Sudan University of Science and Technology

College of Graduate Studies

Design of Westgate Controller for Performance Improvement (Case Study: Allen Diesel Engine 4012)

تصميم بوابة التخلص من الفائض لرفع الكفاءة

(دراسة حالة: ماكينة الان ديزل 4012)

A Thesis Submitted in Partial Fulfillment of the Requirements for the M.Sc in Mechatronics Engineering

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الآية

قال تعالى:

﴿ نَرْفَعُ دَرَجَاتٍ مَّن نَّشَاء و فوق كل ذي عَلِيمٌ ﴾

صدق الله العظيم

سورة يوسف (الاية 76)

Dedication

This research is dedicated to:

- The sake of Allah, my creator and my master.
- My great teacher and messenger, Mohammed (May Allah bless and great him).
- My great father, who never stop giving of themselves in countless ways.
- My dearest wife, who leads me through the valley of darkness with light of hope and support.
- My beloved brothers and sisters, who stand by me when things look bleak.
- My supper heroes Motaman, Mazin, Moanzir and to all of my family, the symbol of love and giving.
- My friends for their encourage and support.
- All the people in my life who touch my heart.

Acknowledgement

All praises be to Allah for blessing myself with opportunities abound and showering upon me his mercy and guidance all through the life. I am praying that He continues the same the rest of my life.

First and foremost I would like to express my gratitude to my supervisor Ust: Abdalla Saleh Ali, Dr. Fath-alrahman Ismaiel for guiding and helping throughout this research, I consider myself extremely fortunate for having the opportunity to work under his supervision over the entire period.

Also I would like to take this opportunity to thank my friends and colleagues especially Eng. Ahmed Hakim, Eng. Sameh Mohamed and Eng. Hamad Alnail for their true help through this master period.

Abstract

Westgate is a gate placed in the path of exhaust gases after combustion and before the arrival of these gases to the compressor. This gate is used to reduce the exhaust air that drives the air compressor due to several variables: pressure, temperature, and speed of the machine. All these variables vary according to the load of the engine. In this thesis, the gate is used to eliminate the surplus on the engine. Several simulation tests are performed to evaluate the performance of the proposed system. The problem is Allen Diesel Engine 4012 that fuel consumption is more than required, that makes excessive exhaust gasses and black smoke, which makes air contamination and that adversely affect the performance. The solution to solve this problem is by adding westgate to exhaust system. In this thesis a simulation system is created after adding westgate. The simulation results show that the performance of the proposed system is good under different optional conditions.

مستخلص

بوابة التخلص من الفائض (من هواء العادم) عبارة عن بوابة توضع في مسار غازات العادم بعد الاحتراق وقبل وصول هذه الغازات الى الضاغط الهوائي. تستخدم هذه البوابة لتقليل هواء العادم الذي يحرك الضاغط الهوائي نتيجة لعدة متغيرات الضغط، درجة الحرارة، وسرعة الماكينة. كل هذه المتغيرات تتغير على حسب حمولة الماكينة. في هذا البحث بوابة التخلص من الفائض تستخدم لدراسة تاثير المتغيرات اعلاه على الماكينة. المشكلة الحالية هي ان لدينا ماكينة الان ديزل 4012 تستهلك كمية كبيرة من الوقود مما ينتج عنه احتراق غير كامل للوقود مسببة سحابة سوداء وتلوث كبير للهواء ومؤثرة على الكفاءة. لحل هذه المشكلة تم اضافة بوابة التخلص من الفائض في مسار غازات العادم. في هذا البحث سيتم عمل نظام محاكاة للنظام بعد اضافة بوابة التخلص من الفائض. تم اجراء العديد من اختبارات المحاكاة لتقييم أداء النظام المقترح. نتائج المحاكاة أظهرت أن أداء النظام جيد تحت شروط التشغيل المختلفة.

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List of Abbreviations

AVR	Automatic Voice Recognition
RTD	Resistant Temperature Detectors
CPU	Central Processing Unit
I/O	Input/Output
ROM	Read Only Memory
RAM	Random Access Memory
EPROM	Erasable Programmable Read Only Memory
EEPROM	Electrical Erasable Programmable Read Only memory
NVRAM	Non Volatile Random Access Memory
IC	Integrated Circuit
LCD	Liquid Crystal Display
USB	Universal Serial Bus
AC	Alternating Current
DC	Direct Current
SRAM	Static Random Access Memory
RPM	Revolution Per Minutes
PWM	Pulse Width Modulation
VSS	Volume Snapshot Service

Chapter One

Introduction

1.1 General Concept

Allen diesel Engine 4012 is a type of Rolls Royse Engine. Its twelve cylinders, V-shape engine. Old mechanical design engine. Allen engine used diesel or crude oil as fuel, there are many applications of this engine, and it is working as marine engine, production engine, generation etc. Its working without Westgate, we want to design a Westgate that controlled electronically to reduced fuel consumption, which automatically reduced black smoke and contamination and making engine performance in good condition.

A westgate is essentially a device that bypasses some exhaust flow around the turbine section of a turbocharger to control maximum boost. A westgate is usually controlled by a pressure actuator that is a connected to manifold pressure. The westgate is normally closed, held shut by spring inside the actuator canister. When preset pressure limit are exceeded, the actuator progressively opens the westgate, allowing exhaust flow to bypass the turbine, thus regulating manifold boost pressure. On the surface, it sound like simple premise, and in fact, a westgate is a simple device. The problem comes from the pressure in the exhaust system, called turbine inlet pressure that can dear against the valve, overpowering the spring in the actuator, and forcing the westgate open the lower than intended boost levels.

Original equipment turbocharger westgate actuator are selected or engineered for a specific boost level and turbine inlet pressure. To keep coast down, such actuators are usually just big enough to do the job at the stock boost levels. If the turbocharger boost is increased for additional air flow and performance, the stock westgate actuator is frequently incapable of holding the westgate fully closed until the higher boost level is reached. This happens because turbine inlet pressure also increased as boost pressure rises. The fix is to use a bigger spring in the westgate actuator to hold it closed until the desired peak boost is achieved, however, that also requires a bigger actuator diaphragm to override the heaver spring when the desired boost level is reached. That's why Banks created the Big head actuator that's used many of its diesel power systems.

The westgate's job is to divert excess exhaust gases away from the turbine. Controlling the speed of the turbine and preventing it from spinning too fast. By controlling and limiting the speed of turbine, the westgate regulates the boost pressure provided by the turbocharger. By preventing the boost pressure from rising indefinitely, the westgate protect the turbocharger and the engine from damage [1].

1.2 Problem Statement

The problem is Allen Diesel Engine 4012 fuel consumption is more than required (too much), that make excessive exhaust gasses and black smoke, which is make air contamination and that adversely affect to performance.

1.3 Objective

The main objectives of this thesis to design of westgate valve with electronic controller to reducing fuel consumption, increase engine performance which reduces contamination by controlling air fuel ratio.

1.4 Methodology

(a) Study and understand the previous work.

(b) Study and understand the Allan diesel engine 4012.

(c) Study and understand the main parts such as sensors, servomotor and microcontroller.

(d) Built the complete simulation block diagram using Proteus software.

(e) Evaluate the performance of the proposed control system based on the simulation result.

1.5 Thesis Layout

This thesis consists of five chapters. Chapter one consists of general concepts, problem statement, objectives and methodology. Chapter two present engine construction, engine systems, engine control methods, engine production equipment, microcontroller and previous studies. Chapter three includes of system block diagram, the main compartments and flow chart. Chapter four consists of contains of simulation result and discussion. Finally chapter five consists of conclusion and recommendations.

Chapter Two

Background and Literature Review

2.1 Introduction

Allen 4012 type engines are of the solid-injection, compression-ignition type and operate on the four-stroke cycle. The engine is pressure charged by means of exhaust gas driven turbo-chargers and has charge air cooling. Engine has two banks in both sides (A left side, B right side). The engines are arranged in V-form with an included angle of 45 degrees between cylinder banks. The standard rotation of the engine is anti-clockwise looking on the flywheel end. The firing order for twelve cylinder engines is as follows:A1, B3, A3, B5, A5, B6, A6, B4, A4, B2, A2, B1 [2].

