

# Throttle Control of Engine by Using PMDC Motor and Drive

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**ABSTRACT:** Engine testing is considered a very important aspect to the health and profitability of the automotive industry, Not only have customers been demanding quality engines, but government regulations have been becoming more strict, while costs keep spiraling higher. There are many types of tests that are performed on engines, and many methods for performing these tests. One such test is to run the engine as it will be used, under a variety of operating and environmental conditions, The purpose of the test is to determine how well the engine performs and whether the total engine and its subsystems maintain their specifications. Also, design flaws or problems can be discovered before production of a new engine gets too far down the road. In order to reduce the expense of running such tests and to ease the gathering of data, test cells are used. The engine is tested at different RPMs and various parameters like oil temperature ,coolant temperature, Oil pressure, Frictional torque, stepper position , Ignition advance ,Fueling time, Lambda value etc are measured and logged. To control the throttle in our experiment we are using PMDC motor. In a DC motor, an armature rotates inside a magnetic field. Basic working principle of DC motor is based on the fact that whenever a current carrying conductor is placed inside a magnetic field, there will be mechanical force experienced by that conductor. When permanent magnet is used to create magnetic field in a DC motor, the motor is referred as permanent magnet DC motor or PMDC motor. Have you ever uncovered any battery operated toy, if you did, you had obviously found a battery operated motor inside it. This battery operated motor is nothing but a permanent magnet DC motor or PMDC motor. Electronic throttle control (ETC) system has worked its way to become a standard subsystem in most of the current automobiles as it has contributed much to the improvement of fuel economy, emissions, drivability and safety. Precision control of the subsystem, which consists of a dc motor driving a throttle plate, a pre-loaded return spring and a set of gear train to regulate airflow into the engine, seems rather straightforward and yet complex. The difficulties lie in the unknown system parameters, hard nonlinearity of the pre-loaded spring that pulls the throttle plate to its default position, and friction, among others. In this paper, we extend our previous results obtained for the modeling, unknown system parameters identification and control of a commercially available Bosch's DV-E5 ETC system. Details of modeling and parameters identification based on laboratory experiments, data analysis, and knowledge of the system are provided. The parameters identification results were verified and validated by a real-time PID control implemented with an xPC Target. A nonlinear control design was then proposed utilizing the input-output feedback linearization approach and technique. In view of a recent massive auto recalls due to the controversial uncontrollable engine accelerations, the re-sults of this paper may inspire further research interest on the drive-by-wire technology. Our main aim to achieve the Throttle control of engine by using PMDC motor and Drive.

**KEYWORDS:** ETC System; System Identification; Nonlinear Control; Input-Output Feedback Linearization; xPC Target-Based Control System

## I. INTRODUCTION

In the automotive industry, one of the fruitful technologies that have emerged from the increasing regulations in terms of fuel economy, emission control, drivability and safety is the drive-by-wire technology that creates the electronic

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throttle control (ETC) system [1,2]. The system comprises of a throttle plate equipped with a pre-loaded spring and is driven by an electronic-controlled dc motor to regulate airflow in the intake manifold. In modern vehicles, the engine control unit computes and maps the throttle plate's angle to many entries such as accelerator pedal position, engine speed, cruise control command, and so forth in order to achieve optimal air-fuel mixtures in the combustion chambers, thereby maximizing fuel economy and minimizing emissions. The ETC system, which responds to the prescribed reference from the engine control unit must operate with fast transient responses and precise control to regulate the throttle plate's angular position [3,4]. Engine test cell consists of all the elements like ECU, dynamometer, throttle controller, field i/o, operator interface (HMI), frontend test cycle required for testing a four cylinder engine. Powertrain performance measurement is a statutory requirement by the government as well as vehicle manufacturer in order to ensure the consistency of the powertrain and adhere emission norms. Here in this project we are going to design and prepare a working model throttle control drive of engine with the help of PMDC motor and economical feedback of position and speed. Conventional FIP based diesel engine or petrol engine speed is controlled by a throttle lever. This lever is connected with the help of wire rope to a throttle actuator. The engine throttle has an opening from 0 to 100%. This in terms of angle comes to 0 to 90 deg. It needs control the position of the throttle lever with the help of PMDC motor and gearbox as per test cycle. The position will be tightly hold for time scheduled in the test cycle. Developments of high performance motor drives are very essential for industrial applications. A high performance motor drive system must have good dynamic speed command tracking and load regulating response. DC motors provide excellent control of speed for acceleration and deceleration. The power supply of a DC motor connects directly to the field of the motor which allows for precise voltage control, which is necessary for speed, position and torque control applications. DC drives, because of their simplicity, ease of application, reliability and favourable cost have long been a backbone of industrial applications. DC drives are less complex as compared to AC drives system. Speed and position control of dc motor could be achieved using mechanical or electrical techniques. In the past, speed and position controls of dc drives are mostly mechanical, requiring large size hardware to implement. Advances in the area of power electronics have brought a total revolution in the speed and position control of dc drives. The use of power electronics for the control of electric machines offers not only better performance caused by precise control and fast response, but also maintenance, and ease of implementation. In parallel with the advance in power electronic there have been great advances in microcontroller-based control systems due to the microcontroller flexibility and versatility. This is because all the control algorithms are implemented in the software. Now days, Induction motors, Brushless D.C motors and Synchronous motors have gained widespread use in electric traction system. Even then, there is a persistent effort towards making them behave like dc motors through innovative design and control techniques. Hence dc motors are always a good option for advanced control algorithm because the theory of dc motor speed control is extendable to other types of motors as well. The motor speed can be controlled by controlling armature voltage and armature current. It is obvious that speed control is possible by varying: Flux per pole,  $\Phi$  (Flux control). Resistance  $R_a$  of armature circuit (Rheostat Control). Applied voltage  $V$  (Voltage Control). The above methods have some demerits like a large amount of power is wasted in the controller resistance. Hence, efficiency is decreased. It needs expensive arrangement for dissipation of heat produced in the controller resistance. By these data that are acquainted we can draw a conclusion that these electric and electromechanical methods are less adaptive so electronic techniques are used for speed control. These methods provide higher efficiency, greater reliability, quick response, higher efficiency. One such technique is Pulse Width Modulation. We apply this technique in our project so as to control the speed and position of the DC motor.

