Monitoring and Control System for Three Phase Induction Motor Using Poly Phase Multifunction Energy Metering IC ADE7758 and Zigbee Protocol

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Abstract: ***Induction machines are used worldwide in many suburban, commercial, engineering and utility applications. They transform electrical energy into mechanical energy. An induction motor may be part of a fan or pump or connected to some other form of mechanical equipment such as a winder, a conveyor belt or a mixer. Induction motors have existed for many years but were always limited in their application because it was difficult to control the speed of the motor. Nowadays induction motors are the preferred choice among the industrial motors due to their rugged construction, the absence of brushes, the modern power electronics, and the ability to control the speed of the motor. Induction machines are used as actuators in many industrial processes. Although induction motors are reliable, they are subjected to some undesirable stresses, causing faults resulting in failure. Monitoring of an IM is a fast up-and-coming technology for the detection of initial faults. It avoids unpredicted failure of an industrial process. Monitoring techniques can be classified as the conventional and the digital techniques This paper proposes a wireless control and monitoring system for an induction motor based on Zigbee communication protocol for safe and economic data communication in industrial fields. A module of transducers and sensors monitors the parameters of induction machine and transmits the data through Zigbee Protocol. Microcontroller based system is used for collecting and storing data and accordingly generating control signal to stop or start the induction machine through computer interface developed with Zigbee***

Keywords: Induction Motor, Zigbee Module, Wireless control and Monitoring System.

1. Introduction

The performance of the motor depends on electrical parameters of the motor, that's why high performance AC motor control methods are very sensitive to motor parameters. Parameters of an induction motor can be measured by experiments like the locked rotor test and no load test [3, 4]. All electrical and non-electrical parameters like frequency, current, voltage, temperature, and speed of the induction motors are very important for a drive system. The performance of an induction motor is directly affected by whole fundamental qualities. If any parameter of induction motor changes then quality of product also changes, hence controlling the machines during the process of production continues to be a dangerous operation in some department of industry.

In this case, remote control and monitoring techniques become good solution. Wireless data communication is used in various industries, such as Wi-Fi, Bluetooth, and 3G because they are capable of high data rate transmission. These devices use system resources a lot. IEEE has developed 802.15.4 that is zigbee.

Zigbee is mostly used in industries in various ways because as per Yanfei L., Cheng W & Li J., Zhu X., Tang N., Sui J it supports devices having low cost, intelligent network topologies and energy saving [5, 6]. Zigbee is bidirectional data transmission wireless protocol that's why data can be received or sent at the same time as well as lot of devices and machines can be controlled.

Why zigbee based system should be used? Because, traditional protection practices for detecting motor defects and protecting motors use various types of protection relays such as temperature relays, over current relays, electromagnetic switches, low and high current protection relays, contactors, and time relays. They increases cost of systems and reduce the efficiency and sensitivity of the system and increase the time for detecting faults. But in digital systems like zigbee based parameter monitoring system cost of system reduces, efficiency and sensitivity of the system increases as compared to traditional system.

As per Çolak İ, Çelik H. Sefa İ. & Bektaş, A., Bayındır R, in some case, motor parameters have been used to display the electrical and mechanical performance of the motor using a PC [13, 14].

In [14], all measurements related to the induction motor were done and protection against the failure of induction motor has been achieved by developing a real time monitoring system against the failure of induction motor. But cost of system is increased due to input traducers like temperature sensors or other sensors used to collect the voltage and current information from the motor network and transfer to the PC as per Bektaş, A., Çolak, İ., Bayındır, R. [14]. The basic structure of Zigbee based parameter monitoring and controlling system consists of two section hardware and software such as Poly Phase Multifunction Energy Metering IC with Per Phase Information ADE7758, Atmel Atmega 16-32 PU microcontroller, a Zigbee 2-mW protocol, three phase induction motor, a wired temperature sensor manufactured by National Semiconductor (LM35) and, a desktop computer, and Visual Basic 6.0 Package to design the interface program.