2.2 Engine Construction

The main parts of engine construction as:

2.2.1 Bedplate and main bearings

The deep-section cast-iron bedplate forms the oil sump and has integrally cast transverse webs that stiffen the structure and support the crankshaft main bearings. Pre-finished thin wall steel backed lined AS 104 type main bearings are standard. An additional main bearing is provided at the flywheel end and is fitted with full thrust ring to locate the crankshaft axially [2].

2.2.2 Crankshaft and flywheel

The crankshaft is a one-piece forging, with an integrally forged half coupling which carries the flywheel. The flywheel has barring teeth and timing marks on the periphery. The main coupling bolts pass through the crankshaft half coupling flange, the flywheel, and the driven machine half coupling flange [2].

2.2.3 Connecting rods and pistons

The connecting rods are arranged in pairs, fitting side by side on the crankpins. Each connecting rod has a detachable bottom cap, the joint faces being serrated for location and inclined to enable the rod to be withdrawn through the cylinder bore. The cap is secured to the connecting rod by four high tensile steel bolts. All the piston rings have chrome plated running faces to reduce wear except for the top ring which has a ceramic coating. The gudgeon pins are fully floating and retained by circles and are drilled to form the piston cooling oil supply path [2].

2.2.4 Entablature and cylinder liners

The entablature is a single casting into which 'wet' type cylinder liners are fitted. It also forms housing for the camshaft and valve operating mechanisms, being secured to the bedplate by bolts and studs. Synthetic compound sealing rings are fitted between cylinder liner and entablature to make a watertight joint of the lower land. Well seal is used on the upper land and a thick section mild steel ring is fitted between the liner and cylinder head [2].

2.2.5 Cylinder heads

The cylinder heads are separately detachable and each is provided with an indicator cock to enable cylinder pressures to be checked. The two inlet and two exhaust valves, seat direct in the head on renewable seats of iron alloy (inlet) stainless steel (exhaust), and each is fitted with two valve springs, with valve rotators fitted in the spring caps of the valves to ensure even heat distribution. The exhaust valve seats are water-cooled and are fitted with two 'Q' rings for water sealing. The valve levers and push rods are of the totally enclosed, pressure lubricated type [2].

2.2.6 Camshaft and cam followers

The camshafts are driven from the flywheel end of the crankshaft by means of a gear train. The shaft is built up in sections, each machined from a solid forging and complete with inlet, exhaust, and starting air valve cams. Each fuel pump cam is split and bolted to a hub, and is accurately located during assembly. The cam followers are of the guided roller type and are pressure lubricated, via drilled passages, from the camshaft bearings [2].

2.3 Engine Systems

The engine systems can be classified as:

2.3.1 Engine starting air system

The engine is arranged for starting by means of compressed air entering directly into the cylinders of 'A' bank. The air receiver valve head is fitted with a fusible plug. Air start relief valves are also fitted in the system. Compressed air is led to the starting air valve, which admits air to the engine distributor main, directly connected to the separate camshaft-operated starting valves, each valve being connected to an automatic starting valve in the cylinder head. Engine and electric motor driven air compressors are installed for charging the air receivers [2].

2.3.2 Starting air module

A 1150 liters capacity air receiver of the vertical floor mounting type is supplied complete with inlet and outlet valves, fusible plug, drain valve and pressure gauge. The receiver is sized to give sufficient capacity for five failed start attempts and one successful start without recharging [2].

2.3.3 Engine lubricating oil system

Incorporated in the lubricating oil system is the lubricating oil cooler/filter module the equipment comprises one lubricating oil centrifuge, strainer, electric pre-heater, suction and discharge pump, pipe work, instrumentation and valves and control panel [2].

2.3.4 Engine fuel oil system

The two types of engine fuel oil system as follows:

(a) Heavy fuel treatment module

Incorporated in the fuel oil system is the heavy fuel treatment oil treatment module with fuel oil centrifuge, which is fitted with two independent self cleaning, fully de-sludge fuel oil centrifuges. The module is to be arranged for local manual start/stop with automatic (self cleaning) operation with auto shutdown on alarm.

(b) Heavy fuel heating and pumping module

The heating and pumping module (installed in the engine ring main fuel system) ensures that the crude fuel is always kept at the correct temperature, viscosity and pressure. The module handles the crude fuel requirements for engines operating simultaneously or individually. Individual fuel pumps and injectors are fitted to each cylinder head, mounted on the top surface of the entablature and actuated by the camshaft, and are supplied fuel oil from the daily service tanks via the pumping module and double compartment fuel oil filter [2].

2.3.5 Cooling water system

For maximum efficiency a closed circuit water system in conjunction with a heat exchanger should be used with these engines. Whilst soft, clean water is desirable in the engine jacket system, it is much more important to retain the same water, since undesirable quantities of scale are formed only where water containing scale-forming salts is being frequently replaced. Loss of water by leakage and evaporation should be reduced to a minimum.

The engines are water cooled, the jacket water passing around the cylinder liner water spaces, then through the cylinder heads. The jacket circulating water pump is driven from the free end of the engine. The engine circulating water is cooled by an air blast radiator. Two radiators are included in the system one for jacket waters the other for secondary water cooling.

The two charge air coolers are of the two-section type, the first section being cooled by jacket water and the second by secondary water. The lubricating oil cooler, is cooled by the secondary water. A thermostatically operated temperature control valve is provided for the jacket water. A thermostatic control valve of the mixing type is provided in the secondary water system [2].

2.3.6 Engine charge air system

Combustion air is drawn into the turbocharger, via turbo charger mounted air filter silencers. Air is then compressed in the turbo charger and discharged through the two-stage intercooler before distribution by the inlet air manifold to the engine cylinders [2].

2.3.7 Engine exhaust system

Exhaust gases enter the turbocharger to drive the compressor via the engine manifold. The turbocharger exhaust then passes through a transition piece, and expansion bellows to the engine exhaust ducting [2].

2.4 Engine Control Method

The engine control can be by different methods

2.4.1 Engine governors

The engines are fitted with Woodward 720 Digital governors, mounted in the Unit Control Panel, with engine mounted hydraulic actuators controlling the fuel racks. The engine governors operate in isochronous mode ensuring that the load on running sets is balanced, and Automatic Voice Recognition (AVR) on each generator maintains constant voltage output and share active load [2].

2.4.2 Over speed trip

An over speed trip is fitted to the flywheel end of the 'B' general bank camshaft. It consists of a tilting weight mounted in a rotating housing and the weight is held in its nonna1 running position byan axial spring. If the engine over speed by exceeding a value of 15% full speeds, the centrifugal unbalance overcomes the spring, the weight tilts, and strikes the trip gear. In doing so it disengages a catch that releases the vertical trip spindle, this spindle moves downwards under the action of a spring and through linkage to the fuel pump control shaft, shuts down the engine. The over speed trip can be tripped by hand by means of the trip handle, in order to check its operation [2].

2.4.3 Crankcase relief valve

These valves are designed to relieve the pressure inside the engine in the event of a crankcase explosion while, at the same time, preventing the admission of air [2].

2.5 Engine Protection Equipment

A low-lubricating oil pressure switch is fitted as standard and the normal type is a dual contact instrument giving an alarm with falling pressure, and a second stage alarm which initiates shut down when the oil pressure has reached a dangerously low level. A jacket water temperature Resistant Temperature Detectors (RTD) provides a first stage alarm at rising temperature with a further temperature switch single type contact instrument that will shut down the engine when the jacket water temperature has reached a dangerously high level. Air manifold temperature is dependent upon the load imposed upon an engine and the circulation and temperature of cooling water through the charge air coolers. Two single stage high and low alarm switches are supplied as standard [2].

2.6 Motor Driven Barring Gear

The generator set will be fitted with an electric motor driven slow speed barring gear arrangement, which will rotate the generator set via a gear wheel fitted to the engine flywheel. The barring gear will be provided with two electrical interlocks, one to prevent the generator setfrom starting unless the gear is disengaged and a second to ensure that the barring gear will not operate until fully engage [2].