## II. LITERATURE SURVEY

There are different types of throttle control designed previously. For education purpose just manual level control with the help of screw and locknut. This arrangement hardly used in the automotive testing environment. In some cases linear actuator is also used based on the position feedback. These actuators are precise but very costly. Also they are prone to fail in case of dusty environment which a testbed does have. Generally the position loops are controlled in hardware. Here we are going to control the loop in PLC/Arduino. The electric drive systems used in many industrial applications require higher performance, reliability, variable speed and ease of controllability. The speed control of DC motor is very crucial in applications where precision and protection are of essence. Purpose of a motor speed controller is to take a signal representing the required speed and to drive a motor at that speed. Different methods

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are used to control the speed of dc motor. For precise speed control of servosystem, closed-loop control is normally used. speed, which is sensed by analog sensing devices (e.g., tachometer), is compared with the reference speed to generate the error signal and to vary the armature voltage of the motor.

## 2.1 Techniques for Speed and position control:

There are several controllers that can be used to control the speed of the motor such as:

- Armature voltage using Rheostat method for low power dc motors.
- Use of conventional PID controllers.
- Neural Network Controllers.
- Phase-locked-loop control
- Ac-dc buck-boost converter with only one switching device used for armature voltage control.
- Fuzzy Logic Controller and etc

## 2.2 Control Loops used in literatures:

A DC motor position control finds wide applications in servo systems, especially in aerospace, automotive and mechatronics applications. The position of a DC motor can be controlled by controlling the Armature Voltage or Field Voltage. The following are few of the simple methods of controlling a DC motor shaft position .

1. Open loop - without feedback of current position, method is ineffective and inaccurate in the presence of load disturbance.
2. On-off controller - motor is turned on with maximum torque till it reaches set point and switches off, this may result in overshoots and oscillations .
3. Single directional control - reaches set point in a single direction only, the angular position of a DC motor can also be controlled by varying the torque generated by varying the armature voltage or field voltage. In most digital applications,
4. PWM (Pulse Width Modulation) is generally used to control the speed of the DC motor. It is relatively easier to generate pulses of varying duty cycles with a microcontroller or microprocessor. The pulses with varying duty cycle when applied to the armature will result in variable torque proportional to the duty cycle. The control methodology used in this project is to apply an average voltage proportional to the error between actual position and the set point and reduce the average voltage as the current position approaches the set point. This kind of control is very effective in systems with high inertia as an inherent property, so that no control effort is reached.

## 2.3 The Controller Designing for Physical Model

Now must be design a controller for the physical model that is changed following of automotive throttle pedal. This controller is one of the ECU circuits. The parts of this controller have been demonstrated in figure 15. In the controller at first car driver pushes the pedal then the pedal signal is transmitted to ECU. The pedal signal is as reference signal. In the ECU throttle butterfly angle signal and reference signal have been compared in comparator portion and the error signal is produced. Then the error signal has been sent to DC motor driver. The driver portion acts by PWM2 method. The duty cycle of PWM signal is dependent to error signal. The higher error leads to higher duty cycle and vice versa. Also in this method, the butterfly direction is changed by getting of positive and negative voltage (as PWM). So two important portion of this controller is comparator and motor driver. In continues we will explain these two portions [7-9].

## III. PROPOSED ARCHITECTURE

### 3.1 Test cycle concept

Throttle Control is one of the basic control required for the testing of an engine. As the engine speed depends upon the throttle opening (position), to achieve stable engine speed, throttle has to be maintained at a particular position. In case of remote engine testing panels, throttle also has to be operated from the remote panel (i.e. from outside the engine test cell). For particular tests like pre-heating cycle, throttle has to be actuated in a defined sequence and at a rapid rate which makes it tedious if throttle is to be set manually. All these provisions of high response remote operation, high resolution of adjustment etc. are taken into consideration in the THROTTLE LEVER POSITION CONTROLLER. To achieve stable operation of throttle at any particular position, because of its' fast response and high holding torque action, a DC servo motor with timing belt and pulley arrangement will be used for throttle actuator.

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The THROTTLELEVER POSITION CONTROLLER under this project will be suitable for all types of fuel injection systems. Throttle actuator is operated in closed loop by taking position feedback. Throttle zero position and range of operation can be shifted electrically from the controller. Throttle Lever Position Controller can be hooked up to Sequential Programmer or Computer Controlled Engine Performance Monitor.

### 3.2 Engine Throttle butterfly valve

Mechanical Throttle Bodies for Small Engines control air flow to the engine. They feature a butterfly valve in the throttle body which opens and closes the passage into the intake manifold to increase or decrease the volume of incoming air.

Mechanical Throttle Bodies offer a simpler alternative to electronic systems while maintaining excellent durability and reliability. They are mechanically linked to the accelerator and are constructed of aluminum or composite materials. Mechanical Throttle Bodies are also designed to provide the manufacturer with packaging flexibility.



