E-learning of Electrical Engineering Subjects in the Context of the EU-Mong Educational Project

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***Abstract*—E-learning becomes more and more important in university to continue teaching activities also in the current pandemic situation. Already before the sanitary emergency, e-learning has grown significantly in recent years. The European Commission has subsidized different projects aimed at developing e-learning, such as the Euro-Mongolian cooperation for modernization of engineering (EU-MONG) in various branches. In the context of this project, this paper highlights the courses of the electrical engineering curriculum (electrical machines, design of electrical systems, distribution systems and distributed generation, photovoltaic and wind power plants) for the grid integration of intermittent renewable sources. These courses are provided by the Italian partner, with some differences in virtual teaching due to the different topics.**

Keywords— E-learning, electrical engineering, education.

I. Introduction

Today e-learning is becoming more and more important, especially in the context of outbreaks like the current COVID-19 disease. There are many educational platforms, as for example MOODLE which supports the open software BBB [1] currently used for the online teaching activities at Politecnico di Torino [2]. Another widespread used e-learning platform is EdX – a massive open online course provider [3]. It hosts online university-level courses in a wide range of disciplines, including some free courses. It also studies new e-learning methods based on how people use the platform. The EdX project was founded in 2012 by the Massachusetts Institute of Technology and the Harvard University in the US. Based on the experience obtained by EdX, the project Open edX started [4].

Open edX is an open-source tool that permits to freely construct platforms for other institutions to share online courses. The success of this software is that it can be managed at different levels. Advanced users can access and improve the open-source code. Basic users can exploit a high number of standard features available in user-friendly interfaces. First at all, the teachers can share course materials, such as videos, slides, scripts, etc. Teachers can also post discussion boards, manage teams, edit grades, and communicate with the students. It is also possible to integrate third-party tools (plugins, javascripts, etc.) in the platform to increase the experience of the students with advanced interactive contents [5]. Some examples are virtual laboratories, the use of external software, and code programming.

The contents of the courses are divided into sections and subsections. In each subsection the teacher selects the type of content. Fig. 1 shows an example of course with different typologies of contents. Videos are the easiest tools, as they can be recorded and then inserted in the platform. Slides are used to add simple or interactive text. Problems can be added and they can range from simple problems with numerical inputs to more interactive problems with hints and feedbacks. Discussions (not present in the figure) permits to discuss with students as in a blog. More advanced contents can be added by advanced coding [6]. A wide range of sources, starting from the official guidelines to external blogs and websites, provide info and explanations on how to organize the contents.

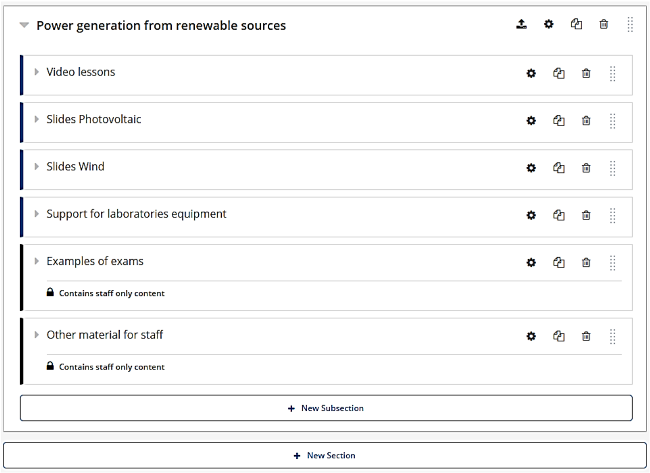

Fig. 1. Example of categories of contents for teachers of the platform Open-edX .

II. The EU-Mong Project

The Euro-Mongolian cooperation for modernization of engineering (EU-Mong) started in 2018. It is a project funded by the European Commission[1] in the frame of "competence building in higher education" and it is mainly based on e-learning [7][8]. The goal of EU-Mong is the modernization of electrical and electronic engineering curricula in Mongolia. It works through sharing facilities and expertise in new methodological and pedagogical approaches and teaching/learning materials development. The Internet courses are created within the project, and they will provide new opportunities for cooperation between Mongolian and EU universities in sharing of knowledge and educational resources.

