Department of Rail Transport
Ministry of Transport

# A STUDY TOWARD STANDARDIZATION OF RAILWAY ELECTRIFICATION AND SIGNALLING SYSTEMS
## (PHASE 1: THAILAND RAILWAY MAINLINE NETWORK)

## Executive Summary Report


Mahidol University

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# Table of Contents

## Table of Contents (Cont.)

## Table of Contents (Cont.)

## Table of Contents (Cont.)

Page

## Table of Contents (Cont.)

## List of Illustrations

หน้า

# List of Table

# Chapter 1

# Introduction

## 1.1 Principle and Rationale

Electrification and signalling systems are key components for efficient railway operations. Currently rail suppliers have developed various electrification and signalling systems. Integrating these different systems on a single network requires unified electrification and signalling standards that facilitate interoperability and enhance safety and efficiency.

The Department of Rail Transport is authorized and responsible for launching standards, guidelines and regulatory measures including monitoring and evaluation of rail operation service to achieve good quality, efficiency, convenience, and safety. Thus, the electrification and signalling standard development project has been carried out. The first phase of the project involves Thailand's mainline railway network to accommodate future connections with the neighbors.

## 1.2 Objectives

1. To collect and compare criteria, standards, and laws on electrification and signalling of rail transportation on the mainline network.
2. To establish standards, ministerial laws, orders, regulations, and suggestions on electrification and signalling of rail transportation on Thailand's mainline network.
3. To establish regulatory measures on electrification and signalling of rail transportation on Thailand's mainline network.

## 1.3 Scope of the Study

Electrification and signalling systems are different for each level of rail transportation network, e.g. urban mass transit, commuter rail, and intercity rail. The first phase of the electrification and signalling standard project focuses on the study and preparation of electrification and signalling standards and regulatory measures for intercity rail on the mainline network. Figure 1 summarizes the study framework in which numbers in the parentheses refer to tasks in the terms of reference (TOR).

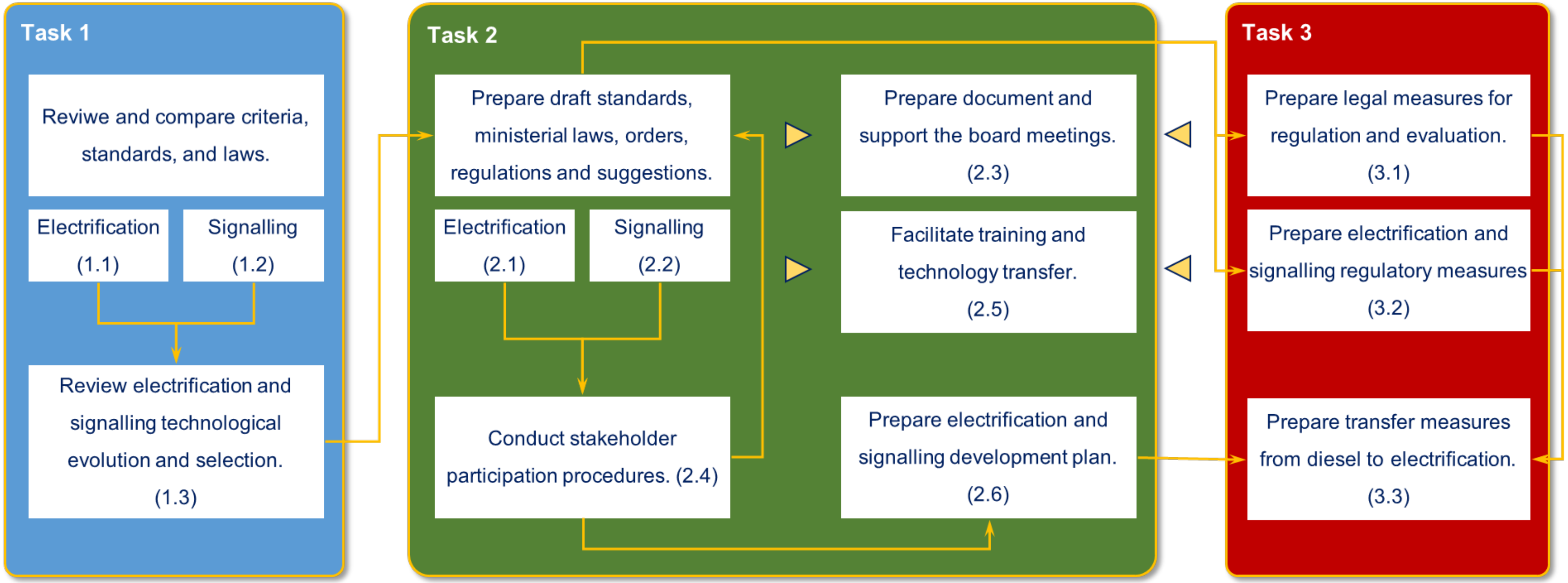



Figure 1 Scope and Process of Work

# Chapter 2

# Electrification System for Mainline Railway Network

## 2.1 Principle and Evolution of Electrification System

Railway network electrification system can be divided into 6 main components as follows:

### 2.1.1 Electrification System

Railway electrification system consists of alternated current (AC) electric railway for mainline and high speed rail, and direct current (DC) electric railway for mass transit. Mainline electric trains are fed through overhead feeding conductor. The current flows from the substation to the train through feeding conductor and fed through the system to drive the motor on the train. The current is then flow back via rail track to the substation. EN 50163 and IEC 60850 classify electrical voltage as shown in Table 1.

**Table 1 Voltage Applications to Electric Train according to EN 50163 and IEC 60850**

| Traction Voltage | Application |
|---|---|
| 600 VDC | Tram, Trolley bus |
| 750 VDC | Tram, Trolley bus, Light rail transit, Mass rapid transit |
| 1500 VDC | Mass rapid transit, Commuter train |
| 3000 VDC | Mainline, High speed rail (old system) |
| 15 KV, 16.7 Hz | Mainline, High speed rail (old system) |
| 25 kV, 50/60 Hz | Mainline, High speed rail |

At present, mainline electrification system normally uses 25 kV alternating current with frequency designated by each country. Mainline and high speed rail in Thailand are likely to use 25 kV 50 Hz bi-phase alternating current with autotransformer (AT) feeding system as shown in Figure 2 Although it is more costly than others, it yields low electromagnetic interference and can control stable voltage. Thus, it becomes more widely-used. Most of old railway networks all over the world have been improved with autotransformer (AT) feeding system.

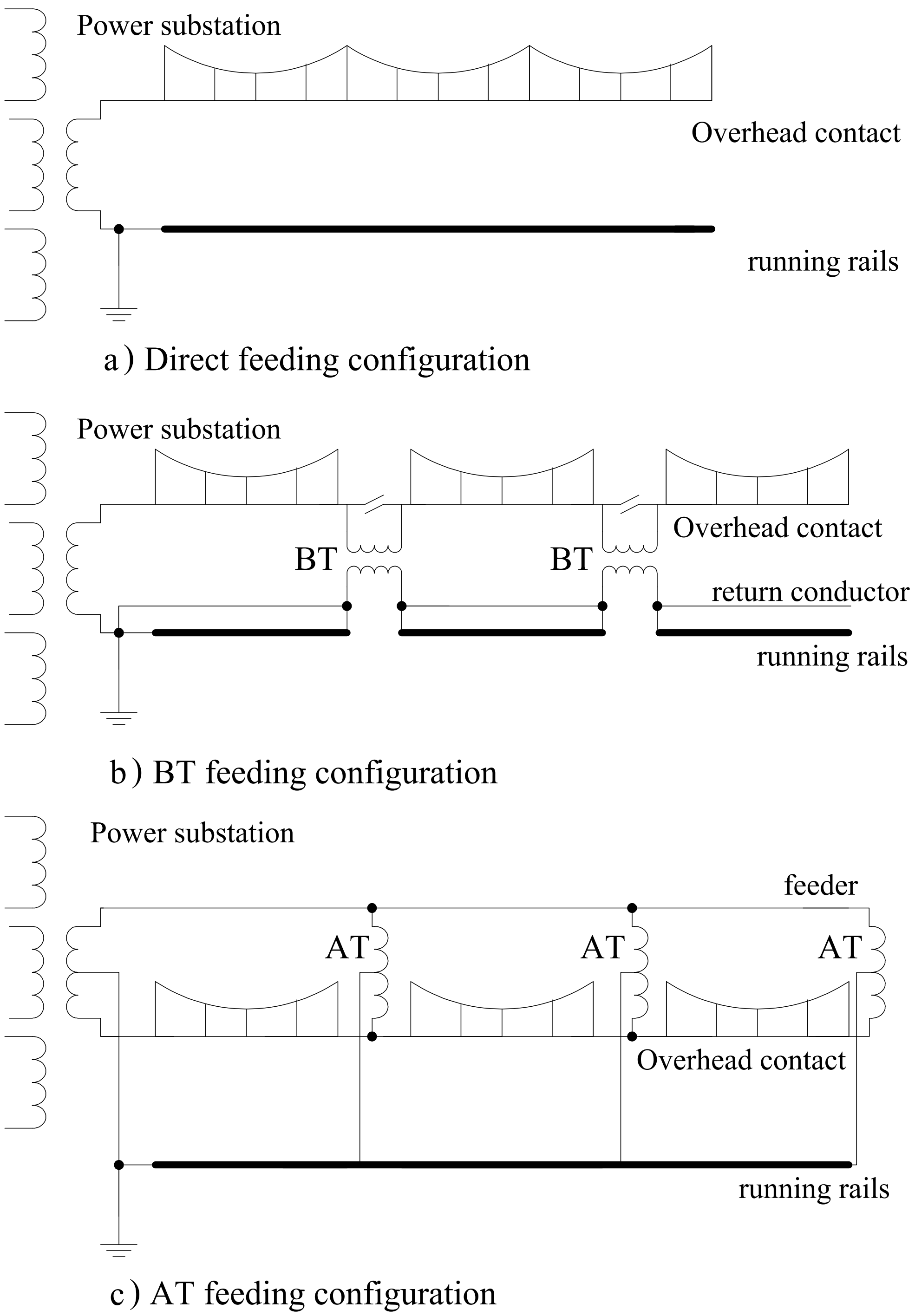



Figure 2 Standard Feeding for Alternating Current Railway System

### 2.1.2 Protection and Insulation

There are various types of transformer protection, e.g. time-delay overcurrent relay (51 51G, I> IN>) transformer differential protective relay (87T, Id/I) over voltage relay (59, U>), under voltage relay (29, U<) over frequency relay (81, f>), under frequency relay (81, f<) and voltage-to-frequency relay (24, U/f>) which is the traditional type of transformer used in Europe. Feeder protection uses overcurrent and differential current relays. Meanwhile, alternating current tractive transformers for modern long-distance railway uses distance protection. Thus, the distance relay function is also added into the protective system. For autotransformers, the secondary coil has a center tap that creates a two-phase circuit feeding to the OCL and the negative feeder as shown in Figure 3