2. The Proposed Wireless, Induction Motor Parameter Monitoring System

A powerful wireless monitoring system has been achieved for an induction motor by using zigbee protocol. This section gives the overview of the wireless parameter induction motor monitoring system. A basic block diagram as shown in fig (1).Its consist of two section 1) Hardware and 2) software

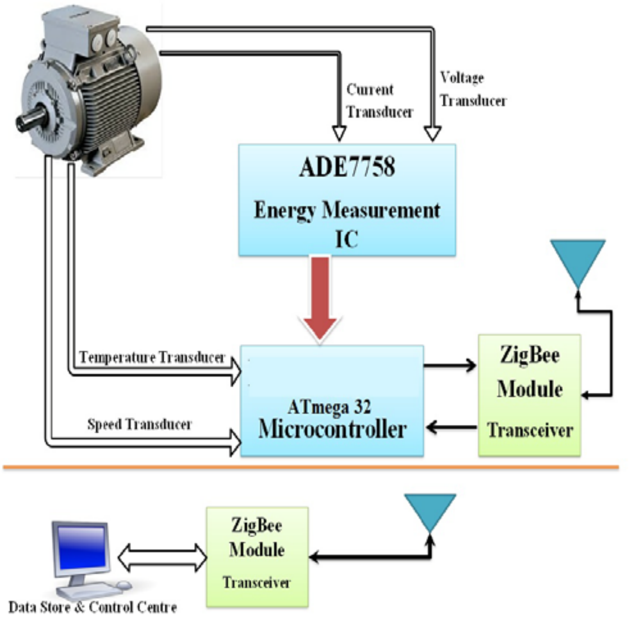

Figure 1: A basic block diagram of system

2.1 Hardware

In this section zigbee protocol is used to setup wireless communication link between PC and Induction motor control circuit. Data is transmitted from PC to control unit by using zigbee device. Control unit consist of sensor and transducers used to monitor the parameters such as voltage, current, and temperature of stator winding and speed of the induction motor. The micro-controller at the transmitter end is so programmed that if the monitoring parameter of induction motor crosses the safety limit, a signal will be generated by the micro-controller which will energize the relay circuit and the contactor cuts the mains supply to the induction motor. And this data is transmitted powerfully and easily to receiver end through wireless Zigbee Communication Protocol (IEEE802.15.4 Standards).

3. Hardware Design

3.1 Zigbee Technology

The ZigBee is the new short range, low power, wireless networking technology for many applications. It is also a research topic in short-distance wireless communication technology. It is widely used in industry, monitoring and control of agricultural area, home and building automation, automatic control, hospital and other fields [15-22]. Because its advantages like low power, low cost, self-organization etc. It has the best specified bottom three layers (Physical, Data Link, and Network), its transmission distance is more than 1 mile and it is compatible with the 2.4GHz and 900MHz frequency bands. As per Gang Z, Shuguang L it is two-way communication technology. This technology has great potentials in sensing and control applications [23]. The ZigBee network layer supports star, tree and mesh topologies as shown in Figure.2

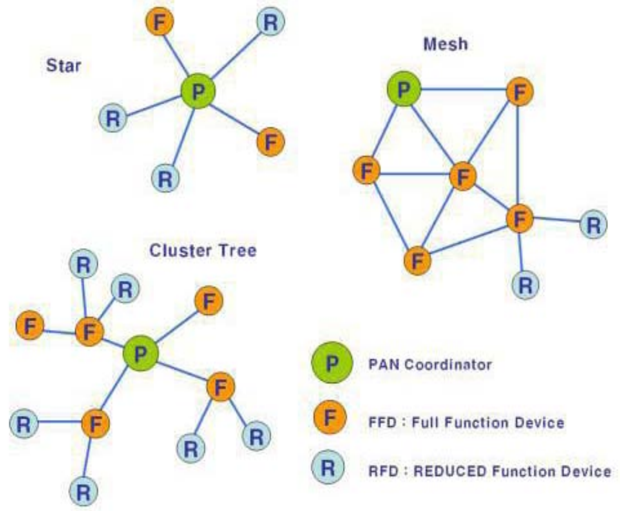

Figure 2: Zigbee Network Technology.

As per Zhu XQ., Wang JM, there can be only one coordinator in each network [24]. In star topology where ZigBee coordinator is responsible for initiating and maintaining the devices on the network, and other devices directly communicate with coordinator. This topology is suitable for networks with a centralized device and for time critical applications. In cluster tree network coordinators are still responsible for the network initiating and maintenance; however, routers can be used to extend the network. Routers control data flow by using hierarchical routing strategies in the network. They also may imply beacon enabled network that is defined in IEEE 802.15.4 for periodical data transmission. In mesh, network coordinators are responsible for starting the network and for choosing certain key network parameters but the network may be extended through the use of Zigbee routers. Routers can be used to extend the network. As per Li J., Zhu X., Tang N. Sui J, a mesh network allows full peer-to-peer communication. If a node fails another route is used for the data delivery [25].

