

# IoT Based Remote Laboratory for Solar Energy Experiments: Design and Implementation

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**Abstract**— Remote laboratories offer real experiences that students deal with over the Internet using computers or smartphones. This paper presents a technical method for connecting real devices in a laboratory so that students can access them over the Internet to conduct real experiments on devices in the lab from anywhere, anytime. The proposed remote lab includes a set of experiments, and each experiment has a set of devices. Each experiment is designed in a way that allows the learner to select a certain experiment and study the functions of each device to achieve its objective. By using the remote laboratory, students will be able to study the basic characteristics of each component used in the experiment and measure several parameters in order to acquire the necessary skills they need. This paper presents the hardware and software design of a remote solar lab and the results obtained from laboratory experiments conducted online. The next step is to implement the proposed system in the Solar Energy Laboratory at the Faculty of Engineering and Technology, Philadelphia University, Jordan.

**Keywords:** Remote laboratory, IoT, Embedded systems, E-learning, Blended learning.

## I. INTRODUCTION

Global studies and experiences indicate that e-learning and blended learning are the necessary alternative to traditional programs to face the continuous increase in the number of students enrolled in universities, as well as to face natural disasters and epidemics, as is the case with Covid-19 [1]. In applied disciplines, there is a great need for specialized laboratories to help students gain scientific skills and knowledge. The cost of creating some specialized laboratories is very expensive in addition to the lack of trainers qualified to deal with the increasing numbers of students during the study period [2].

In e-learning, a range of experiments can be prepared using physical devices in the laboratory in addition to computer simulations. These components and devices can be accessed via the Internet. Students can learn about the purpose of the experiment, its components, the method of connecting devices, and how to obtain the required readings. The experiment page also provides the theoretical aspects and basic properties of each component used in the experiment. Laboratory activities play an essential role in the fields of engineering and applied science. E-learning and distance learning have not shown encouraging results in engineering fields since traditional laboratory activities cannot be covered in a way that enhances skills and knowledge [3].

The Corona pandemic has accelerated the increase in the interest of universities and institutes in the use of e-learning, but this type of learning has become an inevitable necessity in educational systems [1]. Others believe that e-learning and blended learning will be an alternative to traditional education in the near future. Applied majors still face difficulty in dealing with applied courses, laboratories and workshops when adopting e-learning. Several research papers have demonstrated the possibility of creating virtual labs using virtual reality and computer simulation concepts [4], and in other research papers, mixed reality concepts have been used to create the labs [5]. Recently, the concepts of wireless sensor networks and the Internet of Things (IoT) have been used in designing remote laboratories [6,7]. The concept of web based laboratories was promoted with the invention and spread of the Internet in the world [8]. The strong advancement of information and communication technologies has led to the emergence of a number of large educational networks between prestigious international universities such as MIT Open Course Ware and iLab [9].

Remote laboratories have been introduced into engineering education processes and integrated into the e-learning frameworks provided to engineering and science students, as well as to support lifelong learning and student independent learning activities [8]. Remote laboratories provide many advantages to higher education environments, especially in engineering and sciences, as the Internet provides an environment for communicating with anyone, anywhere, anytime [10]. The web-based environment provides learners with problem-solving assistance and tools to conduct experiments [11].

The main purpose of using remote laboratories is to achieve practical activities related to training students through which they can understand theoretical subjects and acquire skills. Such laboratories require reliable hardware and software systems for continuous operation with reasonable cost for sustainable educational projects [12]. They have high scheduling flexibility for both students and teachers, as these laboratories operate 24 hours a day, 7 days a week, without human assistance, and they contribute significantly to reducing both cost and effort. Several remote laboratories have been proposed to train students and professional technicians to improve their skills [13], as well as to improve safety for the trainee when working in a dangerous environment [7].