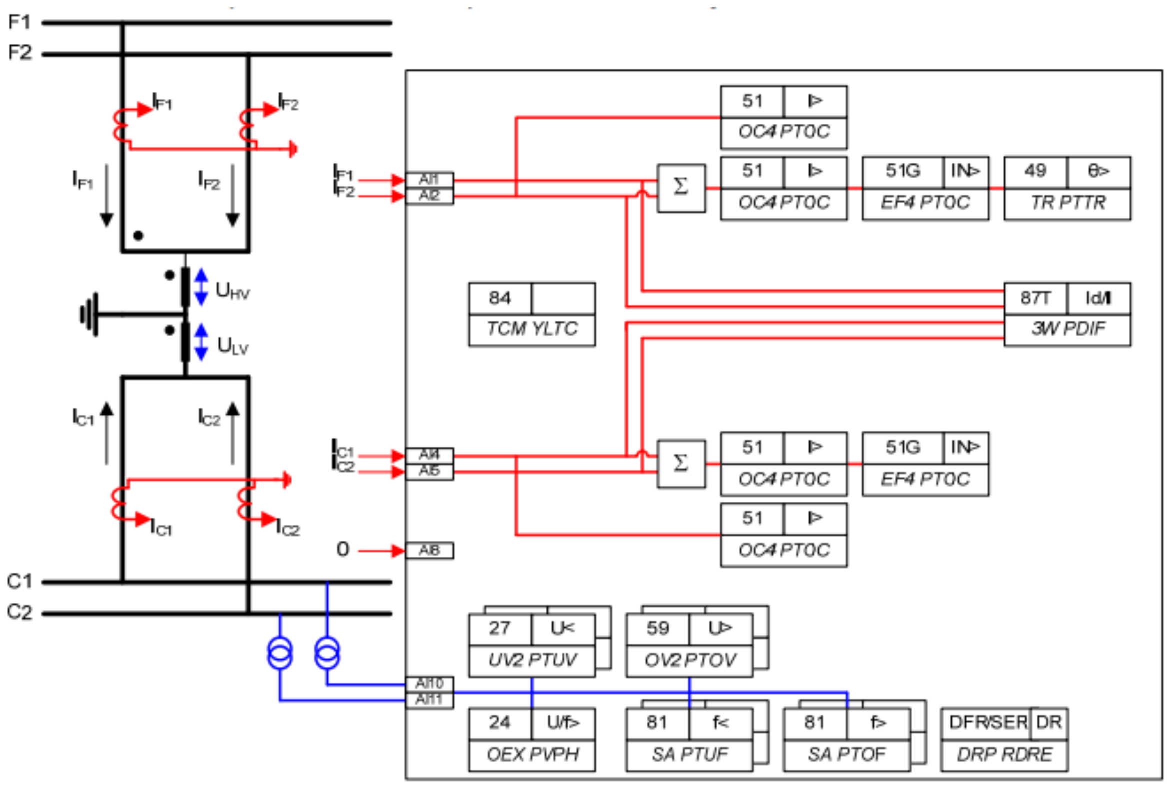
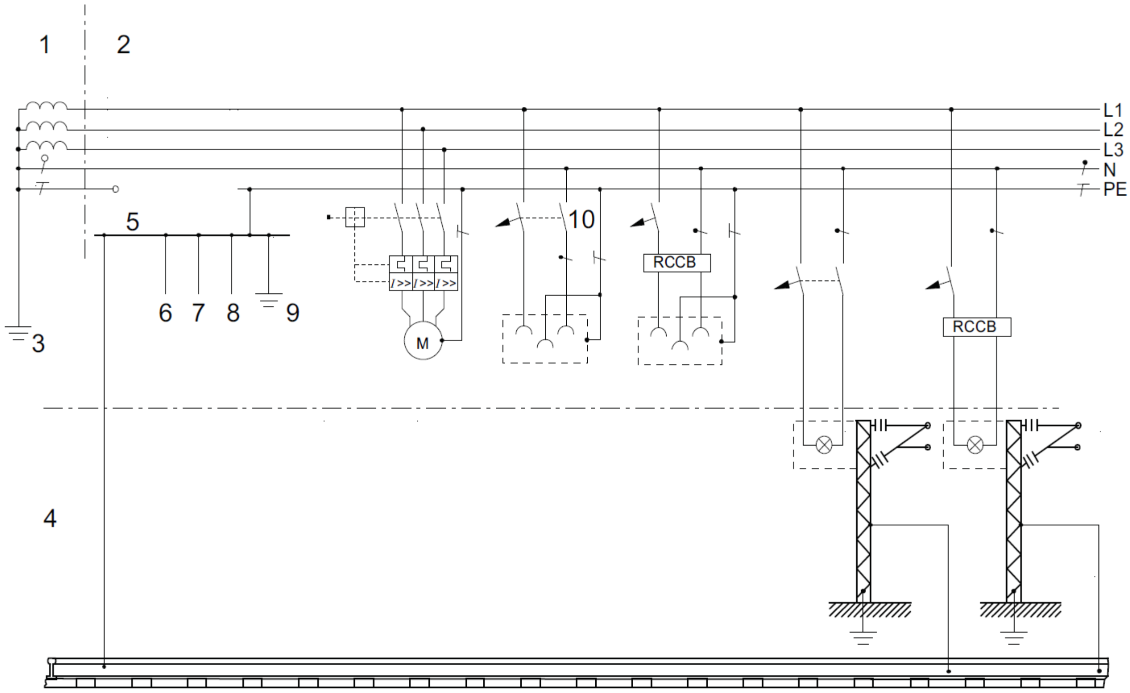



**Figure 3 Autotransformer Protection for Long Distance Electrification Train**

Autotransformer protection is different from that of alternating current tractive transformers. This is because the coil connects to the contact and negative feeder conductors. The relay protection is provided on both sides of the connection. Differential current relay protection is also provided to protect the autotransformer coil. Other types of protection such as over and under voltage or over frequency are normally designed.

### 2.1.3 Earthing

The tractive current is fed through the track. Equipment with current running through must be covered or separated by insulated materials with appropriate earthing. Electrification train refers to EN 50122-1: 2011 which defines earthing for equipment in the electrification system related to reverse traction circuit. Auxiliary feeding system at the railway station or substation may receive electricity from high voltage or low voltage system provided by local electricity authority, or from tractive current feeding system. If the electric equipment of interest is designed to tolerate temporary high voltage (protection class II) according to EN 61140, it does not need earthing. Earthing systems may be Terre-Terre or earth-earth (TT), or Terre-Neutral (TN) as shown in Figure 4 and 5.

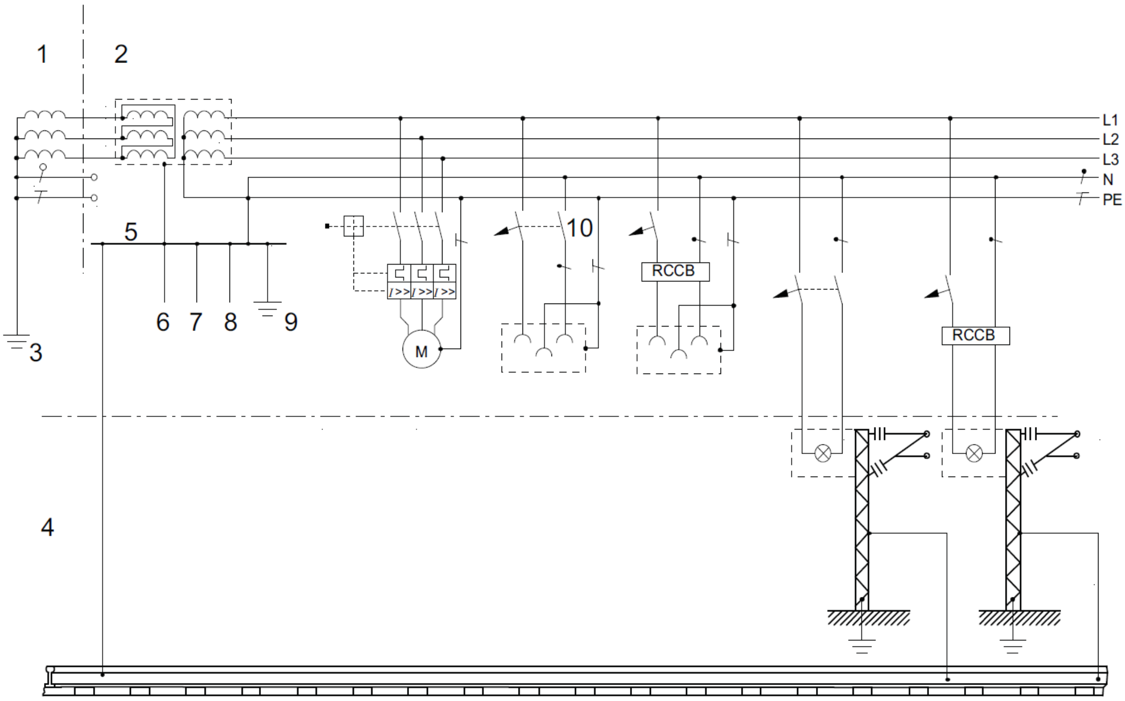



**Key**

| | | | |
|---|---|---|---|
| 1 | electricity supply network | 6 | water and gas pipes |
| 2 | railway network | 7 | heating |
| 3 | public earth | 8 | lightning protection |
| 4 | overhead contact line and current collector zone | 9 | railway structure earth |
| 5 | MEB | 10 | only required for rail potential > 50 V |

Figure 4 TT Earthing in Alternating Current Tractive Electric System

Source: EN 50122-1: 2011




**Key**

| | | | |
|---|---|---|---|
| 1 | electricity supply network | 6 | water and gas pipes |
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| 4 | overhead contact line and current collector zone | 9 | railway structure earth |
| 5 | MEB | 10 | only required for rail potential > 50 V |

**Figure 5 TN Earthing in Alternating Current Tractive Electric System**

Source: EN 50122-1: 2011

### 2.1.4 Transformer Arrangement

Transformer arrangement at the traction station is crucial in railway electrification system design. Using the same frequency as public grid frequency causes unbalanced voltage and high-voltage current in the feeding system. Measures must be established to ensure train electrification system can work with public grid system properly and efficiently. Transformer arrangement can take different forms, e.g. single-phase connection, V connection, Scott connection, Le Blanc connection, and cross-connected transformer.

### 2.1.5 Supervisory control and data acquisition (SCADA)

SCADA is one of the Industrial Control Systems (ICS) in which computer monitors and controls industrial process in physical world. Main components of SCADA for rail system are (1) Remote Terminal Unit (RTU) located at stations to collect data or parameters including commands that enable equipment to work from the Operation Control Center (OCC), (2) Communication System which sends and receives data, and (3) Master Station which is in general located at OCC and commands and monitors parameters from all RTUs. The master station may also control interlocking, making it an interlocking station in case of emergency. An example of SCADA for electrification train is shown in Figure 6

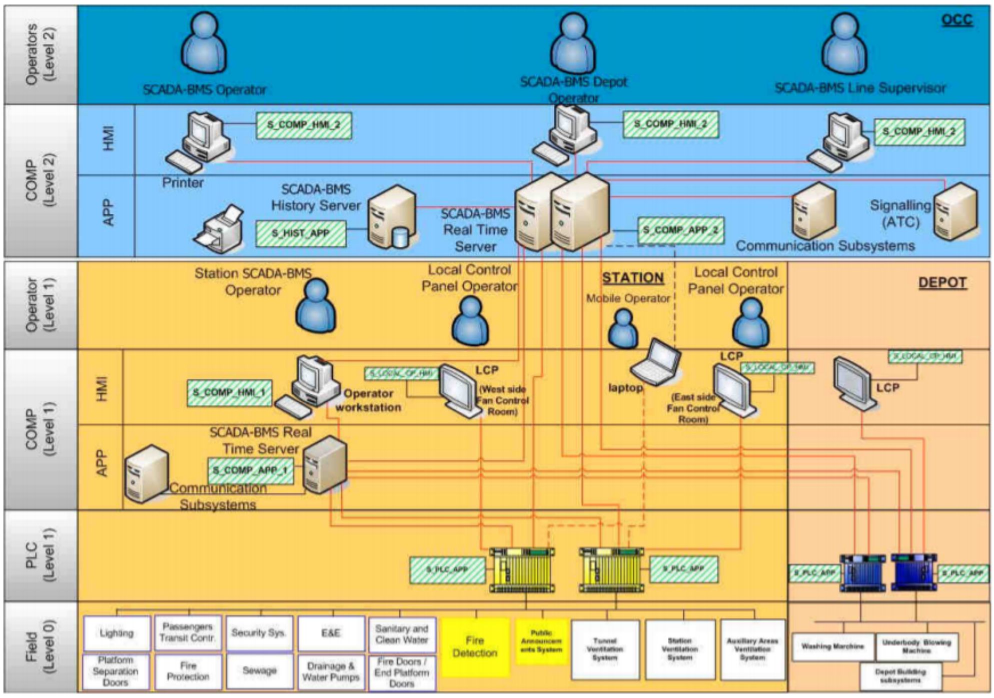



Figure 6 SCADA-BMS logical architecture

Source: http://www.ascgroup.it/wp-content/uploads/2015/10/ASCGroup_SCADA-BMS_TD_EN_V6.pdf

### 2.1.6 Power Quality

Electrification system for mainline railway network involves 25 kV 50 Hz single-phase current. The substation may experience problems on highly unbalanced power and power quality. To maintain balance of power system from MEA/PEA, the substation will receive alternated phase pair electricity from local electricity authority. Transformer connection at the substation highly affects power imbalance. Local electricity authority has requirements for train electrification system connection which require the design of feeding control system at the connection point to ensure that it does not exceed power quality limitations.

## 2.2 Electrification Technology Selection

Two electrification systems are applied to railway traction: direct current (DC) and alternating current (AC). Two feeding systems are also used in railway operations which are third rail and overhead catenary systems.

