handle the exit route.
Line Clear	FALSE	input	Line Block	Line Block is clear. The direction of the line can be turned (direction in).
Line Clear Out	TRUE	input	Line Block	Line Block is clear. The setting of the route can be executed (direction out).
Direction In	FALSE	input	Line Block	Direction In
Direction Out	TRUE	input	Line Block	Direction Out

[1] | Can also be integrated in the Line Block system. In that case the line points is not visible to the interlocking systems.

Picture 4. The generic interface signals.



Picture 5. The model of a Generic Line Block System

Picture 5 describes the signals between two interlocking systems from the point of view of the line block system acting as a master and containing the TVP-system of the line, based on axle counters.

The Line Block System contains an interface to both of the inter-connecting interlocking systems.

5 RISK ANALYSIS OF THE LINE BLOCK

Table 1. About the Line Block system risk analysis

Case	Danger	Consequences	Risk Management
RP1R.1	Train enters the next block or station passing a failed signal.	1) collision 2) injuries, 3) material losses 4) delays	Monitoring the destination signal with active signals. Loosing the monitoring causes warnig which can be transmitted to the train.
RP1R.2	Unexpected occupied/vacant status of the interface track (line)	- " -	Situation is detected and the Line Block System is set to fault state.
RP1R.3	Unavailability of the Line Block in the case of signal failure.	If the signal malfunction prevents the line turnig the Line Block will be out of order to the other running direction.	The Generic Line Block System allows the line to be turned regardles of the signal satus. This enables the basic conditions and the lockable elements of the route to be locked to both directions. The setting of the "proceed" signal to the station exit signal is depengin on the interlocking rules implemented for monitoring the hostile entry signal of the station.
RP1R.4	Trains entering the same track from both ends.	1) collision 2) injuries, 3) material losses 4) delays	The implementation of the interface is based on the Line Block properties. The train entering to the interface track requires always setting of the direction and monitored and secured route conditions of the interconnecting elements.
RP1R.5	Train entering to the interfce track (line) passing "STOP" aspect of a station exit signal.	- " -	When a unit enters the line, the Line Block will be occupied and locked.
RP1R.6	Train leaving the line passing "STOP" aspect of a station entry signal.	- " -	Operational error is detected and the line will be set to fault state.
RP1R.7	Train entering the line from line points. Loosing the line point monitoring.	- " -	Line will be occupied and secured to the set direction on the same conditions as the train had entered from the other end of the line.
RP1R.8	Train enters normally the block section. Hostile train enters the line from the other end and passes a red signal aspect.	- " -	An alarm will be lauched.
RP1R.9	Train enters normally the block. Trailing train follows the train.	- " -	A warning will be lauched.
RP1R.10	The safety signal handling system of the interface fails	- " -	Safety device operated by an active monitoring signal in addition to ambivalence, feedback monitoring and other safety measures of the interconnection signals. Monitoring of the communication system.
RP1R.11	Movement through the boundary in the case of system failure.	- " -	A by-pass simulation enabling the line block system to simulate the interface functionality. Using the by-pass shall be indicated and restricted to the interface track. Special operational rules shall ensure the safe operation.
RP1R.12	Maintenance work at the interface track	Injuries	Track blocking functionality on the interface tracks.

The risk analysis of a Line Block shall be conducted as a part of the planning phase of the Line Block.

6 IMPLEMENTATION OF A LINE BLOCK

The interface between the Interlocking System and the Line Block System is based on signal handshaking between the systems.

By using the Generic Line Block System described above the functionality of the interface can be built as a separate and independent safety system between the two systems.

However, in most of the recent implementations the Line Block System has been a solid part of the other interlocking system.