After the end of the project the curricula and web-based training modules developed will be integrated in the regular M.Sc. degrees in engineering fields of the Mongolian universities, and with this purpose they have been developed. In addition, the Web-based content has two main advantages for the sustainability of the results. First, the students could access the courses from their country, i.e., ensuring virtual mobility without additional financing. Second, the content is easily changeable and upgradeable, that is mandatory for a country in industrializing phase as it is Mongolia nowadays.

A. The needs of the EU-MONG stakeholders

The main recipients of the project are university students and teachers; nevertheless, other stakeholders are involved, such as institutions and enterprises. Regarding the students in engineering master degree, they require high-quality educational materials, and continually up-to-date courses. Courses are selected to meet education needs related to their further work. As a result, the acquired knowledge and skills will permit them to perform successfully the tasks in the industrialization of their country.

Regarding the Mongolian teachers, their main needs are infrastructure, modern equipment and facilities for teaching. They also need techniques for course delivery allowing easy changes and upgrade for the new needs in the country and for higher motivating the students, i.e., ICT-based materials.

From the point of view of higher education institutions, providing M.Sc. degrees in engineering sciences, the EU-Mong project gives the opportunity to share facilities and teachers' expertise. Their share is fundamental to rapidly develop laboratories in the electrical engineering with the best results. In fact, laboratories and other teaching facilities are generally composed of expensive infrastructures and complex equipment. For example, the expertise in building them can help universities minimizing the investment and maintenance cost of laboratories. In the same way, the expertise of teachers and technicians in using the laboratories can help Mongolian partners in increasing the teaching efficiency in these laboratories. Finally, thanks to the EU-Mong project, the Mongolian enterprises will have experienced industrial engineers capable of managing complex equipment and plants, and with knowledge and skills to use and maintain them.

B. The roles of the EU-MONG stakeholders

Students are the main actors in the field trial, referring to a period of two semesters for all the universities in the partnership. They will be the main users, along with the teachers, of the modernized curriculum and the pool of learning resources and the new opportunity of virtual mobility. Teachers will be involved in curriculum development process from the preliminary stage to the review process as the main part of the review team, in course materials development and integration in the M.Sc. programs, in the pilot test and field trial. University management will be involved in analysis and curriculum innovation, and in quality assurance. Regarding the companies, the involvement of company staff in teaching and course development will improve the preparation of future graduates for the industrial environment. They will have the opportunity to use the material created in the EU-Mong project for training their staff. Thus, the large variety of free courses developed by academicians and researchers all over Europe is another benefit for the representatives of the business.

The project partners work out a strategic plan to support sustainability, which foresees different activities for each output/outcome targeting sustainable exploitation of project outcomes/outputs after the funding period.

The expected results of the EU-Mong project (including an Exploitation Agreement about a fruitful future collaboration), which will end in year 2021, are both at local and national levels. At local level, Mongolian universities will have modernized curricula, and modern laboratories upgraded with new equipment. Enterprises in the engineering sector will have better educated young engineers, prepared for the work market and as a result higher employability. At national level, the results will be the improvement of the high education in the country following the national priorities and strategic development. In addition, the successful implementation of modernized curricula in engineering will encourage the curricular reform in other areas of high education in the country. Finally, there will be benefits in the cooperation between European Union and Mongolia, based on the internationalization of the high education, the new links between universities, institutions and companies.

III. E-learning Courses in Electrical Engineering

The lectures include different teaching materials and methods, according to the experience of the teachers and the typology of the topics [9]. Some teachers propose video lectures, others prefer video slides. Scripts, exercises and additional suggested books are always used to support the students in their e-learning.

In some cases, professional translators support the teachers in recording of videos and audio slides, and in checking of the scripts; it is done to guarantee the highest level of quality for technical and non-technical English.

[1] The partners are four European universities/institutions (Technical University of Sofia as the coordinator, Politecnico di Torino, Technical University of Berlin, National Institute of Solar Energy from France, and three Mongolian universities.

The Italian workgroup[2] of the EU-Mong proposes four e-learning courses related to Electrical Engineering. A brief description of the courses (Fig. 2) and of the contents posted on the Open edX platform is presented below.