Third rail system has an advantage on minimal vision pollution as it does not require power feeding structure over the railway track. However, its limitation involves long distance operation and safety. This system is normally used in underground or urban transit systems where no man or cattle are allowed on the track which may be harmed from electric current. Overhead catenary system contains unpleasant feeding wires and structure. It is used for long-distance and fast electrification trains which require high voltage electricity that cannot be accommodated by third rail system.

Third rail system typically uses direct current with 750 V or less, while overhead catenary system uses higher voltage direct current and alternating current. Two electrification systems that are technically potential, commercial feasible and currently used in Thailand are:

(1) Third rail system with 750 V DC

(2) Overhead catenary system 25 kV 50 Hz AC

**Table 2 Comparison of Railway Electrification Systems**

| Factors | Electrification Systems | |
|---|---|---|
| | **Third Rail 750 V DC** | **Overhead 25 kV 50 Hz AC** |
| **Reliability** | High | High |
| **Maintenance** | Lower | Higher |
| **Efficiency**<br>- **Electrification**<br>- **Passenger capacity** | Depends on operation | Depends on operation |
| **Safety**<br>- **Electromagnetic disturbance**<br>- **Touch voltage**<br>- **Stray current**<br>- **Lightning protection** | Lower | Higher |
| **Life Cycle Cost**<br>- **Installation**<br>- **Maintenance** | Lower | Higher |

| Factors | Electrification Systems | |
|---|---|---|
| | Third Rail<br>750 V DC | Overhead<br>25 kV 50 Hz AC |
| **Technical**<br>- The distance to the power station<br>- Impact on other facilities | 1.5 – 2 km<br>Electrolytic corrosion | 30 – 50 km<br>Communication Failure |
| **Characteristics** | Tram, Trolley bus, Light rail transit, Mass rapid transit | Railway Mainline<br>High Speed Rail |

### 2.3 Standards, Laws and Orders on Electrification System

Standards are agreements between agencies or organizations in the commonly interested issues. Standards applied in Europe or EU refers to EN standards established by European standards organizations. Meanwhile, other international standards under EN และ ISO are classified by industry and application.

Six standards involving major components of electrification system include electrification system, protection and insulation, earthing, transformer arrangement, supervisory control and data acquisition (SCADA), and power quality. Table 3 compares related standards applied in key countries.

**Table 3 Comparison of criteria, standards, and/or laws in Electrification System**

| Item | Standard | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | European Union | U.S.A. | U.K. | Japan | China | Australia/ New Zealand | Thailand | Neighboring Country (Malaysia) |
| Electrification System | EN 50163<br>EN 50388<br>EN 50367 | EN 50163<br>EN 50388 | BS EN 50163<br>BS EN 50388<br>BS EN 50367 | JIS E2201 | GB/T 1402<br>GB/T 28027 | AS7530 | Railway Electrification System Connection Requirements of PEA | EN 50163<br>EN 50388<br>EN 50367 |
| Protection and Insulation | EN 50124-1<br>EN 50124-2<br>EN 50633 | EN 50122-1<br>EN 50124-1 | BS EN 50124-1<br>BS EN 50124-2<br>BS EN 50633 | NA | GB/T 32350.1<br>GB/T 32350.2<br>GB/T 32580.301<br>GB/T 32580.302 | AS7530<br>AS7708 | EIT Standard 2001–56 | EN 50124-1<br>EN 50124-2<br>EN 50633 |

| Item | Standard | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | European Union | U.S.A. | U.K. | Japan | China | Australia/ New Zealand | Thailand | Neighboring Country (Malaysia) |
| | | | | | GB/T 32580.303<br>GB/T 32586<br>GB/T 28026.1<br>GB/T 28026.3 | | | |
| **Earthing** | EN 50522<br>EN 50122-1<br>EN 50122-3 | IEEE Std 80 | BS EN 50522<br>BS EN 50122-1<br>BS EN 50122-3 | JIS E3601 | GB/T 28026.1<br>GB/T 28026.3 | AS7708 | EIT Standard 2001–56 | EN 50522<br>EN 50122-1<br>EN 50122-3 |
| Transformer Arrangement | EN 50329<br>EN 60076 | NA | BS EN 50329<br>BS EN 60076 | NA | GB 1094 | NA | NA | EN 50329<br>EN 60076 |
| supervisory control and data acquisition | EN 50155<br>EN 60870 | NA | BS EN 50155<br>BS EN 60870 | NA | GB/T 21413.1<br>GB/T 18657 | NA | NA | NA |
| Power Quality | EN 50121-2<br>EN 50121-5 | IEEE Std 519<br>IEEE Std 1159 | BS EN 50121-2<br>BS EN 50121-5 | NA | GB/T 24338.2<br>GB/T 24338.6 | AS7722 | PRC-PQG-01/2011 and Railway Electrification System Connection Requirements of PEA | NA |

Currently Thailand's electrification mainline projects under study are considered in accordance with available national standards first and then with international standards (EN/IEC) afterward. Table 4 offers a complete list of applicable international standards which are used worldwide. Moreover, most national standards are in line with EN/IEC. Standards issued by MEA and PEA have also been developed from EN/IEC. Therefore, the electrification standards for Thailand should take into account the national standards first and append some international EN/IEC standards to completely cover all issues and suit the context of the country.

## 2.4 Draft Standards, Ministerial Laws, Orders, Regulations and Suggestions on Electrification System

Establishing central standards will guide the national railway development towards the same direction and support the railway regulating agency to work efficiently and safely. The standards also enable railway interoperability which is beneficial to quality and viable railway operation from the government's point of view. Key activities affecting railway development are:

a) Installation
b) Equipment
c) Functions
d) General Specification
e) Safety
f) Operation and Maintenance
g) Testing and Commissioning
h) Interoperability

When mapping the above topics to the electrification procedure in the pre-operation and revenue service phases in V-cycle according to EN 50126 as shown in Figure 7, one can see that all the key issues have been addressed in line with the standard.

The scope of draft electrification system standard is defined in line with key components and activities. Six standards are drafted including major components of electrification system include electrification system, protection and insulation, earthing, transformer arrangement, supervisory control and data acquisition (SCADA), and power quality. Each standard consists of key components and activities as listed above. Figure 8 shows relationship among these standards.

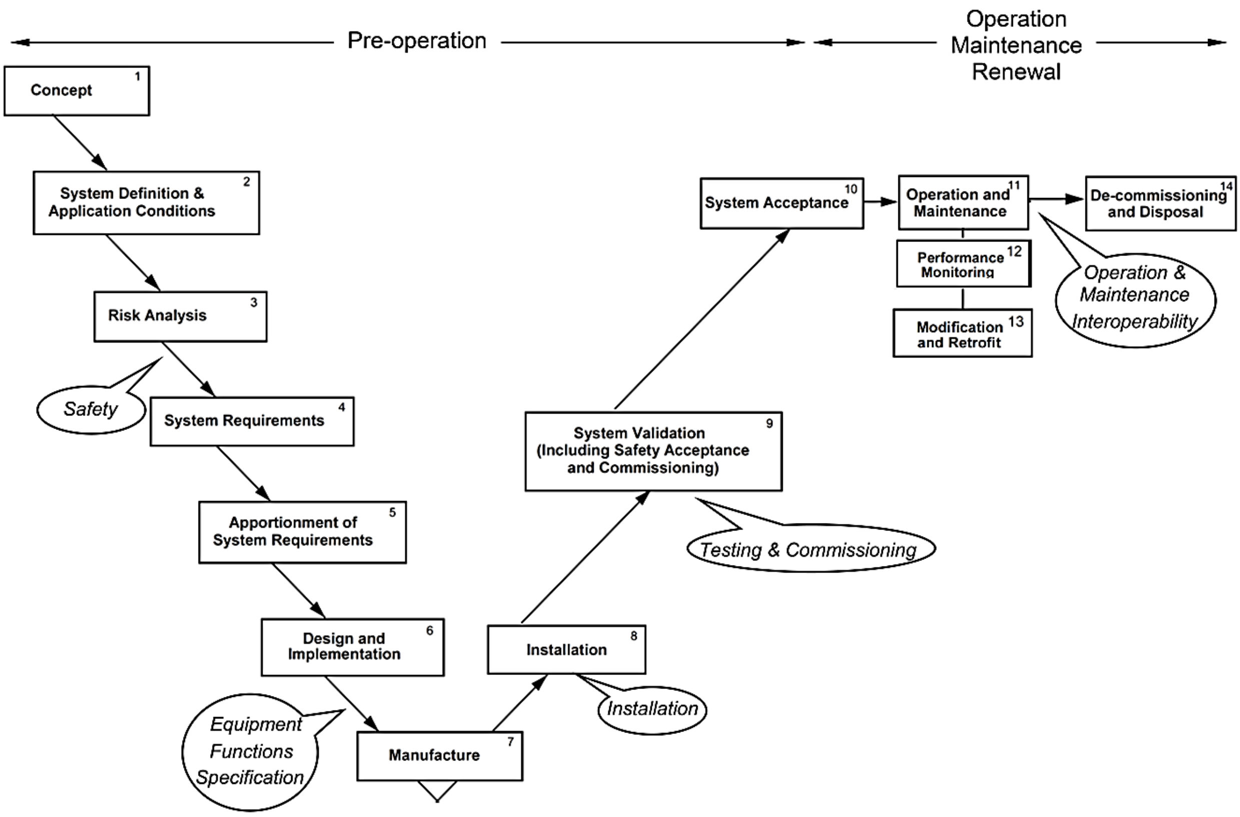



Figure 7 V-cycle according to EN 50126 and Key Study Subjects

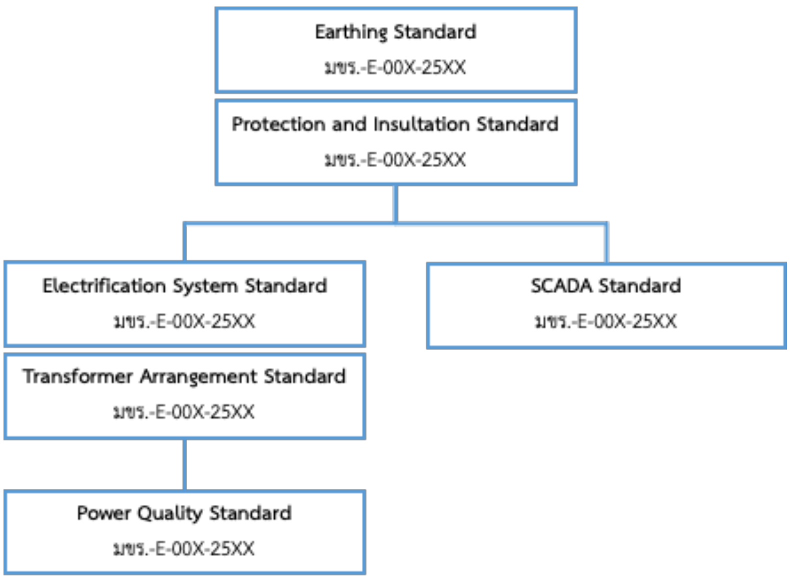



Figure 8 Relationship among Electrification System Standards for Mainline Railway Network

# Chapter 3

# Signalling System for Mainline Railway Network

## 3.1 Principle and Evolution of Signalling System

Railway Signalling System is mechanical, signal and computer systems that controls the trains on the routes. The system will inform the driver about the route status ahead so the driver can decide whether to stop, slow down, or steer to other direction. The system presents various signal patterns as specified in the rules so that the train can progress safely and efficiently. The signalling system controls the train operation to run on schedule. It also controls shunting maneuver at the station or station yard which is designed to work together with supporting technology for operation safety.

### 3.1.1 Interlocking

Signalling control by interlocking can be classified into 3 systems: relay interlocking (RI), computer based interlocking system (CBI), and electronic interlocking (EI).

Relay Interlocking (RI) is driven by electricity only (also known as "all-electric"). It consists of complex relay circuits and logic that check the status and position of each signalling equipment. While electric equipment is working, position shifts will trigger some circuit that locks other equipment that may conflict with the new position. Other circuits will also be closed when equipment they control is safe.

Computer Based Interlocking system (CBI) is built to replace RI. The CBI system uses computer program to design control table under the operating conditions resulted from signaling equipment placement as shown in Figure 9 **Signaling Equipment** is on-route equipment setting running direction. It takes all commands from various types of equipment, then examine and send the results to the **Computer Interlocking**. The CBI calculates and compiles the interlocking status between signalling system and point machine, while the track circuit check the route status and obstacles. The **Computer and Control Display** section will show the results on the computer monitor.