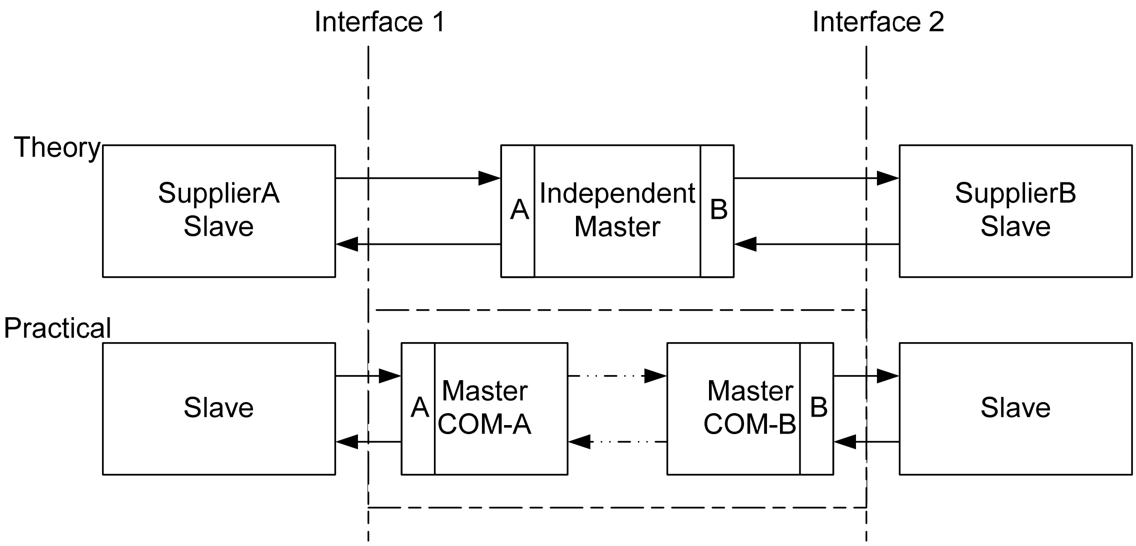
6.1 Separate Line Block System

The interface between two interlocking systems may also be conducted as a separate project - both of the systems will be connected to the Generic Line Block System.

The benefits of having a “third party” interface project:

- Pre-defined interface for the interlocking system suppliers
- Minimal changes to the main interlocking systems
- Off-line verification and validation before commissioning
- Independent project and will for the interface safety

In order to achieve a safe and well defined interface it is essential in good time to plan, define and create a model of the functionality of the interfaces.



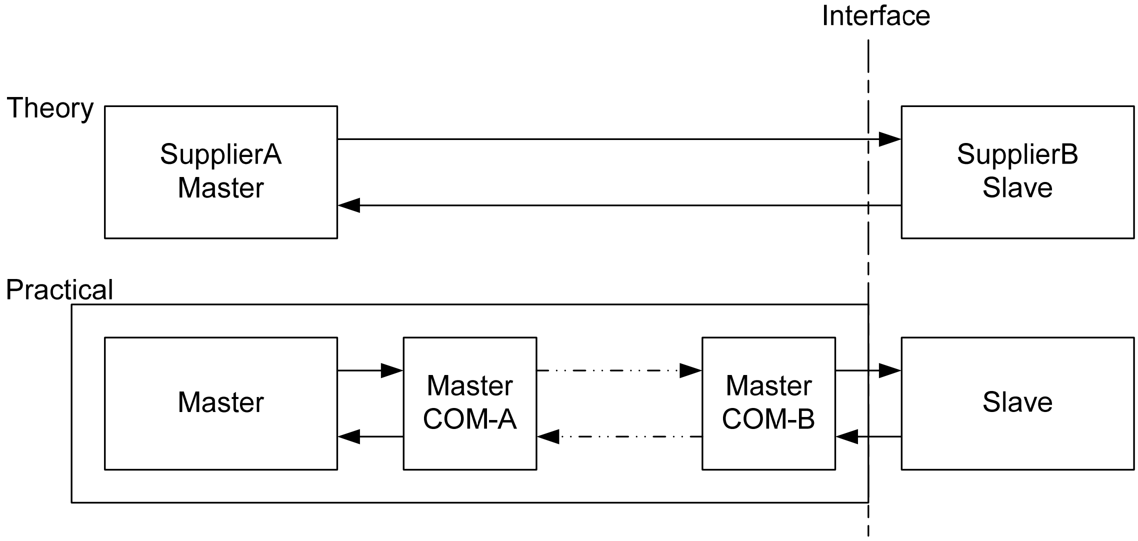
Picture 6. An independent Line Block System

The upper part of picture 6 describes the theoretical model of the independent system. The practical part is describing the "master" dividing to two parts connected together via a communication channel.

