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Implementation of Wireless Closed Loop Control System for Multiple Dc Motors Using Arduino

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Abstract
There have been significant developments and achievements over recent years, linked with the utilization of wireless technology in the industry to provide versatility, scalability, and depressed cost. Wireless Networked Control Systems (WNCSs) depended on Wireless Sensor Networks (WSNs) combines three technologies: control engineering, wireless connection, and computer networks. WNCSs are networks of intelligent and wireless devices equipped with limited communication, computing, and sensing capacities to monitor and control the application. In this article, we build a wireless control system to monitor and control multiple DC motors. The XBee module is used as a wireless device to send and receive data wirelessly between the sender and receiver. Arduino is the microcontroller to control the plant (Dc motors).

Keywords : Multiple DC Motors, Arduino, XbeeS2C (Zigbee), Wireless Sensor Network(WSN), LabVIEW

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تنفيذ نظام تحكم لاسلكي مغلق الحلقة للعديد من محركات التيار المستمر باستخدام الأردوينوا

شذى عادل طه [1] ، أنس علي حسين [2] ، مهدي جلو مرعي [3]

الخلاصة
هناك تطورات وإنجازات هائلة خلال السنوات الأخيرة، مرتبطة باستخدام التكنولوجيا اللاسلكية في الصناعة لتوفير المرونة وقابلية التوسع والتكلفة المنخفضة.تحتوي أنظمة التحكم الشبكية اللاسلكية (WNCS) القائمة على شبكات الاستشعار اللاسلكية (WSNs) على ثلاث تقنيات: هندسة التحكم وشبكات الكمبيوتر والاتصال اللاسلكي. شبكات WNCS هي شبكات من الأجهزة الذكية واللاسلكية المزودة بقدرات اتصال وحساب واستشعار محدودة للتحكم في التطبيق ومراقبته. في هذه المقالة، قمنا ببناء نظام تحكم لاسلكي للتحكم في العديد من محركات التيار المستمرلاسلكيا. تُستخدم وحدة XBee كجهاز لاسلكي لإرسال البيانات واستقبالها لاسلكيًا بين المرسل والمستقبل. Arduino هو متحكم دقيق للتحكم في محركات التيار المستمر.

الكلمات المفتاحية : العديد من محركات التيار المستمر، أردوينوا، XbeeS2C (Zigbee)، شبكة متحسسة لا سلكيه، لاب فيو

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معلومات البحث
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1. Introduction

Many companies today use DC motors. Therefore, speed control of DC motors plays a very important function. Our paper, therefore, focuses on monitoring and controlling the speed of multiple DC motors using the Arduino controller [1]. Communication among various components in wireless networked systems depends on wireless technologies. Owing to benefits such as versatility, configurability, and spatiotemporal sensing, wireless networking is gaining considerable popularity in many application areas. Although the wireless connection was initially used for sensing and communicating with WSNs, a new area has appeared that utilizes similar techniques to allow network systems to be controlled [2]. The explanation for wireless regulation of dc motors' speed is to conquer the industry problem like maintaining a strategic distance from damage to machines and staying away from the moderate ascent period and high overshooting [3]. Wireless Sensor Networks (WSNs) can be used in many areas of use, such as security and military, software for industry 4.0, and climate. The key factor in the network design is the data communication between the data transmission source and the high-efficiency energy circuits consumed. The research area of WFCS is known as Network Management, and Multi-Agent Systems [4].

The motivation of this paper is to control remotely multiple Dc motors using multiple controllers to reduce cost, time, delay, and increase efficiency. To preserve the physical systems' dynamics, quick feedback is also required.

2. Related Work

In 2016, Mohammad et.al. [5], a Multi-Input Multi-Output (MIMO) Wireless Power Transfer (WPT) activated magnetic resonant coupling (MRC) devices, various transmitters (TXs) are used to improve the efficiency of simultaneous power transfer to different receivers (RXs) by constructively integrating their induced magnetic fields, a process called ' magnetic beamforming. '

In 2019, Bongsang et.al. [6] to preserve the stability of multiple plant control during spatial-temporal wireless network alterations used a robust wireless sensor and actuator network. The proposed joint architecture protocol uses a hierarchical cluster-based network to collect the distributed controller of control systems and the clustering, resource allocation, and control task participation scheme of wireless networks.