**Figure 9 CBI System Structure**

Source: http://www.thaiscience.info/Journals/Article/NRCT/10440367.pdf

Electronic Interlocking (EI) is an electronic system which is HIMA Himax PLC under control system with safety integrity level 4 (SIL-4) according to CENNELEC European railway standard. The EI system is a modular system and resizable. It covers all types of equipment such as monitoring station, configuration and preparation of simple to complex signalling.

### 3.1.2 Point Machine

Pint machine is a key component in setting up train routes. It drives the point blade to direct train wheels to the intended mainline or loop track and lock the blade position. Then it sends the signal of turnout direction upstream to confirm the train direction. Three types of turnout point machines are Electro – Mechanical: AC, Electro – Mechanical: DC, and Electro – Hydraulic.

**Figure 10 Point Machine**

### 3.1.3 Token Signalling

Signal tokens may come as steel ball, coin, ticket or other types of signalling object that the signalling staff must submit or show to locomotive staff before the train enters the block between the two specified stations. In the simplest way, the signalling staff will call the adjacent station to check whether a train is obstructing the block. If none exists, the block is said to be clear and the token can be issued to the driver. There are two kinds of tokens: flat and round tokens. Token machine is a large dark-green steel box. Each station has two machines, one to communicate with the upstream station and the other to the downstream station. Communication and other mechanism are induced from copper wires.

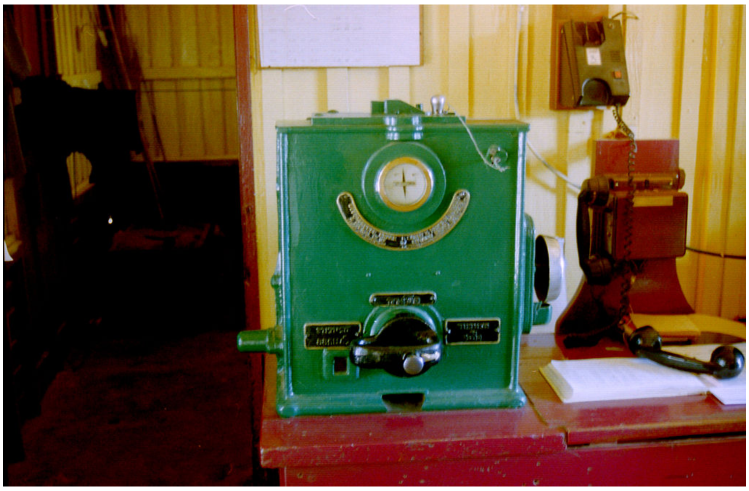


**Figure 11 Token Machine**

Source: https://th.wikipedia.org/wiki/

### 3.1.4 Level Crossing Barrier

Level crossing barrier is equipment that enhance safety to train level crossings. Two kinds of barriers are:

1) Barriers with staff. When blocking the road traffic, these barriers, painted in red and white (or other colors as designed), can be seen from both directions of the road. The red lights are attached at night. Flashing lights are optional on both road and rail sides.
2) Barriers without staff. When blocking the road traffic, this type of barriers is equipped with flashing lights on the left of the road on both directions. Interval warning sound is given. Level crossing signals are also provided on both directions of the rail side. In case of half-length booms, they must be seen from both sides of the road. The red lights are attached at night.

Barriers currently used in Thailand include full-length boom, half-length boom, mechanical sling or rolling panel. These level crossings can be controlled by automated signals or signalling crew.

### 3.1.5 Train Tracking System

Train tracking system provide current train position for the internet users. At present various accepted and modern train tracking technologies are available including radio frequency identification (RFID), closed circuit television (CCTV), and global positioning system (GPS).

### 3.1.6 Train Control System

Each country has different train control system to achieve safe train operation. Currently communication based train control system (CBTC) is commonly used. CBTC applies wireless communication in train operation for efficient and flexible control, tracking, and management. Hardware and software are uniquely designed in detail for each region such as European Train Control System (ETCS), Chinese Train Control System (CTCS), East Japan Train Control system (EJTC) and Indonesian Train Control System (ITCS).

### 3.1.7 Centralized Traffic Control

Centralized traffic control is a signalling and communication form that includes route decision by the train control staff or drivers. It consists of centralized control room, block assignment, and train traffic management in its control section. One of the outstanding points of CTC is the graphic display of the train track section on the controller board. The train control staff can monitor the trains passing into the area. Large train networks can use multiple CTC room, each of which only control its own responsible area. These CTC rooms are normally located near a station or transport hub. The performance of CTC can be benchmarked with the air traffic control room.

### 3.1.8 Frequency

A crucial point in train operation is the ability to control the train to run precisely and safely by relying high frequency electronic devices working together. Some devices depends on signal transmission or communication frequency such as ETCS GSM-R and SCADA. These devices continually receive and transmit electromagnetic signals at different frequencies through atmosphere or cable media. Caution should be made to avoid interference among devices in the same vicinity or from external sources. This is to ensure electromagnetic compatibility of these devices in the electric train environment.

### 3.1.9 Automatic Train Protection System

Automatic train protection system control train speed under designated limit which is set in relation to the distance to the train ahead. In an unusual circumstance, ATP will actuate automatic train braking. ATP also control train movement from the station. If the doors and platform screen doors are not completely closed, ATP will not allow the train to leave the station. ATP is different from ATO on degree of freedom. When the system breaks down, ATO manual control is needed while ATP can continue its control function over the train.

## 3.2 Signalling Technology Selection

### 3.2.1 Axle Counter and Track Circuit

Axle counter and track circuit are train detection devices. It transmit track occupation signal to the interlocking system to prevent another train from entering the occupied block. It manages trains to run on the same route safely and efficiently. Track circuit uses a short circuit between two electrified rails to detect the train, while axle counter uses electromagnetic principle to detect train wheels entering a section. Table 4 shows the comparison between axle counter and track circuit.

**Table 4 Characteristics of Axle Counter and Track Circuit**

| Item | Axle Counter | Track Circuit |
|---|---|---|
| Detection | Occupation, direction, speed, and axles | Occupation |
| Detection principle | Electromagnetic detection | Short circuit between two rails |
| Impact to traction power | None | Needs measurement system and electrical protection circuit. |
| Block distance | No limit | Up to 3.6 km (approx..) |
| Check for rail break | No | Yes |
| Reset | Must be reset when an error occurs (Can be set from a remote control). | No need. |
| Check for point machine and crossing | Yes | Yes (with special circuit design for point machine) |
| Train detection capability | High speed (can detect trains with speed higher than 400 kph) | Medium speed (not exceeding 250 kph) New Chinese device can detect |

| Item | Axle Counter | Track Circuit |
|---|---|---|
| | | speed higher than 250 kph with special technique. |
| Impact from environment | None (except electromagnetic field) | Yes (non-conductivity due to stain on rail and terminal) |
| Installation | Simple | Complex. Needs cuts and drills. |
| Maintenance | Low | High. Needs periodic maintenance. |
| Impact from maintenance | Low. Sensors can be easily removed and replaced. | High. Wiring is needed. |
| Usage (train passing) | Need train passing at least every two years. | Needs frequent train passing to remove rail stains. |
| Total installation cost * | Low | High |
| Maintenance cost | Low | High due to the system components such as wires, joints, and fish plates. |
| Electromagnetic compatibility | International standard applied. | International standard applied. |
| Safety standard | SIL4, RAMs | SIL4, RAMs |
| Protection level | IPXX (equivalent) | IPXX (equivalent) |

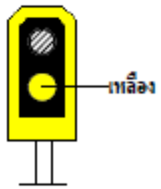
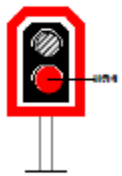
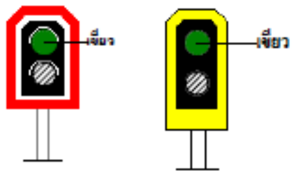
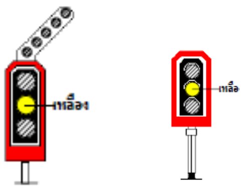
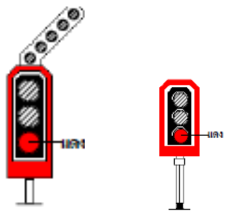
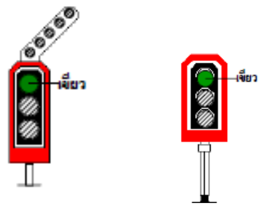
From a study of maintenance cost comparison on blocks shorter than 4 kilometers by State Railway of Thailand

Source: Consultant

### 3.2.2 Color Light Signals: Thailand vs Australia

Color light signals in Thailand and Australia are designated differently. Both countries use 2- and 3-aspect signals, but adopt different designations and arrangements.as shown in Table 5.

**Table 5 Comparison between 2- and 3- Aspect Signals in Thailand and Australia**

| Thailand | | | Australia | | |
|---|---|---|---|---|---|
| 2-aspect color light wayside signals | | | 2-aspect color light wayside signals | | |
| Caution | Prohibit | Permit | Caution | Prohibit | Permit |
|  |  |  |  |  |  |
| 3-aspect color light wayside signals | | | 3-aspect color light wayside signals | | |
| Caution | Prohibit | Permit | Caution | Prohibit | Permit |
|  inside outside |  inside outside |  inside outside |  |  |  |

Source: Consultant

### 3.2.3 ETCS/CTCS/ITCS/ EJTC Comparison

Train operation control systems in many countries are similar but with different hardware and software design. The control is classified by technology as shown in Table 6

**Table 6 Train Operation Control Systems**

| European Train Control System (ETCS) | Chinese Train Control System (CTCS) | Indonesian Train Control System (ITCS) | East Japan Train Control System (EJTC) |
|---|---|---|---|
| Level-0 | Level-0 | Level-0 | Level-0 |
| Level-1 | Level-1 | Level-1 | Level-1 |
| - | Level-2 | | Level-2 |
| Level-2 | Level-3 | Level-2 | - |
| Level-3 | Level-4 | Level-3 | Level-3 |

Source: Consultant

### 3.2.4 Interlocking Comparison

Interlocking system checks devices in other systems related to preparing train to enter or leave the station to cooperate with one another and ensure safety. The interlocking systems can be divided into three types: relay interlocking (RI), computer-based interlocking (CBI), and electronic interlocking (EI). Table 7 shows comparison among the three types.

Table 7 Interlocking System Comparison

| Item | Relay interlocking (RL) | Computer-based interlocking (CBI) | Electronic interlocking (EI) |
|---|---|---|---|
| Human machine interface (HMI) | Display panel with signal light display | Computer display Layer1: HMI | Technician's terminal<br>Key board Printer Datalogger |
| Logic layer | Relay | PLC (Microcomputer)<br>- Level2: Central safety controlling system<br>- Level3: Safety subsystem<br>● ELC – Electronic Level Crossing System<br>● ELC - Electronic Level Crossing EAC- Electronic Axle Counter<br>● Electronic Interface<br>● Wiring of DIO modules<br>● ELC – Electronic Level Crossing System<br>● EAC – Electronic Axle Counter System<br>● Electronic Interfaces | Microprocessor<br>- Panel processor module<br>- Interlocking processor<br>- Diagnostic multi -processor module<br>Data link module |
| I/O Layer | Relay | Object Module<br>- Level4: Interface module<br>Key functions<br>● SM - signal module<br>● PM - points module<br>● DIM - digital input module<br>● DOM - digital output module<br>Other functions<br>● EFL – Electronic Flasher<br>● ECD – Electronic Current Detector | I/O card<br>- Signal trackside module<br>- Point module<br>Datalink module |

| Item | Relay interlocking (RL) | Computer-based interlocking (CBI) | Electronic interlocking (EI) |
|---|---|---|---|
| | | • RM – Relay Interface<br>• IP – Indication panel<br>• GSM – SMS diagnostic<br>• LPM – Lighting Protection<br>• TERM – Electronic Thermostat<br>• ETIM – Electronic Timer<br>• EODT – Electronic Off-Delay Timer | |
| Software | No | PLC software | Embedded software |
| Speed | Low | High | Moderate |
| System Expansion | Unlimited relay increase. | Add computer and software. | - Add processor module<br>- Add software<br>(Some hardware limitations) |
| Equipment Size | Large | Small | Moderate |
| Energy Consumption | High | Low | Moderate |
| Safety Standard | SIL4 | SIL4 | SIL4, RAMs |
| Maintenance | Moderate | Low<br>Mean Active Corrective Maintenance Time (MACMT)<br>- Building devices < 40<br>- Track devices < 30 | Low |
| Electromagnetic compatibility | International standard applied | International standard applied | International standard applied |

Source: Consultant

### 3.2.5 Electro – Mechanical และ Electro – Hydraulic Point Machines

Point Machine, also known as switch machine or switch motor, is installed on the track to divert the train from the original route when needed. The point machine is controlled by a lever, rods and pulleys, or or electric motor to direct the trin to the desired direction. Common types of point machine are Electro – Mechanical: AC Electro – Mechanical :DC, and Electro – Hydraulic. Table 8 compares characteristics of the three types of pint machine.