2.7 Microcontroller

A microcontroller is a computer-on-a-chip, or, if you prefer, a single-chip computer. Micro suggests that the device is small, and controller tells you that the device might be used to control objects, processes, or events. You can find microcontrollers in all kinds of things these days. Any device that measures, stores, controls, calculates, or displays information is a candidate for putting a microcontroller inside. The largest single use for microcontrollers is in automobiles just about every car manufactured today includes at least one microcontroller for engine control and often more to control additional systems in the car. In modems, printers, and other peripherals. In test equipment, microcontrollers make it easy to add features such as the ability to store measurements, to create and store user routines, and to display messages and waveforms. Consumer products that use microcontrollers include cameras, video recorders, compact-disk players, and ovens. And these are just a few examples.

A microcontroller is similar to the microprocessor inside a personal computer. Examples of microprocessors include Intel's 8086, Motorola's 68000, and Zilog's Z80. Both microprocessors and microcontrollers contain a Central Processing Unit (CPU). The CPU executes instructions that perform the basic logic, math, and data-moving functions of a computer. To make a complete computer, a microprocessor requires memory for storing data and programs, and Input/Output (I/O) interfaces for connecting external devices like keyboards and displays.

In contrast, a microcontroller is a single-chip computer because it contains memory and I/O interfaces in addition to the CPU. Because the amount of memory and interfaces that can fit on a single chip is limited, microcontrollers tend to be used in smaller systems that require little more than the microcontroller and a few support components. Examples of popular microcontrollers are Intel's 8052 (including the 8052-BASIC), Motorola's 68HC11, and Zilog's Z8.

Using a microcontroller can reduce the number of components and thus the amount of design work and wiring required for a project. At the core of many of these specialized computers is a microcontroller. The computer's program is typically stored permanently in semiconductor memory such as Read Only Memory (ROM) or Erasable Programmable Read Only Memory (EPROM). The interfaces between the microcontroller and the outside world vary with the application, and may include a small display, a keypad or switches, sensors, relays, motors, and so on. Options for storing programs. Instead of using disk storage, most microcontroller circuits store their programs on-chip. For one-of-kind projects or small-volume production, EPROM has long been the most popular method of program storage. Besides EPROMs, other options include Electrical Erasable Programmable Read Only Memory

(EEPROM), ROM, Non Volatile Random Access Memory (NVRAM), or battery-backed, RAM, and Flash EPROM. The program memory may be in the microcontroller chip, or a separate component.

To save a program in EPROM, you must set the EPROM's data and address pins to the appropriate logic levels for each address and apply special programming voltages and control signals to store the data at the selected address. The programming process is sometimes called *burning* the EPROM. You erase the contents by exposing the chip's quartz window, and the circuits beneath it, to ultraviolet energy. Some microcontrollers contain a one-time-programmable, or field-programmable, EPROM.

This type has no window, so you can't erase its contents, but because it's cheaper than a windowed Integrated Circuit (IC), it's a good choice when a program is finished and the device is ready for quantity production.

Several techniques are available for programming EPROMs and other memory chips. With a manual programmer, you flip switches to toggle each bit and program the EPROM byte-by-byte. This is acceptable for short programs, but quickly becomes tedious with a program of any length. Computer control simplifies the job greatly. With an EPROM programmer that connects to a personal computer, you can write a program at your keyboard, save it to disk if you wish, and store the program in EPROM in a few easy steps. Data sheets for EPROMs rarely specify the number of erase and reprogramming cycles a device is guaranteed for, but a typical EPROM should endure 100 erase/program cycles, and usually many more. EEPROMs are much like EPROMs except that they are electrically erasable no ultra violet source is required. Limitations of EEPROMs include slow speed, high cost, and a limited number of times that they can be reprogrammed (typically 10,000 to 100,000).

(a) ROMs: Are cost-effective when you need thousands of copies of a single program. ROMs must be factory-programmed and once programmed, can't be changed.

(b) NVRAM: Typically includes a lithium cell, control circuits, and RAM encapsulated in a single IC package. When power is removed from the circuit, the lithium cell takes over and preserves the information in RAM, for 10 years or more. You can reprogram an NVRAM infinite number of times, with the only limitation being battery life.

(c) Flash EPROM: Is electrically erasable, like EEPROM, but most Flash devices erase all at once, or in a few large blocks, rather than byte-by-byte like EEPROM. Some Flash EPROMs require special programming voltages. As with EPROMs, the number of erase/program cycles is limited.

(d) Other memory: Most systems also require a way to store data for temporary use. Usually, this is RAM, whose contents you can change as often as you wish. Unlike EPROM, ROM, EEPROM, and NVRAM, the contents of the RAM disappear when you remove power the chip (unless it has battery back-up).

(e) I/O Options: Most systems require interfaces to things like sensors, keypads, switches, relays, and displays. Most microcontrollers have ports for interfacing to the world outside the chip [3].

Chapter Three

System Structure

3.1 Introduction

Westgate controlling at Allan diesel engine is most important in that engine to controlling fuel consumption during variable loads, that also reducing contamination at exhaust gasses. To controlling westgate opening angle there are some parameters should be consider, 1’st parameter is pressure by using pressure sensor, 2’nd parameter is temperature by using temperature sensor, 3’rd parameter is speed by using speed sensor, using servo motor to open and close the gate (controlling westgate angle). All this components connect with Arduino Uno that connects with Liquid Crystal Display (LCD) and the gate.

3.2 System Block Diagram

The system block diagram is shown in Figure 3.1

Figure 3.1: System block diagram

3.2.1 Pressure sensor

A pressure sensor, as the name suggests, is a device that senses and measures pressure (usually of gases or liquids). The pressure sensor in electronic circuits is in the form of an integrated circuit that acts as a transducer, it replicates (in the form of an electrical signal) the signal it receives as a function of imposed pressure. A pressure sensor is also known as a pressure transducer, pressure transmitter, pressure sender, pressure indicator, piezometer and manometer. Figure 3.2 shows the pressure sensor [6].

Figure 3.2: Pressure sensor

3.2.2 LM35 temperature sensor

A temperature sensor is the instrumentation equipment which is used to measure temperature or heat on the operating machine parts. Temperature sensing is performed by equipment called thermocouple. A thermocouple is a temperature-measuring device consisting of two dissimilar conductors that contact each other at one or more points. It produces a voltage when the temperature of one of the points differs from the reference temperature at other parts of the circuit.

The LM35 is one kind of commonly used temperature sensor that can be used to measure temperature with an electrical o/p comparative to the temperature (in °C). It can measure temperature more correctly compare with a thermostat. This sensor generates a high output voltage than thermocouples and may not need that the output voltage is amplified. Figure 3.3 shows the LM35 temperature sensor [6].

3.2.3 Speed sensor

A speed sensor or Vehicle Speed Sensor (VSS) is a type of tachometer. It is a sender device used for reading the speed of engine or a vehicle's wheel rotation. It usually consists of a toothed ring and pickup. Figure 3.4 shows the speed sensor [6].

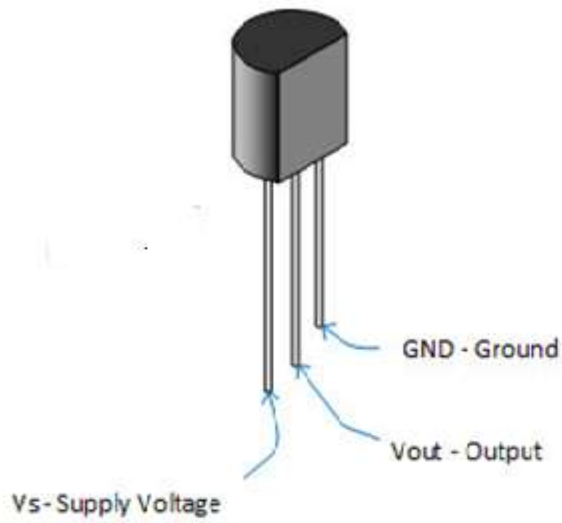

Figure 3.3: LM35 temperature sensor

Figure 3.4: Speed sensor

3.3 Arduino Uno

Arduino is an open source platform it is based on a simple microcontroller board and also it has an environment for writing software for the board. Arduino Uno is a microcontroller board based on the ATmega328P. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16MHz quartz crystal, a Universal Serial Bus (USB) connection, a power jack, and a reset button.

