Experience to Electrical Engineering Students the Principles of Smart Grid Platform

Hen Friman

Abstract— World Energy Consumption relies heavily on coal, oil, and natural gas. Fossil fuels are non-renewable, that is, they rely on finite resources that will eventually dwindle, becoming too expensive or too environmentally damaging to retrieve. In contrast, renewable energy resources, such as wind and solar energy, are constantly replenished and will never run out.

Due to the rising need for professionals and academics with a background and understanding in the Smart Grid and Renewable Energy fields, Holon Institute of Technology ("HIT") developed a new program at the Faculty of Electrical Engineering. The Renewable Energy program gives the students technical and practical aspects of energy use (technology and methodology of the study) and energy efficiency. The program also deals with minimizing the environmental impacts of energy use, as well as with energy economy and environmental policy. HIT offers its students a well-equipped laboratory, containing state of the art equipment in various fields such as: photovoltaic energy systems, a smart grid telecommunications and information security platform, wind and water energy work stations, and power electronics equipment. This article presents the latest teaching and conclusions obtained in experiments conducted on the system platform.

***Keywords*—** Electrical Engineering, Energy Crisis, Renewable Energy, Smart Grid.

I. Introduction

HIT – Holon Institute of Technology was established in 1969 and became an independent public academic institution of higher education in 1999, certified by the Council of Higher Education of Israel. HIT focuses on the teaching of sciences, engineering, computer science and technology, management of technology and design. It also emphasizes multi-disciplinary theoretical and practical research of innovative technologies from a professional scientific, economic and cultural perspective. HIT trains highly qualified students in the realms of science, engineering, management and design, and plays an important role in their integration upon graduation into key positions within the industry.

HIT aspires to quality and excellence in teaching and innovative research, and strives to introduce novel and unique cutting-edge teaching and research technologies. HIT also prides itself on its advanced academic achievements, application of innovative techniques and interdisciplinary professionalism that lead to creative teaching and new technologies. HIT aims to utilize the intellectual and professional potential of each and every student, so that they can fully integrate into the fast-paced technological world of today. Providing superior technological and scientific education enables HIT graduates to enter key leadership positions in both the private and public sectors.

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II. Electrical Engineering

A. *Faculty of Engineering*

The last decades have been dominated by the rapid changes introduced by the technology revolution, which has a tremendous influence on our daily lives. Today we are facing a myriad of new challenges. Technology-based industry has matured in many ways and the required skills for future engineers are much more complex in a world where "machines/computers" execute many of the engineering tasks. Most of all, we are facing a new generation of sophisticated students, who were born into the digitized/multimedia world. The mission of the study program is to encourage and initiate academic development, through the development of new study programs and methods, while being responsive to the rapidly changing trends in the field. The proper education of the undergraduate students must also be a function of market needs and predictions of how technology will develop in the foreseeable future. In order to ensure that our graduates are well qualified to meet the future needs of the market, meticulous attention must be paid to maintain a high standard in the fundamental courses and impart practical tools and skills. It is also important to introduce a wide variety of new subjects. The aims and goals of the Engineering faculty are to provide the students with a rich and comprehensive study program, and keep the study program updated to meet the ever-changing requirements for engineers of the future, enrich the student's theoretical knowledge as well as teach practical and design skills and knowledge; adapt its teaching methodologies and techniques, focusing on understanding as a goal; enable students to achieve skills such as self-learning and to acquire expertise via practice by understanding constantly update the teaching methods and the study program maintain relationships with the various relevant industry sectors introduce the students to state-of-the-art equipment and facilities, for conducting experiments that reinforce their

understanding of the theoretical and practical issues studied in the courses promote research in the various fields; and explore cooperation with other institutes in Israel and abroad.

B. Renewable Energy and Smart Grid Excellence Centre

The Energy field is thriving, due to several factors: the world energy crisis, political trends that create a rise in oil prices and other environmental topics. All of these have brought upon us the emergence of new and fascinating fields dealing with Energy. The introduction of renewable energy sources to the electrical grid and the realization of the need to optimize the current network with modern tools, have both led to a new research field: The Smart Grid.

