UNIVERSITY OF GAZİANTEP
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UNIFICATION OF EXISTING TRAIN CONTROL SYSTEMS IN TURKEY AND DEVELOPING NEW SUBSYSTEMS AS A CONCEPT OF "TTCS"

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IN
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Prof. Dr. Celal KORAŞLI

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ABSTRACT

UNIFICATION OF EXISTING TRAIN CONTROL SYSTEMS IN TURKEY AND DEVELOPMENT OF NEW SUBSYSTEMS UNDER THE CONCEPT OF “TTCS”

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This study presents several innovative approaches for unification of the existing train control systems in Turkey. The major factors required in operation of such control systems are less energy consumption, more safe and functional operations. These factors are highlighted at every design stage of the proposed system.

The system comprises several subsystems under the control of TTCS (Turkish Train Control System) to perform level crossing, unified signalling and determining instant variable overlap distance, and also provides alternative solutions to the existing subsystems in the present ETCS. The proposed subsystems on TTCS shall provide efficient operations and safer cruising with less energy consumptions. However, further developments for the proposed subsystems are required in both technical and managerial aspects.

Keywords: Train control system, Turkish Train Control Systems (TTCS), European Train Control Systems (ETCS), railway signalling, level crossing

ÖZET

TÜRKİYE’DE KULLANILAN MEVCUT TREN KONTROL SİSTEMLERİNİN BİRLEŞTİRİLMESİ VE YENİ ALTSİSTEMLERİN TTCS KAVRAMI İLE GELİŞTİRİLMESİ

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Bu çalışma, Türkiye de kullanılmakta olan kontrol tren kontrol sistemlerinin birleştirilmesi için çeşitli yenilikçi yaklaşımlar sunmaktadır. Sistemin operasyonel işlevselliğinde, diğer kontrol sistemlerine göre önemli faktörler daha az enerji tüketimi, daha güvenli seyir imkanı ve çeşitli fonksiyonellikleridir. Tüm tasarım aşamalarında bu faktörler göz önünde bulundurulmuştur.

Sistem, TTCS (Türkiye Demiryolu Kontrol Sistemi) kontrolü altında çalışmakta olan, hemzemin geçişi, birleştirilmiş sinyal yaklaşımı ve anlık değişken örtüşme mesafesi işlevlerini yerine getirmek üzere çeşitli alt sistemlerden oluşmakta ve hali hazırda kullanılmakta olan ETCS ye alternatif çözümler önermektedir. TTCS ile önerilen alt sistemler ile verimli operasyonlar, daha güvenli seyrüseferler daha az enerji tüketimi ile gerçekleştirilebilecektir. Ancak bu alt sistemlerin teknik ve yönetsel açılardan daha fazla gelişmeleri gerekmektedir.

Keywords: Tren kontrol sistemi, Türk Tren Kontrol Sistemi (TTCS), Avrupa Tren Kontrol Sistemi (ETCS), demiryolu sinyalizasyonu, hemzemin geçit.

Bir hayatı paylaşırken,

Eşim, Yol arkadaşım

Dilan'a...

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LIST OF SYMBOLS/ABBREVIATIONS

DDS	Digital Display System
ETCS	European Train Control System
CTCS	Chinese Train Control System
TTCS	Turkish Train Control System
LC	Level Crossing
FRS	Functional Requirement Specification
ATP	Automatic Train Protection
ATS	Automatic Train Stop
TCS	Train Control Systems
HMB	Horizontally Moving Barrier
WP	Working Proper Signal
CBCU	Central Barrier Control Unit
SBCU	Single Barrier Control Unit
TC	Track Circuit

CHAPTER I

INTRODUCTION

In the current decade, Turkish Railways are facing a major and rapid change. In the next ten years, the Turkish Railway Network will go through the special periods of the major developments and extension. There are more than 10,000 kilometres of electrified and non-electrified line in operation in Turkish railways. With the development of the Turkish Economy, it is estimated that new railway lines are needed and will be constructed. In addition, the dedicated passenger lines and a high speed railway line will be constructed in the next few years [1].

There are a few signaling systems in use and they are not interoperable in the Turkish Railways due to the reasons of historical and technical reasons resulted from different signaling systems which were constructed at different historical period, and to the difficulties of integrating signaling systems. Europe had faced the same problems before the ETCS (European Train Control System) project began in 1992 [1].

The concept of the present TTCS is simply unification of the existing subsystems. Although there are some different applications in order to unify the system operation, ın the present study new approaches are suggested for Level Crossing, Variable Overlap Distance and line side Signaling systems. Principally there are similar features between the existing Advanced train control systems and proposed TTCS.

Advanced train control systems and subsystems require rules for efficient and safer operation and less power consumption. Principally, an advanced train control system consists of four main parts [1,2]:

- The central control system
- The station control systems and wayside systems
- The on-board control systems
- The communication network including mobile communication.

In general, at the design stage of any advanced train control system includes the following stages to provide a quality operation [1,2];

- Re-designing the subsystems for special line applications,
- Safety assessments of the system and subsystems.
- Simulation, verification and testing.

In this study, as a concept of TTCS, a set of new subsystems are proposed to support the existing advanced train control systems;

- Level Crossing,
- Unified (RGB-LED) Signal Aspects,
- Variable Overlap Distance.

With the development of modern data communication, computer and control techniques, the proposed TTCS may be applied in main lines, light rail and underground lines in cities, and it is expected that solving the technical problems, there is possibility that these subsystems may be used in futuristic train control systems.

1.1. The Structure of Thesis

In this study, three subsystems are proposed to make the existing train control systems to fulfil the required rules of operation is the main concept behind of this study. In Chapter II, an overview about historical advances on the existing signaling systems (ETCS and CTCS) and basic definitions of the railway signaling are explained. In Chapter III; the recommended innovations on the proposed subsystems are demonstrated. Results and Discussions are introduced in Chapter IV, and finally, conclusions on the study are summarized in Chapter V.

CHAPTER II

AN OVERVIEW OF EXISTING SIGNALLING SYSTEMS ON THE WORLD

2.1 Introduction

For safe and efficient railway system signaling is an essential part of train operations on the railways. Today, the importance of the signaling and train control is not discussable. Safe train activities depend on reliable and manageable signaling systems. In this chapter, an attempt to explain, in simple definitions, how railway signaling system is concluded and how it operates in real life [2,3].

2.2 Background

In the first times, companies are focused mechanical-visual solutions for the train control. In the beginning days of railway improvement there was no preset signaling and no communication system for the trains. The flags, symbols visual indicators without any automatic control are the bases of this visual approach. So they could stop before any accident to occur only using their eyes.

During the operation of the trains with visual and mechanical signaling systems, some problems were encountered; the hard brakes and the weak contact between rails and wheels can cause accidents. Even if there is no accident after a hard brake, deceleration on the train is enough to damage passengers and load on the train.

It was quite difficult to stop the train without any equipment. The observation distance is not enough to stop the train. The classical method for train protection is not safe. Another control mechanism is necessary to inform the train driver about the previous situation. So the block concept was born.

2.2.1 ETCS

In 1992, the system has been developed for whole Europe and installed on selected regions in a number of countries. European Train Control System (ETCS) is a solution to combine all European track-train transmission based train driving supervision system. The expected results are cost reduction large implementation scales, easy maintainability and decrements on repairing costs.

To control and manage the European Rail Traffic, as a subsystem of ERTMS, ETCS was put forward. ETCS is the result of all updated requirements on control and management development on the European railway network.

The number of high speed trains and high speed lines were increasing dramatically in Europe. In order to connect the European high speed lines to each other, apart from the different languages, regions and cultures there is a chance occurred.

There exist well-built technical barriers on railway network to cross-European borders. Different ATP usage is the hardest part of this problem. The ATP systems are unsuitable to co-operate, communicate and control. Since all manufacturers produced their own products [2,3]. The solution on ATP unification is to make compatible all manufacturers' products.

Supported by the European Union and Governments in Europe, the European researchers, European academicians and the six main European railway signaling suppliers called as UNISIG began to cooperate for ETCS ten years ago Unifying all manufacturers is the base of this organization.. The free contribution from different disciplines to the system development helps to improve more flexible and more operational system. [2,3]. The target of ETCS can be summarized as the following seven titles. [2,3].

1) Interoperability;

ETCS is able to interoperate all trains along the all Europe region. Different signaling systems in different countries in Europe able to use a unified signaling system.

2) Safety;

ETCS applications, even with level 0, will improve the safety of train operation by providing only ATP or cab signaling to the conventional lines.

3) Capacity;

With ETCS idea, the line capability and efficiency of operations by from 10% to 30%.

4) Availability;

ETCS standardization, fewer on-board systems are proposed; this means fewer interfaces and connection.

5) Cost-effectiveness;

Depending to the fewer products, investment costs could be decreased dramatically.

6) Less on-board equipment;

A single and standardized Man-Machine Interface (MMI) is provided.

7) Open market;

Monopolies for railway signaling in Europe, which is managed by a few companies, will be broken.

The applications of ETCS are divided into five levels. They are Level 0, level STM, level 1, level 2 and level 3 [2,3].

- **Level 0:** ETCS on-board system (ATP) is installed on trains running on the existing line without ETCS or national system [3].
- **Level STM:** train is equipped with ETCS operating on a line equipped with a national system to which it interfaces by use of a STM [3].
- **Level 1:** apart from on-board system, balises or Euro-loops are added to the wayside system, and in-fill information transmission is implemented [3].
- **Level 2:** radio system (GSM-R) is applied between trains and wayside system, and the fixed block system is implemented [3].

- **Level 3:** based on radio system, a moving block system is implemented [3].

Now, ETCS is a reality, as a solution on railway traffic management systems commonly in use on the world. In France, Italy and the Netherlands test activities are concluded in 2002 or early 2003 [1,2,3].

2.2.2 CTCS

Chinese Railway has the similar obstacles like Europe. The incompatible signaling systems are the most complaining part of the problem which could solve a unified national system. The concept of CTCS is proposed as an innovation shall include other signaling systems for high speed lines and conventional lines, passenger lines and cargo lines as well [1].

The idea of CTCS is define a unified signaling system. Otherwise, the aim is combining the existing systems in use for Chinese Railways which commonly in use. For this reason, CTCS had developed a typical signaling system in Chinese Railways which can operate on whole China without any obstacle [1].

The standards on CTCS are defined by a group of engineers that observes the similarity and affinity between the signaling systems in use. The management and defining protocol rules of data transmission between the subsystems was the first one the duty of this engineering group. The other unification and standardizations are safety and reliability, capacity increments, easy maintenance, lower deal and open markets for CTCS action [1].

As a result of a serious study on CTCS, Chinese Railway Network, CTCS will be divided into the five levels as from 0 to 4:

- **Level 0:** It consists of the existing track circuits, universal cab signaling (the digital, microprocessors-based cab signaling that is compatible with the six kinds of track circuits. CTCS level 0 is only for the trains with the speed less than 120km/h [1].

- **Level 1:** It consists of the existing track circuits, transponders (or balises) and ATP system. It is for the train with the speed between 120km/h and 160km/h. On the on-board system (ATP) which is used [1].

- **Level 2:** It consists of digital track circuits (or analogue track circuits with multi-information), transponders (balise) and ATP system. It is used for the trains with the speed higher than 160 km/h. There is no wayside signaling in block for the level 2 anymore. ATP system can get all the necessary information for train control. With this level, fixed block mode is still applied [1].

- **Level 3:** It consists of track circuits, transponders (balises) and ATP with GSM-R. In the level 3, the function of the track circuit is only for train occupation and train integrity checking. All the data concerning train operation information is transmitted by GSM-R. GSM-R is the core of the level. At this level, the philosophy of fixed block system is still applied [1].

- **Level 4:** It is the highest level for CTCS. Moving block system function can be realized by the level 4. The information transmission between trains and wayside devices is made by GSM-R. GPS or transponders (balises) are used for train position. Train integrity checking is carried out by on-board system. Track circuits are only used at stations. The amount of wayside system is reduced to the minimum in order to reduce the maintenance cost of the system. Train dispatching can be made to be very flexible for the different density of train operation on the same line. The division of CTCS is only preliminary. It could be changed a little bit during CTCS working. However, the frame, the goals and the outline of CTCS has been make out and described. According to the above definitions, function requirements specification (FRS) and the system specification (SRS) have been started by the Chinese railway engineers [1].

2.3 Definition of Basic Units in Train Control Systems

2.3.1 Block

Railways are provided with signaling principally to make certain that there is always enough distance connecting trains to permit one to stop before it hits which is traveling in front. “This is achieved by separating each track into sections that called "blocks". Each block is protected by a signal placed at its entrance [2].” If the block is occupied by a train, the signal will put on show a red "aspect" as we call it, to confirm the train to stop. If the section is empty (not occupied by the train), the signal shows green otherwise can commanded as "continue to travel" [2].

Shown in Figure 2.1, the block occupied by Train 1 is protected by the red signal aspect at the entrance to the block. The block behind is empty and a green signal will permit Train 2 to travel along this block. This enforces the vital rule or railway signaling that says only one train is allowed onto one block at any time. When a block is empty, the protecting signal will show green indication. If a block is busy, the red signal defensively will shown [2].

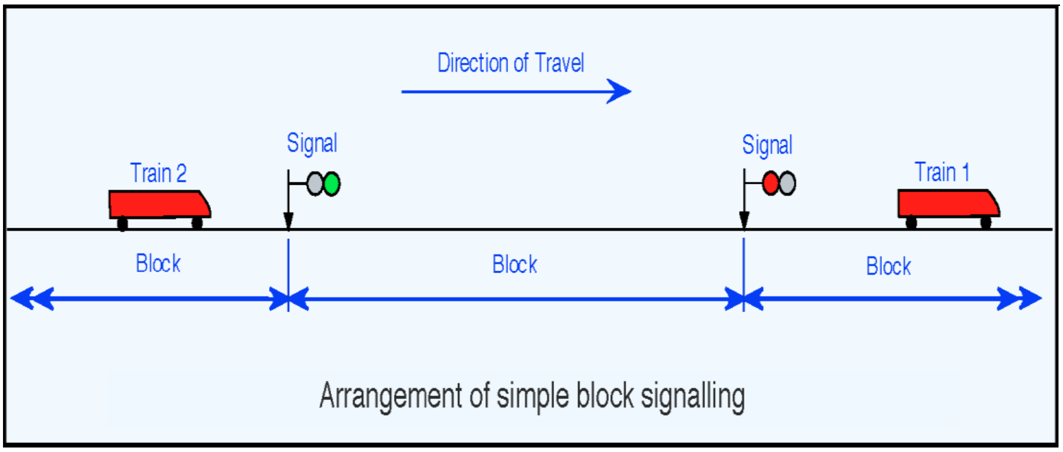


Figure 2.1 Schematic of signal block section.

2.3.2 The Track Circuit

The philosophy of track circuit is a development which is used for train detection. Electrical design of track circuits consist of 2 main parts; transmission and receiving circuits. Even if there is occupation on the track circuit, trains are monitored and detected automatically. Low voltage applied to the rails, via a series of relays or electronic devices takes decision on movement shows what the driver should do (stop or proceed). In order to ensure safety, any other cause of current interruption will also cause to create a "stop" signal. The defined situations (fail safe or vital) by the help of track circuit on a occupied track is essential to inform driver. In order to prevent the confusion on the drivers mind, in any case of failure, the red signal will be displayed [2].

I) Track Circuit - Block Unoccupied

There are different frequencies flows on the track. The wheel of the train behaves as a conductor, the relays or the electronic devices create an occupation signal on the related track. Electrically, a low voltage source from a battery is applied to one of the travelling train on rails, the block and returned current behaves as a simple electrical circuit.

The track circuit at entrance detects the electrical energy and connects a separate supply to the green aspect of the signal directly [2]. For other cases, regarding to international safety instruction, signal shows red. The unoccupied track circuit presentation is shown in Figure 2.2.

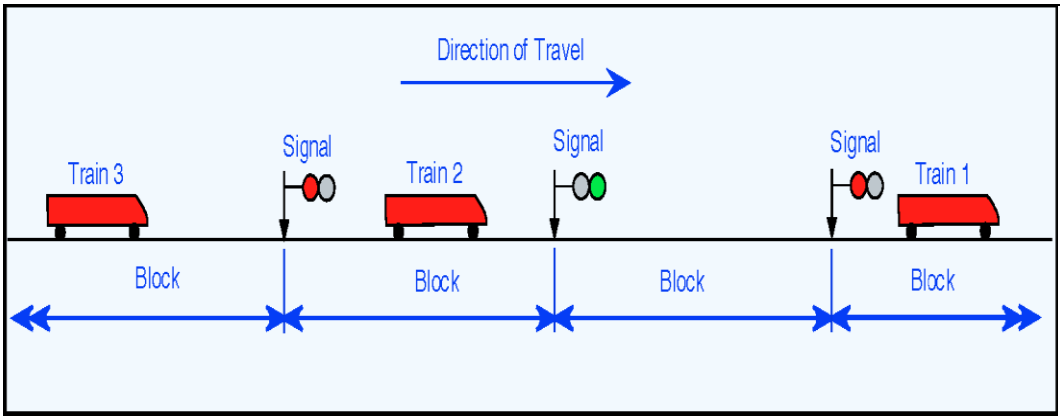


Figure 2.2 Track Circuit - Block Unoccupied

II) Track Circuit - Block Occupied

As shown in Figure 2.3 is a train enters the block, the conductivity of wheels make short circuits, and the relay is de-energized. Because of the de-energized relay or electronic design, the signal shows red aspect. In case of any failure on the system, the track circuit behaves similar with de-energized case [2].

Bonding (short circuit) and insulation (open circuit) is essential to define blocks and track circuits. A block shall be insulated from its neighboring blocks. Each block may create a closed circuit internally. These are known as semi-automatic signals. [2].

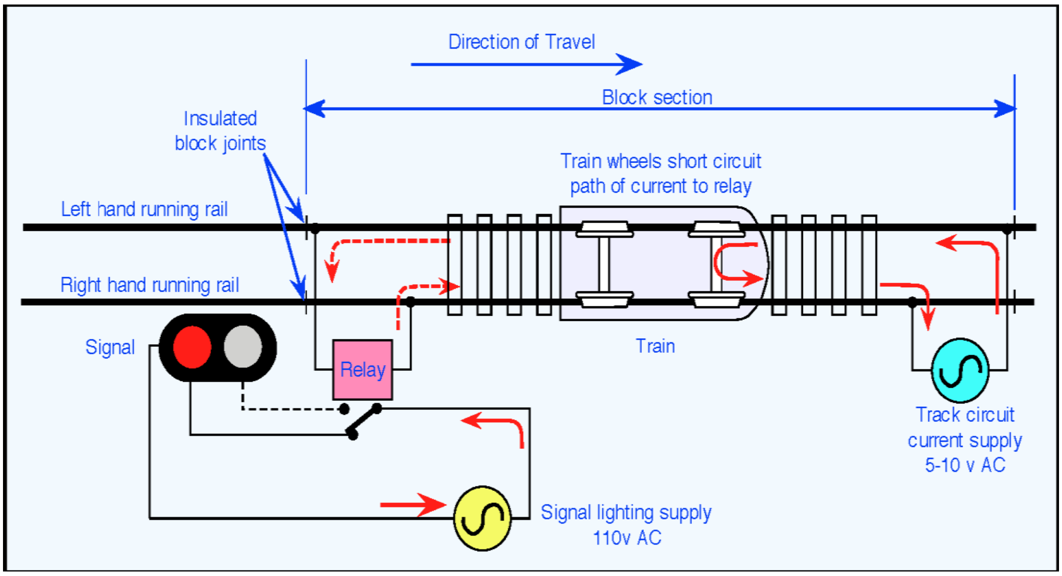


Figure 2.3 Track Circuit - Block Occupied

2.3.3 Signals

I)Multi-Aspect Signals

For multi aspect signals, such as three or four aspect, regarding to the safety instructions the red aspect principle works based on track circuits. Two-aspect, red/green or stop/proceed signal needs a warning of a red signal ahead to give information to the driver. The idea of warning signals are improved for track circuited signaling system; the warning signal provides information to the driver what the situation a few block further, starting from the red signal to the green. Thus signaling schematic presentation is shown in Figure 2.4 [2].

