Development of Thailand Railway Station Management Training System based on SCADA System Simulation

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***Abstract* - The railway Station Management System (SMS) is a vital component of the modern railway system. However, Thailand is working to modernise its railway and has an insufficient SMS training platform. This article presents the development of an SMS simulation using the Supervisory Control and Data Acquisition (SCADA) system concept, including reliability modelling with reliability block diagrams for training in Thailand. Its main functions are for control, alarm monitoring, and data event simulation of integrated systems in a railway station. The various subsystems are both the power supply system and facility management systems, including the operation of low-voltage power supply, lift and escalator, security, fire protection, pump and drainage, environment control, and platform screen door. We developed an SMS training system that consists of both hardware and software components. This system demonstrates how SCADA in the railway station functions and improves training for the student and railway operator.**

Keywords - Station Management System, SCADA, Railway Station, Reliability Modelling with Reliability Block diagram

I. INTRODUCTION

The railway transportation system is currently of interest in Thailand. The Thai government has planned for and invested in many railway projects. One major topic is the railway Station Management System (SMS) because the modern railway station employs the SMS for the convenient operation and lack of available human resources. Supervisory Control and Data Acquisition (SCADA) [1–3] is used for station management. However, training tools on SMSs are insufficient in Thailand and require specialists with a deep understanding of the railway SMS. Currently, training comprises lectures or instruction on a live system causing interruptions to daily operation. Therefore, an adequate training platform for the railway SMS is needed for training station operators and students. The project for this platform was named 'Development of Railway Station Management System in Thailand' and has received funding and support from the National Science and Technology Development Agency (NSTDA). To ensure the success of the project, a comprehensive set of railway SMS training and demonstration tools has to be verified for sufficient instruction on the railway SMS for the State Railway of Thailand (SRT) training centre.

We propose the development of a railway SMS applying the SCADA concept to the training platform. The system has functions for the control, alarm monitoring, and data acquisition of integrated systems in railway stations, including power supply, low-voltage, lift and escalator, security, fire protection, pump and drainage, environment control, and platform screen door subsystems. We developed the hardware and software components of this training system. A Graphical User Interface (GUI) is the main component of the software to communicate with the hardware device. The training platform for railway station management was developed to educate student and railway operators

A hardware interface design, divided into two open racks including a remote terminal unit and remote input/output unit, which communicate with wired industrial protocol and design, meets the cost budget for the input/output list of each module in the station. A Graphic User Interface (GUI) and database comprise the main software development. The system can communicate to the hardware for controlling and monitoring the status of these station systems. The implementation result shows a simulation system in which the user can monitor and control the subsystems through the GUI that works directly with the hardware component.

This article is organised as follows. Literature review and limitations of current systems in section II, Section III presents the theory about SCADA. In section IV, the SMS system architecture and design are described. The simulation implementation and results of railway station management system are shown in section V, and the final section states the conclusion.

II. LITERATURE REVIEW AND LIMITATIONS OF CURRENT SYSTEMS

A simulation of SCADA is presented in [4], which used open-source SCADA software for development. However, railway systems cannot use open-source software since an industrial standard close to the real-world system does not exist. Another study on SCADA was proposed in [5]. However, this work described SCADA in the power system and energy control and lacks an integrated module for a railway station with building management and power systems. Various research efforts are presented about

SCADA in railway systems [6–9] but do not focus on the SMS. The authors in [10] proposed a simulation of the railway station management with train models using a microcontroller as the main controller hardware of the simulation system and open-source software. Railway simulation training has been presented in [11]. However, this system focused on a railway signalling and interlocking system that did not include a railway SMS. Previous works have investigated a SCADA training platform [12–14] that can ensure suitable SCADA education. In addition, we proposed a system in previous works [15][16] that can fulfil the development of a comprehensive training platform for railway operation and control in Thailand. However, this project concentrated only on railway operation and control and did not include the railway SMS.

III. SCADA SYSTEM

SCADA [1] is a controlling and monitoring system architecture that uses computers, data communication networks, a remote terminal unit or programmable logic controller, and a human user interface for supervisory management to monitor, control, and acquire data or information in real time and over long distance. The stored data from all systems are then sent to the system control centre. SCADA usually consists of the following main elements:

1) The Human Machine Interface (HMI) is the GUI on computers and workstations that shows a diagram of the system modules controlled and displayed using SCADA.

2) A workstation unit is a central control client that stores data or other information.

3) A communication network is a wired system that transfers information between devices in SCADA and establishes protocols for communication.

4) The Remote Terminal Unit (RTU), or Programmable Logic Controller (PLC), is connected to the sensors and actuators in the process and communicates to the supervisory system.