In 2019, Fabian et.al. [7] offer a wireless embedded system that tames failures that impede control efficiency (e.g. Loss of messages and jitter) and control architecture that utilizes the core features of this device to demonstrably ensure feedback reliability for linear time-invariant dynamics physical processes. They are the first who describe and evaluate close loop control and coordination through a wireless network of multi-hop for updating intervals of twenty to fifty milliseconds, by using experiences on the cyber-physical tested with twenty wireless node sand multi-cart pole systems.

3. Hardware Development

Hardware of this wireless system basically constitutes of two parts: station part and plant part.

- **Station Part Design :** Components of the station part of system are given below

i. **Arduino Uno :** It is an MCU board, dependent on the ATmega328P as shown in Figure (1), which is low power.AT mega328P has 32KB to save program code; 1KB for Electrically Erasable Programmable Read-only Memory (EEPROM). It also has 14 pins for digital input/output (I/O) where six of these pins are utilized as the output of Pulse Width Modulation (PWM), 6 pins are utilized as analog inputs, reset button, a power jack, ground pins, and USB connection. On this side, it represents a link between software and hardware. It is programmed by using the Arduino IDE program. [8]

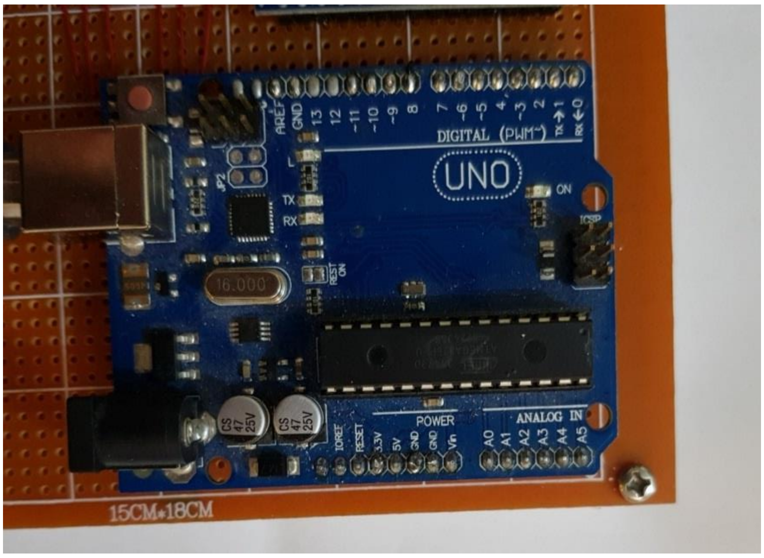

Figure 1 : Arduino Uno

ii. **XBee S2C (ZigBee):** The XBee module is worked at the ISM 2.4 GHz frequency band also needs a low power. This module provides a low power WSN and costs as well as is designed to meet up with IEEE 802.15.4 standards. Reliable data is offered to transmission between the devices by using this module. The most important issue to consider when utilizing ZigBee is the setup of the XBee S2C module to send and receive data remotely. It is programmed using the XCTU program [9]. Figure (2) shows the module of the XBee S2C.

