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Training of trainers for South-East Asia in the Industry 4.0 context: implementation of platforms

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Abstract—Asean-Factori 4.0 is a Key Action 2 of the European Union. This project, managed by Universit  Claude Bernard Lyon 1, regroups three European partners: Lyon (FR), Ruse (BG) and Grenoble (FR) together with 7 partners in South-East Asia (Asean) in Cambodia, Laos and Thailand. The main concept of the project is to train Asian teachers, around innovative platforms proposed by the European colleagues. The Asian institutions should create together a network of excellence; to this aim, each Asian institution will receive a specific platform with a specific focus and from a specific brand. The paper describes the state of advancement and the work achieved by the Grenoble partner (UGA, Univ. Grenoble Alpes) together with the Asian partners: ITC (Institute of Technology of Cambodia, KH), NUOL (National University of Laos, LA) and MFU (Mae Fah Luang University, TH). A first training was organized in Grenoble in the spring 2022. ITC and MFU attended on-site whereas NUOL attended on-line. A second training is organized on-site at the Asian partner institution, after the transfer of the platform in Asia; the purpose is for the partners to take their platform in hand.

Keywords— Automation, Industry 4.0, Asean countries, European Key Action 2 project

I. INTRODUCTION

Asean-Factori 4.0 is a European project accepted for 3 years from 2020 to end 2022 by the European Commission under the framework of the ERASMUS+ Key Action 2 CBHE (Capacity Building in High Education) program. The project aims at developing new Curricula around Industry 4.0 in South-East Asian countries. Industry 4.0 is a concept in which,

around PLC (Programmable Logic Controller) and other possible types of industrial controllers, communication is widespread (and ubiquitous) at every level using various wired and wireless communication networks, specialized (ModBus, CAN (Control Area Network), ProfiBus...) or more classical IT-oriented (TCP/IP, Transport Control Protocol/Internet Protocol), in an open context (around Internet) possibly open to the Cloud strategies. The idea is first to develop the concept of industrial control among the use of PLCs and second to raise awareness about the Industry 4.0 aspect, which consists in taking care of the network and its environment. The openness of the network brings some cybersecurity risks which should be taken in account in the development of Industry 4.0.

The project duration was initially three years, beginning in January 2020. Due to the pandemics, the project was reorganized and will normally last one year more. This project aims at enhancing existing curricula in the field of automation in the 7 Asean (South-East Asian) partners of the project coming from three countries: Cambodia, Laos and Thailand. Concerning Grenoble, we work with the following partners: ITC (Institute of Technology of Cambodia, KH), NUOL (National University of Laos, LA) and MFU (Mae Fah Luang University, TH). Concerning the other platforms and partners, two of these platforms are designed by the Ruse partner in Bulgaria [1], one is designed by Lyon.

In order to fit well with the needs of the Asian partners and give a meaning to the network of centers of excellence, it has

been accepted that the platforms should focus on various applications whereas the brands should be different from one center of excellence to another, in order for the whole network of centers of excellence to have a global knowledge and know-how on the various technologies existing on the market.

In the first step of the project (from January 2020 to the summer 2021), two main actions have been held. The first one consisted in proposing seminars around several aspects of Industry 4.0, targeting bachelor students. The second action consisted in designing an automation platform to be transferred in Asia. These aspects have been presented in [2].

During this 2021-22 academic year, hopefully thanks to attenuation of the pandemics, it was possible to welcome two Cambodian teams in Grenoble beginning of February and one from Thailand in March for a training of trainers about Industry 4.0 [3] [4] and PLC labs. A training was organized on-line for the Lao team, due to the impossibility for the Lao partners to come to France. The next step which is on the way is to send the platforms developed in Grenoble to our Asian partners and to organize a second training, on-site, for the Asian institutions to take their platforms in their hands.

The next section deals with the developments of the platforms, before they are sent to Asia. Section III gives details about the organization in Grenoble of the first training of trainers for the Asian partners. In Section IV, we develop the second training organized in Asia. Section V concludes and presents future activities.

II. DEVELOPMENT OF THE PLATFORMS

One of the main aspects of the project is to develop platforms for Asian partners. At UGA, we have a lab center containing various platforms in the field which was presented in previous papers [5] [6]. These existing platforms are the base of the new platforms developed for the project. The aim of these platforms, around a PLC, is also to focus on some specific applications, such as supervision, cyber-security, wireless networks...