IV. RAILWAY STATION MANAGEMENT SYSTEM DESIGN

SMS design start from system architecture hardware and software design with reliability based on station information in Bangkok, Thailand. Detail of design as:

A. System Architecture

The system architecture of the SMS consists of hardware, software, and the communication interface. The system hardware includes a communication network of computer workstations, RTU, and Remote Input/Output (Remote I/O) set that interfaces with system software to control and monitor the subsystems in a railway station, such as the power supply system. The software of this SMS system focuses on the design of GUI and RTU. Details of the system architecture are shown in Fig .1 and Fig. 2.

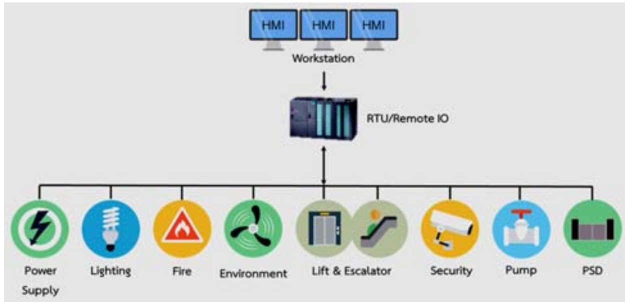


Figure 1. Diagram of the overall system interface.

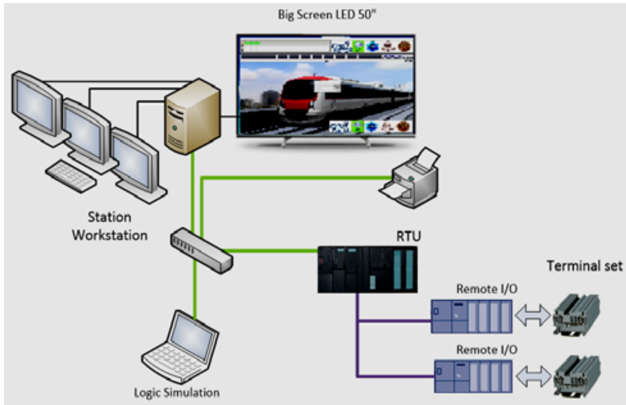


Figure 2. Diagram of the computer system architecture.

B. Hardware Design

The main controller hardware of this system, the RTU IEC 6087-5-104 protocol with PLC Siemens s7-300 with CPU 315-2 PN/DP,.is divided into two racks, as shown in Fig. 3. The first rack includes the main RTU set, and the second rack is the Remote I/O using Remote IO ET 200S PN and DP, which is a device set that interfaces with Profibus DP/PN and Profinet protocols. Both racks relate to I/O terminals for testing input and output and communication with the computer workstation. This hardware our design is appropriated with costs in hardware management of the project. Moreover, using this hardware due to almost of railway SMS in Thailand and our system, station prototype is used in this RTU system. It is suitable for training students and operators through our simulation and real-time operation at the station.

DOI 10.5013/IJSSST.a.21.04.12

ISSN: 1473-804x online, 1473-8031 print

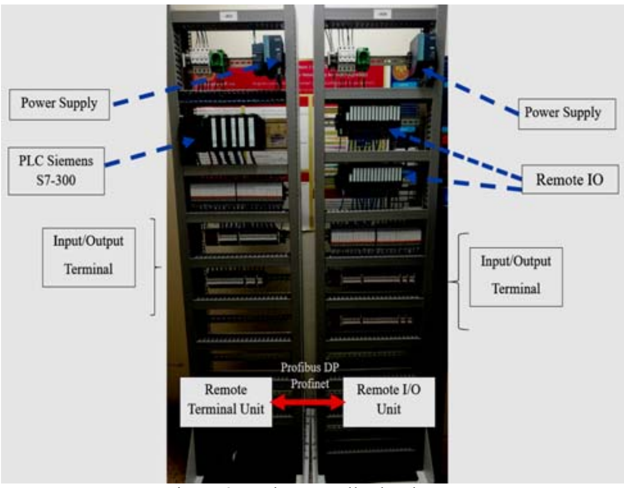


Figure 3. Main controller hardware.

For the I/O list design, the system is limited by the budget of the hardware set. However, the primary function was completed. A necessary function was designed for digital and analogue I/O points to support all railway station modules. The total I/O lists comprise 256 points, as shown in Table I. Also, examples of the function or signal name of I/O list, state or status, state value, type, and tag in RTU set of all modules are shown in Table II.

TABLE I. TOTAL I/O LISTS DESIGN.

No	Input/ Output	RTU	RIO1	RIO2	Summary (Points)
		Main PN/DP	*Profibus DP*	*ProfiNet*	
1	Digital Output	64	32	32	128
2	Digital Input	32	32	32	96
3	Analog Output	8	4	4	16
4	Analog Input	8	4	4	16
Total		112	72	72	256

TABLE II. EXAMPLE OF I/O LISTS DESIGN OF POWER SYSTEM.

