Design and implementation of access monitoring and control based on SCADA system

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Article Info

Article history:

Received Apr 24, 2022
Revised June 9, 2022
Accepted June 28, 2022

Keywords:

Control education
Distance learning
Educational lab online
On-line monitoring
Remote laboratories
SCADA system

ABSTRACT

The supervisory control and data acquisition (SCADA) system is considered a pioneer system in the field of remote education. Three laboratories are designed for the alternating current (AC) Machine Lab, while the programmable logic controller (PLC) is used to connect the system to the Internet by designing an interface to the system through the DIAView program, where each student has his account and a specific time to implement the experiment and write the result in a report window. In this system, teacher and students can assess the system through a specific window. The teacher can access, control and monitor the performance of the students. The teacher can evaluate each student. Student can access and control the laboratories. The methods to turn on the single-phase induction motor include capacitors, auto transformer and variable frequency drive (VFD). VFD is considered an advanced system at present, to which an intelligent system has been added. Moreover, an overload protection system has been introduced, where it would shut down the Lab and show an error message. The system can work as a local area and public area when connected to the university of KUFA system Moodle server.

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1. INTRODUCTION

Coronavirus (COVID-19) is the biggest challenge facing education systems, as institutions and governments are turning to an alternative solution to real-world education [1], [2]. Where after the outbreak of the COVID-19 virus recently, and the prevention of human gatherings that lead to the outbreak of the disease. Universities resorted to pouring interest in distance education, and this was evidenced by the remarkable growth in distance education in recent times [3], [4].

Universities were resorted to the remote laboratory in the field of education. For many reasons including: i) The spread of Coronavirus (COVID-19), e-learning support [5]; ii) The expensive laboratory instruments [6], [7], lead to a small number of them being insufficient for the great number of students [8]; iii) Recurring maintenance [9]; iv) It enhances the support and collaboration among universities of different countries including the transfer of experiences, information, workshops and educational courses [10]; v) In support of the initiative put forward by the United Nations Educational, Scientific and Cultural Organization (UNESCO), Education For All (EFA) [10], [11]; and vi) In addition to the fact that the student, teacher and material may be in different geographical locations. All this have led to the necessity of adopting a remote educational system by collecting students and the teacher in one laboratory.

Access remote labs are through many ways, in Technical Education Faculty at Firat University, Turkey, that used to design a user interface using visual studio with ASP.NET to develop web pages for the SCADA system to access remotely the Process Control laboratory [9]. The labs can be accessed through ThinVNC where they provide a server and display on a PC or tablet [5]. The data can be accessed through an OPC server that connects to any device [6], perhaps it was necessary to introduce a system into the field of education for meets the actual needs of students and teachers under the circumstances. Supervisory Control And Data Acquisition (SCADA) system are going through the educational field, also intended for industrial and training purposes [6].

SCADA system is defined as one of the leading and widespread systems. Especially, for the control of remote equipment [12], [13], SCADA system is used in industrial control systems (ICS), power stations, water systems [14]. The term SCADA is associated with practical industries to achieve certain economic goals because it manages a group of integrated operational units [12]. SCADA includes linking the hardware elements to a central data center for processing and displaying them on Human Machine Interface (HMI) or computer screen [12], [15], [16].

SCADA system is considered very useful in the field of remote laboratories [6]. Perhaps the largest cooperation between universities in 2005, the cooperation of eight universities from Germany to participate in remote laboratories, which are called the German LearNet Initiative [17]. It's worth noting that the implementation of remote laboratories is more difficult than the implementation of virtual laboratories. No system is completely open-source, for example (MATLAB, LabVIEW). Usually, LabVIEW is used due to considered convenient and fast in collecting, storing, analyzing data and diagnosing faults [18]. Where used in the virtual lab [18]–[20]. due to it, the system of virtual tools can be expanded according to the need [18], [19]. In 2021, a remote laboratory has been created, where it has advantages, the most important of which is direct interaction with the lab equipment that operates it and observes it through a camera, and this is what virtual labs lack [5].

