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Human Machine Interface (HMI) For DC Motor Drives with Self Generator

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Abstract: Direct current (DC) motor has already become an important drive configuration for many applications across a wide range of powers and speeds. The ease of control and excellent performance of the DC motors will ensure that the number of applications using them will continue grow for the foreseeable future. This paper is mainly concerned about reducing the total power consumed by the DC drives by 30% and also to ease the control over the control system with the help of an HMI. Here the microcontroller generates the PWM signals for the DC motor drive circuit based on the inputs given from the HMI. In HMI Visual Basic 8.0 is used to create the faceplate of the motor. A generator is couple with the motor and the load through the means of line shafting. This arrangement makes the motor to supply both the load and the generator simultaneously. Whenever the motor supplies the load the generator in turn generates the power. This power generate by the generator is stored in the battery and then it is supplied to the motor and the source supply to the motor from the mains is cut off. Whenever the battery loses power the motor is supplied from the source supply. This concept reduces the period of time that the motor is supplied from the source supply which makes it to consume less power from the mains.

Keywords: Human Machine Interface, DC Motor drive, Liquid Crystal Display, PIC16F877A MCU.

I. Introduction

The core objective of this paper is to reduce about 30% of the total power consumed by the industrial drives and to ease the control over entire control system for the operators with the help of a HMI. Direct current (DC) motors have variable characteristics and are used extensively in variable-speed drives. DC motor can provide a high starting torque and it is also possible to obtain speed control over wide range. DC motor plays a significant role in modern industrial. These are several types of applications where the load on the DC motor varies over a speed range. These applications may demand high-speed control accuracy and good dynamic responses. In home appliances, washers, dryers and compressors are good examples. In automotive, fuel pump control, electronic steering control, engine control and electric vehicle control are good examples of these. In aerospace, there are a number of applications, like centrifuges, pumps, robotic arm controls, gyroscope controls and so on. And also in industries involving multiple drives the control system should be handled in a smooth way i.e. the operators must not find any difficulties in controlling the overall drive operations. Another major factor for a multiple drive installed industry is the total consumption of the drives. The power consumed increases with increase in number of drives.

Hence for an industry involving multiple DC drives the following factors must be handled with care: Speed control, Easy interface between the operators and the drive control system and total power consumption. In order to achieve the objective of the paper, there are several scope had been outlined. A graph of speed versus time is obtained by using Visual Basic 6.0 at computer to observe the performance of the system

II. PROPOSED SYSTEM -Hardware Implementation

The Motor control parameters are fed by the process operator via 'Human Machine Interface (HMI)' console. The Human Machine Interface (HMI) is developed with Visual Basic 8 . As Micro Control Unit (MCU) fetches the motor control parameter by the HMI via MCU's 'Universal Asynchronous Receiver Transmitter' (UART) port, it produces a corresponding Pulse Width Modulation (PWM) Signal. The PWM signal is used by the DC Drive circuit to drive the DC motor to the set point RPM value fed by the operator.

A Generator is coupled directly or via gear box with the DC Motor, the generated power will charge a 'DC battery' through 'Battery charger circuit'. The MCU triggers the 'source selecting circuit' when the motor achieve its 90% of its speed & battery is full, where the MCU measures DC motor running RPM by the Dynamo tacho generation method. Initially the 'Source selecting circuit' supplies the Regulated 12v dc 'source supply' to the 'DC Drive Circuit' and latter when it is triggered by the MCU, then 12v dc 'Battery Supply' is supplied to the 'Drive Circuit' cutting off the Regulated 12v dc 'source supply'. 'ULN driver circuit' is for driving the

Start, Stop, Trip lamps and for driving a relay in the 'Source Selecting Circuit'. The 'Protection Circuit' plays as an interlock for the Control System under abnormal conditions for the Motor Control Circuits. The 'Source Supply' Circuits are for the power supply of the electronic hardware. And Liquid crystal Display (LCD) is used to display the motor status, tripe & warning alert information is shown in fig 1.