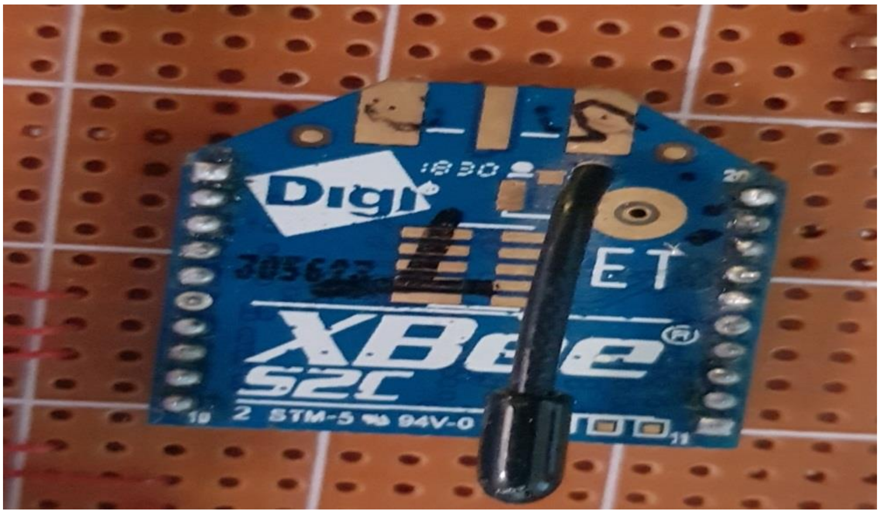

Figure 2 : Module of the Xbee S2C

iii. **Arduino NANO :** The Arduino Nano in WSN serves as a medium to the sensor for providing the data to the interface in the computer working as a base station to read the pulse of the DC motors and then, read the rpm of the motors. The Arduino NANO contains eight pins (A0_A7) of the analog interface. The analog pins of Arduino are usually interfaced with the sensors that have an analog output. The RPM output from the node of the sensor can also be compared with the value that we set in the interface. The output coming from nodes of the sensor can also monitor on a serial monitor introduced by Arduino software programming. The Arduino platform is extensively utilized for developing WSNs in open-source H.W and S.W, leading to low power, inexpensive, and the most versatile system used with wireless monitoring [10] .Fig. (3) Shows the module of Arduino Nano we used.

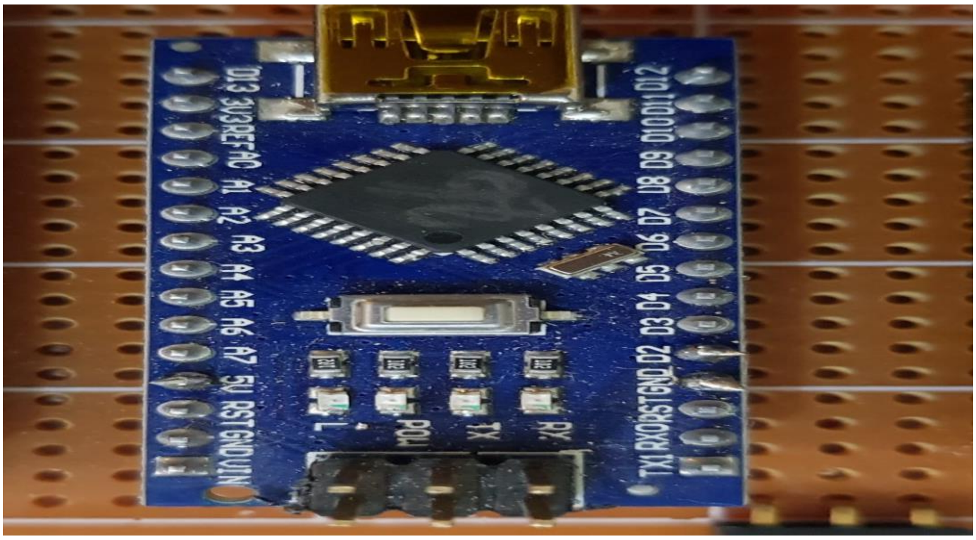

Figure 3: Module of the Arduino Nano

- **Plants Part Design** : Components of the plants part of system are given below:

i. **XbeeS2C (ZiBbee)**: As is shown above.

ii. **Arduino Uno:** As shown above.

iii. **DC Motor:** The device is called a motor, which transforms electricity into mechanical energy. DC supply is used by dc motor to generate mechanical output. Compared to conventionally used AC motors, the benefits of using these types of motors are: dc motors have greater control performance, dc motors have a standard ninety eight percent efficiency, dc motors have better overload and peak voltage characteristics. As a consequence of all these benefits, in areas where constant speed is to be maintained at varying loads, these devices have a wide range of applications. Some of these applications are such as conveyor belts, elevators, cranes, ski lifts, e, mixers, etc. So a purposeful and necessary place to work is to regulate the speed of a DC motor [11]. Figure (4) shows the Dc motor we used.

