The Training of Renewable Energy Systems: Undergraduate Studies

V. Esen, S. Varbak Nese, S. Saglam, B. Oral

***Abstract*— As in all over the world, interest in usage of renewable energy sources has increased in Turkey. Due to intersection of universities leadership on the research and the technology field with the renewable energies innovative feature, it is convenient to provide these provide renewable energy trainings in higher education. To provide practical training to have qualified personnel, new laboratories are required to be established in this field. Therefore, it is becoming extremely important to provide practical training in the field of renewable energy at undergraduate and postgraduate level in universities. In this study, practical working example is provided the scope of has been established in technical equipment of the renewable energy laboratory within Marmara University Faculty of Technology Electric Electronic Engineering Department. This study intends to provide guidance to further studies in renewable energy education.**

Index Terms—**Engineering education, Power engineering education, Renewable energy sources, Vocational training.**

I. Introduction

ENERGY needs of countries is increasing due to the improvement of life quality and technological development [1,2]. Besides, public awareness on the environmental impact of fossil fuels formed and environmental incentives of governments has increased the interest in renewable energy sources [3,4]. Concordantly, new energy policies of many countries are directed to the use of clean and renewable sources [1]. As a result of the growing encouragement and technological development in the field of renewable energy, requirement for more research and technical people has emerged as a growing need [5]. Engineering education plays a crucial role in meeting this need in the whole education system [6].

V. ESEN, Istanbul Arel University, Vocational School, Department of Electricity, Sefakoy Campus, Istanbul, Turkey. (e-mail: vedatesen@arel.edu.tr)

S. VARBAK NESE, Marmara University, Technology Faculty, Department of Electrical and Electronics Eng., Istanbul, Turkey. (e-mail: secil.varbak@marmara.edu.tr)

S. SAGLAM, Marmara University, Technology Faculty, Department of Electrical and Electronics Eng., Istanbul, Turkey. (e-mail: ssaglam@marmara.edu.tr).

B. ORAL, Marmara University, Technology Faculty, Department of Electrical and Electronics Eng., Istanbul, Turkey. (e-mail: boral@marmara.edu.tr)

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Development of theoretical and practical concepts in engineering training is based on practical experiments. [7]. In this context, undergraduate and graduate levels of renewable energy education, besides the technical information students to gain the creative and innovative features, it is possible with practical work [8].

The present study highlights the importance of supporting students with the application of theoretical knowledge in the field of renewable energy. In Marmara Universtiy Technology Faculty founded a RES (Renewable Energy Sources) laboratory for the undergraduate and graduate students to be able to conduct practical work. The technical equipment and the examples of applications in the said laboratory are presented in detail.

II. Renewable Energy Education in the World and Turkey

Education is vital in social development and energy is key to sustainable development [9, 10]. Increased sensitivity about energy security of countries, supporting policies and decreasing energy costs have increased the integration of renewable energy systems to the power system. 100 GW of renewable energy capacity has been added to power system in the last three years worldwide [11].

As is the case in all development processes, this rapid progress has created the need for qualified personnel. To meet the need, diversified training programs have emerged [10]. In the world, renewable energy education at undergraduate level includes various courses and research programs [12]. However, graduate programs have a priority compared to undergraduate program in renewable energy education [13].

Today, there are no private programs at undergraduate level in the field of renewable energy [10]. However, graduate programs on renewable energy sources are offered, and short-term training programs are also available. In addition, associate degree programs are offered in the United States and a large number of vocational courses are available in many European countries [13]. Increasing the usage of renewable energy sources in Turkey is inevitable for the following reasons [1]:

- Import dependency (more than half of its energy),
- Limited fossil energy sources,
- Rapidly growing energy consumption,
- Increased environmental awareness,
- Advantages of geographical position for the usage of renewable energy sources.

In Turkey, 4% of electricity generation was provided from renewable energy sources of the country in 2014; and the utilization of renewable energy sources for the purpose of electrical energy generation is promoted by the related laws and regulations [14].

This field has steadily increasing number of advantages and incentives and accordingly education on the field should be offered in line with the following aims [1]:

- To increase public awareness and introduce basic concepts through short-term courses at college level and media,
- To meet the need for trained field staff with certificate and diploma courses,
- To meet design, development and evaluation needs with the bachelor's degree in the field of energy engineering,
- To train scientists and engineers with graduate courses for sustainable development of technology.

However, renewable energy education in Turkey is mostly offered at the tertiary level [15]. Although graduate training has focused on renewable energy sources, elective courses are rapidly increasing in the related departments. In addition, vocational courses are offered for field staff [16].