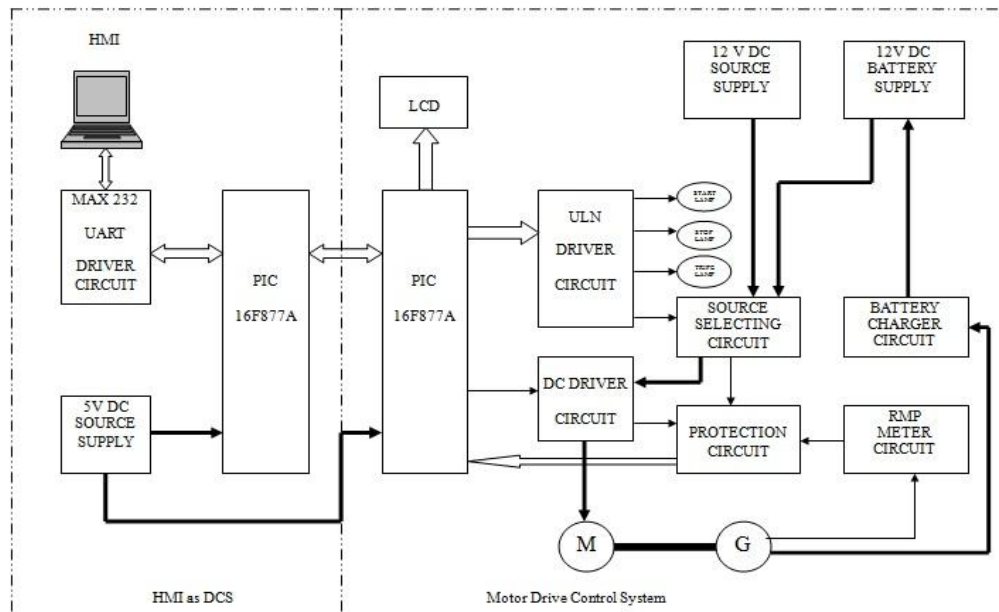


Fig. 1: Block diagram of Human Machine Interface

PIC 16F 877A MCU:

The micro-controller is used to monitor the overall operations and it controls the overall process. The selection of micro-controller is based on the application and the economy of the system. Here we use two microcontrollers to ease the programming and to get a faster response for the inputs. For both the micro-controllers we use PIC16F877A shown in fig 2&3. The first Micro-controller is used for HMI interfacing which is to convert serial inputs available from the HMI to Parallel commands to the second Micro-controller. The second MCU controls the motor drive operations and also gives appropriate signals to the protection circuit during abnormal conditions such as battery failure, Drive system failure, and loss of source supply.

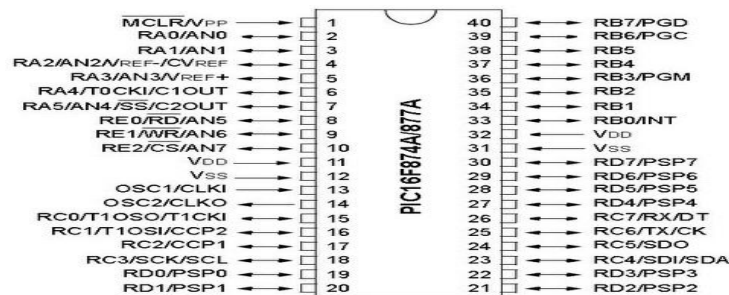


Fig. 2: Pin diagram of PIC16F877A MCU

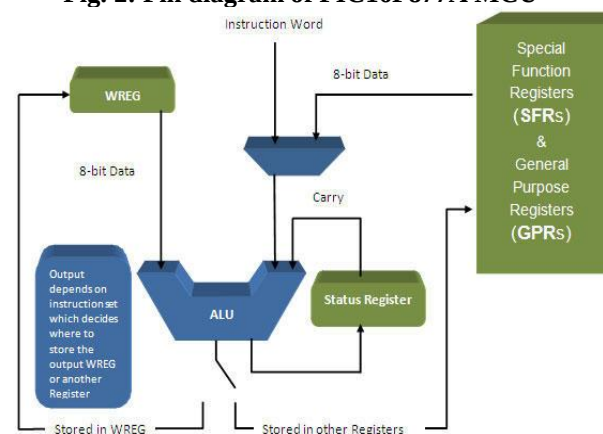


Fig.3: Architecture of PIC16F877A

The function of LCD drive module is to assist the operator in knowing the current situation of the entire control system by displaying it in the LCD display. During warning conditions the LCD display is the only means through which the operator can identify the abnormality. The LCD display is used to display the input command which is given via HMI such as start, stop and also used to display any abnormal situations. Here a 16 x 2 LCD display is used. Here the LCD display is interfaced with the Motor drive Microcontroller unit shown in fig 4.