Major advantages of using Arduino Uno are it is very inexpensive, clear programming, it is an open source, extensible software and hardware, and simply connect it to computer with a USB cable or power it with an Alternating Current (AC) to Direct Current (DC) adapter or battery to get started. Figure 3.5 shows the Arduino Uno board [7]. Table 3.1 shows the main specifications of the Arduino Uno board.

Figure 3.5: Arduino Uno board

Table 3.1 The main specifications of the Arduino Uno board

No	Description	Specification
1	Microcontroller	ATmega328
2	Operating voltage	5V
3	Input voltage (recommended)	7-12V
4	Digital I/O pins	14 (of which 6 provide PWM output)

5	Analog input pins	6
6	DC current per I/O pin	40mA
7	Flash memory	32KB (ATmega328) of which 0.5KBused by boot loader
8	Static RAM (SRAM)	2KB
9	EEPROM	1KB
10	Clock speed	16MHz

3.4 Liquid Crystals Display

A LCD is a flat-panel display or other electronically modulated optical device that uses the light-modulating properties of liquid crystals. Liquid crystals do not emit light directly, instead using a backlight or reflector to produce images in color or monochrome. LCDs are available to display arbitrary images (as in a general-purpose computer display) or fixed images with low information content, which can be displayed or hidden, such as preset words, digits, and seven-segment displays, as in a digital clock. They use the same basic technology, except that arbitrary images are made up of a large number of small pixels, while other displays have larger elements. Figure 3.6 shows the LCD [8].

Figure 3.6: LCD

3.5 Servomotor

A servomotor is a rotary actuator or linear actuator that allows for precise control of angular or linear position, velocity and acceleration. It consists of a suitable motor coupled to a sensor for position feedback. It also requires a relatively sophisticated controller, often a dedicated module designed specifically for use with servomotors. Figure 3.7 shows servomotor [6].

Figure 3.7: Servomotor

3.3 Flow Chart

As shown in figure 3.8wesgate system flow chart, when system is started, the sensors search for any change in system parameters such as pressure, temperature and engine speed (RPM), when any change occurs, the sensor sends signal to controller to modify gate opening according to change.

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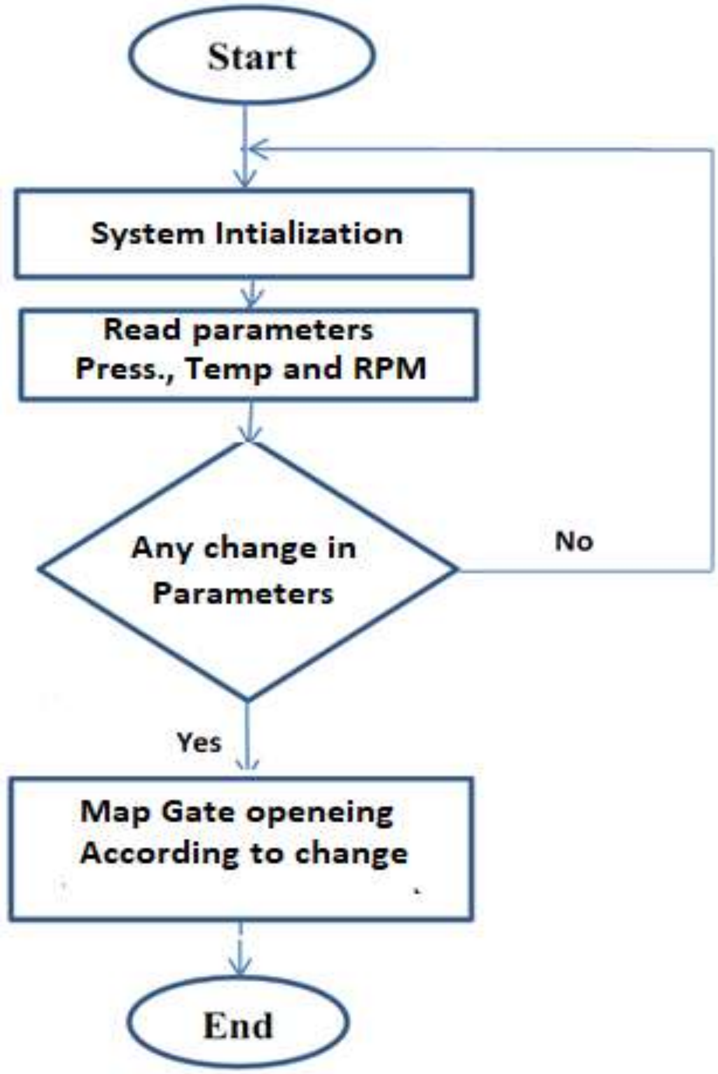

Figure 3.8: Flow chart of wesgate system

Chapter Four

Simulation Result and Discussion

4.1 Introduction

This suction is showing simulations in different operation situation and simulation results with discussions. Figure 4.1 shows the complete circuit diagram using Protues software.

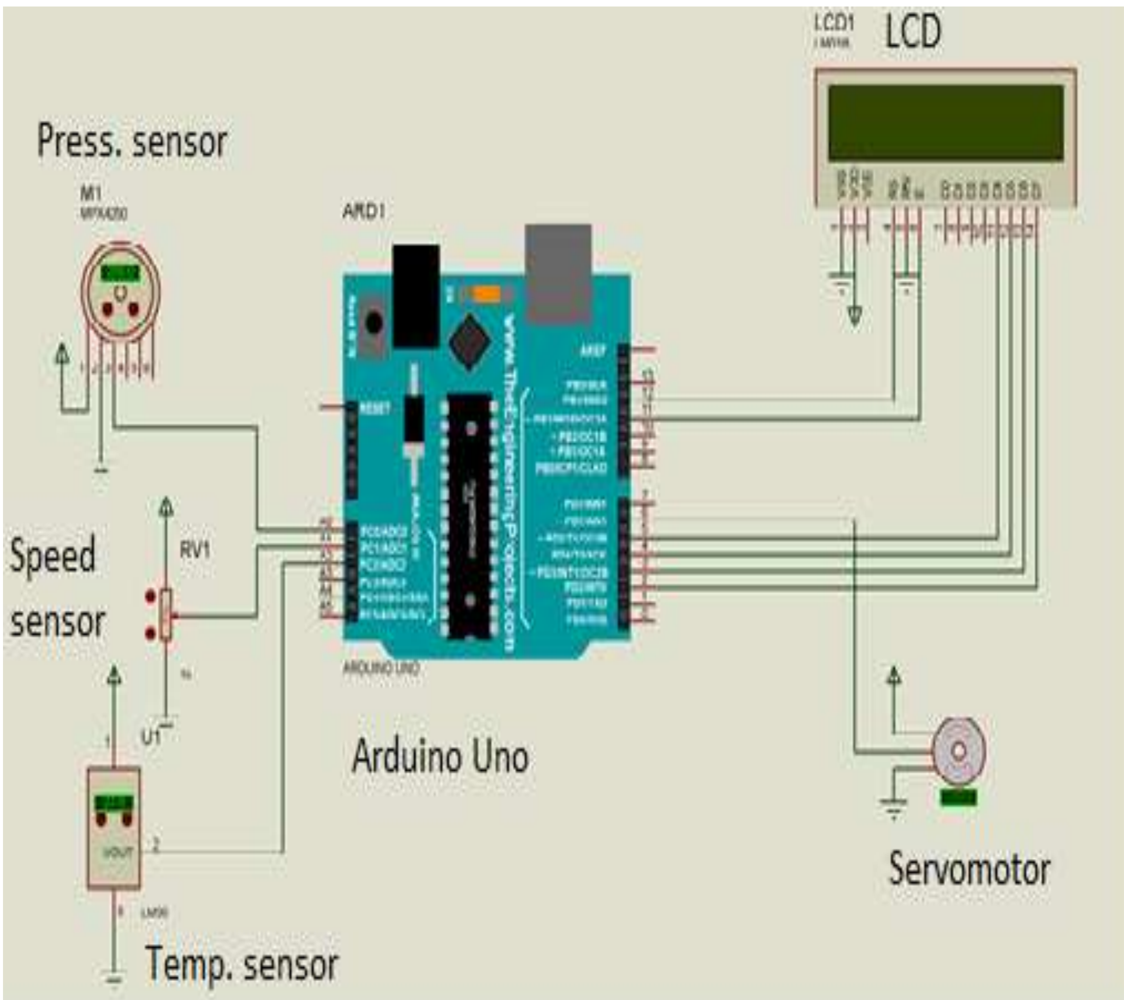

Figure 4.1: System circuit diagram using Protues software

The maximum parameters using in this simulation are: when westgate opening (servomotor) with full angle is 180 degree, maximum engine speed is 750rpm, maximum temperature is 150^{o}C, and maximum pressure is 114.30Pa.