3.2 Digi -Zigbee Module

Zigbee modules are designed with low to medium transmit power and for high reliability wireless networks. The modules require minimum power and provide reliable delivery of data between devices and the interfaces provided with the module help to directly fit into many industrial applications. The modules operate with IEEE 802.15.4 baseband.

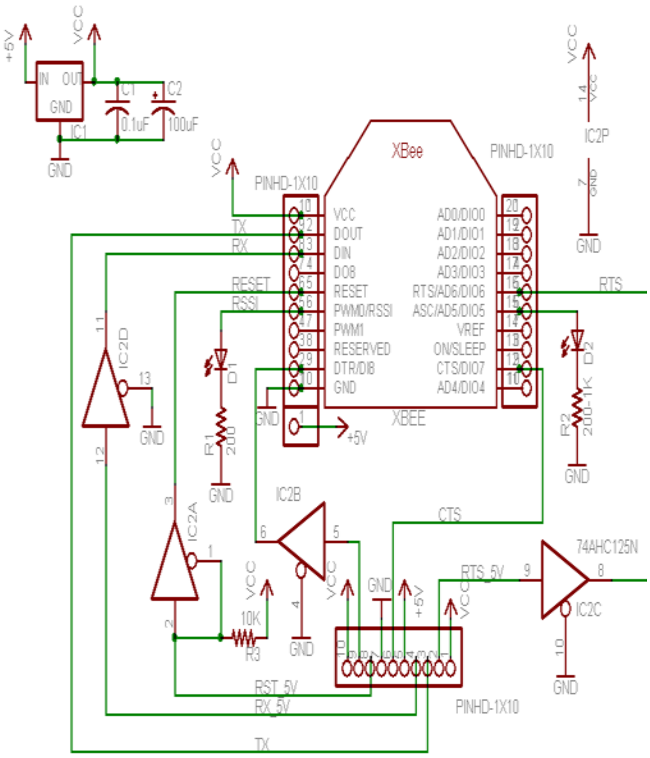

Figure 3.2: Zigbee interfacing board circuit

3.3 Features of Zigbee Module

1. 802.15.4/Multipoint network topologies
2. 2.4 GHz for worldwide deployment
3. 900 MHz for long-range deployment
4. Fully interoperable with other Digi Drop-in Networking products, device adapters and extenders,
5. Common ZigBee footprint for a variety of RF modules
6. Low-power sleep modes
7. Multiple antenna options
8. Industrial temperature rating (-40º C to 85º C)
9. Low-power consume and long-range variants available

Poly Phase Multifunction Energy Metering IC ADE7758

The ADE7758 is a high accuracy, 3-phase electrical energy measurement IC with a serial interface and two pulse outputs. It incorporates second-order Σ-Δ ADCs, reference circuitry, a temperature sensor, a digital integrator, and all the signal processing required to perform active, apparent, and reactive energy measurement and rms calculations.

The ADE7758 is suitable to measure active, reactive, and apparent energy in various 3-phase configurations, like DELTA services, with both three and four wires. It provides system calibration features for each phase, that is, phase calibration; rms offset correction, and power calibration. The VARCF logic output provides instantaneous reactive or apparent power information and the APCF logic output gives active power information. It has a waveform sample register that allows access to the ADC outputs. The part also incorporates a detection circuit for short duration high or low voltage variations. The voltage threshold levels and the duration of the variation are user programmable. A zero-crossing detection is coordinated with the zero-crossing point of the line voltage of any of the three phases. This information can be used to measure the period of any one of the three voltage inputs. The zero-crossing detection is used inside the chip for the line cycle energy accumulation mode. This mode permits faster and more accurate calibration by synchronizing the energy accumulation with an integer number of line cycles. Data is read from the ADE7758 via the SPI serial interface. The interrupt request output () is an open-drain, active low logic output. The IRQIRQ output goes active low when one or more interrupt events have occurred in the ADE7758. A status register indicates the temperament of the interrupt.