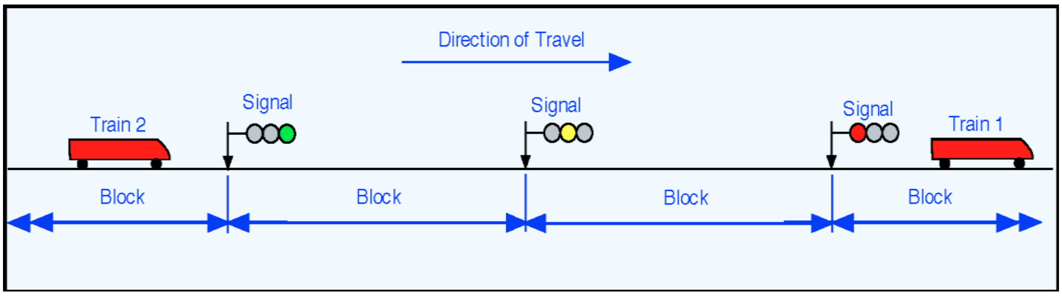


Figure 2.4 Schematic of 3-aspect signalled route (showing the additional yellow aspect provided to allow earlier warnings and thus higher speed operation.)

Figure 2.4 shows a line section; 3-aspect signals include a yellow aspect apart from red/green signal. The block on the right side, occupied by Train 1. This block is protected by the red indicator signal, located at the entrance of the block. A yellow signal informs the driver, there is red aspect previously. The empty block provides information to the driver to keep safe braking distance for Train 2. The other empty block in left side is (no occupation on the track) and shows a green signal to inform that entrance is available to that block.

The driver of 2nd train observes the green signal located at entrance. For three aspect signal system, the 2nd train has at least two empty blocks on the movement direction. [2].

II)Four-Aspect Signaling

On a dedicated line, it is possible to use different trains that have different speed capabilities. For a train which is travelling faster for the other trains on the line it is essential to increase the safe breaking distance. The principles of four-aspect signals depend to the train position is shown in Figure 2.5 [2].

Four aspect signaling is an alternative solution to increase the efficiency with the help of more frequently train operations. But there are some the complexities on the four aspect signal approach; such as complexity of combining two aspects and commanding these instructions by a driver, maintenance costs, and the risk on the lamps.

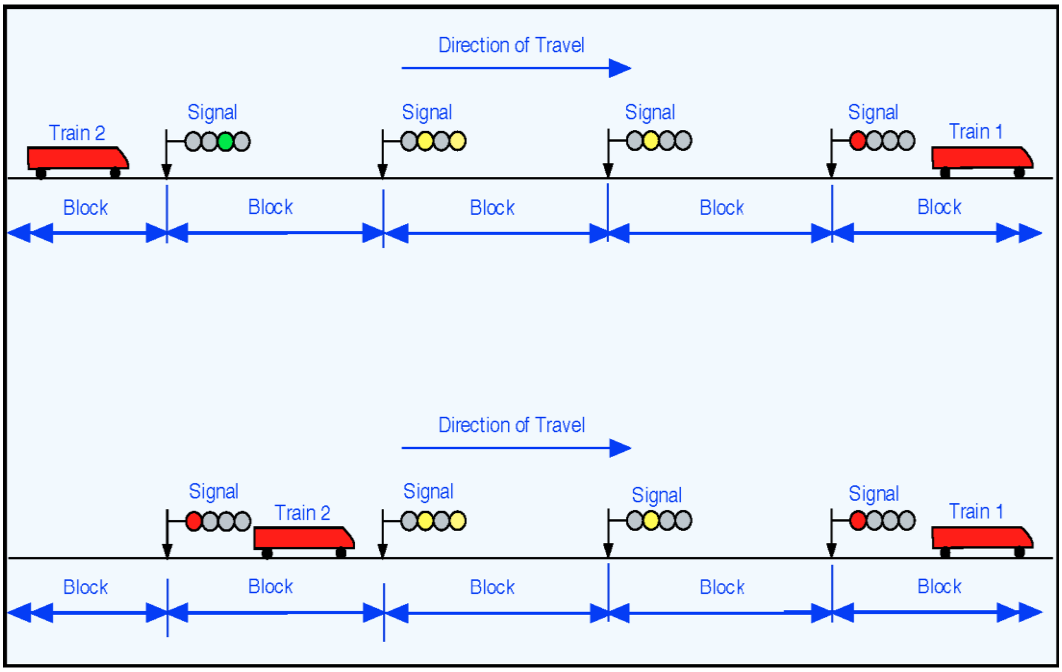


Figure 2.5 Schematic of 4-aspect signalled route showing the double-yellow aspect.

The principle operation of the multi aspect signals (4 - 3) is similar to each other. The operation is similar with the 3-aspect system except that two warning indicators are provided before a red indication signal.

In 4 aspect approach, there are a few combination of aspects occurs. For example, yellow over yellow and a single yellow also has meanings to provide safe and efficient operations. For a safe train operation the visual instructions created by signal is important to command properly.

More signal aspects has mainly two purposes; First, it provides early cautions of a red signal for higher speed trains, Second, performing a better track operation depending to speed limitation and block lengths [2,4].

2.3.4 A Safe Braking Distance

Braking distances has a mandatory role for safety and efficiency of lines. Since a train cannot stop instantly because of technical reasons. The braking capability of a train is limited.

“As an example; a train travelling at 160 km/hr will take more than 1600 m to stop [2]”.

If the system forced to stop in a shorter distance, the rails and the mechanical part of the train can face damages and the traveling comfort it not a desired huge acceleration and deceleration.

As expressed so far there is a risk that a train could pass a stop signal, then be stopped by the ATP enforcement system and still cause an accident that the train in front. The problem has long been recognized and can be solve by the condition of a space for a train to stop in, an "overlap concept" [2,5,6].

2.3.5 The Overlap

The overlap is a distance allowed to train to stop in safe, even if it passes a red signal. This distance shall be adjusted to the train characteristics and shall be calculated to these characteristics. If there is only one type train it is easy to calculate this distance. But there are a few types of train exists in the system , calculations on overlap distance is not easy [2].

For the railway controlling systems, it is not easy to calculate all the various braking distances of different types of trains and because it is impossible to predict when a driver might react to a stop signal, a fixed value of 185 meters is used. On underground metros which use ATP systems, the distance is calculated by a precise formula based on

(i) Known braking capacity of the train,
(ii) The gradient at the location concerned,
(iii) The maximum possible speed of the trains using that section,
(iv) An allowance for the sighting of the signal by the driver and a small margin. [3,4].

The result of the calculation is called the "safe braking distance". The overlap incorporates this safe braking distance. For the mentioned calculation, the factors are summarized as internal and external factors. These factors are demonstrated in the Table 2.1. [5,6].

2.1 Internal and external factors on overlap calculations

Overlap calculation (internal factors):	**Overlap calculation (external factors):**
-emergency deceleration factor	The overlap calculation is adjusted with:
-origin trapping speed	-track profile
-theoretical distance to the end of MA	-braking system maintenance limits
-ATP system time response	-rail/Wheel adherence weakness
-full braking application delay as shown in section 2.7	-odometer accuracy
	-wheel diameter maintenance limits

The overlap distance has been defined as result of the following formula [5,6] (A.1):

$$t_r = t_e + t_b + t_f \tag{2.1}$$

$$d_r = V_i * t_r \tag{2.2}$$

$$d_b = \frac{1}{2} * \frac{(V_f - V_i)^2}{ae} \tag{2.3}$$

$$ae = af + \frac{(9.81 * i)}{1000} * \frac{1}{(1 + cmr)} \tag{2.4}$$

$$t_r = t_e + t_b + t_f \tag{2.5}$$

Where;

af	Acceleration imposed by train [m/s^2]
I	Characteristic gradients
Cmr	Rotating inertia balance (of tare weight)
V_f	Final Speed [m/s]
V_i	Initial Speed [m/s]
ae	Acceleration applied to actual train [m/s^2]
d	Overlap distance [m]
t_r	Delay time for application [s]
t_e	ETCS-TTCS on board system time response [s]
t_b	Train braking system time response [s]
t_f	Time necessary for full application of the brakes [s]
d_r	Reaction distance [m]
d_b	Breaking distance [m]

*Distance shall be calculated on the worst case conditions.

CHAPTER III

RECOMMENDED INNOVATIONS IN TTCS

In this Chapter, in the concept of TTCS, the proposed innovations explained in detail. Flow charts, design structure and innovative hardware equipment are introduced with the help of tables, drawings and simulations.

3.1 The TTCS Level Crossing (TTCS LC)

In this section, as a subsystem of TTCS, a new LC system for more safe and efficient operation is explained.

Barriers are electromechanical equipment which operates under the mutual effects of the both mechanical and gravitational actions on the stock. This system is liable to fail in the case of supply failure, if there is no redundant source; the barriers will automatically be kept closed without any delay under the action of the gravitational force on the stock, as usual.

The recommended barrier system which shall act as part of TTCS, is a Horizontally Moving Barrier (HMB), which comprises both horizontally moving stock associated with red lights and a warning bell. In order to increase the reliability of the system an integrated solar panel will be used with the new design; however in any case of supply failure on all supply systems, the barriers will automatically be kept closed without any delay under the action of the gravitational force on the stock.

3.1.1 The Features of the Horizontally Moving Barrier (HMB) System

In the TTCS concept using HMB, although some of the features of the ETCS LC system as explained in Section 3.1, such as the speed detection of the train by the system and all other safety instructions are kept the same, the following features are standing as advantages over the existing ETCS LC system. These advantages are;

- More safer barrier
- Less Energy Consumption (horizontal movement).
- Informing other trains about the broken barriers.
- Solar panel support for electricity interruption.
- In order to decrease the effect of electricity interruption, solar based power supply redundant with national network.

3.1.2 Power Supply System Hierarchy

One of the innovative features of the HMB LC is the solar energy based power supply which is used as a primary power source. In the case, failure of this primary source, the existing public network will be activated as a secondary supply. This means in any case failure any of these sources, the continuity of system operation will always be maintained.

Also, if the storage elements (batteries) connected to the solar panel could not provide enough energy for the movement of barrier, the existing public network will be switched in with the aid of an electronic board (see section 4.1). The hardware equipment has a mandatory role to decide which source is to be activated.

If both of these sources are faced to a failure, the barrier will operate with the aid of gravitational force achieved to close the barrier to vehicle traffic in both directions as fast as possible. The stock of the barrier is adjusted as, free movement always perceive horizontal shift to vehicle traffic. Operation of the supply system follow is the systematic shown in Figure 3.1.

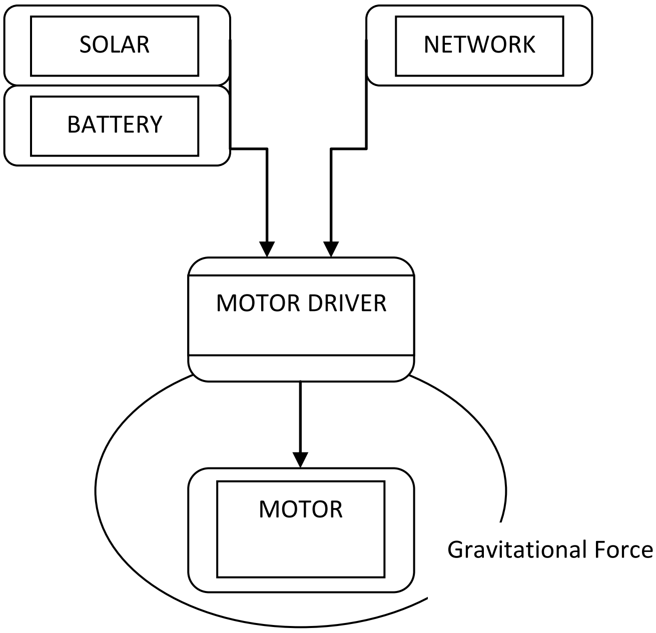


Figure 3.1 Power supply system hierarchy

3.1.3 The Basic Operational Phases of Horizontally Moving Barrier

System is aimed at to solve the some disadvantages of classical barrier system. The operational phases of a single barrier are described in four basic steps as shown in Figure 3.2 and Table 3.1.

Step 1: Triggering

This step, in the case of the train located at *B entrance* phase, the signals of LC are operating to red with visual and audible auxiliary warning equipment, in order to cut the traffic to pedestrians and wheeled vehicles. Regarding to the structure of railway, the lengths of track circuits and the probable speed of the train are mandatory variables on calculations to define *triggering and delayed triggering* times. These triggering times will be calculated for each LC, based on worst possible conditions.

Step 2: Availability Control

The decision of train movement (Restricted speed, ATP and ATS activation) will be taken at this step. This phase has a major importance on the safe transition of a train; within the critical area known as, interlocking area. The safety signals shown in Table 3.1, will be detected by single barrier control unit (SBCU), and the Central Barrier Control Unit (CBCU) will be informed by single barrier control circuit. Upon entrance of the train in to this area, HMB system produces a Working Proper (WP) signal. If the WP signal is not produced, transfer process fails, on board equipment (ATP- ATS) will force the train to restricted speed transition or stop. In the case of the correct generation of WP signal and transmission to the central control unit, the transition of the train will proceed within the safe speed ranges.

Step 3: Safe Train Transition

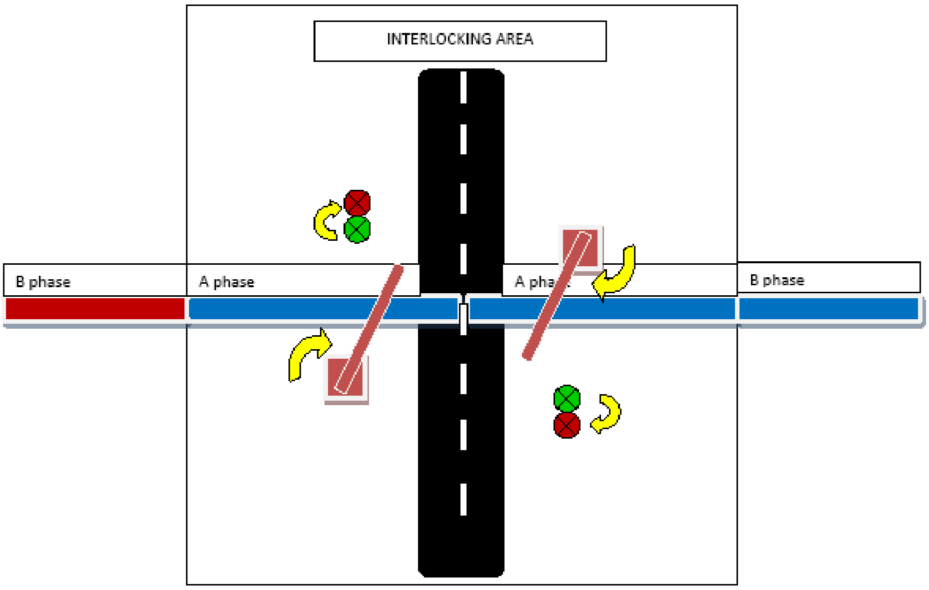
In this stage, the system will detect that the train is just passed from *Entrance Phase* to *Exit Phase within the interlocking area A.*

Step 4: The Transition of Pedestrians and Wheeled Vehicles

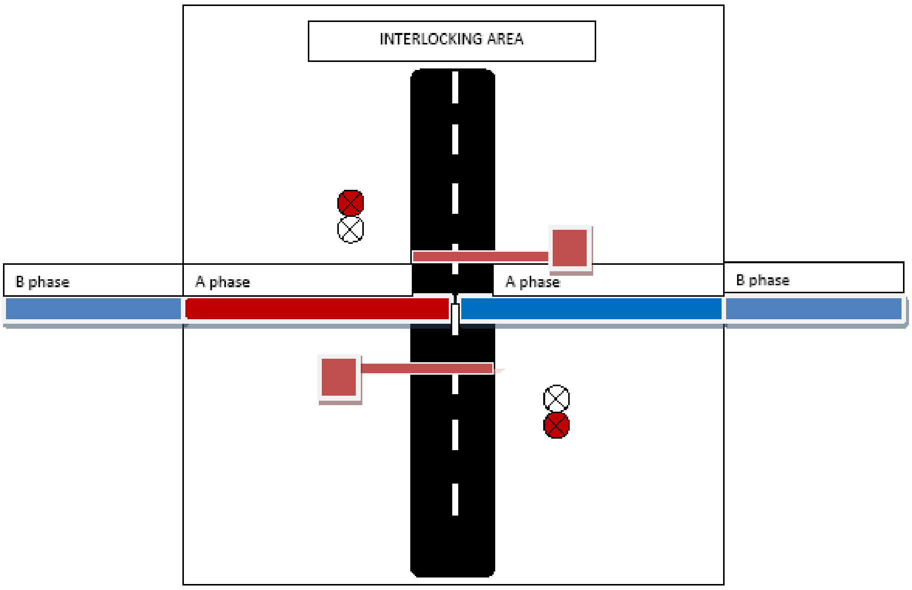
As a final stage, the movement of barrier again starts to open the roads to vehicles and pedestrian traffic. At the end of movement, the signals to pedestrians and wheeled vehicles will turn to green until a new triggering cycle will be initiated.

