FACULTY OF ENGINEERING

DEPARTMENT OF ELECTRICAL ENGINEERING

TITLE: DESIGN AND DEVELOPMENT OF A DC MOTOR SPEED CONTROLLER USING A MOBILE PHONE'S SMS DATA

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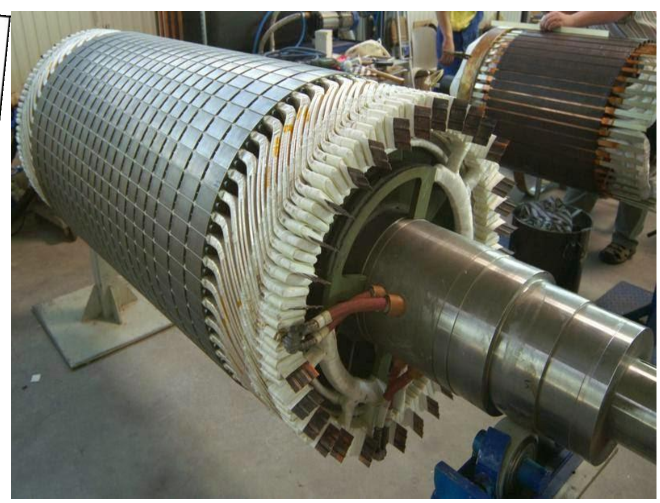

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ABSTRACT

This project is mainly focused on the implementation of DC motor control from remote locations. The first part outlines the basic principles of DC motor speed control using power electronics, and presents in detail, the technical standards of GSM technology. This knowledge is then used to design and develop a prototype for DC motor speed and direction control using SMS data. Collectively, this document can serve as a stepping stone for future work in this area. The last section explains the test results of the prototype, and possible practical applications are identified. Analysis and inferences are presented in the conclusion, and the document is complete.

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CHAPTER ONE: PROJECT OVERVIEW

1.1 INTRODUCTION

Electric machines mainly comprise of generators and motors. They play an important part in our daily lives, and their importance is even greater in industry. Typical applications of electric motors include

1. Electric locomotives
2. Steel mills, textile mills
3. Electric fans
4. Vacuum cleaners
5. Hair dryers in saloons
6. Washing machines and dishwashers

In general, d.c motors operate more efficiently with low voltages which is why they are more common in household motor applications. A.C motors however, are more frequent in high voltage applications. Early in the generation of electricity, during the late 1880s, direct current was mostly dominant. This led to d.c machines gaining ground over a.c machines. As more research was done in power systems generation and transmission, it was soon discovered that a.c generation was more economic. This is the main reason why today, a.c generation has largely replaced d.c generation, even though advances in power electronics have ensured that d.c generation is not totally obliterated. Although a.c machines have essentially taken over in generation, d.c machines are still extensively used in other applications.

A single electric machine can be manipulated to operate as either a motor or as a generator, and this implies that the study of either, is in essence, the study of the other.

Classification of Electric Motors

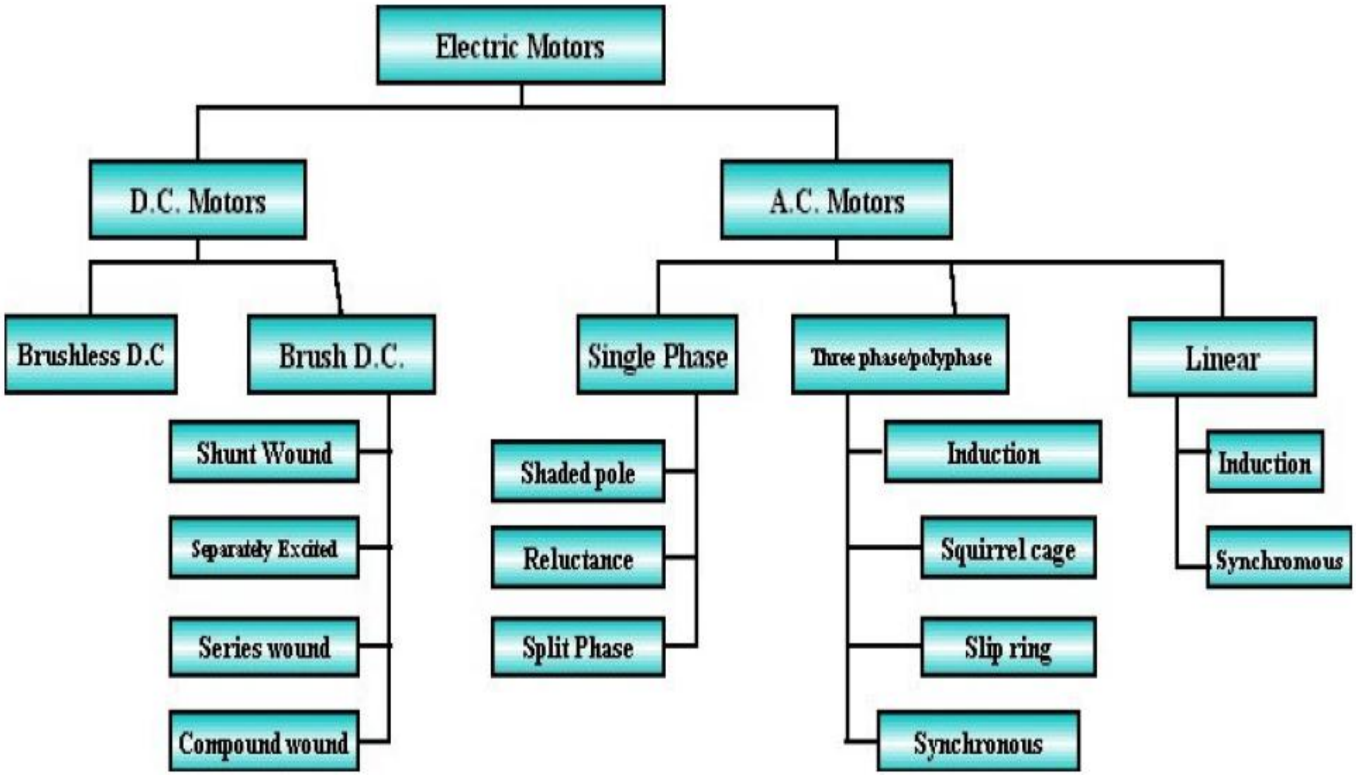


Fig 1.1 Different classes of electric motors (A Guide to Energy Efficient Motors, online - 20 October 2014)

Most electric motor applications require flexibility of control. D.C motors can be easily controlled as compared to a.c motors. Also, the developments made in power electronics have further simplified d.c motor control. For this reason, d.c motors have continued to be in use despite the advantages of a.c motors. It can therefore be concluded that both a.c and d.c motors are being used in today's industry and as such, it is imperative that the study of electric motors encompasses both a.c and d.c motors.

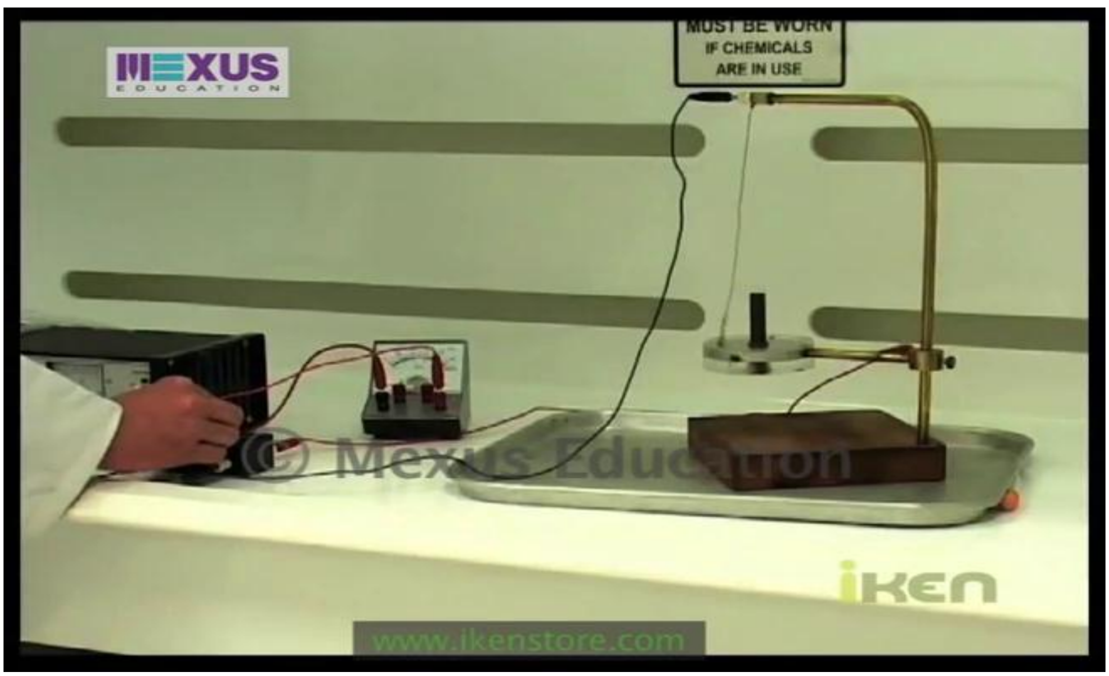
In industry, it is often tedious, time-consuming and sometimes dangerous to control motors or large machines in general, using conventional controls. GSM technology makes it possible to control systems from remote locations by use of a mobile phone's SMS data. Some of the applications of GSM are robot motor control and home appliance control. Advantages of using GSM technology include;

1. Increased security.
2. Allows for emergency response if need be.
3. Universal data transfer.
4. Its architecture is openly distributed on the OSI 7-layer model.
5. It is a worldwide standard.

This project undertakes to design and develop a prototype for a motor speed controller applying GSM technology.

1.2 BACKGROUND

In 1820, in Copenhagen Denmark, Hans Christian Oersted noticed that a current carrying metal wire deflected a compass needle that was placed near it. This phenomenon was later explained by Michael Faraday who suggested that a current carrying conductor created a circular magnetic field around it. This theory was proved to be correct because it was consistent with all the laboratory observations. One year after Oersted's initial discovery, Faraday set up the apparatus shown below, and this, although primitive, can be viewed as the first ever electric motor.



Set-up used by Faraday to explain magnetic fields around a current-carrying conductor. (www.ikenstore.com (20 October 2014))

At the center was a permanent magnet (black cylindrical bar) with its South Pole upwards, placed in a mercury bowl, and using a conductor (silver wire) immersed in the mercury, a circuit was completed as shown. The wire was hinged at the top and free to move at the end immersed in mercury.

Faraday predicted that when an electric current was allowed to pass through the wire, it would form a circular magnetic field that would interact with the field from the permanent magnet, causing circular motion. This prediction was correct. And from here on, it was seen that speed at which the wire moved was dependent on the current passing through it, and the strength of the magnets. These are the fundamental principles of motor speed control.

Global Systems for Mobile Communication (GSM), is a mobile communication standard that is internationally recognized. It is strictly controlled by a memorandum of understanding and operates at 900MHz, 1800MHz and 1900MHz. GSM was originally formed in 1982, but the commercial system startup was not until May 1991 (GSM Fundamentals, Agilent Technologies). Today GSM can be applied in different sectors of industry. It can be used in motor speed control, making production more efficient and improving safety conditions.

1.3 PROBLEM STATEMENT

Heavy machines are sometimes dangerous to humans, particularly to those who work in close proximity with them. In Zimbabwe, there have been many reported accidents that have happened as a result of humans working too close to heavy machinery.