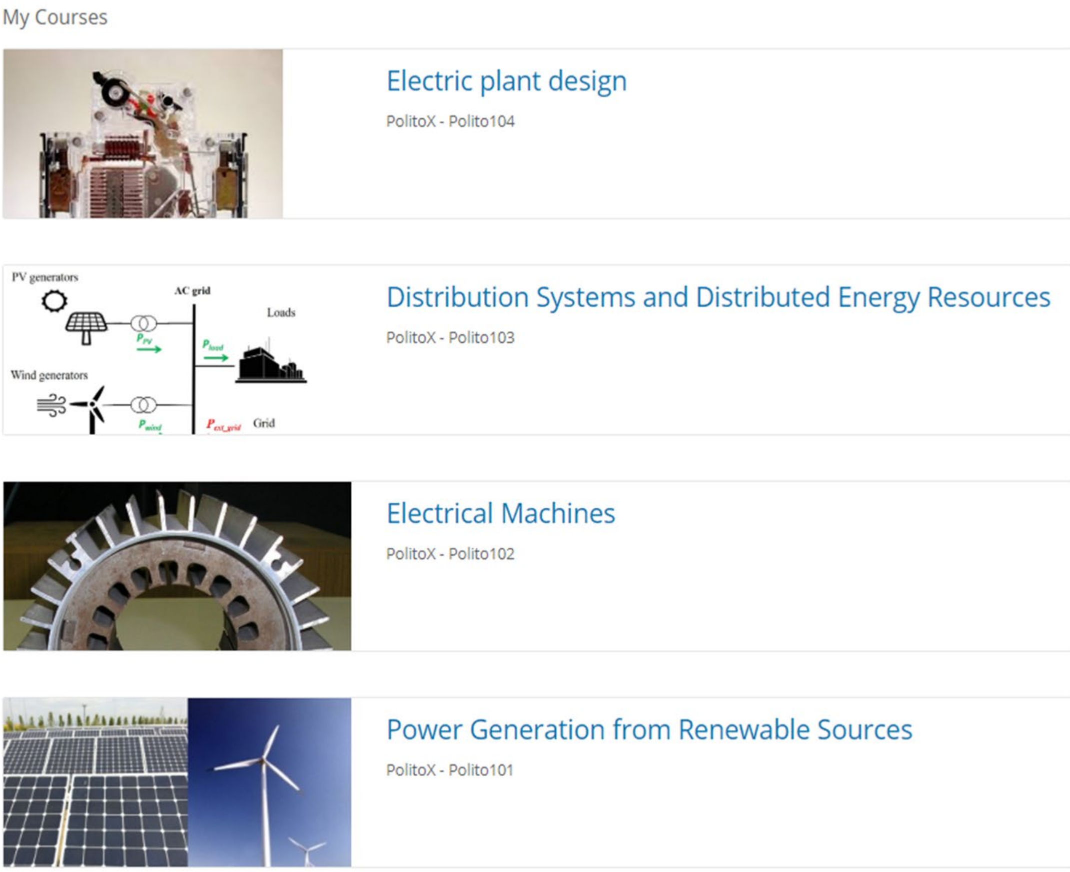

Fig. 2. Screenshot of the courses in Electrical Engineering.

A. Electrical Machines

The course "Electrical Machines" is held by prof. Luca Ferraris. The course aims to provide the methodological bases for understanding the operating principles and key operational concepts of electromechanical equipment and in general a rational, proper and safe use of electrical equipment. The operating principles of the main electrical machinery are introduced, in view of their application in industrial processes, and the tools to evaluate the performance will be detailed with numerical exercises.

A.1. Learning outcomes

The successful completion of this course enables the students to:

- know the principles of the main electro-mechanical equipment and electrical machinery used in industry;
- know the criteria for use and application fields of the electrical machinery;
- analyze and evaluate the performance of electric machines with special attention to wind power; and,
- make the choice of the appropriate electrical equipment to be included in mechanical systems.

A.2. Teaching methods on the Open edX platform

The audio slides are recorded in professional English by the teacher: they include written text, multimedia and the recording of the explanation of all the contents. The total duration of the content explanation is more than 8 h. Furthermore, the slides used in the audio slides are available for the students to support them in the study of the contents. Practice activities consist of the numerical exercises. For deepening, it is suggested to read the book [10].