Table 3.1 Occupation signals for LC system

Steps	**Phases**				**WP Signal Production and transfer by SBCU**
	Entrance		**Exit**		
	B_ent	**A_ent**	**A_exit**	**B_ent**	
Step 1	1	0	0	0	0
Step 2	0	1	0	0	1
Step 3	0	0	1	0	0
Step 4	0	0	0	1	0

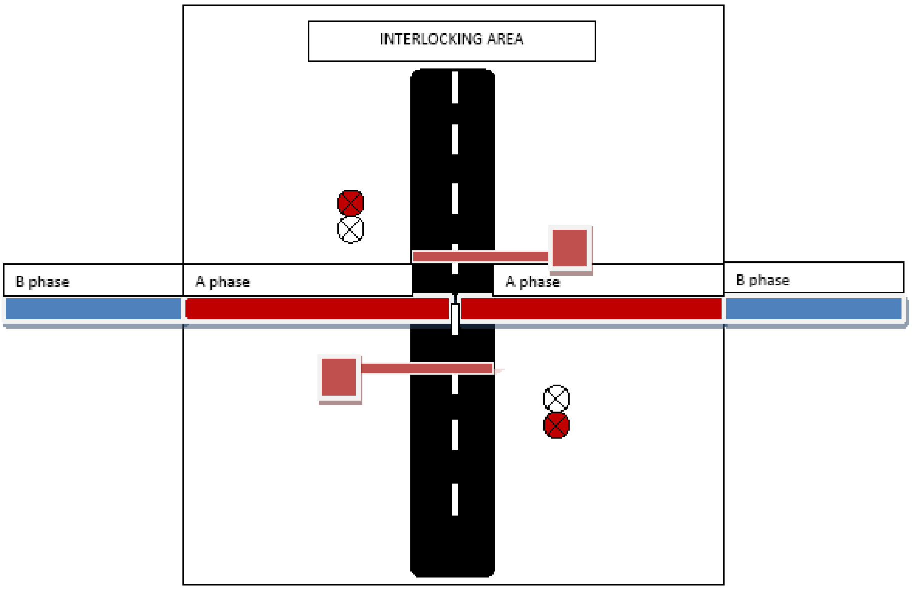


Step 1

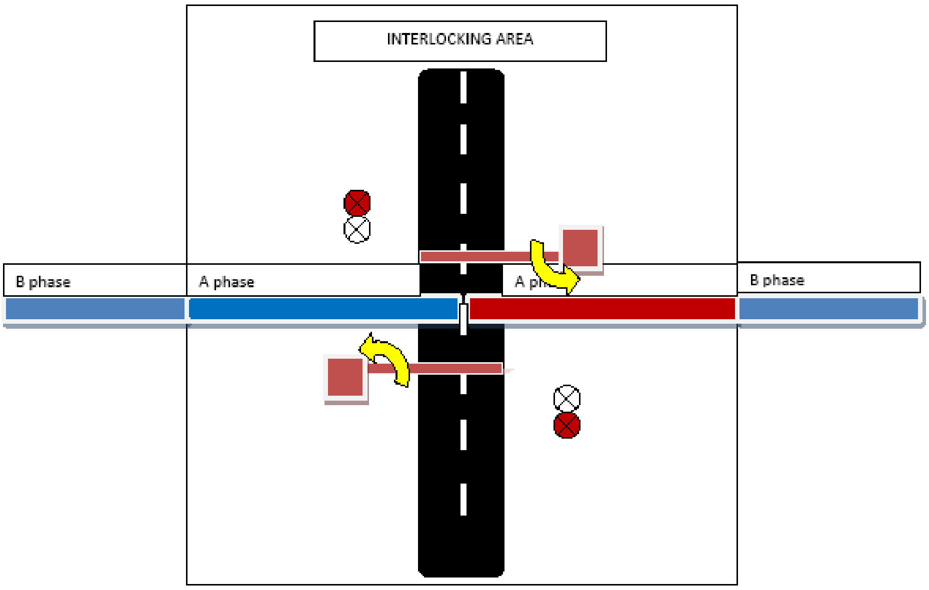


Step 2

Figure 3.2 a) Operational steps of HMB (Step1 and Step2)



Step 3



Step 4

Figure 3.2 Operational steps of HMB (Step3 and Step4)

For safe train transitions along any interlocking area two methods of LC system triggering (announcement) are found to be the best suited, method. For example a default triggering signal is produced to inform SBCU in the case if the train moves at a speed 120 km/h or more. Otherwise delay triggering cycle will be performed on SBCU, if train speed is less than 120 km/h, delay time for a triggering will be decided according to the speed of the train. So for interlocking area transition constant triggering time will not be taken into account for LCS operation. Hence, both default and delayed triggering operations allow more efficient usage of lines.

Figure 3.3 demonstrates the software steps for triggering according to the speed limitations, which is integrated to the HMB LC system operation, for an example speed limit of 120 km/h.

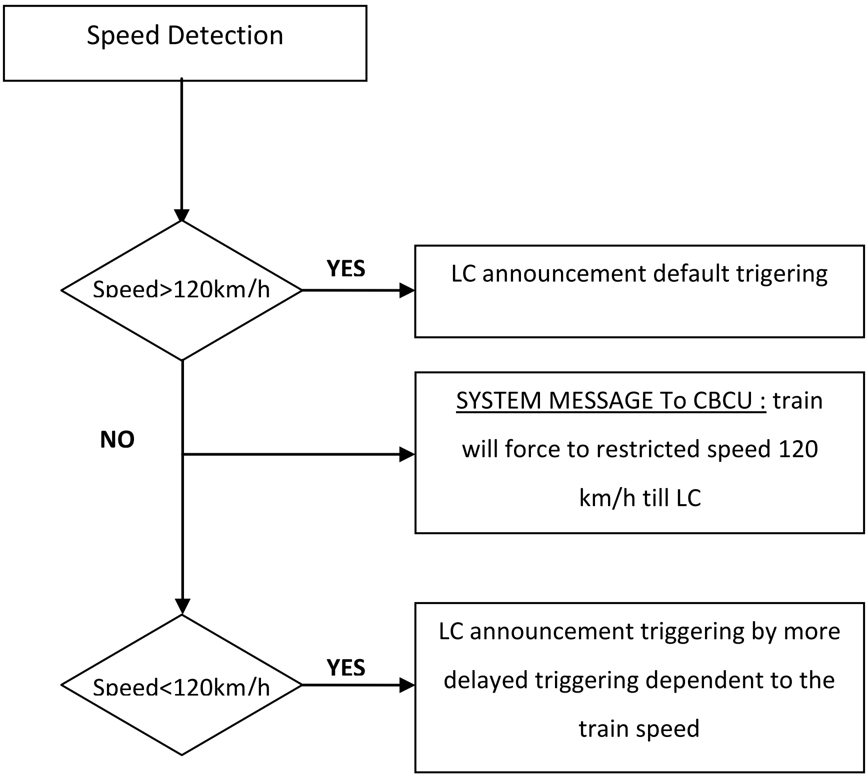


Figure 3.3 The hierachical motion of HMB defined for 120 km/h limit speed.

3.1.4 Single Barrier Control Unit

The operational steps displayed in the blocks of Figure 3.2 are implemented for the present hardware design, which comprises the following triggering levels;

1) DM data transfer from the main board to the related barrier board.

2) SBCU entrance signal (Figure 3.2)

3) Broken barrier detection.

   a) If the Working Properly (WP) signal is not generated, process change into Restricted Mode.

   b) If the barrier is not broken and WP signal is active, the process will go on according to the steps 3 and 4 as described in Figure 3.2

This possible input data to CBCU is described in Table 3.2

Table 3.2 Input data to SBCU

Name of signal	Principle code	Data length	Type of signal
Phase A Entrance	A_EN	1 bit	Digital
Phase A Exit	A_EX	1 bit	Digital
Phase B Entrance	B_EN	1 bit	Digital
Phase B Exit	B_EX	1 bit	Digital
Entrance Signal	EN	2 bits	Digital
Exit Signal	EX	2 bits	Digital
Occupation Signal	OS	1 bit	Digital
Barrier Driver	BD	1 bit	Digital
Broken Barrier Detector	BBD	1 bits	Digital
Barrier Position Data	BP	2 bits	Digital
Existing Domestically Signaling System Integration	EDSSI	2 bits	Digital
Bell Trigger Signal	BTS	1 bit	Digital
Redundant	---	2 bits	Digital

Working Proper (WP) Signal

At the end of step 4 of Figure 3.2, the WP signal generated from SBCU will be directed to CBCU as package information which includes encrypted data. In any case, after each closure of a single barrier; WP signal will be directed to CBCU in order to inform that all trains in the previous block are allowed to move in safe. With the help of this information, the trains will be informed by onboard equipment and will pass through the interlocking area at a controlled speed.

WP signal controls two distinct events in one encryption signal for broken and defected barrier stock, which will be sent though stock barrier for signal transmission.

3.1.5 Central Barrier Control Unit

Along a track all single barrier units will communicate with this master device (CBCU) to allow any broken or inactive barrier.

In the case of failure on SBCU a local WP signal is generated and CBCU will be informed by this information. This allows CBCU to inform all onboard equipment in all trains forwarding through the previous block. This possible input data to CBCU is described in Table 3.3

Table 3.3 Input Data to CBCU.

Name of signal	**Data length**	**Type of signal**
Position of train (PT)	8 bit	Digital
Direction of train (DT)	2 bit	Digital
Speed of the Train (ST)	0	Analogue
Train identification (TID)	5 bit	Digital

Response of CBCU to the input data:

a) If the speed and position data will not match to the prescribed data, an Automated Train Protection (ATP) signal will be generated by CBCU and forwarded to the ATP on-board equipment.

b) If the speed and position data matches to the constraint data, the train transition will be allowed to continue.

The CBCU output data as a response to the input data (Table 3.3) is indicated in Table 3.4.

Table 3.4 Output Data from CBCU

Name of signal	**Principle code**	**Data length**	**Type of signal**
Working Properly	WP	4 bit	Digital
System Fault	SF	2 bits	Digital

In Figure 3.4, the communication protocol between CBCU and SBCU is introduced. Basically, train speed and train ID data will be compared, with the aid of side equipment, to the database imposed on CBCU. If both train ID and speed data match to CBCU data base, transmission of WP signal will be completed without any error. Hence, the system allows the train will be allowed to travel in the pre-assigned safe speed range.

The positions of side and ETCS equipment are shown in Figure 3.5. In the case of a fault, detected by CBCU, CBCU will transmit a WP signal to all trains travelling along the previous block.

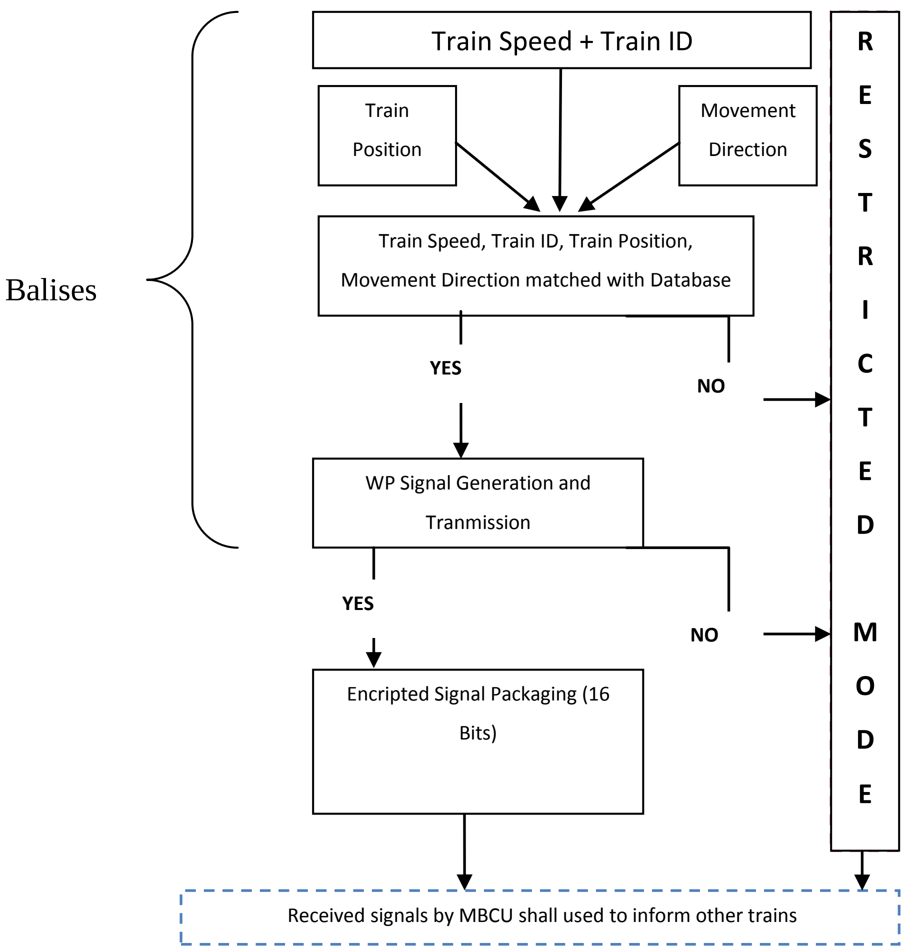


Figure 3.4 Flow chart of the HMB LC system (see Appendix A5 for software program)

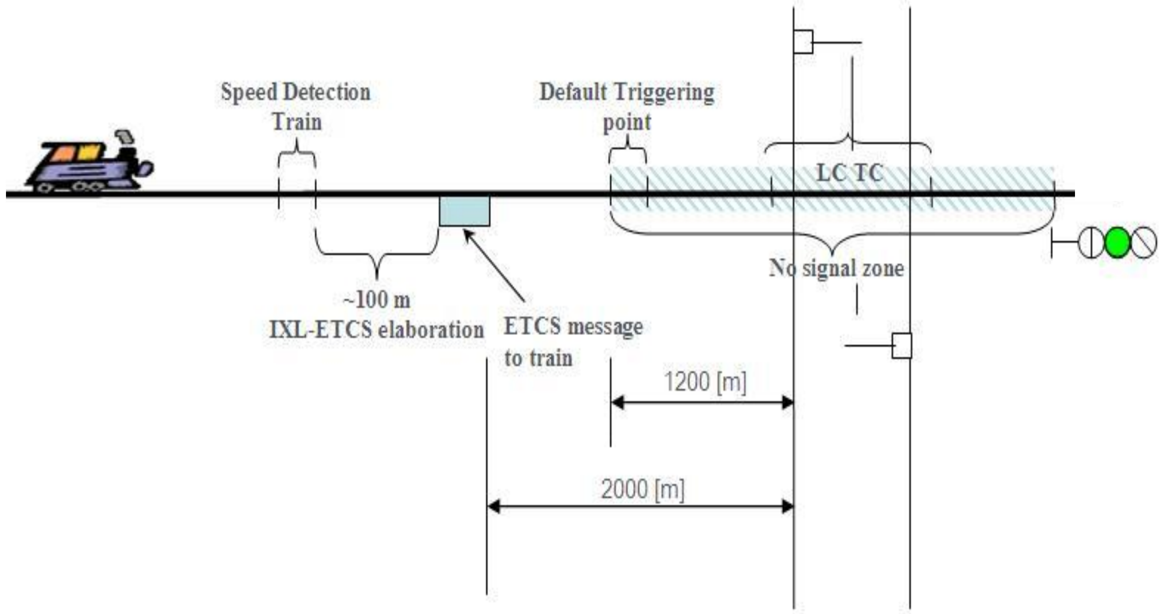


Figure 3.5 Equipment positioning and ETCS system description [3]

3.2 The Concept of Digital Display in place of Classical 4-aspect Display

In Section 2.5, 4-aspect classical display system in use in different countries is explained. The 4-aspect classical display system can produce 7 or more combinational instructions (Table 3.5) (A.1). The displays are instructive information to the train driver to execute decisive actions for safe transition along the blocks (to avoid any possible accident). Associated instructions with 4-aspect and 3-aspect display systems should be known and interpreted by the driver. However, usage of these two display systems even on the same track may sometimes cause conflict which may produce undesirable results, to be avoided by any means.

In this section an innovative tool is recommended to eliminate interpretation of both display systems. This system, known as Digital Display System, unifies outcome of these two signaling, and is expected to be more functional, reliable, simple to understand, easy maintainable, more visual and efficient. This new system, allows the train driver to be informed for train transitions between blocks and able to adjust itself to the undesirable operational conditions that trains can face resulted from weather conditions, maintenance or other influences.

Table 3.5 4-Aspect signals and their descriptions.

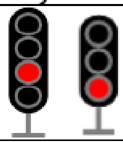
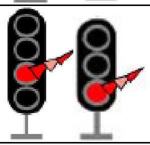
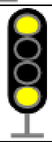
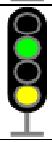
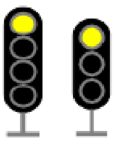
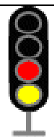
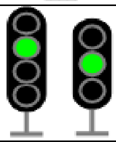
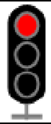
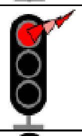
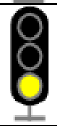
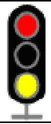
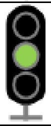
Symbol	Aspect	Description
	*Red*	• *STOP:* *stop the train without overrunning the signal. No train can pass the signal.*
	***Blinking Red***	• ***STOP with authorization to go on (Degraded Signal)*** *Where it cannot be assured that line is free from rolling-stock, train is authorised after stopping to go on up to next signal driving on sight not exceeding 25 Km/h speed.*
	***Yellow*** *over* ***Yellow***	• ***Proceed with confirmation to reduce speed to 30 Km/h*** *The expected next signal will be a STOP signal or a Proceed signal for a switched path.*
	***Green*** *over* ***Yellow***	• ***Proceed with confirmation to reduce speed to 30 Km/h*** *The expected next signal will be a Proceed signal on straight route*
	***Yellow***	• ***Proceed with caution*** *Next signal will be a STOP signal, Proceed signal with speed reduction or Proceed with caution signal.* *Driver must reduce the speed to be able to stop the train at the next signal.*
	***Red*** *over* ***Yellow***	• ***Proceed with confirmation to reduce speed to 25 Km/h*** *Proceed with shunting speed to trucated or unsignalled track.* *Driver must drive on sight not exceeding 25 Km/h speed.*
	***Green***	• ***Proceed*** *Train can pass the signal at the maximum allowed speed*

Table 3.6 3-Aspect signals and their descriptions.

Symbol	Aspect	Description
	*Red*	• ***STOP:*** *stop the train without overrunning the signal. No train cannot pass the signal.*
	*Blinking Red*	• ***STOP with authorization to go on (Degraded Signal)*** *Where it cannot be assured that line is free from rolling-stock, train is authorized after stopping to go on up to next signal or buffer driving on sight not exceeding 25 Km/h speed.*
	*Yellow*	• ***Proceed with caution not exceeding 30Km/h*** *Next signal will be a STOP signal, Proceed signal with speed reduction or Proceed with caution signal.* *Driver must reduce the speed to be able to stop the train at the next signal.*
	*Red over Yellow*	• ***Proceed not exceeding 25 Km/h*** *Proceed with shunting speed to trucated or unsignalled track.* *Driver must drive on sight not exceeding 25 Km/h speed.*
	*Green*	• ***Proceed not exceeding 30Km/h*** *Train will pass the signal with speed restriction over switch, next signal will be a Proceed signal..*

3.2.1 Properties of Proposed "Digital Display System" (DDS)

The present DDS operates the lines more efficient and safer compared to classical display systems since the risk involved for interpreting the combinational information of 3- or 4- aspect display signaling systems are reduced by just one signaling system.