As it was seen previously, Grenoble is in charge of 3 platforms for the three partners: ITC, NUOL and MFU.

First of all, for each of the three platforms, one of the innovations is the use of a specific emulation process card. This consists in an embedded Linux system on a ST-card, together with a network interface controller (NIC), various digital and analog inputs-outputs, some leds and switches are available [6]. This card can be programmed using a specific programming development. This emulation card is used in order to run a simulated system. The NIC allows the emulation process card to dialog with the other devices of the installation, as a normal process. The input-output interfaces allow a direct physical connection between the PLC and the emulation process card, this is one of the most interesting aspects of this card, since from the PLC perspective, there is an actual connection via the IO interfaces. The switches on the emulation process card allows to manually control the IO and leds are ON when their relative signal is ON. A software is used on a PC to remote control the emulation process card. Thanks to this architecture, it is possible to test various types of processes, for instance in partnership with companies, without having to install the complete physical process; it gives the platform an interesting generalization. This emulation card is available on the three platforms developed by UGA. The next paragraphs describe the three platforms.

The first lab is dedicated to the cyber-security of industrial systems. This lab is based on Schneider® technology. It is composed of a PLC, with direct Input-Outputs and a CAN network interface. An electrical motor is provided, in order to control a simple process, the motor. An emulation card is also provided, as the one which is described before. A distant HMI (Human Machine Interface) is used to supervise and possibly remote-control the system. In the industry 4.0 context, one of the aspects is to study the communication between the various devices of the system, especially between the PLC and the HMI: we can analyze how the communication is achieved, using an industrial protocol (example: Modbus) encapsulated in TCP/IP, which is the case of Modbus-TCP. The specific application of this platform is cryptography which is nowadays a challenge not only in the classical IT world but also in the Industry 4.0 context. For that we based our platform strongly on an existing Cyber-security platform provided by Schneider. As a complement to the automation devices and components described above, a Stormshield® Sni 40 Industrial Firewall and a manageable switch are available on the platform. An Industrial Firewall has some specific characteristics: its packaging is more robust (like the ones of PLCs) for industrial environments, some industrial protocols are managed by the firewall which allows for instance some specific rules for Modbus-TCP traffic, and finally it is possible to “program” some specific rules allowing or not some values on some variables. To give an example, if a hacker would like to increase the speed of the motor, a specific rule in the industrial platform may forbid this. Thanks to these elements, various strategies, such as the use of a Demilitarized Zone (DMZ) can be configured and tested. Finally, this platform allows achieving many applications such as the control of the engine but also of simulated processes (using the emulation card), the remote supervision of the system thanks to the HMI, and other activities around automation. In order to have the platform fully operational, some student projects and internships were organized. During the fall 2022, two students aims at developing pedagogical videos on how works the global platform and explaining the cyber-security possibilities. 4 videos were provided. During the spring 2023, two other students, within a four-month internship, extended the platform (new IO cards, the emulation card) and also translated in English and tested some labs textbooks which were available in French only on the initial platform. 8 cyber-security labs are so provided. The platform was finished and validated in July; it has been sent to Cambodia and is used there within the frame of the second training (see section IV of the present paper).

The second platform is oriented towards wireless networks, with an application particularly in the field of smart buildings. This platform is based on a Wago® PLC. As for the other platforms, some Inputs-Outputs will be directly and physically connected to the PLC. A motor is provided on the platform in order to test study cases. An emulation card (such as the one described at the beginning of the section) is also provided, to allow to simulate any kind of physical process, with an actual control coming from the PLC. Some wireless interfaces are provided, based on the EnOcean network, but also on LORA. A Human-Machine Interface is provided with a web-server. A switch organizes the communications. This platform aims at illustrating some applications oriented towards Smart Buildings and also in the field of Internet of Things. A master student was dedicated to this platform as his final project. He participated in the definition and

implementation of the platform and prepared it to be sent to Asia. The platform has been used during the second training in NUOL, beginning of July 2022. This experiment is explained in section IV.

