Network Architecture of ETAT Education and Training Centers for Automation 4.0

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Abstract. Automation 4.0 comprises the latest technologies that enhance classic automation to communicate with machines in a connected manner and to enable more flexible and more intellegent automation in smart factories. Industry 4.0 has become a global trend over the past ten years to combine the benefits of automation with the needs for flexible production. This trend has reached, in addition to industrialized countries, also newly industrialized countries like Thailand, with the aim to strengthen the global competitiveness. In the ETAT project, partners from Europe as well as Thailand combine their competences to build up a network of so-called Smart Labs around Bangkok area and thus take an important step towards Automation 4.0 in Thailand. Using Thailand as an example, this work shows how industrially emerging countries can sustainably strengthen their qualification with regard to Automation 4.0 by setting up such networks of education and training centers. In addition to explaining the general architecture of the network, the specific characteristics of all six established ETAT Smart Labs are presented and discussed.

Keywords: Industry 4.0, Smart Manufacturing, Automation 4.0, Engineering Education, Training

1 Introduction

Since the birth of Industry 4.0 in 2011 [1], the Fourth Industrial Revolution has had a major impact on the way goods are produced worldwide, increasing the degree of flexible automation and digitization. Automation, with the introduction of industrial robots, first control systems and computer chips, is a particular core element of the Third Industrial Revolution, but has achieved a renaissance through Industry 4.0 in the direction of automation that is more flexible, connected and much easier to implement, especially also for small and medium sized enterprises. Automation 4.0 provides a smart factory system organized as Cyber-Physical Production System (CPPS) where the extraction, manufacturing and assembly processes are carried out where machines work autonomously and communicate with each other with Industrial Internet of Things (IIoT). Intelligent machines and robots work collaboratively, communicate with each other, and solve problems with high autonomy [2].

The Thai government has implemented a number of policies to harness the potential of the fourth industrial revolution. These policies can be categorized into three broad categories, namely, digital infrastructure, skill formation, and target industries [3]. With "Thailand 4.0" is an economic model that aims to unlock the country from several economic challenges resulting from past economic development models which place emphasis on agriculture (Thailand 1.0), light industry (Thailand 2.0), and advanced industry (Thailand 3.0). These challenges include "a middle income trap", "an inequality trap", and "an imbalanced trap". The main goals of Thailand 4.0 are increase of (i) economic prosperity, (ii) of social well-being, (iii) raising human values and (iv) environmental protection [4]. The Thai government is developing new growth hubs by starting with the Eastern Economic Corridor (EEC) which covers Rayong, Chonburi, and Chachoengsao provinces, with a total area of 13,000 square kilometers. The government is set to accelerate the area's readiness to support all aspects of Industry 4.0, investment and economic growth, and fully expects that the EEC will be an important center for trade, investment, regional transportation, and a strategic gateway to Asia [4, 5]. In addition to technological advances Thailand needs human capital development to catch up with new global trends towards Industry 4.0 and Automation 4.0. The fast-changing global economic landscape shapes the strategies of countries and firms and is crucial to the future of Thailand 4.0 [6].

In order to support this development of human capital, the European Commission finances research projects through the Erasmus+ program. In particular, there are capacity building projects that enable industrially emerging countries to cooperate with European partners to promote knowledge exchange and strengthen bilateral cooperation. In this context, the Erasmus+ project ETAT (Education and Training for Automation 4.0 in Thailand) tries to support education and training on Automation 4.0 in the area of Bangkok by means of didactic measures and the establishment of a network of so-called ETAT Smart Labs [7]. In the following we describe the architecture of this newly established network, the specific characteristics of each of the Smart Labs. With this work we want to encourage also other countries to follow the example of Thailand in establishing similar networks for education and training on Automation 4.0.