No	Signal Name	State/Status	State Value	Type	Tag
1	OCS Switch Q1	Switching State	OFF	DO	Q0.1
2	OCS Switch Q1	Switching State	ON	DO	Q0.0
3	OCS Switch Q1	Switching State	OFF	DI	I0.1
4	OCS Switch Q1	Switching State	ON	DI	I0.0
….	…	…	…	…	…
147	Escalator Operation/Running	Status	Run/Stop	DI	I8.0
148	Escalator UP Direction	Status	Up/Stop	DI	I8.1
149	Escalator Down Status	Status	Down/Stop	DI	I8.2
150	Escalator Emergency Stop Switch Operated	Alarm	Appear/Disappear	DI	I8.3

C. Reliability Modelling with Reliability Block Diagram Design

The reliability block diagram (RBD) can be designed easily in a simple system; however, for a more complex system, there are several steps needed to ensure the completeness of the RBD. The overall process of developing the RBD is summarised in Fig. 4

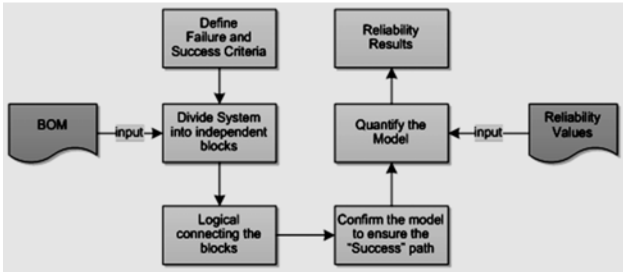
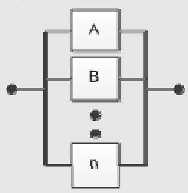
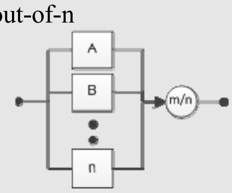


Figure 4. RBD development flowchart.

The connections between the hardware components (blocks) can be categorised into three types: series, parallel, and m-out-of-n, as shown in Table III. Further reading for the variation of each type is recommended when a complex system is being analysed.

TABLE III. TYPES OF RELIABILITY BLOCK CONFIGURATION

Configuration	Interpretation
Series 	Failure of any component will cause the total failure of the series connection.
Parallel 	At least one unit must be working for the system to function.
m-out-of-n 	*m* units out of the total number *n* units required for the system to successfully operate.

System reliability R_s formula [18]

-1) Series configuration. The system reliability of the series configuration is given by the product of each component in the series:

$$R_s = R_A \cdot R_B \cdots\cdots R_n \qquad (1)$$

where R_A, R_B,…R_n represent the individual reliability of each component A, B, … n.

-*2)* Parallel configuration. The system reliability can then be given by the following equation:

$$R_s = 1 - \prod_{i=1}^{n} (1 - R_n) \quad (2)$$

-*3)* m-out-of-n configuration. The system reliability equation of the *n* items where *m* items out of *n* are required for system success. The system reliability is given by the following:

$$R_s = \sum_{r=0}^{n-m} \binom{n}{r} \cdot R^{n-r} \cdot (1-R)^r \quad (3)$$

To derive the reliability values of the SMS system, the reliability values of each component shall be obtained from the manufacturer or international standards. Table IV summarises all the components and reliability values for the design.

TABLE IV. PART LIST AND FUNCTION INFORMATION

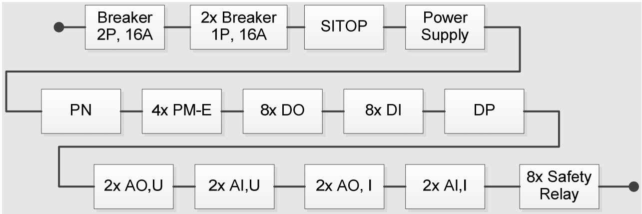
Part Name	MTBF	FPMH per Unit	MTTR per Unit[1]
Remote Terminal Unit			
Miniature Circuit Breaker 2P 16A	294,118	3.40	0.5
Miniature Circuit Breaker 1P 6A	588,235	1.70	0.5
SITOP PSU100S 1-phase, 24VDC 10A	1,614,510	0.62	0.5
Power Supply 24VDC 10A	1,504,280	0.66	0.5
CPU 315-2PN/DP	2,480,589	0.40	0.5
DO 32 x 24VDC 0.5A	144,540	6.92	0.5
DI 32 x 24VDC	268,056	3.73	0.5
AO 4 x 12bit	207,612	4.82	0.5
AI 8 x 14bit	409,968	2.44	0.5
Remote I/O			
Miniature Circuit Breaker 2P 16A	294,118	3.40	0.5
Miniature Circuit Breaker 1P 6A	588,235	1.70	0.5
SITOP PSU100S 1-phase, 24VDC 10A	1,614,510	0.62	0.5
IM151-1 DP Standard	1,235,160	0.81	0.5
IM151-3 PN Standard	1,075,728	0.93	0.5
PM-E 24VDC	7,911,156	0.13	0.5
8DO, 24VDC 0.5A	3,447,936	0.29	0.5
8DI, 24VDC 0.5A	2,204,892	0.45	0.5
2AO, U	522,972	1.91	0.5
2AO, I	522,972	1.91	0.5
2AI, U, Standard	567,648	1.76	0.5
2AI, I Standard, for 2-wire	567,648	1.76	0.5
Relay 24VDC 1 Contact			0.5
Workstation			
PC Workstation	54,000	18.52	0.5
Monitor	54,000	18.52	0.5
Colour Printer	42,804	23.36	0.5