2. METHOD

There are two types of labs: the remote lab and the virtual lab. The remote lab required the internet, but it has the most important advantages. One of the most important is direct interaction with the lab equipment. Remote lab operates and observes through a camera [5]. In this paper, the wireless SCADA system was connected to the university of KUFA system Moodle servers. This system allowed the student to used one laboratory or more laboratories at anytime and anywhere via the Internet. The access monitoring of the SCADA system is characterized by its low cost compared with the present laboratory. This is allowed more than one student to use the lab, through an account for each student. The SCADA system was designed and implemented in the department of electrical engineering laboratories at the university of KUFA.

2.1. Hardware

The hardware consists of three main parts, the control center (C.C), labs and the internet network. In this project three labs were designed and used to control the direction and speed of Single-Phase Induction Motor (SPIM). The direction and speed of the induction motor were controlled in three ways by capacitors, autotransformer and variable frequency drive (VFD), as shown in Figure 1.

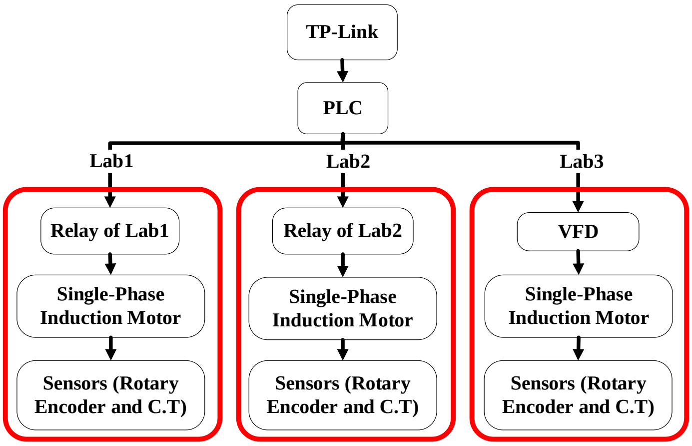


Figure 1. Block diagram of the system.

Laboratories were worked and connected with control center. Laboratories were connected with PLC and programmed through WPL Soft program. In Lab1 and Lab2, data (voltage, current and Hertz) were pulled through delta power meter (DPM) device. DPM device connected via Modbus RS-485 with PLC. In Lab3, VFD was connected to the PLC. VFD is pulled data via Modbus RS-485. The rotary encoder device was used to measure the speed for all laboratories.

The three laboratories were designed, implemented, accessed from different places, and connected remotely online to a control center. laboratories were included capacitors, autotransformer, VFD, relays, SPIM and sensors ((current transformer (C.T) and rotary encoder). The control center included circuit breaker (C.B), TP-Link, PLC and DPM, as shown in Figure 2.