Agency of Accident		Year 2013	Year 2014	Total
Electrical Installations Including Electrical Motors	Operation of Rotating Machines, Motors	17	4	21
	Conductors	4	4	8
	Transformers	4	4	8
	Control Apparatus	3	3	6
	Refrigerating Plants	5	4	9
	Others	21	32	53

Table 1.1 Summary of the accidents related to electrical machines in Zimbabwe, for 2013 and 2014. (Partial extract from NSSA OSH annual Reports – 5 February 2015)

Table 1.1 clearly shows the dangers of human interaction with heavy machines. As can be seen, of the 105 accidents due to the agency of accidents described, upto ***27, i.e 25.7%*** (refer to regions in blue font) may be attributed to the interaction of humans with rotating machines, and 13 fatalities resulted from these accidents alone. The complete summary of accidents related to electromechanical machines that incorporate motors is given at the back of this document. Many of these accidents can be avoided if workers control such machines from remote locations where there would not be in any danger. The main reason why people must so often be too close to heavy machines is the need to control them, and controls are usually on the electric machines. GSM technology makes this possibility of a remote control mechanism become a reality. Also, some of the accidents reported were a direct result of electrical machines being operated by unskilled, and unauthorised personnel. Therefore, it becomes very important for engineers to come up with a way of making it impossible for unskilled or unauthorised personnel to operate industrial electromechanical machines.

To summarise, there are 2 main issues that need to be addressed. First, too many accidents have occurred due to people controlling heavy machines from close proximity, and second, accidents have also happened due to unauthorised control of these machines. As such, there is need to develop a mechanism that ensures these accidents are reduced to zero.

1.4 AIM

The aim of this project is to design and develop a modern d.c motor speed controller using a mobile phone SMS data.

1.5 OBJECTIVES

1. To research on, and understand the principles of motor speed control.
2. To research on the functionality and applications of GSM technology.
3. To design and develop a prototype for a d.c motor speed controller using GSM technology.
4. To analyse and discuss the advantages and disadvantages of such a system.

5. To identify practical applications of such a system, and suggest how it can be improved in future.

1.6 JUSTIFICATION

Apart from their industrial applications, motors are employed in home appliances were speed control is necessary, e.g. fans, washing machines, dish-washers and dryers. For most individuals, it can be a nuisance to have to walk to the appliance and make adjustments but, GSM technology makes it possible for one to control such appliances using their mobile phone’s SMS messages.

As the world moves more and more towards adoptation of international standards, it is important that systems are developed that are in sync with global policies. International standardization has gained a lot of ground in recent years particularly in Accounting, Economics, Medicine, and to some degree, Science. Use of GSM in motor speed control can go a long way in enhancing this globalization endeavor.

The robotics industry is one of the fastest growing industries today. Robots utilize a lot of motors within them, and so motor speed control has a significant bearing on the functionality of robots. Hence, use of GSM has the potential to increase the impact of robotics on society.

GSM technology makes it possible for systems to be controlled from remote locations. This reduces the interaction between humans and machines and this can go a long way in reducing accidents related to electrical machines.

Also, because GSM allows access to code, this means that control systems can be designed to operate under the exact desired conditions thereby improving efficiency and security.

In light of all this, it is without a doubt, necessary to study and invest in the field of motor speed control using GSM.

1.7 METHODOLOGY

The project is divided into 2 parts,

1. Research

2. Implementation

The first part is about gathering all the relevant information about the project. This includes a qualitative research on the principles of motor control using power electronics and, the technical standards that govern the functionality of GSM.

The second part is the implementation. First, a detailed block diagram with all the required circuit elements must be drawn and from this, it is be possible to come up with a complete circuit diagram. The second step of implementation is software development. After this has been done, the required equipment can be purchased and assembled in the lab, to produce a working motor speed controller using a mobile phone's SMS data.

<u>Data collection methods</u>

To gauge the significance of this project, and its relevance to modern day industry, it is necessary to find out how many accidents occur as a result of humans interacting with heavy, motor-based electrical machines. All this information is available at NSSA.

Other research methods applicable include:

- Research on the internet.
- Consultation of relevant personnel.
- Research in UZ libraries.
- Industrial visits.

<u>Data Analysis</u>

Data analysis is done using the conventional methods, and these include plotting distribution curves and calculating percentages.

CHAPTER TWO: DC MOTOR CONTROL AND GSM TECHNOLOGY

2.1 THE STANDARD DC MOTOR

Fig 2.1. (Left) Large Industrial DC Motor, and (Right), large DC motor being controlled from close range which is clearly dangerous practice. (www.covingtonelect.com, 24 January 2015)

In general, a DC Motor is an electromechanical machine that converts electrical energy to mechanical energy. The behavior of DC Motors is mainly based on the principle that, if a current carrying conductor is placed in a magnetic field, that conductor will experience a force.

The magnitude of this force is given by:

$$F = Bil.$$

<u>The Motor Equation</u>

Considering a coil that has 1 turn and hence 2 sides;

The emf produced in such a coil if it is placed in a magnetic field is given by

$e_t = 2Blv$ where, B – the average flux density

l – length of the coil

v – velocity of the conductor

Also, by definition

Magnetic flux per pole, $B = \frac{\Phi}{A}$ where, A – area of pole

And this area is given by, $A = \frac{2\pi rl}{p}$

Therefore $B = \frac{\Phi p}{2\pi rl}$

And hence, $e_t = 2\frac{\Phi p}{2\pi rl}lv$

$= \frac{\Phi pv}{\pi r}$ but $v=r\omega$

So, $e_t = \frac{\Phi p\omega}{\pi}$

If this dc machine has N turns,

Emf produced in that coil, $E_a = N\frac{\Phi p\omega}{\pi a}$

The equation is being divided by ‘a’ because the coils in the machine are connected in parallel paths that are determined by the number of poles.

Now if we define an armature constant K_a as

$K_a = \frac{Zp}{2\pi a}$ where Z = 2N since a single turn has 2 conductors.

Then $E_a = K_e\omega$ given that $K_e = K_a\boldsymbol{\Phi}$

Hence, at the terminals, an emf that is less than E_a will be delivered because the armature has some resistance.

And thus, $V_t = E_a + I_aR_a$, which is the motor equation.

Motor Torque Equation

By application of the Lorenz Force Law, the force acting on a conductor of length l and carrying a current of I amps is;

$$F = Bil, \text{ but } B = \frac{\Phi p}{2\pi r l}$$

So, $F = \frac{\Phi p i}{2\pi r}$ and if the I_a is the total average current flowing in the conductor, then

$$I = I_a/a$$

By definition,

Torque, T = Fr

Thus the torque per conductor,

$$T_{cond} = \frac{\Phi p i}{2\pi}$$

$$= I_a \frac{\Phi p}{2\pi a}$$

Because there 2 conductors per turn, the average torque for N conductors is;

$$T_{ave} = 2NT_{cond}$$

$$= NI_a \frac{\Phi p}{\pi a}$$

$$= K_a \mathbf{\Phi} I_a \qquad \text{where, the armature constant, } K_a = \frac{Np}{\pi a}$$

The torque constant K_t and the armature constant K_a depends on the construction of the machine. In the case of a separately excited machine, the flux can made constant such that;

$$T_{ave} = K_t I_a \qquad \text{where } K_t = K_a \mathbf{\Phi}$$

2.2 TYPES OF DC MOTORS AND THE THEORY BEHIND MOTOR CONTROL

There are many types of DC Motors but only two are discussed below to illustrate different ways of speed control that are currently in use in industry.

1. The Seperately Excited DC Motor

As shown in figure 2.2, a seperately excited DC Motor consists of two independent sources, the field voltage, V_f, and the armature voltage,

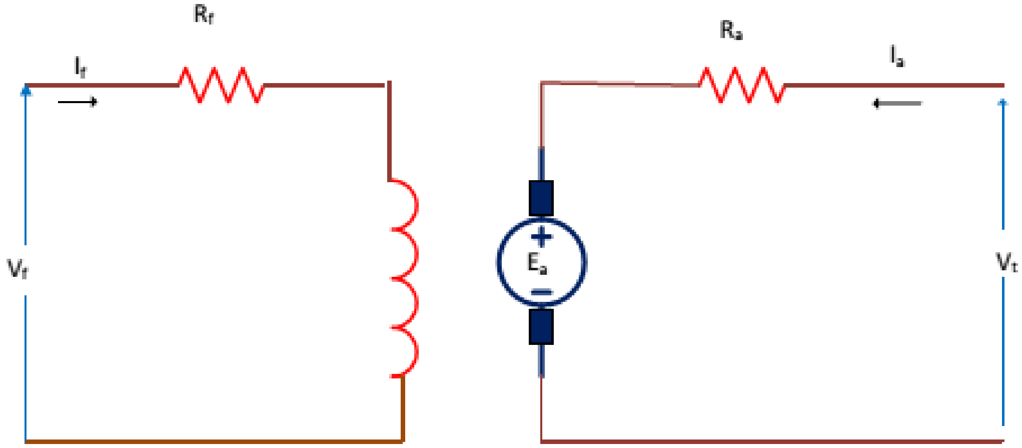


Fig. 2.2. Simplified representation of a Seperately Excited DC Motor.

From the figure above,

$$I_f = V_f / R_f \text{ but, } \mathbf{\Phi} = K_i I_f$$

And, $$E_a = K_a \mathbf{\Phi} \omega$$

By simple substitution and application of the motor equation,

$$\text{Torque } T = K_a \mathbf{\Phi} I_a$$

$$= K I_f \, . \, (V_t - K I_f \omega)/R_a, \quad \text{where } K = K_a K_i$$

And, this is the torque developed in a seperately excited d.c motor.

Once an expression for torque has been obtained, it is easy to determine how speed can be controlled. First, ω is made the subject of the formula and by varying any of the other parameters, speed can be controlled.

Therefore, for seperately excited d.c motors, the speed,

$$\omega = \frac{V_t}{KI_f} - \frac{R_a T}{(KI_f)^2}$$

Thus speed can be controlled by varying:

1. V_t
2. I_f
3. R_a

2. *The Series DC Motor*

The series DC Motor, also referred to as simply, the series motor, is shown in figure 2.3. Here, the field and the armature currents are in series hence they share the same value.

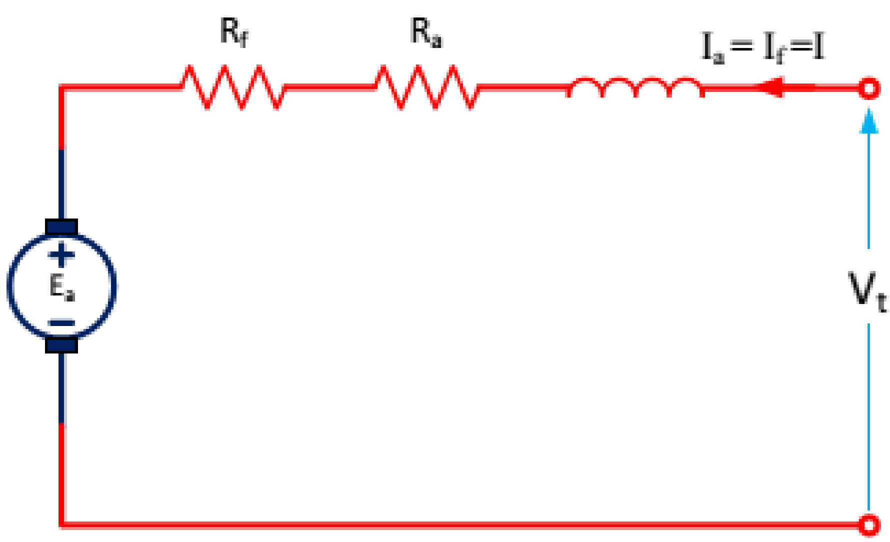


Fig 2.3. Equivalent circuit of a Series Motor.

Here the field and armature circuits are in series, hence from the diagram above,

$$I_f = I_a = I$$

The resistors are in series, so,

$$R_t = R_a + R_f$$

And, $$E_a = K_a\boldsymbol{\Phi}\omega$$

By substitution into the motor equation

Torque, $$T = (V_t)^2/(K\omega + R_t)^2$$

Therefore, for a d.c series motor, the speed,

$$\omega = \frac{V_t}{K}\sqrt{\frac{K}{T}} - \frac{R_t}{K}$$

So the speed can be varied by changing

1. V_t
2. The field by field tapping.

Use of Power Electronics in Motor Speed Control.

The methods of motor speed control described in the previous section, sometimes referred to as classic methods, are not always easy to realise. However, this challenge is overcome by the application of power electronics technology.
Control of motor speed by use of power electronics can be either open loop or closed loop. In closed loop control, there is feedback which allows for error correction and as such, closed loop control is the preferred choice.

