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Design of a novel electronic circuit for AC induction motor speed control

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ABSTRACT

Recently, interest has increased in the technology of manufacturing and controlling agricultural robots by remote control system using Arduino shield. Forward speed control and steering are the most important points in the designing of agricultural robots. Due to the high prices of DC motors and unavailability in the local markets with the desired power, thus this study the possibility of using AC motors by inventing an inexpensive method through which a robot can be operated using AC motors and it can also be operated and controlled remotely using an Arduino board Via Bluetooth, which leads to reduce the manufacturing costs of the robot and thus reduce the operating costs in performing the required process.

1. Introduction

AC power control already exists in our daily life-style but there are some limitations for presence control technology, such as some AC power control devices could not control remotely and provide limited power controlling range. To improve the presence of power control technology. Wireless remote AC power control provides many benefits such as extended range, elimination of the need for wire, less maintenance, provide safe and reliability. Lamp, heater, and AC induction motor are the most common electrical appliances in this modern world. These AC loads could be found at every residence house and industry area (Tat and Haur, 2020).

Controlling AC power (like switching on/off, changing the brightness of the lamp, controlling fan speed, etc.) is not a new thing, it already exists in our daily lifestyle. However, existing AC power controlling is an inconvenience as the user is required to go near to the appliance to control the device. Therefore, controlling AC power remotely is becoming the trend when the concept of the Internet of Things (IoT) is becoming an increasingly growing conversation topic in the world. IoT enables the embedded system, handphone, electrical appliances, software, sensors, etc. to collect and exchange data wirelessly. Bluetooth technology is one of the best ways to implement IoT (Cyient, 2020).

Bluetooth was initially designed for interconnecting small, battery-operated devices that surround us, forming a low-power, short-range wireless Personal Area Network (WPAN). On the other hand, a LAN (Local Area Network) normally covers a significantly larger area, such as an office floor, a building, or even several buildings (Keymitt, 2020).

Induction motors are the most widely used motors for appliances, industrial control, and automation. It is very important to control the speed of induction motors for efficient control strategies and for reducing operating costs too (Kumar et al., 2013).

Speed control techniques of induction motor

Speed control of the induction motor plays a very important role in some of the applications. Some of these strategies are discussed below.

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1. Cyclo-converter was used to control the speed, by direct control of supply frequency. The frequency applied can be varied by the converter which changes the speed of the motor, as speed is directly proportional to frequency and inverse proportional to a number of poles in the motor under consideration (Sindura and Kartheek, 2013).
2. Speed control can also be achieved using the PWM technique. The operation can be carried out using 8051 microcontrollers (Pawar et al., 2015).
3. The motor speed can be controlled with the help of Variable Frequency Drives (VFDs). VFDs maintain the voltage to frequency ratio of the supply which provides effectively good torque output. The use of these VFDs is one of the most effective means of speed control (Shinde *et al.*, 2014).

2. Materials and methods

To solve the problems related to the use of AC induction motors in robot manufacturing, the electronic circuit is shown in Figure 1 was designed, which consists of the following parts:

a. Arduino Uno (ATmega328P).
b. Bluetooth module (HC-06).
c. Smartphone (Oppo A1).
d. Smartphone application.
e. 2 - Servo motor (TowerPro SG90).
f. 2- Voltage regulator dimmer thermostat.
g. 2- Relay model.
h. The power source (2 Gasoline generators).
i. 2. AC induction motor (2 hp)
j. Forward speed sensor (FC-33).