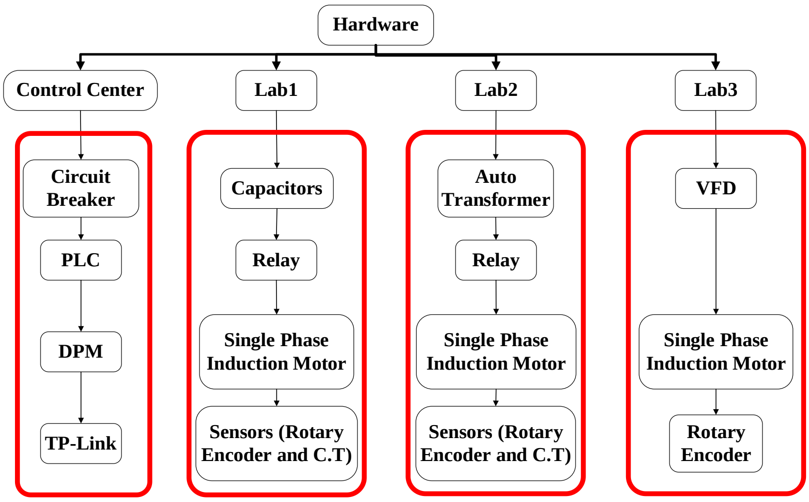


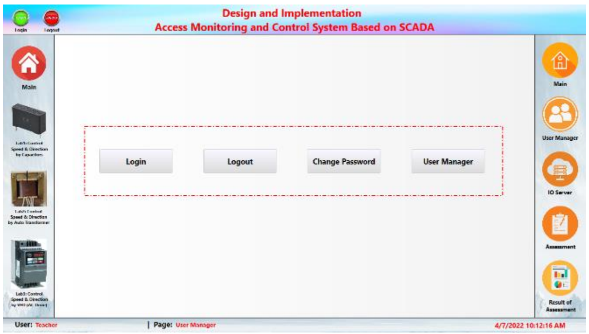
Figure 2. Overview of hardware of the system

2.2. Software

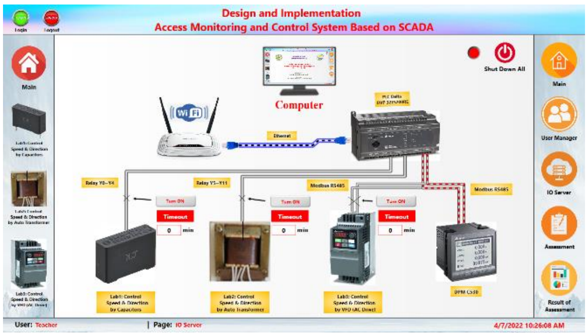
Software is an interface between the hardware and the user. Software divided into three parts. First part is the applications software. The applications software were programs that designed, employed and connected with hardware to build the entire system and remotely control. The applications software were used: DCI soft, WPL soft and DIAView. Second part is the program languages. Where the PLC is programmed by two ways: textural language and graphical language. The PLC is programmed in the ladder diagrams (LAD) of graphical language by WPL soft [21], [22]. Third part is the windows. Windows were designed using DIAView to allowed and accessed by the students and teacher. The windows were divided to two parts. The first part is the teacher's windows. Teacher's windows were included user manager, IO server, result of assessment and results. The second part is the student's windows. Student's windows were included assessment, report, Lab1, Lab2 and Lab3.

The teacher's windows are: i) User manager: Through this window, just the teacher can enter it, to add and delete the student's account, specify the username and password for each student. In addition, it added expiration time for each account so that when the time is up, the system makes a logoff for the account, as shown in Figure 3(a); ii) IO server: This window is considered the main control by the teacher over the entire system. Just the teacher can enter it, that can turn on and turn off any lab, as well as shut down all of the system at any time. The most important feature of this system is the ability of the teacher to add time out for each lab. As the lab closes when the time is up. Moreover, the student cannot run any lab without adding time out from the teacher, as shown in Figure 3(b); iii) Result of assessment: After assessing the system through the assessment window. Only the teacher can access this window and review the feedback and assessment of the system, as shown in Figure 3(c); and iv) Report: After adding the results from the results window by the student. Only the teacher can access this window, evaluate students, and submit their marks, as shown in Figure 3(d).

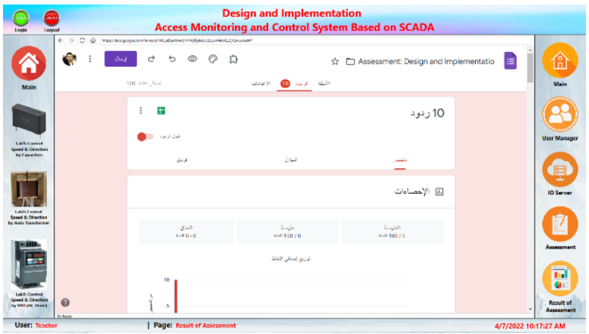
The student's windows are: i) Assessment: This window can be accessed by the student and the teacher. Where the system is assessed and notes, ideas and suggestions are added to the system, as shown in Figure 3(e); and ii) Results: The student and the teacher were allowed to enter this window. Through which the student can add the results be obtained after completing the experiment and send them to the teacher, as shown in Figure 3(f).