A.3. Assessment

Regarding the final assessment, different methods are possible; the teacher proposes a written test, and a compulsory oral exam. The written exam consists of the solution of two exercises, in about 1.5 h. Topics of the exercises are: magnetic circuits, evaluation of the working conditions of transformers, asynchronous and DC machines.

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[2] The workgroup is composed of the coordinator prof. Filippo Spertino, and other four professors, an administrative and a technician.

B. Analysis and Design of Electrical Systems

The course "Analysis and design of electrical systems" is held by prof. Paolo Di Leo and prof. Angela Russo. The course is aimed at providing the fundamental elements of electrical installations design with professional focus. The course enables the students to acquire specific professional skills, through the illustration of the main design principles and solutions, the application study of traditional and advanced components for electric systems and building automation, with the detailed analysis of the criteria for component selection and sizing. The last part of the course is devoted to some basic concepts on electrical installations for users and their preliminary design.

B.1. Learning outcomes

The successful completion of this course enables the students to enhance their:

- knowledge on professional aspects concerning electrical installations design and multi-disciplinary integrated design;
- ability to identify the design objectives and to translate the operating choices into specific documents (technical reports, schemes and drawings, economic assessments);
- ability to interpret and apply laws and standards;
- knowledge of design solutions for electrical installations in ordinary and non-ordinary environments.

For deepening, it is suggested to read [11] and [12].

B.2. Teaching methods on the Open edX platform

The audio slides are used as the main remote teaching method. The audio slides are available for the students to support them in the study of the contents. Furthermore, a script of the proposed topics is provided by the teachers as a support for the students; this document was translated in English by a professional translator to guarantee the proper use of technical words related to electrical engineering. Finally, four exercises (to be performed with the calculator) are provided with their respective solutions; the total time required to solve the four exercises is approximately 8 h.

This course starts with theoretical notions and includes design activity, which is an experimental task. Thus, in this course the optimal teaching procedure requires workgroups, design activities and the use of professional design software. Each theoretical presentation is followed by the development of the related design documentation. The students should be organized into groups of 3-4 persons. Each group will develop reports and drawings, according with a given plan. The student should develop ability in using the graphic software, such as Autocad, and the electric system design software. By performing these tasks, they will acquire not only hard skills related to electric system design, but also soft skills, such as team working.

B.3. Assessment

At the end of the course, each group must hand out its project, before the examination. Each student will be subject to a written examination, followed by an oral discussion of the project. The duration of the written test is 3 h. During the written test it is possible to use only a portable calculator and the notes provided by the teachers. The final grade is given in consideration of the results achieved in the written test, the oral test and the project, evaluating the acquisition of the expected learning outcomes.

C. Power Generation from Renewable Sources

The course "Power Generation from Renewable Sources" is held by prof. Filippo Spertino with the assistance of PhD Alessandro Ciocia. The course deals with the main technologies about Photovoltaic (PV) generators and wind turbines, including the usage of automatic data acquisition systems to check the real performance of components, to calculate the productivity and to correctly design the main components of these power systems.

C.1. Learning outcomes

At the end of the course, the students will know the solar and wind resources, the main technologies about the photovoltaic generators and wind turbines (including general aspects of power electronics), and will be able to calculate the electricity productivity and to correctly design the main components of these power systems.

The course is organized with 40 h of lectures and 20 h of classwork exercises and laboratories. Classroom exercises are scheduled for a total of about 14 h, starting from a summary of electric circuits. In the first part of the course (photovoltaic generators), theory and corresponding exercises permit to obtain the following abilities:

- calculation of the electrical parameters of the PV modules in conditions different from the rated STC by nameplate data of the manufacturers;
- calculation of reverse currents in PV strings connected in parallel;
- determination of the optimum coupling between PV generator and inverter; and,
- calculation of the energy production in a PV system, and usage of PVGIS software for estimation of solar irradiation and PV energy.

In the second part of the course (wind turbines), the students learn how to:

- calculate mechanical quantities in a wind turbine;
- use the simplified equivalent circuit of the asynchronous machine, in the application of the Doubly Fed Induction Generator; and,
- calculate the energy production of a wind turbine.

During the course, laboratories, for a total of about 6 h, are offered to the students as a support in the learning by practical activities. They consist of the measurement of the current-voltage (*I-V*) curve for a PV module under dark conditions; the measurement of the *I-V* curve of an irradiated PV module; the measurement of the output characteristics for a transistor operating as a switch; the measurement of efficiency and power quality for single-phase inverter.

