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Teaching induction machine laboratory using ProjectX

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Abstract

In electrical engineering computer simulation tends to replace almost entirely the classic experimental laboratories for different reasons: easier to be used by students and teachers, wide possibility of experiments, possibility of seeing a very quick response to fault situations, etc. In this context, the University of Pitesti, from Romania, enrolled in the Leonardo da Vinci Transfer of Innovation '*One Teacher and One Student working with ProjectX*', along with other six European VET educational institutions in order to develop a practical methodology that could apply in all of them. The purpose of the project is to create a common platform that has the purpose to help teachers work especially with students with different study paths due to their particularities.

Keywords: electrical engineering, induction machine, educational institution, common platform

1. Introduction

The current headlines of almost all publications, both on paper as online, contains topics like: electric car, renewable energy, energy efficient devices, industrial and home robots and appliance, intelligent house, solar panel, wind energy production etc. ("Discover Magazine," n.d.). In recent past the engineering education is becoming more popular among youth (Temiz and Akuner, 2009). This is due to the fact that technology is more advanced and is present in every aspect of work and social life.

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At the same time technical universities loose contact with daily activity required in regular engineering jobs. Computer simulation is used in almost every field of education, and engineering education is not an exception. Computer simulation has a wide variety of advantages and benefits for its users (Temiz and Akuner, 2009). Nevertheless graduates from educational programs that lose sight of hand-on experimental applications are facing an important handicap when they look for a job.

In electrical engineering, as in other fields of engineering education, computer simulation tends to replace almost entirely the classic experimental laboratories for different reasons: easier to be used by both students and teachers, wide possibility of experiments, possibility of seeing a very quick response to fault situations, etc. The hand-on experiments have an important role in education of future engineers (Zacharia and Olympiou, 2011) and practitioners (Renken and Nunez, 2013) (Iorgulescu and Savulescu, 2013).

In this context, the University of Pitesti enrolled in the Leonardo da Vinci Transfer of Innovation 'One Teacher and One Student working with ProjectX', along with other six European VET educational institutions in order to develop a practical methodology that could be applied in all of them. The purpose of the project is to create a common platform that has the purpose to help teachers work especially with students with different study paths due to their particularities (Bostan et al., 2014).

The participant institutions are from six European countries: Spain, Romania, Finland, France, UK and Turkey. Each ProjectX from each institution will be evaluated by other two partner institutions both in project meeting in person as also by email according to the project time management. The ProjectX should be an independent entity that can be accessed by students and it should provide all necessary information as far as: what it should be accomplished, what materials are required to fulfill the practice, what is the minimum bibliography, what are the expectancies after finishing the project, what is the connection of the practice with the industry ("One Teacher and One Students working with ProjectX," n.d.).

A result of applying the results of this project will be an answer to the need of change and encourage mobility through lifelong learning programs, which is a necessity that Universities need to adapt to in order to offer better educational programs (Chiţiba, 2012). Also as a result of direct practical relation of this approach with the industrial environment, both students and teachers could develop a positive attitude toward learning (Hursen, 2014).

2. The induction machine

The induction machine is the most used electric machine in industry (Hasni et al., 2012). The squirrel cage induction machine is the most efficient as far as production and maintenance cost of all the induction machines.

Induction machines could be found in very simple applications like conveyors to very advanced applications like cement mills and petroleum refineries. From the specialty literature it is known the fact that the squirrel cage induction machine is difficult to control. But the fact that its production and maintenance cost is the lowest of all electric machine makes it to have a big popularity in industrial applications.

Because of this wide spread of this machine, it is very likely that maintenance specialists, engineers, technicians or electricians, will encounter in their working experience this machine. In order to be able to ensure maintenance, these professionals have to have a common base regarding the use of this machine: electric connection to the voltage supply, basic functionality principles, ways of starting and braking, etc. This is the reason of choosing it as the topic of one of the ProjectXs developed at the University of Pitesti under the project '*One Teacher and One Student working with ProjectX*'.