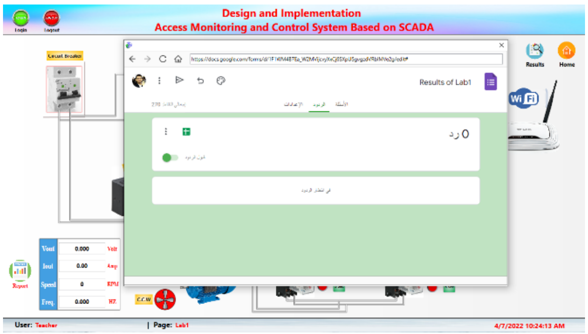
(a)



(b)

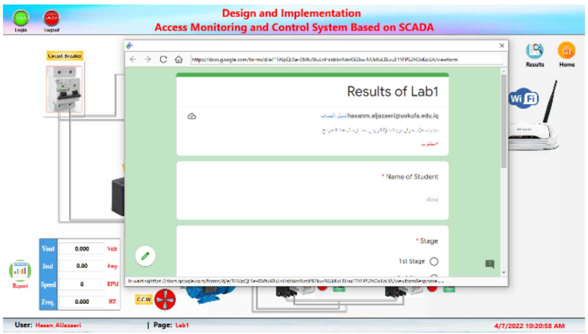


(c)



(d)

(e)



(f)

Figure 3. Windows of the system (a) user manager, (b) IO server, (c) assessment, (d) result of assessment, (e) report, and (f) results

Access to windows, some of which are for the teacher, and some for the student, where each account has its own rules, as shown in Table 1. Figure 4 shows prototypes of the SCADA design on the project (a) main window, (b) Lab1 window, (c) Lab2 window and (d) Lab3 window. The system has its protection system, where no one can enter the system without obtaining a user name and password of his own, and upon each login attempt, the system checks the entered information, as shown in Figure 5. In order to protect the power circuit components from overloading and short circuit, current sensors are used to continuously monitor the load current.

Table 1. The roles of each account in the system.

Users	Roles
System Admin	He is responsible for designing the system and has the right to modify it and fix any problem that occurs.
Teacher	He is responsible for setting (timeout) for each Lab, as well as evaluating students and can stop any Lab or all system.
Student	He is responsible for turning on the labs and uploading the results only.