As a conclusion of the course, the teachers offer a (video recorded) guided tour to some of the PV plants operating inside the Politecnico di Torino headquarter. It consists of a good opportunity for the students to see currently used components of the PV plants, such as PV modules, power converters, cabinets, etc.

C.2. Teaching methods on Open edX platform

The video lessons consist of recordings related to the photovoltaic and wind power systems with a total amount of more than 50 h. All the lessons are divided in 1.5 h units with both the visualization of the teacher and the visualization of the interactive whiteboard. The lessons include theoretical lessons, exercises and laboratories. Furthermore, the slides used in the video lessons and scripts of the proposed topic are provided as a support for the students. Finally, the teacher provides contents to support the development of experiments in laboratories (four experiences in laboratories) and examples of written exams with the solutions for the final evaluation of the students. For deepening, it is suggested to read the book [13].

C.3. Assessment

Regarding the final assessment, different methods are possible, and the teachers propose a method, that is already used in courses in Italy. The proposed assessment includes a written test, with an optional oral exam. The written exam lasts 2 h. The students have to provide short discussions, drawings and formulas, and solve numerical exercises regarding the classroom exercises. Theoretical questions are worth 20 points, while a total of 10 points can be obtained by solving the exercises. During the written exam students can use an electronic calculator, but it is not permitted to use other documents regarding the program of the course. The space available for the answers, on the single sheet of the written exam, is limited to test the ability of the student to summarize the concepts. It helps to test the ability to synthesize, fundamental in every work activity. In case of few students, the oral exam is possible: as in case of the written exam, it deals with the whole program of the course. During the oral exam it is not possible to use any document.

D. Distribution Systems and Distributed Energy Resources

The course “Distribution Systems and Distributed Energy Resources” is held by prof. Gianfranco Chicco. The course provides the fundamental notions on distribution system modeling and analysis also in the presence of distributed energy resources (DER). The impact of the DER introduction in the electrical networks is studied by addressing theoretical aspects and application examples concerning distributed generation, distributed storage and demand response. The analysis techniques include the probabilistic power flow solved with the Monte-Carlo method, in which the backward-forward sweep method is used for distribution network calculations. Scenario analysis is used to understand the DER impact in distribution systems.

D.1. Learning outcomes

At the end of the course, the students will gain skills for interacting with the operators of the electrical system by using the correct terminology and by showing appropriate knowledge to discuss the basic issues concerning DER. The minimum objectives to be reached as learning outcomes include the ability to:

- use the right terminology in addressing the problems concerning distribution networks and DER applications;
- define the models of the components used in distribution systems and writing the equations describing the distribution system operation;
- identify the operational characteristics of the main DER components; and,
- interpret the problems concerning the DER introduction in the electrical systems.

D.2. Teaching methods on Open edX platform

The audio slides are used as the main remote teaching method. The topics are divided into three main parts, namely, (i) distribution system structure and operation, (ii) distributed generation, and (iii) demand response and storage. The slides used are available for the students to support them in the study of the contents. Finally, it is presented an example of exercises to be performed by the students with the support of the computer. For deepening, it is suggested to read the books [14][15].

D.3. Assessment

Regarding the final assessment, the teacher chooses the oral exam. It lasts about 1 h per student and consists of the discussion of the topics presented in the lessons. The solution of numerical problems can be required to the students during the exam. During the oral exam it is not possible to use any course material.

IV. Focus on Laboratory Practices

The course “Power Generation from Renewable Sources” offers innovative laboratory practices to the students of Politecnico di Torino. In the context of EU-MONG, the Italian partner shared its experience, results and feedback from students to permit to Mongolian teachers to replicate these practices.

In the traditional assessment of power and energy production from PV systems, the calculations are based on the nameplate data of the manufacturers. The laboratories are created by following an innovative procedure in which the first step is the measurement of the actual performance (in situ) of the main components. Then, gaining these results, students will acquire the competence to perform an accurate estimation of energy production. Thus, the laboratories permit practical experience related to the operation of the photovoltaic generators, and electronic devices and components (i.e. transistors and AC/DC converters). In addition, the students acquire practical knowledge of devices used to measure voltage and current.