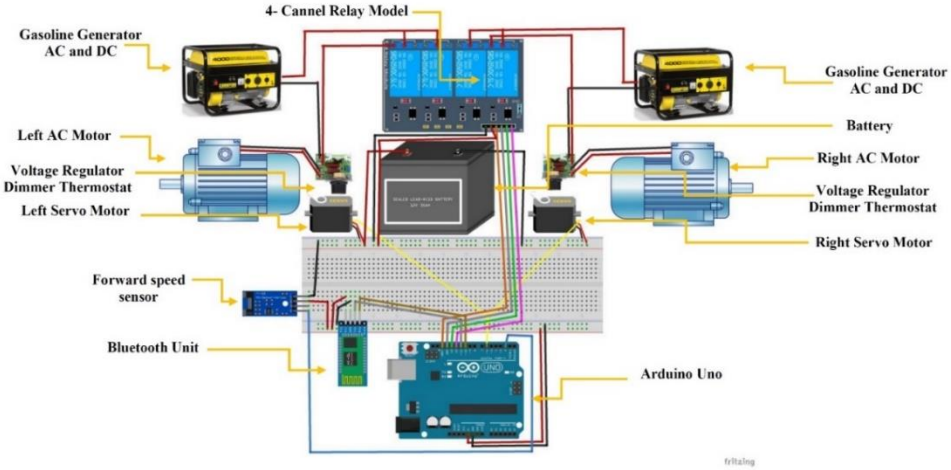

Figure 1. Electronic circuit components.

a. Arduino Uno (ATmega328P)

Arduino Uno is an open-source microcontroller board based on the ATmega328P. It has 6 analog inputs, 14 digital input/output pins 6 can be used as PWM outputs, a USB connection with a computer or laptop, an input power jack 7-12 VDC, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with an AC-to-DC adapter or battery to get started.

b. Bluetooth module (HC-06)

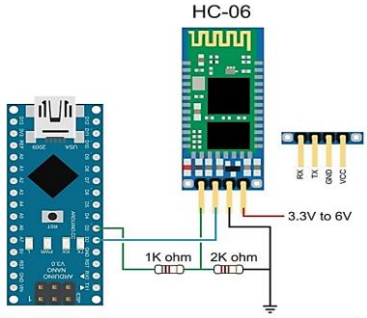

Figure 2. Bluetooth module (HC-06).

Bluetooth module (HC-06) is designed for establishing short-range (100 meters theoretically) wireless data communication between two microcontrollers or systems. This is the cheapest method for wireless data transmission and more flexible compared to other methods and it even can transmit files at a speed up to 2.1Mb/s (Figure 2).

c. Smartphone application

The android application was designed by using MIT App Inventor which is a web application integrated development environment originally provided by Google and used to create an application software for android phones After constructing the app, the Android application package (apk) file will be created and downloaded from the MIT app inventor and be installed on Android smartphone.

The mobile application was designed in a way that allows a wide range of control over the speed of AC motors in order to obtain the desired speed accurately, and on the other hand, another method has been added that enables the user to use stable speeds that can be relied upon during the spraying process, depending on the required application rates. Where the application has been equipped with six buttons, which represent six forward speeds for the machine (Figure 3).

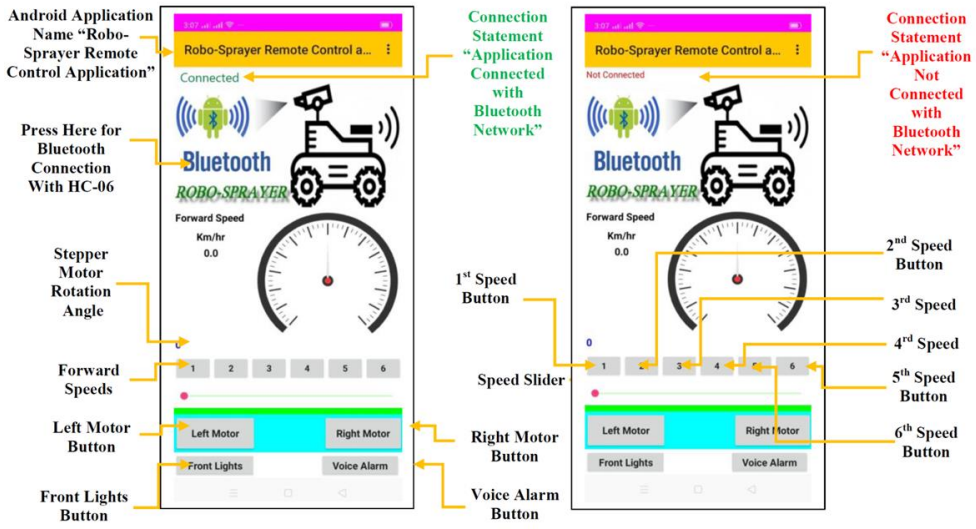

Figure 3. Smartphone mobile app designed by MIT App Inventor.