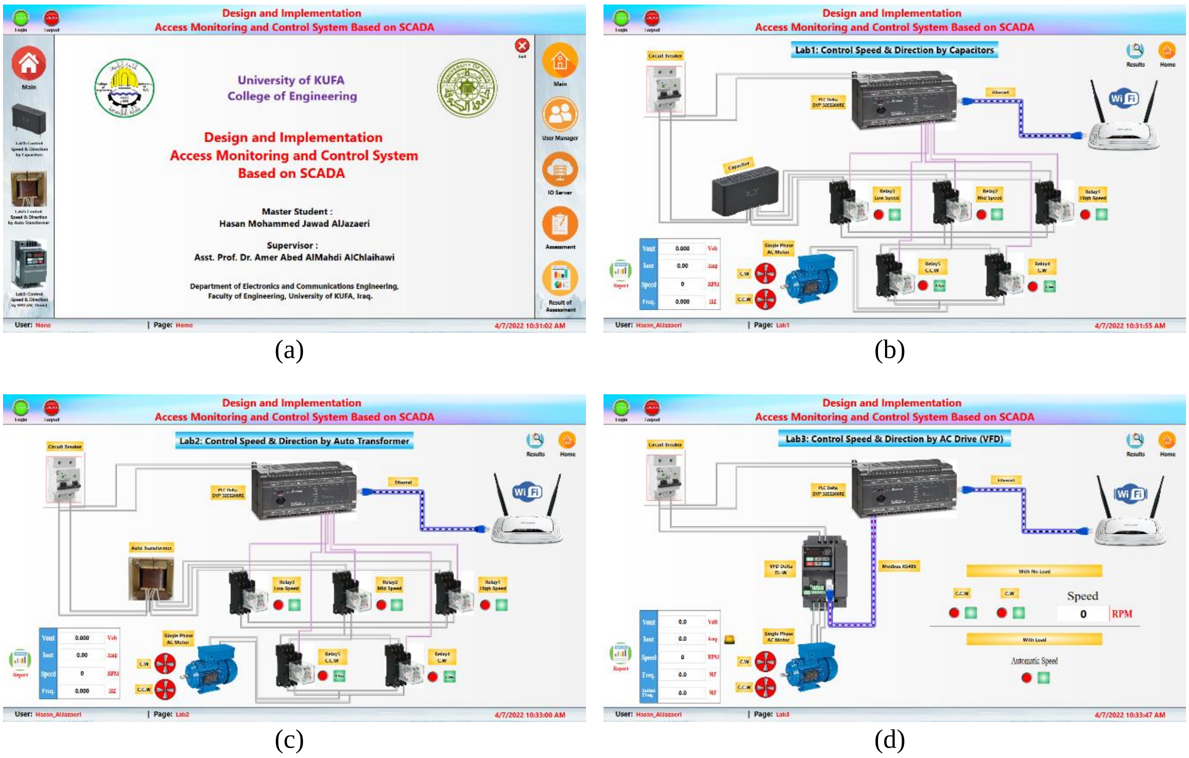


Figure 4. Prototypes of the SCADA design on DIAView software (a) main window, (b) Lab1 window, (c) Lab2 window, and (d) Lab3 window

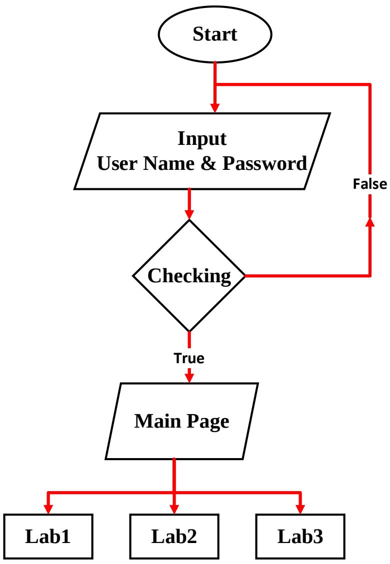


Figure 5. Flowchart of the system

3. RESULTS AND DISCUSSION

In order to check the effect of the load on the SPIM speed, the SCADA system was tested without and with the load. The measurements were recorded and compared between them, in terms of speed, current, voltage and frequency. This is to clarify the performance of the entire system and to show how the load applied to the SPIM is handled, as shown in Figures 6-8.

In order to demonstrate the effectiveness of the proposed control loop, the experiment was applied and the results we obtained through the sensors. It is worth mentioning, that all the speed results recorded from the rotary encoder were compared using the Tachometer device used in the laboratory. Where it turns out that the error rate is low.

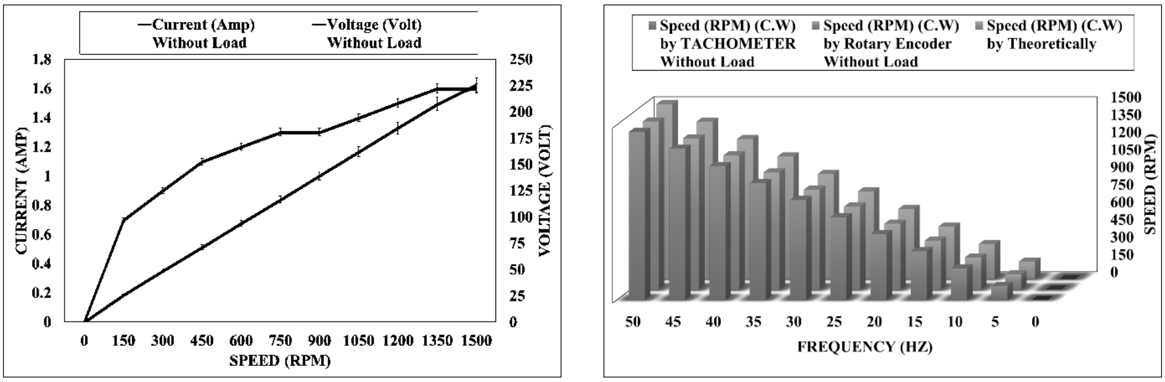
Considering the decrease in the speed of the induction motor when the load is added to it. The velocity has been processed back to the velocity in the case of no load. By velocity equation added in PLC which changes frequency through VFD [23]–[25].