As shown in Figure. 3.7, the system is a well-known both graphical and numerical display plate. The DDS is in the form of a ring; the numeric information display takes place at the centre and warning indicator is on the outer ring. The ring display of DDS is also provided with red, yellow and green embedded indicators (LED installed). The red and yellow selections are made by CTC, or in-built manual adjustment tools. The DDS informs the driver directly for track conditions resorting to the driver's interpretation. The visual description for the DDS is demonstrated in Figure 3.6

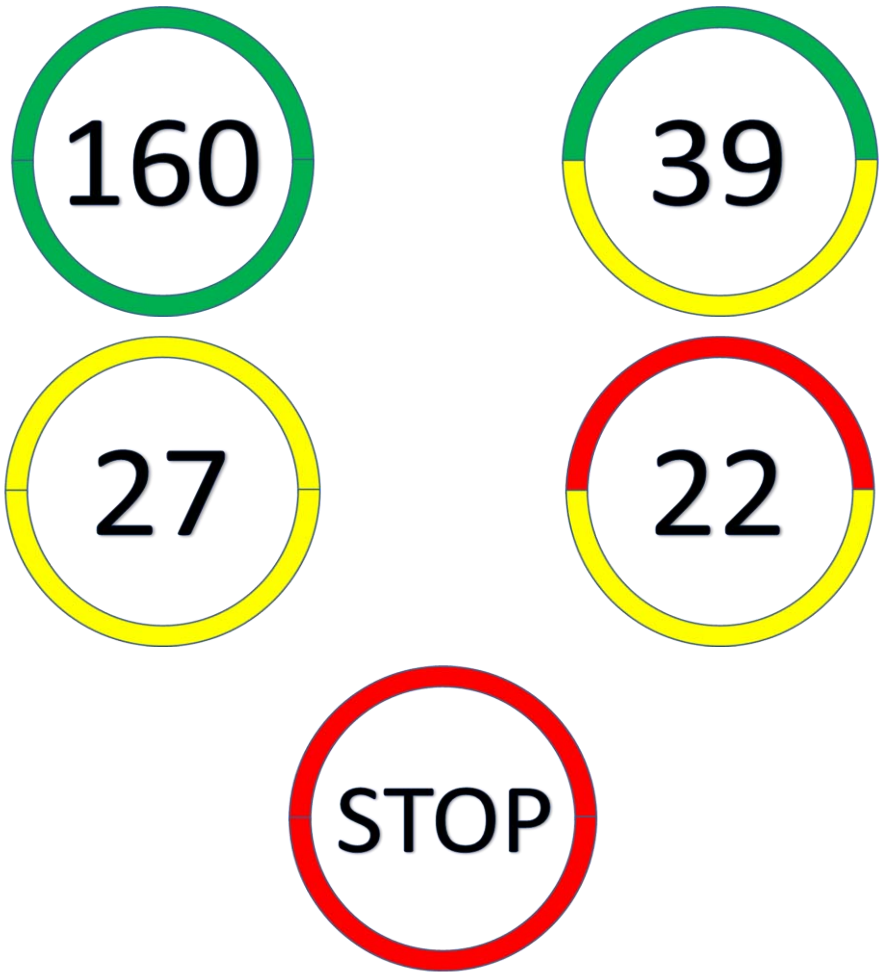


Figure 3.6 DDS visual descriptions

The operation of DDS will follow the result of comparison of actual speed of a train to the allowed speed limits. The flow of information for selection of warning colours and the numeric displays is shown in the flow chart of Figure. 3.7

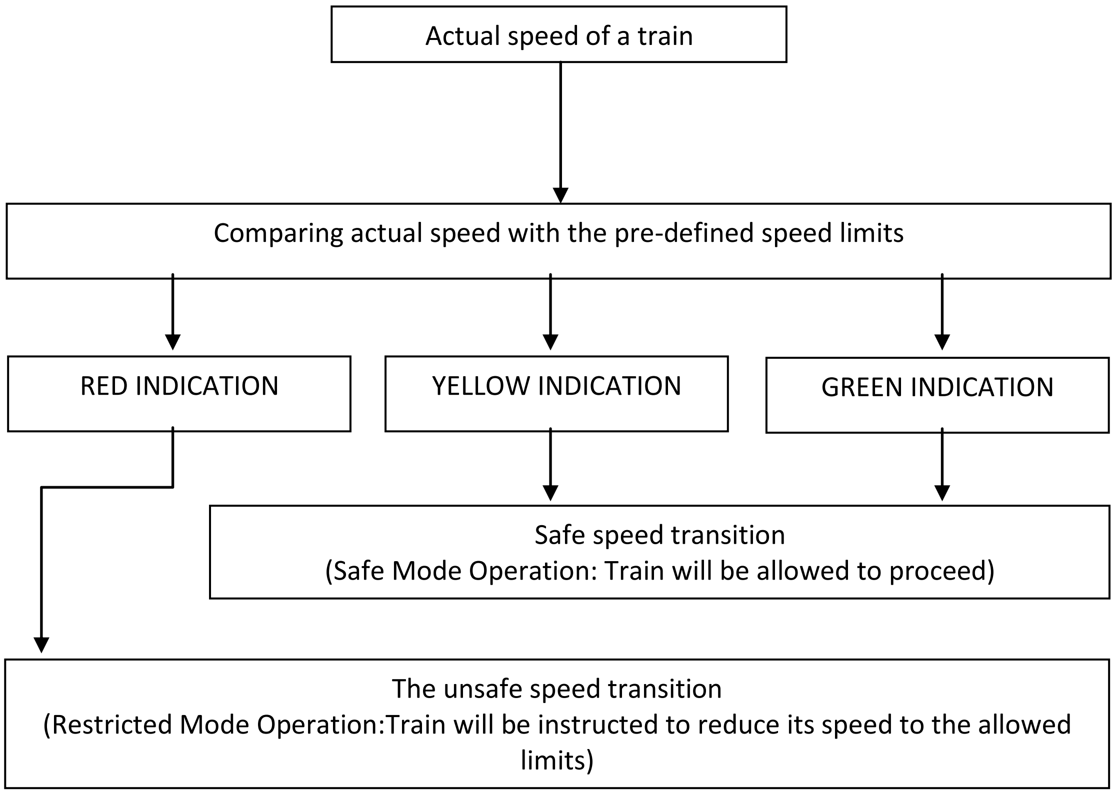


Figure 3.7 Flow chart of signal system (see Appendix A6 for software program)

The DDS can also be used along tracks operating under ETCS at levels 0 and 1. Usage of this system at Level 2 and Level 3 is not necessary because these levels do not need any signals for operation of line-side equipment.

In order to decrease cabling cost, the cables serving ETCS are preserved for driving the DDS. The systematic of the cabling to drive the DDS is indicated in Figure. 3.8. Thus, a decoding electronic circuit design inside of a graphical signal is still necessary for this innovation.

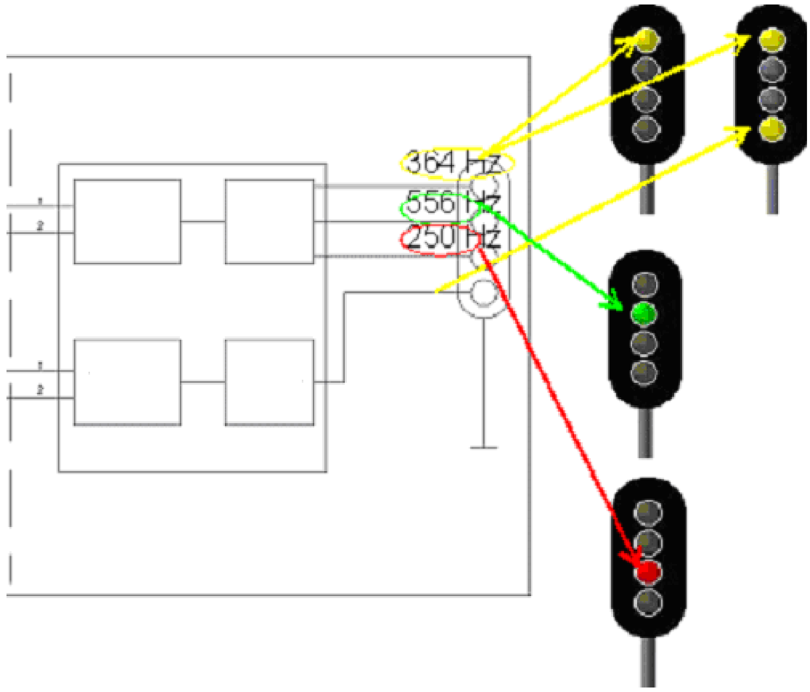


Figure 3.8 ETCS driving 4-Aspect display system and signalling cables.

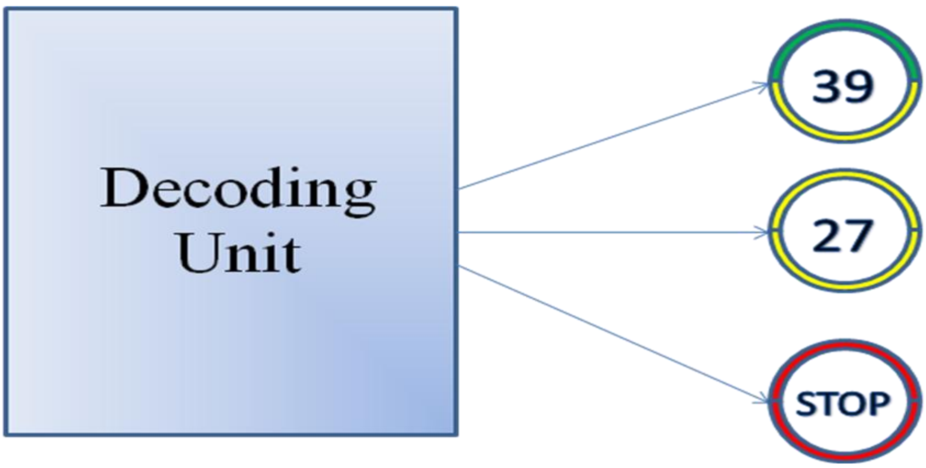


Figure 3.9 ETCS driving the present DDS using the same signalling cables.

The numeric and coloured display shall be adjusted for safe operations for each track block. In order to increase the operational efficiency, the proposed system refuses the constant speed limits for red and yellow indications, since the speed selection should be made according to the track occupation and track conditions to be decided by CTC. Hence, it is expected that the efficiency of track usage and train operation will increase. The classical signal aspects and proposed signal aspects are shown in Figure 3.10

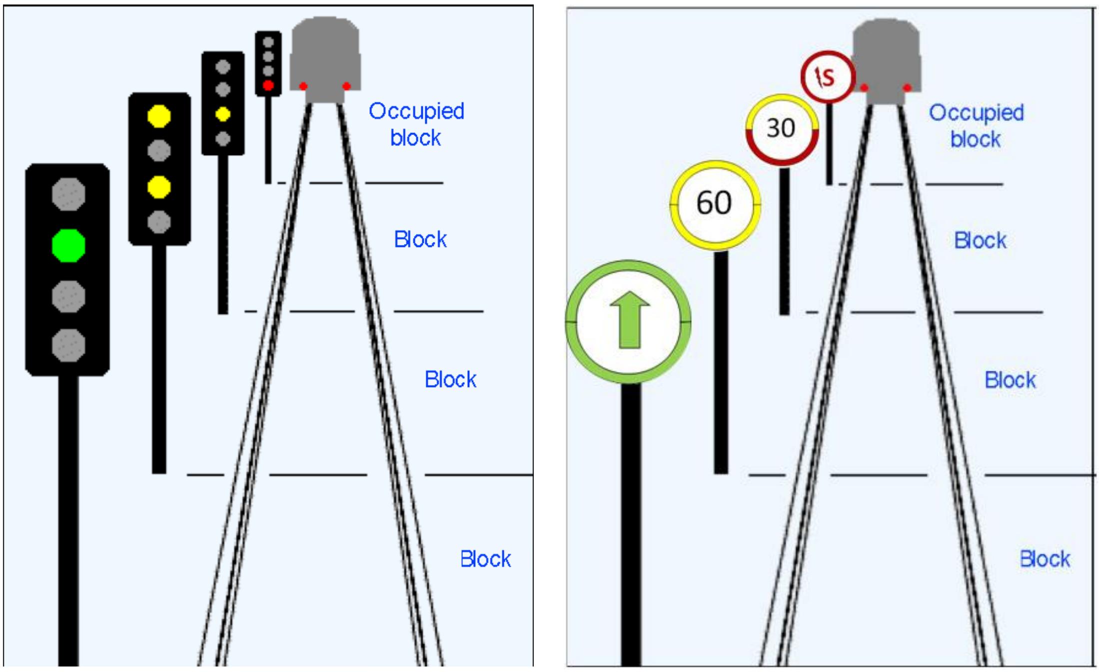


Figure 3.10 Classical and proposed signal displays aspects

3.3 Variable Overlap Distance

Overlap distance (Section 2.3.5) and braking distance (Section 2.3.4) are two vital parameters for safe train operation. The classical overlap distance calculation still in use, explained in section 2.7 provides information for safe operation of the trains. However, the braking distance changes with both internal and external factors (Section 3.3.1). Maintenance time, types of train, climatic conditions and other issues should be accounted for each braking action. Therefore, it is necessary to redefine the overlap distance in TTCS concept. It should be revised based on related parameters affecting the brake performance.

3.3.1 Determination of Dynamic Overlap Distance

As a result of previous breaking performances, a sample of data for safe breaking distance is given in Table 3.7. The safe breaking distance computation is based on the breaking ratio of a train and the maximum cruise speed. The safe braking distances given in the table are constants obtained from the classical method of calculations. Since track conditions and previous braking performance are not taking in to account, the results cannot be considered as accurate.

Table 3.7 A sample of safe breaking distance data to be used as an input to the classical method of calculation considering the worst case scneronio.

Breaking Ratio (%)	Maximum Speed (km/h)				
	60	70	120	160	175
38	510 m	x	X	X	x
51	x	574 m	X	x	x
83	x	x	1072 m	1846 m	2190 m
100	x	x	925 m	1584 m	1877 m
135	x	x	723 m	1225 m	1447 m

In this study, including the worst case scneronio, dynamic overlap distance may be computed taking into account previous breaking performances of the train. Hence the data collected on the experienced breaking cycles allow us to take a decision for the next breaking response of the train. Based on this performance, the breaking curves and overlap distances may be determined according to the systematic ot the neural network shown in Figure 3.11. The computation based on a multilayer neural network; the input variables *x* are the internal and external factors such as weather conditions, slope of the track, etc., stored in the [X], and the weights *w* are the breaking performance, memorised in [W] matrix [7].

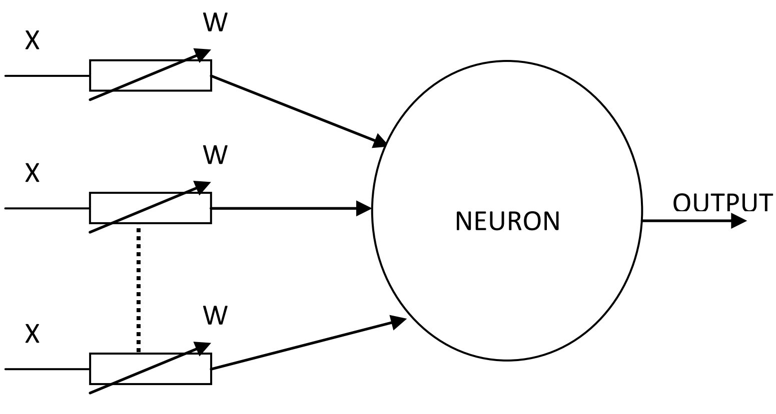


Figure 3.11 Neural Architect

The output of the network provides the information for the next break performance of the train.

The result of the computation provides dynamic breaking distance considering several internal and external parameters affecting breaking performance rather than using a constant breaking distance used as in the case of classical method of calculation. Further, another outcome of the computation is dynamic overlap distance resulted from the predefined worst case scenario. In the case match of dynamic overlap distance and worst case scenario conditions, decisions for safe operation will be taken by the CTC authority.

In general, dynamic braking performance of a train travelling follows the curve, shown in Figure 3.12. This data shall be the CTC system database and shall be used continuously to decide on the train performance. It is surely expected that this dynamic performance will vary for instant track conditions and train characteristics. The ATP curve on this Figure represents the worst case braking distance performance computed using the rules of classical method of braking distance calculation.

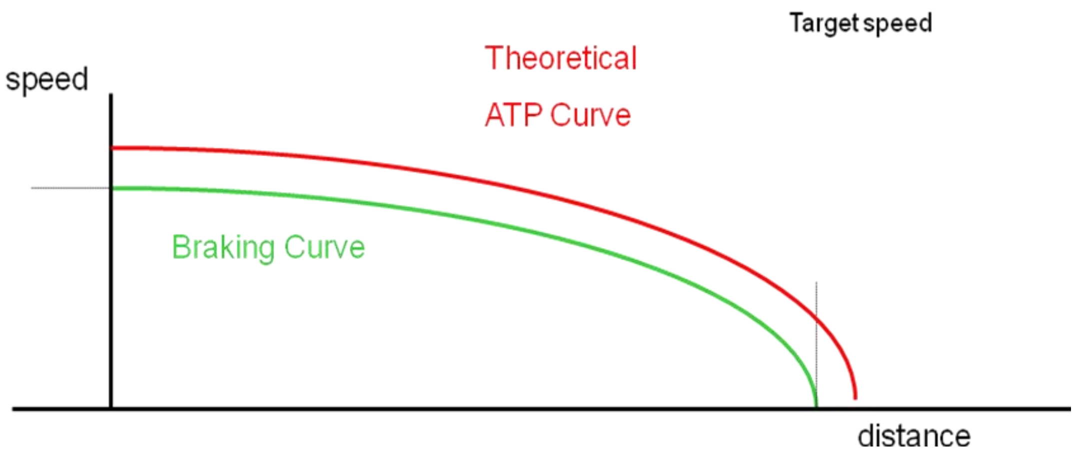


Figure 3.12 Theoretical and dynamic braking overlap curves

In this study, braking performance of a train travelling at a maximum speed of 160 km/h is taken as an example case. For an incremental speed interval of 1 km/h, the quantified incremental speed variations are shown in Figure 3.13, and the data extracted is given in Table 3.5. For a case, if there is a match between the present dynamic curve and the ATP curve, the preference shall be given to the ATP curve.

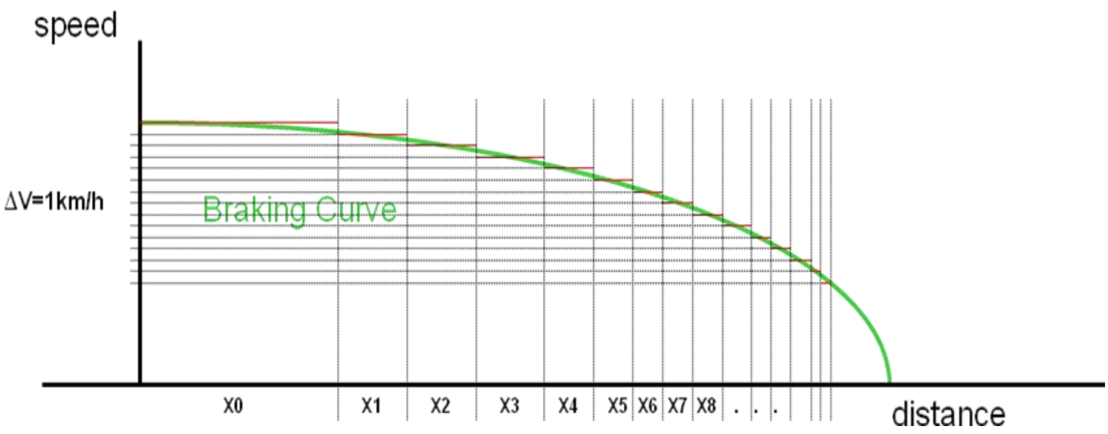


Figure 3.13 Quantisation of distance wrt actual incremental speed

Table 3.8 Incremental braking distance determined from incremental speed interval quantized for a maximum speed of 160 km/h for the past 10 dedicated braking levels.