4.2 Simulation Results

In this section, simulation results are presented to evaluate the effectiveness of the proposed control system under different operation conditions.

4.2.1 Case one

Figure 4.2 shows the effect of parameters on servomotor, when engine speed is zero rpm, pressure is medium 57.15Pa and temperature is maximum 150^{o}C, this operation conditions are effect on servomotor angle to open with 36 degree.

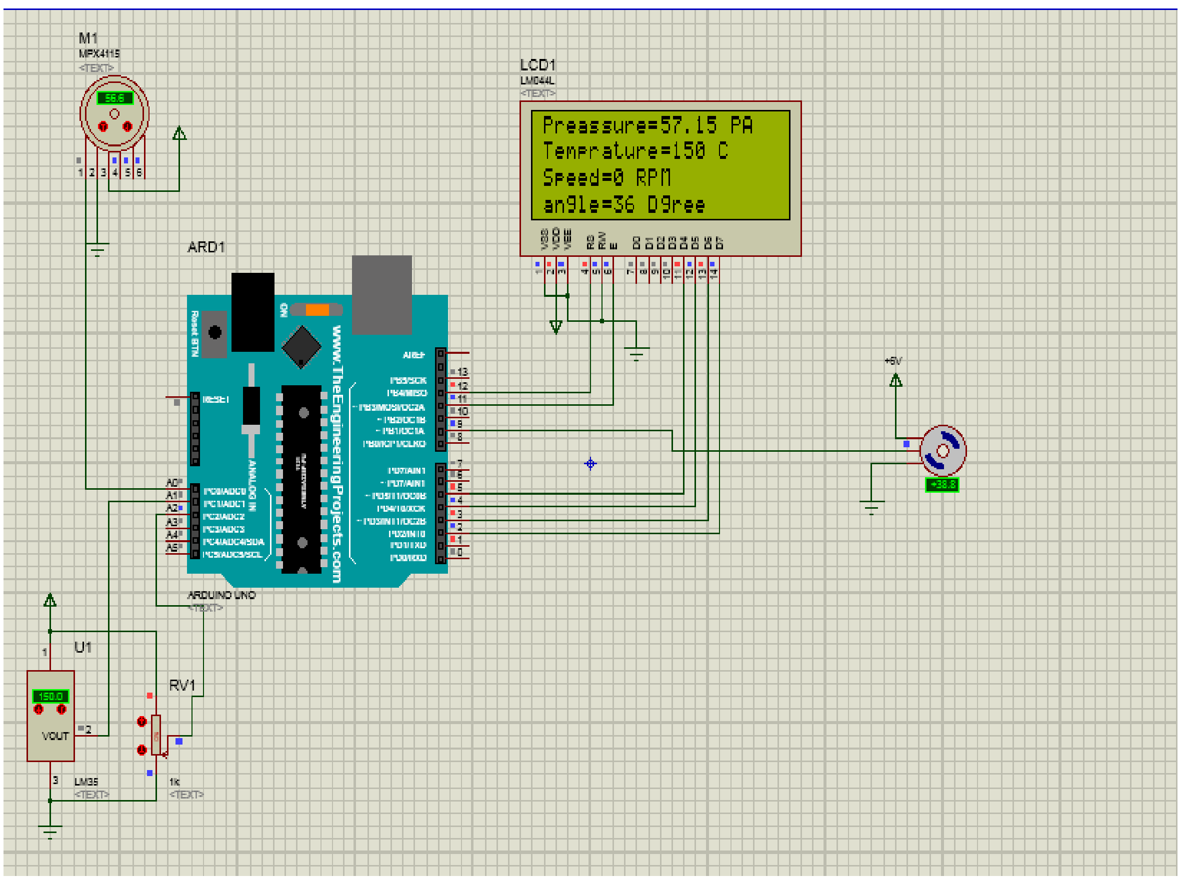

Figure 4.2: System response when zero speed, medium pressure and maximum temperature

4.2.2 Case tow

Figure 4.3 shows the effect of parameters on servomotor, when engine speed is maximum 750rpm, pressure is 57.15Pa and temperature is medium 75°C. This operation conditions are effect on servomotor angle to open with 156 degree.

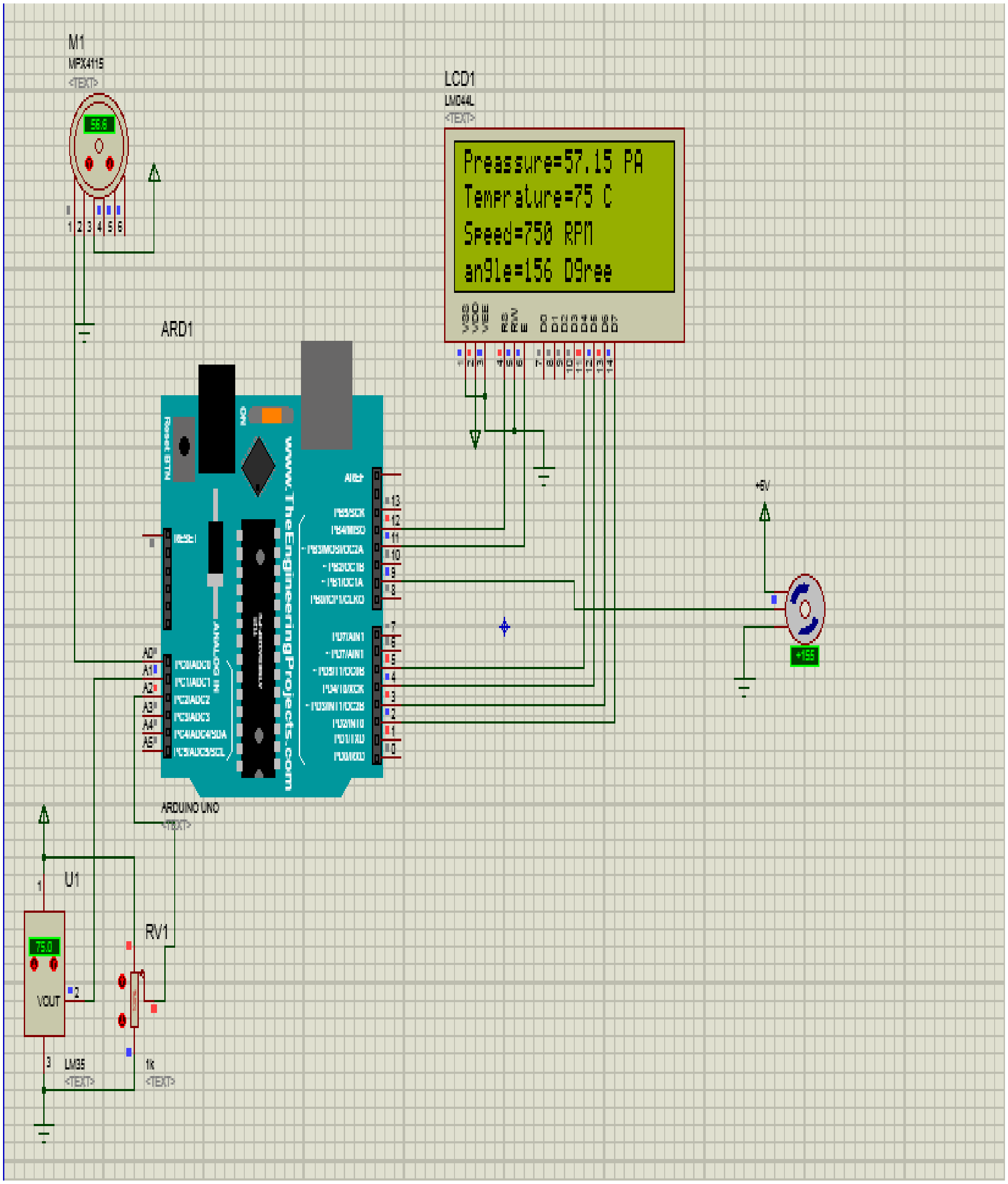

Figure 4.3: System response when maximum speed, medium pressure and temperature

4.2.3 Case three

Figure 4.4 shows the effect of parameters on servomotor, when engine speed 375rpm and pressure are medium 57.15Pa and temperature is maximum 150°C. This operation conditions are effect on servomotor angle to open with 103 degree.