$$\text{RPM (N)} = \frac{120\,\text{f}}{\text{P}}$$

where:
RPM (N) is revolution per minute,
f (Hz) is frequency,
P is number of poles.

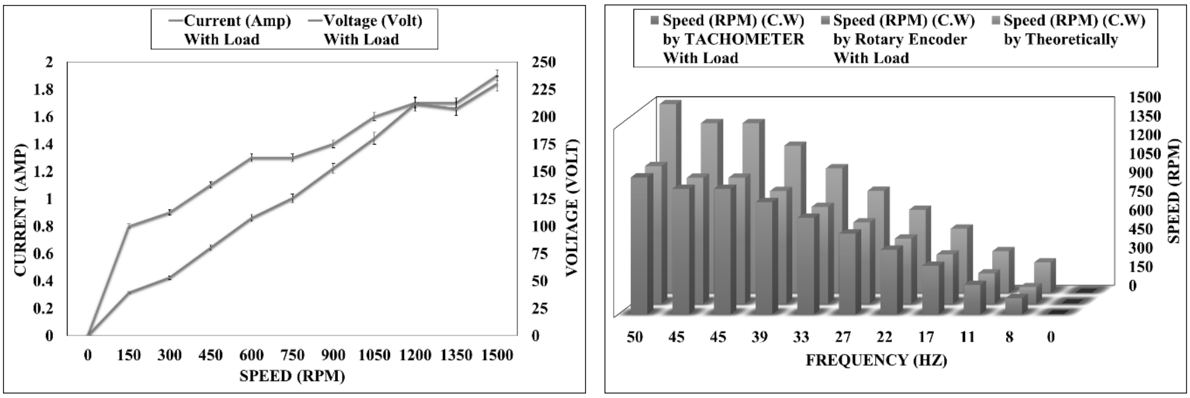
After running Lab3 in case with no load is applied to the single-phase induction motor. The results for voltages and currents are shown. Where the highest current and voltage at speed 1500 RPM, as shown in Figure 6(a). Figure 6(b) shows speed measurements in three ways, to show the difference between them and to show the percentage of error. Where the speed was calculated theoretically, rotary encoder and TACHOMETER.

When applied fan load to the single-phase induction motor and turn on the SCADA system. The results for voltages and currents were increased because it is directly proportional to speed, as shown in Figure 7(a). Figure 7(b) shows speed measurements in three ways, to show the speed measurement is theoretically higher than the other ways because the error rate is indifferent to it. It turns out that the speed reaches a maximum value of 1000 RPM due to the frequency reaching a maximum of 50 Hz. Also, the specifications of the single-phase induction motor used have a frequency of 50 Hz.



(a) (b)

Figure 6. Results of Lab3 without load relationship between (a) speed with voltage and current and (b) speed with three ways



(a) (b)

Figure 7. Results of Lab3 SCADA with load relationship between (a) speed with voltage and current and (b) speed with three ways

Figure 8 shows a comparison of the results with no load and with load after turning on the SCADA system. Figures 8(a) and 8(b) shows the relationship between the speed with voltages and currents. It is seen that the voltages and currents increase if the SCADA system is turned on progressively. Figure 8(c) shows how much the frequency is increased to compensate for the lost speed due to the load applied to the single-phase induction motor. Figure 8(d) shows the difference and comparison of speed measurements with and without load using rotary encoder and TACHOMETER. It turns out that the error rate is very low.