ΔV=1km/h	1st break perform (meter) W_0=0.1	2nd break perform (meter) w_1=0.1	3rd break perform (meter) w_2=0.1	....	10th break perform (meter) w_{10}=0.1	Average performance distance (meter)	Calculated breaking performance (meter)
1st km/h (160-159)	x_0=100	x_0=97	x_0=93	...	x_0=104	y_0=98.50	109
2nd km/h (159-158)	x_1=99	x_1=96	x_1=92	...	x_1=100	y_1=96.75	107
3rd km/h (158-157)	x_2=98	x_2=X	x_2=X	...	x_2=X	y_2=98	105
4th km/h (157-156)	x_3=98	x_3=94	x_3=X	...	x_3=X	y_3=96	104
...	...	...	...		...	...	...
160 th km/h(1-0)	x_{160}=1	x_{160}=1	x_{160}=2		x_{160}=2	y_{160}=1.5	3

X: Assumed no case scenario(X=100 km/h).
Weights are initially assumed to be any constant less than 1.

These quantisation levels are chosen for each 1 km/h ranges and the corresponding relative distances determined for each incremental speed are shown in Figure 3.14. Based on this graphic, the elements of normalised distance input vector **X** = [X_0 …..

X_{160}] and of the normalised weight matrix **W**= $\begin{bmatrix} w_{00} \ w_{01} \dots w_{0\,160} \\ w_{1\,0} \ w_{11} \dots w_{1\,160} \\ \vdots \\ w_{10\,0} \ w_{101} \dots w_{10\,160} \end{bmatrix}$ can be derived as shown in Table 3.8.

The elements of the weigth matrix are initially as selected as constant and varies according to the breaking performances in order to prevent instant failures.

The system repeatedly checks deceleration for a dedicated speed interval. The outcome of the estimation compares the ATP curve to the estimated dynamic breaking performance results. As a result of this comparison an 8 bit data binary coded data is generated for the defining next breaking performance for a given breaking level [7,8].

CHAPTER IV

EXPERIMENTAL WORK AND TEST RESULTS

4.1 Experimental Works

To verify the theoretical results, a model train is used and the all required electrical wiring is installed. The setup is shown in Figure 4.1.

Figure 4.1 An overwiev to the track layout

4.1.1 Detection System

For the proposed model consist of subsystems for detecting breaking curve data, train speed, the LC enterence and exit signals. All necessary inputs are being detected by the help of reed relays installed along the track shown in Figure 4.2. The outputs of the reed relays are directeted to a 5x7 LED display to determine the location of the train (Figure 4.3).

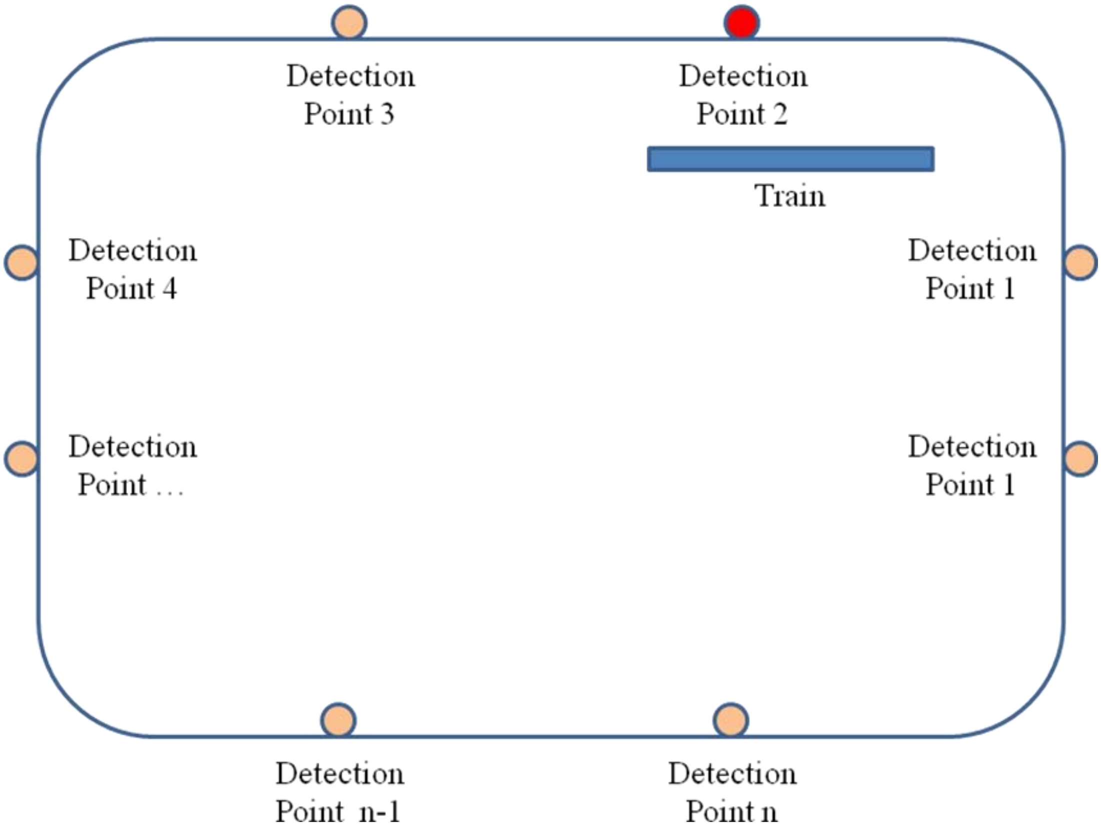


Figure 4.2 Activated and deactivated detection points on the track

Detection Monitoring and Availibility Checking Center is included a 5X7 keypad which lets to the system to create manually and virtual occupations to invertining on the tracks in the case of any failure on the system and to perform meintanance procedure.

Basicly the system is able to check even if there is an occupation or not. Virtual occupations on the related tracks are also availible with the help of 5X7 display. The first 3rd rows are used for train detection the 4th row is used for the LC system, such as closure signal, enterance and exit signals. All these signals shall be produced by keypad manually to perform cold tests on LC system without a train[9,10].

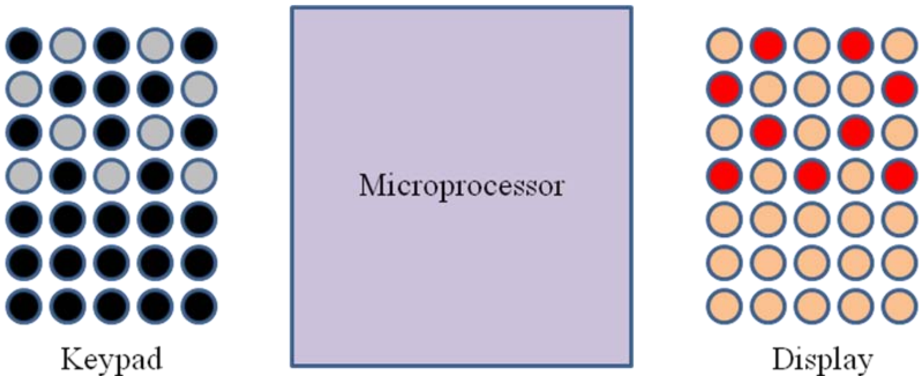


Figure 4.3 Detection monitoring and availibilities on the TTCS center

4.1.2 Level Crossing

Before starting to the construction of the level crossing detector, a simulation circuit shown in Figure 4.4, is used and tested for LC performane. The circuit consists of the SBCU, 4 digital outputs to drive stepper motor, 8 bit digital output for transferring the speed data. All these simulations, and PCB designs are performed under Proteus and ISIS programmes.

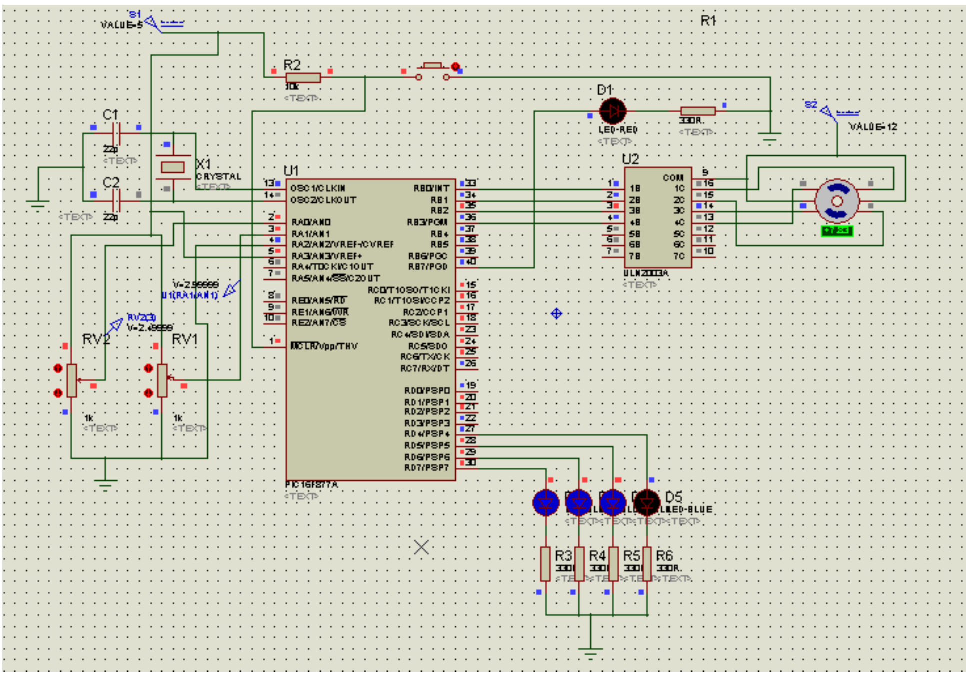


Figure 4.4 SBCU Simulation

In this study usage of solar energy for operation of horizontally moving barrier (HMB) is planned in case of any power failure and efficient energy consumption.

The power supply system hierarchies (see section 3.1.2)including the solar energy supply system is stimulated to test adaptation to the existing main network.

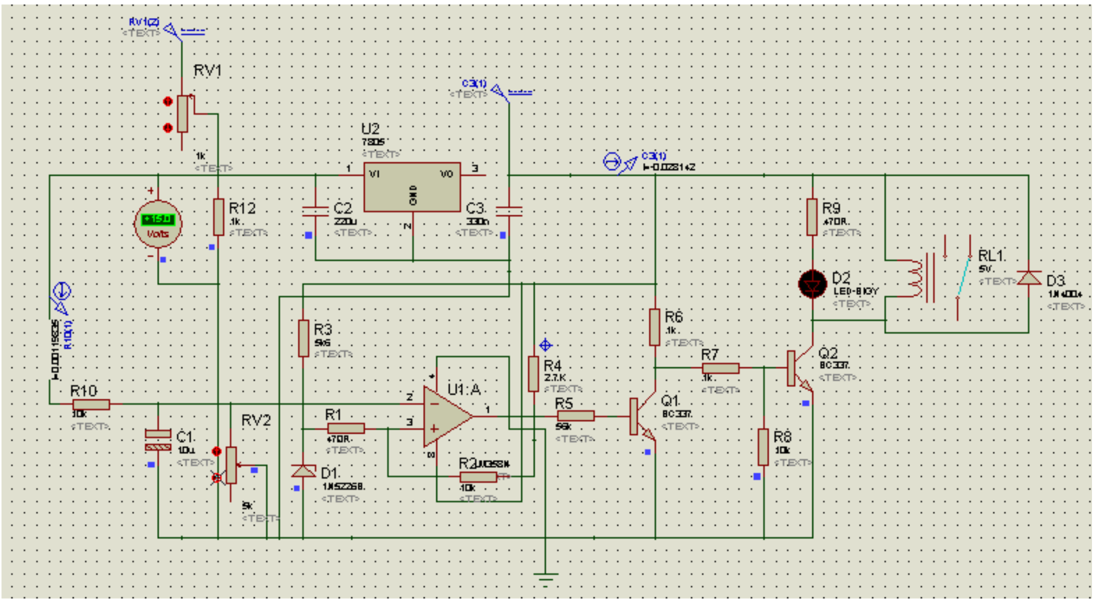


Figure 4.5 Power decision circuit simulation

The interface between the hardware equipment and the microcontroller is shown in Figure 4.6. LC system consists of Microcontroller circuit, stepper motor driver and the power decision circuits.

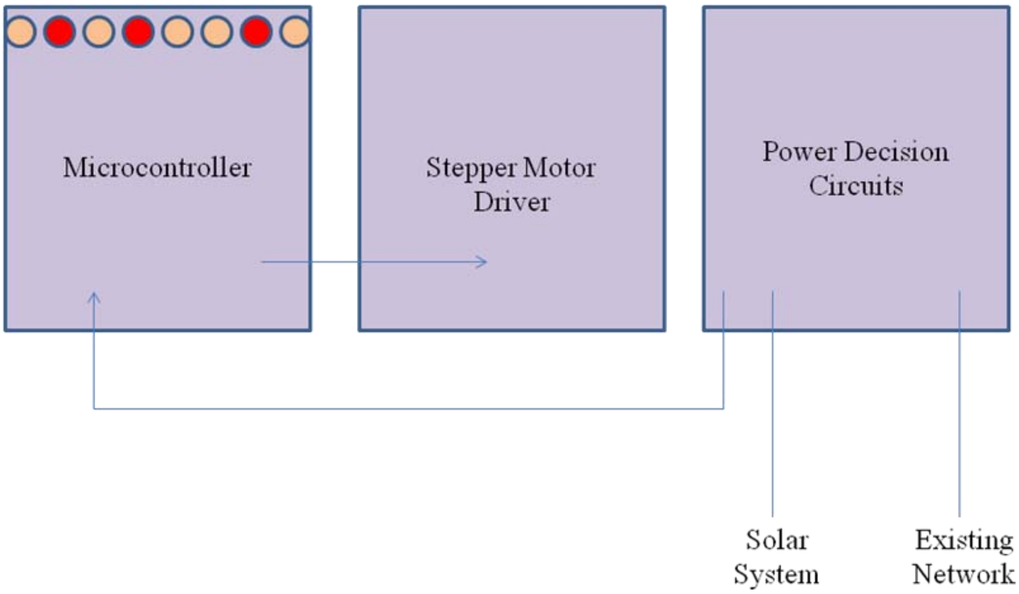


Figure 4.6 Block diagram of the level crossing (LC)

Operation of HMB barrier for complete closure is checked as shown in the Figure 4.7 the continuity of LC barrier stock bar is also checked by the microcontroller (A5).

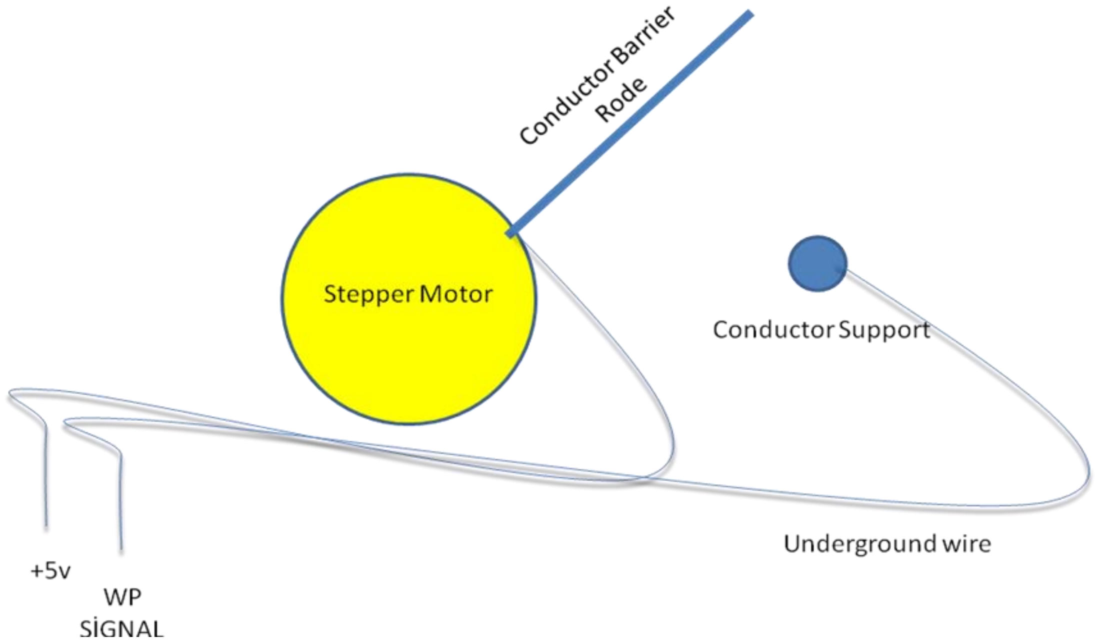


Figure 4.7 Horizontally Moving Barrier (HMB)

4.1.3 Digital Display Signal (DDS) System

On the prototype TTCS model the digital speed records obtained from the track transducers are displayed on the DDS before sending to the CTCS. DDS system in the simulated model consists of a digital display unit drived by a microcontroller. A sample of data record is displayed in Figure 4.8. The speed measurements are based on pulse counting techniques for more sensitive results. Incremental detection lenght, for pulse clocking is adjusted to 1.5 meter.