Regarding the measuring instruments, the students will start from the simplest one to the most complex one: first, digital multimeters, then oscilloscopes, and finally automatic data acquisition systems [16][17][18]. In the first laboratory experience, the students will learn the main differences between handheld and bench multimeters. In case of simple troubleshooting, a high resolution is not required for measurements. In this case, handheld digital multimeters are the best solution, with a low number of bits (generally 12÷16) with sampling rates up to several tens of thousands samples per second to calculate the root mean square values. On the other hand, bench multimeters provide a higher number of bits, ranging between 18 and 24. These high-performance instruments are used by the students for practical exercises requiring higher accuracy.

Fig. 3. Handheld and bench multimeters used in the 1st lab test.

In the next laboratory experience, digital oscilloscopes are used by the students to display and analyze the waveform of electric signals, i.e., the graph of the instantaneous voltage and current signals as function of time. Students learn how to work with manual or automatic function, starting from the use of triggers on voltage or current signal. The oscilloscopes have high sampling performance that can reach sampling rates up to 1 GSa/s; on the contrary, the resolution is lower (generally 8 bits) than multimeters. Thus, the students use oscilloscopes for looking at signal shapes, measuring the signals amplitude and frequency, and testing malfunctioning of electronic equipment.

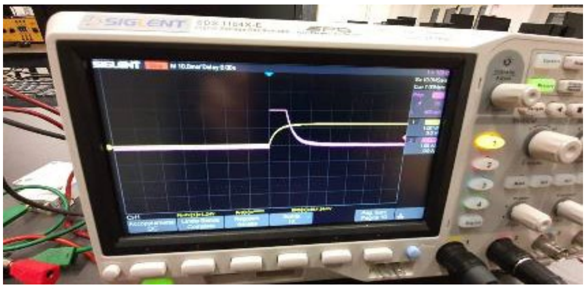

Fig. 4. Oscilloscope (8 bits, 1 GHz) used in the 2nd lab test.r

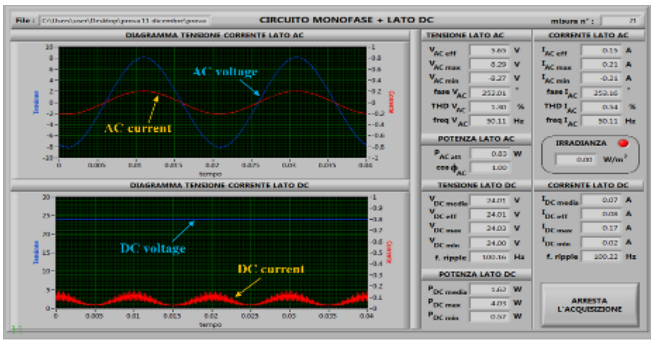

Fig. 5. Screenshot of the software of the automatic data acquisition System used by the Italian students.

In the last laboratory experience, Automatic Data Acquisition Systems (ADAS) are used by the students to automatically measure from sensors, transmit data to a computer, and store it. These instruments reach an optimal compromise between high levels of resolution and high sampling rates. Their resolution can be 16 bits or higher, and the sampling rate can be millions of values per second.

A. Measurement of the dark I-V curve of solar cells

In the first laboratory practice, students check the performance of solar cells with no irradiance (dark conditions), in case of both forward bias and reverse bias. From a theoretical point of view, solar cells are described by an equivalent circuit consisting of a current source and an antiparallel connected diode with two resistances. The current source explains the photovoltaic conversion; the diode takes into account phenomena of diffusion and recombination of hole-electron pairs; the resistances quantify the series and shunt losses [19][20]. After the theoretical description, the students trace the *I-V* curve of solar cells in dark condition. In particular, students use the power supply to apply voltage from zero up to the open-circuit voltage of the PV module. In this way, students understand that photovoltaic modules are diodes. Thus, at low voltages no conduction occurs, while, after a threshold voltage, the current exponentially increases [21]. Students trace a great number of points close to the threshold to better appreciate the exponential trend of the curve. The same procedure is repeated in case of reverse bias. In this case, the current in the circuit is only tens of milliamperes (much lower than the amps measured in case of forward bias). Students can store few points, reaching voltages up to -20 V and observing the linear current trend.