The introduction of alternative (renewable) energy sources for the electrical grid and the realization that there's a need to improve and optimize the current network using modern tools, has brought upon a new research field called The Smart Grid.

The Smart Grid field creates a new interaction among various disciplines. Its goal is to create an electrical grid that is controlled by computers that are inter-connected via a cutting edge communication network. This is an entirely new technological and conceptual revolution.

Following the receipt of an award for research, funded by the Chief Science Officer of Israel, a research group and the renewable energy and smart grid excellence centre were founded in HIT in June 2011 with the purpose of encouraging research and creation in the field of energy.

At the heart of the centre, the renewable energy and smart grid laboratory was established. The laboratory is equipped with state of the art equipment and experiments, including: photovoltaic energy, water energy, wind energy, fuel cells and smart meters and smart grid equipment. The laboratory is a “paper free” laboratory.

Our Team's vision is to combine the vast knowledge of the institute's researches in this field, and to create national excellence and research centre for the advanced energy fields.

This group is unique in that it includes HIT's researches and leading industry figures from various energy fields, as well as Design researchers, HIT's maintenance manager, and students.

The centre's objectives are in one hand to teach and enrich students with the most recent technologies in this field and on the other hand, to create scientific collaborations that will lead to receiving prestigious grants, as well as to publishing joint essays. Collaboration with the industry enables the establishment of joint ventures which will promote both research and the institute in this field.

When you submit your final version, after your paper has been accepted, prepare it in two-column format, including figures and tables.

III. The Energy field

In recent years, the world has become more aware of the pollution on Earth. It is no secret that our world became filled with greenhouse gas, CO_2, NO, NO_2, and so on. These gases are by-products of our industry (cars, factories, power stations etc.), and they hurt us by warming the globe, damaging our oceans and the living-beings. That way we breathe more toxic gases which hurt our body. The Solution to this problem was to minimize the amount of emitted substances from the industry as soon as possible, and to do it worldwide. Focused on this decision, humanity searched for an alternative way to produce green power. Building alternative energy systems e.g. Wind turbines, photovoltaic cells, watermills and so forth, became more popular in our world. They all connected to the transmission lines of the grid and gave us the ability to consume the green energy from the grid. By this, power stations reduced the pollution significantly [1]. At first, the alternative energy sources provided a good solution, producing power to the costumers, but then all the countries suffered numerous blackouts. The problem was that the distribution lines knew how to handle one source of power generation, and sent the power over the grid to the costumers. With those alternative energies there were thousands of little manufacturers which also sent power to the grid. These many manufacturers caused an overload in the grid and created power outages across the countries [2]. To overcome this obstacle, engineers invented the Smart Grid. The Smart Grid goal was to manage the electricity demand in a sustainable, reliable and economic manner. The Smart Grid provides us control of electricity in the grid in real time and delivers it to the customers, who consume the exact amount of power they need. Furthermore, the Smart Grid can manage the incoming power to the grid through the various energy sources and send the energy through the distribution lines to the costumers in an effective way. The Smart Grid using smart meters, that can read the information over the grid and send it to the control room, using communications protocols. At the control room, the information is processed and updated on the main hub to enable new interrupts, which are used to command the smart meters and maintain the power quality in the grid. As the Smart Grid became more popular in countries all over the world, the amount of electrical engineers needed increased. Therefore, we need to train more engineers on the Smart Grid platform in order to meet that demand. The training must include all the components of the Smart Grid – theoretically and practically [3].