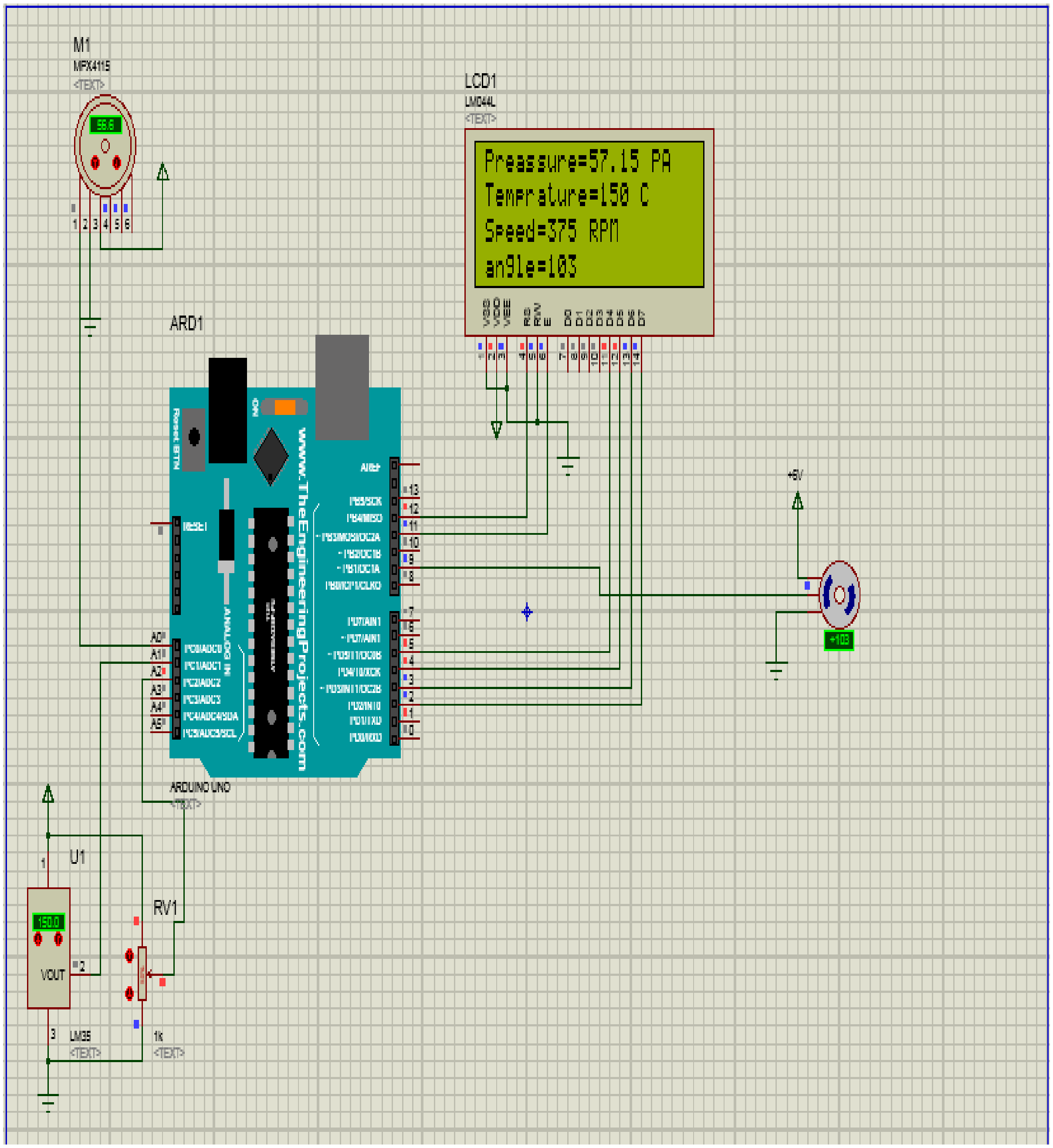

Figure 4.4: System response when medium speed, pressure and maximum temperature

4.2.4 Case four

Figure 4.5 shows the effect of parameters on servomotor, when engine speed is 375rpm, pressure 57.15Pa and temperature 75°C all are medium. This operation conditions are effects on servomotor angle to open with 90 degree.

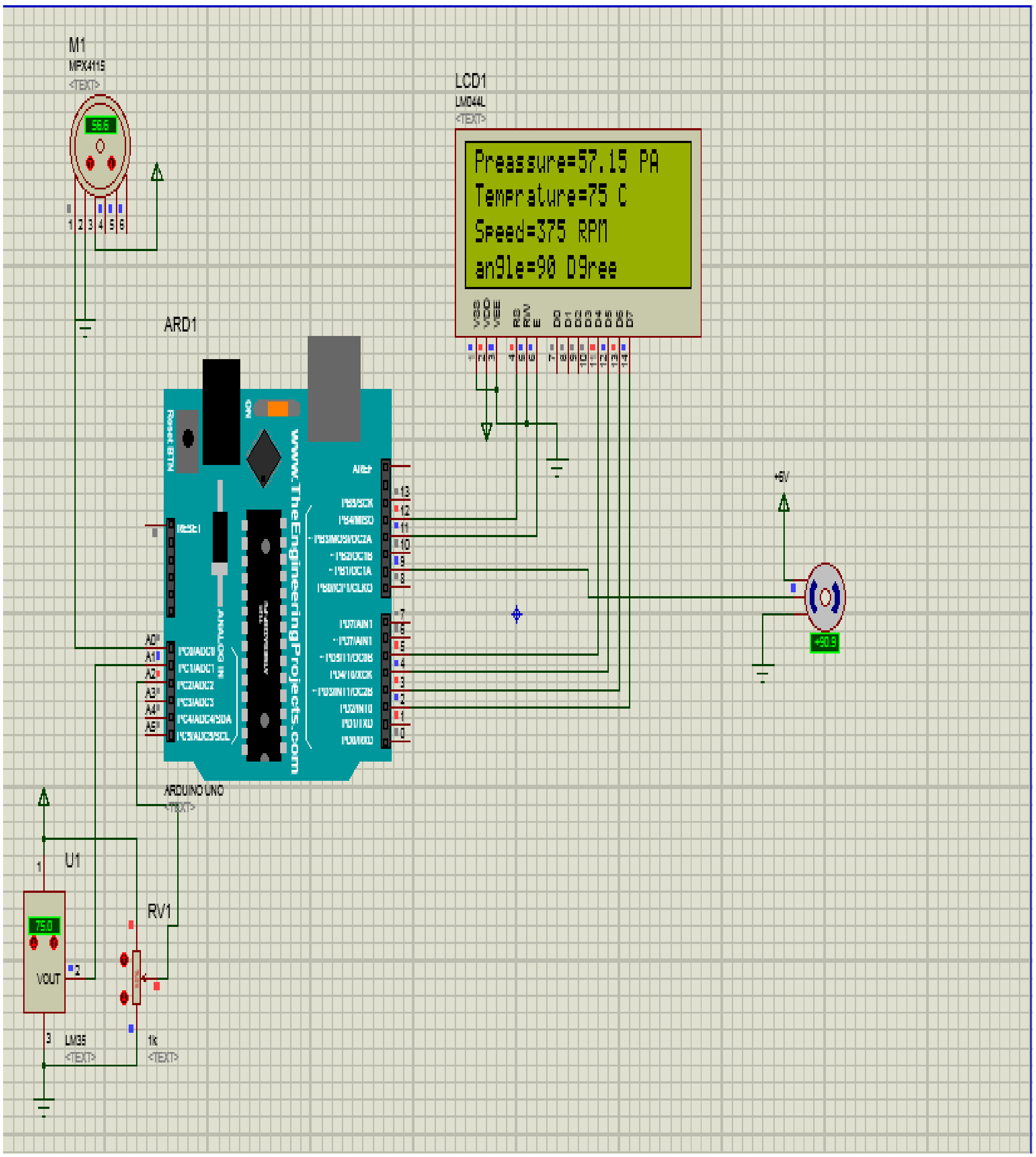

Figure 4.5: System response when medium speed, pressure and temperature

4.2.5 Case five

Figure 4.6 shows the effect of parameters on servomotor, when engine speed 375rpm, temperature 75^{o}C are medium and pressure is 114.3Pa is maximum. This operation conditions are effect on servomotor angle to open with 100 degree.