6.2 Line Block System as a part of one supplier's Interlocking System

The functionality and the interface signals are part of the "Master" system.

The lack of definitions in the Master/Slave signals and the overall system has caused practical problems in the commissioning phase of the systems.



Picture 7. Line Block System as a part of the other Interlocking System

The lower part of the picture describes the practical solution. A sub-station of the "Master" interlocking system has to be situated in connection to the "Slave" system. A communication channel connects the locations together.

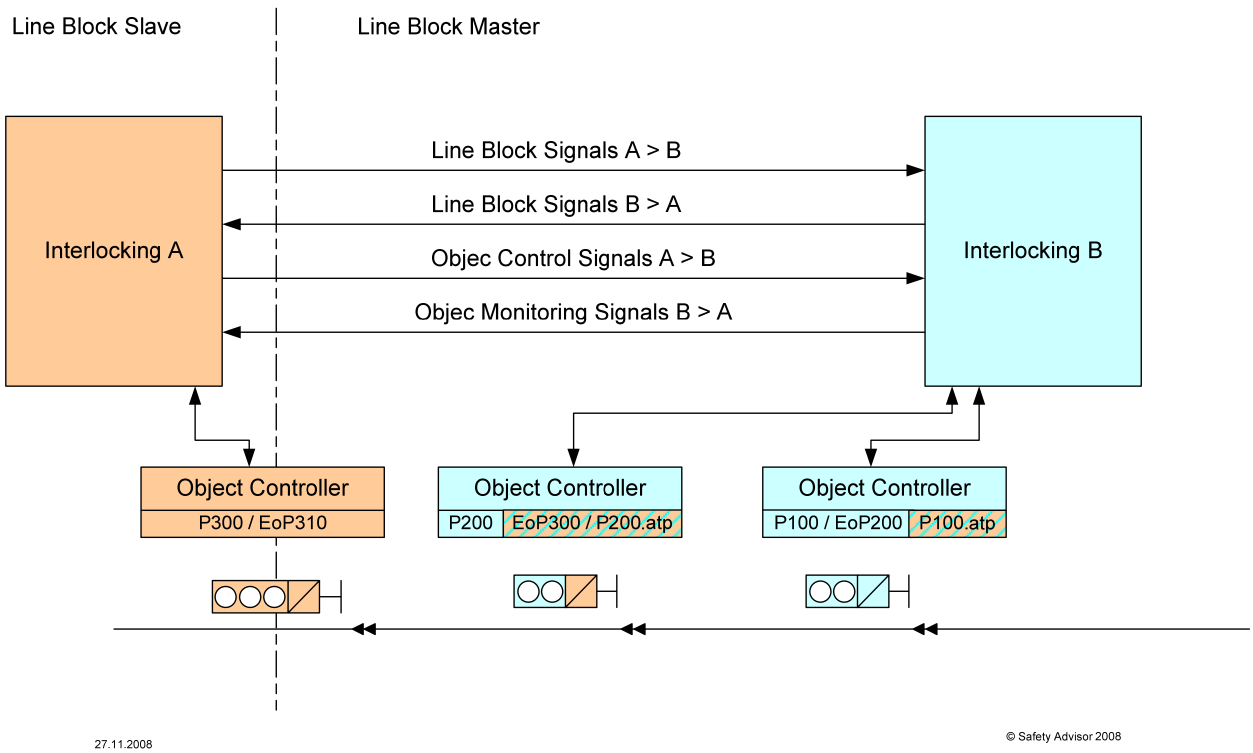
6.3 Other interface signals

In some implementations the structure of the practical system may include a need to position some central elements controlled by one system in the area of the other system. Because of the technical reasons (in the picture 8) the ATP aspects and distant signals of the Interlocking System A have been located in the area controlled by the sub-stations of the Interlocking System B.

However, in this case these elements in the System B-area will be controlled by the signals of the System A.

Different colours represent the control functions ad responsibilities of each system. The area having both colours, represent a control function that has dependencies from both of the systems.

The ATP-aspects on the location of the visual signal P300 are based totally on the functionality of the System A.



Picture 8. Controlling the elements across the interface.

On the location P200 the distant signal EoP300 is physically controlled by the equipment of the System B but the functions of the System A. The ATP-aspects on the same location are formed by applying the functions of both the Systems A and B.