IV. Smart Grid

The Smart Grid does not have one definition that is universally accepted. It can be described both in simple terms and in ways that are more complex. It used to be a dream and just an idea but now it is one of the most talked about topics in modern electrical system. Simply put, the Smart Grid is an intelligent grid. The traditional grid can only transmit or distribute electric power. This modern grid is able to store, communicate and make decisions. The Smart Grid transforms the current grid to one that functions more cooperatively, responsively and organically [4]. The possibilities of the Smart Grid are vast in the advent of modern technology and increasing interdependence among the grid players. There are tremendous

opportunities for experimentations, tests and trials. The Smart Grid can provide a "platform to maximize reliability, availability, efficiency, economic performance, and higher security from attack and naturally occuring power disruptions" [3, 5]. The Smart Grid classifies as actors devices (such as smart meters and solar energy generators), systems (such as control systems), programs, and stakeholders that make decisions and exchange information necessary for performing applications; applications as tasks performed by one or more actors within a domain [1]

V. Energy Laboratory

Due to the need to train more engineers, a new program was developed at HIT, about the field of Smart Grid. This program provides students with theoretical and practical knowledge on the Smart Grid platform. The Smart Grid lab works under a "Next Generation Lab", meaning that the lab is paperless [Fig. 1]. All the theoretical background and the exams are computerized on a "MOODLE" platform [6]. In the experiments, the students must first read theoretical background. After they finish reading the theoretical part, they need to answer an entrance examination about the subject. All the questions are taken from a database of questions, and are selected randomly. Passing the exam shows that the knowledge was acquired properly. Upon completion of the exam, the first stage of the experiment appears in the system. When the students complete the first stage, the MOODLE automatically continues to the second stage of the experiment and so on. All the stages in the lab provide the students with the materials they need to finish them, meaning that all stages in the experiment are escorted by "GOOGLE DOCS" sheets which show dynamic graphs and can be supervised by the lab instructors in a real-time. The students have to analyse the graphs they received during the stages and understand exactly how the graphs were built, and what formula can describe the graphs in each stage. At the end of the experiment, when all stages are done, the MOODLE lets the students take a final exam, which includes questions about the experiment results that the students received. At the end of the exam the students are automatically graded with no report needed, and the data of each student is saved in the MOODLE for analysis of the results later on by the instructors [6, 7].

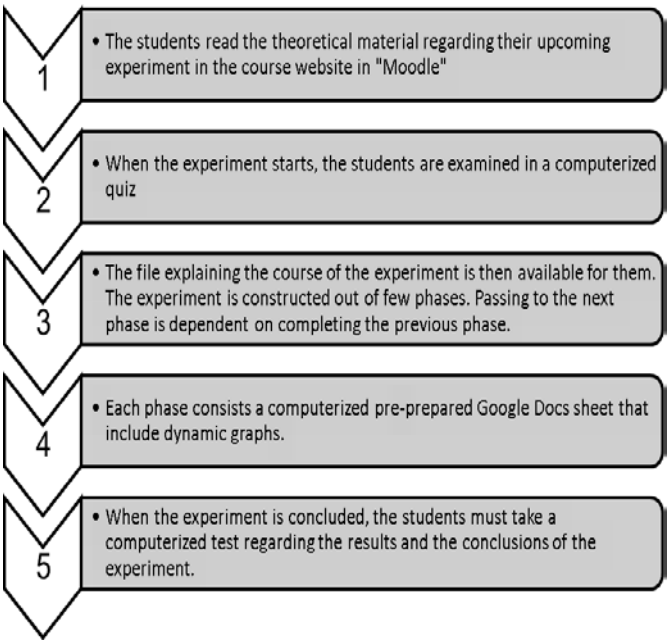

Fig 1. The smart grid Computerized Lab.

The emerging clean-energy smart grid environment in the electric power sector has necessitated that related educational programs evolve to meet the needs of students, faculty, and employers alike. In order to prepare the next generation of power engineering professionals to meet the challenges ahead in the electric power sector, a new curriculum must be developed that includes core power engineering principals coupled with emerging aspects of smart grid technologies and clean energy integration. Such curriculum also needs to consider not only the end-use side of the power system within the smart grid definition, such as smart metering, communications and demand response aspects, but also other key enabling technologies throughout the whole transmission and distribution system and the entire energy supply chain. These include areas such as energy storage technologies, advanced power electronics at the transmission and distribution levels, networked control systems, automation, renewable and alternative energy systems integration, system optimization, real-time control, and other related topics. In addition, the evolution of power programs and curriculum in this emerging area must take into account significant input from industry constituents engaged in the manufacturing, implementation, operation, and maintenance of the new smart grid technologies and systems. By working collaboratively with industry to meet future employer needs, programs with newly developed course offerings will be able to better prepare students and existing professionals alike for the rapidly growing clean-energy, smart grid environment. The Smart Grid transforms the current grid to one that functions more cooperatively, responsively and organically. The opportunities: the smart grid as enabling engine [Fig. 2].