Abbreviations and assumptions
MTBF – Mean Time Between Failures
FPMH – Failure Per Million Hours
MTTR – Mean Time To Repair, the average time (h) required for corrective action.

[1] The MTTR of each component in the RTU/Remote IO cabinets is assumed to be within 30 minutes, while the diagnostics and test require no time. Thirty minutes should cover all the repair activities.

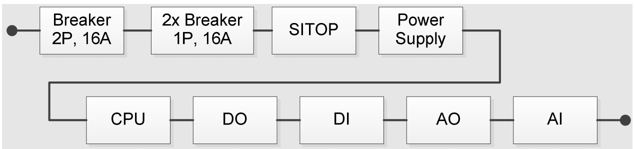
According to Fig. 2, which shows the overall system architecture, and (1), (2), and (3) that derive the reliability of the SMS system, a bottom-up approach is applied to the subsystem level, and the first step to reliability modelling is to evaluate these subsystems:

1) Remote I/O unit. The failure of any component in the RTU will result in the failure of the RTU. The component configuration of the RTU is in series, as shown in Fig. 5.



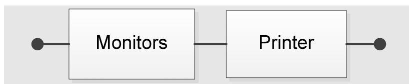
RDB of Remote I/O unit

2) RTU Unit: Similar to the Remote I/O, the failure of a single set of remote I/O subsystems can be arranged in a series configuration per Fig. 6.



RBD of RTU unit

3) Workstation and Printer Unit: The failure of the monitor and printer is considered a minor failure and connected by a series configuration, as shown in Fig. 7.



–Figure 5. RBD of Workstation and Printer

D. Station Data

For the prototype of this system, we selected the Bang Bamru Station as suggested by the SRT [17], the project advisor, because it was suitable for our costs. This station is a new intercity railway that services the Red Line in Bangkok, Thailand. Currently, it is under construction with plans to operate in 2022. The Bang Bamru Station is shown in Fig. 8, and the layout is illustrated in Fig. 9.

Figure 6. Bang Bamru Station of the Red-line railway in Thailand.

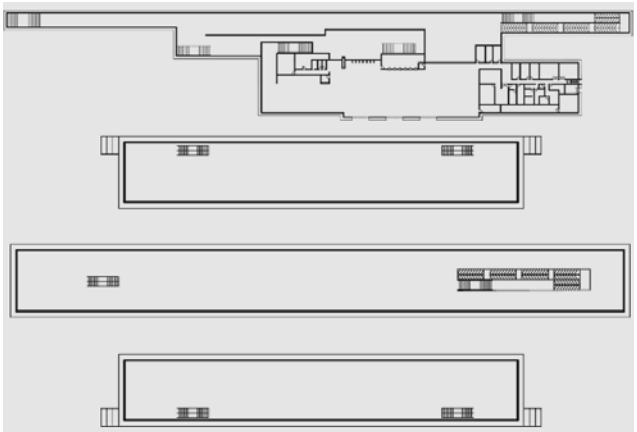


Figure 7. Bang Banru Station layout.

E. Software Design

The system software was developed in two parts – HMI and RTU controller. An overview of the software design is shown in Fig. 10. The system applies the main functions of the SCADA concept, including controlling, monitoring, alarm notification, and data logging.

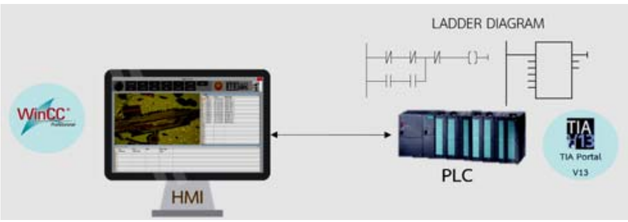


Figure 8. System software overview.