2 Overall Architecture and Network of ETAT Education and Training Centers

2.1 Overview

The ETAT project has been able to establish a strong connection among Europe and Thailand, with the objective of sharing knowledge about Automation 4.0 related topics. In doing so, European partners are in charge of collaborating with Thai Universities for developing training centers that will be used to transfer the knowledge among students and practitioners from industry in Thailand. The network of education and training centers is geographically located in the region of Bangkok as shown in Fig. 1. European partners like the University of Applied Sciences of Carinthia, the University of Antwerp, the University of Oviedo, the University of Porto, the Free University of Bozen-Bolzano, the EduNet World Asociation, and the Slovak University of Technology in Bratislava are supporting the setup of the network with their expertise and knowledge. The ETAT Smart Labs are installed at 6 universities, (1) the Burapha University, which also acts as coordinator, (2) the Rajamangala University of Technology Tawan-ok, (3) the Rajabhat Rajanagarindra University, (4) the King Mongkut's University of Technology North Bangkok, (5) the Kasetsart University, and (6) the King Mongkut's Institute of Technology Ladkrabang. Each ETAT Smart Lab develops peculiar applications based on a common PLC technology platform. The design of specific applications, as indicated in Fig. 1, includes the implementation of partner-specific equipment, which will differ from case to case. In this way, the same concepts can be taught on the basis of the background of students and practitioners from industry. In the next sections, the design and implementation of each ETAT Smart Lab is going to be introduced.

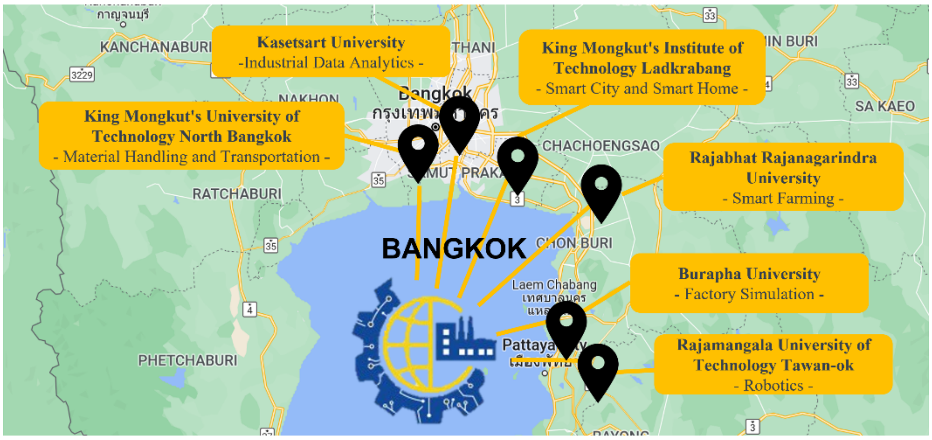

Fig. 1: ETAT worldwide network

2.2 Factory Simulation at Burapha University (BUU)

Fig. 2 shows the schema of the ETAT Training Center for Smart Factory 4.0 at BUU. The base components of this smart lab are a PLCnext unit, a switch, and an engineering PC. These components will build up a fundamental training for control system based on PLC concept. In this concept, the PLCnext technology is used due to its versatile and flexible use. As shown on Fig. 2, the communication can be established with TCP/IP protocol. One can control the PLCnext over the internal network or over the Internet. Furthermore, the process data can be transferred over the Internet to a local or cloud server. It is particularly useful for SCADA and data analytics purposes. Another component is the specific component, which is the Factory Simulation 24V. This component includes 4 main stations namely sorting line with color detection, multi-processing station with oven, automated high-bay warehouse, and a vacuum gripper robot. These stations are controlled by the PLCnext. The training system covers the ordering process, the production process, and the delivery process, which are digitized and networked.