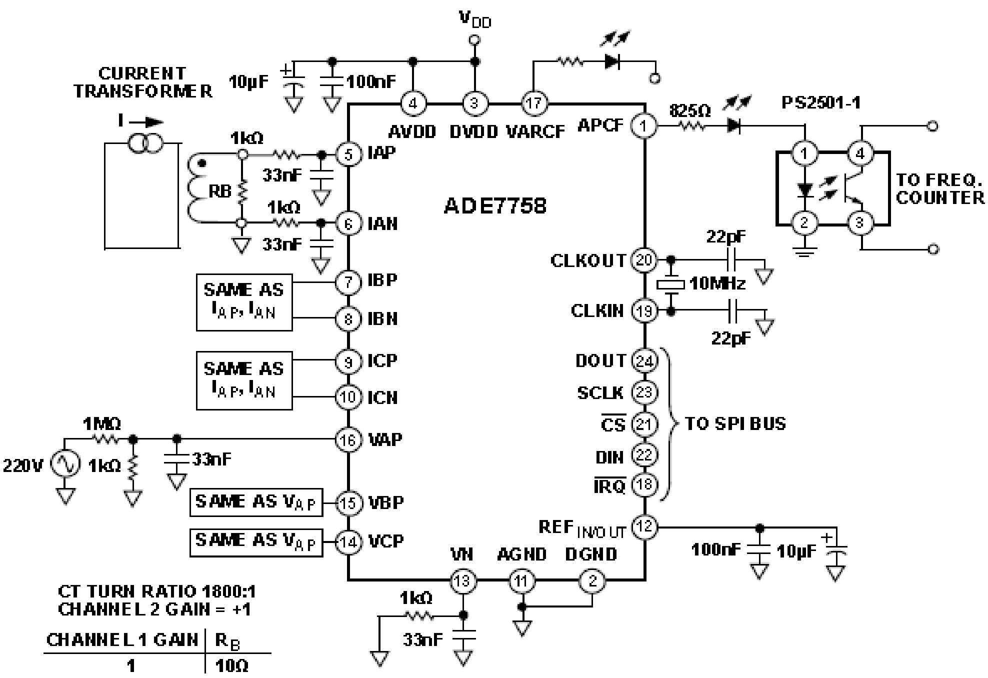

Figure 3.3: Circuit Diagram for ADE7758

3.4 Peak Current Detection

The ADE7758 can be programmed to record the peak of the current waveform and produce an interrupt if the current exceeds a preset limit. Peak Current Detection Using the PEAK Register The peak absolute value of the current waveform within a fixed number of half-line cycles is stored in the IPEAK register.

3.5 Over Current Detection Interrupt

The over current event is recorded by setting the PKI flag (Bit 15) in the interrupt status register. If the PKI enable bit is set to Logic 1 in the interrupt mask register, the IRQ logic output goes active low. Similar to peak level detection, multiple phases can be activated for peak detection. If any of the active phases produce waveform samples above the threshold, the PKI flag in the interrupt status register is set. The phase of which over current is monitored is set by the PKIRQSEL [2:0] bits in the MMODE register.

3.6 Peak Voltage Detection

The ADE7758 can record the peak of the voltage waveform and produce an interrupt if the voltage exceeds a preset limit. Peak Voltage Detection Using the VPEAK Register, the peak absolute value of the voltage waveform within a fixed number of half-line cycles is stored in the VPEAK register.

3.7 Over Voltage Detection Interrupt

The content of the VPINTLVL [7:0] register is equivalent to Bit 6 to Bit 13 of the 16-bit voltage waveform samples; for that reason, setting this register to 0x9D represents putting the peak detection at full-scale analog input. By setting the PKV flag (Bit 14) in the interrupt status register and the overvoltage event is recorded. If the PKV enable bit is situate to Logic 1 in the interrupt mask register, the logic output goes active low IRQ

3.8 Active Power Calculation

Electrical power is defined as the rate of energy flow from source to load. It is given by the product of the voltage and current waveforms. The resulting waveform is called the instantaneous power signal and it is equal to the rate of energy flow at every instant of time. The unit of power is the watt or joules/sec. Following equation gives an expression for the instantaneous power signal in an ac system.