Fig No 01 Engine Throttle butterfly valve

### 3.3 Interface Block Diagram

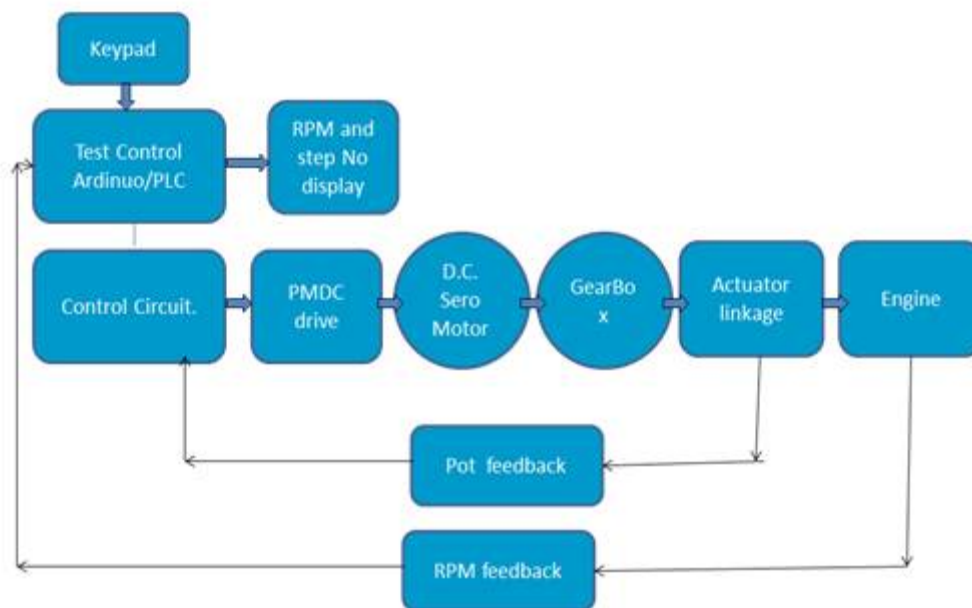


Fig No 02 Interface Block Diagram

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As show in the Block diagram the mechanical throttle of engine is connected with the wire rope to actuator linkage which is driven by the PMDC motor with gearbox. The DC sero motor will be controlled with the PMDC drive . The control strategy used is PWM . The driver ciricuit will generate the PWM signals for the Drive. The actual parameter entry and display will be done with help of arduino connected LCD and Keypad. Feedback loop is closed by Pot/encoder and RPM magnetic Pickup sensor.

### 3.4 Control Block Diagram:

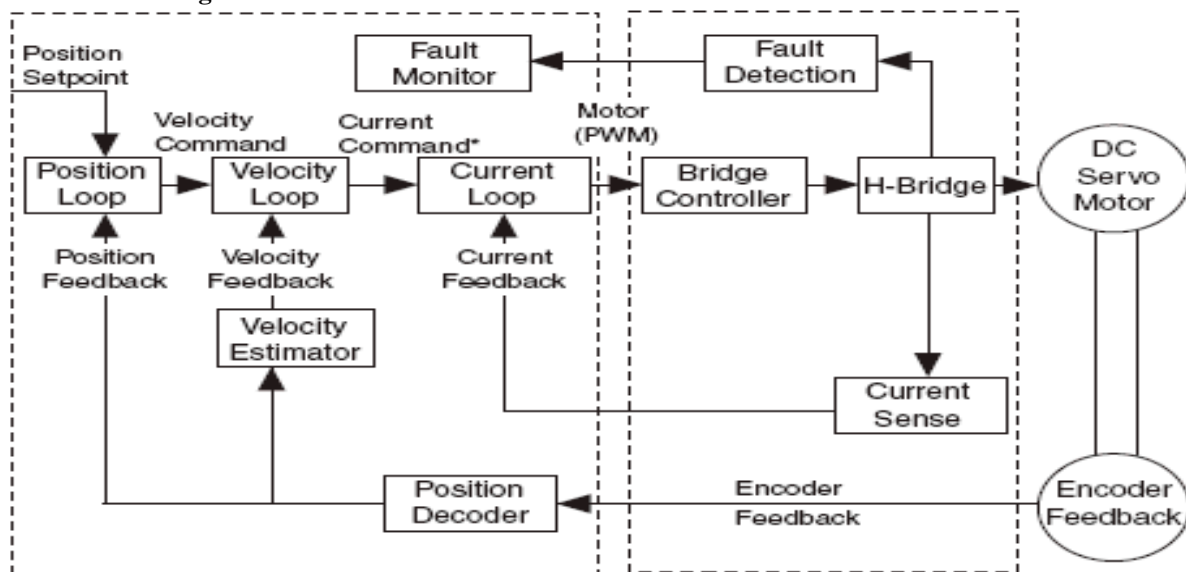


Fig No 03 Control Block Diagram

## IV. MAJOR COMPONENTS

### 4.1 PMDC Motor.

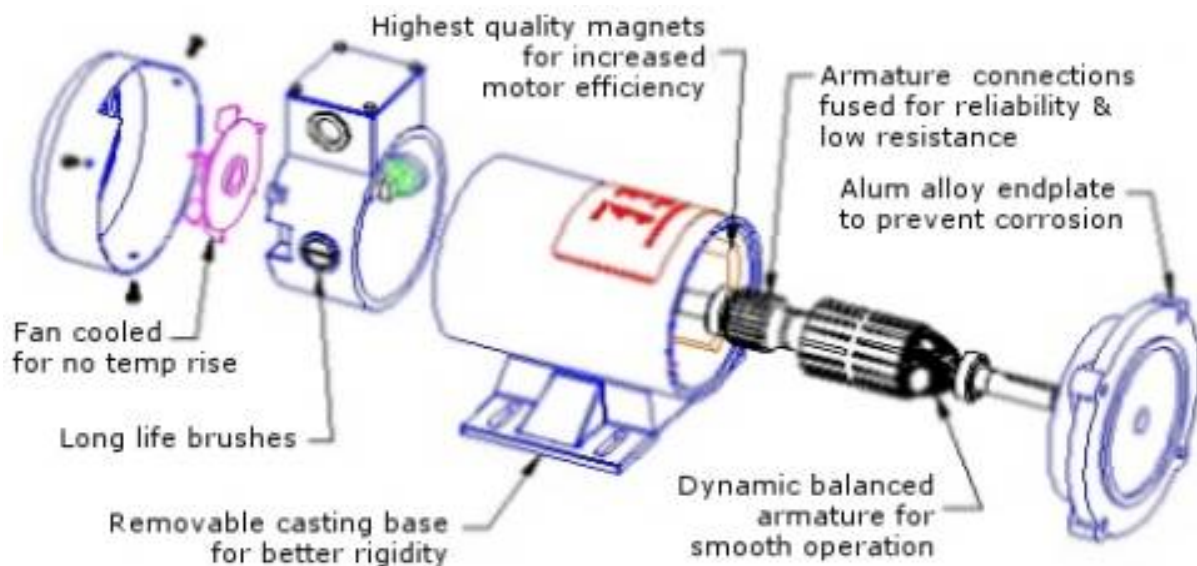


Fig No 04 PMDC Motor.