Also, the mobile app is equipped with two buttons, namely the right motor and the left motor, through which the robot's movement can be controlled on roads as well as rotating in the field while performing the desired operation easily, as each button is connected to a relay, where if pressing the button in the mobile app sends a signal to the Arduino board, then the Arduino board sends a signal to the relay, then the relay cuts off the electrical current to the motor in the desired direction to rotate through it (Figure 4).

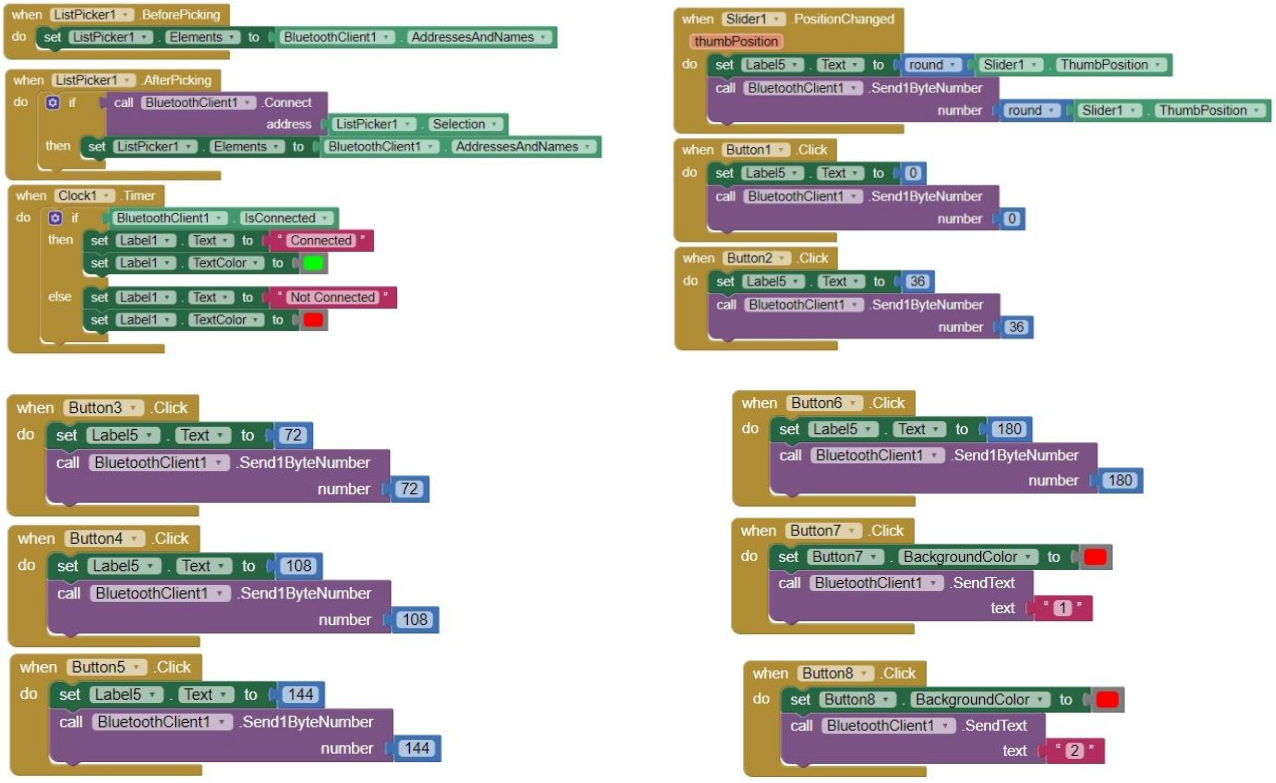

Figure 4. Programming code for the smartphone mobile app designed by MIT App Inventor.

d. Servo motor (TowerPro SG90)

The servo motor can be rotated approximately 0 - 180 degrees (90 in each direction). Thus, this proposed control methodology is applied to rotate the dimmer wirelessly (Figure 5).