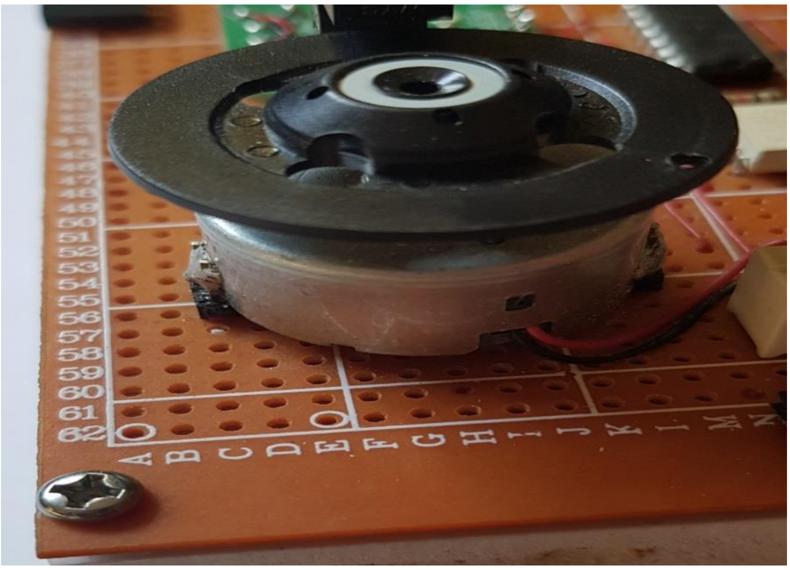

Figure 4: Module of Dc Motor

iv. **DC Motor Speed Sensor Circuit:** In order to read the dc motor speed, a perforated disk mounted on the DC motor pole was added, Fig.5 shows that the disk is about an 8 or 1 slot so that light LED can pass across an aperture on a photodiode. Between LED and photodiode, the disk is located. If the LED gives light to a photodiode, the output of the photodiode is high (logic1). If the photodiode is not struck by LED light, the output will therefore be logic 0 (low). Circuits of LEDs and photodiodes are shown in Fig. 6. The result is split by 8 (number of holes) how times photodiode high will be correlated with a speed of DC motor in rpm units within a span of a minute.[12]

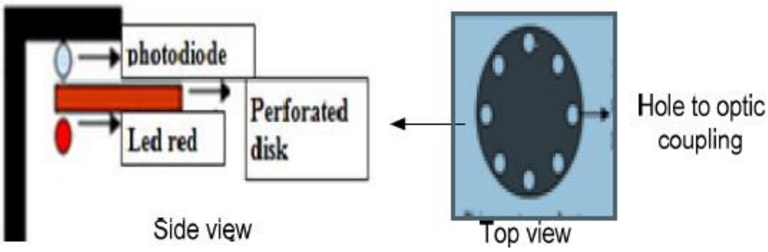

Figure 5 : Perforated disc

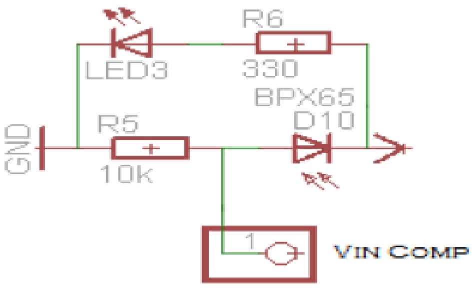

Figure 6: LED and photodiode circuit

4. Software Development

The interface that controls the system is designed by using the LabVIEW program. Fig.7 shows the LabVIEW program.

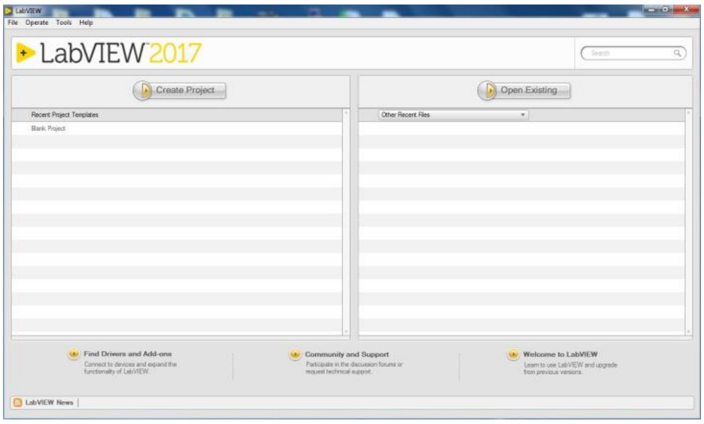

Figure 7: The LabVIEW program

4.1 LabVIEW

LabVIEW was defined as the environment of programming to control the hardware. The GUI is utilized to simulate the managed instrument on the pc, monitors itself.