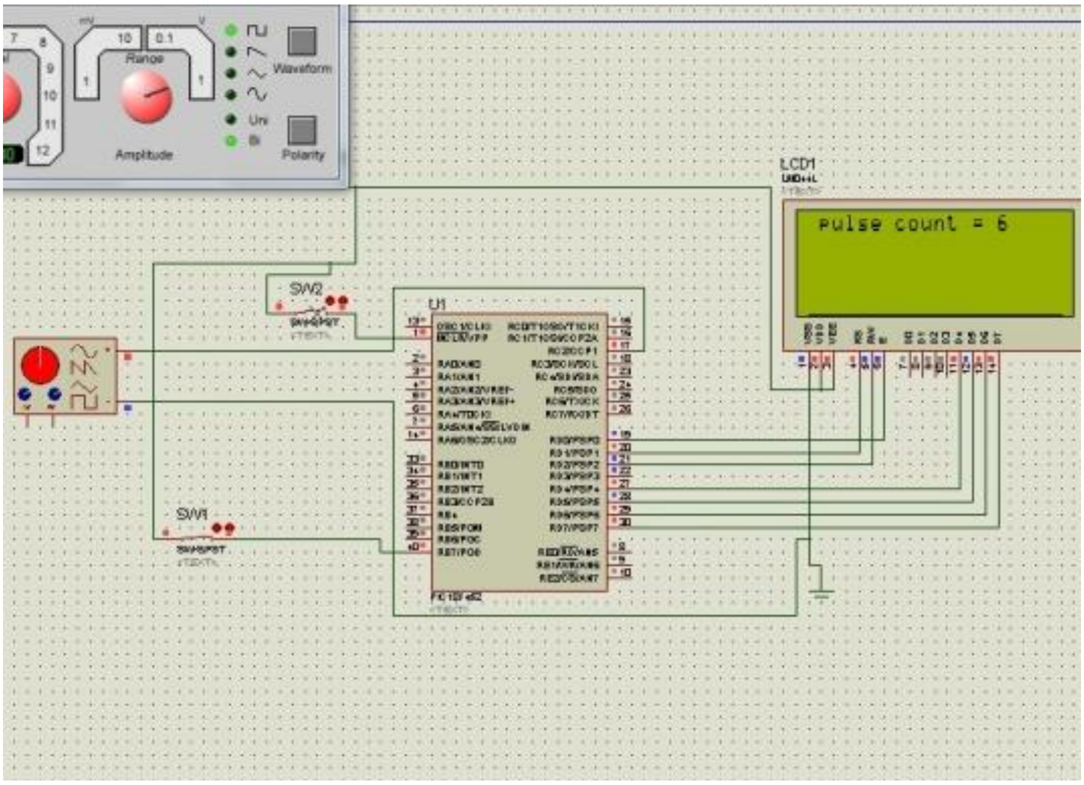


Figure 4.8 Speed measurement-pulse counter

Time interval between two detection points over a dedicated line, keeping the display duration between two screens is predesigned as 1 second. An analogue and digital information related to safe operation of a train is displayed in Figure 4.9. [9,10]

Bear in mind that the information on DDS are the data for this simulation. In actual fact this type of records are obtained by on board equipment only on critical track sections such as level crossing blocks this type of speed measurements is done by track side equipment and reflected to the CTC via GSM-R.

Figure 4.9 Speed display screen and the results of decision on CTC

Another embedded software on DDS provides train speed information to CTC system and the train driver. This information shall be used by CTC system to actuate track side signalling equipment which corresponds to the green-yellow-red warning signs, for safe train transfer. Outcome of the several descisions is diplayed in Table 4.1.(A6)

Table 4.1 Decision Table

Outcome of the Simulation wrt Actual Speed	Corresponding CTC Decisions to be generated
Actual Speed< Predefined Yellow Limit<Predefined Red Limit	GREEN
Predefined Yellow Limit<**Actual Speed**<Predefined Red Limit	YELLOW
Predefined Yellow Limit<Predefined Red Limit**<Actual Speed**	RED

4.1.4 Variable Overlap Distance

Variable overlap concept is another new approach in this study. In the classical method the constant overlap distance in some cases results in some undesirable results which may sometimes affect the safe breaking performance.

In the present study, the breaking performance is computed and the result is used to estimate, so called, dynamic overlap distance which is believed to provide safer and efficient operations on any section of the track.

To determine the dynamic overlap distance on the prototype system, the binary code result of the neural computation (Section 3.3.1) is used to classify the breaking performance [8]: If the breaking performance code is is different from 0, the breaking performance is fully recognised by the onboard equipment and the train will stop within the predefined limits, and if the code is 0 or close to 0, that corresponds to no breaking mechanism is avalible to stop the train. The result of overlap distance computation is described in the steps of operation shown in Figure 4.10.

The steps of operation:

1) Reseting overlap database; initialising microcontroller

2-3-4) Input data of 1st Train; TID, speed, breaking performance, dynamic overlap distance

5-6) Input data of 2nd Train; TID, speed, breaking performance, dynamic overlap distance

6) Results: TID validification, time interval between Train1 and Train2, Decisions for safe overlap distance achievement[9,10] (A7).

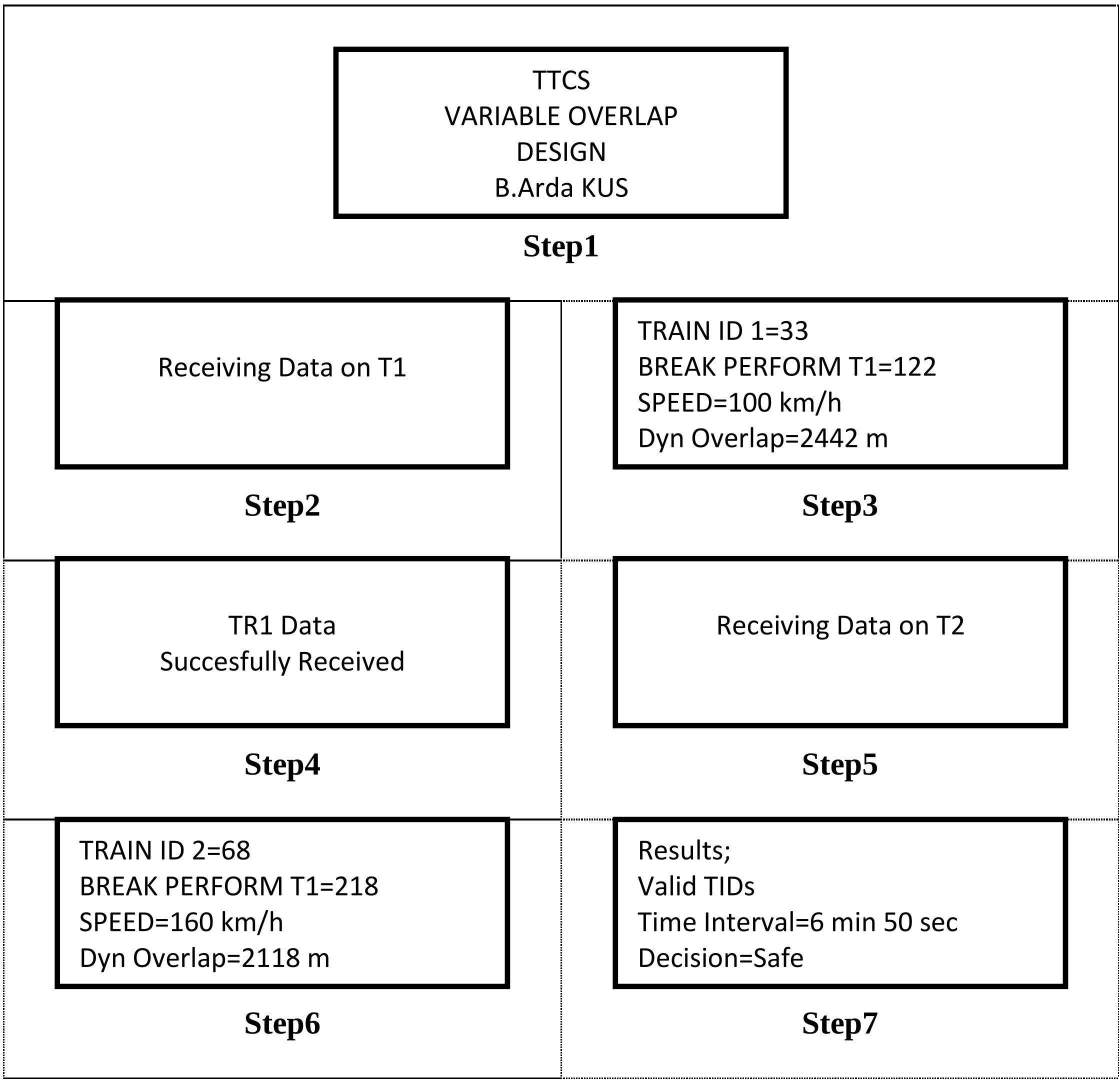


Figure 4.10 Steps on overlap distance estimator

4.2 Tests

An experimental test board is shown in Figure 4.11, to perform the reliability operation for location detection. The information provided will be directed to CTC to monitor the train speed and its location on the track. The test board consists of reed relay triggered detection points and horizontally moving barrier system. The system operation is performed initially with a magnet (cold test) and later with a model train (hot test). In both tests train locations are monitored on the LED display shown in Figure 4.12 and the speed estimated with DDS (line side equipment) is displayed and directed to CTC. As explained in Section 3 the operation of TTCS subsystems is achieved with the line side equipment in the set up.

In this study proposed concepts are realized with four major tests as explained in the following sections.

i) Detection points operation

Tests on detection point system are performed as shown in Figure 4.11 and Figure 4.12. tests are summarised at Table 4.2.

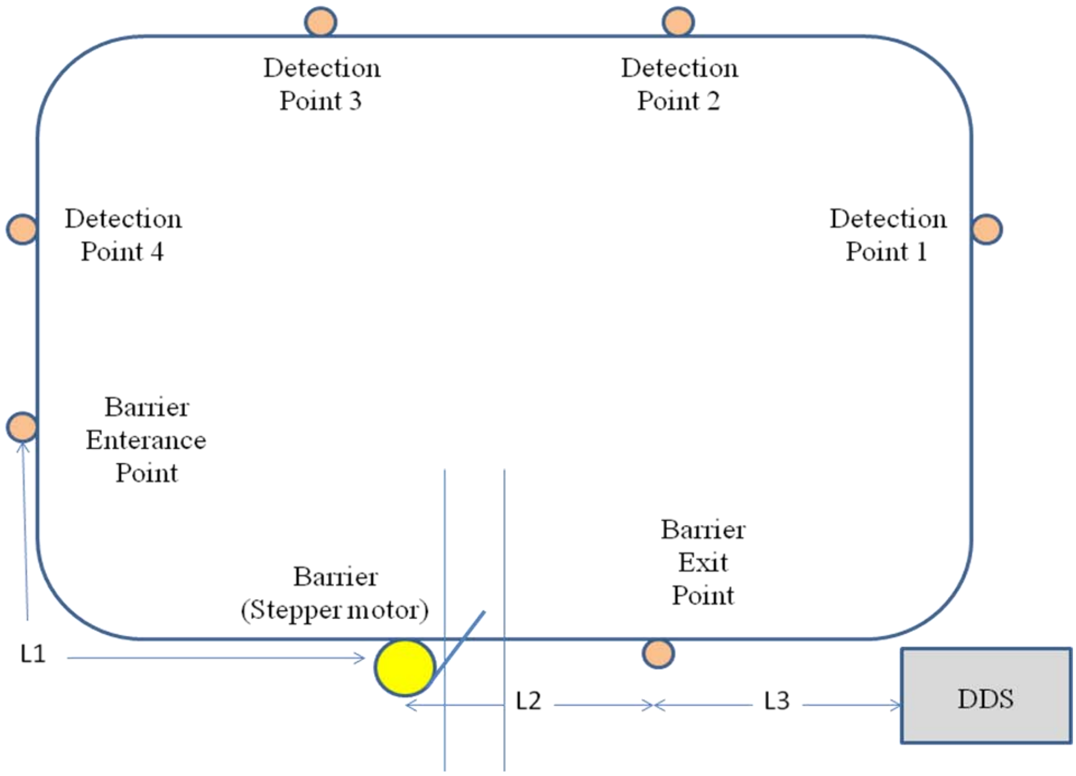


Figure 4.11 Detection points on test board

The LED display unit (5X7) shown in Figure 4.12 is a part of CTC system and it is fed from the line side reed relays.It is segmented into three sections; one for train detection, the other is for barrier detection and speed measurement, and the rest is spared as redundancy.

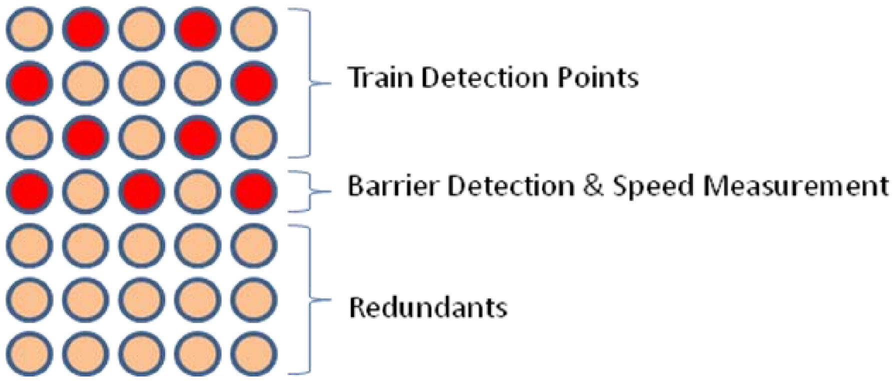


Figure 4.12 Train avalibilities monitored in CTC

The results for the effectiveness of monitoring and availability detection points obtained under normal operating conditions for a train speeding at a predefined speed are summarized in Table 4.2.

Table 4.2 Results of train avaibilities

Title of Test	Satisfactory / Unsatiffactory
Hot test on DP1	S
Hot test on DP2	S
Hot test on DP3	S
Hot test on DP4	S
Hot test on Barrier Enter P.	S
Hot test on Barrier Exit P.	S

ii) SBCU operation

Testing of single barrier control unit (SBCU) located at level crossing in the LC block for correct operation system is also performed together with the previous detection point monitoring tests. Test results on SBCU for monitoring of and occupation on the barrier system indicate succesfull operation as demonstrated in Table 4.3.

Table 4.3 Test results on SBCU

Title of Test	**Satisfactory / Unsatiffactory**
Cold Test on Detection of Enter Point	S
Closure of Barrier	S
WP Signal Generation	S
Cold Test on Detection of Exit Point	S
Speed measurement and generation of the 8 bit speed data for a predefined length	S
Transmitting speed data to Graphical Signals.	S

iii) DDS operation

The final decision for safe operation of the train which is resulted from operation of SBCU is tested and the results are shown in Table 4.4. The table includes speed data (8 bit) received by DDS,the speed limitations on RED and YELLOW adjustments and all DDS features.

Table 4.4 Test results on DDS

Title of Test	**Satisfactory / Unsatisfactory**
Receiving speed data by Graphical Signals.	S
Manual adjustment of RED limit	S
Manual adjustment of YELLOW limit	S
Screening the actual speed of the train	S
Screening the limits on both RED & YELLOW	S
Screening the decision on the movement autherity	S

iv) Dynamic Overlap operation

The tests on dynamic overlap distance estimator is done to check the safe breaking performance. The test results are shown in Table 4.5. Test includes TID data, its speed, screening decision on the TID conflict, received breaking performance of the train.

Table 4.5 Test results on dynamic overlap calculator.

Title of Test	**Satisfactory / Unsatiffactory**
Received TID data	S
Received speed data of the train	S
Screening decision on the TID conflict	S
Received Breaking Performance of the train	S
Calculations on the Overlap Distance	S
Screening the decision on Overlap Distance	S
Screening the decision on the movement autherity	S

The tests performed to check the proposed operations, explained in the preceding sections, indicate satisfactory performance at every stage of the model train movement. However, during the tests some unexpected problems raising from electromagnetic interference and discontinuities on the track are faced, corrective measurements are taken by correcting the DC supply output and screening the detection point cables.

CHAPTER V

CONCLUSION

As a new concept TTCS is proposed to unify the existing subsystems operating under the ETCS. TTCS is made up of three innovative subsystems namely Horizontally Moving Barrier (HMB) at level crossing blocks, Digital Display Signaling (DDS) as line side device and variable overlap estimator at Central Train Control (CTC) to produce signaling information to the line side warning indicators. The proposed system is attractive in the sense of design and usage of the line side warning indicators. The operation of subsystems are tested on a prototype model.

The results indicates succesfull operation of the subsystems and their mutual responses and common responses to the central control system.

The proposed subsystems, compared to the classical control systems render more enhenced braking performance, accurate control of overlap distance and avoids nonhierarchical signaling. In this respect, the proposed system with further modification and introduction of some supplementary devices, gives the hope for the prospective usage of the subsystems in the national train control system.

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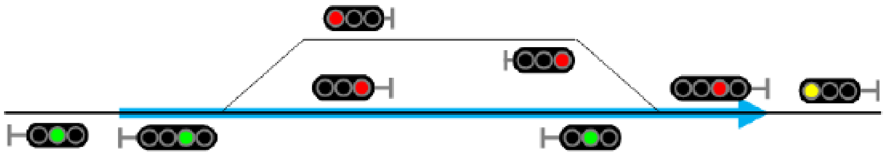
[10]Gökhan DİNÇER, Cihan GERÇEK (2009),Proteus ile Şematik Çizim ve Simulasyon, ISBN: 9756897244

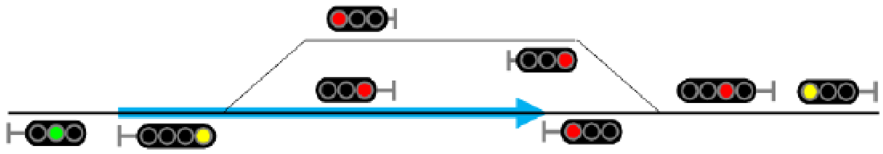
APPENDICES

A.1 Examples relating to some of the most common cases of signalling on line with both single and double tracks

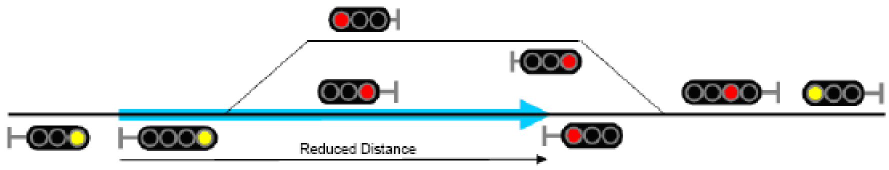
TRANSIT WITH SIGNALS PROCEED ASPECT



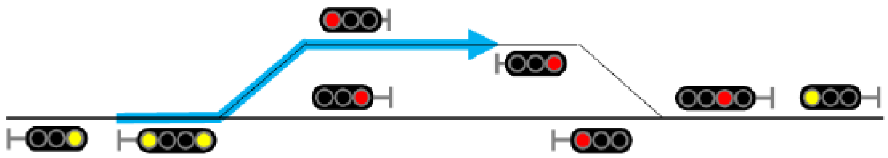
ARRIVAL ON STRAIGHT ROUTE WITH STOP



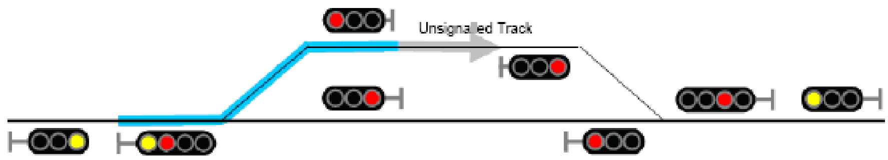
ARRIVAL ON STRAIGHT ROUTE WITH STOP (REDUCED DISTANCE)