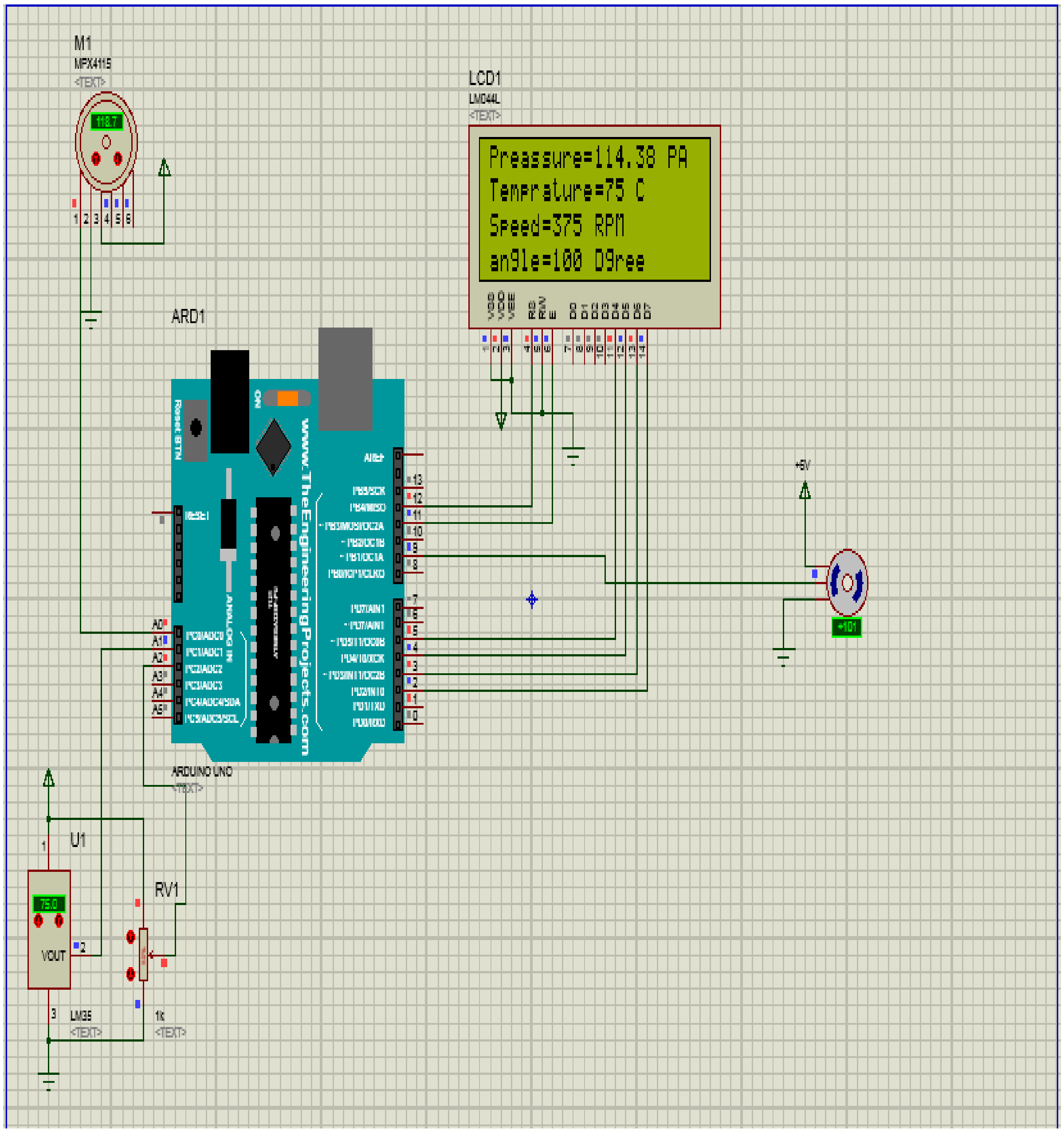

Figure 4.6: System response when medium speed, temperature and maximum pressure

4.2.6 Case six

Figure 4.7 shows the effect of parameters on servomotor, when engine speed is medium 375rpm, pressure 114.3Pa, and temperature 150^{o}C are maximum. This operation conditions are effect on servomotor angle to open with 113 degree.

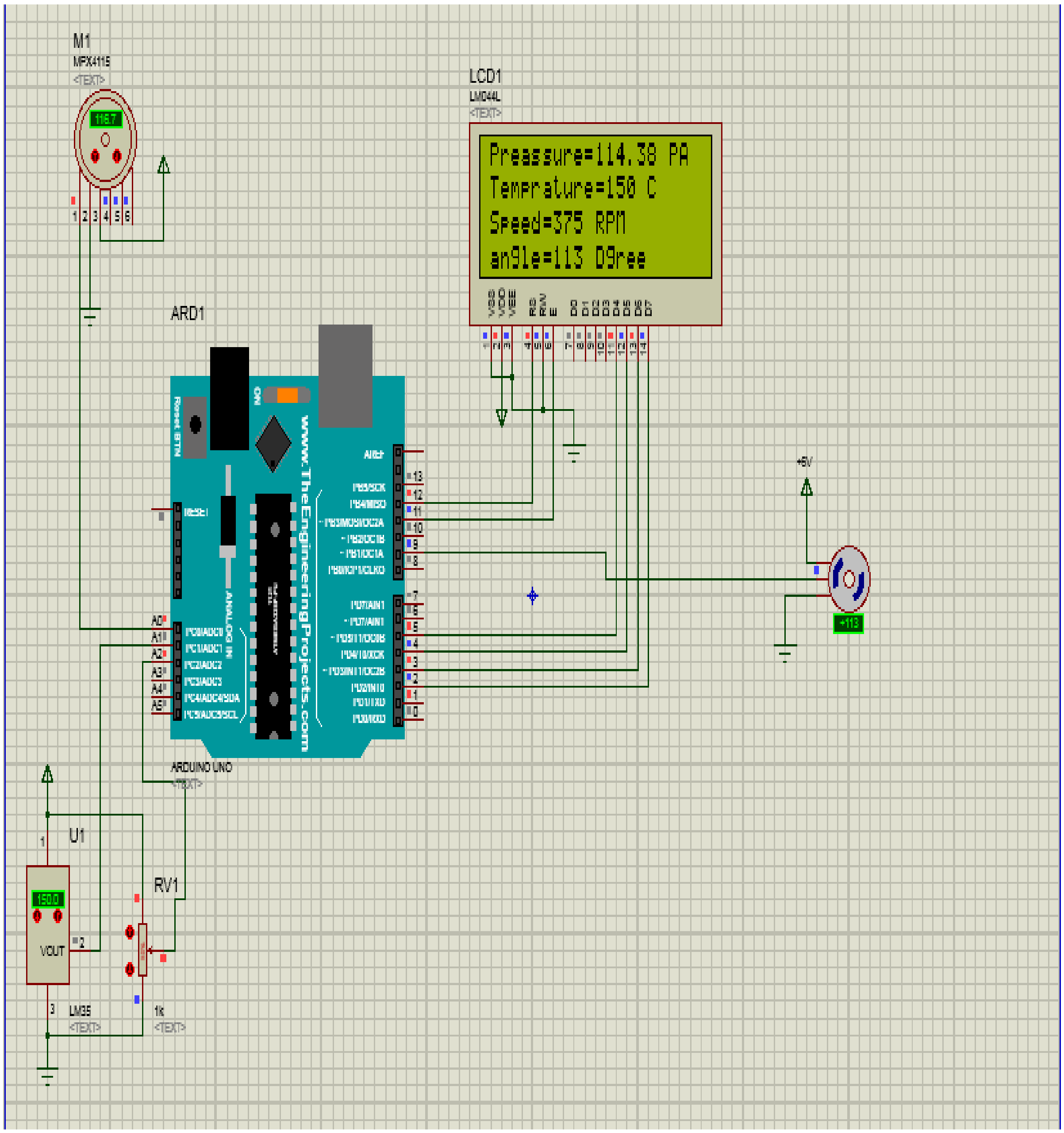

Figure 4.7: System response when medium speed, maximum pressure and temperature

4.2.7 Case seven

Figure 4.8 shows the effect of parameters on servomotor, when all parameters are maximum, engine speed is 750rpm, pressure is 114.3Pa and temperature is 150^{o}C. This operation conditions are effect on servomotor angle to open with 180 degree.