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## 4.2 Engine throttle wired (Mechanical) connection

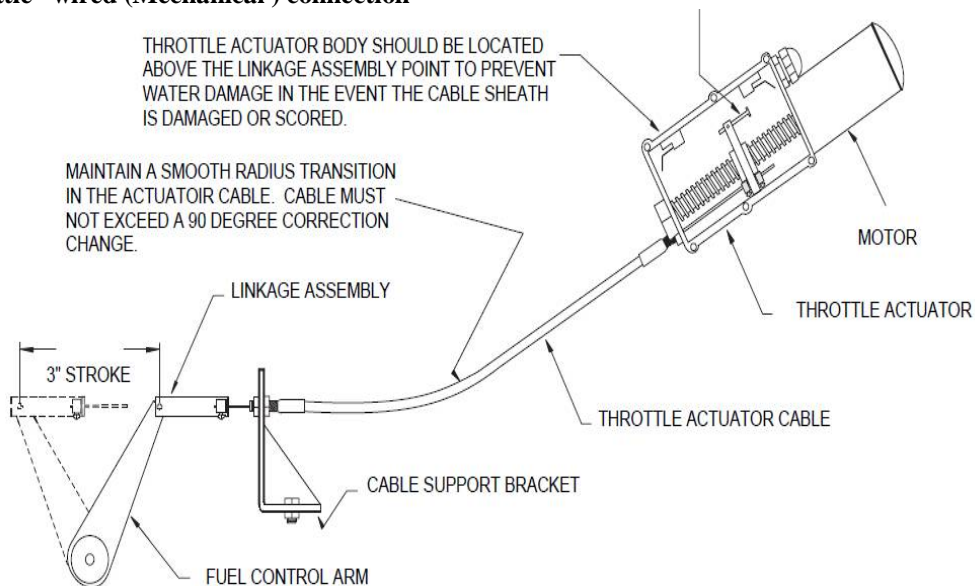


Fig No 05 Engine throttle wired (Mechanical) connection

## 4.3 Cycle entry and display elements

### A) % scale display (Angle display) Meter and feedback.

For feedback we can use encoder or pot for velocity control and RPM sensor from speed control. The feedback pot or encoder needs to be mounted on the final linkage of the controller. Sixty teeth gear wheel with sensing proximity will be used for this application.

### B) Keypad for position entry.

Numerical keypad will be used for the entry. The cycles entered can have Step number, RPM set point and time allotted for the step.

### C) Display for RPM

2X20 line lcd display will be used. This display can be used while setting up the cycle also. Also this display can be used for the displaying the parameters Step number, RPM set point and time allotted for the step.

## V. PMDC MOTOR



Fig No 06 PMDC Motor

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## 5.1 Design and Operation:

Permanent magnet DC (PMDC) motors provide a comparatively simple and reliable DC drive solution in applications requiring high efficiency, high starting torque and a linear speed/torque curve. With the great strides made in ceramic and rare earth magnet materials, combined with electronic control technology, the PMDC motor is a cost-competitive solution for adjustable speed applications - delivering significant performance in a relatively compact size. The single design feature which distinguishes the permanent magnet DC motor from other DC motors is the replacement of the wound field with permanent magnets. It eliminates the need for separate field excitation and attendant electrical losses in the field windings.

## 5.2 Advantages:

Perhaps the most important advantage of PM field motors is their smaller overall size made possible by replacing the wound field with ceramic permanent magnets. The PM motor's ring and magnet assembly is considerably smaller in diameter than its wound field counterpart, providing substantial savings in both size and weight. See Fig. 1. And since the PMDC motor is not susceptible to armature reaction, the field strength remains constant. If we examine the field construction of the wound field DC motor versus the PMDC field motors, we can explain the differences in armature reaction and corresponding differences in speed/torque characteristics of the two motor types. The armature magnetizing force in a wound field construction "sees" a very high permeability (low reluctance) iron path to follow. In the PM field design, this armature magnetizing force is resisted by the low permeability (high reluctance) path of the ceramic magnet, which tends to act as a very large air gap. The net result is that the armature cannot react with the field in a PMDC motor, thereby producing a linear speed / torque characteristic throughout its entire torque range.

PMDC motors offer benefits in a number of ways:

- a) They produce relatively high torques at low speeds, enabling them to be used as substitutes for gear motors in many instances. PMDC motors operated at low speeds are especially useful where "backlash" and inherent mechanical "windup" of gearing in gear motors cannot be tolerated. It should be noted that if PMDC motors are continuously operated at high torque levels (above rated), they can generate serious overheating, or motor damage can result.
- b) The linear speed / torque curve of PMDC motors, coupled with their ability to be easily controlled electronically, make them ideal for adjustable speed and servo motor applications.
- c) The linear output performance characteristics of PMDC motors also make it easier to mathematically predict their dynamic performance. See Fig. 3. The PMDC motor's high starting torque capability can be a valuable asset in many "motor only" (non-gearmotor) applications as well as inertial load applications requiring high starting torque with less running torque. PMDC motors function well as torque motors for actuator drives and in other intermittent duty applications. The size reduction in PMDC motors is generally accomplished without any significant change in the temperature rise rating for a given horsepower. In fact, the electrical efficiency of the PMDC motor is very often 10% to 15% higher due to the elimination of field copper losses which occur in wound field motors. PMDC motors can be produced in TENV (totally enclosed non-ventilated) construction, eliminating the need for fans and providing much greater application flexibility. With their higher inherent efficiency, PMDC motors and gearmotors offer lower current drain for more efficient battery operation in portable applications. The permanent magnets also provide some self-braking (less shaft coast) when the power supply is removed. PMDC motors require only two leads (shunt-wound motors require four). The leads can be reversed by simply changing the polarity of the line connection. Dynamic braking is achieved by merely shunting the two leads after disconnecting them from the power source. Permanent magnet DC motors also provide similar performance characteristics to shunt-wound DC motors when used with all common control methods (except field weakening).

## 5.3 Design Considerations:

While today's ceramic magnets have properties which make them very reliable, certain characteristics of these materials must be thoroughly understood if proper operation of ceramic magnet PMDC motors or gearmotors is to be obtained. At lower temperatures (0°C and below), ceramic magnets become increasingly susceptible to permanent demagnetizing forces. Strong armature fields capable of producing permanent demagnetization of the magnets take on greater importance at lower temperatures. Therefore, special attention must be given to overload current conditions including "starting," "locked rotor" and "plug reversing" when applying PMDC motors to low temperature use. Plug

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reversing requires current limiting, even at normal temperatures. The design of the motor's power supply is also important.

PWM and SCR controls are designed to provide current regulating and / or limiting features to protect the motor or gearmotor. The actual application parameters involved vary with each particular PMDC motor design, since the protection against demagnetization is part of the motor's design and must be considered accordingly. It is best to consult the manufacturer if low temperature use or plug reversing is contemplated. As operating temperature increases, the residual or working flux of PMDC motors decreases at a moderate rate. This flux decrease is much like the decrease of field flux strength in wound field motors as copper resistance increases with temperature.