**Table 8 DC, AC and Hydraulic Point Machine Comparison**

| Function | Electro – Mechanical | | Electro – Hydraulic |
|---|---|---|---|
| | AC | DC | |
| Power source | Alternating current | Direct current | Hydraulic |
| Voltage | Medium – high<br>110V, 220 V, 380 V | Low – high<br>24-700V | Low – medium<br>Depending on type of motor |
| Electric current | Medium | High | Low |
| Power transmission | Reducer gear or rack | Reducer gear or rack | Hydraulic piston |
| Blade rod | Steel rod (equivalent) | Steel rod (equivalent) | Steel rod (equivalent) |
| Blade drive force | 2,000-6,000 N | 2,000-6,000 N | 6,000-17,000 N |
| Blade drive time | 5-8 seconds | 5-8 seconds | 4-10 seconds |
| Blade lock | Lock mechanism (equivalent) | Lock mechanism (equivalent) | Lock mechanism (equivalent) |
| Position detection | Blade detection rod | Blade detection rod | Blade detection rod |
| Manual control | Yes | Yes | Yes |
| Switch signal when manual controlled | Yes | Yes | Yes |
| Protection level | IP (Equivalent) | IP (Equivalent) | IP (Equivalent) |
| Safety level | SIL 1-4 | SIL 1-4 | SIL 1-4 |
| Electrical safety | Low (Traction power is directly fed to the point machine.) | Low (Traction power is directly fed to the point machine.)) | High (Pressure unit can be separated outside) |

| Function | Electro – Mechanical | | Electro – Hydraulic |
|---|---|---|---|
| | AC | DC | |
| Signal control and transmission | Contact switch | Contact switch | Contact switch |
| MTBF | >500,000 hours (Siemen S700K) | >500,000 hours | > 30 year |
| MTTR | 20 minutes | 20 minutes | 35-40 minutes |

Source: Consultant

#### 3.2.6 Frequency

Communication technology selection for wireless signalling system (ETCS Level 2) for Thailand must consider interoperability of the control system used in Thailand and neighboring countries. The focus must be put on communication between the two systems when trains are running across the border.

### 3.3 Standards, Laws and Orders on Signalling System

Signaling system analysis and comparison should focus on two main issues: train control system and signalling standard. Advanced train control systems used in other countries including European Union (ETCS), China (CTCS), Indonesia (ITCS), and Japan (EJCS) are summarized in Table 9

**Table 9 ETCS/CTCS/ITCS/EJTCS Characteristics**

| ETCS | EJTCS | CTCS | ITCS | Signalling | Communication | Train Detection | Automatic Train Protection |
|---|---|---|---|---|---|---|---|
| Level-0 | Level-0 | Level-0 | Level-0 | Track side signal | - | Track circuit/ axle counter | Intermittent ATP |
| Level-1 | Level-1 | Level-1 | Level-1 | | Balises | | |
| - | Level-2 | Level-2 | - | Cab signal | Encrypted track circuit | | Continuous ATP |
| Level-2 | - | Level-3 | Level-2 | | frequency | | |
| Level-3 | Level-3 | Level-4 | Level-3 | | | Frequency and balises | |

Source: Consultant

Although signalling systems are different by country, their structures are similar, for example, ETCS-2 used in the European Union and the United Kingdom, TVM 430 in France, CTCS-3 in China, ATC (digital) in Japan, ITCS-2 used in Indonesia and ATC (digital) in Singapore.

Standards regulating train signalling equipment can be classified into three groups as follows:

1. Train Signalling Equipment Standards for regulating mechanical and electrical functions and specific properties of the equipment. The standards in most countries will be similar in terms of characteristics and basic information. Then specific parameters are applied to suit geographical and environmental conditions. Examples are

    1.1. Thai industrial standards (TIS)

    1.2. European Union industrial standards including EN, IEC, CENELEC, DN, CE, etc.

    1.3. Japan industrial standards (JIS)

    1.4. Association of American Railroad (AAR) standards

    1.5. China's Guobiao standard (GB)

2. Signalling System Standards developed by UNISIG, a consortium of signalling manufacturers. The standards designated central agreement that covers all components of signalling system under UNISIG SUBSET-XXX.

3. International safety standards including EN50126-RAMs , SIL(1-4)-Safety standard, and EN61131-Programable control.

### 3.4 Draft Standards, Ministerial Laws, Orders, Regulations and Suggestions on Signalling System

Nine signalling standards are drafted according to the key train signalling components. Each standard consists of 8 topics as follows:

a) Installation
b) Equipment
c) Functions
d) General Specification
e) Safety
f) Operation and Maintenance
g) Testing and Commissioning
h) Interoperability

These 9 standards, as shown in Figure 10, cover all key signalling components including central traffic control system, wayside signalling, interlocking system, point machine, axle counter, track circuit, level crossing barrier, and automatic train protection system. These components receive commands from train timetable, assign routes to trains and ensure safe operations. They consider the interaction with its surrounding components within signalling and other systems that require data exchange to manage mainline train movements.

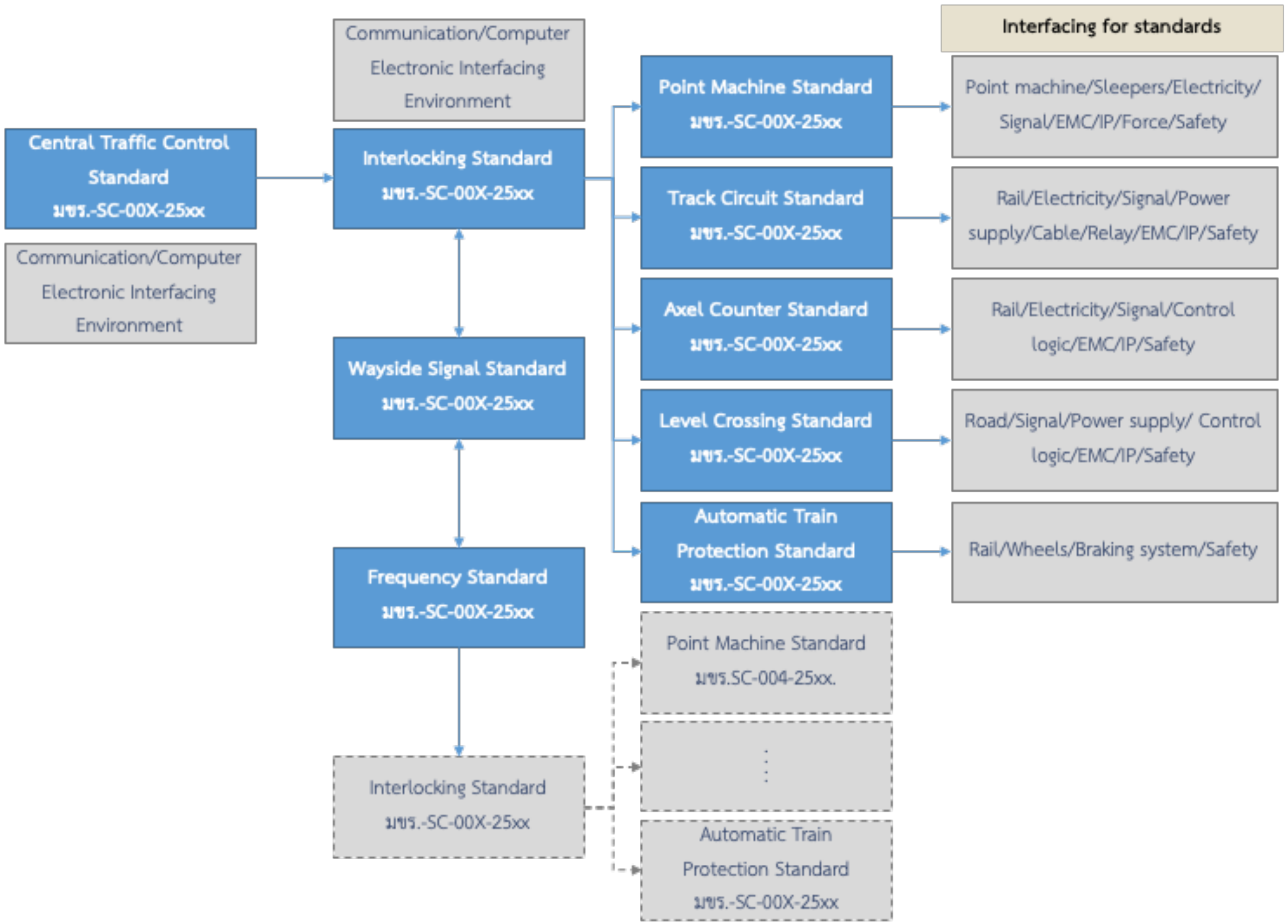



**Table 10 Relationship among Signalling System Standards for Mainline Railway Network**

# Chapter 4

# Electrification and Signalling Development Plan on Mainline System

## 4.1 National Policies and Strategies on Rail Development

Railway development program must consider related policies, strategies and development plan as follows:

### 4.1.1 20-Year National Strategy

The second national strategy, build competitiveness; Issue 4, infrastructure connects Thailand to the world; Sub-issue 1, connect transport network seamlessly, specifies regional transport network connection from East Asia to South Asia seamlessly so as to develop Asian Economic Corridor. Land, water and air transport networks must be developed, while water and rail transports are given more priority.

The sixth national strategy, keep balance and improve government administration system; Issue 3, downsize government units to suit mission and promote public participation in national development; Sub-issue 1 suitable size of government unit, specifies arranging government organizations that splits regulating and service providing agencies to ensure operation efficiency and fair competition.

### 4.1.2 12$^{th}$ National Economic and Social Development Plan (2017-2021)

Strategy 7 infrastructure and logistics system development gives priority to transport and logistics system improvement by promoting rail as the national main transport network and accommodate connection with other modes. The development goal is set with a corresponding indicator which is to improve domestic freight rail transport share to 4%.

#### 4.1.3 Thailand 20-year Transport Development Strategy (2018-2027)

The strategy plan designates intercity passenger and freight rail development. This includes both meter (1.000 m) and standard (1.435 m) gauge tracks. The goal is set to increase rail mode share and promote the energy-saving and environmental-friendly transport systems.

#### 4.1.4 Ministry of Transport Strategic Plan (2017-2021)

Strategy 2 "safety and security" addresses regulations on rail transport to accommodate international and border freight transportation. This also includes establishing safety and security standards and regulatory measures, but does not mention specifically about electrification and signalling system improvement.

#### 4.1.5 National Railway Master Plan

Meter gauge railway development plan consists of double track and new line projects. The objectives are to increase line capacity and enhance coverage area nationwide. The master plan aim to increase train speed and safety by reducing train passing. Effective train operation and punctuation will attract freight forwarders to shift mode to rail, resulting in reducing energy consumption and transport expenses for the country.

#### 4.1.6 State Railway of Thailand (SRT) Enterprise Plan (2017-2021)

Under 2021 Action Plan, Strategy 1 and Tactic 1.1 "Develop Regional Network" consists of 12 double track projects on existing lines and 2 new line construction projects. In addition, the resolution by the Board of State Enterprise Policy, issue 2/2561, dated 30 May 2018, assigns SRT to use a common signalling system in the red line commuter projects so that electric trains can share tracks with current intercity trains.