On the location P100 both the main and distant signals are controlled by the System B. The ATP-aspects on the same location are formed by applying the functions of both the Systems A and B.

For transporting safety related signals between systems there are several technologies:

– Safety Related Communication Protocols
– Safety Related Signal Interface

6.3.1 Protocols

In treating safety related signals between systems special safety protocols are necessary. The protocols define the functionality (safety action) in case of illogical operation, communication loss or disturbance.

6.3.2 Safe signal interface

Traditional, potential free, feedback controlled, ambivalent signals are proven in practise for maintaining the integrity of the safety related information.

An ambivalent signal transports a bit of binary information by using two opposite signal statuses. The information is interpreted only when the signals are opposite.

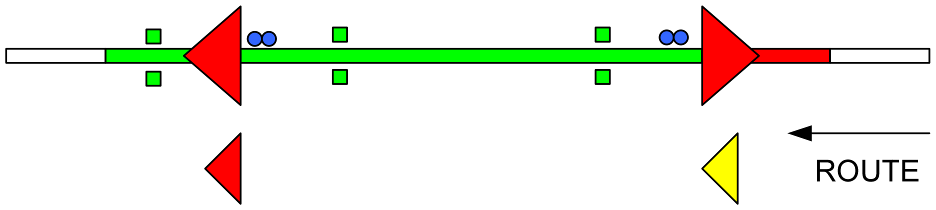
Signal 1	Signal 2	Interpretation
FALSE	FALSE	FAULT
TRUE	FALSE	TRUE
FALSE	TRUE	FALSE
TRUE	TRUE	FAULT

In the picture 8 the System A controls the functions of the elements by the ambivalent control signals produced by the System B.

7 MODELLING OF THE LINE BLOCK SYSTEM INDICATIONS

The operations of the Generic Line Block System are modelled in the simple "animations" attached to this document.

The functional model of the Line Block System is useful in understanding and testing the actual implementation of the Line Block System.



Picture 9. The indications of the Generic Line Block System

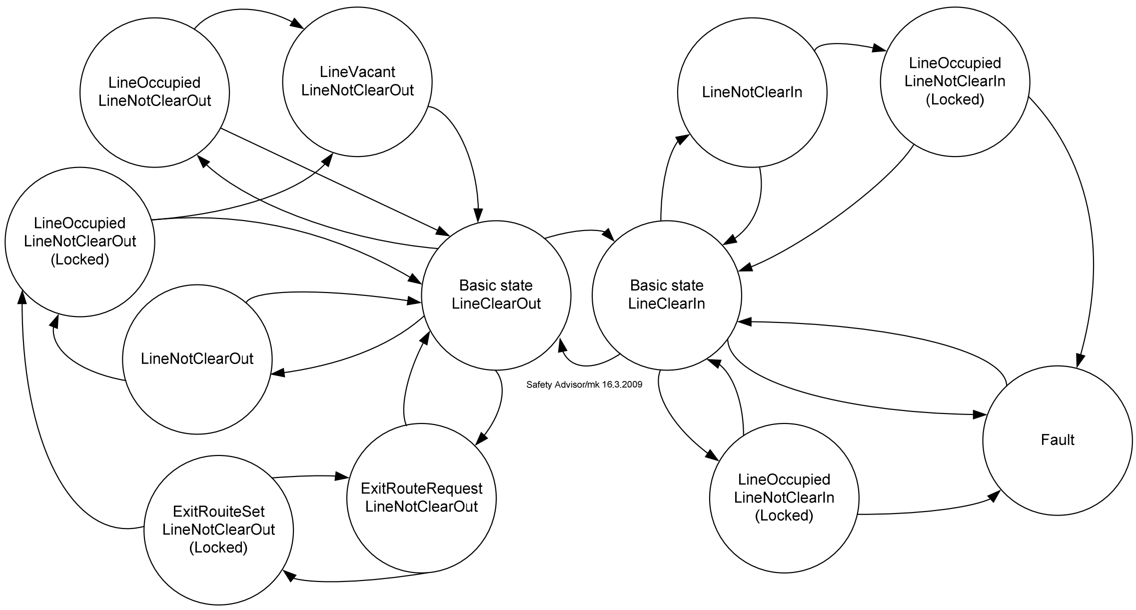
The animations using the Line Block System indications can be used to clearly describe the functionality of the desired Line Block System. The document collects the main operational cases and their impact on the system safety performance.