First, the HMI was developed using Siemens WINCC software. The HMI is software that engages the user with a GUI to monitor, control, gather data, and field alarms from the RTU unit. The GUI has 14 pages that allow the user to view the home page, system configuration alarm log, power supply system, low-volt system, lift and escalator, pump, security, lighting, platform screen door, fire protection, and environment control system.

The second part developed was the RTU controller. The RTU is controlled by ladder and related programming using Siemens TIA Portal V13 software. We designed the GUI for transmitting and receiving signal data between the HMI and RTU following the hardware I/O list.

V. IMPLEMENTATION RESULTS AND DISCUSSION

Digital and analogue input and output of all modules from the I/O list design were implemented for the system simulation and training. The output could be tested by clicking on a switch on the screen, and a status light will show on the tag point of the RTU on the screen.

The input could be tested by simulation at terminal and logic simulation via TIA Portal software. The simulation at terminal used a cable wire connected to a 24V port at the I/O terminal and to a digital input terminal port with the tag point of I/O list. The status would be indicated by the light on the RTU port, and the event will show on the screen, as shown in Fig. 11.

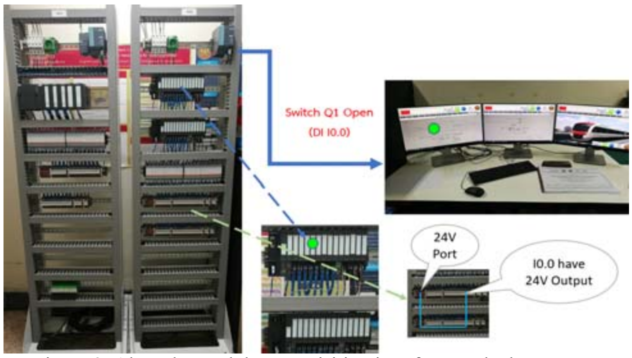


Figure 9. Alarm log and data acquisition interface on the homepage.

The SMS model RBD consists of major and minor failures. A major failure is any failure effect to the railway station service or a passenger during operation. A minor failure does not affect the railway service, e.g. printer error. The RBD model will appear on the screen, as shown in Fig. 12.

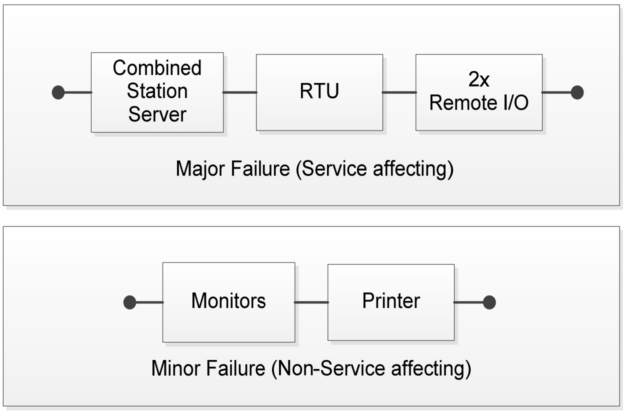


Figure 10. SMS model RBD for major and minor failures.

From Table IV and the reliability of the SMS system in Figs. 5, 6, and 7, the FPMH can be calculated, as listed in Table V.

TABLE V. FPMH BASE ON RBD SMS MODEL

Item	Qty	FPMH
Combined Station Workstation	1	24.46
Monitor	1	18.52
Printer	1	46.72
RTU	1	33.31
Remote I/O	2	30.35

From Table V, MTBF for the SMS model were calculated, as shown in Table VI, based on consequences.

TABLE VI. FPMH BASE ON RBD SMS MODEL

Consequences	Major (FPMH)	Minor (FPMH)
Total loss of the system.	24.46	n/a
Loss of human interfaced control of the system. The system is still working; the workstation will need to be repaired as soon as possible.	n/a	18.52
Loss printing capability. SCADA operation is not impacted.	n/a	46.72
Loss of monitoring and controlling functions	33.31	n/a
Loss of any I/O leading to a fault of the system	60.70	n/a
Total FPMH	118.47	65.24

It follows that the total major and minor failures and the service and inherent availabilities were as listed in Table VII.

TABLE I. FAILURE SUMMARY

Total major failure MTBF (hours)	8,440.62
Total minor failure MTBF (hours)	15,327.29
All Failure MTBF (hours)	5,443.13
Service Availability	99.9941%
Inherent Availability	99.9908%

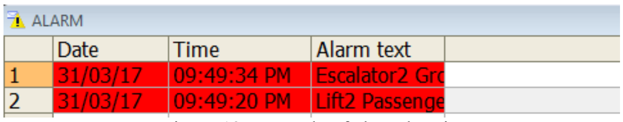
The system was then implemented. The following sections describe design details design and GUIs of all modules, including homepage, alarm and data logging, power supply system, low-volt system, lighting system, security system, fire alarm system, lift and escalator system, pump and drainage system, environment control system, platform screen door system and system configuration system.