Figure 5. Servo motor.

Specification

- Voltage: 4.8-6 V.
- Speed: 0.24 sec/ 180 degree (4.8 V) ~ 0.2 sec / 180 degree (6.0 V).
- Torque: 1.6 kg/cm (4.8 V).
- Dead Band Width: 5 µsec.
- Temperature: (-30 - 60) ºC.
- Cable Length: 25 cm.

e. Voltage regulator dimmer thermostat

The Voltage regulator dimmer thermostat is widely used for resistance load such as heating wire, filament lamp and most (not all) single-phase AC motors. The voltage regulator is designed with a large heat sink for better heat dissipation (Figure 6).

Figure 6. Voltage regulator dimmer thermostat.

***Specification*:**

- Heat Sink and Big Aluminum cooling.
- Main dimensions: 4.8 cm x 3.6 cm x 2.85 cm
- Pick power: 2000W.
- Efficiency is higher than 90 %.
- Voltage: 50-220 V.
- High-temperature FR-4 circuit board.

The system described in this manuscript works as following steps

1. First, both the system and the motor are started.
2. Sending a signal from smartphone mobile application via Bluetooth to Arduino units, (includes speed value or direction of moving).
3. The Servo motor will rotate with the desired angle associated with the forward speed.
4. As a result of rotating the servo motor, the dimmer is also rotated at the same angle of rotation, thus reducing the current entering the AC motor, which leads to the desired speed for the forward movement of the machine.
5. The relay controls the direction of machine movement by cutting the current from one of the two motors in the direction of movement and connecting the current to the other motor, as well as connecting the current to both motors when the machine is moving forward or cutting the current from both motors for stopping the machine.

3. Results and discussions

In order to test the electronic circuit that was designed in this paper, the unit was installed on an agricultural robot used to spray pesticides as shown in Figure 7.

3.1. The specifications of the robot used were as follows

1. Robot Traction System consists of a pair of 2 hp AC induction motors.
2. The power system consists of a pair of generators with a net capacity of 2.5 kW, which can generate both direct current and alternating current, as DC is used to charge batteries and operate electrical and electronic circuits in the robots while alternating current is used to operate AC motors.

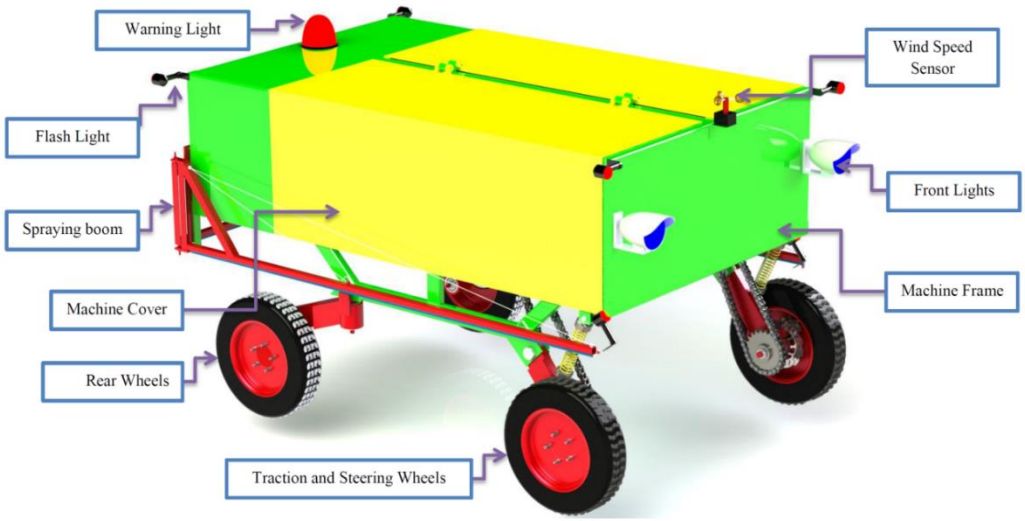

Figure 7. The main components of the spraying robot.