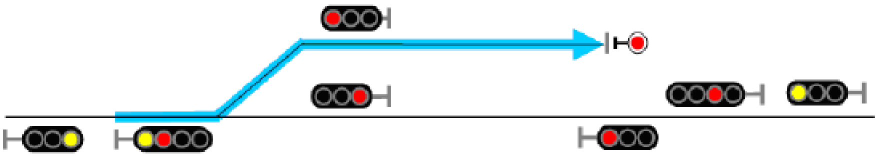
ARRIVAL ON SWITCHED ROUTE WITH STOP



ARRIVAL WITH SWITCHED ROUTE TO UNSIGNALLED TRACK

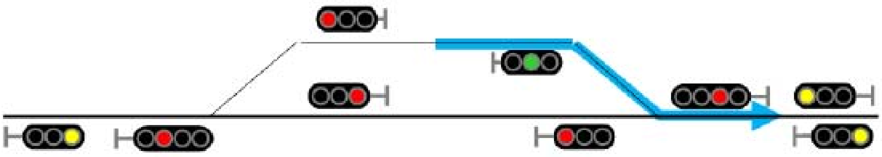


ARRIVAL WITH SWITCHED ROUTE TO TRUNCATED TRACK

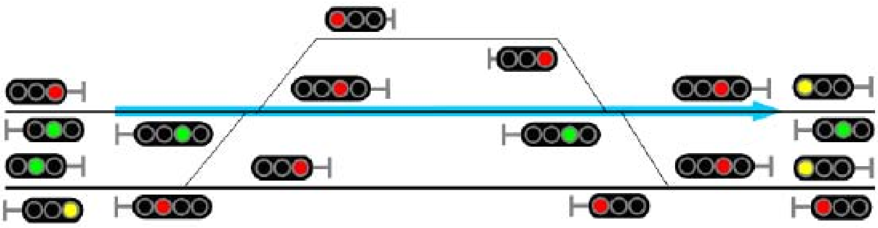


ARRIVAL WITH SWITCHED ROUTE TO A TRUNCATED AND UNSIGNALLED TRACK

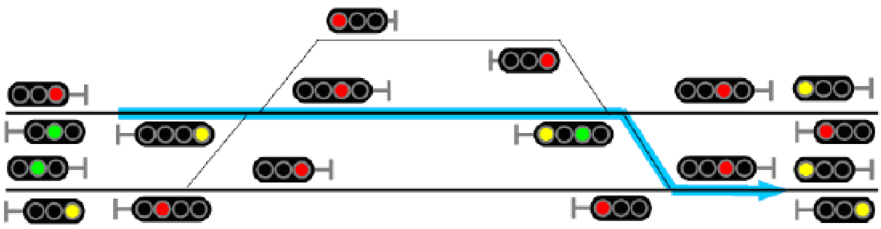
7.8 START FROM SWITCHED TRACK



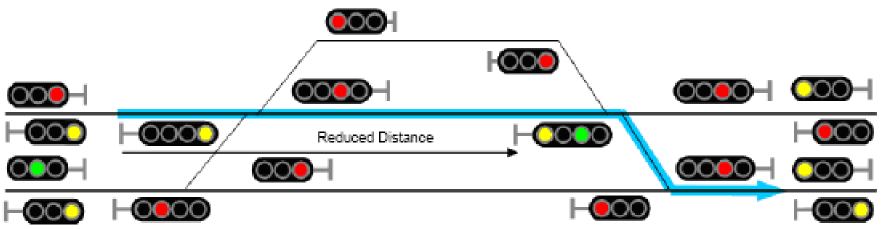
FREE TRANSIT ON STRAIGHT ROUTE



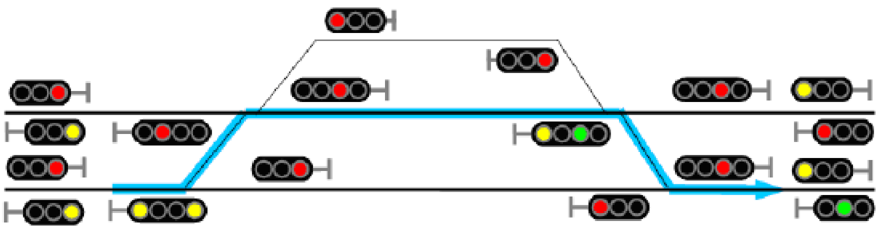
FREE TRANSIT WITH SWITCHED ROUTE



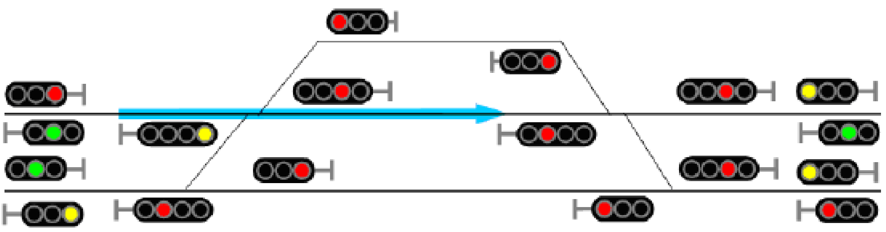
FREE TRANSIT ON SWITCHED ROUTE (REDUCED DISTANCE)



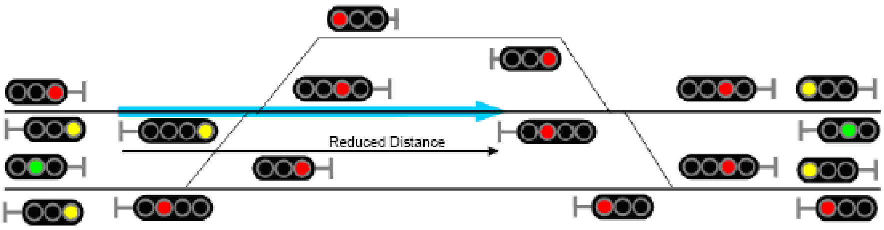
FREE TRANSIT WITH DOUBLE SWITCHED ROUTE



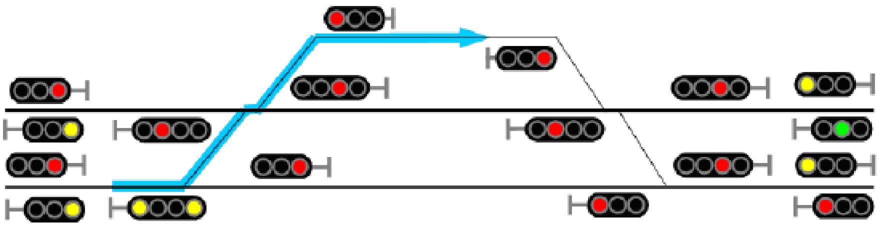
ARRIVAL ON STRAIGHT ROUTE WITH STOP



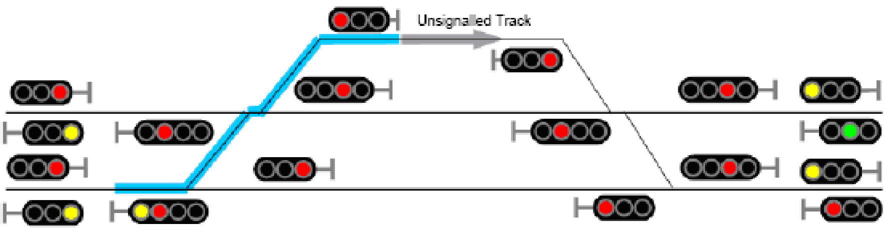
ARRIVAL ON STRAIGHT ROUTE (REDUCED DISTANCE)



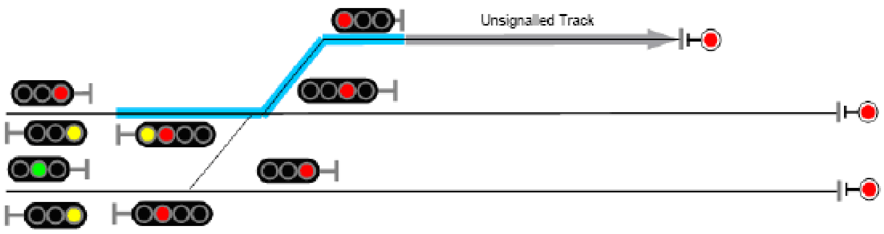
ARRIVAL ON SWITCHED ROUTE WITH STOP



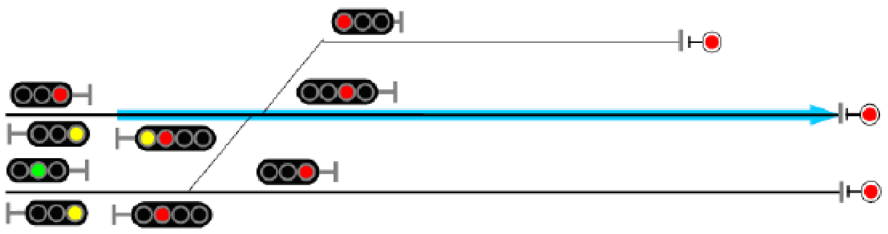
ARRIVAL ON SWITCHED ROUTE TO UNSIGNALLED TRACK



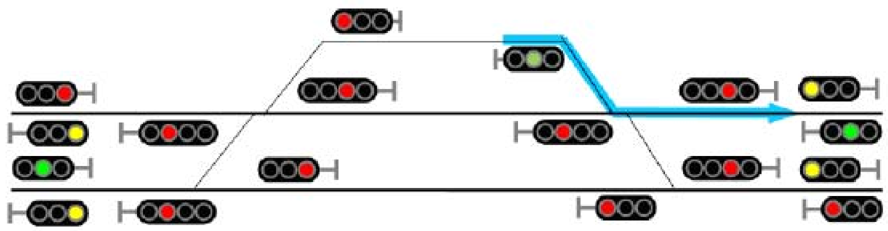
ARRIVAL ON SWITCHED ROUTE TO UNSIGNALLED TRACK WITH BUMPER



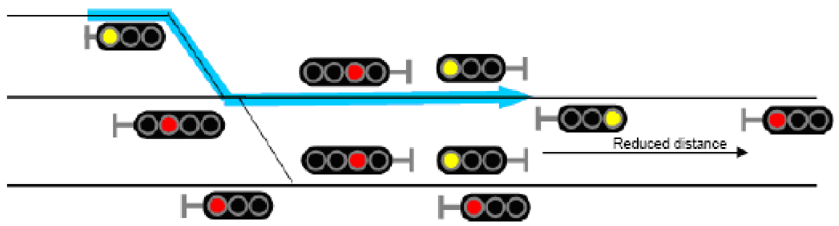
ARRIVAL ON STRAIGHT ROUTE TO HEAD STATION BUMPER



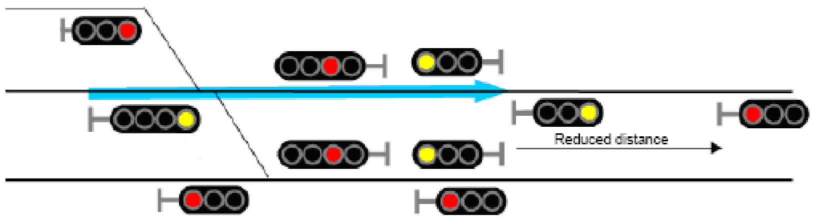
START FROM SWITCHED TRACK



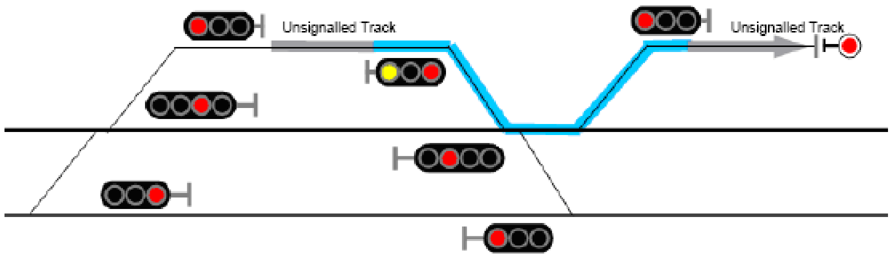
START FROM SWITCHED TRACK WITH REDUCED DISTANCE



START ON STRAIGHT ROUTE WITH REDUCED DISTANCE



START FROM UNSIGNALLED TRACK TOWARDS UNSIGNALLED TRACK



A.2 Overlap length calculation

Turkey Railway System

Mersin-Toprakkale-Boğazkőprű line

Overlap Lenght calculation

DOCUMENT ISSUE

	NAME	DEPT.	SIGNATURE	DATE
Prepared by:	Bisesti F.	FDT/SW/ML3		23/05/2011
Approved by:	Pagliuca R..	ML3		23/05/2011
Authorized by:	La Peccerella G.	PE		23/05/2011

TRACEABILITY of REVIEWS

REV.	DATE	CO	Prepared by:	Approved by:	Authorized by:	Reason for revision
00.00	14/02/2011	---	Lovotti S.	Sabatelli A.	La Peccerella G.	First issue
01.00	12/04/2011	CO729776	Bisesti F. Pappalardo R.	Pagliuca R. Napolitano G.	La Peccerella G.	Modified after customer comments
02.00	23/05/2011	CO730886	Bisesti F. Pappalardo R.	Pagliuca R. Napolitano G.	La Peccerella G.	Modified after input from TCDD

INDEX

1 PURPOSE

The purpose of this document is to define the value of the overlap zone lenght taking in to account the safety requirements for the provision of overlaps.

2 APPLICABILITY

This specification will apply to the operating activities of the *Mersin-Toprakkale-Boğazköprü* line.

3 REFERENCES

Ref.	Identifier	Description	Revision Or Issue	Date
[1]	DRR No11051	Document Review Report DRR Nº11051	Issue 01	22/04/2011
[2]	B.11.2.DDY.0.14.10.00-4 09.01-8728	Maximum wheelbase and breakin g distance of trains	n.a.	19/04/2011

4 ACRONYMS

ACCM	Proper Name for Multistation Computer Based Interlocking System
ETCS	European Train Control System

5 DEFINITIONS

Overlap

The distance beyond a Stop Signal must be clear, and where necessary locked, before the stop signal preceding the stop signal in question can display a proceed aspect.

Release speed

A speed value calculated within ETCS to allow a train to approach the end of its movement authority in a safe way.

6 FORMULA

The Overlap distance has been defined as result of the following formula:

$$d = d_r + d_b$$

where:

$$d_r = V_i \cdot t_r$$

$$d_b = \frac{1}{2} \cdot \frac{(V_f - V_i)^2}{ae}$$

$$ae = af + \frac{(9.81 \cdot i)}{1000} \cdot \frac{1}{(1 + cmr)}$$

$$t_r = t_e + t_b + t_f$$

af	acceleration imposed by train [m/s^2]
i	characteristic gradients [‰]
cmr	Rotating inertia balance (of tare weight)
V_f	End speed [m/s]
V_i	Start speed [m/s]
ae	Acceleration applied to the actual train [m/s^2]
d	Overlap distance [m]
t_r	delay time for application [s]
t_e	ETCS on board system time response [s]
t_b	Train braking system time response [s]
t_f	Time necessary for full application of the brakes [s]
d_r	Reaction distance [m]
d_b	Breaking distance [m]

Distance will be calculated considering the worst conditions.

7 MANDATORY INPUT

In order to calculate the correct value of the overlap length using the reference formula, the following input from TCDD are mandatory:

- ETCS Level 1 release speed
- ETCS on board system time response
- Train braking system time response
- Time necessary for full application of the brakes
- Odometry accuracy

8 INPUT AVAILABLE

Until now , after the ASTS's requests, the following input received (ref. [2]) are available:

- ETCS Level 1 release speed = 25 km/h
- Breaking distance = 88 [m] + 10% = 96.8 [m]

The breaking distance (88 [m]) has been taken from table ATTACHMENT–D, where:

- type of train : "REAKING DISTANCE OF A FREIGHT TRAIN WITH 38% OF BREAKING FACTOR"
- slope: 25 [‰]
- release speed: 25 [km/h]

It's not clear if ASTS can consider this distance includes the train braking system time response and the full application of the braking deceleration factor considered as the worst case for the worst train allowed running on the project area.

9 HIPOTHESYS

Since many mandatory inputs above mentioned are missing, in order to calculate the overlap length value, ASTS did the following hypothesis:

first hypothesis:

- Breaking distance = 96.8 [m] (includes Train braking system time response (t_b) and Time necessary for full application of the brakes (t_f).
- Start speed = 27[km/h]≡7,5[m/s] [included Release speed= 25 [km/h] and Odometry accuracy = 2 [km/h] (according The ETMS/ETCS TSIs)]

- delay time for application tr =1 [s] [includes only ETCS on board system time response= 1 [s] (according The ETMS/ETCS TSIs)]

second hypothesis:

- Breaking distance (d_b) = 96.8 [m]
- delay time for application t_r =20 [s], includes
  - ETCS on board system time response= 1 [s] (according The ETMS/ETCS TSIs)]
  - Train braking system time response (t_b) = 2 [s]
  - Time necessary for full application of the brakes (t_f) = 17 [s]
- Start speed = 27[km/h]≡7,5[m/s] [included Release speed= 25 [km/h] and Odometry accuracy = 2 [km/h] (according The ETMS/ETCS TSIs)]

10 CONCLUSION

According to the above mentioned hypothesis, ASTS calculated the following value:

first hypothesis:

$$d = d_r + d_b = 7{,}5 \cdot [m/s] \cdot 1 \cdot [s] + 96{,}8[m] = 104{,}3 \cdot [m]$$

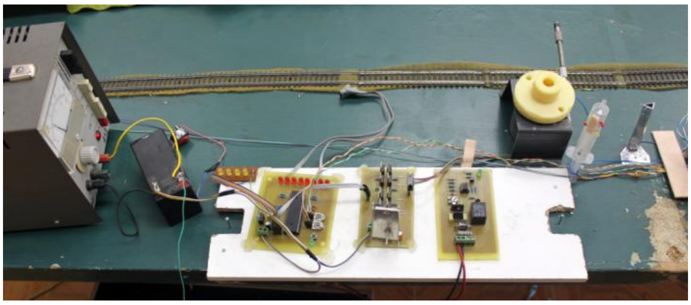
second hypothesis:

$$d = d_r + d_b = 7{,}5 \cdot [m/s] \cdot 20 \cdot [s] + 96{,}8[m] = 246{,}8 \cdot [m]$$

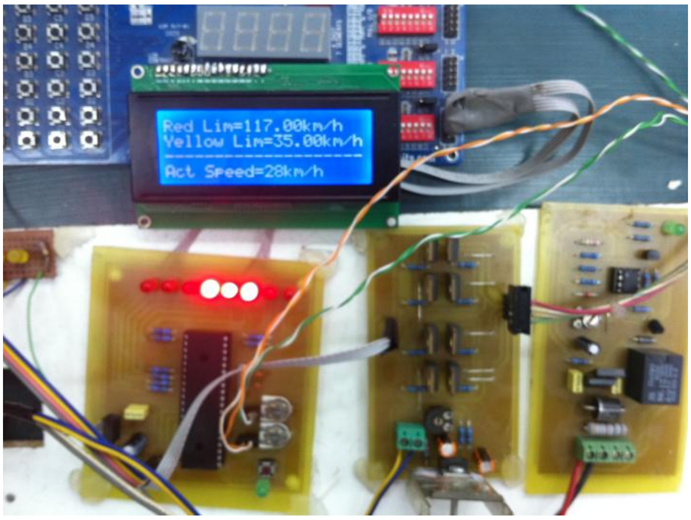
Since the mandatory input are missing, ASTS needs to underline that is bounded to choose a calculated value. Although the latter appears to favour the maximum security, ASTS considers it quite unrealistic and shall tend to prefer the first that provides an adequate level of security and gives a good operating flexibility to the stations in the same time.