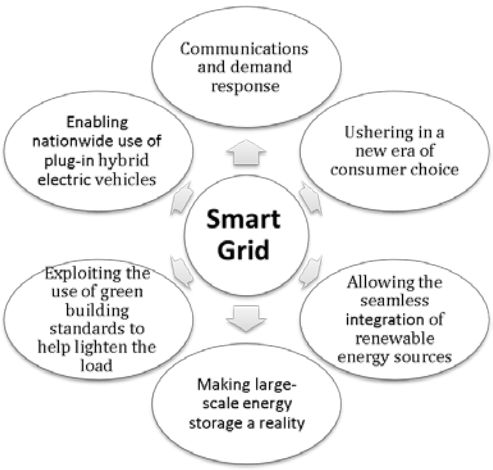

Fig 2. The smart grid as enabling engine.

On the Smart Grid platform (GT-7000 Smart Grid Technology Panel, by "Marcraft" [8]), a variety of loads are installed with the function of changeable power consumption, simulating electricity appliances that we use on a daily basis. The loads installed on the system are – air conditioner, water pump and electric boiler [Fig. 3 and Fig 4]. These three consumers are connected wirelessly to the control room – The Cloud. On the Cloud we can see the electricity demands of each load in real time, and the user-student can control the load during the ”peak hour”. The user-student can also control the load mechanically by using the main electrical panel switches and circuit breakers. Using a variety of control options, the user-student is granted with the ability to control the power consumption of the load efficiently and effectively in real time. In addition, the Smart Grid platform allows accurate monitoring of power consumption at any given time. This can give the user-student the ability to build graphs that describe the electricity consumption.

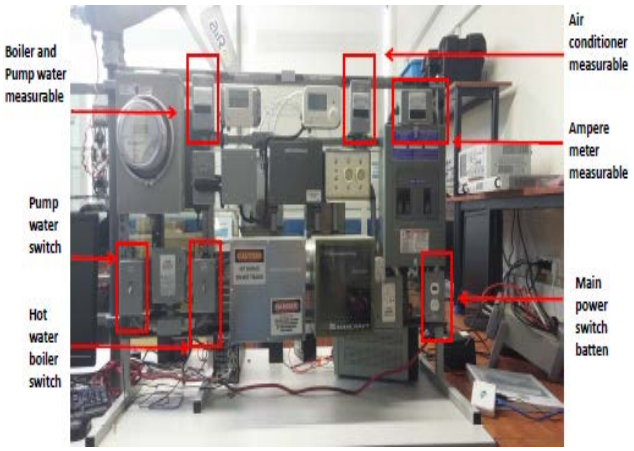

Fig 3. The represented the Smart Grid platform in HIT Forward view

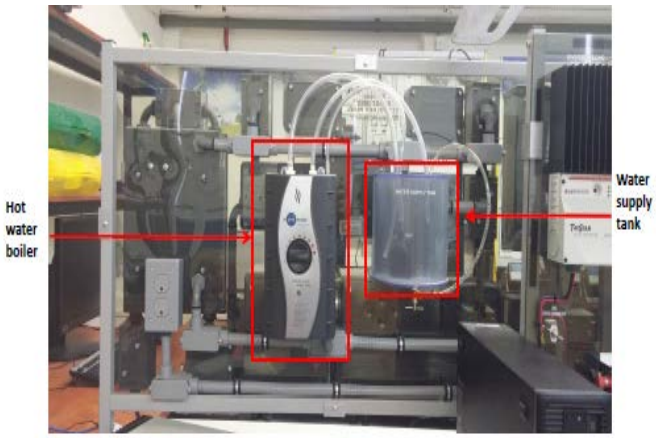

Fig 4. The represented the Smart Grid platform in HIT Back view.