Figure 8. The spraying robot.

3.2. The cost of the components that were used to create the electronic circuit

The following Table 1 shows the costs of the components required to design the control circuit of AC induction motors for 2 motors, according to the aforementioned diagram, which is represented in purchasing the main components that make up the electronic circuit.

We found that the cost of the electronic circuit through which it is possible to control a robot that uses AC motors in steering and generating the necessary power for movement using two AC motors, one motor capacity is 2 hp, where a total cost is equal to only 790 EGP (approximately 40 USD), which is very low when compared to using DC motors and motor drivers.

Table 1

The cost of the components that were used to create the electronic circuit.

Item	Unit Price (EGP)	No. of items	Total
Arduino Uno (ATmega328P)	145	1	145
Bluetooth module (HC-06)	125	1	125
Servo motor (TowerPro SG90)	60	1	60
Voltage regulator dimmer thermostat	175	2	350
Relay model	110	1	110
Total cost			790

3.3. Testing of the electronic circuit

Tabular data in a Table 2 shows the parameters that were measured during the operation of the machine to test the performance of the speed electronic circuit that was used in operating the spraying machine.

The electrical measurements included measuring the voltage and electric current of the AC induction motor at different speeds by the digital Multimeter, as well as measuring the forward speed of the spraying machine by rpm speed sensor (HC-89).

Table 2

The parameters measured during testing of the speed control circuit.

Speed button	Current, (A)	Voltage, (V)	Consumed power, (kW)	The rotation angle of the servo motor	forward speed, (Km/hr)
1st speed	6.71	221	1.48	0 º	9.33
2nd speed	5.98	204	1.22	36 º	8.39
3rd speed	5.47	191	1.04	72 º	7.46
4th speed	4.85	185	0.90	108 º	6.84
5th speed	4.67	172	0.80	144 º	6.22
6th speed	4.12	164	0.68	180 º	5.49

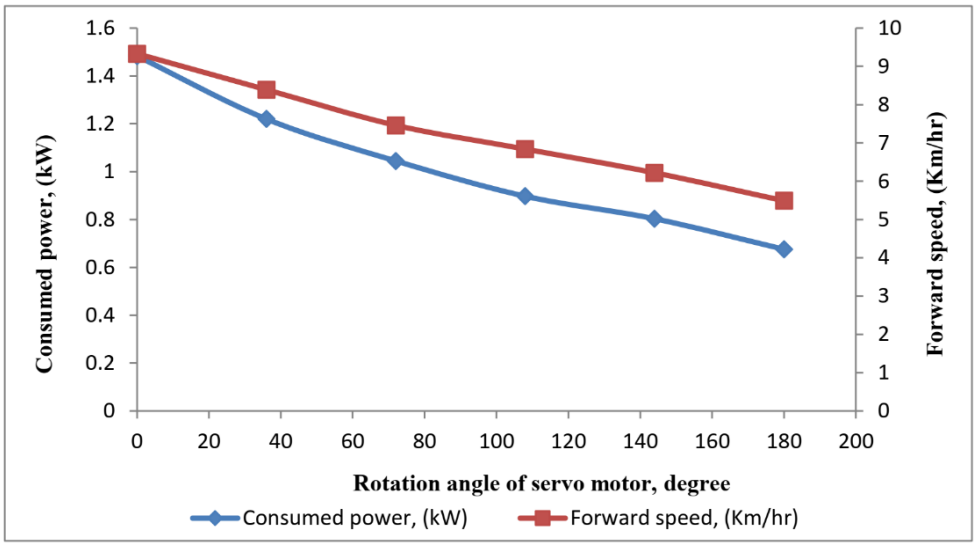

Figure 9. The relation between the forward speed, power consumed, and the servo motor rotation angle for one generator.