3. ProjectX – starting the induction machine

If a maintenance specialist needs to deal with a simple installation it is very likely he/she will encounter simple starting methods for the induction machine: direct connection and star-delta connection. If the technological process includes automated operations, then it is likely that the automation for that process to be provided by a PLC (more or less complex).

In our opinion a technician should be aware of all these three approaches to the induction machine.

In this section it is described the theoretical and practical aspects related to the study of the use of induction machine.

3.1. Previous knowledge

In order to be able to maintain an electric installation of any kind, the student should be aware of basic standard dedicated symbols used by the CAD department. The students should be able to identify all the electric elements indicated in the design.

At the same time the student/future specialist should be able to identify the elements of all apparatus included in his/her project regardless of its stage: design, implementation or maintenance.

In this part of the project, students are getting familiar with interpreting the functionality of the analysed schematic, the datasheet of all components.

3.2. Direct start of the induction machine

Direct connection of the machine consists of connecting its terminals direct to the electric panel according the schematic as indicated in figure 1. It is important for students to learn from this simple application to follow the connections in the schematic as indicated in the design. Even though there are situations when connection might not be important from the functionality point of view, students need to be used to respect the electric connections as indicated by the designer.

In this application the most important concept to be learned is the auto-maintaining function provided by the contact KM1:13-14 located in page 2 of the project. Once this concept is fully understood it can be applied successfully in PLC programming to ensure the same functionality: to maintain the motor in function at the release of the starting push button S2.

Force schematic   Command schematic
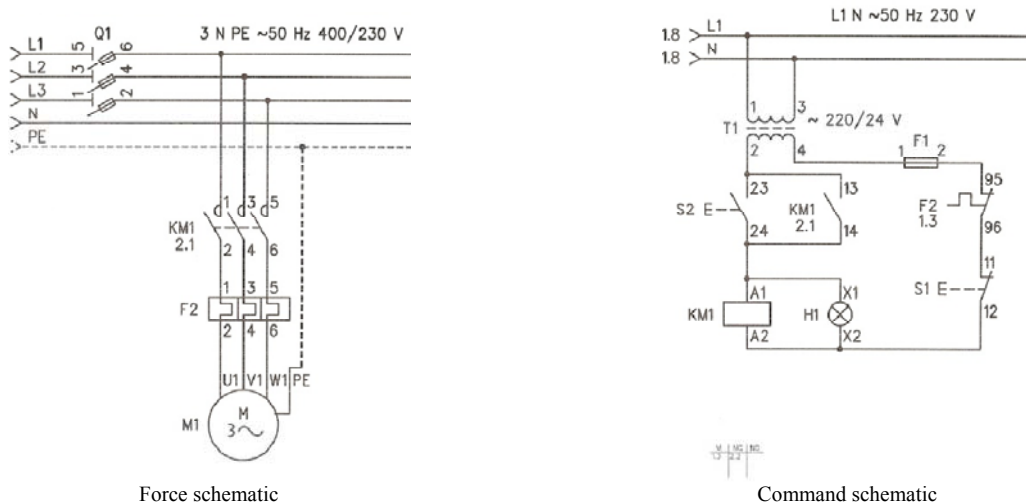
Figure 1. Direct start connection