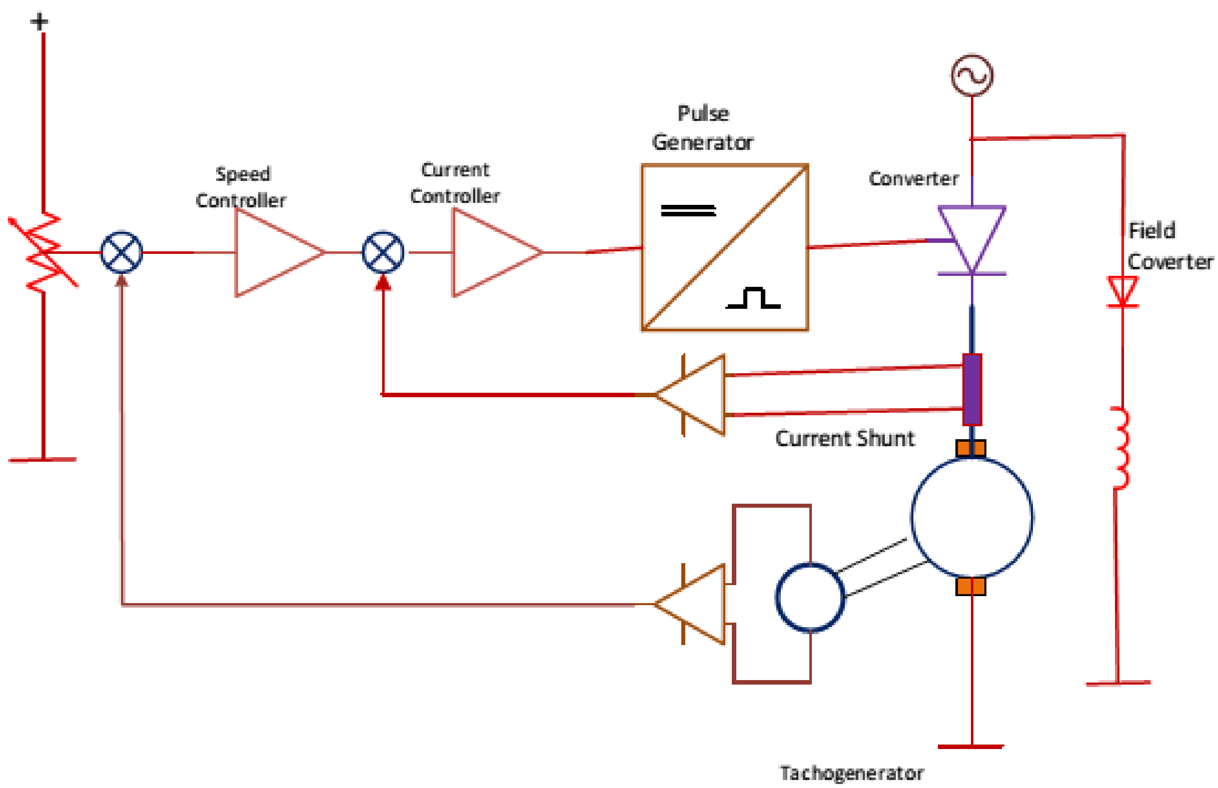


Fig. 2.4. Illustration of closed loop DC Motor Speed Control

Sometimes in industry, there is need for unattended precise motor speed control. The set up shown in fig 2.4 is well adapted for this purpose. The way in which this mechanism operates is explained below:

The potentiometer is used to set the desired speed and this speed is compared to the speed being measured by the tachogenerator. The error is corrected by the speed controller. The current controller is responsible for protecting the motor from damage due to overcurrent. The current controller's output is converted to digital pulses in the pulse generator. These pulses then drive converter, which in turn drives the DC motor.

The pulses produced by the pulse generator can be controlled by a microcontroller, which is capable of communicating to a GSM modem. This implies that it is possible to make this efficient system even more efficient by incorporating a remote control mechanism.

2.3 GSM TECHNOLOGY

Introduction

To recap, the main aim of this project is achieve motor speed control through the use of a mobile phone SMS data. The use of mobile phone SMS data is a cellular service provided by mobile systems. The table below gives a summary of how mobile systems have evolved in the past.

Year	Mobile System
1981	Nordic Mobile Telephone (NMT) 450
1983	American Mobile Phone System (AMTS)
1985	Total Access Communication System (TACS)
1986	Nordic Mobile Telephony (NMT) 900
1991	American Digital Cellular (ADC)
1991	Global System for Mobile Communication (GSM)
1992	Digital Cellular System (DCS) 1800
1994	Personal Digital Cellular (PDC)
1995	PCS 1900 – Canada
1996	PCS – USA

Table 2.1. Evolution of Mobile Telecommunication Systems Over the years. (Web Proforum Tutorials, http://www.iec.org, 27 December 2014)

The first ever mobile systems to be developed back in the early 1980s were analogue in nature. However, the major challenge that was faced by these systems was their inability to handle the growing demand in a cost-effective way. This gave birth to digital mobile systems. Some of the advantages of digital systems over analogue systems include,

1. greater ability to meet growing demand cost effectively
2. ease of signaling
3. low levels of interference

As cellular telecommunications continued to evolve, all the digital systems being developed still had one major flaw, there had no standardized specifications. This problem was solved by GSM. Below is a table that summarises how GSM has continued to develop over the past decades, to become the leading mobile system that it is today.

Year	Milestone
1982	GSM formed
1986	Field testing
1987	The Narrowband Time Division Multiple Access (TDMA), chosen as the access method
1988	First Memorandum of Understanding signed by over 18 Countries
1989	Validation of GSM Systems
1990	Pre-operation System
1991	Set up of the commercial system start up
1992	Coverage of larger systems and airports
1993	Coverage of main roads
1995	Coverage of rural areas

Table 2.2. The development of GSM (Web Proforum Tutorials, http://www.iec.org, 27 December 2014)

The GSM Network

The Groupe Special Mobile, also known as the Global System for Mobile Communication Technology has a relatively simple network and this is summarised in the block diagram below:

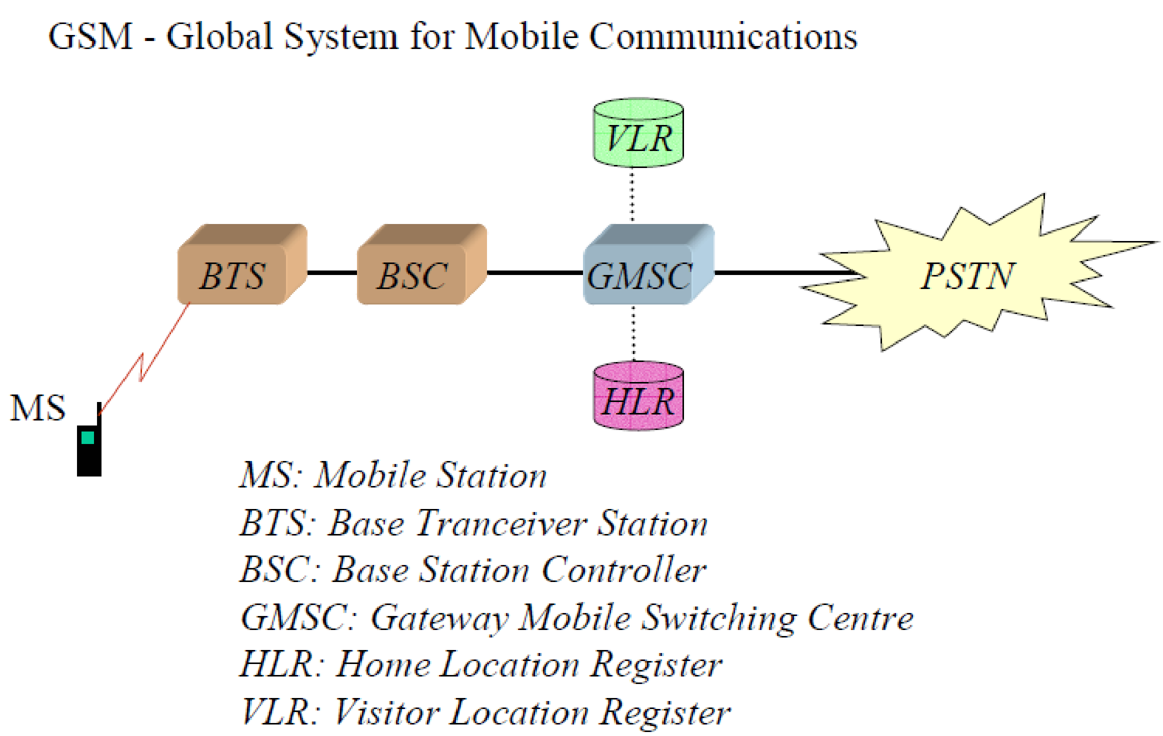


Fig. 2.5. The major elements of a GSM Network (www.usyd.edu.au – 29 December 2014)

GSM does not provide requirements, it gives recommendations. Its specifications define all necessary functions and interface requirements are provided in detail, but it does not address hardware. The advantage of this characteristic is that designers are not needlessly restrained and operators are able to buy equipment from different suppliers.

GSM Subscriber Services

Below is a list of some of the services offered by GSM:

1. dual tone multi-frequency signaling (DTMF)
2. facsimile group III
3. short message services (SMS)
4. cell broadcast
5. voicemail
6. fax mail

Amoung these functions, of particular interest to this project is the Short Message Service. This facility supports the sending of short messages of not more than 160 alphanumeric characters, to and from a mobile station.

The GSM Short Message Service always ensures that messages reach their intended destinations. For example, if a text message is sent to a mobile phone that is either powered off, or out of the coverage region, that message is not lost and will reach its destination once that mobile phone is powered back on or is placed within range again.

Attributes of GSM

- Allows access to code
- GSM is an open source system
- Used by approximately 82% of the world's subscribers

GSM uses Digital Communication System (DCS) and is the world's main 2G standard.

The major setback when using the GSM Short Message Service in controlling systems is that there is usually a substantial delay between the time a message is sent and the time that message reaches the intended mobile station.

In conclusion, after careful consideration and thorough analysis, of the possible telecommunications systems which can be used to provide motor speed control using SMS, clearly GSM is the obvious choice.

CHAPTER THREE: DESIGN AND IMPLEMENTATION

3.1 FOUR QUADRANT DRIVE OPERATION AND MOTOR CONTROL TECHNIQUES

a) <u>The Four Quadrant Drive Operation</u>

Motion control of electromechanical machines is easily achieved by use of drive systems. Drives incorporate prime movers, and these prime movers are responsible for providing the actual motion or movement of the rotating machine. The energy used by prime movers to provide the motion can come from various sources such as, hydraulic motors, electric motors, and diesel or petrol engines. Drive systems that use electric motors as their prime movers are called electrical drives.

Drive systems, whose application is imperative in this design, operate in four quadrants.