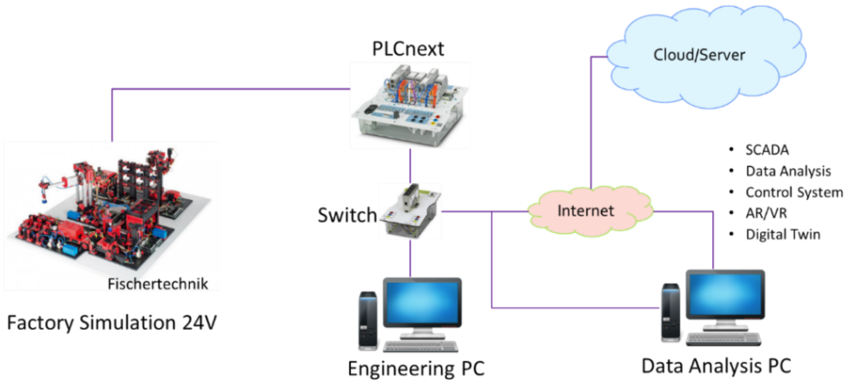

Fig. 2: BUU – ESL for factory simulation

2.3 Robotics at Rajamangala University of Technology Tawan-ok (RMUTTO)

The Rajamangala University of Technology Tawan-ok (RMUTTO) focuses its attention on robotics to characterize the ESL application. Therefore, the ESL includes demonstrative aspects about coding, industrial communication, and industrial robotics, from a theoretical, as well as a practical perspective. The trainees also have the chance to program control exercises in the ESL. In particular, the basic ESL has been equipped with an ABB robotic arm, which is controlled through the PLCnext system. Those systems are wired together through the input/output ports and to the local network via an Ethernet cable. Finally, the robotic system must be controlled remotely through a dedicated human-machine interface (HMI), which can be hosted on a computer, a tablet or a smartphone. For enhancing the security of the overall architecture, the connections are set on a local level (data are not transferred through the Internet).

On top of the physical demonstrator, RMUTTO also proposes a structured teaching approach which consist of a theoretical part and a hands-on lab experience. During the theoretical lessons, trainees are going to learn more about embedded systems, computer vision and robotics control through Robot Operative System (ROS). The practical experience aims at putting into practice the theory learned applying it to a real-world case study (the ESL).

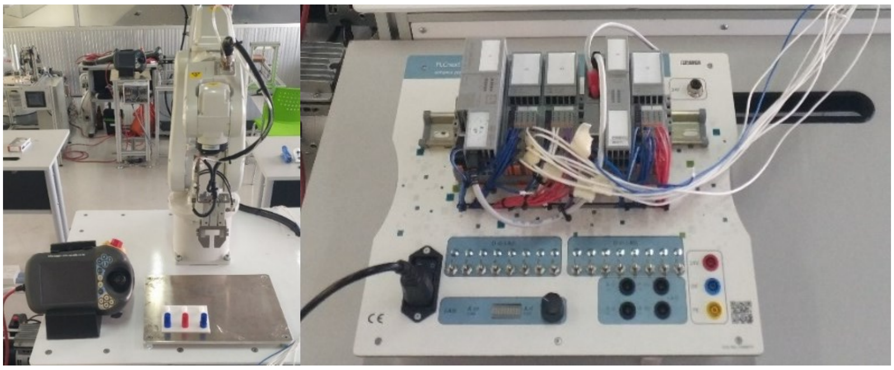

Fig. 3: RMUTTO – ESL for robotics applications

2.4 Smart Farming at Rajabhat Rajanagarindra University (RRU)

As for partner specific equipment, RRU have experience in training and using Internet of Things (IoT) for agriculture. They designed an ESL emulating a smart farming system by using IoT to monitor and control a smart green house. The resulting ESL configuration and architecture is depicted in Fig. 4.
Observing Fig. 4., PLCnext is here used to monitor and control the smart green house, which includes light sensors, temperature and humidity sensors, soil moisture sensors, CO_2 sensors, and relays. The data collected by the mentioned sensors are sent to the HMI and are stored in a cloud storage unit. Finally, the ETAT Smart Lab at RRU is used to train students in computer science, information technology, and electrical engineering on the first and second semester of 2022.