The term LabVIEW is an abbreviation for “Laboratory Virtual Instrument Engineering Workbench" which is a graphical programming language focused on graphical icons rather than a set of simulation programming codes. These programs are known as Virtual Instruments, owing to their operational emulation of physical instruments, such as temperature monitoring, spectral scopes, pressure gauges, and cathode-ray oscilloscopes. In LabVIEW, the data of the program will be flown from left to right and errors will be easily detected during the program execution..Fig.8 shows the interface in Labview.

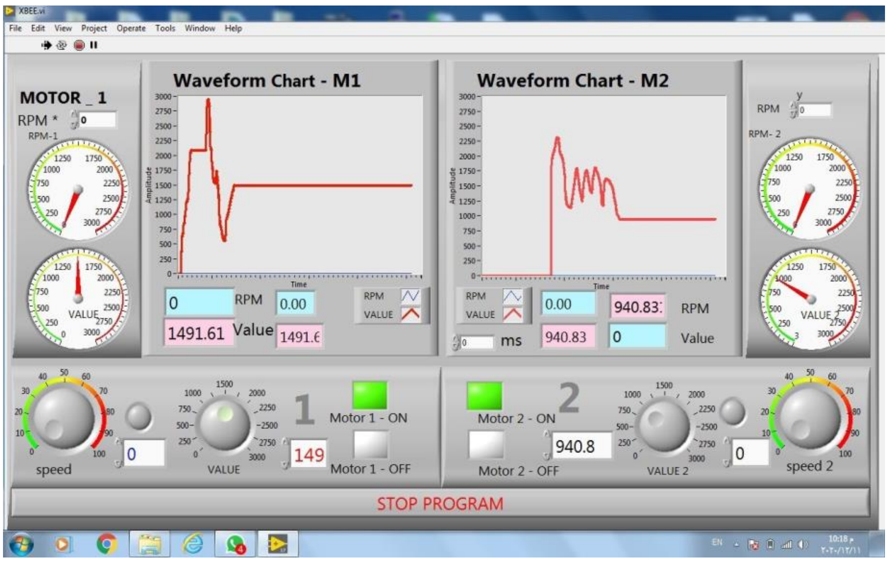

Figure (8) Interface in LabVIEW

5. System Description

This system is designed by the integration of WSN with the LabVIEW program to acknowledge the speed of dc motors and provide feedback speed of dc motors by using the Zigbee module. This section will show the description and connection of controller and plants units.

5.1 Description of Station Unit Part

The components of this unit are Arduino Uno, two Arduino NANO, two Zigbee modules, and the GUI is the person who controls the system. Arduino Uno is the heart of the system, it represents the interface between the hardware and software of the system. It takes control signals from the GUI through the serial port and gives it to the first Zigbee module, the ADC is done in this part. The first ZigBee module search for wireless network to connection when it found WSN, it will send a control signal to the plant unit. The second Zigbee work as a receiver, it receives the speed of dc motors and being forwarded to Arduino NANO modules. Each Arduino has serial port to PC to transfer RPM to GUI. In GUI compare the value of RPM with the value we set if the RPM is greater than the value we set, the motors will be shut down else the motors will turn on. Figure (9) shows the implementation of the station unit.