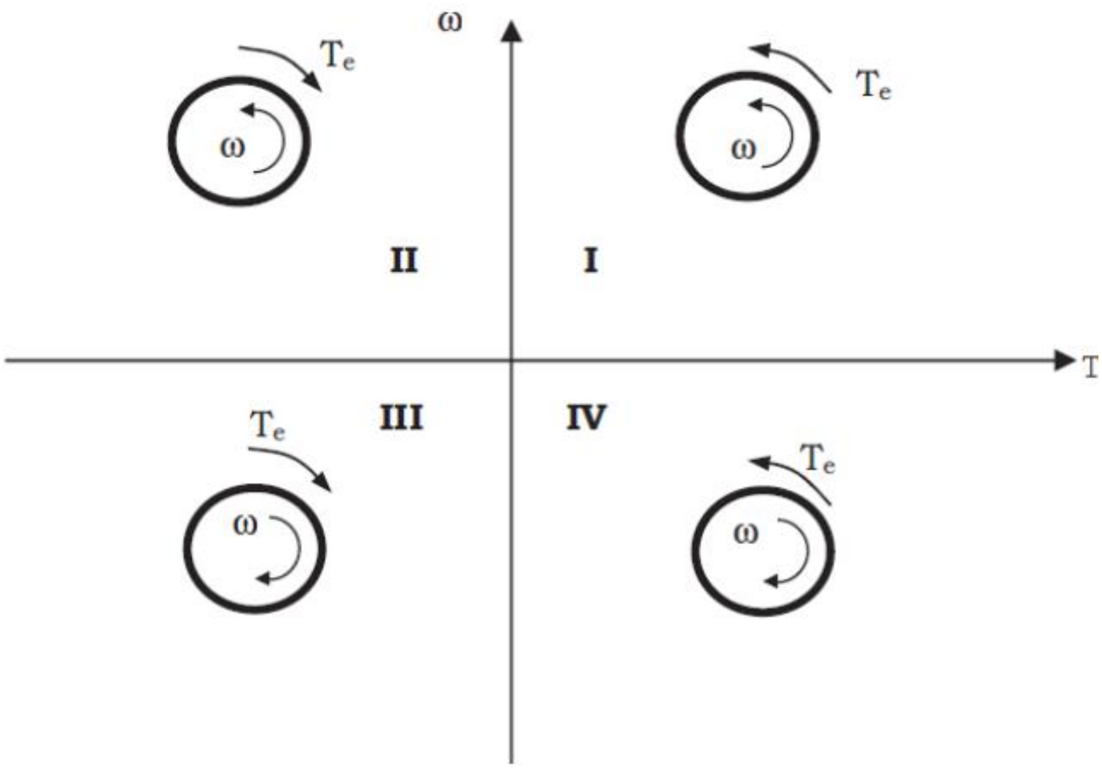


Fig. 3.1 Four Quadrant Drive Operation (Electrical Drives, MEP 1422, 19 November 2014)

Key: Counter-clockwise motion is taken as positive

Clockwise motion is taken as negative

T_e – Torque,   ω – angular speed

First Quadrant

Here the torque and speed are both positive. To rotate, the motor requires mechanical energy. In this quadrant, energy is converted from electrical to mechanical and hence the motor rotates. This mode of operation is called, **forward motoring.**

Second Quadrant

In this case, motor torque and speed are in the opposite direction. Energy is converted from mechanical to electrical. The product of the speed and torque is negative (mechanical power). Therefore, the motor brakes. This is called **forward braking.**

Third Quadrant

Here both torque and speed are negative. The product of speed and torque is positive. Energy is converted from electrical to mechanical and this results in **reverse motoring.**

Fourth Quadrant

In the fourth quadrant, torque is positive but speed is negative. Power is therefore negative. Mechanical energy is converted to electrical energy and this mode of operation is called **reverse braking.**

b) Methods of Motor Control

Basically, motors are controlled by finding a way to vary the voltage or current that flows through. To achieve motor control, there are three main methods to consider:

(i) Use of a variable resistor.

This would involve connecting the motor to be controlled, in series with the variable resistor. The main problem with this technique is that the motor is a 'variable electrical load' that requires more power when starting than when running. Also, energy would be lost in the resistor as heat. Therefore, the use of a resistor for motor control is inefficient and not recommended.

(ii) Variable frequency method.

Usually applied to ac machines, this method is a viable alternative to the use of a resistor, but it also has its downside. Variable frequency control produces harmonics at the output and if current is switched for long enough, the load current becomes discontinuous. Also, for it to be applied with DC motors, there is need for complex circuitry which makes it expensive.

(iii) Pulse Width Modulation (PWM)

PWM, as applied to motor speed control, is a technique of delivering energy as a series of pulses instead of a continuously varying signal. By adjusting the width of the pulse, the flow of energy to the motor is regulated, thereby controlling the motor.

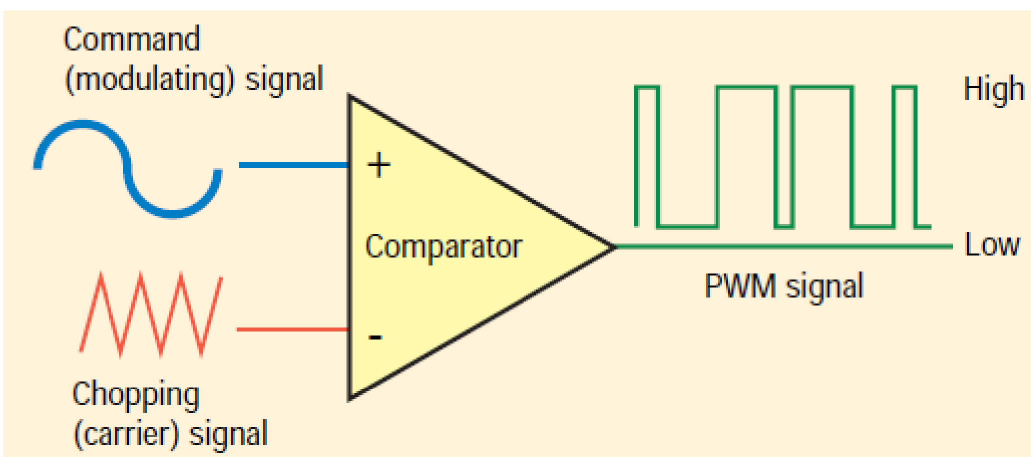


Fig 3.2. How PWM works, (www.motionsystemdesign.com, 28 February 2014)

The principle of operation of PWM is illustrated in fig 3.2. A simple Op-Amp acts as a comparator and it has a saw-tooth signal as its carrier and will convert a sinusoidal control signal into a pulse width modulated signal. It can also be observed that, the larger the control signal, the wider the corresponding pulse width will be.

PWM is sometimes referred to as constant frequency control and does not produce any harmonics.

3.2 DESIGN BLOCK DIAGRAM

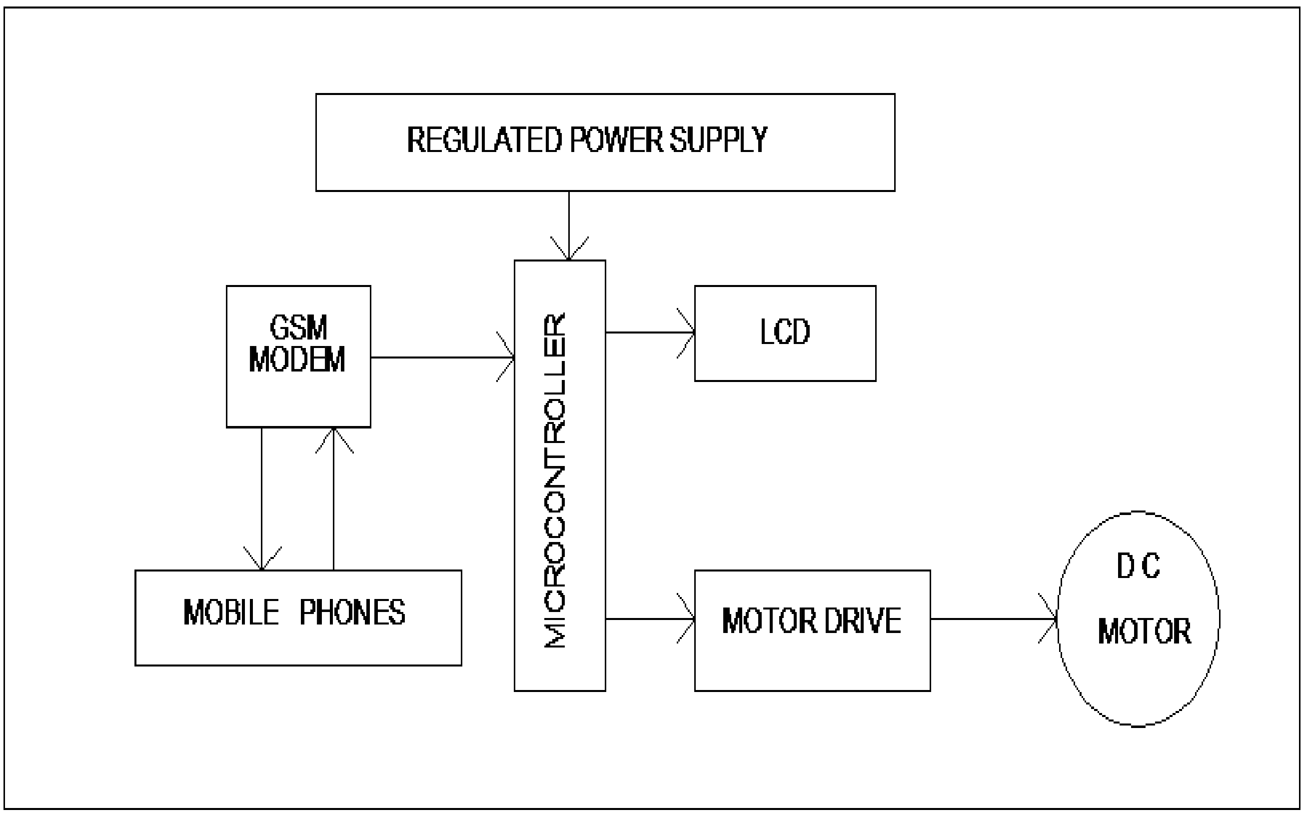


Fig 3.3 Block diagram design of the GSM controlled DC motor.

The mobile phones appropriate for the design are those that support GSM and these types of phones are the most common nowadays. The GSM modem is a SIM900

GSM module with an RS232 serial to allow for communication with the microcontroller, which in this case is an ATmega328P mounted on a board to form the Arduino Uno R3. The signal that is produced by a microcontroller is too small to drive a DC motor, but it can activate the motor drive which in turn drives the DC motor.

The LCD displays the status of the motor at any given time. For fidelity of the readings given by the LCD, it is important that a speed sensor be placed on the motor shaft and send the actual motor speed to the LCD. A suitable speed sensor would be the Hall Effect Speed Sensor, however, this and other viable alternatives are not available locally. For this reason, the LCD is not incorporated in the prototype implementation.

3.3 THE STANDARD SIM900 GSM MODULE

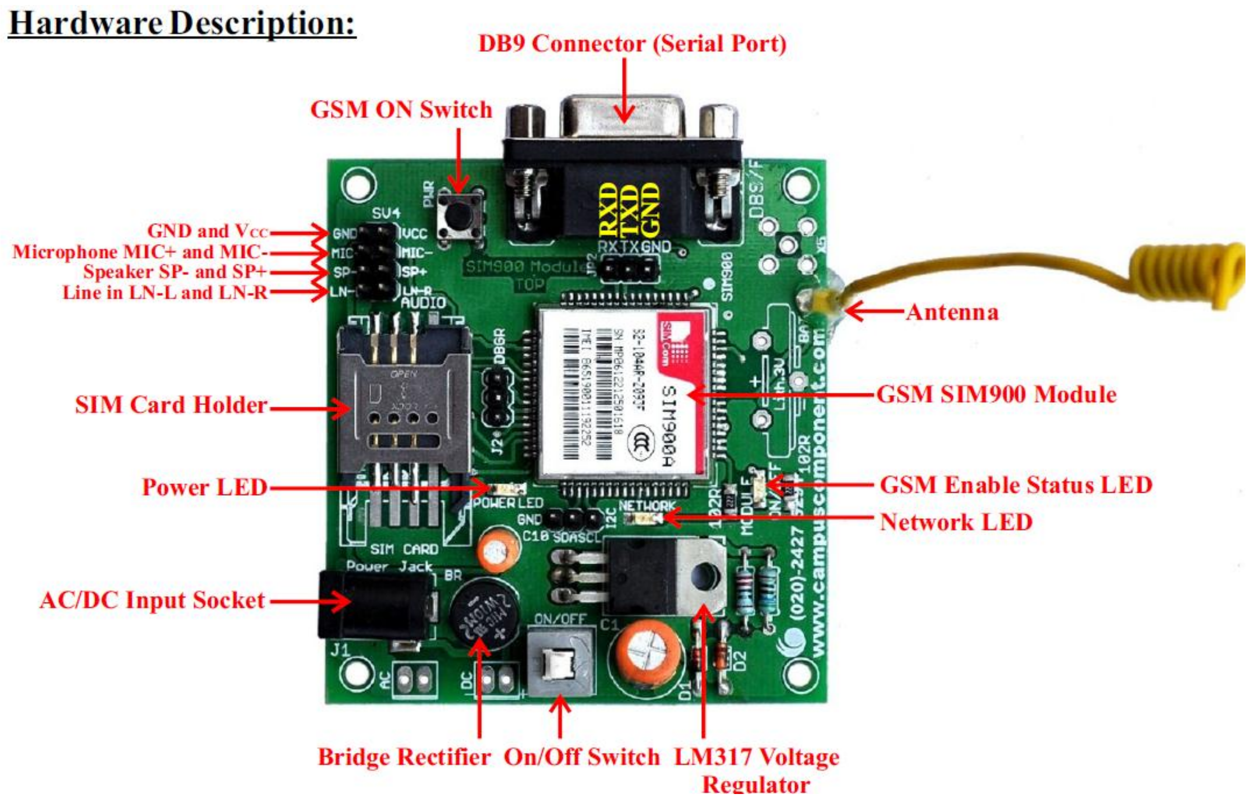


Fig 3.4 Standard SIM900 GSM Module (www.simcom.com – 15 March 2015)

A GSM modem is basically a wireless modem that operates over a GSM wireless network. GSM modems support MMS, SMS and data link in a wireless network. Modern GSM modems have the RS232 port to allow for interfacing with either a microcontroller or a PC.