A. Homepage

The homepage GUI of the simulation software is presented in Fig. 13. It is the first screen the user sees when launching the software. A user must log in by username and password, selecting user roles as administrator, student, or trainer. There are buttons for selecting other GUIs.

The alarm button takes the user to the alarm log page. When a system has an alarm, the alarm's detail will appear on this page, as shown in Figs. 14.

Figure 11. Homepage GUI of this system.



–Figure 12. Example of alarm logging

B. Power Supply System

The power supply system GUI is illustrated in Fig. 15. This railway line uses the overhead catenary system as a power supply. This GUI simulates the main switch (Q1 to Q6) operation that receives high-voltage power supply (25 kV) from the bulk substation to the power line of the overhead catenary system. Each main switch is controlled with a button on the left side of the screen. Moreover, this GUI allows the user to monitor the status of each main switch. The colour of the switch is green when it is functioning properly and red when there is a problem. An alarm notification will also appear on the screen.

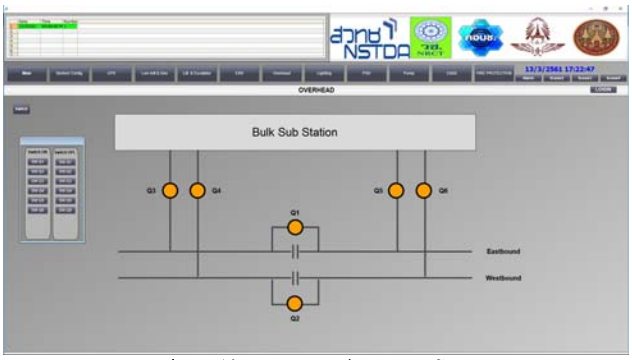


Figure 13. Power supply system GUI.

C. Low-Voltage System

The low-voltage power supply system supplies standard power to the station (220V and 50 Hz in Thailand). The low-voltage GUI can control and monitor the Main Distribution Board (MDB) switch, modelled case circuit breaker (MCCB), and power generator. The system operates with a tie switch. The main power supply generator will take over when the low-voltage power system fails. The low-voltage power supply system GUI is shown in Fig. 16.

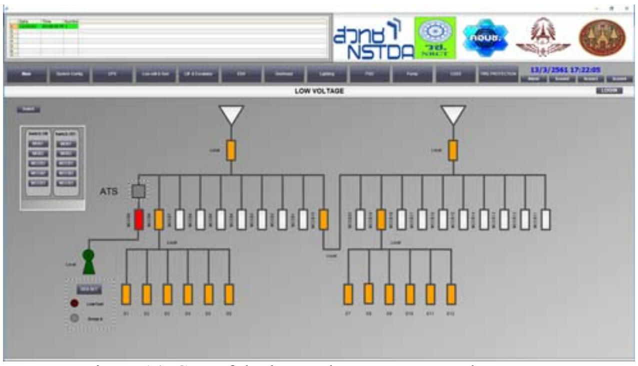


Figure 14. GUI of the low-voltage power supply system.

D. Lighting System

The lighting system GUI allows the user to monitor the status of lighting during operation. This system was designed by dividing one lightning zone into eight zones because of the limitations of I/O, including a platform level 3 zone, station level 3 zone, and underpass level 2 zone. The menu in the GUI has options to change the zone being monitored. When a digital input of the lighting zone is tested, a light symbol on the GUI will change to green, and data will be logged on all of the operations. The GUI of the lighting system is shown in Fig. 17.

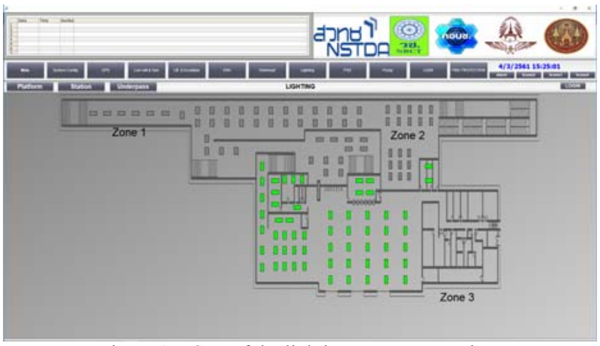


Figure 15. GUI of the lighting system operation.

E. Security System

The security system in this station consists of the video surveillance system and Control Access Security System (CASS). This GUI can monitor the status of video surveillance cameras and main room gate of the station, as shown by the icons in Fig. 18. An icon will turn red when a system fails, and alarm notification will appear on the screen.

Figure 16. GUI of the security system with an example of a CASS alarm.