### 4.2 Projects Related to Electrification and Signalling System Development

#### 4.2.1 Feasibility Study of Railway Electrification on Four Double Track Routes

SRT commissions a feasibility study of Railway Electrification on four double track routes which include

- Northern Line: Bang Sue Junction – Ban Phachi Junction – Pak Nam Pho
- Northeastern Line: Ban Phachi Junction – Kaen Khoi Junction – Thanon Chira Junction

- Southern Line: Bang Sue Junction – Nong Pla Duk Junction – Hua Hin Junction
- Eastern Line: Bang Sue Junction – Makkasan – Chachoengsao - Pattaya

The feasibility study of railway electrification aims for efficiency enhancement of public transportation and increase in ridership. The trains are expected to increase speed up to 120-160 kilometers per hour.

#### 4.2.2 Hat Yai – Padang Besar Electrified Double Track Feasibility Study and Design Project.

A feasibility study and design project for electrified double track connecting Hat Yai (Thailand) and Padang Besar (Malaysia) is conducted on a 48-kilometer section. The system is designed to be fed by the overhead catenary system (OCS) using 25 kV 50 Hz AC to connect with Malaysian railway. It accommodates speeds up to 160 km/hr with feeder stations near Khlong Ngae Station, located 25 km from Hat Yai.

It is forecasted to serve 4,732 passengers per day and freight 3,500 tons per day. The project plans to run 20 trains per day in 2021 (opening year) and gradually increase the frequency through out the years. The economic internal rate of return is 18.78% which is better than diesel option. The government will invest all infrastructure, electrification, signalling, and communication systems. SRT will invest in rolling stocks and undertake operation and maintenance responsibility for project lifetime.

#### 4.2.3 Mainline Double Track Project Progress

The progress of dounble track project for mainline which is in line with the railway master plan and State Railway of Thailand's business plan, including signalling system installation projects are shown in Table 11

**Table 11 Double Track Project Progress (as of April 2020)**

| Project | Contract | Distance (km) | Contract start - end |
|---|---|---|---|
| Chachoengsao – Khlong Sip Kao – Kaeng Khoi | 1st Contract | 97 | 19 Feb 16 – 18 Feb 19 |
| | 2nd Contract | 9 | 19 Feb 16 – 18 Mar 18 |
| Thanon Chira Jct. – Khon Kaen | | 187 | 19 Feb 16 – 18 Feb 19 |
| Lop Buri – Pak Nam Pho | Ban Klap – Khok Krathiam | 32 | May 18 – Apr 22 |
| | Tha Khae – Pak Nam Pho | 116 | 1 Feb 18 – 31 Jan 21 |
| Map Kabao – Thanon Chira Jct. | Map Kabao – Khlong Khanan Chit | 58 | 1 Feb 18 – 31 Jan 21 |
| | Khlong Khana Chit – Thanon Chira Jct. | 69 | Jun 19 – May 22 |
| | Railway Tunnel | 5 | Apr 18 – Mar 22 |
| Nakhon Pathom – Hua Hin | Nakhon Pathom – Nong Pla Lai | 93 | 1 Feb 18 – 31 Jan 21 |
| | Nong Pla Lai – Hua Hin | 76 | 1 Feb 18 – 31 Jan 21 |

| Project | Contract | Distance (km) | Contract start - end |
|---|---|---|---|
| Hua Hin – Prachuap Khirikhan | | | 1 Feb 18 – 31 Jul 20 |
| Prachuap Khirikhan – Chumphon | Prachuap Khirikhan – Bang Saphan Noi | 84 | 1 Feb 18 – 31 Jan 21 |
| | Bang Saphan Noi – Chumphon | 88 | 1 Feb 18 – 31 Jan 21 |
| Lop Buri – Pak Nam Pho | Signalling System | - | - |
| Map Kabao – Thanon Chira Jct. | Signalling System | - | - |
| Nakhon Pathom - Chumphon | Signalling System | - | - |

Source: State Railway of Thailand, 2020

### 4.3 Electrification System Development Plan for Thailand's Mainline Network

#### 4.3.1 Electrification System Cost Analysis

Investment cost for electrification system may be analyzed from a concept of life cycle cost (LCC). The life cycle costs can be divided into three parts: construction and installation, operation, and maintenance.

4.3.1.1. Construction and installation cost

Construction and installation cost is evaluated from an Italian railway study by Gattusoa, D. and Restuccia, A. (2014). The study estimates the cost of the electrification system including substations and supplementary equipment within a range of €1.0-1.2 million per kilometer. Adding factors including 2.5% inflation rate, minimum wages ratio between Thailand and Italy, and proportion of wages to total costs, the construction and installation cost for electrification system in Thailand is estimated at THB 43 million per kilometer.

4.3.1.2. Operation cost

Operation cost consists of power (electricity), personnel, and travel. The cost calculation involves estimation of electricity needed to run the train, number and wages of personnel needed to control the electrification system, and travel costs for these personnel in form of welfare. The total amount of each item is escalated to future value using corresponding inflation rate.

4.3.1.3. Maintenance cost

Maintenance cost is calculated based on the following assumptions:

1) Routine maintenance is performed every year with a cost of 0.5% of the construction and installation cost;

2) Periodic maintenance is performed every 7 years with a cost of 2.0% of the construction and installation cost;

3) Replacement. Lifetime of all equipment is 30 years. Replacement is required after that period. However, this maintenance cost component is disregarded as the life cycle is longer than the analysis period.

The 2.5% inflation rate is applied based on a report on Thailand's weighted average consumer price index, basic CPI section in 2016-2019.

The electrification cost for all 26 projects on Thailand's mainline network is THB 187,606,248,000. The operation cost during the next 20 years is THB 29,080,789,455 and the maintenance cost throughout the next 20 years is THB 36,288,432,140. These are 2021 values for a total distance of 4,363 kilometers.

**4.3.2 Electrification System Development Program for Thailand's Mainline Network**

Electrification system development should start from the central section and expand to the regional network so that train operation is seamless and convenient to manage locomotive and rolling stocks. The operation will be effective and line capacity will be maximized. Table 12 shows electrification system construction and installation plan.

**4.3.3 Electrification System Development Action Plan for Thailand's Mainline Network**

Projects will be prioritized and associate with the corresponding action plan. This will be the tool to set up budget for each project and connect action plan to the strategic plan of the Ministry of Transport as shown in Table 13

**Table 12 Construction and Installation of Electrification Projects on Thailand's Mainline Network**

| No | Project | Year | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 | 2032 | 2033 | 2034 | 2035 | 2036 | 2037 | 2038 | 2039 | 2040 | 2041 | 2042 |
| 1 | Bang Sue Jct - Rangsit | | | | | | | | | | | | | | | | | | | | | |
| 2 | Bang Sue Jct - Taling Chun Jct | | | | | | | | | | | | | | | | | | | | | |
| 3 | Rangsit - Ban Phachi - Pak Nam Pho | | | | | | | | | | | | | | | | | | | | | |
| 4 | Rangsit - Ban Phachi - Thanon Chira Jct | | | | | | | | | | | | | | | | | | | | | |
| 5 | Taling Chun Jct - Nong Pla Duk Jct - Hua Hin | | | | | | | | | | | | | | | | | | | | | |
| 6 | Bang Sue Jct - Makkasan – Chachoengsao Jct - Pattaya (inc. Sriracha Jct – Laem Chabang) | | | | | | | | | | | | | | | | | | | | | |
| 7 | Chachoengsao Jct - Khlong Sip Kao Jct - Kaeng Khoi Jct | | | | | | | | | | | | | | | | | | | | | |
| 8 | Pak Nam Pho - Phitsanulok | | | | | | | | | | | | | | | | | | | | | |
| 9 | Thanon Chira Jct - Khon Kaen | | | | | | | | | | | | | | | | | | | | | |
| 10 | Hua Hin - Chumphon | | | | | | | | | | | | | | | | | | | | | |
| 11 | Pattaya – Map Ta Phut (inc. Khao Chi Jan Jct – Ban Phlu Ta Luang) | | | | | | | | | | | | | | | | | | | | | |
| 12 | Phitsanulok - Den Chai (inc. Bang Dara Jct - Sawankhalok) | | | | | | | | | | | | | | | | | | | | | |
| 13 | Den Chai - Chiang Mai | | | | | | | | | | | | | | | | | | | | | |

| No | Project | Year | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 | 2032 | 2033 | 2034 | 2035 | 2036 | 2037 | 2038 | 2039 | 2040 | 2041 | 2042 |
| 14 | Khon Kaen – Nong Khai | | | | | | | | | | | | | | | | | | | | | |
| 15 | Thanon Chira Jct – Ubon Ratchathani | | | | | | | | | | | | | | | | | | | | | |
| 16 | Chumphon - Surat Thaini (inc. Ban Thung Pho – Khirirat Nikhom) | | | | | | | | | | | | | | | | | | | | | |
| 17 | Surat Thaini - Hat Yai Jct - Songkhla (inc. Thung Song Jct – Kantang and Khao Chum Thong Jct – Nakhon Si Thammarat) | | | | | | | | | | | | | | | | | | | | | |
| 18 | Den Chai – Chiang Rai – Chiang Khong | | | | | | | | | | | | | | | | | | | | | |
| 19 | Ban Phai - Mukdahan – Nakhon Phanom | | | | | | | | | | | | | | | | | | | | | |
| 20 | Hat Yai Jct – Padang Besar | | | | | | | | | | | | | | | | | | | | | |
| 21 | Hat Yai Jct – Su-gnai Kolok | | | | | | | | | | | | | | | | | | | | | |
| 22 | Khlong Sip Kao Jct - Aranyaprathet (inc. Bang Khlong Luek Border Pass) | | | | | | | | | | | | | | | | | | | | | |
| 23 | Nong Pla Duk Jct – Suphan Buri | | | | | | | | | | | | | | | | | | | | | |
| 24 | Nong Pla Duk Jct - Kanchanaburi – Nam Tok | | | | | | | | | | | | | | | | | | | | | |
| 25 | Wongwian Yai - Mahachai | | | | | | | | | | | | | | | | | | | | | |
| 26 | Ban Laem – Mae Klong | | | | | | | | | | | | | | | | | | | | | |

**Table 13 Electrification System Action Plan**

| Topic | | | | Responsible Person | Month | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
| 1 | Engineering | | | | | | | | | | | | | | | | | | | | | |
| | 1.1 | Route and Building Survey | | | | | | | | | | | | | | | | | | | | |
| | | 1.1.1 | Route and building survey | Electrical Engineer | ■ | ■ | ■ | | | | | | | | | | | | | | | |
| | | 1.1.2 | Operation risk evaluation | Electrical Engineer | | | | ■ | | | | | | | | | | | | | | |
| | 1.2 | Coordination with Relevant Agencies | | | | | | | | | | | | | | | | | | | | |
| | | 1.2.1 | Summary of structure modification | Electrical Engineer | | | | ■ | | | | | | | | | | | | | | |
| | 1.3 | Installation | | | | | | | | | | | | | | | | | | | | |
| | | 1.3.1 | Electrification system installation | Electrical Engineer | | | | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | |
| 2 | Workforce and Expertise | | | | | | | | | | | | | | | | | | | | | |
| | 2.1 | Workforce Enhancement | | | | | | | | | | | | | | | | | | | | |
| | | 2.1.1 | Emergency expert recruitment | Human Resource | ■ | | | | | | | | | | | | | | | | | |
| | | 2.1.2 | Human resource development by agency | Human Resource | ■ | ■ | ■ | | | | | | | | | | | | | | | |
| | 2.2 | Expertise Development | | | | | | | | | | | | | | | | | | | | |
| | | 2.2.1 | Power distribution system training | Expert | | | | ■ | | | | | | | | | | | | | | |
| | | 2.2.2 | Review and design | Expert | | | | | ■ | | | | | | | | | | | | | |
| | | 2.2.3 | Bulk substation | Expert | | | | | ■ | | | | | | | | | | | | | |
| | | 2.2.4 | High voltage equipment | Expert | | | | | ■ | | | | | | | | | | | | | |
| | | 2.2.5 | Medium voltage equipment | Expert | | | | | ■ | | | | | | | | | | | | | |
| | | 2.2.6 | Traction equipment | Expert | | | | | ■ | | | | | | | | | | | | | |
| | | 2.2.7 | Low voltage equipment | Expert | | | | | ■ | | | | | | | | | | | | | |
| | | 2.2.8 | SCADA | Expert | | | | | | ■ | | | | | | | | | | | | |
| | | 2.2.9 | Earthing and bonding | Expert | | | | | | ■ | | | | | | | | | | | | |
| | | 2.2.10 | Environmental and safety in workplace | Expert | | | | | | | ■ | | | | | | | | | | | |
| | | 2.2.11 | Learning from on-site installation | Electrical Engineer | | | | | | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | |
| 3 | Knowledge Transfer to Community | | | | | | | | | | | | | | | | | | | | | |
| | 3.1 | Coordination with Local Agencies | | | | | | | | | | | | | | | | | | | | |
| | | 3.1.1 | Community street risk assessment | Electrical Engineer | | | | | | | | ■ | ■ | ■ | ■ | | | | | | | |
| | | 3.1.2 | Risk assessment for building near railway track | Electrical Engineer | | | | | | | | ■ | ■ | ■ | ■ | | | | | | | |
| | 3.2 | Public Knowledge Transfer in Cooperation with Local Agency | | | | | | | | | | | | | | | | | | | | |
| | | 3.2.1 | Electrification train safety and hazard | Electrical Engineer | | | | | | | | | ■ | ■ | ■ | ■ | | | | | | |
| | | 3.2.2 | Warning signs | Electrical Engineer | | | | | | | | | ■ | ■ | ■ | ■ | | | | | | |
| | 3.3 | On-site Risk Investigation | | | | | | | | | | | | | | | | | | | | |
| | | 3.3.1 | Earthing and bonding installation | Electrical Engineer | | | | | | | | | | | | ■ | ■ | ■ | ■ | ■ | ■ | |
| | | 3.3.2 | Route protection | Electrical Engineer | | | | | | | | | ■ | ■ | ■ | ■ | | | | | | |

## 4.4 Signalling System Development Plan for Thailand's Mainline Network

### 4.4.1 Signalling System Cost Analysis

Similar to that of electrification system, investment cost for signalling system may be analyzed from a concept of life cycle cost (LCC). The life cycle costs can be divided into three parts: construction and installation, operation, and maintenance.