For a GSM board to communicate with either a PC or a microcontroller, it must be properly configured. Various software programs can be used to do this configuration. For the XP operating system, Microsoft HyperTerminal is incorporated. It can be accessed by following these steps,

Start –- Programs –- Accessories –- Communications –- HyperTerminal.

Microsoft HyperTerminal is then used to send AT commands to the GSM modem.

For the Linux OS, Mincom may be used in place of HyperTerminal.

For Windows 7, there is no HyperTerminal incorporated. However, a small program called Putty can be used instead. This program is easy to download, is available for free, and no installation is required. Using Putty, extended AT commands, i.e, AT commands specific to the GSM modem being used, are then used to configure it.

List of Some Common AT Commands

AT + IPR = 9600: transfer rate set at to 9600.

AT & W: save parameters.

AT + CMGR: read message from memory location.

AT + CMGD: delete the message from memory location.

AT + CMGF: convert message to machine instruction format.

AT + CPMS: selection of SMS memory.

3.4 BRIEF INTRODUCTION TO ARDUINO

Arduino is a programmable hardware platform that is flexible and well suited for student prototype development projects. There are a number of Arduino versions available on the market today, and these include the Arduino NG (New Generation), the Arduino Diecimila, the Arduino Duemilanove, and the latest Arduino UNO, which has 2 subversions, Arduino Uno R2 (Revision 2) and Arduino Uno R3 (Revision 3).

Open Source Hardware

The Arduino platform is very useful for projects that are based on microcontrollers. However, even more important is the fact that the Arduino community is deeply entrenched in the emerging practice of open source hardware. Open source hardware engages in a distributed model for hardware development with contributions from people around the world. Therefore, one of the distinguishing features of the Arduino Ecosystem is that it embodies openness in design, collaboration, architecture and philosophy.

Programming the Arduino

Generally, this is mostly done in C, through the formulation of sketches. In Arduino, programmes are called sketches. The programming environment used is the Arduino IDE (Intergrated Development Environment). To simplify programming, Arduino has libraries. These libraries are a convenient way of sharing commonly used utility functions and code. IDE comes with a set of standard libraries but users are also allowed to formulate their own 'user installed libraries.'

To get started in Arduino,

1. Download and install Arduino IDE
2. Connect the Arduino board to a PC using USB and install drivers.
3. Launch the Arduino application and select the appropriate board and port.
4. Upload a sketch.

3.5 HARDWARE EQUIPMENT

1. Arduino Uno R3

Fig. 3.5 The Arduino Uno R3 (www.microrobotics.co.za – 17 April 2015)

Features

- ✓ It use an ATmega16U2 in place of the 8U2 found on earlier versions and this implies that it has 16K flash memory instead of 8K, hence faster transfer rates
- ✓ Microcontroller: ATmega 328P
- ✓ Recommended Input voltage: 7-12V, with 6-20V limits
- ✓ 14 Digital I/O pins with 6 that give PWM output
- ✓ 6 Analogue Input pins
- ✓ 50mA DC for the 3.3V pin
- ✓ 40mA DC per I/O pin
- ✓ 2KB SRAM, 16MHz clock speed, 1KB EEPROM

2. The Brush Motor 6V

   This is 130 size DC motor and is usually used in the Pololu plastic gear motors. It works well with lower power motor controllers.

Fig. 3.6 The Brush Motor 6V (www.microrobotics.co.za – 17 April 2015)

Features

- ✓ Recommended operating voltage: 3-12V
- ✓ Weight – 18g, shaft diameter – 2mm, dimensions – 25X15X20mm
- ✓ At 6V: rpm – 11500, free run current – 70mA, stall current – 800mA
- ✓ Shaft diameter – 2mm
- ✓ Torque: 26gcm = 0.26Nm

3. GSM/GPRS Module

Figure 3.7 shows a GSM GPRS Module being used in this project. This hardware is a reliable, ultracompact wireless module. In essence, it is a breakout board that uses SIM900. The module communicates with microcontrollers through AT commands (GSM 07.07, 07.05 and SIMCOM enhanced AT commands).

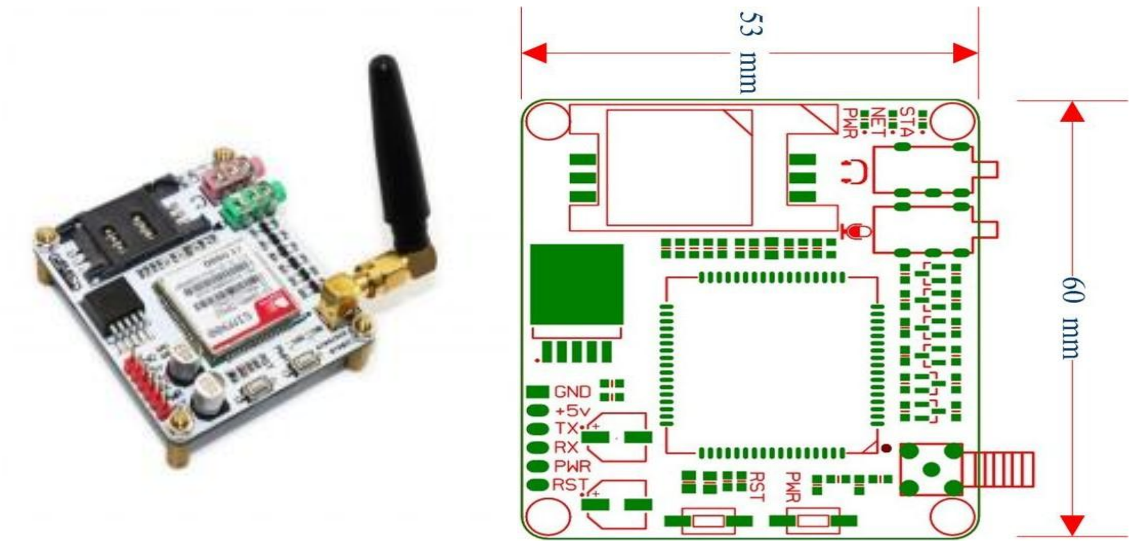


Fig. 3.7 GSM/GPRS module (left), and its open schematic (right), (www.microrobotics.co.za – 17 April 2015)

Features:

- ✓ +5V power supply and fully compatible with Arduino
- ✓ Quad band 850/900/1800/1900 MHz GPRS multi-slot class 10/8
- ✓ Voltage supply range, 3.1-4.8V
- ✓ Free connection to serial port, i.e. serial port can be controlled by either software or hardware

4. L293D Motor Driver

The l293d is a quadruple half-H driver that can drive 2 DC motors simultaneously. It can provide bidirectional drive currents of upto 600mA, at voltages that range from 4.5V to 36V.

Optimal operating temperature for the l293d ranges from 0˚C to 70˚C.

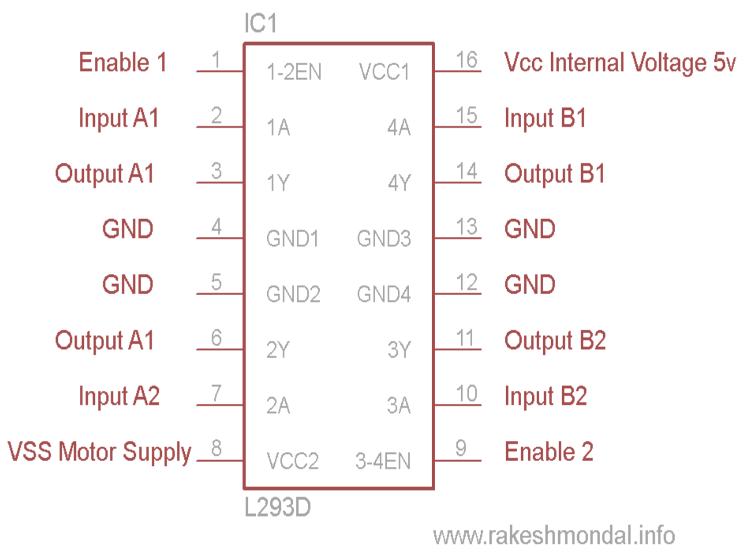


Fig 3.8 L293D pin diagram (www.rakeshmondal.info – 2 March 2015)

3.6 INTERFACING AND SOFTWARE DEVELOPMENT

INTERFACING

This section describes the actual physical connections of the different hardware elements used in the prototype. There is need to explain how the mobile phone is linked with the GSM/GPRS module, the GSM/GPRS module to the Arduino Uno, the Arduino Uno to the L293D, and the L293D to the DC motor.

So first, the mobile phone is linked to the GSM/GPRS module over a wireless GSM network.

GSM/GPRS module with Arduino Uno

Arduino Uno has at least one serial port that is used to establish communication with other devices. The serial communication is established through digital pin 0 (Rx), and digital pin 1 (Tx). These pins are also under use when the board is in communication via USB.

For interface between the modules,

Connect Tx pin of GSM/GPRS module to Rx pin of the Arduino

Connect Rx pin of GSM/GPRS module to Tx pin of the Arduino

Connect GND pin of GSM/GPRS module to GND pin of the Arduino

Arduino Uno with L293D

The output pins of the L293D driver do not give a PWM signal, i.e, they can only be either high or low. This therefore implies that these pins can only control the direction of the motor, but not the speed. The table below shows how direction control is achieved:

PINS		DIRECTION
1Y (3)	2Y (6)	
0	0	No Rotation
0	1	Counter-Clockwise
1	0	Clockwise
1	1	No Rotation

Table 3.1 Truth table for motor direction control.

For speed control however, the key is to vary the enablement of the driver pins. The voltage applied to pin 1 (1-2EN) of the l293d is directly proportional to the speed of the motor. This pin is connected to an Arduino digital pin (PWM), i.e, a digital pin which can also give a PWM signal.

The connections between the Arduino Uno and the L293D are summarised below:

Connect pin 1 (1-2EN) of l293d driver to digital pin 3 (PWM) of the Arduino

Connect pin 2 (1A) of l293d driver to digital pin 9 (PWM) of the Arduino

Connect pin 3 (1Y) of l293d driver to input 1 of DC motor

Connect pin 4 and 5 of the l293d driver to the ground

Connect pin 6 (2Y) of l293d driver to input 2 of DC motor

Connect pin 7 (2A) of l293d driver to digital pin 2 of the Arduino

Connect pin 8 (V_{cc} 2) of l293d driver to a 6V regulated power source

Pin 8 is responsible for powering the DC Motor, and the second side of the l293d is not being utilized in the prototype design.

L293D to DC Motor

The connection between these 2 is done as shown in the diagram below:

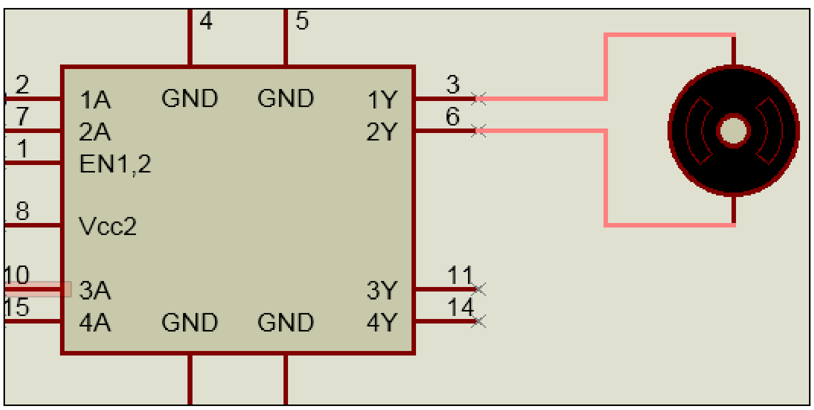


Fig. 3.9 Connection of DC Motor to L293D.