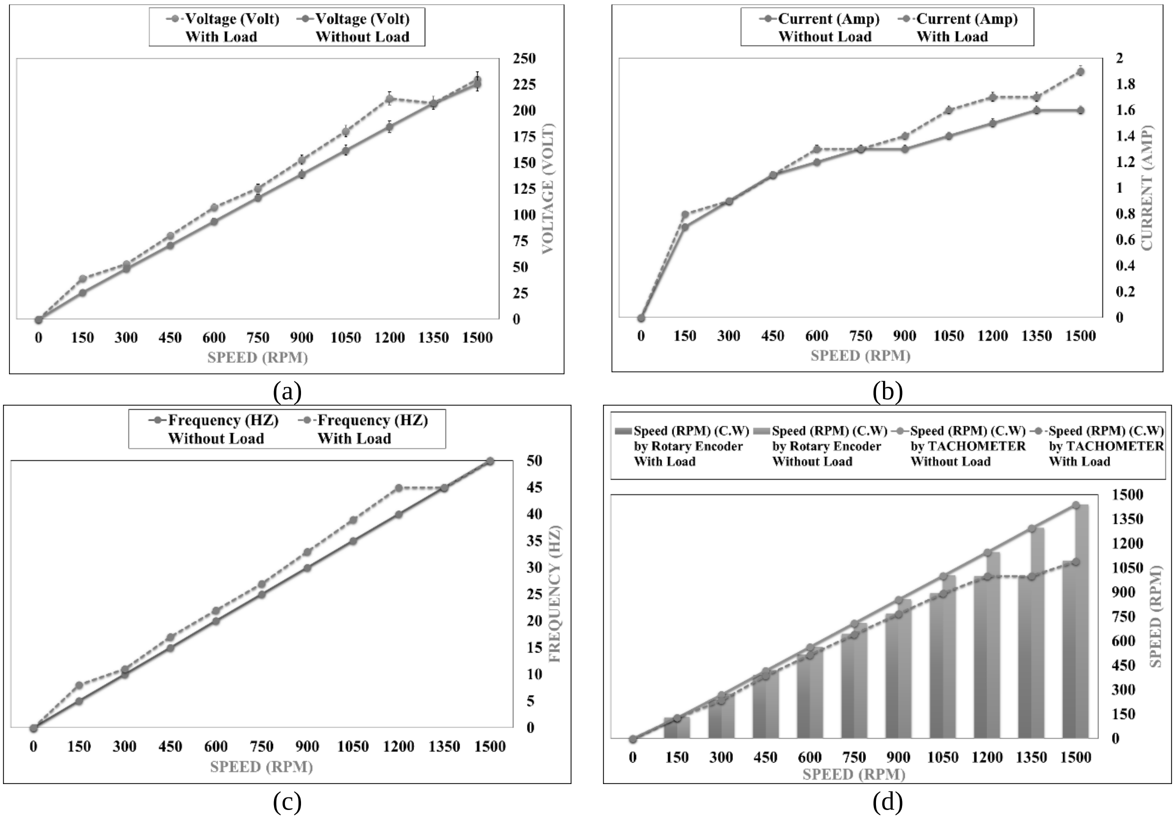


Figure 8. Results of Lab3 SCADA without and with load relationship between (a) speed with voltage, (b) speed with current, (c) speed with frequency and (d) speed by rotary encoder and TACHOMETER

4. CONCLUSION

This paper presented the design and implementation of alternating current (AC) machines laboratory based on the SCADA system. Three laboratories were designed as a working model and all experiments were carried out and results recorded. This system is distinguished by the following: i) It is easy for the student to conduct experiments, obtain results and send them to the teacher; ii) The assessment of students by the teacher is easy and fast; iii) Providing time for each student and for each experiment, where each student has a time assigned to him by the teacher; iv) Addressing the small number of laboratories compared to the number of students; v) Reducing the number of connecting wires compared to the old system; vi) Accuracy of the measurements; and vii) Easy access to laboratories anytime and anywhere. The future work of this system would potentially revolutionize engineering lab-wide education. Especially when adding other laboratories and connecting them to the distribution control system (DCS), developing the project and converting it on a web page or mobile application.

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