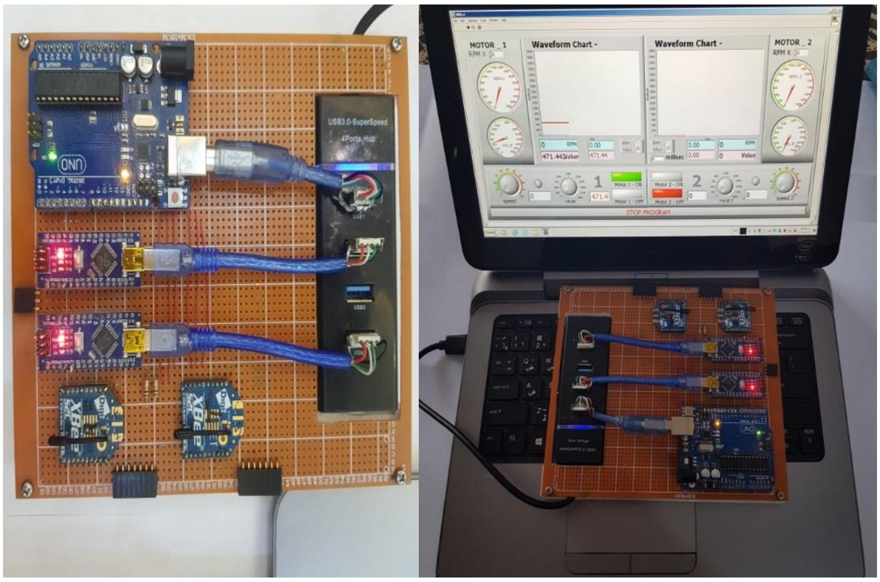

Figure 9: The implementation of the station unit

5.2 Description of the Plant Part

The hardware components of this unit are Two Arduino Uno, Two Zigbee modules, Two DC motors, and Two dc motor speed sensors each is responsible for one dc motor. The first Zigbee module is set as AT ROUTER and it starts with the search for a Zigbee module that has the same PAN ID to receive control signals from the station. After that, control signals are forwarded to Arduino Uno modules to analyze it and transmit through light to dc motors. Photocoupler is used as an electrical isolator and Driver is used to protect appliances from damage because of high current .DC motor speed sensors measured the speed of dc motors according to the pulses in the sensor. Sensors send the measured readings to the second Zigbee. The second Zigbee is also set as a ROUTER and transmit measured readings to the

Zigbee in the station that has the same PAN ID. Relay responsible for ON/OFF the motors .Figure (10) shows the implementation of the plant unit.

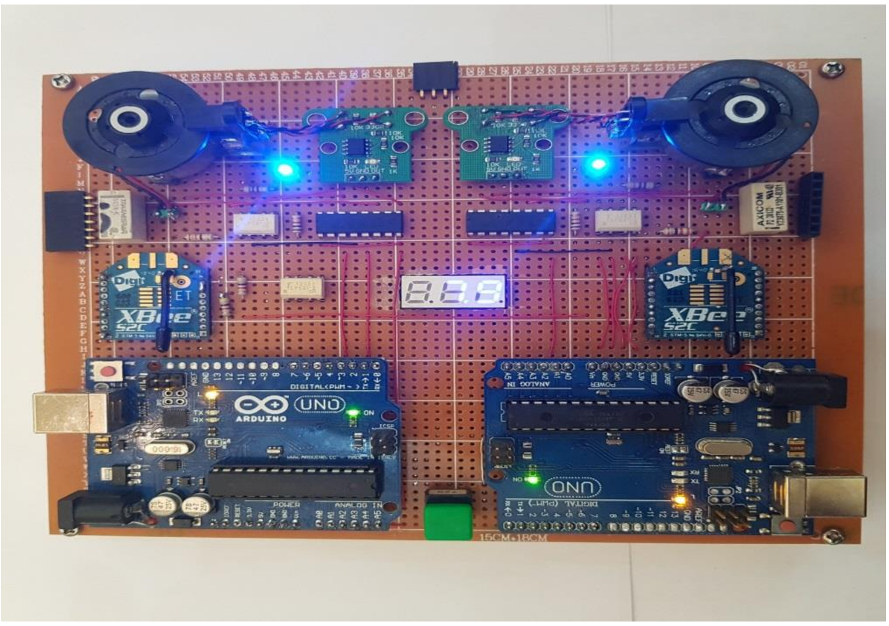

Figure 10: The implementation of the plant unit

6. Results and Discussion

We built the control system to monitor and control the speed of two dc motors remotely. We set a specific value of speed for each motor in the range between 0 and 3000, the RPM of each motor must not be exceeded this value. If RPM exceeded the value of speed we set, the motor will be turned off else that the motor will be turned on.

In the GUI, the red waveform represents the value of speed we set and the blue waveform represents the RPM of motors. Figure (11) shows the first motor is ON because the value we set is 1734.72 and the RPM is 1040 that means the RPM has not exceeded the value we set.