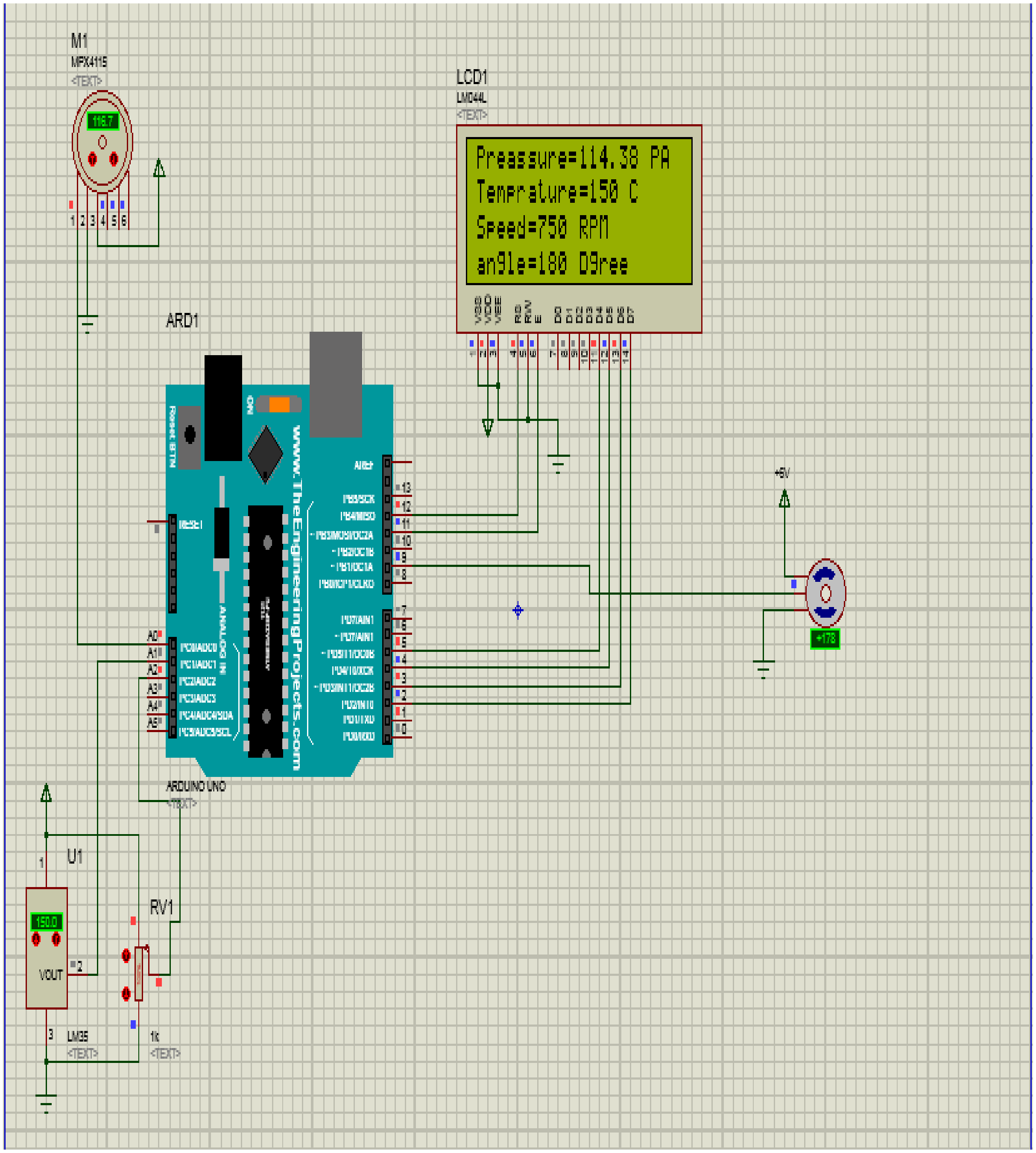

Figure 4.8: System response when maximum speed, pressure and temperature

4.3 Discussions

From simulations results we found that when temperature is increased servomotor angle is also increased more than effect of speed and pressure on servomotor angle. That means temperature is more effective to servomotor angle than other parameters.

Chapter Five

Conclusion and Recommendations

5.1 Conclusion

The aim of this research was to design and fabricated a westgate controller for Allen Diesel Engine. From the results in previous section and discussions following conclusion can be drawn. The westgate controller shown as servo motor connected with Arduino Uno board to connect between parameters and servomotor.

The readings of parameters can effect on the angle of servomotor and shown in LCD. By using simulation found the angle of servomotor is changed when one or all parameters are changed.

5.2 Recommendations

This thesis still has many improvements that can be done to improve it accuracy and reliability. There are some suggestions for the future research and development.

- Researcher in futures can apply this simulation in practice.
- Adding humidity to the parameters.
- Replacing mechanical fuel injectors by electronic fuel injectors.

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Appendix

Arduino Code

```
#include <LiquidCrystal.h>
LiquidCrystallcd(12, 11, 5, 4, 3, 2);
floatpa,r;
int T;
intsp;
#include <Servo.h>
int sum;
Servo myservo;
void setup() {
  // put your setup code here, to run once:
Serial.begin(9600);
lcd.begin(20, 4);
myservo.attach(9);
myservo.write(50);
void loop() {
  // put your main code here, to run repeatedly:
lcd.clear();
pa=(analogRead(A0)/9.4002)+0.095/0.009;
r=analogRead(A1);
T=r*500/1023;
sp=analogRead(A2);
sp=map(sp,0,1023,0,750);
sp=constrain(sp,0,750);
sum=sp+T+pa;
```

```
sum=map(sum,0,1014,0,180);
sum=constrain(sum,0,180);
Serial.print("angle=");Serial.println(sum);
myservo.write(sum);
lcd.setCursor(0, 0);
lcd.print("Preassure="); lcd.print(pa); lcd.print(" PA");
lcd.setCursor(0, 1);
lcd.print("Temprature="); lcd.print(T);lcd.print(" C");
lcd.setCursor(0, 2);
lcd.print("Speed="); lcd.print(sp);lcd.print(" RPM");
lcd.setCursor(0, 3);
lcd.print("angle="); lcd.print(sum);lcd.print(" Dgree");
delay(20);
#include <LiquidCrystal.h>
LiquidCrystallcd(12, 11, 5, 4, 3, 2);
floatpa,r;
int T;
intsp;
#include <Servo.h>
int sum;
Servo myservo;
void setup() {
  // put your setup code here, to run once:
Serial.begin(9600);
lcd.begin(20, 4);
myservo.attach(9);
myservo.write(50);
void loop() {
```

```
  // put your main code here, to run repeatedly:
lcd.clear();
pa=(analogRead(A0)/9.4002)+0.095/0.009;
r=analogRead(A1);
T=r*500/1023;
sp=analogRead(A2);
sp=map(sp,0,1023,0,750);
sp=constrain(sp,0,750);
sum=sp+T+pa;
sum=map(sum,0,1014,0,180);
sum=constrain(sum,0,180);
Serial.print("angle=");Serial.println(sum);
myservo.write(sum);
lcd.setCursor(0, 0);
lcd.print("Preassure="); lcd.print(pa); lcd.print(" PA");
lcd.setCursor(0, 1);
lcd.print("Temprature="); lcd.print(T);lcd.print(" C");
lcd.setCursor(0, 2);
lcd.print("Speed="); lcd.print(sp);lcd.print(" RPM");
lcd.setCursor(0, 3);
lcd.print("angle="); lcd.print(sum);lcd.print(" Dgree");
delay(20);
```