Finally, the measurements uncertainty is calculated by students starting from the datasheet uncertainty of the multimeters used in the practice.

B. Measurement of the I-V curve of irradiated solar cells.

In the second laboratory practice, students trace the *I-V* curve of irradiated solar cells and measure their performance with a digital oscilloscope. They have to set the parameters of the oscilloscope; for example, they define the trigger on the current signal in order to catch a single shot evolution. They also build the circuit, in which the PV module charges a capacitor [22]. The capacitor is initially discharged, and when it is connected to the PV generator (by the closing of a circuit breaker) it works from short-circuit to open-circuit condition. At the beginning, the PV module works in open-circuit condition: after the closing of switch, voltage is zero because the capacitor is discharged, and the current is the maximum that solar cells can provide (the short-circuit current). Then, the voltage linearly increases, while the photo-generated current is almost constant. Finally, capacitor voltage saturates reaching the open-circuit voltage of the PV generator; thus, no current flows in the circuit.

After the analysis of the transient acquired by the oscilloscope, students download data on the PCs and represent the irradiated *I-V* curve. Finally, they calculate the performance of the PV generator and the other main electrical parameters.

C. Measurement of the output I-V curve for a transistor

In the third laboratory practice, students trace the output *I-V* curve of a transistor operating as a power switch. In particular, they work with an Insulated Gate Bipolar Transistor (IGBT). This device has three terminals: a collector, a gate and an emitter. Students learn that a voltage applied between the gate and the emitter permits to control the operation of the transistor. This control voltage must be higher than the activation threshold; in this case, the transistor is activated. Students vary the power supply, and measure the current (only a few amperes for safety) flowing in a circuit composed of a power supply (bias), a series connected resistor, and the collector-emitter terminals.

D. Measurement of the waveforms of a DC/AC converter and its performance.

In the fourth laboratory, students use an ADAS to calculate the performance of a Pulse Width Modulated (PWM) inverter. The acquisition boards used in the Italian laboratories have eight channels: two are used to measure DC current and voltage, other two are used for AC signals. Students have to build the measurement circuits and to use proper components on DC and AC side to filter the input/output signals to reduce the harmonic distortion. In particular, on DC side, students connect an inductor to filter the current, while, on AC side, they build a low pass filter with an inductor and a capacitor. Then, they learn the operating principles of DC/AC converters. An inverter converts DC quantities into AC signals, but the DC/AC conversion leads to losses. At full load, the efficiency of the converters is adequate, while at partial load the no-load losses impact on the inverter production, determining a lower efficiency. Then, students check the effects of the filters on the inverter performance. Finally, the students evaluate the total harmonic distortion for both voltage and current signals, with different loads [23].

V. Conclusions

One of the main goals of the “Euro-Mongolian cooperation for modernization of engineering” (EU-Mong) project is to help Mongolian universities in the creation of new curricula in the industrial engineering field, according to the future work market. The courses, proposed by the Italian partner (Politecnico di Torino) for the Electrical engineering curriculum, are devoted to prepare future electrical engineers to work with grid-connected renewable based systems, e.g., PV generators and wind turbines. For this reason, electrical engineers need knowledge and skills related to electrical machines, such as the operation of the induction machines, necessary for wind power systems. In the same way, a strong background related to the proper design of grid-connected electrical systems, distribution lines and devices is needed. Then, students can understand the operation of PV plants and wind turbines, and their connection with the grid. The courses are offered by the free platform Open edX, which permits an e-learning that can be customized using different contents (videos, audio slides, scripts, etc.) on the basis of the proposed topics, and that can be continuously updated. The importance of e-learning is confirmed by the current pandemic situation; students can continue their studies also in case of physical distancing.

Finally, in order to complete the background of the new electrical engineers, the Italian students have practical laboratory experiences. Laboratory practices are developed in order to reach two goals. First, they study and better understand the operation of electronic devices and components of photovoltaic generators. The proposed innovative procedure is not simply based on nameplate data of components, but provides actual values measured from students. Thus, students acquire the competence to perform the assessment of photovoltaic energy production with high accuracy. In addition, the students work with different kinds of measurement systems, learning pros and cons of each one. This competence will be useful in their whole working life as electric engineers.