Complete Circuit Schematic

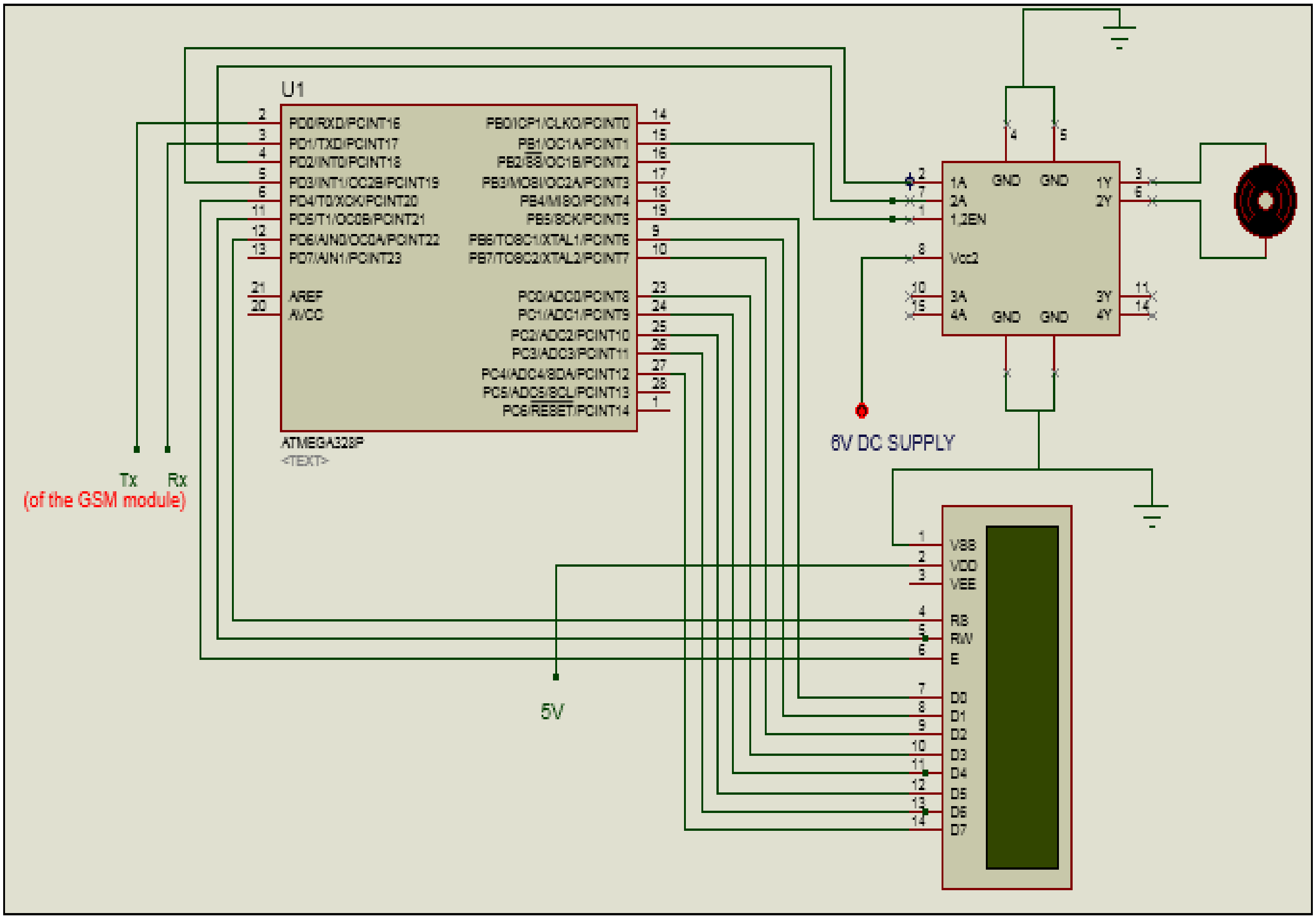


Fig. 3.10 The complete circuit diagram of a gsm based dc motor controller (excluding the mobile phone and gsm modem)

The circuit diagram shows how the different circuit elements connect to the ATmega328P microcontroller. However, in the actual hardware implementation, the ATmega is not being used in isolation. It is being used as part of the Arduino Uno board. This board makes the microcontroller's pins easier to access and it generally makes the interfacing easier and more convenient.

SOFTWARE DEVELOPMENT

The main objective of this prototype is to achieve wireless speed and direction control. Operations should occur as follows:

Every SMS to be sent to the control system must be of the form,

$$*wX_1x\ X_2yX_3$$

Where;

‘ * ’ is used as an identifier, any SMS sent that does not begin with this identifier will be discarded.

‘ w ’ designates speed control, the speed will be determined by the value taken by X_1, and this value ranges from 0 to 8.

‘ x and y ’ are responsible for determining the direction of the motor rotation, in accordance with the binary values taken by X_1 and X_2.

For example, the SMS ‘*w8x1y0’ would mean that the DC motor would rotate at full speed, in the CCW direction.

Flow Chart Diagram

As can be seen in figure 3.11, the code first puts the system in waiting mode. When an SMS is received, it is authenticated by checking whether the first character is ‘*.’ The system then checks the status of ‘w’ which determines the speed of the motor. Afterwards, the status of x_ & y_ is checked to determine the direction of rotation. The system then discards current SMS and maintains current status until another SMS is received.

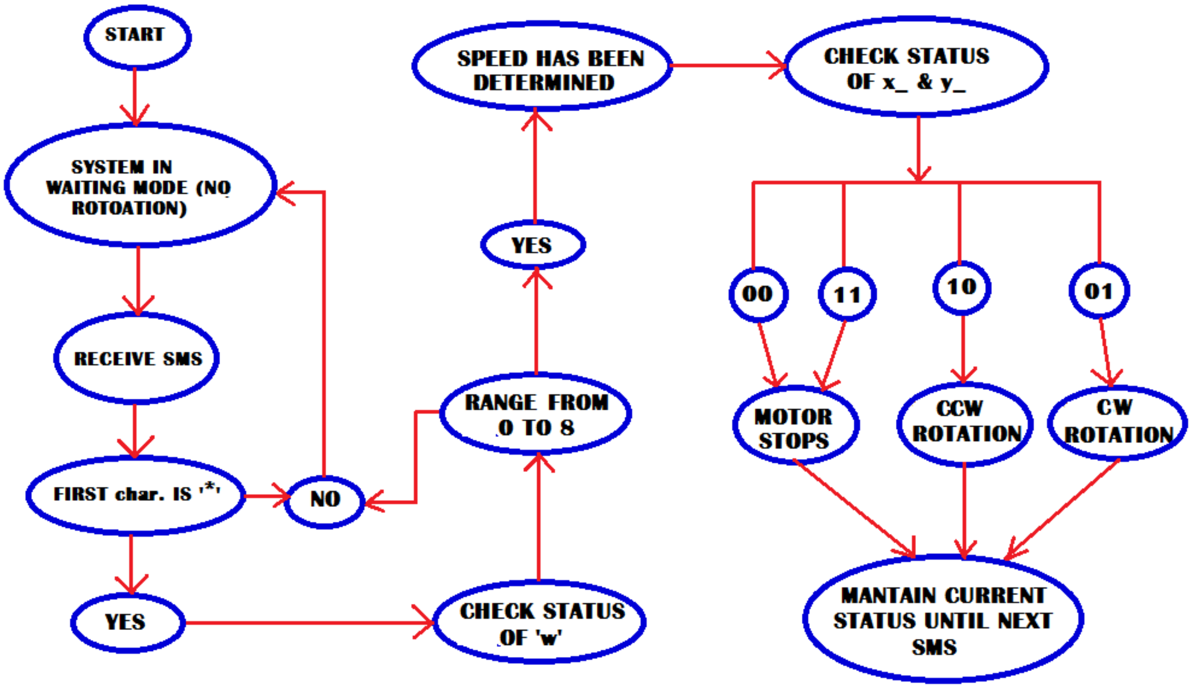


Fig. 3.11 Software Flow Chart Diagram.

<u>The doSomething Command</u>

This command can be used to enhance security of the system. It can be invoked in such a way that only when a certain condition has been specified, then the system will 'doSomething.' It is therefore a very useful tool in programming the microcontroller.

The complete code for this project is included in the bibliography.

CHAPTER FOUR: DESIGN ANALYSIS, APPLICATIONS & FUTURE WORK

4.1 CHAPTER OVERVIEW

Chapter 3 explains how a GSM based DC Motor speed controller was successfully designed. This chapter uses that and other external information to come up with the advantages and disadvantages of the design. The prototype is extensively tested to determine its behavior and the results are described. Experiments are also done to determine SMS delay patterns. Possible industrial applications are outlined and, the last part gives suggestions on how this design can be improved in future.

4.2 DESIGN ANALYSIS

The figure below shows the complete prototype.

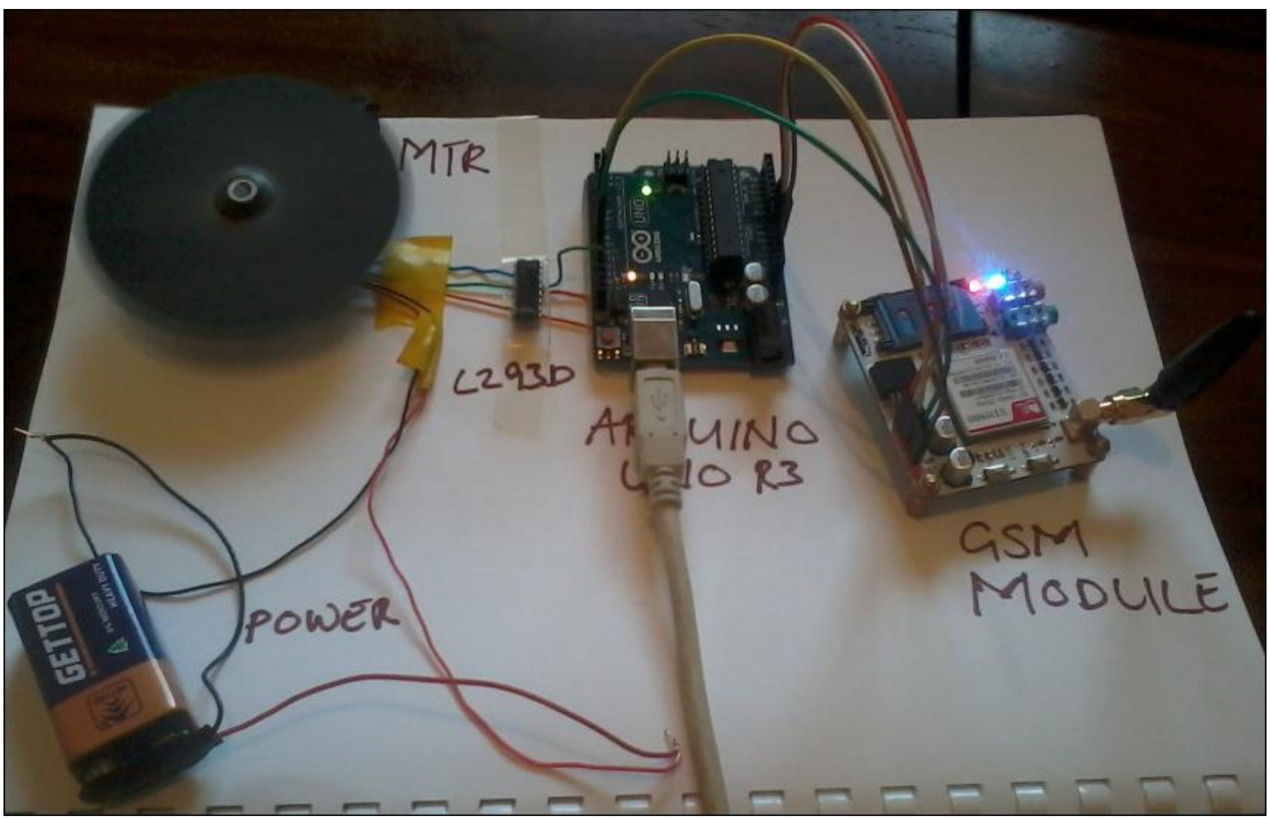


Fig. 4.1 The prototype.