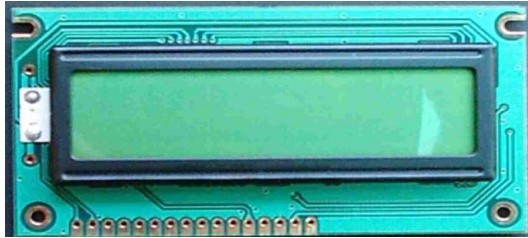


Fig.4: LCD display

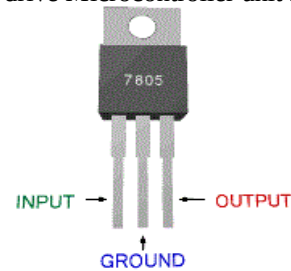


Fig. 5: 7805 pin diagram

The 7805 IC is used in the power supply module to get a regulated 5V supply. The feature of this IC is that for any input voltage upto 15V the output of the IC will be exactly 5V. The output of this IC is used to supply for the MCU and the other ICs shown in fig 5.

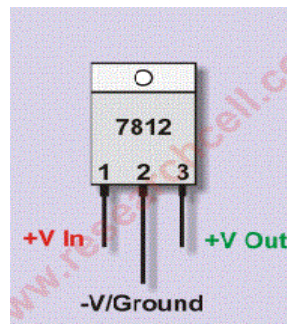


Fig. 6: 7812 pin diagram

The 7812 IC is used in the power supply module to get a regulated 12V supply is shown in fig 6. The feature of this IC is that for any input voltage up to 15V the output of the IC will be exactly 12V. The output of this IC is used to energize the relay coil. The communication standard used in the PCs is RS-232 standard. The RS-232 standard defines information being transferred between data processing equipment and peripherals are in the form of digital data which is transmitted in either a serial or parallel mode. Parallel communications are used mainly for connections between test instruments or computers and printers, while serial is often used between computers and other peripherals. In this system we use Max232 IC as a UART. It is used to provide serial asynchronous transmission between the HMI and the MicroController. Asynchronous transmission means serial transmission in which there is start bit followed by the data and followed by a stop bit is present. An example of asynchronous transmission is shown where the presence of a start bit and stop bit in addition to the data bit is shown in fig 7.

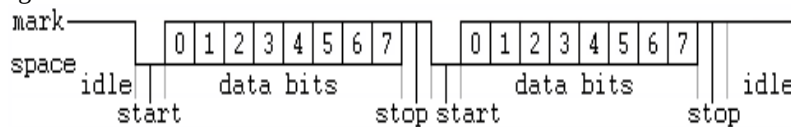


Fig.7: Data bit

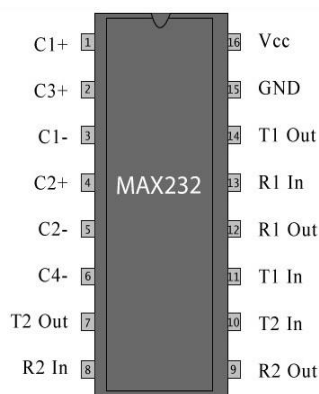


Fig. 8: MAX 232 pin diagram

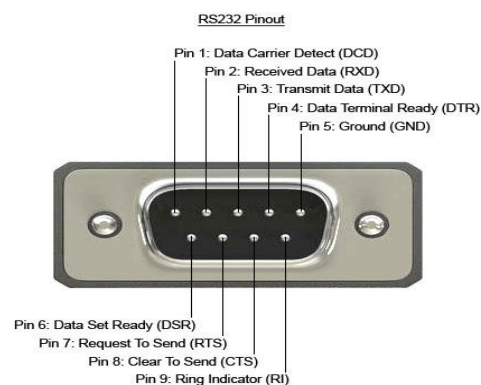


Fig. 9: ULN drive circuit

The function MAX232 is to adjust the level of the signals so communication can take place between the PC and the microcontroller. The signal level on a PC is -10V for logic zero, and +10V for logic one. Since the signal level on the microcontroller is +5V for logic one and 0V for logic zero. MAX232 is used as an intermediary stage that will convert the signal levels shown in fig 8.