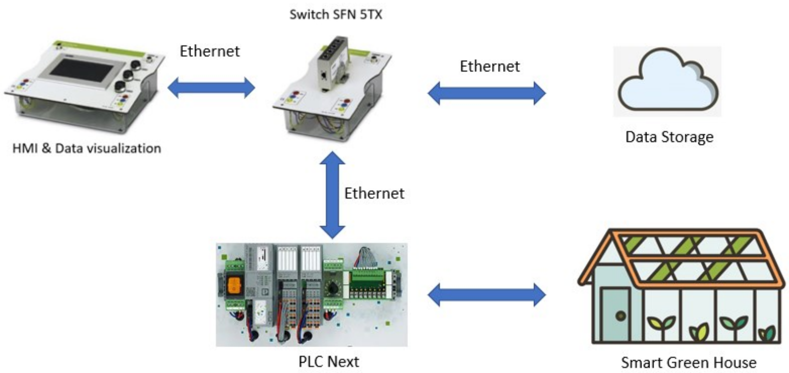

Fig. 4: RRU – ESL for smart farming

2.5 Material Handling and Transportation at King Mongkut's University of Technology North Bangkok (KMUTNB)

The ESL located at the King Mongkut's University of Technology North Bangkok mainly focuses on Industrial Internet of Things (IIoT) for practicing with edge-data collection, analysis, and presentation, automation in material handling for learning about autonomous mobile robots (AMRs) and robot manipulators in material handling, and automation in transportation with demonstration of railway signaling, operation, and control by PLCs combined with HMIs. The specific equipment is mainly controlled by PLCs over the favorite industrial network communications e.g; PROFINET, Ethernet/IO, and Modbus TCP. Visualization of the process can be shown through HMI devices, and web-based monitors. This training set supports teaching and learning in IIoT. Beginning with data collection direct from a production line (PLCs over the PROFINET network and factory IoT edges over the Modbus network), then cleaning and analyzing data, before visualizing them with proper tools, utilizing web technology, e.g., Node.js. For practical implementations, KMUTNB proposes two different applications. The first training set (Fig. 5) is to simulate an industrial workspace with cooperation between human and robots, and among collaborative robots. Deploying the Robot Operating System (ROS), as a common platform operation for AMRs and robot manipulators, will take advantages from open-source community. This furthermore gives the possibility to connect to the Linux-based PLC, which controls other sensors and actuator e.g. conveyor, and proximity sensor over the PROFINET network. The second application deals with knowledge in logistics and transportations. The training set will demonstrate the railway operation and control system, which must be compliant

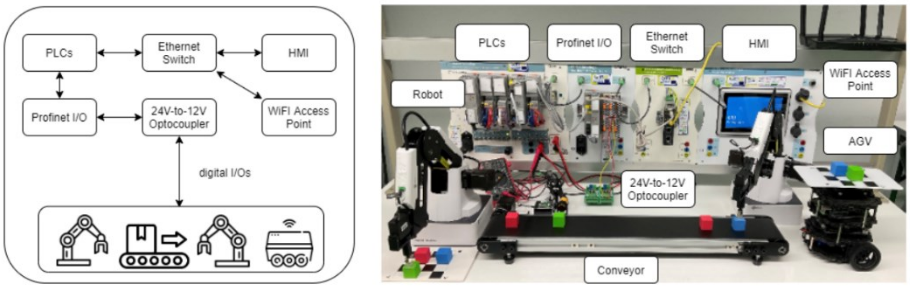

Fig. 5: KMUTNB – ESL-1 for automated and mobile material handling

with the European Train Control System (ETCS). The modified N-scale railway models are directly controlled by PLC over the PROFINET network and visualize the train operation status with HMI devices. The architecture of the second ESL application is reported in Fig. 6.

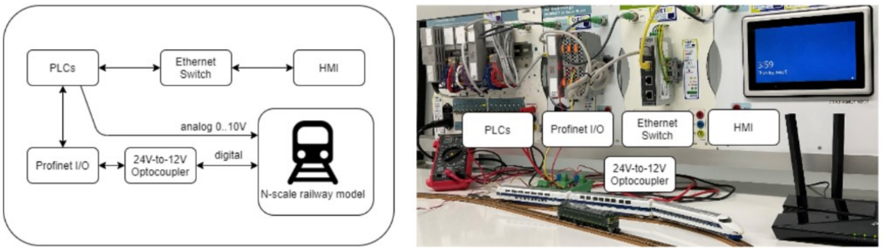

Fig. 6: KMUTNB – ESL-2 for transportation

2.6 Industrial Data Analytics at Kasetsart University (KU)

At the Kastetsart University, the ESL is connected to an industrial logistic sorter machine. The aim of the hands-on experiences taught at KU mainly deals with big data analytics for manufacturing systems. With this objective, the theoretical and practical training unit aims improving skills in the fields of industrial data science, decision support systems, data mining technologies and their applications, and knowledge management and expert systems.