The design responds to all SMS messages as expected and the components do not heat up even if used frequently for upto 4 hours. A small paper disk of 8cm diameter was used as the load. This made it easier to see the direction of the motor, and a white strip was placed on this disk so that speed could be measured using a tachometer.

When using this mobile app to control a DC Motor, the following observations were made:

1. Generally, the motor responds slowest to the ‘stop’ command compared to all the other commands, disregarding the effects of inertia.
2. Type of phone used does not affect the prototype functionality in any way.
3. Delay is affected by the service provider (e.g Telecel, Econet, Net-One, etc.) being used.
4. Delay is usually higher when the system is used after it has been off for ~ > 1hour, but will gradually decrease as more SMSs are sent.

Delay Patterns

In control systems that use SMS data, delay is inevitable. However, this delay can be quantified and depending on the application, the cost calculated. Therefore it is imperative to conduct experiments to determine how the delay varies throughout the day.

The delay patterns of the design can be studied using many different techniques. The results obtained here are limited to the analysis procedure used and it should also be noted that an Econet to Econet control mechanism is used i.e, both the sending and receiving SIM cards are from Econet.

Procedure:

A day of the week is selected randomly (14-05-15), and 10 tests are randomly done in every 3hour period. The tests involve recording the duration between the instant the ‘send’ button is pressed on the mobile phone, to the instant the motor begins to respond. This is aimed at coming up with a pattern of how the SMS delay varies throughout the day.

Below is the data obtained from the tests:

Time of day	0000-0600	0600-0900	0900-1200	1200-1500	1500-1800	1800-2100	2100-0000		Time of Day	Average Delays
	3.22	11.94	9.99	12	10.23	13.34	7.34		0000-0600	5.11
	2.97	8	13.42	15.28	9.08	16.78	6.97		0600-0900	12.06
	5.86	8	10.68	9.78	9.79	15.39	8.83		0900-1200	12.24
	13.94	34.46	12.12	17.76	11.03	14.77	7.76		1200-1500	18.82
	4.22	8.44	13.06	16.95	8.98	17.76	6.6		1500-1800	10.52
	4.7	9.76	1.32.01/10.45	20.84	11.73	4.98	6.22		1800-2100	14.7
	5.33	11.94	10.96	19.6	10.47	16.77	5.34		2100-0000	6.79
	3.9	11	15.55	36.44	12.01	16	8.89			
	2.99	8.64	11.68	20.98	11.32	16.94	5.78			
	4.01	8.43	12.68	18.54	10.58	14.24	4.17			
Averages	*5.114*	*12.061*	*12.23777778*	*18.817*	*10.522*	*14.697*	*6.79*			

Table 4.1. Table showing the time taken for motor to respond to SMS texts throughout the day, values were taken on the 14th of May 2015 at the UZ compass.

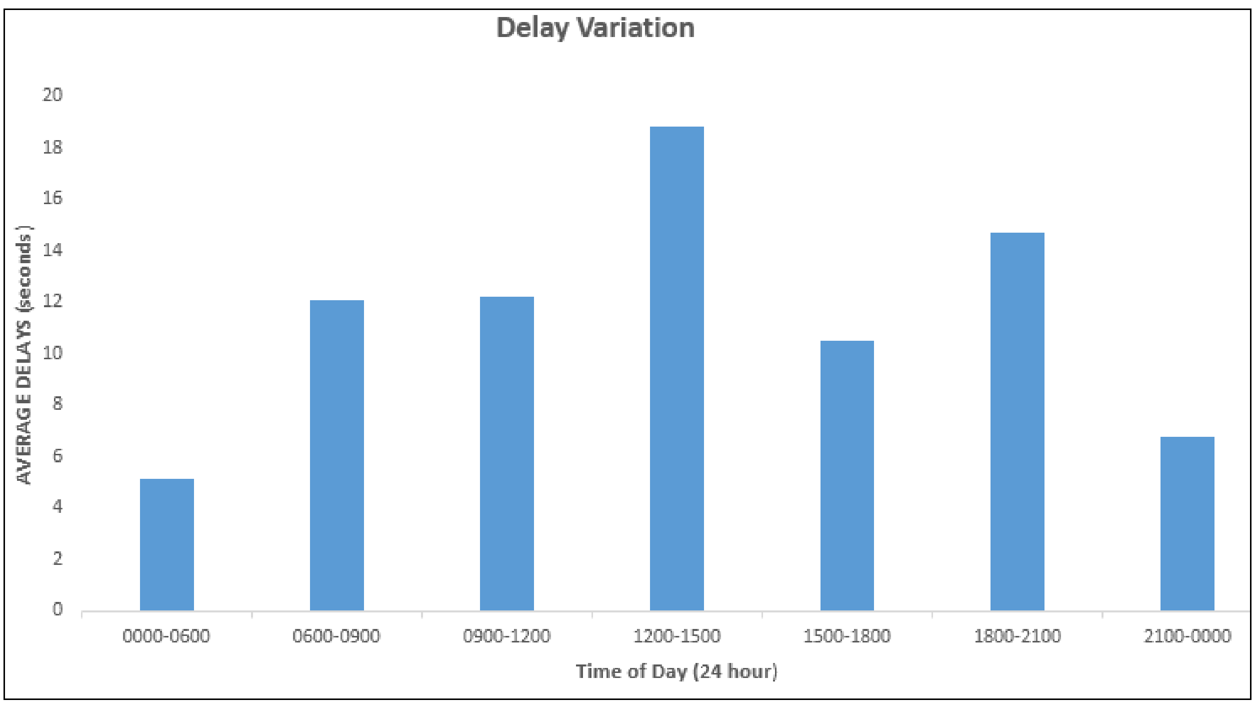


Fig. 4.2 Bar graph showing the delay variation.

4.3. ADVANTAGES AND CHALLENGES ASSOCIATED WITH USE OF THE DESIGN

ADVANTAGES

1. Facilitates Motor Control from remote locations.
2. The design is capable of facilitating motor control from remote locations. This attribute improves safety in the sense that it reduces the number of people that have to work in close proximity with the machine in case an accident occurs. It also saves time since management can control motor activity without having to be on site.

3. Offers better security
   The design developed operates by use of a mobile phone's SMS data. This implies that, if need be, only authorized personnel can be given the necessary details required to control the machine (motor), thereby increasing security.

The first two advantages address the issues that were outlined in the problem statement, in section 1.3.

4. Easy to modify
   GSM technology, which is extensively applied in this design, offers access to code. This means that necessary modifications, adjustments or configurations can be easily achieved, thereby enhancing adaptability.

5. Increased safety
   Conventionally, if a motor malfunctions, it is often necessary for personnel to have to approach that machine and activate safety mode or power it off. This is dangerous practice since a machine that is not working properly is largely unpredictable. The design explained in this document counters this problem by making it possible for one to be able to stop the machine from a safe distance, hence eliminating some of the risk.
   Also, in wet conditions, control of motors by a mobile phone is a safe alternative.

CHALLENGES

1. Delay

   It is common knowledge that in Zimbabwe, the service providers namely Econet, Telecel and Net One, are struggling to handle the growing number of users. As such, their networks are often overloaded and this leads to SMS messages taking longer than expected, to reach their intended destinations. This downside negatively impacts the efficiency of the design in that, in case of an emergency, the system might not respond as fast as would be necessary.

2. Compatibility Issues

   To incorporate the designed technology into local industry will require making modifications, and sometimes even replacing some of the existing equipment. Examples include, having to create an environment in which a microcontroller can operate in, and having to change motor drives. In the short term, this is viewed as uneconomic and can be a major stumbling block when trying to convince industry owners to invest.

4.4 POSSIBLE APPLICATIONS

1. DC motor control from remote locations

The majority of electromechanical machines used in industrial sectors such as chemical, nuclear, power generation or furniture manufacturing incorporate DC motors.

In nuclear and chemical plants, it is imperative that there is always a mechanism to enable control of these machines from remote locations. For instance, there are some chemical plants were operations involve dealing with chemical gases so dangerous that gas masks are unable to guarantee safety, and these gases may also be dangerous to the skin. Conventionally, in many chemical plants, the safety procedure in case of valve failure, involves manual shut down of the plant from within the facility and this practice presents unprecedented risk to the persons responsible for activating these procedures.

Remote control of machines will make sure the priority of every person present at a plant if and when an accident occurs, will be to evacuate, and then shut down the plant from a safe distance. This will help protect the workers and ensure that atmospheric release of toxic gases is kept at a minimal. The same goes for nuclear power plants.

2. Control of Fans

Imagine, on a hot and sunny day, in South Saharan Africa, a person relaxing a few meters from a fan. When, for this person, the wind gets too much, he/she would have to walk to that fan and make the necessary adjustment. However, this would definitely be hideous and frustrating. Motor speed control using GSM makes it possible for this individual to adjust the fan using his/her mobile phone. People today keep their mobile phones on them and so this prototype would make fan control a lot less painful!

3. Operation of Oil Circuit Breakers

Fig 4.3 Oil Circuit Breakers at a substation, (left) before accident, (right) after accident. (Incident occurred at Mbuyelo Coal mine in South Africa - 2011, but a similar accident also occurred at a ZETDC substation in Ruwa in 2010)

Oil Circuit breakers have the potential to explode when being operated, especially when racked in. The racking in and racking out of such oil circuit breakers involves rotating an L-shaped handle in a clockwise or counter-clockwise direction as appropriate. When the incident shown in the picture above occurred, the technician who was working on the breakers lost his right arm.

However, since the operation of these breakers requires rotation, DC motors of the appropriate torque can be employed quite easily. This makes it possible for racking in and racking out to be done from a safe distance, hence eliminating the risk of having to be nearby a potential explosion.

4.5 FUTURE WORK

Although this project improves the existing systems significantly, it can still be developed further to make it even more relevant to modern day industry. This section outlines some suggestions on future work that can be done to make this design better.

- **The Internet of Things (IoT)**

  The idea of the internet of things first came about in 1999 and it has come a long way since. IoT refers to a system whereby all things, be it animals, humans, objects or machines, are all given a unique identifier, and an ability to transfer information over a network, without the need for direct interaction between devices. This theory of IoT evolved from the fact that as the internet grew, it became clear that connection of MEMS (micro-electromechanical systems) and wireless technologies to the internet would revolutionise industry immensely.

  Achieving motor control by use of GSM, is a step towards the realisation of complete online motor control and monitoring, thereby furthering the IoT endeavor.

- **Use of multimedia**

  Since it is possible to achieve motor control using SMS Data and GSM. GSM supports multimedia hence this design can be developed further to make it work with voice messages and pictures. In this advanced version, SMS messages would be replaced by voice messages and pictures, and this would aid the monitoring process.

CHAPTER FIVE

5.1 CONCLUSION

The aim of this project was to design and develop a DC Motor speed and direction controller using a mobile phone's SMS data. To achieve this, three primary objectives had to be met. These were, to do a research on the principles of motor control, review the technical standards of GSM technology, and use this knowledge to design and build a prototype. All the objectives were met, and a functional prototype was developed.

The problem statement identified two of the major causes of accidents in modern day industry, i.e, close proximity interaction of humans with large and potentially dangerous electromechanical machines, and the operation of such machines by unauthorised and unskilled personnel. The SMS format used in the prototype, $*wX_1xX_2yX_3$, if kept secret, ensures that control access is granted only to those with the relevant clearance. Also, the ability to achieve control from remote locations ensures that humans do not have to work close to large industrial machines. Hence, this design eliminates both causes stated in the problem statement.