The third lab is based on a Siemens® PLC. The main purpose of this platform is to study the supervision aspects, and the communication in a distributed master/slave strategy. It is composed of a PLC with inputs-outputs and a Profibus interface. A Remote Unit is also provided on this platform. Two emulation cards (described at the beginning of the section) are provided on this platform, one for the PLC and one for the Remote Unit. An HMI is provided to allow remote supervision, and also specifically to study the network infrastructure and message exchanges. A network architecture is provided around a switch allowing to analyze all the messages exchanged by all the participants of the network (PLCs, HMIs, computers...). In the spring 2023, a master student was working on the definition and implementation of the platform. Unfortunately, due to high delays on the device delivery due to the “electronic” crisis, it was not possible to finish and validate this platform. We expect to have the possibility to finish it and send it to Asia before end of October 2022.

For each of these platforms, a technical work has been achieved in Grenoble in order to set the platforms. Most of this work was actually achieved with the help of students. The pedagogic aspect is also important. We have defined the contents of the platforms according to some concepts we consider to be relevant for engineering programs nowadays. Various pedagogical tools: videos, slides, textbooks, lab textbooks, have been designed by the teachers and students of the UGA team. As it was mentioned before, one of the purposes of the project is to build a network of centers of excellence, in order for the Asian partners of the project to keep working altogether and sharing their experiences and applications field altogether, also after the end of the project.

III. FIRST TRAINING IN GRENOBLE

After some delays due to the pandemic situation, the first training was finally organized in Grenoble in spring 2023. The purpose of this training was for the colleagues to discover the platforms, work on them, to appropriate both the technical and the pedagogical aspects, in order in the future for these teachers to be able to manage and use these platforms with students. This training lasted two weeks. It was organized on-site beginning of February with ITC (which was actually together with RUPP (Royal University of Phnom Penh) in Grenoble), and end of March with MFU. Unfortunately, it was not possible for our Lao colleagues to come to France, so their first training was organized on-line.

For on-site trainings, the content of these two weeks was organized in three sub-parts.

The first sub-part regards courses: the purpose is to give partners some basics or more advanced concepts regarding their centers of excellence. The course has been adapted to the exact background and needs of the Asian colleagues and their expectations. For some aspects of the course, these are new concepts for the Asian colleagues and it is more to increase their expertise whereas some other courses aim at being taught later by our Asian colleagues to their own student. The course is composed of five sections. The first section is an introduction to PLCs: what are PLCs, how they can be used, their hardware architecture and configuration, the way to

program them, with practical examples, linked to the actual hardware architecture of each PLC. The second section deals with the PLC within its environment, and supervision issues. The purpose of this section is to present the interactions between the PLC and the supervision, the CIM architecture, the various industrial network protocols potentially existing. The third section focuses on cyber-security issues: this part is dedicated to a presentation of the main concepts and challenges around cyber-security, the specific challenges of Industrial Control Systems. The fourth section deals with emulation aspects, how to use the emulation card, how to develop emulated processes and how to interact with the emulation card within the lab. The fifth section deal with wireless networks and telecommunication aspects, what are the main challenges in the industry 4.0 environment, and how to use them within the proposed lab. Each of the five sections described above last around half a day. These courses give everybody a general overview of the needed knowledge, even if each of the specific center of excellence is specialized in one of the topics, considering first that some of these aspects are general background interesting for everybody and also that depending on the needs of local students or companies, it may be interesting to evolve in the future beyond the first need expressions of the centers of excellence. This part is interesting for the Asian partners also to prepare their own courses, for the future.

The second sub-part is the labs. This is the most important part of the training since the Asian colleagues will have work on the labs, on the specific PLCs they will have for their centers of excellence, and so this training is really oriented towards “training of trainers”. For that, before the arrival of the Asian colleagues, we (the UGA team, composed of teachers but also some master and PhD students) prepared some labs, adapted to the type of platform designed for the Asian partners. When the colleagues attended the first training in Grenoble, their platforms were not ready yet, so we worked altogether on the platforms available in the lab room in Grenoble, these platforms being close to the ones which will be sent to Asia. During the first week of the training in Grenoble, the colleagues achieved the labs proposed, under the supervision of the UGA team. At the beginning of the second week, and based on the competences acquired during the first week, the Asian colleagues were asked to design their own problem, as if they had to manage students, and then they developed and implemented their own projects.