III. LABORATORY SCOPE AND EXPERIMENTS

In the laboratory, experiments are planned to explain scientific and engineering fundamentals of renewable energy based electricity generation. Cognitive experiences of the students are supported by psychomotor experiences for persistent skills development using laboratory equipment. Wind and solar energy test equipment are used to recognize wind and solar components in the power systems. During the selection process of the test equipment, their specific qualities such as their usability for different applications and adaptability for new technologies are taken into consideration. Therefore, test equipment is convenient for graduate level trainings.

For scientific researches, the laboratory is equipped with professional solar simulator (Fig. 1). In the simulator, AM 1.5 solar spectrum intensity can be obtained from a circle of 16 cm in diameter with 300W ceramic xenon lamp. Also, ambient temperature change is only 3-4^{0}C. So, it can be used to explore solar cells and their characteristics. At the same time, age related efficiency changes and power quality effects for grid connections of photovoltaics can be examined under simulated real conditions. As a power quality study, the effects of harmonics generated by electronic inverter can be examined for grid connection.

In addition to graduate level studies, undergraduate level experiments which can be carried out in solar equipment (Fig. 2) and their supplementary benefits for technical equipment usage are listed below.

- Light intensity and temperature measurements: Different types of light source are used to measure and examine light intensity using Solarimeter, Luxmeter and Pyranometer. Photovoltaic panel surface temperature is measured with infrared thermometer.
- Exploring photovoltaic panels: Photovoltaic panel peak voltage and peak load current are measured and compared with the panel production values.
- Load effects on photovoltaic panel output voltage: Different types of loads are used to examine the effects of load characteristics on photovoltaic panel output voltage.

Fig. 1. Solar simulator

- Temperature effects on photovoltaic panel output voltage: Photovoltaic panel surface temperature is increased incrementally and photovoltaic panel output voltage is measured and analyzed.
- Inverter output voltage-Load type correlation: Under the fixed light intensity, inverter output voltage is measured and analyzed using power quality analyzer for different load characteristics (Fig. 3).

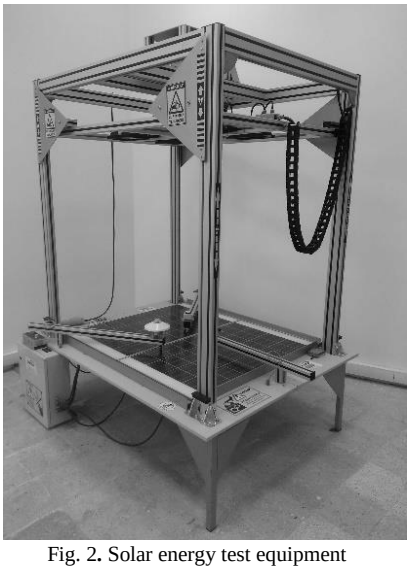

Fig. 2. Solar energy test equipment

In the wind energy test equipment, 0-12 m/s wind speed can be supplied (Fig. 4). On the other hand, the distance between fan and wind turbine can be changed to increase wind speed. Different wind turbines with suitable dimension blades and

turbine simulators can be tested. So, graduate level studies for the determination of optimum load conditions, blade design, pitch angle control, blade faults and electrical faults of generator can be realized. In addition to these studies, wind energy experiments for undergraduate level are listed below and necessities of them are explained.

Fig. 3. Data acquisition and measurement instruments

- Wind speed measurements: This parameter is very important to determine the area to install a wind turbine/farm. The measurement of wind speed is performed with this experiment to teach anemometer usage, possible measurement errors and the parameters which affect wind speed knowledge.
- Wind speed-wind turbine cycle correlation: Cut-in and cut-off speeds, tachometer usage and vibration measurement qualifications are introduced to the trainees in this education program.

Fig. 4. Wind energy test equipment.

- Wind speed-output voltage of wind turbine correlation: Wind speed value can be changed in this test-rig. So, output voltage change, wind turbine response can be analyzed according to wind speed changes.
- Wind speed-load current of wind turbine correlation: Load current changes with wind speed can be investigated. The efficiency of investigated wind turbine in terms of meeting load demand is explored.
- Exploring output power of wind turbine for different loads: Output power is explored for different load types. So, the person who completes this program gains knowledge about interconnecting of turbine response.

For measurements from test equipment a Matlab/Simulink program is generated (Fig. 5). Data of wind and solar energy test equipment rigs are transferred to computer through data acquisition card. This measurement type is preferred because of its feasibility. The students can also practice the basics of data acquisition and signal processing techniques.