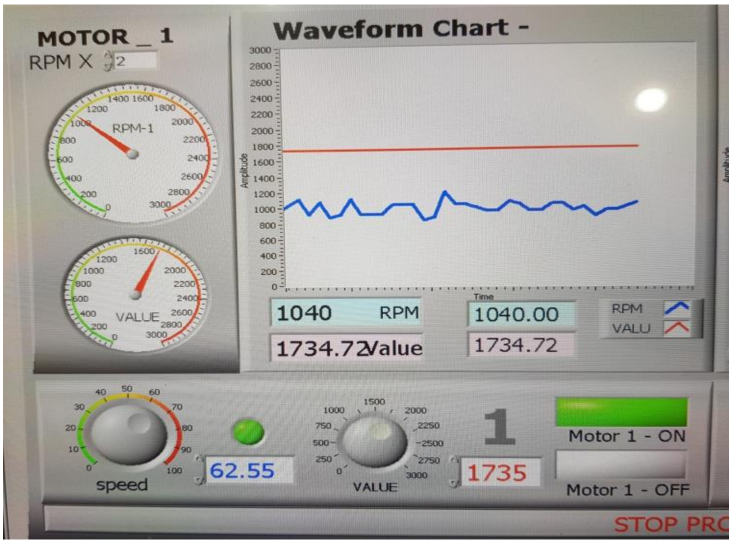

Figure 11: the first motor is ON

In Figure (12), the first motor is OFF because the value we set is 1734.72 and the RPM is 2000 that means the RPM has exceeded the value we set.

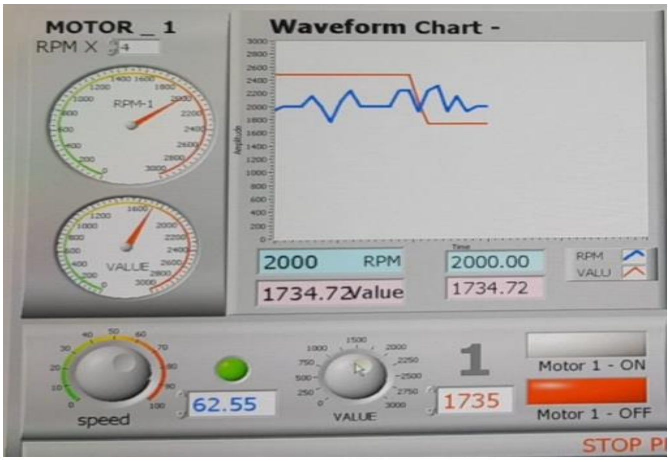

Figure 12: the first motor is OFF

In Figure (13) the second motor is OFF because the value we set is 410.80 and the RPM is 1410 it means the RPM has exceeded the value we set.

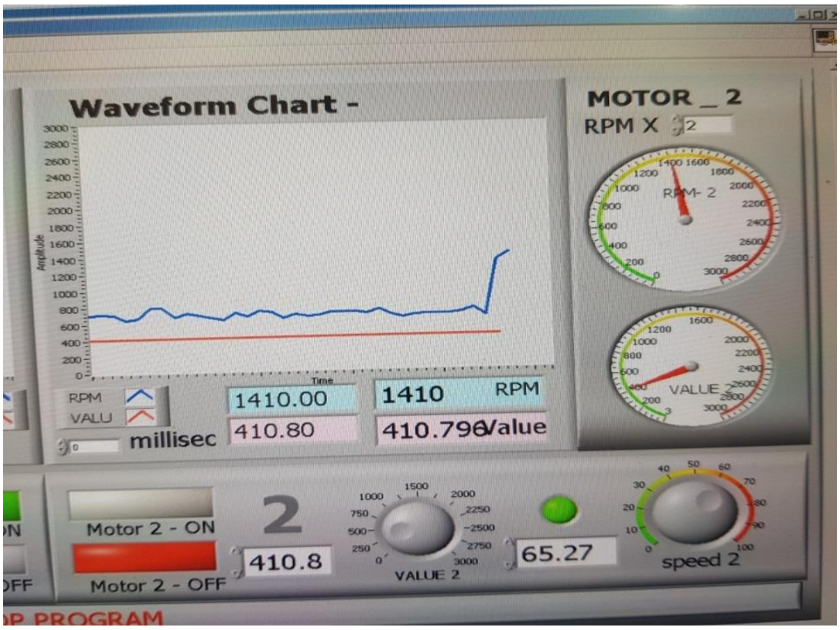

Figure 13: the second motor is OFF

In Figure (14) the second motor is ON because the value we set is 840.89 and the RPM is 645 it means the RPM has not exceeded the value we set.