For real time control, the major drawback associated with using SMS is the delay, and in some instances, failed SMS delivery. These can have significant repercussions in some sectors of industry, and so care must be taken when choosing were and how to apply the motor controller designed.

Excluding the labour, effort and expertise put in successfully completing this project, the cost of building the prototype was USD$72 + R1120. This project has the ability to save human life. Though it depends on one's morality, no value can be placed on human life, and so the design is cost effective.

The use of GSM instead of other wireless receivers makes this prototype truly modern. GSM also gives it unlimited room for further improvement, particularly in online control and monitoring of industrial machines.

Lastly, the process of gathering and selecting appropriate information for this project was extremely strenuous. This was mainly because there are times when 'reputable' texts contradict. It can therefore be difficult to decide what information to discard. However, the process of working through this project and compiling this document, was a thoroughly satisfying experience!

5.2 REFERENCES

1. Electric Machinery, 6th Edition, A.E Fitzgerald, C. Kingsley and S. D Umans, McGraw Hill 2003
2. Concise Higher Electrical Engineering, Chikuni E, Okoro O. I, Khan, M. T. E Juta, Academic Publishers 2008
3. Principles of Electric Machines and Power Electronics by P. C Sen, 2nd Edition
4. International Journal of advanced Technology in Engineering and Science, Volume 2, Issue No. 05, May 2014, www.ijates.com
5. Introduction to Robotics by P. J. M Kerrow, Addison Wesley, USA 1991
6. GSM Architecture and Channel Structure, University of Sydney, www.usyd.edu.au
7. Mexus Education, www.ikenstore.com (24 0ctober 2014)
8. Academic@microchip.com (20 October 2014)
9. A Guide to Energy Efficient Motors – International Copper Promotion Council (India) Complete, 2013
10. PT-design, www.motionsystemdesign.com, October 2000.
11. SIM900B_HD_V01 Hardware Design, Shanghai SIMCom Wireless Solutions Ltd, 2010 – www.simcom.com
12. SIM900 GSM/GPRS RS232 Modem- User Manual, www.rhydolabz.com, 10 December 2011
13. Introduction to Arduino, A piece of cake! By Alan G. Smith, September 30, 2011. ISBN: 1463698348
14. Basic Pulse Width Modulation by Gerald Recktenwald (pdf), September 16, 2011
15. Arduino Programming Notebook by Brian W. Evans, First Edition, August 2007
16. urlhttp://www.aishack.in/2010/07/the-three-motors-youll-ever-use-in-robotics/
17. http://arduino.cc/en/uploads/Main/arduino_Uno_Rev3-02-TH-zip
18. http://arduino.cc/en/uploads/Main/arduino_Uno_Rev3-shematic.pdf
19. http://arduino.cc/en/Main/ArduinoBoardUno
20. Adafruit learning system, Arduino Lesson 13. DC Motors (pdf), created by Simon Monk

21. C Programming For Arduino by Julien Bayle, PACKT publishing, Birmingham-Mumbai, 2013
22. GPRS Tutorial, MorganDoyle Limited, http://www.morgandoyle.co.uk
23. Future Electronics, GSM Shield SIM900 Get Starting (pdf), www.fut-elctronics.com
24. Arduino Tips, Tricks, and Techniques, created by Ladyada (pdf), last updated 17 January 2014
25. L293, L293D Quadruple Half-H Drivers (pdf), SLRS008B-September 1986, revised June 2002
26. Eelectronics.stackexchange.com/questions/77562/Arduino-uno-rx-tx-pins
27. m.instructables.com/id/GOduino-II-Arduino-L293D-Variable-Speed-Motor-/
28. Beginning Arduino Programming by Brian Evans, Apress publishers, 2011
29. AT Commands, GSM Reference guide, MultTech Systems, PN S000293A Revision A, 2003
30. Arduino Workshop, by John Boxall, no starch press, San Francisco, 2013
31. Arduino Cookbook, by Michael Margolis, Nicholas Weldin, March 2011

5.3 BIBLIOGRAPHY

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NSSA 2013 AND 2014 OSH ANNUAL REPORTS: ACCIDENTS RELATED TO ELECTROMECHANICAL MACHINES

Agency of Accident		Year 2013	Year 2014	Total
Transmission Machinery	Transmission Shaft	1	5	6
	Transmission Belts, Cables, Pulleys, Pinions, Gears	24	15	39
	Conveyor Belts	39	33	72
	Other	21	29	50
Metal Working Machines	Power Press	3	4	7
	Lathes	8	1	9
	Milling Machines	5	5	10
	Abrasive Wheels	2	1	3
	Mechanical Shears, Slitters, Cutters	18	11	29
	Forging Machines, Casting	6	3	9
	Rolling	10	5	15
	Other	40	107	147
Wood and Assimilated Machines	Circular Saw	1	3	4
	Other Saws	22	18	40
	Molding Machines	5	6	11
	Overhead Machines	0	1	1
	Other	25	70	95
Other Machines N.E.C	Earthmoving Machines, Excavating and Scrapping Machines except means of Transport	12	17	29
	Spinning, Weaving and Other Textile Machines	151	88	239

	Manufacture of Food Stuffs, beverages	34	21	55
	Machines for the Manufacture of Paper	4	2	6
	Machines for Printing	6	1	7
	Packing and Wrapping Machines	10	6	16
	Office Machines	2	5	7
	Other	82	120	202
Electrical Installations Including Electrical Motors	Rotating Machines, Motors	17	4	21
	Conductors	4	4	8
	Transformers	4	4	8
	Control Apparatus	3	3	6
	Refrigerating Plants	5	4	9
	Others	21	32	53
Electrical Hand Tools	Grinder	56	48	104
	Sandblaster	0	1	1
	Saws	24	20	44
	Welding Tools, Soldering Irons	32	16	48
	Jackhammer	5	7	12
	Electric Drill	17	18	35
Total		719	738	1457

Table 6.1. Summary of the reported accidents related to electromechanical machines for 2013 and 2014. All the machines referred to here, use electric motors.

Code uploaded in the Arduino:

```
#include <SoftwareSerial.h>
char inchar;
```

```
int a;
SoftwareSerial SIM900(3, 4);  // RX and TX pins respectively
int pwm = 11;   // pin able to offer pwm signal for speed control
int mc2 = 7;   // mc is an acronym for motor control
int mc3 = 8;   // pin 10 is for speed control

void setup()
{
Serial.begin(19200);
// Setting the pins to control the motor
// declaring respective pins as outputs
pinMode(mc2, OUTPUT);
pinMode(mc3, OUTPUT);
analogWrite(pwm, 100);  // setting initial values
digitalWrite(mc2, LOW);
digitalWrite(mc3, LOW);
// now initialising the gsm module
SIM900power();
SIM900.begin(19200);
delay(15000); // for gsm shiel to get in sync with econet network
SIM900.print("AT+CMGF=1\r"); // selecting sms text mode instead of binary
delay(200);
SIM900.print("AT+CNMI=2,2,0,0,0\r");
// when sms infor is received by the gsm TX, block out
// contents of that sms to avoid reccurrance
```

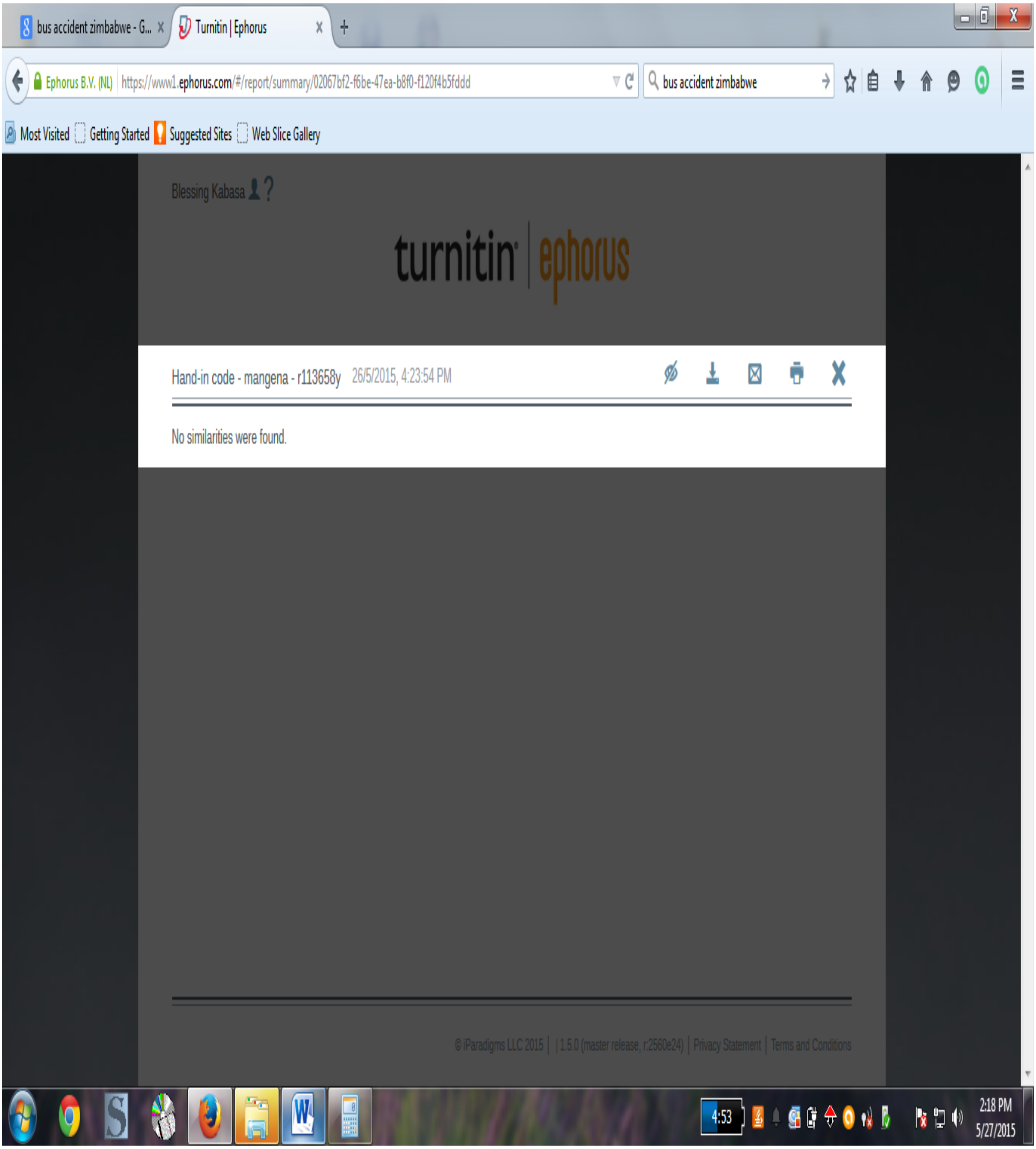
```
delay(200);
Serial.println("Ready...");
}
void SIM900power()
// powering up the gsm modem
{
digitalWrite(5, HIGH);
delay(2000);
digitalWrite(5, LOW);
delay(8000);
}
void loop()
{
// When a character is received from sent sms the
// following sequence of events occur.
if(SIM900.available() >0)
{
inchar=SIM900.read();
if (inchar=='*')
{
delay(10);
inchar=SIM900.read();
if (inchar=='w')
{
delay(10);
```

```
char inchar=SIM900.read();
if (inchar >= '0' && inchar <= '8')
{
int speed = map(inchar, '0', '8', 0, 255);
analogWrite(pwm, speed);
}
else
{
digitalWrite(pwm, LOW);
}

delay(10);
inchar=SIM900.read();
if (inchar=='x')
{
inchar=SIM900.read();
if (inchar=='0')
{
digitalWrite(mc2, LOW);
}
else if (inchar=='1')
{
digitalWrite(mc2, HIGH);
}
delay(10);
```

```
inchar=SIM900.read();
if (inchar=='y')
{
inchar=SIM900.read();
if (inchar=='0')
{
digitalWrite(mc3, LOW);
}
else if (inchar=='1')
{
digitalWrite(mc3, HIGH);
}
delay(10);


}
SIM900.println("AT+CMGD=1,4"); // Delete sms to clear
                          // memory for next sms.
}
}
}
}
}
```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