Human Machine Interface:

Human machine interface is the successor of Man machine interface (MMI). A MMI requires real time inputs which have to be physically given by the humans to change its state of operation. Whereas the HMI has the advantage of making the system to work on its own by giving instructions to it in beforehand without the need for a human every time. Here we use a computer as the HMI device. It is established with help of Visual basic8.0 which forms the faceplate for the motor control. The inputs from the HMI are fed serially to the MCU unit. The ULN is a relay driver IC. It triggers the relay circuit to switch between the Source supply and Battery supply. The ULN in turn is operated by the Micro-Controller Unit. Here we use ULN2803A IC shown in fig 9. It is 18-PIN IC. The PIN diagram of ULN2803 is shown in fig 10.

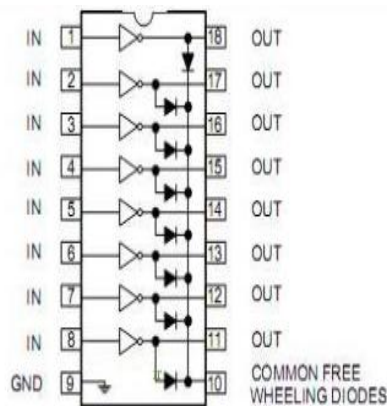


Fig. 10: ULN 2803 pin diagram

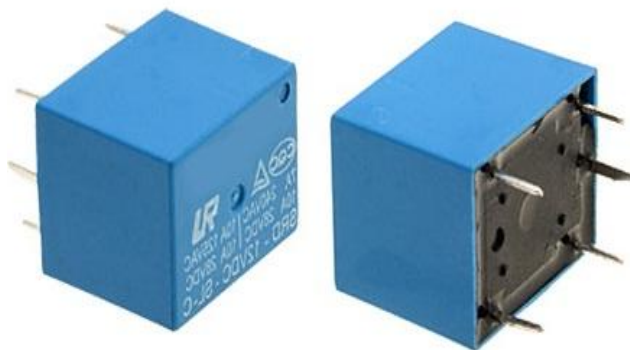
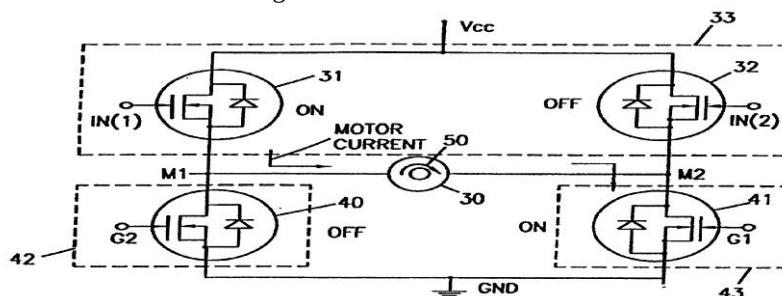


Fig.11: Relay pin diagram

ULN 2803 function:

The function of ULN 2803 is to trigger the 12V DC relay. The DC relay coil gets energized for 12V whereas the microcontroller unit's output is 5V. This ULN 2803 supplies the relay coil with 12V supply whenever the microcontroller wants the source select circuit to switch between the supplies. In turn the ULN IC is controlled by the microcontroller. The ULN IC also supplies the lamps that indicate the abnormality conditions such as warning, trip. The source select switch is nothing but a relay which is used to switch the supply given to the drive circuit between source and battery. Here we use a 12v DC relay. The motor drive MCU gives control signal to the source select circuit to switch between the source and the battery supply which is based on the battery voltage. The battery voltage is fetched by the MCU in terms of the RPM of the generator which is calculated through dynamo tachogeneration. Here the relay coil gets energized at 12V whereas the MCU's output voltage is 5V; therefore there is a need for relay driver. The relay is a switch that can switch between normally open and normally close terminals. The source supply is given to the normally close pin and the battery supply is given to the normally open circuit whenever the microcontroller senses the battery's voltage reached the set value it triggers the relay to switch from source supply to battery supply shown in fig 11. The drive circuit is used to drive the DC motor depending on its gate signals. The gate signals to the drive circuit can be either given from a Pulse Width Modulator (PWM) or it can be directly from the Micro-controller with the help of appropriate coding. In this model we are using a separate MCU for drive circuit i.e the PWM signals are generated from the MCU itself. The drive circuit used in this system is a H-bridge network. An H-bridge network is shown below. The H-bridge network requires 4 diodes and a minimum of 2 MOSFET unidirectional operation of a DC motor is shown in fig 12.