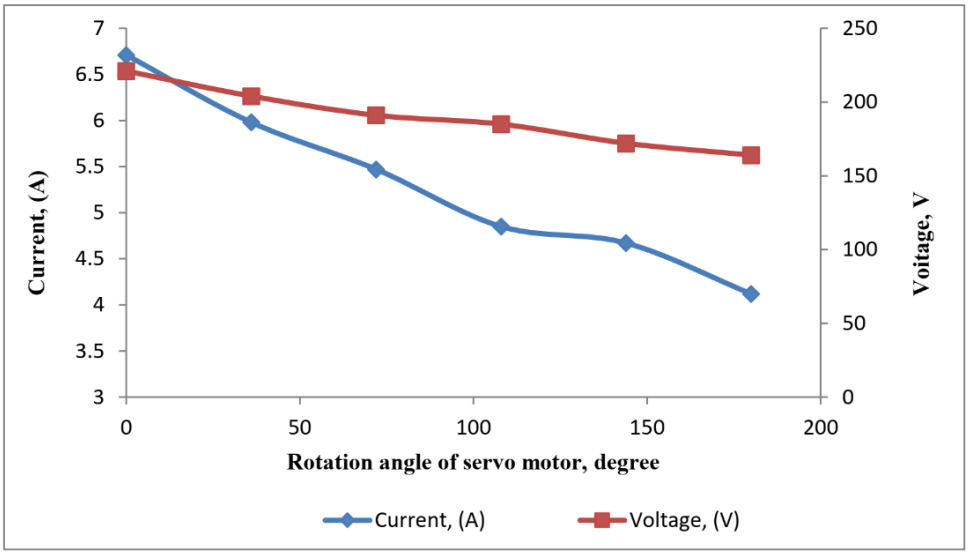

Figure 10. The relation between the voltage, current, and the servo motor rotation angle for one generator.

Table 2 and Figure 9, Illustrates the effect of the rotation angle of the servo motor on consumed power and forward speed of the spraying machine, Results shows that increasing the rotation angle of the servo motor decreases the consumed power from 1.48 to 0.68 kW, while the forward speed of the spraying machine decreased from 9.33 to 5.49 km/hr.

Table 2 and Figure 10, shows the effect of the rotation angle of the servo motor on the output voltage and current, Results shows that increasing the rotation angle of the servo motor decreases the voltage from (221 to 164 V), The data also indicate that decreasing the output current from (6.71 to 4.12 A) by 38.60 %.

4. Conclusions

The design of an electronic circuit to control AC induction motors leads to an increase in the efficiency of the use of local resources in the manufacturing process for various agricultural robots, and this is what has been achieved in this research, where the manufacturing cost was about $ 40, and it can be controlled using a smart mobile via Bluetooth, and it has been proven Efficient operation and control of the agricultural robot.

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تصميم دائرة إلكترونية جديدة للتحكم في سرعة محرك التيار المتردد الحثي

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الملخص العربي

في الآونة الأخيرة، ازداد الاهتمام بتكنولوجيا تصنيع الروبوتات الزراعية والتحكم فيها عن طريق نظام التحكم عن بعد باستخدام الأردوينو Arduino. يعد التحكم في السرعة الأمامية والتوجيه من أهم النقاط في تصميم الروبوتات الزراعية. نظراً لارتفاع أسعار محركات التيار المستمر وعدم توفرها في الأسواق المحلية بالقدرة المرغوبة، فإن الهدف من هذه الدراسة هو إمكانية استخدام محركات التيار المتردد من خلال ابتكار طريقة غير مكلفة يمكن من خلالها تشغيل الروبوت باستخدام محركات التيار المتردد ويمكن تشغيله والتحكم فيه أيضًا. حيث يتم التحكم فيها عن بعد باستخدام الأردوينو Arduino عبر البلوتوث، مما يؤدي إلى تقليل تكاليف تصنيع الروبوت وبالتالي تقليل تكاليف التشغيل لأداء العملية المطلوبة.