$V(t) = \sqrt{2} \times VRMS \times \sin(\omega t)$ eq.1

$I(t) = \sqrt{2} \times IRMS \times \sin(\omega t)$ eq.2

Hence

$P(t) = V(t) \times I(t)$

$P(t) = IRMS \times VRMS - IRMS \times VRMS \times \cos(2\omega t)$

The average power over an integral number of line cycles (n) is given by the expression in Equation

$$P = \frac{1}{nT}\int_0^{nT} p(t)\,dt$$
$$= Vrms \times Irms$$

Where:

'T' is the line cycle period.

P is referred to as the real or active power.

The active power is equal to the dc component of the instantaneous power signal P (t), that is VRMS × IRMS. This is the relationship used to calculate the active power in the ADE7758 for each phase.

3.9 Reactive Power Calculation

A load that contains a reactive element like inductor or capacitor, it produces a phase difference between the applied ac voltage and the resulting current. The power associated with reactive elements is called reactive power, and its unit is VAR. Reactive power is defined as the product of the voltage and current waveforms when one of these signals is phase shifted by 90°.

$$v(t) = \sqrt{2V}\sin(\omega t - \theta)$$
$$i(t) = \sqrt{2}\,I\sin(\omega t)$$
$$i'(t) = \sqrt{2}\,I\sin\left(\omega t + \frac{\pi}{2}\right)$$

Where:

v = rms voltage.

i = rms current.

θ = total phase shift caused by the reactive elements in the load.

Then the instantaneous reactive power q(t) can be expressed as

$$q(t) = v(t) \times i'(t)$$
$$q(t) = VI\cos\left\{-\theta - \frac{\pi}{2}\right\} - VI\cos\left\{2\omega t - \theta - \frac{\pi}{2}\right\}$$

The average reactive power over an integral number of line cycles (n) is given by the expression in Equation

$$Q = \frac{1}{nT}\int_0^{nT} q(t)\,dt = V \times I \times \sin(\theta)$$

3.10 Apparent Power Calculation

It is defined as the amplitude of the vector sum of the active and reactive powers.

There are two ways to calculate apparent power

1. The arithmetical approach
2. The vectorial method.

The arithmetical approach uses the product of the voltage rms value and current rms value to calculate apparent power. Following equation describes the arithmetical approach mathematically.

$S = VRMS \times IRMS$

Where: S is the apparent power.

The vectorial method uses the square root of the sum of the active and reactive power, after the two are individually squared.

$$S = \sqrt{P^2 + Q^2}$$

Where:

1. S is the apparent power.
2. Q is the reactive power
3. P is the active power.

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The apparent energy calculation in the ADE7758 uses the arithmetical approach.

3.11 Period Measurement

The ADE7758 provides the period or frequency measurement of the line voltage. The period is measured on the phase specified by Bit 0 to Bit 1 of the MMODE register. The period register is an unsigned 12-bit FREQ register and is updated every four periods of the selected phase. Bit 7 of the LCYCMODE selects whether the period register displays the frequency or the period. Setting this bit causes the register to display the period. The default setting is logic low, which causes the register to display the frequency.

When set to measure the period, the resolution of this register is 96/CLKIN per LSB which represents 0.06% when the line frequency is 60 Hz. At 60 Hz, the value of the period register is 1737d. When set to measure frequency, the value of the period register is approximately 960d at 60 Hz and this is equivalent to 0.0625 Hz/LSB.

3.12 Speed Monitoring

Speed of revolution of induction motor can be measured using IR sensor. An encoder is a rotational transducer that converts angular movement into digital impulses.

3.13 Temperature Monitoring

Temperature of stator winding can be measured through LM35 Direct to digital temperature sensor. The Direct–to–Digital Temperature Sensors measure temperature through the use of an onboard proprietary temperature measurement technique.

4. Software Design

4.1 Software Tools

Mikro C pro for AVR (Studio) and AVR Flash Load are two softwares used to program microcontroller

4.2 Programming Microcontroller

The compiler for high level language helps to reduce production time. For programming ATmega 32 AVR Studio is used. The programming is done in embedded C language

4.3 AVR Studio

AVR studio is software used where machine language code is written and compiled. After compilation machine source code is converted to hex code to be burnt into the microcontroller. The program is written in C language code.