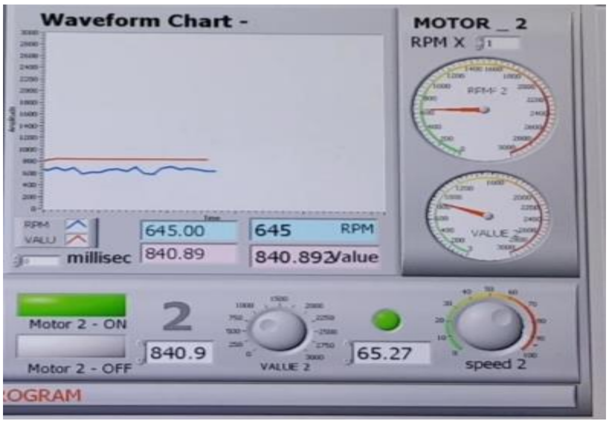

Figure 14: the second motor is ON

Finally, the entire project is shown in Figure (15).

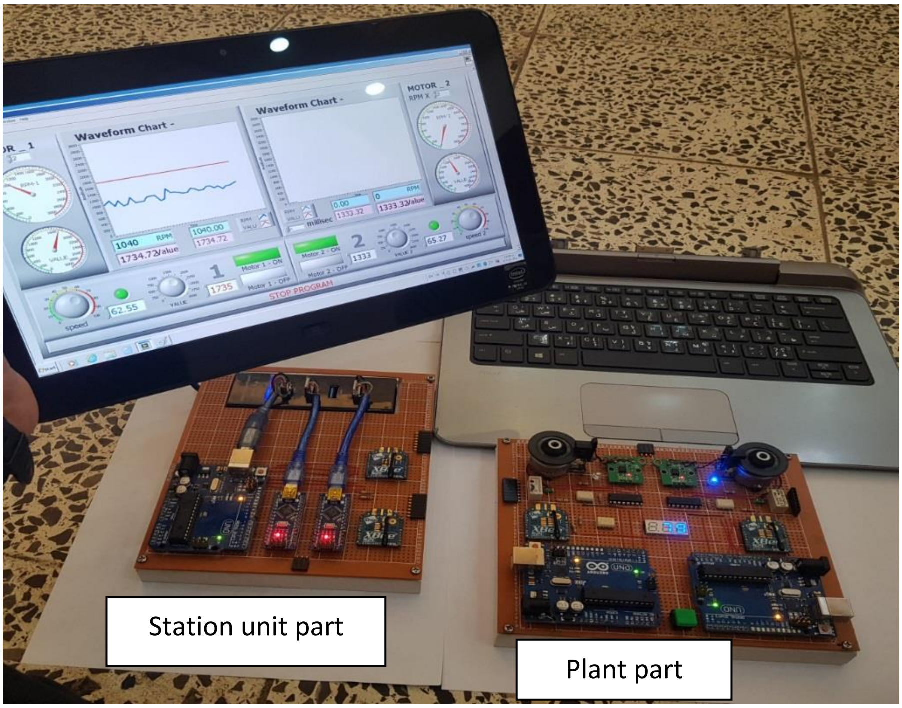

Figure 15: The entire project

7. Conclusions

In this article, we tried to solve the problem of controlling multiple dc motors wirelessly. The wireless control system is suitable for our Dc motors to, reduce cost, time delay, and increase efficiency. Shortly, wireless service systems technology is expected to become more prevalent in the residential setting and will be useful in health care assistance, and control on a lot of devices. The use of Zigbee for data transmission between the station unit and plant unit is implemented practically for controlling the operating of Dc motors. The quality of the Dc motors will be enhanced accordingly by using the wireless system.

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