Keeping in mind the fact that the finality is to program a PLC for this operation, one aspect is to develop the logic equation of the direct start process, indicated in equation 1:
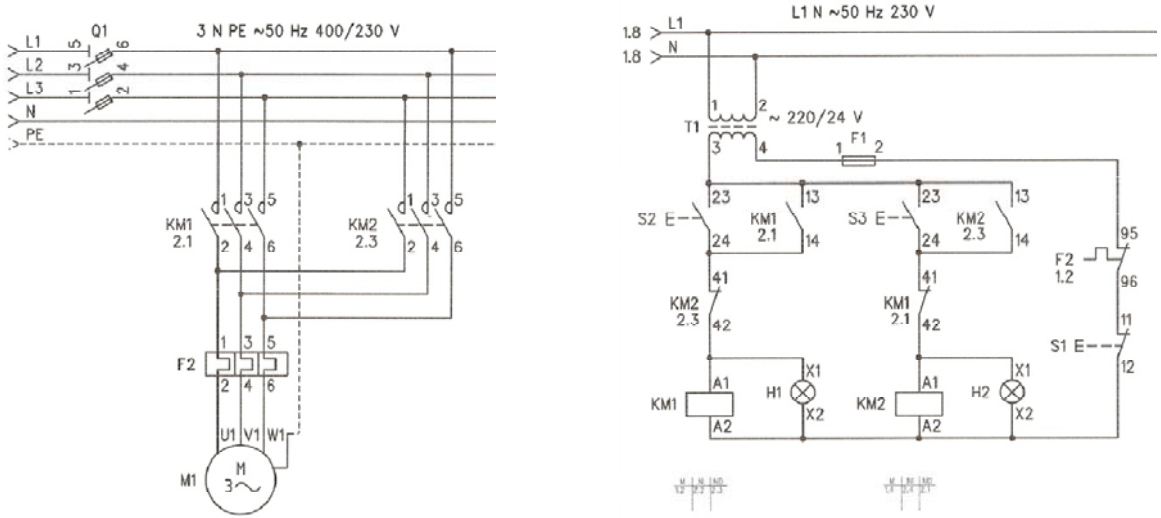
KM1 = (S2 **AND** (**NOT** S1)) **OR** (KM1 **AND** (**NOT** S1))   (1)

The graphic representation of the logic equation 1 is indicated in figure 2:

Figure 2. Graphic representation of the logic equation
for direct start of the induction machine

The next level is to develop the schematic for the direct start with the possibility of changing the sense of rotation in figure 3.

Force schematic   Command schematic

Figure 3. Direct start connection with change of sense of rotation

The logic equation of direct start with change of rotation is indicated in equation 2:

KM1 = (**NOT** KM2) **AND** ((S2 **AND** (**NOT** S1)) **OR** (KM1 **AND** (**NOT** S1)))
KM2 = (**NOT** KM1) **AND** ((S3 **AND** (**NOT** S1)) **OR** (KM2 **AND** (**NOT** S1)))   (2)

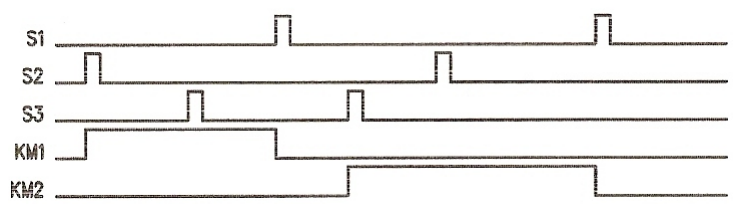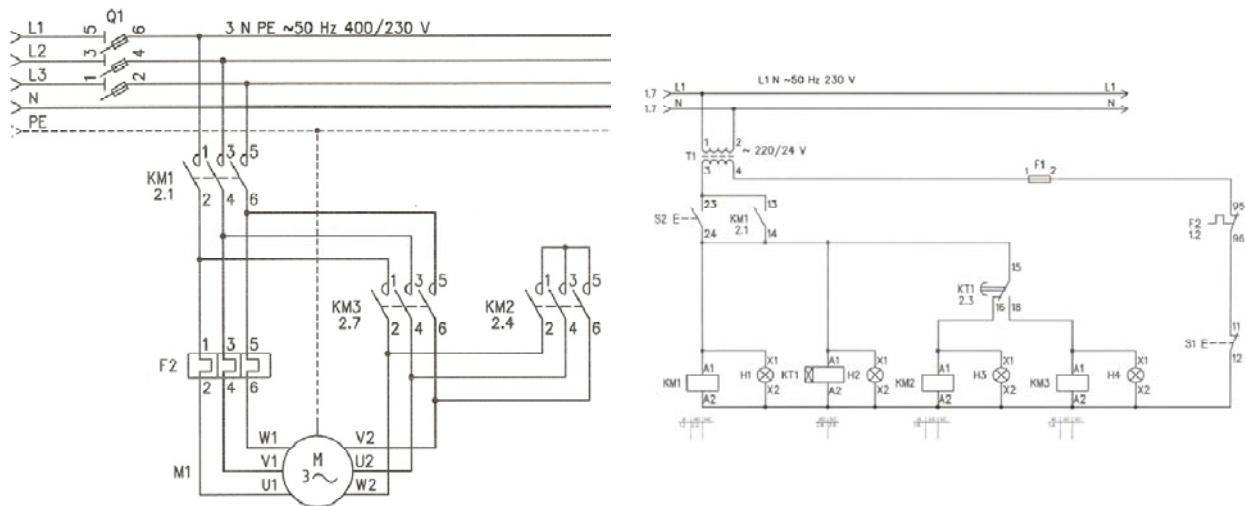The graphic representation of the logic equation 2 is indicated in figure 4:

Figure 4. Graphic representation of the logic equation
for direct start of the induction machine with change of sense of rotation

3.3. Indirect star-triangle start of the induction machine

Star-triangle method of starting the induction machine is used when it is desired to reduce the starting current absorbed by the machine when connected to the grid.

Force schematic   Command schematic
Figure 5. Indirect star-triangle start of the induction machine

The logic equation of direct start with change of rotation is indicated in equation 3:

KM1 = (S2 **AND** (**NOT** S1)) **OR** (KM1 **AND** (**NOT** S1))
KM2 = (**NOT** KT1+) **AND** ((KM1 **AND** (**NOT** S1)) **OR** (S2 **AND** (**NOT** S1)))
KM3 = KT1+ **AND** ((KM1 **AND** (**NOT** S1)) **OR** (S2 **AND** (**NOT** S1)))   (3)
KT1 = (KM1 **AND** (**NOT** S1)) **OR** (S2 **AND** (**NOT** S1))

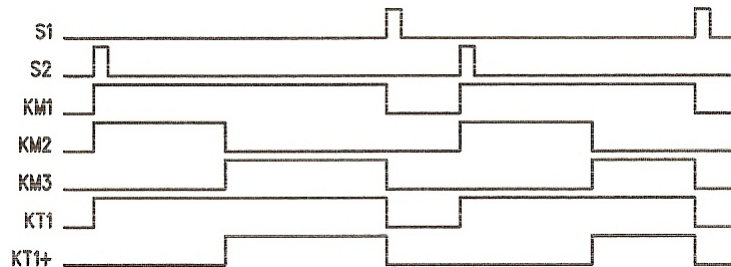The graphic representation of the logic equation 3 is indicated in figure 6:

Figure 6. Graphic representation of the logic equation
for indirect star-triangle start of the induction machine

3.4. Indirect star-triangle start of the induction machine with the change of direction of rotation

The indirect star-triangle method for starting the induction machine also has to permit the change of sense of rotation.
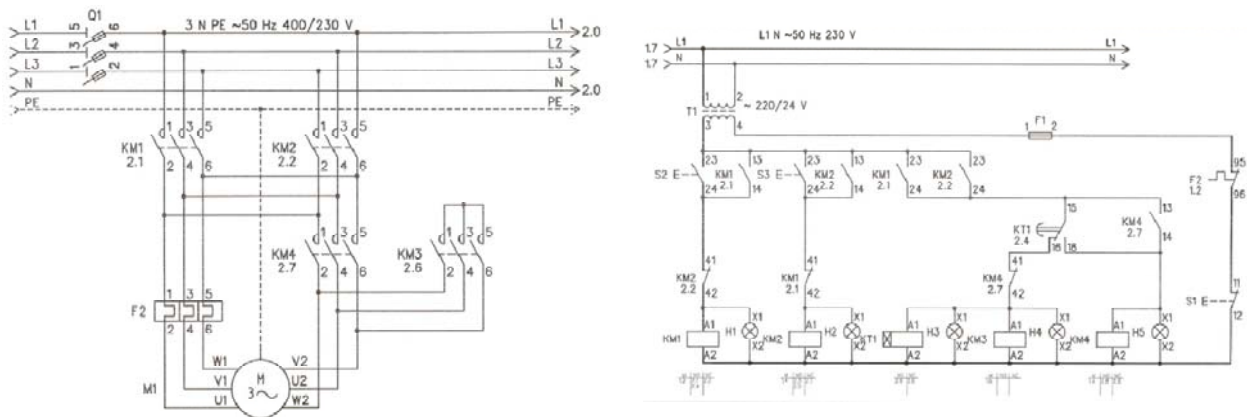
Force schematic   Command schematic
Figure 7. Indirect star-triangle start of the induction machine with change of sense of rotation