L298 pin diagram:

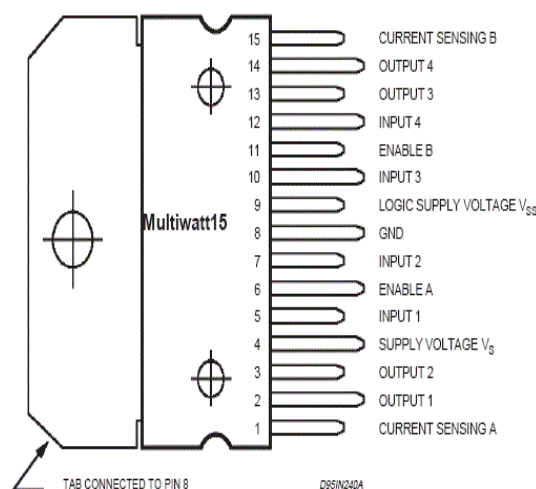


Fig. 13: L298 pin diagram

The function of L298 IC is to drive the DC motor. It is a driver IC. It is a 15- pin IC shown in fig 13. The MOSFETS that are used in the H-bridge network shown in fig 14 are realized through this IC which is shown in the fig. below. The figure shows that the entire H-bridge network is reduced in terms of size and components and hence reduces the complexity.

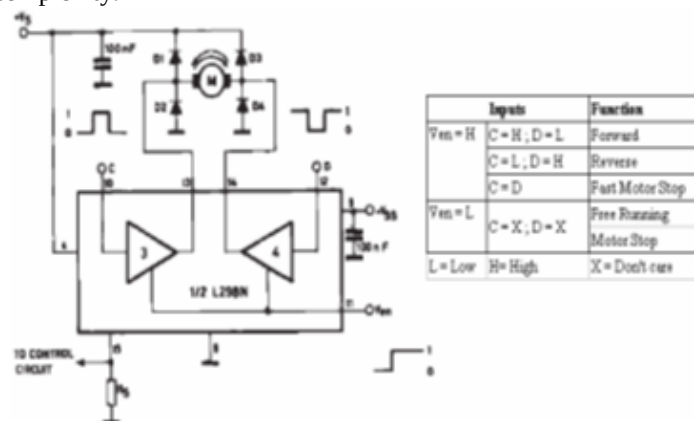


Fig. 14: High bridge network using L298

Fuse link/Diagram:



Fig. 15: Fuse link



Fig.16: 5408 pin diagram

Here in the prototype of the model we are going to use a permanent magnet DC motor since it does require an additional field circuit shown in fig 15&16. But this paper can be implemented to all the types of DC motor since we are employing armature voltage control for the speed control of the motor. Here we are going to implement line shafting which makes the motor to supply both the load and the generator. Here a generator is coupled to the motor through line shafting. This generator which is coupled to the motor allows it to generate its own power supply. A stepper motor is used as generator in the prototype of the project. The use of stepper

motor for generator allows the speed measurement of the motor to be obtained through DC dynamo tachometer. A battery is used to store the power generated from the generator. The battery then supplies the drive circuit. The prototype of this proposed system uses a 12 volt DC motor, Hence a 12V, 1.5A battery is used in this system.

III. Experimental Analysis

Dead Time Analysis:

Dead time is the time of values of the quantity being measured for which it gives no reading. The motor that does not respond at very low input voltage supply due to frictional forces exhibits nonlinearity. There is a dead time at each speed. Figure 17 shows a graph of dead time versus motor speed. From Figure 17, the dead time of the system is decreasing as the motor speed is increasing. This is because for higher speed, the error speed at starting up condition will be higher. So, more voltage will supply to motor to induce more T_{motor} to overcome frictional forces. Thus, the motor will start running earlier and the dead time become smaller.