4.4.1.1. Construction and installation cost

Cost estimation of construction and installation of signaling system on the main railway line Based on the analysis of the data of the 7 double-track railway projects that have been implemented. The investment costs are divided into fixed costs per station and variable costs per kilometer. The cost of construction and installation of the signaling system will be assessed using linear regression analysis techniques as follows

$$y = 10,541,025x_1 + 367,210,627x_2 + 14,178,207x_3 + 247,086,902$$

โดยที่ $y$ = Construction and installation of signalling systems

$x_1$ = Distance (kilometers)

$x_2$ = Junction Station (Location)

$x_3$ = Station (Location)

4.4.1.2. Operation cost

Operation cost is evaluated based on the components of signalling operation which consists of power, personnel, and travel. The cost calculation involves estimation of electricity needed to operate signalling system, number and wages of personnel needed to control the signalling system, and travel costs for these personnel in form of welfare. The total amount of each item is escalated to future value using corresponding inflation rate.

4.4.1.3. Maintenance cost

Maintenance cost is calculated based on the following assumptions:

1) Routine maintenance is performed every year with a cost of 0.5% of the construction and installation cost;

2) Periodic maintenance is performed every 7 years with a cost of 2.0% of the construction and installation cost;

3) Replacement. Lifetime of all equipment is 30 years. Replacement is required after that period. However, this maintenance cost component is disregarded as the life cycle is longer than the analysis period.

The 2.5% inflation rate is applied based on a report on Thailand's weighted average consumer price index, basic CPI section in 2016-2019.

### 4.4.2 Signalling System Development Program for Thailand's Mainline Network

Signalling System Development Program for Thailand's Mainline Network shall be implemented in line with the double track program so that the budget is spent cost-effectively and so as to achieve highest operation effectiveness and safety. Meanwhile operation and maintenance staff can also be trained seamlessly. Construction and installation will occur approximately two years after civil works. Signalling installation for a double track project will take 3-4 years depending on environment condition of the project. Construction and Installation program is shown in Table 14.

**Table 14 Construction and Installation of Signalling Projects on Thailand's Mainline Network**

| No. | Doubletrack Project | Year | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 | 2032 | 2033 | 2034 |
| 1 | Chachoengsao - Khlong Sip Kao - Kaeng Khoi | | | | | | | | | | | | | | | | | | |
| 2 | Thanon Chira Jct – Khon Kaen | | | | | | | | | | | | | | | | | | |
| 3 | Map Kabao – Thanon Chira Jct | | | | | | | | | | | | | | | | | | |
| 4 | Lop Buri - Pak Nam Pho | | | | | | | | | | | | | | | | | | |
| 5 | Nakhon Pathom - Chumphon | | | | | | | | | | | | | | | | | | |
| 6 | Denchai – Chiang Rai – Chiang Khong | | | | | | | | | | | | | | | | | | |
| 7 | Ban Phai - Mukdahan – Nakhon Phanom | | | | | | | | | | | | | | | | | | |
| 8 | Khon Kaen – Nong Khai | | | | | | | | | | | | | | | | | | |
| 9 | Thanon Chira Jct – Unbon Ratchathani | | | | | | | | | | | | | | | | | | |
| 10 | Pak Nam Pho - Denchai | | | | | | | | | | | | | | | | | | |
| 11 | Denchai – Chiang Mai | | | | | | | | | | | | | | | | | | |
| 12 | Chumphon - Surat Thani | | | | | | | | | | | | | | | | | | |
| 13 | Surat Thani - Hat Yai Jct - Songkhla | | | | | | | | | | | | | | | | | | |
| 14 | Hat Yai Jct – Padang Besar | | | | | | | | | | | | | | | | | | |

Remark : Orange bars refer to sections where signalling system has been installed;

Blue bars refer to section under installation;

Yellow bars refer to sections under land acquisition process; and

Red bars refer to sections pending for approval.

### 4.4.3 Signalling System Development Action Plan for Thailand's Mainline Network

Action plan for ETCS-1 signalling installation and operation for Thailand's mainline network is shown in Table 15.

**Table 15 Signalling System Development Action Plan for Thailand's Mainline Network**

| Activity | Responsible Party/Agency | Implementation Period | Budget | Remarks |
|---|---|---|---|---|
| 1. System design<br>- Survey and identify locations<br>- Signaling system design<br>- Train signaling system design | <br>Contractor / Project owner<br>Contractor / Project owner / DRT<br>Contractor / Project owner / DRT | 12 months | 300 million (10% of project cost) | - Follows train operation conditions.<br>- Follows train operation control standard. |
| 2. Infrastructure<br>- demolition and temporary equipment installation<br>- Signalling equipment room<br>- Signalling equipment board<br>- Connection with other systems | <br>Signalling Contractor<br>Civil Contractor<br>Civil Contractor<br>Signaling Contractor / Project owner | 12 months | 300 million (20% of project cost) | - Old system must be able to allow normal train operation throughout service period.<br>- Signalling system must connect to other existing systems effectively. |
| 3. Signalling system installation<br>- Preparation<br>- Tools<br>- Point machine<br>- Track circuit<br>- Axle counter<br>- CBI<br>- Wayside equipment<br>- Level crossing barriers<br>- Central traffic controller (CTC) | Signaling Contractor / Project owner / DRT | 24 months (up to quantity of work and route length) | - 63% of project cost<br>- Budget is up to devices varying upon train route length. | - Follows manufacturer's specifications.<br>- Follows signalling standards.<br>- Follows other relevant standards. |

| Activity | Responsible Party/Agency | Implementation Period | Budget | Remarks |
|---|---|---|---|---|
| - Local operator workstation<br>- Signalling and communication system<br>- Automatic train protection (ATP)<br>- Wiring for signalling system<br>- Axle counter and interlocking<br>- Power supply<br>- Power reserve | | | | |
| 4. System testing<br>- Subsystem testing<br>- Communication system testing<br>- System integration testing | Signalling Contractor / Project owner / DRT | 6 months | 150 million (5% of project cost) | - Follows manufacturer's specifications.<br>- Signalling standards.<br>- Comminication and other relevant standards. |
| 5. Training<br>- Signalling control staff<br>- Maintenance works | Project owner and/or operator<br>Operator / maintenance div. | 6 months | 60 million (2% of project cost) | - Specify competency of the trainees.<br>- Specify on-site and/or on-the-job training for key positions.<br>- Testing and evaluation of training program. |

#### 4.5 Diesel-to-Electrification Transfer Measures

Measures for transferring from diesel engine to electrification are set to enhance benefits and safety to users. Economic rates of return for the four routes are in a high range with an average of 13.84%. In addition the maximum speed will increase and pollution will be reduced by 20-30%.

### 4.5.1 Diesel-to-Electrification Transfer Measures for Service Efficiency Enhancement

**a. Geographic Measures**

- In the beginning stage, use new system or electrification system for infrastructure and traction parts in Bangkok and vicinity including main routes to the key provincial cities.
- In the later stages, convert diesel engine to electrification to enhance potential and line capacity.
- Conduct a feasibility and safety study for electrification train operation on existing lines and diesel train operation on new lines, while diesel-to-electrification transfer is not completed..

**b. Density Measures**

- Study the lines in need of urgent transfer, prioritized by passenger demand or density.

### 4.5.2 Diesel-to-Electrification Transfer Measures for Air Pollution Reduction

**a. Construction or Transfer Stage**

- Appoint a construction monitoring board with missions to inspect and monitor electrification work progress. The board will ensure that the owner agency and concessionaire reduce air pollution according to the air and noise reduction action plan, and supervise construction to be in line with prevention and reduction measures as provided in EIA report.

**b. Service Stage**

- Measure air quality and noise level at the stations. Move facilities away from the station to reduce environmental impact to passengers.
- Monitor environmental impact by experts. This includes total suspended particulate (TSP), particulate matter (PM 10), carbon monoxide (CO), and noise level at the station which may cause health impact. Inspection must be conducted around and under the station building and ticketing area.

## 4.6 Electrification and Signalling Standard Regulatory Measures

Department of Rail Transport participate in evaluation of overall performance from design and test reports by project consulting engineers. DRT may provide comments and suggestion based on standards as summarized in Table 16.

**Table 16 Tasks Performed by Department of Rail Transport during Design and Installation Period**

| Stage | Standard Regulation Role |
|---|---|
| Project specifications based on TOR | Investigate relevance of standards specified by DRT with project owner and consulting engineers. |
| Design | Evaluate overall design calculation and drawings by project consulting engineers |
| Subsystem testing before installation | Evaluate overall testing report by project consulting engineers |
| Integrated system testing | Evaluate overall testing report by project consulting engineers with independent consultant engineers (ICE) |

# Chapter 5

# Regulatory Measures for Rail Electrification and Signalling Systems

## 5.1 Related Laws and Orders

Railway laws and orders including other related regulations can be classified as follows:

### 5.1.1 Railway Laws

(1) State Railway of Thailand Act, B.E. 2494 and Amendment (7th edition), B.E. 2543

The act addresses railway committee appointment with authority to establish policy and regulate SRT undertaking. The committee can also set regulation on SRT operation and on orders and punishment for SRT employees.

(2) Railway and Highway Placement Act, B.E. 2464 Amendment, B.E. 2477

Section 15 specifies that the Railway Department is authorized to issue regulations and set tariff on signalling and train lamp as seen appropriate.

(3) Train Operation Regulations and Orders, B.E. 2549 of SRT

This act enforces train operation by SRT employees. It addresses some regulations on signalling such as wayside sign board, whistle sign board, turnout, and other signals.

(4) Mass Transit Authority of Thailand Act, B.E. 2543

Section 4 provides the following definitions:

"Energy System" refers to substation, voltage regulator station, generator, wires, rails or equipment for transmit electrical or other power to electrified train, including building and equipment of such system.

"Train Control System" refers to train control center, system, control signals and signs that are installed or provided for benefit and safety in electrified train operation, including building and equipment of such system.

"Communication System" refers to voice, image and data communication to facilitate safety for train operation and for passengers, including building and equipment of such system.

(5) Ministerial Law in Safety for Life, Body, and Properties, Cleanliness and Order in Electrified Railway System Area, B.E. 2547

This act specifies that MRTA provide floor marking, traffic signage or install traffic signal, and assign meanings and types of traffic signs according to land transport laws (Section 8).

In summary, there are only a few laws and regulations related to railway signalling system, mostly found in Train Operation Regulations and Orders, B.E. 2549. Meanwhile, railway electrification related laws do not exist.