The logic equation that implements this process is indicated in equation 4:

KM1 = (**NOT** KM2) **AND** ((S2 **AND** (**NOT** S1)) **OR** (KM1 **AND** (**NOT** S1)))
KM2 = (**NOT** KM1) **AND** ((S3 **AND** (**NOT** S1)) **OR** (KM2 **AND** (**NOT** S1)))
KM3 = (**NOT** KM4) **AND** (**NOT** KT1+) **AND** ((KM2 **AND** (**NOT** S1)) **OR** (KM1 **AND** (**NOT** S1)))
KM4 = (KT1+ **AND** ((KM2 **AND** (**NOT** S1)) **OR** (KM1 **AND** (**NOT** S1)))) **OR** (KM4 **AND** ((KM2   (4)
AND (**NOT** S1)) **OR** (KM1 **AND** (**NOT** S1))))
KT1 = (**NOT** KM4) **AND** (**NOT** KT1+) **AND** ((KM2 **AND** (**NOT** S1)) **OR** (KM1 **AND** (**NOT** S1)))

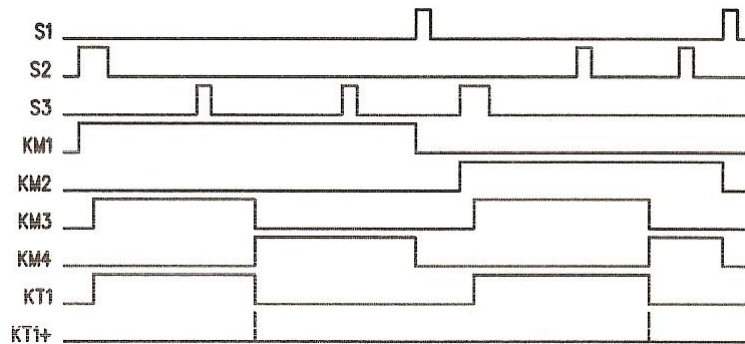The graphic representation of the logic equation 7 is indicated in figure 8:

Figure 8. Graphic representation of the logic equation
for indirect star-triangle start of the induction machine with change of sense of rotation