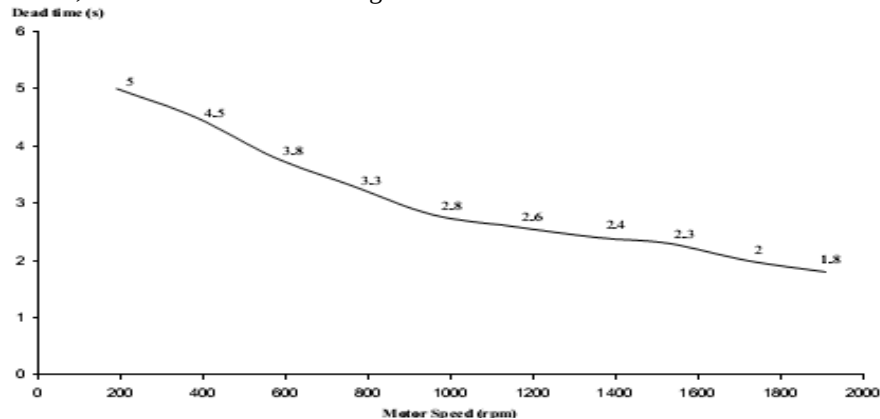


Fig.17: Dead time analysis

Power Consumption Analysis:

As the power consumption of the motor drive and its control system is reduced, by the 'regenerative power' produced by the 'generator' which is directly or indirectly coupled with motor drive. The below table(1) and graph show the total amount of regenerative power produced utilized by the system.

Where Power = Voltage * Current, as we keep the current constant of 2A.

Voltage (V)dc	Current (A)	Power(Watt)	Power consumption per hour(Wh)
5	2	10	600
7.5	2	15	900
12	2	24	1440

Table 1: power consumption based on motor drive voltage supplied to DC motor

$P_r = P_s - P_{\text{loss}}$, we take 20% of the power is loss due mechanical friction and magnetic induction loss by the generator, So we take generator of higher efficiency design 20% more than the driving motor

Where,

$P_s \rightarrow$ Source Power,

$P_r \rightarrow$ Regenerated Power

Let the Drive Circuit Module utilized dc source supply of 70% and it uses 30% from the generator supply. The totally 70% of the power consumed by the motor drive module from DC Source supply, remaining 30% of the power is saved by the regeneration process.

To calculate the 70% of DC source power consumed in 1 hour:

$$X = (70 * 60)/100 = 42 \text{ min}$$

To calculate the 30% of regenerative power consumed in 1 hour:

$$X = (30 * 60)/100 = 18 \text{ min}$$

So we assume the motor drive runs on the source supply for 42 min/hour, and remaining 18min/hour is runs on the regenerated power shown in table 2.

Voltage (V) dc	Power (Watt)	Power consumption per 70% of an hour(Wh)	Power consumption per 30% of an hour(Wh)	Total power Consumption per an hour (Wh)	Total power consumption saved per hour(Wh)
5	10	420	180	600	180
7.5	15	630	270	900	270
12	24	1008	432	1440	432

Table 2: Total power Consumed and saved by the system per hour.

Suppose the drive motor runs for 10000 hours annually on its max RPM, so power consumption the motor drive is 24,0000 unit. Where 15 INR per unit so for $(15 * 24,0000) = 3,600000$ INR , the 70 % is 2,520000 INR and 30% is 1,080000 INR shown in fig 18.

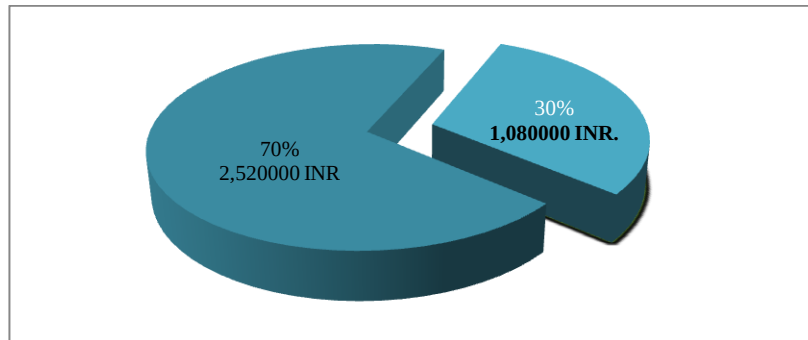


Fig. 18: Shows the amount of power saved annually by the motor drive system

DC Motor Speed Control Result:

Microcontroller acts as proportional (*P*) controller in the DC motor speed control system. At each speed, the result was collected by applying normal load, overload and then suddenly for no load condition. The performance of the system at each speed is shown in Figure 19 to Figure 22 respectively.