All the know-how to perform these lab experiences is shared with Mongolian partners in order to replicate them, and create Italian-Mongolian twin laboratories.

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VI. References

[1] BigBlueButton, Open source web conferencing system, [Online] https://bigbluebutton.org/about/, (accessed on 28.05.2020).
[2] Politecnico di Torino, [Online] https://www.polito.it/ateneo/?lang=en (accessed on 28.05.2020).
[3] EdX® project. [Online] https://www.edx.org/ (accessed on 28.05.2020).
[4] Open EdX® project, [Online] https://open.edx.org/ (accessed on 28.05.2020).
[5] Open EdX® project, Description of the platform, [Online] https://open.edx.org/the-platform/ (accessed on 28.05.2020).
[6] Open EdX® project, Open edX XBlock Tutorial. [Online] https://edx.readthedocs.io/projects/xblock-tutorial/en/latest/index.html (accessed on 28.05.2020).
[7] Euro-Mongolian cooperation for modernization of engineering education (EU MONG), [Online] http://eu-mong.eu/ (accessed on 28.05.2020).
[8] S. Tzanova, Work in Progress: Competence Building in Engineering Education in Mongolia, *Proc. EDUCON 2020*, 27-30 April 2020, pp. 33-36.
[9] Open edX® platform of the EU-MONG project. [Online] http://34.90.160.25/ (accessed on 28 .05.2020).
[10] N. Mohan, *Electric machines and drives: a first course*, Wiley, 2012.
[11] M. Patel, *Wind and Solar Power Systems*, CRC Press, 2017.
[12] V. Cataliotti, *Impianti elettrici* vol. I, II, III. Flaccovio, 2018 (in Italian)
[13] F. M. Gatta, *Impianti elettrici*, Esculapio, 2012 (in Italian)
[14] W.H. Kersting, *Distribution systems modeling and analysis*, CRC Press (ISBN 0-8493-0812-7), 2001.
[15] D.N. Gaonkar (ed.), *Distributed Generation*, Intech, 2010. [Online] http://sciyo.com/books/show/title/distributed-generation.
[16] SDM3045X datasheet [Online] siglentna.com/wp-content/uploads/dlm_uploads/2017/10/SDM3045X_DataSheet_DS06034-E02B.pdf.
[17] 87V handheld Multimeter datasheet [Online] fluke.com/en/product/electrical-testing/digital-multimeters/fluke-87v
[18] F. Spertino, A. Ciocia, F. Corona, P. Di Leo and F. Papandrea, "An experimental procedure to check the performance degradation on-site in grid-connected photovoltaic systems," *IEEE 40th Photovoltaic Specialist Conference (PVSC)*, Denver, CO, 2014, pp. 2600-2604.
[19] M.B.H. Rhouma, A. Gastli, L.B. Brahim, F. Touati, M. Benammar, "A simple method for extracting the parameters of the PV cell single-diode model", *Renewable Energy*, vol. 113, pp. 885-894, 2017.
[20] F. Spertino, A. Ciocia, P. Di Leo, S. Fichera, G. Malgaroli, A. Ratclif, "Toward the Complete Self-Sufficiency of an nZEBs Microgrid by Photovoltaic Generators and Heat Pumps: Methods and Applications", *IEEE Transactions on Industry Applications*, vol. 55, no. 6, pp. 7028-7040, Nov.-Dec. 2019.
[21] J. Ahmad, F. Spertino, A. Ciocia, P. Di Leo, "A maximum power point tracker for module integrated PV systems under rapidly changing irradiance conditions," *2015 International Conf. on Smart Grid and Clean Energy Tech.*, Offenburg, pp. 7-11, 2015.
[22] F. Spertino, J. Ahmad, A. Ciocia, P. Di Leo, A. F. Murtaza, M. Chiaberge, "Capacitor charging method for I–V curve tracer and MPPT in photovoltaic systems", *Solar Energy*, vol. 119, pp. 461-473, 2015.
[23] F. Spertino, G. Chicco, A. Ciocia, G. Malgaroli, A. Mazza, A. Russo, "Harmonic distortion and unbalance analysis in multi-inverter photovoltaic systems," *2018 International Symposium on Power Electronics, Electrical Drives, Automation and Motion (SPEEDAM)*, Amalfi, pp. 1031-1036, 2018.