## 5.4 Features

Because of their high starting torque characteristic, care must be exercised in applying PMDC gearmotors. A PMDC gearmotor application should be carefully reviewed for any high inertial loads or high starting torque loads. These types of loads could cause the motor to transmit excessive torque to the gearhead and produce output torque which exceeds its design (rated) limits. PWM or SCR speed controls with built-in current limiting circuits, or overload slip clutches are sometimes employed to protect gearing used with PMDC motors.

- Continuous duty operation
- DC power supply (battery or speed controls)
- Reversibility at rest or during rotation with current limiting
- Relatively constant and adjustable speed
- Starting torque 175% and up of rated torque
- High starting current, relative to full load running ent

## VI. PMDC DRIVE

PMDC motor drives PMDC motor control is very direct, where the rotation speed of the shaft is proportional to the applied voltage, while the instantaneous torque can be linearly controlled by controlling the armature current. PMDC motor drivers are built based on two types of power electronics converters – either phase controlled rectifier or switched mode DC/DC converter. The second one is often preferred due to the higher efficiency, wider control range and better dynamic characteristics. The four-quadrant PMDC motor drive discussed in this paper is of the switched mode DC/DC type and allows speed control as well as direction control. The topology of such four-quadrant PMDC drive is shown at figure. The topology is presented with equivalent electronic switches S1 to S4 and with their antiparallel diodes (incorporated or otherwise discrete), while the series connected  $L_a$ ,  $R_a$  and  $e_a$  are the equivalent circuit of the PMDC motor – representing the inductance and resistance of the winding and the back EMF. This base topology can be viewed as constructed from two power legs – the first consisting of switches S1, S3 and diodes D1, D3 and the second respectively from S2, S4 and D2, D4. The principle of operation is based on connecting the DC voltage source –  $V_{DC}$ , either in forward direction by commutation of switches S1 and S4 or in reverse direction by commutating switches S2 and S3. As the speed control is done by regulating the amount of voltage applied to the motor via Pulse Width Modulation (PWM). In most cases, for simplification of the control, one of the commutated switches either in forward or reverse is constantly 'on' while the other one is used for the PWM control by switching the supply voltage. For example in forward direction S4 can be constantly switched on while S1 is used for the PWM control. This paper discusses different measures for increasing the efficiency of this base structure by properly selecting and combining the electronic switches.



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## 6.1 flow chart for speed control

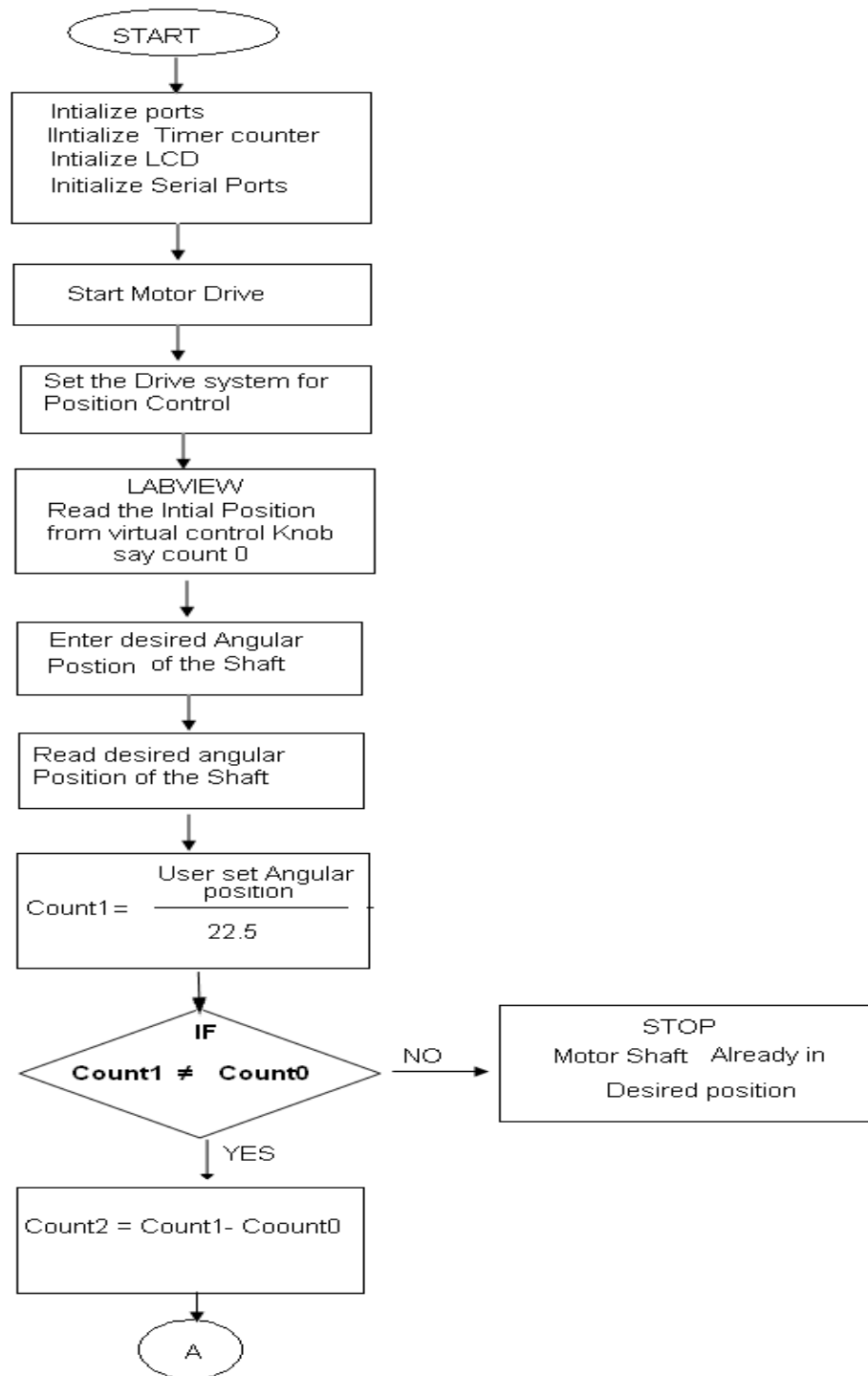


Fig No 07 flow chart for speed control

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## 6.2 Flow chart for speed control continued