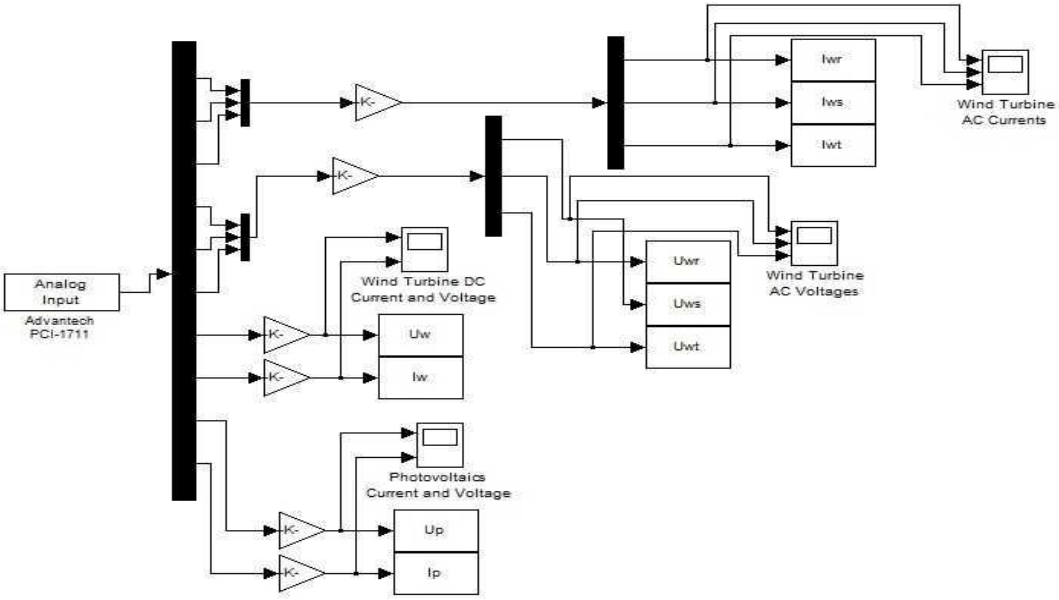

Fig. 5. Hybrid system Matlab Simulink Model

IV. CONCLUSION

All over the world, with the increased use of renewable energy sources the training of qualified personnel has become mandatory in the sector. It is possible to train qualified personnel who have the skills to follow new technologies, plan, make decisions, manage and apply projects according to local conditions. In this study, a new test equipment was designed utilizing previous studies in order to provide trainees with the basic engineering skills in this field.

In this context, the following training outcomes are identified, learned, understood and applied by the trainees.

- Renewable energy sources used for electrical energy generation,
- Principles of energy conversion,
- Measurement and evaluation of meteorological data,
- System response according to meteorological conditions,
- Determining the appropriate field conditions and installation of renewable energy conversion systems,
- Solar and wind based electrical energy generation in power systems,
- The operation of hybrid systems,
- Grid connection and power quality,
- Results of extreme operation conditions (faults, strain, etc.).

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BIOGRAPHIES

VEDAT ESEN was born on June 30, 1982 in İstanbul, Turkey. He graduated from Marmara University, Technical Education Faculty, İstanbul, in 2009 and received M.Sc. degrees from Marmara University, Institute of Pure and Applied Sciences, in Istanbul, Turkey, in 2011. He has been started Ph.D. studying in department of Electrical and Electronics Engineering Marmara University, Institute of Pure and Applied Sciences in 2011. He is currently instructor in İstanbul Arel University. His current interests are power systems and renewable energy systems.

SEÇİL VARBAK NEŞE was born in Istanbul, Turkey. She received B.Sc. degree from Kocaeli University, M.Sc. degree from Afyon Kocatepe University and Ph.D. degree from Marmara University. She is currently working as a research assistant in electrical-electronics engineering department in technology faculty at Marmara University. Her interest areas are renewable energy systems, electrical power systems, signal processing and fault diagnosis techniques.

ŞAFAK SAĞLAM, was born on September 11, 1976 in Samsun, Turkey. He graduated from Marmara University, Technical Education Faculty, Istanbul, in 1997, and received MS and PhD degrees from Marmara University, Institute of Pure and Applied Sciences, in Istanbul, Turkey, in 2000 and 2006 respectively.

He has been employed as a research assistant and assistant professor in Technical Education Faculty between 1997 to 2012. Presently Dr. Sağlam is an Associate Professor in Technology Faculty Electrical and Electronics Engineering Department at Marmara University. His special fields of interest include renewable energy sources, illumination and power systems.

BÜLENT ORAL, was born on July 05, 1970 in Çorlu, Turkey. He graduated from Marmara University, Technical Education Faculty, Istanbul, in 1994, and received MS and PhD degrees from Marmara University, Institute of Pure and Applied Sciences, in Istanbul, Turkey, in 1997 and 2004 respectively. He has been employed as a research assistant, lecturer and assistant professor in Technical Education Faculty between1994 to 2012. Presently Dr. Oral is an Associate Professor in Technology Faculty Electrical and Electronics Engineering Department at Marmara University. His special fields of interest include energy policy, electricity market and renewable energy systems.