From a technical perspective, students and practitioners from industry are able to exploit the demonstrator to collect data generated on the industrial sorting machine through the PLCnext infrastructure, to send them to a cloud-based storage unit and to finally elaborate such data through machine-learning based approaches. By doing so, training participants have the opportunity to deeply study the flow of data and its further exploitation in industrial settings. The industrial sorting machine is illustrated in Fig. 7.

Fig. 7: KU – ESL for industrial data analytics

2.7 Smart City and Smart Home at King Mongkut's Institute of Technology Ladkrabang (KMITL)

King Mongkut's Institute of Technology Ladkrabang is responsible in the ETAT project in terms of smart city and smart home scheme. There are actually two kinds of applications designed to exploit the ESL platform: (1) a building automation system and (2) flood warning system via mobile application, using PLCnext technology equipment and other specific equipment. In the building automation system, face and temperature detector are used to detect persons for access control in a room or in a building. The temperature detector snaps people faces and records their temperature then sends data to PLC. Inside the controlled room, the motion sensor will control lights in terms of switch on and switch off. In abnormal situations, the smoke detector (or PM 2.5 sensor) will detect the abnormal case and sends the warning messages via cloud for further data analytics. The building automation system application is composed as described in Fig. 8.

Fig. 8: *KMITL – ESL-1 for building automation*

The second application is a flood warning system via a mobile application. This system uses ultrasonic sensors to measure water level at four simulated water sources as in community to warn people who live near the water sources or near places which have high risk of flooding. When the height of the water reaches the critical value that was set in the application, it sends notifications to the people's mobile device via cloud. Moreover, line bot is used to let the people knows the potential risk from rising water levels. Water level data in each simulated stations can be collected for displaying in dashboard for data analytics or creating flooding prediction model in the future. The flood warning system is configured as shown in 9.

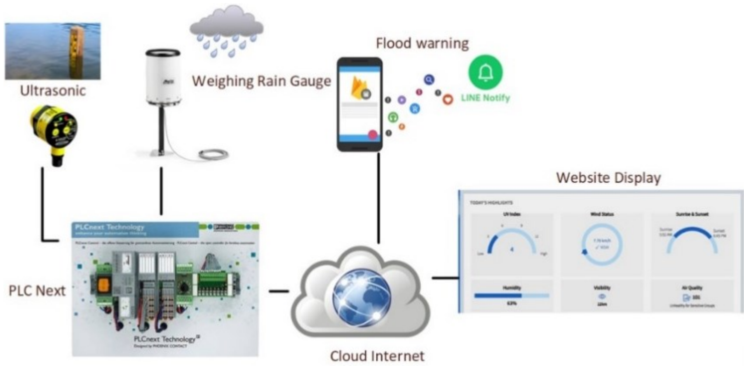

Fig. 9: KMITL – ESL-2 for flood warning

3 Conclusions

Through the cooperation of various universities and different disciplines, a network of demonstrators and training units for different applications has been established around the metropolitan area of Bangkok. The core technology and the core structure is always the same, which enables standardization and a geographically distributed training structure for learning the latest PLC technologies.

At the same time, the network also enables training in connection with a variety of different applications that are important for the territory in Thailand and especially in Bangkok. This also creates important synergy opportunities among the universities in the alliance by allowing participants to access different applications. In the future, the various ETAT Smart Labs will have to be networked in such a way that remote training can also be provided at the various locations. Another challenge and outlook might be to increase the number of possible application scenarios for each of the ETAT Smart Labs within the own field of expertise.

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