[5]

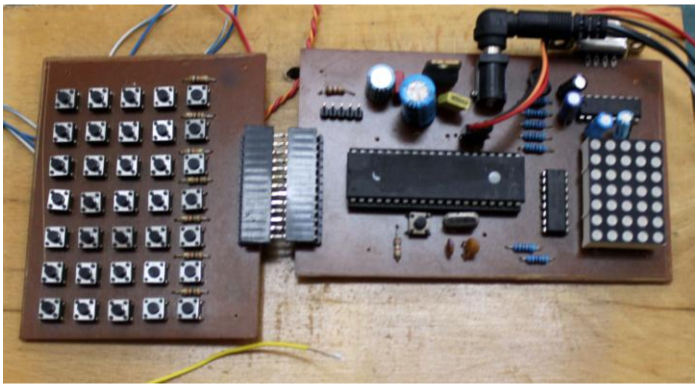
A.3 The prototype photographs



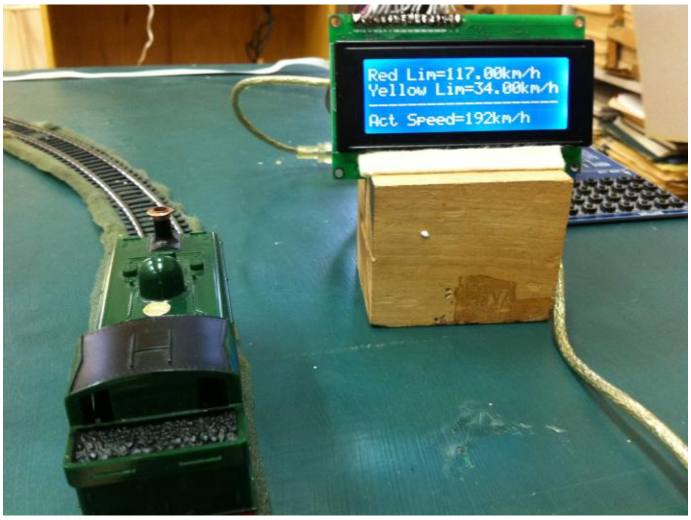
Photograph A.3.1 HMB Prototype



Photograph A.3.2 Speed measurement & microprossessor unit



Photograph A.3.3 Detection monitoring and availibility checking center



Photograph A.3.4 DDS prototype

Photograph A.3.5 General view of the Prototype

A.4 The rows and columns of the matrixes inverting code principles

```
Equation 2.1: A Weight Matrix
[1 3 5]
[2 4 6]

    The weight matrix can be defined in Java as follows:

Matrix weightMatrix = new Matrix(2,3);

    The threshold variable is not multidimensional, like the
weight matrix. There is one threshold value per neuron. Each
neuron in the second layer
has an individual threshold value. These values can be stored in
an array of Java double variables. The following code shows how
the
entire memory of the two layers can be defined.

Matrix weightMatrix = new Matrix(2,3);
double[] thresholds = new double[3];

    These declarations include both the 2x3 matrix and the three
threshold values for the second layer. There is no need to store
threshold values for the first layer, since it is
 not connected to another layer. Weight matrix and threshold
values are only stored for the connections between two layers,
not for each layer.

    The preferred method for storing these values is to combine
the thresholds with the weights in a combined matrix. The above
matrix has two rows and three columns.
The thresholds can be thought of as the third row of the weight
matrix, which can be defined as follows:

Matrix weightMatrix = new Matrix(3,3);

    The combined threshold and weight matrix is described in
Equation 2.2. In this equation, the variable w represents the
cells used to store weights and the variable t
represents the cells used to hold thresholds.

Equation 2.2: A Threshold and Weight Matrix
[w w w]
[w w w]
[t t t]
[8]
```

A.5 HMB microcontroller PIC-C codes

```
#include <16f877a.h>
#device ADC=8
#fuses XT, NOWDT, NOPROTECT, NOLVP, NOBROWNOUT, NOPUT, NOWRT, NODEBUG,
NOCPD
#use delay (clock=4000000)
#use fast_io(a)
#use fast_io(b)
#use fast_io(c)
#use fast_io(d)

int i=0, speed=20;
int ldr1=0,ldr2=0, delta_ldr=0;
const INT halfstep[]=
{0x08, 0x04, 0x02, 0x01};
const INT fullstep[]=
{0x01, 0x02, 0x04, 0x08};

#INT_AD
void ADC_INT()
{
  output_high(pin_b7);
  delay_ms(100);
  output_low(pin_b7);
}

void main(VOID)
{
  //module init
  enable_interrupts(INT_AD);
  enable_interrupts(GLOBAL);
  setup_psp(PSP_DISABLED);
  setup_spi(SPI_SS_DISABLED);
```

```
setup_timer_1(T1_DISABLED);
setup_timer_2(T2_DISABLED ,0,1);
setup_CCP1(CCP_OFF);
setup_CCP2(CCP_OFF);

setup_adc(adc_clock_div_32);
setup_adc_ports(AN0_AN1_AN2_AN4_AN5_VSS_VREF);



//port init
set_tris_a(0b11111111); //A all input
set_tris_b(0x00); //B
set_tris_c(0x00); //C
set_tris_d(0x00); //D all output
set_tris_e(0X00);
//ADC
WHILE(1)
{
  set_adc_channel(0);
  delay_us(20);
  ldr1=read_adc();
  delay_ms(20);



  set_adc_channel(1);
  delay_us(20);
  ldr2=read_adc();
  delay_ms(20);

  output_c(ldr1);

  delta_ldr=abs(ldr1-ldr2);

  output_d(delta_ldr);
  delay_ms(20);
```

```
      if(ldr1>ldr2)
       {
         output_high(pin_e0);  // E0 çıkışı 1
         output_b(fullstep[i]);
         delay_ms(speed);


         if(i==3) i = - 1;
         i++;
       }
      else if(ldr1<ldr2)
      {
        output_low(pin_e0);  // E1 çıkışı 1
        output_high(pin_e1);  // E1 çıkışı 1
         if(i==3)  i=-1;
         i++;
         output_b(halfstep[i]);
         delay_ms(speed);


      }
      else
       ;
   }
}
```

A.6 DDS microcontroller PIC-C codes

```
#include <16F877.H>

#device ADC=8 // 10 bitlik ADC kullanılacağı belirtiliyor.
#fuses XT, NOWDT, NOPROTECT, NOBROWNOUT, PUT, NOLVP,nocpd, nodebug
#use delay(clock = 4000000)
#include <EXLCD420.c>
//#use fast_io(c) //Port yönlendirme komutları D portu için geçerli

float voltaj0,voltaj1;
unsigned int actspeed;
unsigned int speed[2];
void main()
{
 setup_psp(PSP_DISABLED);       // PSP birimi devre dışı
 setup_CCP1(CCP_OFF);          // CCP1 birimi devre dışı
 setup_CCP2(CCP_OFF);          // CCP2 birimi devre dışı
 setup_adc(adc_clock_div_32);   // ADC clock frekansı fosc/32
 setup_adc_ports(ALL_ANALOG);   // Tüm AN girişleri analog
 setup_timer_0(RTCC_INTERNAL|RTCC_DIV_2);
 setup_timer_1(T1_DISABLED);     // T1 zamanlayıcısı devre dışı
 setup_timer_2(T2_DISABLED,0,1); // T2 zamanlayıcısı devre dışı


  lcd_init();

  printf(lcd_putc,"\f--------TTCS--------");
  delay_ms(300);
  printf(lcd_putc,"\n-----LCD Signals----");
  delay_ms(300);
  printf(lcd_putc,"\n-------Design-------");
  delay_ms(300);
```

```
   printf(lcd_putc,"\n-----B.Arda KUS-----");
   delay_ms(4000);
   printf(lcd_putc,"\f");
   delay_ms(300);
   printf(lcd_putc,"\n");
   delay_ms(300);
while(true)
 {
 enable_interrupts(GLOBAL);
 enable_interrupts(int_timer0);

    set_adc_channel(0);   // RE0/AN5 ucundaki sinyal A/D işlemine tabi tutulacak
    delay_us(200);        // Kanal seçiminde sonra bu bekleme süresi verilmelidir
    speed[0]=read_adc();     // ADC sonucu okunuyor ve bilgi değişkenine aktarılıyor
    voltaj0=1*speed[0];// Dijitale çevirme işlemine uğrayan sinyalin gerilimi hesaplanıyor
    delay_us(20);
    actspeed=input_d();
    delay_ms(200);


    set_adc_channel(1);   // RE1/AN6 ucundaki sinyal A/D işlemine tabi tutulacak
    delay_us(200);        // Kanal seçiminde sonra bu bekleme süresi verilmelidir
    speed[1]=read_adc();     // ADC sonucu okunuyor ve bilgi değişkenine aktarılıyor
    voltaj1=1*speed[1];  // Dijitale çevirme işlemine uğrayan sinyalin gerilimi hesaplanıyor
    delay_ms(200);
    printf(lcd_putc,"\fRed Lim=%fkm/h",voltaj1);   // AN6 ucundaki sinyalin gerilim değeri
LCD'ye aktarılıyor
    printf(lcd_putc,"\nYellow Lim=%fkm/h ",voltaj0); // LCD'ye yazı yazdırılıyor
    printf(lcd_putc,"\n--------------------"); // LCD'ye yazı yazdırılıyor
    printf(lcd_putc,"\nAct Speed=%ukm/h",actspeed);
    delay_ms(3000);

    if ((actspeed<speed[0])&(actspeed<speed[1]))
    {
    printf(lcd_putc,"\f--------GREEN-------");
```

```
    printf(lcd_putc,"\nThe Train is in Safe");
    printf(lcd_putc,"\n--Limited Speed is--");
    printf(lcd_putc,"\n-----%fkm/h---------",voltaj1);
    delay_ms(3000);
    }
    if ((actspeed>speed[0])&(speed[1]>actspeed))
    {
    printf(lcd_putc,"\f-------YELLOW-------");
    printf(lcd_putc,"\nThe Train is in safe");
    printf(lcd_putc,"\n--Limited Speed is--");
    printf(lcd_putc,"\n-----%fkm/h---------",voltaj0);
    delay_ms(3000);
    }
    if ((actspeed>speed[0])&(actspeed>speed[1]))
    {
    printf(lcd_putc,"\f---------RED--------");
    printf(lcd_putc,"\n--------STOP!-------");
    delay_ms(500);
    printf(lcd_putc,"\f--------------------");
    printf(lcd_putc,"\n--------------------");
    delay_ms(500);
    printf(lcd_putc,"\f---------RED--------");
    printf(lcd_putc,"\n--------STOP!-------");
    delay_ms(500);
    printf(lcd_putc,"\f--   AUTOMATIC   --");
    printf(lcd_putc,"\n--     TRAIN     --");
    printf(lcd_putc,"\n--   PROTECTION   --");
    printf(lcd_putc,"\n--    ACTIVATED   --");
    delay_ms(1000);
    }
  }
}
```

A.7 Overlap estimator microcontroller PIC-C codes

```
#include <16F877.H>

#device ADC=8 // 10 bitlik ADC kullanılacağı belirtiliyor.
#fuses XT, NOWDT, NOPROTECT, NOBROWNOUT, PUT, NOLVP,nocpd, nodebug
#use delay(clock = 4000000)
#include <EXLCD420.c>
//#use fast_io(c) //Port yönlendirme komutları D portu için geçerli

float voltaj0,voltaj1;          // ondalıklı tipte voltaj isminde değişken tanıtılıyor
unsigned int TID1,TID2;
unsigned int BP1,BP2;
unsigned int speed[2];
signed int difspeed;
signed int difBP;
signed int actoverlap;
signed int sqrsp1;
signed int sqrsp2;
float difvoltaj;
signed int difTID;
void main()
{
  setup_psp(PSP_DISABLED);       // PSP birimi devre dışı
  setup_CCP1(CCP_OFF);           // CCP1 birimi devre dışı
  setup_CCP2(CCP_OFF);           // CCP2 birimi devre dışı
  setup_adc(adc_clock_div_32);   // ADC clock frekansı fosc/32
  setup_adc_ports(ALL_ANALOG);   // Tüm AN girişleri analog
  setup_timer_0(RTCC_INTERNAL|RTCC_DIV_2);
  setup_timer_1(T1_DISABLED);     // T1 zamanlayıcısı devre dışı
  setup_timer_2(T2_DISABLED,0,1); // T2 zamanlayıcısı devre dışı


   lcd_init();
```

```
  printf(lcd_putc,"\f--------TTCS--------");
  delay_ms(300);
  printf(lcd_putc,"\n--Variable Overlap--");
  delay_ms(300);
  printf(lcd_putc,"\n-------Design-------");
  delay_ms(300);
  printf(lcd_putc,"\n-----B.Arda KUS-----");
  delay_ms(4000);
  printf(lcd_putc,"\f");
  delay_ms(300);
  printf(lcd_putc,"\n");
  delay_ms(300);
while(true)
 {
 enable_interrupts(GLOBAL);
 enable_interrupts(int_timer0);



    delay_ms(2000);
    printf(lcd_putc,"\f                    ");
    printf(lcd_putc,"\n   Receiving Datas    ");
    printf(lcd_putc,"\n       on TR1         ");
    delay_ms(3000);
    printf(lcd_putc,"\f       Wait         ");
    delay_ms(200);
    printf(lcd_putc,"\f       Wait.        ");
    delay_ms(200);
    printf(lcd_putc,"\f       Wait..       ");
    delay_ms(200);
    printf(lcd_putc,"\f       Wait...      ");
    delay_ms(200);

    set_adc_channel(0);   // RE0/AN5 ucundaki sinyal A/D işlemine tabi tutulacak
    delay_us(20);        // Kanal seçiminde sonra bu bekleme süresi verilmelidir
    speed[0]=read_adc();     // ADC sonucu okunuyor ve bilgi değişkenine aktarılıyor
```

```
voltaj0=0.6*speed[0];// Dijitale çevirme işlemine uğrayan sinyalin gerilimi hesaplanıyor
delay_us(20);
TID1=input_d();
delay_ms(200);
BP1=input_c();
delay_ms(200);
printf(lcd_putc,"\f                ");
printf(lcd_putc,"\n    TR1 Datas     ");
printf(lcd_putc,"\nReceived Succesfully");
delay_ms(3000);



printf(lcd_putc,"\fTrain ID=%u",TID1);
printf(lcd_putc,"\nBreak Perform T1=%u",BP1); // AN5 ucundaki sinyalin dijital karşılığı LCD'ye aktarılıyor
printf(lcd_putc,"\nSpeed=%fkm/h",voltaj0); // AN5 ucundaki sinyalin gerilim değeri LCD'ye aktarılıyor
printf(lcd_putc,"\nAct Overlap=%fm",voltaj0); // LCD'ye yazı yazdırılıyor
delay_ms(3000);
printf(lcd_putc,"\f                 ");
printf(lcd_putc,"\n   Receiving Datas    ");
printf(lcd_putc,"\n      on TR2        ");
delay_ms(3000);
printf(lcd_putc,"\f      Wait        ");
delay_ms(200);
printf(lcd_putc,"\f      Wait.       ");
delay_ms(200);
printf(lcd_putc,"\f      Wait..      ");
delay_ms(200);
printf(lcd_putc,"\f      Wait...     ");
delay_ms(200);



set_adc_channel(1);   // RE1/AN6 ucundaki sinyal A/D işlemine tabi tutulacak
delay_us(20);        // Kanal seçiminde sonra bu bekleme süresi verilmelidir
```

```
speed[1]=read_adc();     // ADC sonucu okunuyor ve bilgi değişkenine aktarılıyor
voltaj1=0.6*speed[1];  // Dijitale çevirme işlemine uğrayan sinyalin gerilimi hesaplanıyor
TID2=input_d();
delay_ms(200);
BP2=input_c();
printf(lcd_putc,"\f             ");
printf(lcd_putc,"\n     TR2 Datas");
printf(lcd_putc,"\nReceived Succesfully");
delay_ms(3000);



printf(lcd_putc,"\fTrain ID=%u",TID2);
printf(lcd_putc,"\nBreak Perform T2=%u",BP2);  // AN6 ucundaki sinyalin dijital karşılığı
LCD'ye aktarılıyor
printf(lcd_putc,"\nSpeed=%fkm/h",voltaj1);    // AN6 ucundaki sinyalin gerilim değeri
LCD'ye aktarılıyor
printf(lcd_putc,"\nAct Overlap=%fm ",voltaj1); // LCD'ye yazı yazdırılıyor
delay_ms(3000);



difvoltaj=(voltaj1-voltaj0);
difTID=(TID2-TID1);
difspeed=(speed[1]-speed[0]);
difBP=abs(BP1-BP2)*0.390625;
sqrsp1=(speed[0])*(speed[0]);
sqrsp2=(speed[1])*(speed[1]);
actoverlap=(sqrsp1-sqrsp2)/2*(BP2);

printf(lcd_putc,"\fAct Overlap=%um ",actoverlap); // LCD'ye yazı yazdırılıyor
delay_ms(3000);
if(difTID==0)
{
printf(lcd_putc,"\nTID Conflict");
delay_ms(3000);
```

```
}
else
{
printf(lcd_putc,"\nVALID TID");
delay_ms(3000);
}
if (difspeed<=0)
{
printf(lcd_putc,"\fDelta S=%fkm/h",difvoltaj);
printf(lcd_putc,"\nSafe Operation");
delay_ms(3000);
}
else
{
printf(lcd_putc,"\f  Delta S=%fkm/h",difvoltaj);
printf(lcd_putc,"\n-----Restricted-----");
printf(lcd_putc,"\n---Mode Operation---");
printf(lcd_putc,"\n-----ACTIVATED------");
delay_ms(3000);
printf(lcd_putc,"\f     The Train      ");
printf(lcd_putc,"\n  is going to Stop  ");
printf(lcd_putc,"\n        in          ");
printf(lcd_putc,"\n     5 Seconds      ");
delay_ms(1000);
printf(lcd_putc,"\f     The Train      ");
printf(lcd_putc,"\n  is going to Stop  ");
printf(lcd_putc,"\n        in          ");
printf(lcd_putc,"\n     4 Seconds      ");
delay_ms(1000);
printf(lcd_putc,"\f     The Train      ");
printf(lcd_putc,"\n  is going to Stop  ");
printf(lcd_putc,"\n        in          ");
printf(lcd_putc,"\n     3 Seconds      ");
delay_ms(1000);
printf(lcd_putc,"\f     The Train      ");
```

```
    printf(lcd_putc,"\n  is going to Stop  ");
    printf(lcd_putc,"\n       in         ");
    printf(lcd_putc,"\n     2 Seconds      ");
    delay_ms(1000);
    printf(lcd_putc,"\f     The Train      ");
    printf(lcd_putc,"\n  is going to Stop  ");
    printf(lcd_putc,"\n       in         ");
    printf(lcd_putc,"\n     1 Second      ");
    delay_ms(1000);
    printf(lcd_putc,"\f                 ");
    printf(lcd_putc,"\n                 ");
    printf(lcd_putc,"\n                 ");
    printf(lcd_putc,"\n                 ");
    delay_ms(1000);
    }
}
}
```