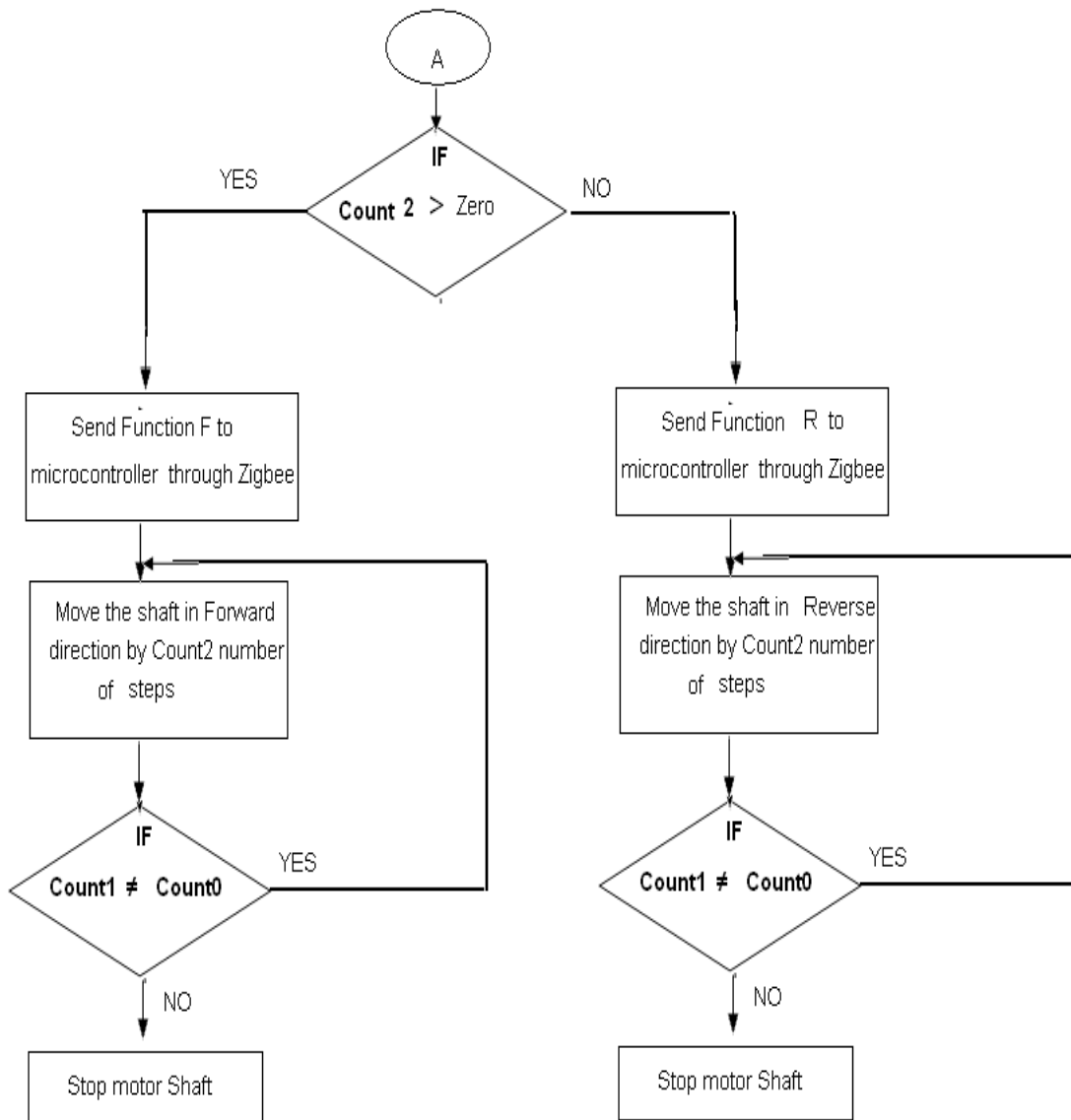


Fig No 08 Flow chart for speed control continued

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## 6.3 Flow Chart Poistion Control