3.5. PLC start of the induction machine

All the methods already presented are manually commanded by the operator. These schematics are very likely to be encountered in almost any industrial facility anywhere. This is also the reason they are covered in almost any manual for any level of education for technicians and even for engineers (bachelor level).
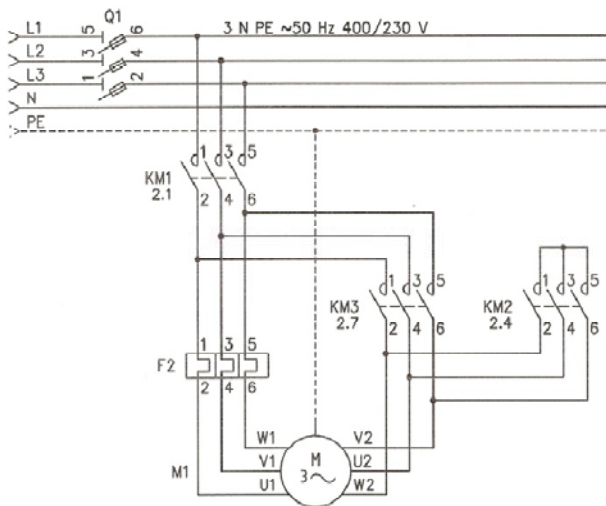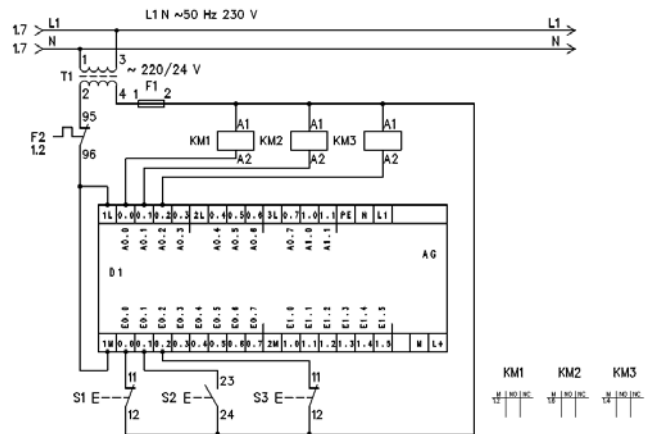
Force schematic   Command schematic
Figure 9. Indirect star-triangle start of the induction machine with PLC command

In figure 10 is indicated the PLC command for the indirect star-triangle start of the induction machine.
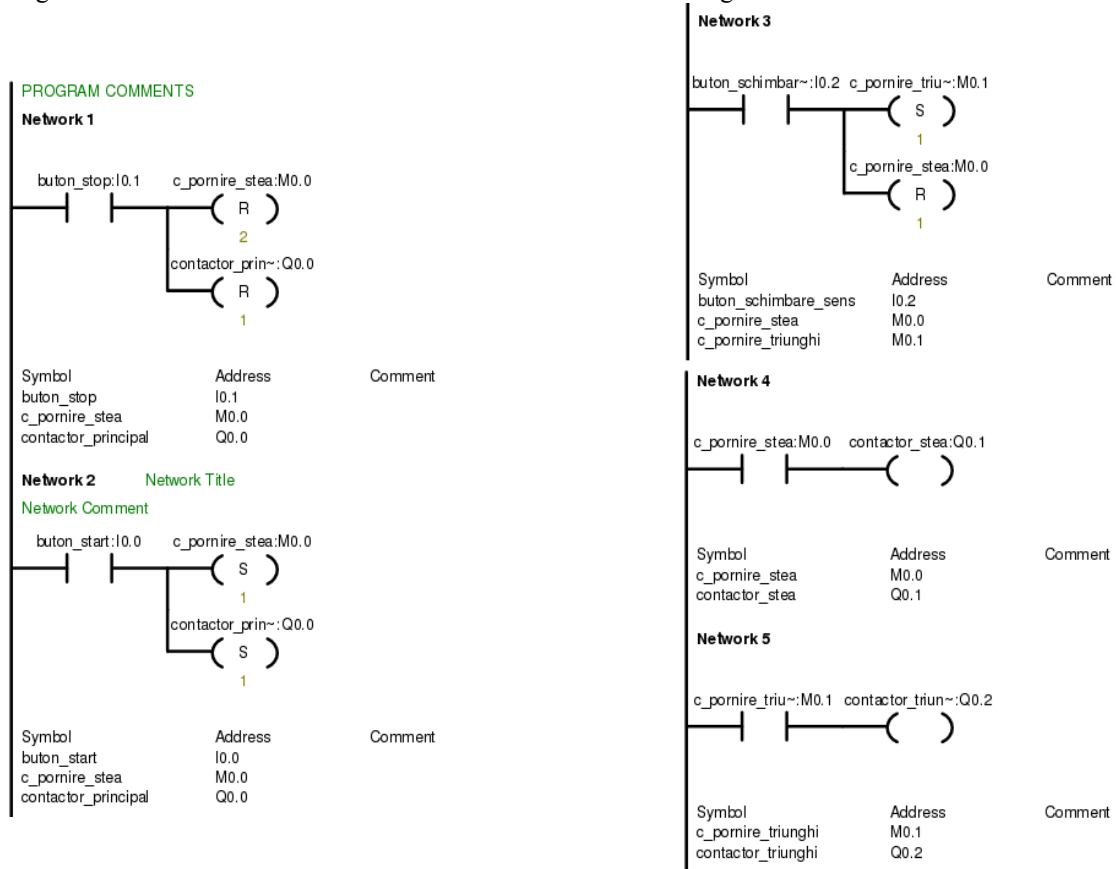