The Smart Grid system also allows connecting an external power from a renewable energy system to the consumer on the platform. Renewable energy systems described on the Smart Grid platform are – photovoltaic cells, wind turbines and DC batteries (simulates more renewable energy system). To connect those systems to the platform consumers and to the electrical grid, we need to convert the DC voltage into AC voltage [9]. This conversion made by the Inverter component on the system platform. When the Smart Grid platform is connected to renewable energy system, the user-student can see that the current is taken, almost entirely, from the production of the renewable energy and not from the electricity grid.

VI. Losses in the Smart Grid component

At the beginning of the lab experiment, the student will read the theoretical materials regarding the Smart Grid platform and its components (transformers, motor and heating elements, etc.). During the experiment, while the Smart Grid is connected to renewable energy, the student will be required to track the incoming current system. When tracking the input current and orderly registration of results, the student will be able to realistically see that there are losses in the entire electrical system. By measuring the input current and the voltage that the renewable energy source delivers to the inverter, the power that comes to the inverter can be calculated. By measuring the input current of the system and by knowing the voltage needed to operate all consumers, the power that comes to the Smart Grid platform can be calculated. By using conversion formulas from DC power to AC power and by subtracting the incoming power and the input power how entered to the Invertor, we can get the waste of energy that exist in the system. By that action the student understands tangibly the waste of energy that exists in the various consumers. Teaching about system losses is critical,

because most of the students will work at or have a connection to the Smart Grid system. Understanding this lab experiment will be a milestone in the student's professional life. In addition, the importance of knowledge of these losses, called "Energy Efficiency", can save electrical consumers, private and industrial, a lot of money. Through proper design, the power system manufacturers will be able burn less fossil fuels and thus emit fewer pollutants into the environment we live in [3, 6, 9].

VII. Feedback Questionnaire

Because of the laboratory's innovative yet experimental method of teaching, it is important to know the students' appreciation for it. Each student fills an anonymous computerized feedback questionnaire at the end of all experiments. In this questionnaire they are asked about the overall satisfaction from the new experimental teaching method [Fig. 5].

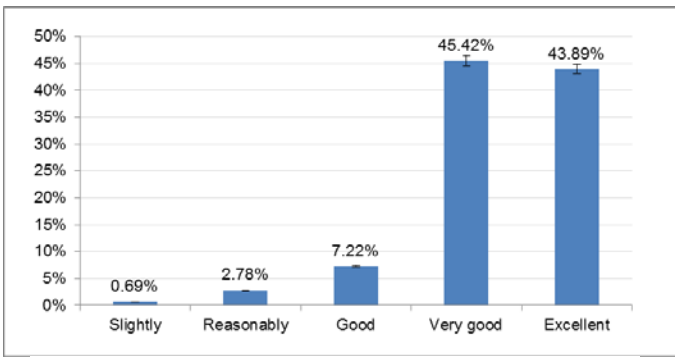

Fig 5. General satisfaction from the new experimental teaching method

The method shows real ability and success, and higher rates of satisfaction. It seems that the laboratory is very popular among students of electrical engineering. To meet the demand, additional laboratory groups are opened every semester. Recently the Renewable Energy and Smart Grid Excellence Centre purchased new experiment sets in order to open an advanced laboratory, which will deal with renewable energy in the area of fuel cells.

VIII. Conclusion

The exact future of the Smart Grid may be difficult to predict, but recent innovations display a dynamic merging of sectors, mechanics and communities. The combination of an interactive laboratory and a Smart Grid platform shows the student a broad range of concepts about the term "Energy Efficiency", by using Smart Grid platform combined with alternative energy sources. The students will learn important skills, such as: which algorithm the system use at any given time, and changing the consumption from the grid by using alternative energy sources. These important skills are necessary to the training program of engineers on Smart Grid system, and the laboratory provides them with a variety of experiments. This laboratory will be a milestone in the learning of Smart Grid and monitoring electricity consumption, in the Israeli and the global grid.

Acknowledgment

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