F. Lift and Escalator System

Lifts and escalators operate in the station to provide comfort to passengers. The system can monitor the operating statuses of six lifts and five escalators. The GUI of this system in Fig. 19 shows the status of a running escalator by a green escalator icon and an arrow in the direction of operation. Fig. 20. shows an example of an alarm notification of a faulty lift with the colour red.

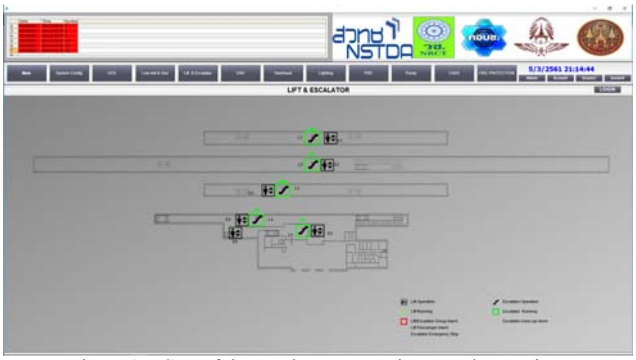


Figure 17. GUI of the escalator system in normal operation.

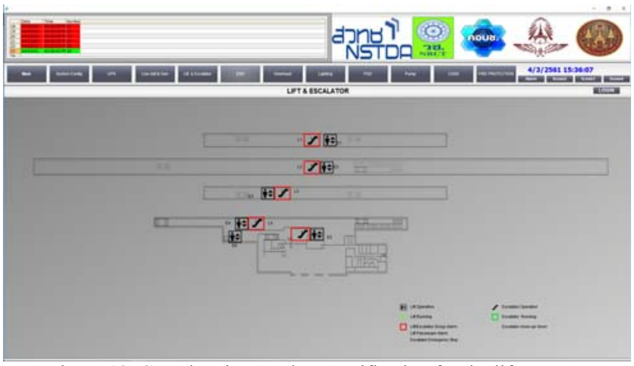


Figure 18. GUI showing an alarm notification for the lift system.

G. Fire Protection System

The fire protection system is a crucial function of the railway station, which consists of a fire alarm system and the FM200 system. The fire alarm system is simulated with virtual smoke detection that can be monitored through the GUI. The detection area is divided into three sections – platform level, ground level, and Electrical and Mechanical (E&M) room. Fig. 21 shows a smoke detection simulation with an alarm of the detection area.


Figure 19. GUI of the fire protection system.

The other part of the fire protection system is called the FM200 system. This system provides a waterless fire protection system that extinguishes fire harming the computer system. The user can monitor the FM200 status within the GUI of six rooms of the station, including the control room, communication room, signalling room, station power supply room, power generator room, and electrical room. If an alarm occurs, it will display a red icon on the screen. The GUI and example of FM200 operation are shown in Fig. 22.

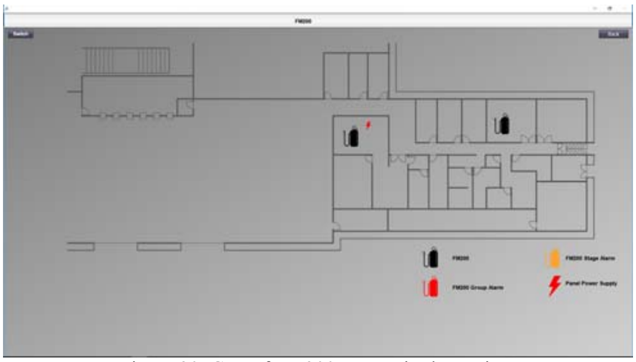


Figure 20. GUI of FM200 system in the station.

H. Pump and Drainage System

The pump and drainage system is used to drain water from the station. The user can monitor the status of pump power running, pump alarm, and water tank flooding alarm. An example of the operation of this system GUI is present in Fig. 23.

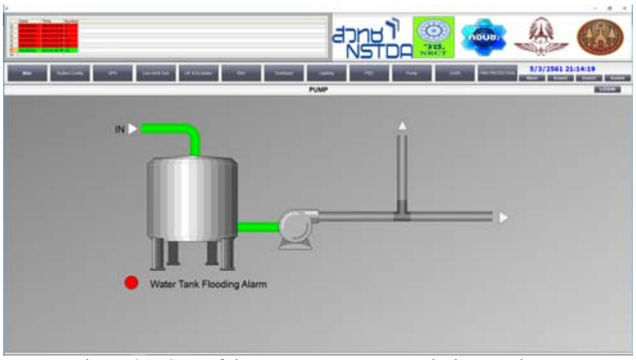


Figure 21. GUI of the water pump system during an alarm.