Figure 10. PLC program for indirect star-triangle start of the induction machine

Nevertheless, as the cost of PLC production lowers and the installations have to be as flexible as possible, it is necessary to introduce VET students the use of these control devices. Even if actual programming of PLC is dedicated for engineers, it is a good practice for the future technicians to be aware of the general use and connection in the schematic of controlling devices.

What VET graduates need to know is that PLC programming is done starting from the industrial process. Also it is very important to understand that the program of PLC is directly connected with logic equation that describes the function of the controlled industrial process.

4. Learning outcomes of the practice with ProjectX

The ProjectX is focused in obtaining four learning outcomes that the students have to acquire. Each learning outcome is described as: knowledge, skills and competences.

Learning Outcome 1:		Analyze the electric schematic for starting an induction machine
Knowledge:	**Skills:**	**Competences:**
To know the electrical symbols used in electric schematics	Understand the function of schematic for starting electric motors	Cognitive competence: to be able to read an electric schematic Functional competence: to be able to analyze the function of a basic electric schematic Personal competence: to be able to communicate with team members when analyzing a schematic; Ethical competence: to be able to work in team
Learning Outcome 2:		**Perform electrical installations and electrical maintenance for industrial premises**
Knowledge:	**Skills:**	**Competences:**
To identify the appropriate terminals of involved components in the force and command schematic	Perform connections in the command and force schematics. Use the appropriate tools to detect a defect in a schematic: voltmeter, ohmmeter, and ammeter.	Cognitive competence: to identify the appropriate terminals of the electric apparatus Functional competence: be able to wire different apparatus in the schematic. To be able to connect in an electric circuit basic measurement apparatus: V, Ω, A Personal competence: to be able to communicate with team members when analyzing a schematic; Ethical competence: be able to work in team
Learning Outcome 3:		**Install programmable automated systems**
Knowledge:	**Skills:**	**Competences:**
To identify the terminals of a certain PLC and the required voltages' levels to be applied.	Perform connection to the PLC terminals according the schematic.	Cognitive competence: to identify the appropriate terminals of the PLC using the manual Functional competence: be able to wire different terminals of the PLC according the schematic Personal competence: to be able to communicate with team members when analyzing a schematic; Ethical competence: be able to work in team
Learning Outcome 4:		**Write simple PLC program for sequential control systems**
Knowledge:	**Skills:**	**Competences:**
To be able to understand basic instructions to program a PLC	To be able to use basic instructions to program a PLC	Cognitive competence: to identify different visual basic symbols used in PLC programming Functional competence: be able to use visual basic instructions for PLC programming Personal competence: to be able to communicate with team members when analyzing a schematic; Ethical competence: be able to work in team

At the end of using this ProjectX, the students will have more knowledge about implementing an electrical schematic to start induction machines in different ways, specific skills and competences.

Working in this way, gives the student certain autonomy of the teacher, as he/she can work independent, knowing in advance what it is required at the end of class. Students acquire not only technical knowledge, but also this way of working helps them to develop in a personal way.

5. Conclusions

This paper presented a way of teaching the starting of the induction machine in different ways: both classic as advance methods.

The students will be able to:
- Read technical schematic
- Implement an electric schematic using classic apparatus and PLC
- Develop self-esteem as they have a great independency

The fact that this method is developed at the same time in different educational institutions in Europe is setting basis for student and teacher exchange.

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