The third and last sub-part is the “social” and “discovery” activity. A tour of the city and a social dinner were organized. We organized also the visit of the Gscop laboratory, which is the research lab in the field with the greatest expertise in Grenoble. A visit of a Teaching Department (Dept. of Mechanical and Manufacturing Engineering) was also organized for the colleagues to see how a teaching Dept. is organized in France.

For the on-line training, unfortunately, it was not possible to organize the last part: “social” and “discovery” activities. The main challenge for the organization of this training was to define how to organize it on-line. Based on our own experience of lab teaching during the pandemics, and in order to be resilient to possible difficult connections (between Vientiane and Grenoble), it was decided to prepare an architecture on which we can simulate the PLC and that the training focused mainly on the programming of the PLC itself, without taking into consideration the other devices available

on the platform for NUOL. It was decided to keep this part for the second training. The part dedicated on classes was achieved in the same way as for the ITC and MFU trainings, but on-line.

As a conclusion on this part, the organization of the first training in Grenoble was a good experience. The Asian colleagues were taught on the concepts of Industry 4.0 and trained on hardware close to their platforms. They were able during the second week to design and develop their own problems, which is a good result from the point of view for the “training of trainers” perspective. Of course, the on-line training for the third partner was more difficult to achieve, this aspect should be taken in account for the second training.

IV. SECOND TRAINING IN ASIA

After the first training organized in Grenoble and aiming to learn the concepts of Industry 4.0 and to be trained on PLCs close to the final platform, the second training is organized in Asia, in order to train people on the actual platform, and maybe to remind some concepts, if needed. The second training was organized in NUOL beginning of July 2022 and in ITC end of August 2022; it will be organized later for MFU. The organization of the second training is the following:

- Installation of the platform in its Asian environment, in a room dedicated as the Center of Excellence. Connection of the platform to the local network.

- Work with the Asian colleagues, to transfer the competences to allow them to work autonomously on the platform.

During the second training in NUOL, one of our Lao colleagues gave a class to a group of 6 students, about PLCs, and then the students were asked to achieve a lab. It was a short experimental training of 2 days.

Another aspect, linked to dissemination, is to meet some people in the Asian institution, for instance the Dean and other colleagues, in order that the existence of the Center of Excellence is known internally, in particular by the various Departments or Faculties which may be interested: for instances “Electronics/Automation” and “Computer/Information Technologies”.

Finally, some time is dedicated to the advancement of the project, notably with a meeting with the Project coordinator, and some reflections about the next steps of the project: implementation of the new courses and labs within existing curricula [7], and preparation of future trainings targeting students and a vocational training towards employees in companies.

The global objective of the second training: giving the platforms and the various pedagogical documents prepared for the platform, the pedagogical documents of the courses, was achieved with some of the partners. Of course, the Asian partners need to invest some times by themselves to take charge of the new platform.

V. CONCLUSIONS

On the conceptual dimension, the purpose of the project is to transfer the concepts of Industry 4.0 among which: automation: control, instrumentation, supervision, but also communication (wired and wireless), dependability and even cyber-security in an industrial context, these notions aiming at being part of new recognized curricula in the Asian institutions. The global project aims at proposing a network of centers of excellence in the field of Industry 4.0 providing

some focuses on each of the concepts of Industry 4.0. Each Center of excellence (6 within the project) will get from the project a dedicated platform with a specific application and a specific PLC environment from a specific brand.

In UGA (Grenoble), we are working in partnership with 3 Asian partners. For ITC, a Schneider-based platform [8] with a focus on cyber-security is now in Phnom Penh, and the second training is held end August 2022; for NUOL a Wago-based platform with a dedicated focus on wireless networks is available in Vientiane and was used during the second training; for MFU, a Siemens-based platform focusing on emulation and remote control is on finalization, some delays are due to the electronic “crisis” in the world, the second training is planned later.

Despite the pandemics but also the “electronic devices crisis”, and consequently correlated delays, the project has well advanced. Two platforms are now in Asia. The two Asian partners have been trained on their platforms thanks to firstly a first training in France (or on-line for NUOL) and a second training with the actual platform in Asia. The next steps will be the actual use of the platform with students in Asia, and the setting of a vocational training for employees of companies.

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