I. Environment Control System

The environment control system comprises the air-conditioning and temperature-control systems. The user can monitor the system in three main rooms in the station – the control room, communication room, and signalling room. This interface page will receive data from the input port. If there is an alarm, the symbol for the module changes to red. A GUI of this system is shown in Fig. 24.

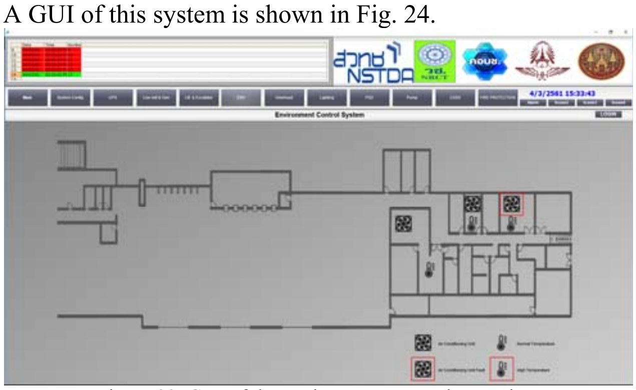


Figure 22. GUI of the environment control operation.

J. Platform Screen Door System

The Platform Screen Door (PSD) system \ protects the passenger at the platform level. This system can monitor and operate the PSD. The GUI of the PSD system is shown in Fig. 25.

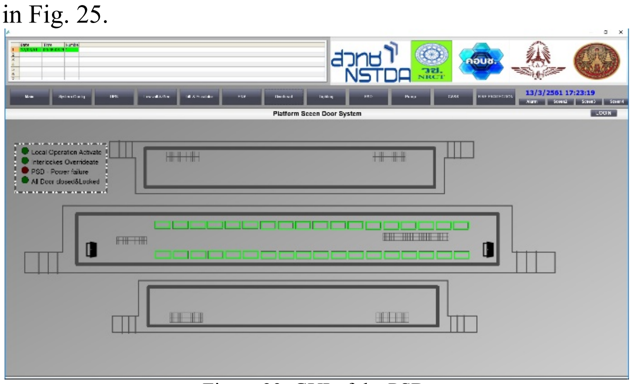


Figure 23. GUI of the PSD.

K System Configuration

The system configuration GUI shows whether the hardware device and communication line as running normally. An alarm notification appears on the GUI when a communication line or some hardware device has failed. Fig. 26 illustrates the GUI and failure operation of the communication line between the RTU and Remote I/O Unit in which a cable line icon turns red, and a red circle in the screen appears.

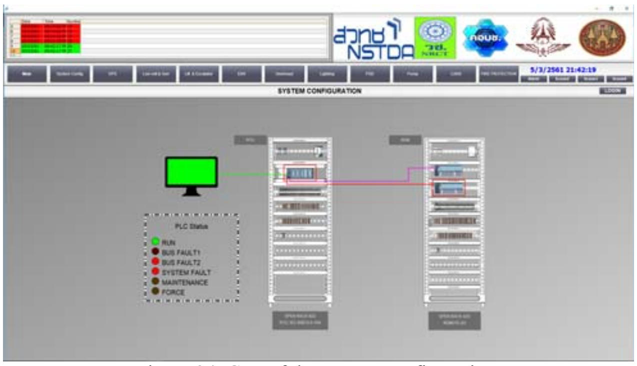


Figure 24. GUI of the system configuration.

This system interface between the hardware component and computer with railway station SMS is shown in Fig. 27.


Figure 25. Station management system.

After the research was complete, this system was launched at the SRT training centre in Bangkok to educate SRT vocational school students and railway station operators.

VI. CONCLUSION AND FUTURE WORK

A training system was created for a railway SMS using SCADA concepts to control, monitor, alarm, and acquire data of integrated subsystems in a railway station. The hardware was designed with an RTU and working schemes of I/O Lists. The software uses concepts of an HMI to monitor and control a railway station.

The implementation resulted in a simulation system that can use software to monitor, control, alarm, and acquire data through a GUI working with a hardware component. The paper further describes case studies demonstrating how the SCADA concept was applied to train Thailand railway station operators and railway students.

The results of MTBF and availability for the SMS model from section V indicate that the components that are critical to the service are the RTU and the Remote I/O units, while the failure rate of the servers is significantly lower than the RTU. The service and inherent availabilities were high (more than 99.95%). We can provide the SMS system for railway stations and training centres in Thailand. In the future work, we will focus on the MTBF and availability of SCADA base on integrated modelling with redundant and non-redundant.

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ACKNOWLEDGEMENT

This research was funded and supported information by the Thailand National Science and Technology Development Agency (NSTDA), Ministry of Science and Technology, Thailand. We appreciate the support and knowledge shared by the State Railway of Thailand (SRT) and SRT training centre.

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