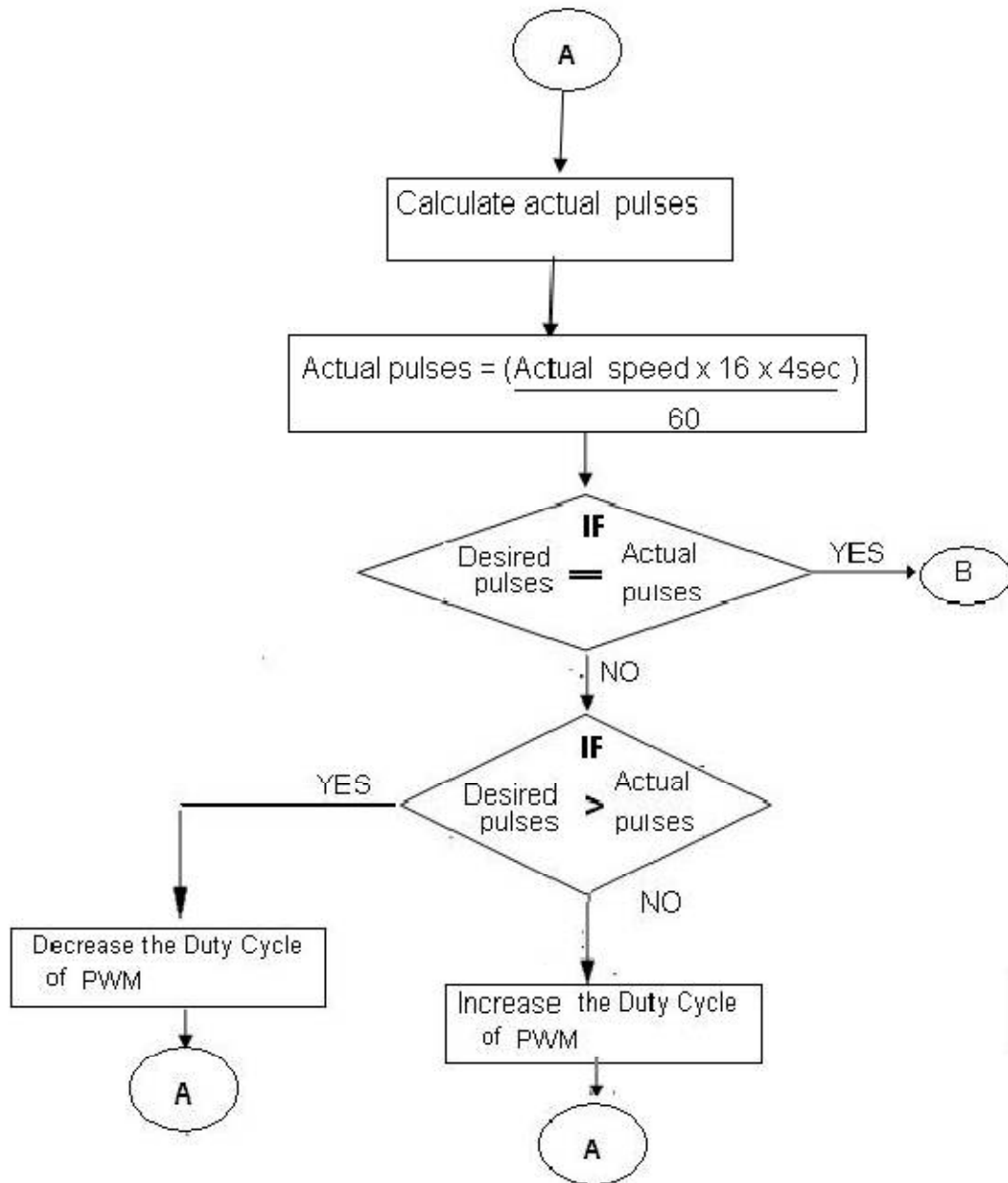


Fig No 09 Flow Chart Poistion Control:

## V. EXPERIMENTAL RESULTS

Now a reference signal as pedal signal (see figure 20) is exerted on controller then the butterfly position has been demonstrated in figure . In below figure some vibrations has been existed in up and down border sides. In below figure

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we accommodated the curves of figures 20 and 21 and in figure 23 the error signal between those signals has been demonstrated. The maximum errors in the error signal are 7 percents. These errors appear in limp home zone mostly

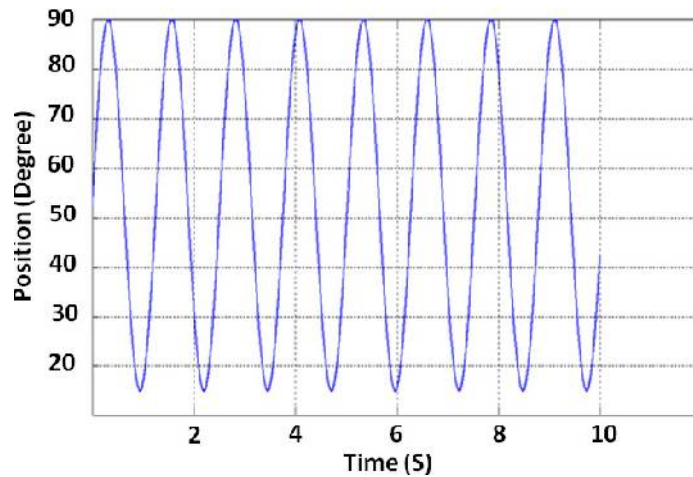


Fig No 10 . The reference signal

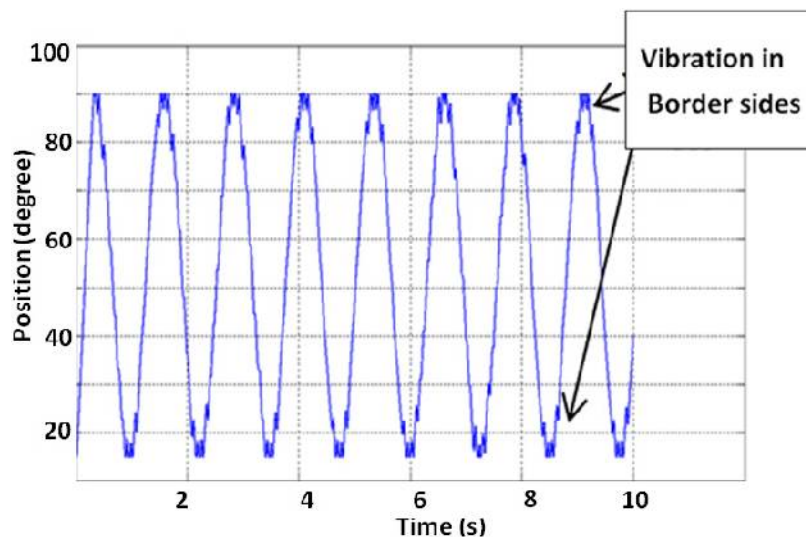


Fig No 11. The butterfly position

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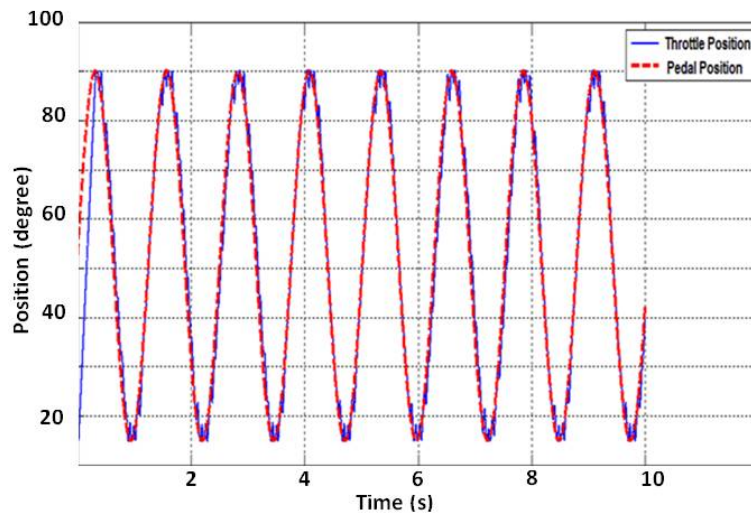


Fig No 11 Accomodation of before signals (figure 20&21)