### 5.1.2 Laws related to Other types of Transport

(1) Telecommunication Undertaking

- Telecommunication Business Act, B.E. 2544 and Amendment, B.E. 2549
- Organization to Assign Frequency Waves and to Regulate the Radio Broadcasting, Radio Television and Telecommunications Services Act, B.E. 2553 and Amendment (3rd Edition), B.E. 2562
- Radio Communication Act, B.E. 2498 and Amendment (3rd Edition), B.E. 2535
- Ministerial Laws specifying that Radio Communication and Radio Communication Station are exempted from licensing B.E. 2547

(2) Road Transport

- Land Transport Act, B.E. 2522 and Amendment (13th Edition), B.E. 2557

(3) Air Transport

- International Carriage by Air Act, B.E. 2558 and Amendment (2nd Edition), B.E. 2560

(4) Profession Institutional and Certification กฎหมายเกี่ยวกับสถาบันและการรับรองวิชาชีพ

- Royal Decree Establishing Profession Qualification Institute (Public Organization), B.E. 2554 and Amendment (2nd Edition) B.E. 2562
- Engineer Act, B.E. 2542

### 5.1.3 Legislative Drafting Related Laws and Other Laws

(1) Constitution of the Kingdom of Thailand, B.E. 2560

(2) Legislative Drafting Rules and Ex Post Evaluation of Regulation Act, B.E. 2562

(3) Official Permission Facilitation Act, B.E. 2558

(4) Royal Decree on Criteria and Approaches for Good Governance, B.E. 2546 and Amendment (2nd Edition), B.E. 2562

(5) Royal Decree on Law Suitability Review, B.E. 2558

(6) Royal Decree on Agenda Submission and Cabinet Meeting, B.E. 2548

## 5.2 Standard, Ministerial Law, Order, and Regulation Drafting Approach

### 5.2.1 Present Condition

Currently legislative study process for ministerial law, order, and regulation drafting approach is undertaken considering fundamentals of law drafting and principle of proportionality as follows:

(1) Study the principle of the subject of law drafting

(2) Study information on the subject of law drafting

(3) Establish structure of draft ministerial laws, orders, standards and regulations.

(4) Consider legislative contents, mechanism and its relationship to be included in the draft.

(5) Compare with similar laws in effect.

(6) Use simple words with good Thai Grammar

### 5.2.2 Law and Regulation Hierarchy

The result of draft ministerial rules, standards, orders, regulations and suggestions must conform and follows to the context of Draft Rail Transport Act B.E. ... These will be placed into Thailand's railway law hierarchy as seen in Figure 12.

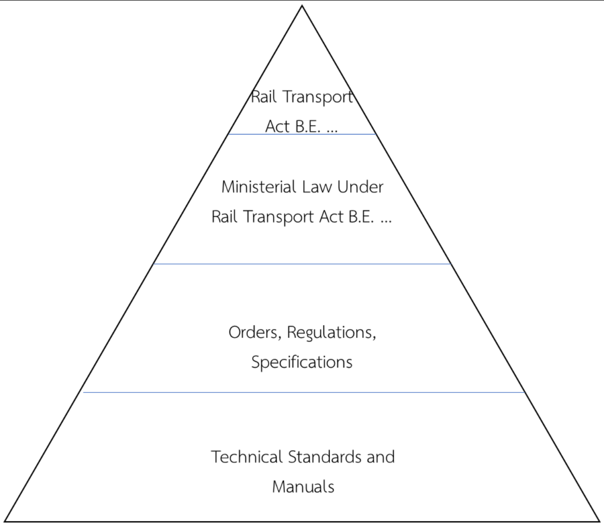



**Figure 12 Thailand's Railway Standard Framework after Announcement of Rail Transport Act[1]**

Source : Office of Transport and Traffic Policy and Planning

Thailand's law hierarchy is arranged by considering the legislative organization. Law hierarchy consists of six levels which are (1) constitution, (2) act, decree, and codes, (3) royal decree, (4) ministerial law or announcement (5) regulations or ordinance, and (6) command announcement.

[1] A study of Thailand's Railway Standard Development, Executive Summary, Office of Transport and Traffic Policy and Planning Naresuan University and Chiang Mai University, page 26, Retrieve from http://www.otp.go.th/uploads/tiny_uploads/ProjectOTP/2559/Project06/ExeSumReportThai.pdf, on 20 May 2020.

### 5.2.3 Law drafting process

Law drafting process must be conducted in line with Section 77[2] of the Constitution of the Kingdom of Thailand, B.E. 2560. Public hearing from all sectors are also considered including limitations, problem condition, demand, suggestions and other supporting measures from stakeholders. The result is brought to consideration for ministerial law, order, and regulation drafting so that they can be abided in short-, medium- and long-terms.

### 5.2.4 Regulation Options

Draft Rail Transport Act B.E. ... contains contents regarding rules on ministerial law, standards and regulations as follows:

(1) Issue a ministerial law on rail operation standard by the Minister of Transport (Section 7),

(2) Issue an announcement attached to the ministerial law by Department of Rail Transport authorized by the Director of DRT. (Section 15).

When draft Rail Transport Act B.E. ... is announced in the government gazette, DRT by the minister of transport and the Director of DRT is authorized by law to take actions in enforcing electrification and signalling standard implementation.

Based on law enforcement, regulation options should be carried out from the ministerial law on electrification and signalling standards. The main contents of the ministerial law include designation of rail operation licensees, project owners, rail-related government agency to follow electrification and signalling standards as specified by DRT.

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[2] Constitution Section 77 "The government shall provide essential laws and immediately cancel those that are unnecessary or outdated or obstruct living and working so that they are not burden to people. The government shall provide people access to, and understanding the laws so they can abide them properly.
Before issuing a law, the government shall facilitate public participation (PP) from stakeholders, analyzed impact from the law systematically from all sides, and reveal the PP result to public. The Result shall also be used in drafting the law in all stages. When the law is effective the government shall evaluate effectiveness of the law every specified period by hosting a public participation for stakeholders to improve all laws in line with revolved context.
The government shall use permission system and committee system in specific laws when necessary, set criteria for officer's judgement and process time period for each stage as specified in the law, and assign criminal punishment for serious misconducts."

### 5.3 Draft Ministerial Laws and Standard Announcement Attached to Ministerial Law

Regulations relating railway signalling on mainline network in Thailand are found in SRT's Train Operation Regulations and Orders, B.E. 2549. Regulations regarding electrification are not available at present.

Thus, ministerial laws are proposed to cover general contents. The laws will authorize DRT to release electrification and signalling standards. The standard contents shall be divided into topics so as to properly apply to practice and avoid confusion.

Two draft ministerial laws prepared including:

(1) Draft ministerial law on railway signalling system standards, and

(2) Draft ministerial law on railway electrification system standards

Both ministerial laws are included in Appendix 5-A and B respectively.

### 5.4 Electrification and Signalling System Regulation Measures

Electrification and signalling system regulation measures should consider regulating factors and processes as follows:

#### 5.4.1 Electrification and Signalling Standards

Regulating standards should follows the standards that are being developed for the Department of Rail Transport for future use. These include:

**1.** Electrification Standards

Electrification Standards consist of:

1) Electrification System Standard (มขร.-E-00X-25XX )
2) Protection and Insulation Standard (มขร.-E-00X-25XX )
3) Earthing Standard (มขร.-E-00X-25XX )
4) Transformer Arrangement Standard (มขร.-E-00X-25XX )
5) Power Quality Standard (มขร.-E-00X-25XX )
6) SCADA Standard (มขร.-E-00X-25XX )

**2.** Signalling Standards

Signalling Standards consist of:

1) Centralized Traffic Control Standard (มขร.-SC-00X-25XX )
2) Interlocking Standard (มขร.-SC-00X-25XX )
3) Token Signaling Standard (มขร.-SC-00X-25XX)
4) Point Machine Standard (มขร.-SC-00X-25XX)
5) Track Circuit Standard (มขร.-SC-00X-25XX)
6) Axel Counter Standard (มขร.-SC-00X-25XX)
7) Level Crossing Standard (มขร.-SC-00X-25XX)
8) Automatic Train Protection System Standard (มขร.-SC-00X-25XX)
9) Frequency Standard (มขร.-SC-00X-25XX)

If any operation cannot be regulated directly by applicable standard, international standard should be applied such as EN, IEC, and CENELEC.

### 5.4.2 Regulation Cycle

Regulation cycle should start from a project feasibility study stage. After that conditions applied to components must be considered at every stage. Design must be modified to the effective standards. Then system testing, commissioning, test operation and project management must all conform to the specified standards.

### 5.4.3 Law Enforcement

The ministerial laws specify main contents for operation under standards developed by the Department of Rail Transport. The standards are annexed at the end of the ministerial laws. In case DRT makes modification to existing standards or develops additional standards, the laws are still effective and relevant parties must follow them. The implementation must not be at a lower level than the standards specified by DRT.

### 5.4.4 Regulation by Contract

Each project has different technical and operational details. Specific conditions must be followed for each project. Contract documents must contain these technical and safety details, specifications, and conditions including service efficiency and project implementation. Regulation can be conducted by correction, fining, contract termination and compensation.

# Chapter 6

# Supplementary Tasks for Standard Preparation

## 6.1 Document Preparation and Meeting with Related Agencies

The consultant prepared documents and provide experts to participate in meetings on electrification and signalling standards with the Railway Standard Subcommittee and other related agencies.

## 6.2 Curriculum Setup, Training and Technology Transfer

### 6.2.1 Basic Training on Electrification and Signalling Systems

Basic Training on Electrification and Signalling Systems was organized on Wednesday 19 August 2020 at 8:00 – 17:00 at Kamolmat Room 6$^{th}$ Floor, The Sukosol Hotel, Samsen Nai, Phayathai, Bangkok. Personnel from various relevant agencies attended the training including representatives from Department of Rail Transport (DRT), State Railway of Thailand (SRT), Mass Rapid Transit Authority of Thailand (MRTA), SRT Electrification Train Company (SRTET) and Bangkok Transit System (BTS) Co. Ltd., for a total of 39 participants.

### 6.2.2 Technology Transfer on Electrification and Signalling Systems

Technology Transfer on Electrification and Signalling Systems was organized on 13-14 November 2020 at Samyan Mitrtown Hall (Mitrtown Room), 5$^{th}$ Floor, Rama4 Road, Wang Mai, Pathumwan, Bangkok. Personnel from relevant agencies attended the event including representatives from Department of Rail Transport (DRT), State Railway of Thailand (SRT), SRT Electrification Train Company (SRTET), Traffic and Transport of Bangkok Metropolitan Administration (BMA), Mass Rapid Transit Authority of Thailand (MRTA), Bangkok Transit System (BTS) Co. Ltd., Krungthep Thanakom Co. Ltd., and general public, for a total of 70 participants.

### 6.3 Public Relation and Exhibitions

Two rail electrification and signalling system exhibitions were arranged. The first was held at 09.00 – 18.00 on 16 September 2020, and the second at 10.00 – 18.00 on 13-14 November 2020 at Samyan Mitrtown 5$^{th}$ Floor, Rama 4 Road, Wang Mai, Pathumwan, Bangkok. Both events have been successfully carried out with great feedbacks from participants which include executives and personnel of DRT and related agencies, high school and college students, and general public.

### 6.4 Public Participation Process for Stakeholders

#### 6.4.1 The First Public Participation Process for Stakeholders

The First Public Participation Process for Stakeholders was held at 13:00-16:30 on 16 September 2020 at Samyan Mitrtown Hall (Mitrtown Room), 5$^{th}$ Floor, Rama4 Road, Wang Mai, Pathumwan, Bangkok. It was the project orientation with aim to introduce project rationale, scope, methodology, and timeframe. Initial comments were expressed from participants and contact were established. Attendants were representatives from Department of Rail Transport (DRT), Office of Traffic and Transport Policy and Planning, State Railway of Thailand, Mass Rapid Transit Authority of Thailand (MRTA), State Railway of Thailand (SRT), Traffic and Transport of Bangkok Metropolitan Administration (BMA), SRT Electrification Train Company (SRTET), Bangkok Transit System (BTS) Co. Ltd., Electricity Generating Authority of Thailand (EGAT), Metropolitan Electricity Authority (MEA), Provincial Electricity Authority (PEA), Office of National Broadcasting and Telecommunication Commission, (NBTC), Thailand Institute of Scientific and Technological Research , AMR Asia Co. Ltd., KTT Consultant Co. Ltd., and general public, for a total of 48 participants.

#### 6.4.2 The Second Public Participation Process for Stakeholders

The second public participation process for stakeholders involves presentation of outcome and standard implementation approach including receiving comments for improvement. Contents and list improvement will be summarized in the seminar. This event will be held in December 2020.