8 STATE MACHINE MODELLING OF THE SYSTEM

By using the state machine modelling the complicated relations of separate systems can be formally split to unambiguous states and events causing the state transitions.

Picture 10 indicates a state machine diagram describing the Line Block System states form the point of view of one end of the line. The Block status Basic state can be either “Line Clear Out” or “Line Clear In”.

The state transitions are always based on external events. For instance the dispatcher can change the line direction just by issuing the related command. The line will be locked by the route set to the line.



Picture 10. The State Machine Model

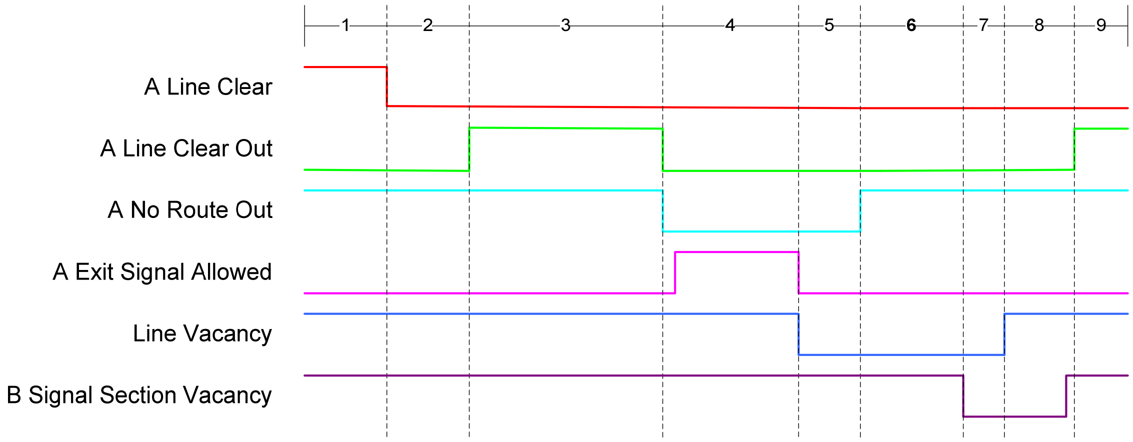
By drawing the state machine so that the System A is on the left and System B on the right side of the machine, you can at the same time analyse the dualistic operation of the Line Block System on the both Interlocking Systems.

By creating the state machine model as animations it is possible to analyze the state transition effects on the both systems.

By completing the drawing it is possible to model all the functions and states of the systems. In the Infinite State Machine all the possible external signals are included and treated in all possible states.

9 SIGNAL TIME GRAPH AS A MODELLING METHOD

Time graph



1) Line Block direction towards A
2) Line Block changing direction (by a command)
3) Line Block clear in direction A->B
4) A train route is set from A to line; Exit signal allowed
5) Train enters the line; >Exit route is released
6) Train is on the line
7) Train is entering the B region
8) Line becomes vacant
9) Overlap becomes vacant and Line Block clear

Picture 11. Signal Time Graph in modelling Line Block Signals

In the graph the Line Block System signal states have been described as the function of time. In the time graph all the signals having affects on functionality of the interface subsystem under investigation have to be presented.

“Line Clear”-signal means that it is possible to turn the direction of the line. During the direction turning both the signals “Line Clear” and “Line Clear Out” signals are out of control (TRUE- status) due to the fact that the Block is not stable to any direction.

On the other hand during the forming of the train route, the “Line Clear Out” signal informs to the connecting interlocking system that the train route is allowed to be set (basic conditions). When the route is set (the sections 3 to 4 in the graph) the signal is not any more controlled. The “Exit Signal Allowed” will replace it in controlling the block, locking and signal dependencies of the Line Block System for the set route.

As a planning method the Time Graph is practical for seeking potential unclear or impossible state transitions causing the system to become unstable or even safety critical.

As a problem solving method, the signal time graphs measured from the actual functional system with a multi channel analyser, is fast and revealing.