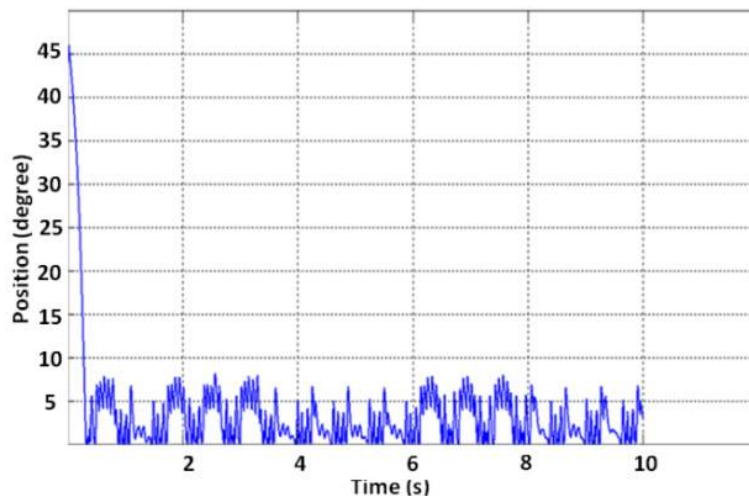


Fig No 12. Error signal

The controller circuit consists of 2 portions. They are controller and driver portions. The controller portion can be Microcontroller or FPGA. In the structures that have many inputs and outputs, FPGA is useful but in this structure Microcontroller is enough the structure has been demonstrated in figure.

In this structure at first the Microcontroller receives the pedal and butterfly position signals then transmits proper comments to bipolar chopper portion. In the bipolar chopper portion the positive or negative PWM signals are produced

$$I = 12 / 1.6 = 7.5A$$

to DC motor driving. In the bipolar chopper portion, the H bridge structure has been used [12, 13]. The maximum current of driver portion is gotten Ohm law. The coil resistance of throttle is 1.6 ohms and the voltage supply is 12 volts then the consuming current is:

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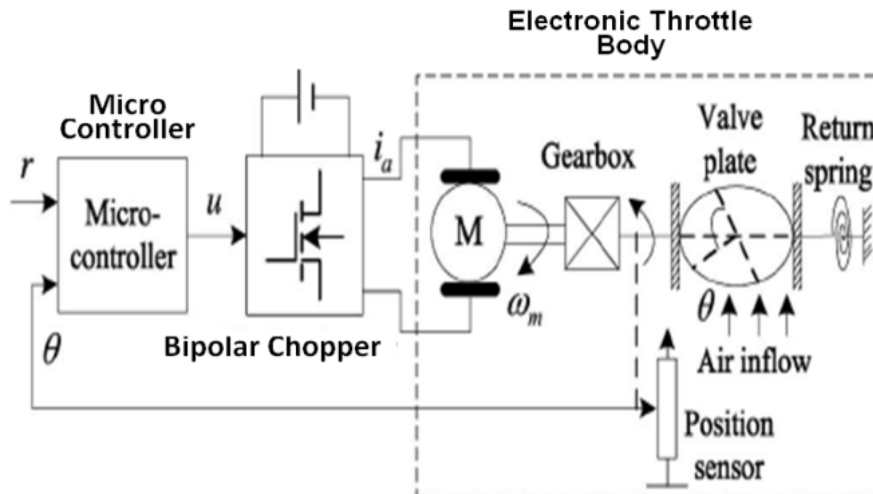


Fig No 13. The controller structure by Microcontroller [6]

The H Bridge of this circuit consists of MOSFET IRF3205 and driver ICs IR2110. The freewheeling diodes (1N5818 Schottky diodes) have been used to protection of transistors from returned currents. The mechanism of this controller has been explained in flowchart of figure.

## VI. CONCLUSION AND FUTURE WORK

### Conclusion

From the consideration of all the above points I conclude that In a DC motor, an armature rotates inside a magnetic field. Basic working principle of DC motor is based on the fact that whenever a current carrying conductor is placed inside a magnetic field, there will be mechanical force experienced by that conductor. Electronic throttle control (ETC) system has worked its way to become a standard subsystem in most of the current automobiles as it has contributed much to the improvement of fuel economy, emissions, drivability and safety. Precision control of the subsystem, which consists of a dc motor driving a throttle plate, a pre-loaded return spring and a set of gear train to regulate airflow into the engine, seems rather straightforward and yet complex. The difficulties lie in the unknown system parameters, hard nonlinearity of the pre-loaded spring that pulls the throttle plate to its default position, and friction, among others. In this paper, we extend our previous results obtained for the modeling, unknown system parameters identification and control of a commercially available Bosch's DV-E5 ETC system. Details of modeling and parameters identification based on laboratory experiments, data analysis, and knowledge of the system are provided. The parameters identification results were verified and validated by a real-time PID control implemented with an xPC Target. A nonlinear control design was then proposed utilizing the input-output feedback linearization approach and technique. In view of a recent massive auto recalls due to the controversial uncontrollable engine accelerations, the results of this paper may inspire further research interest on the drive-by-wire technology. Our main aim to achieve the Throttle control of engine by using PMDC motor and Drive.

### Future Work-

- a) Selection of motor.
- b) Component selection & manufacturing of Drive
- c) Close loop technique and ckt development.
- d) Command source and feedback display development
- e) Installation and wiring work
- f) Performance analysis.

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- [14] IEEE paper no.(05600865) efficiency enhancement of four-quadrant PMDC motor control through combination of power electronics switchesAngelMarinov\*, VencislavValchev\*\* \* Technical University, Varna, Bulgaria, e-mail: igdrazil@abv.bg \*\* Technical University, Varna, Bulgaria, e-mail: [vencivalchev@hotmail.com](mailto:vencivalchev@hotmail.com).
- [15]IEEE paper No. 00639556)Adaptive ANN Rule-Based Controller for A Chopper FedPMD C Motor Electric Vehicles DriveHussein F. Soliman and A.M. SharafElectrical Eng. Dept. The University of New Brunswick Box 4400/ Fredrecton, N.B. E3B 5A3, CANADAM. Mansour, S. A. Kandil, M. H. El-ShafiiDept. of Electrical Eng. Ain Shams UniversityCairo, Abassia, AbdoBashaEGYPTPhone 506-453-456 1, Fax 506-453-3589.