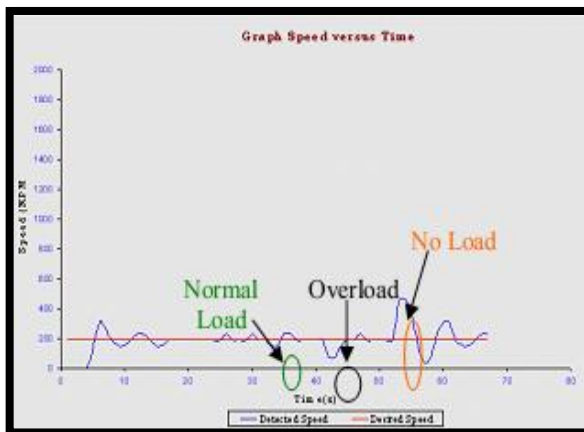


Fig. 19: DC motor running at speed 190.74 rpm

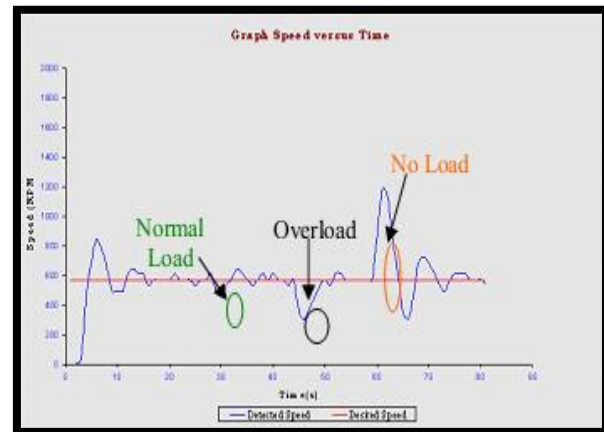


Fig. 20: DC motor running at speed 572.21 rpm

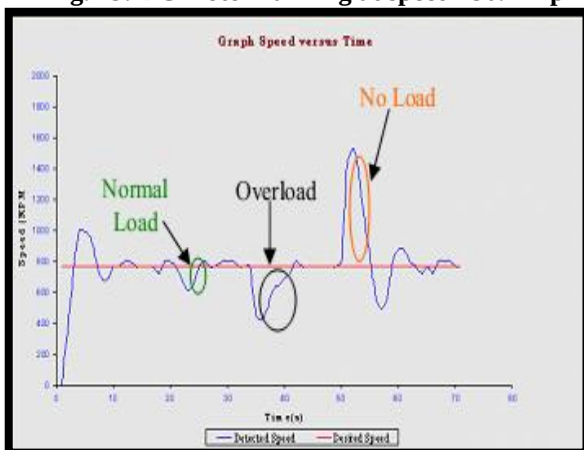


Fig. 21: DC motor running at speed 762.95 rpm

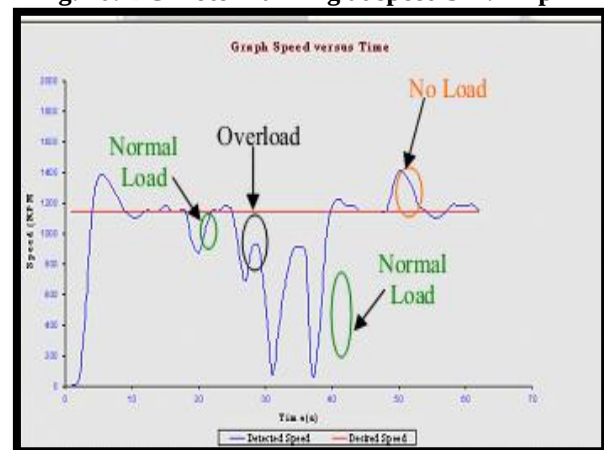


Fig. 22: DC motor running at speed 1144.43 rpm

IV. Conclusion

Recent developments in science and technology provide a wide range scope of applications of high performance DC motor drives in area such as rolling mills, chemical process, electric trains, robotic manipulators and the home electric appliances require speed controllers to perform tasks. DC motors have speed control capabilities, which means that speed, torque and even direction of rotation can be changed at anytime to meet new condition.

The goal of this paper is to design a control system for the DC drive that would ease the operations at work and to reduce the total consumption of the drives by 30% which are successfully fulfilled.

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