4.4 AVR Flash

It is software that accepts only hex files. Machine code converted into hex code after that hex code has to be burnt into the microcontroller with the help of AVR Flash. It is a programmer which contains a microcontroller in it other than the one which is to be programmed. The program is written in the AVR Pro microcontroller in such a way that it accepts the hex file from the Mikro C pro for AVR and burns this hex file into the microcontroller which is to be programmed.

1. Microcontroller Software Compiler generates a Hex file.
2. Hex file accepted and sent to MCU program Loader.
3. Hex file programmed into Target Microcontroller device.

5. Experimental Results and Discussion

5.1 Experimental Setup

Following figure 5.1 shows the actual experimental setup. In this setup induction motor is connected with three phase power supply through a current transformer. Microcontroller reads all inputs such as temperature, currents, voltages and speed and sends data to base station using zigbee module.

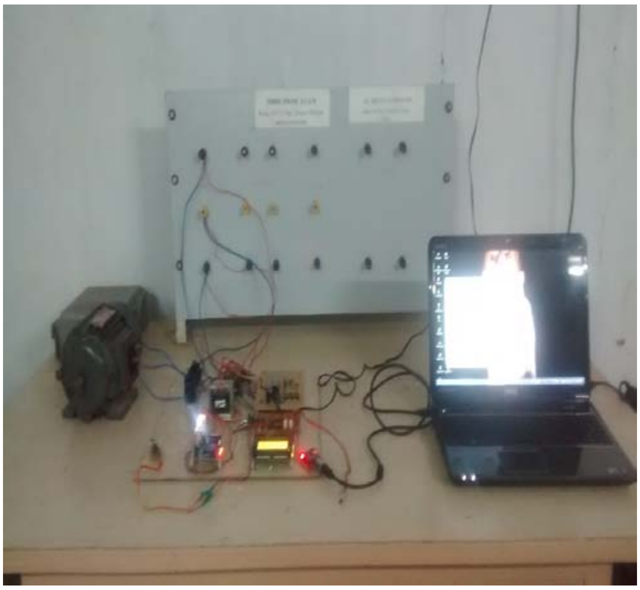

Figure 5.1: Experimental Setup

5.2 Results

Following figure 5.2 shows the actual results. Figures 5.2 shows that when no load apply to motor, then following window appears on screen

Figure 5.2: Result on LCD

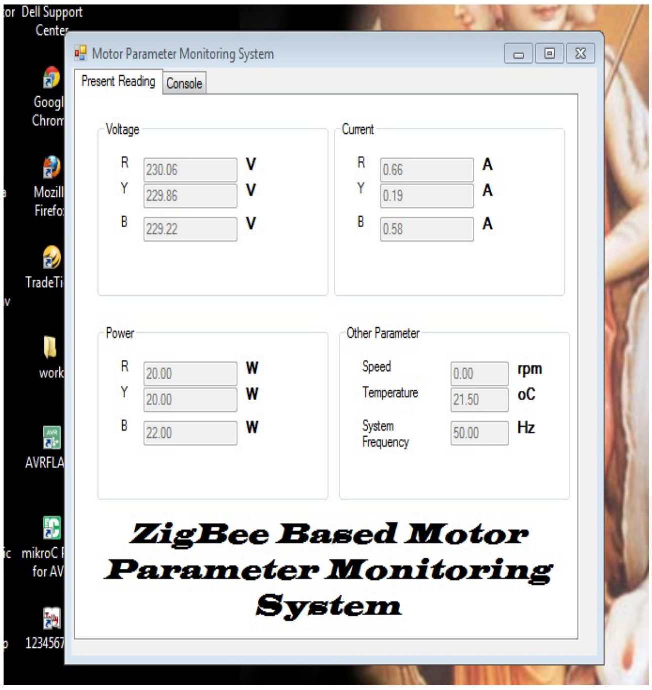

Figure 5.3: Result on monitoring screen

6. Conclusions

In this way a parameter monitoring system for induction motor using Zigbee protocol is realized and tested. It is capable of performing some operations like running the motor through RF control interface, measuring parameters, stopping, monitoring all the parameters of the induction motor such as phase voltages, phase currents, winding temperature, power, speed. All parameter values are transferred to the controlling computer and by using GUI all these parameter values are displayed on the monitor. It can be used for industrial applications as well as educational purposes and it can be adapted in experimental researches successfully

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