American Journal of Engineering Research (AJER) 2017
American Journal of Engineering Research (AJER)
e-ISSN: 2320-0847 p-ISSN : 2320-0936
Volume-6, Issue-7, pp-191-206
www.ajer.org
Research Paper Open Access

Computer Aided Modelling and Design of Automatic Control System for Industrial Based Electro-Hydraulic Actuator in Mash Filter Machines

Obieribie Vincent Oluchukwu, Engr. Dr C.C. OHIA and
Engr. Dr S.A. Akaneme
Department of Electrical/Electronic Engineering
Chukwuemeka Odumegwu Ojukwu University, Uli,
Anambra State Nigeria.
Vin_link@yahoo.com

ABSTRACT: *This research work effectively characterizes the design and modelling of an optimized embedded based electro-hydraulic control system for a mash filter machine that would be adopted for industrial automation in a brewery by adopting Simulation Based Virtual Prototyping Methodology (SBVPM). The control based electro-hydraulic actuator is also characterized. The actuator is used for controlling the movements in mash filter machines in a brewery. This research also evaluates the time response of the electro-hydraulic actuator in a modelling environment before its actual deployment in the brewery so as to help the design engineer in optimizing the performance of the system. Mathematical modelling of the hydraulic actuator and its components is done and based on the mathematical equations, MATLAB/Simulink models of the actuator and its components were made. The time response of the actuator is obtained by using MATLAB/Simulink Software and a unified virtual simulation model is effectively characterized in PROTEUS ISIS 8.0. The time response graphs which are obtained in this simulation are used for performance evaluation with an existing system.*

Keywords: *Electro-Hydraulic Actuator, Mash Filter, Brewery*

Date of Submission: 15 -05-2017 Date of acceptance: 20-07-2017

I. INTRODUCTION

Automatic control, particularly the application of feedback, has been fundamental to the development of automation. Its origins lies in the level control, water clocks, and pneumatics/hydraulics of the ancient world. Automatic control entails the application of control theory for regulation of processes without direct human intervention. In the simplest type of an automatic control loop, a controller (a device using mechanical, hydraulic, pneumatic or electronic techniques often in combination, but more recently in the form of a microprocessor or computer, which monitors and physically alters the operating conditions of a given dynamical system) compares a measured value of a process with a desired set value and processes the resulting error signal to change some input to the process in such a way that the process stays at its set point despite disturbances(Salgado et al, 2001).

An Automatic Control System (ACS) is a pre-set closed-loop control system that requires no operator action. This assumes the process remains in the normal range for the control system. An automatic control system has two process variables (a process variable is the current status of process under control) associated with it; a controlled variable and a manipulated variable. A controlled variable is the process variable that is maintained at a specified value or within a specified range. A manipulated variable is the process variable that is acted on by the control system to maintain the controlled variable at the specified value or within the specified range.

Functions of Automatic Control in any automatic control system, the four basic functions that occur are; Measurement, Comparison, Computation and Correction. There are three functional elements needed to perform the functions of an automatic control system; a measurement element, an error detection element and a final control element (Salgado et al, 2001). An automatic control system (ACS) sustains or improves the functioning of a controlled object. In a number of cases the auxiliary operations for the ACS is basically;

starting, stopping, monitoring, adjusting etc. and they can be automated. In summary it can be said that automation is the use of control systems for operating different equipment such as processes in factories, aircraft, machinery, etc. by reducing human intervention. Many different devices are used as control systems depending on the equipment to be controlled (e.g. digital or analogue devices) and the needs of control (e.g. speed, Proportional Integral Derivative PID regulation). Some of the most common devices are: FPGAs (Field-Programmable Gate Array), industrial PCs (Personal Computers) and PLCs (Programmable Logic controllers). PLC is the most popular control device for industrial processes such as control of heavy equipment, cooling / ventilation, chemical processes etc. PLCs are appropriate devices for processes with both digital and analogue instrumentation (e.g. digital and analogue valves, temperature sensors, digital pumps, etc.) and with strong requirements in reliability under harsh environment.

Hydraulic is one of the drive systems used in the control of machinery and equipment just like pneumatics or electricity. In recent technologies, hydraulics is been used in production machinery and their drive systems due to its environmental friendly nature. Hydraulic machines are machinery and tools that use liquid/ fluid power to do simple work; here hydraulic fluid is transmitted throughout the machine to various hydraulic motors and hydraulic cylinders and becomes pressurised according to the resistance present (Hunter et al, 1991). Hydraulic machinery is operated by the use of hydraulics, where a liquid is the powering medium. It is based on a simple principle of transferring mechanical energy from one point to other with the help of incompressible fluids as the medium as shown in fig. 1 below. The fluid is controlled directly or automatically by control valves and distributed through hoses and tubes. The popularity of hydraulic machinery is due to the very large amount of power that can be transferred through small tubes and flexible hoses, and the high power density and wide array of actuators that can make use of this power. One of the fundamental features of hydraulic systems is the ability to apply force or torque multiplication in an easy way, independent of the distance between the input and output, without the need for mechanical gears or levers

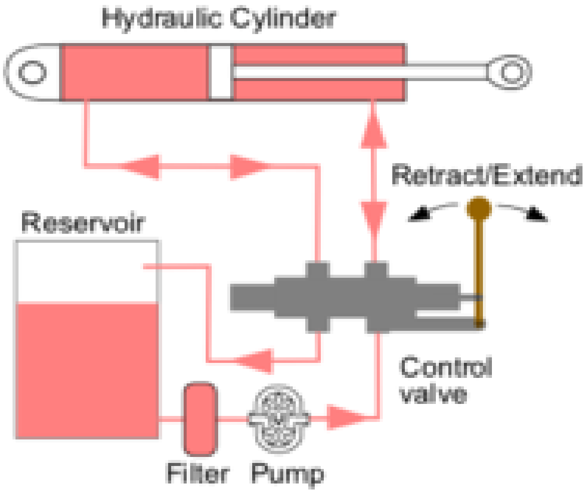


Fig 1: simple hydraulic circuit (Hunter et al, 1991).

For the hydraulic fluid to do work, it must flow to the actuator and/or motors, then return to a reservoir. The fluid is then filtered and re-pumped. The path taken by hydraulic fluid is called a hydraulic circuit of which there are several types. Open centre circuits use pumps which supply a continuous flow. The flow is returned to tank through the control valve's open centre; that is, when the control valve is centred, it provides an open return path to tank and the fluid is not pumped to a high pressure. Otherwise, if the control valve is actuated it routes fluid to and from an actuator and tank. The fluid's pressure will rise to meet any resistance, since the pump has a constant output. If the pressure rises too high, fluid returns to tank through a pressure relief valve. Multiple control valves may be stacked in series (Hunter et al, 1991). This type of circuit can use inexpensive, constant displacement pumps. Closed centre circuits supply full pressure to the control valves, whether any valves are actuated or not. The pumps vary their flow rate, pumping very little hydraulic fluid until the operator actuates a valve. The valve's spool therefore doesn't need an open centre return path to tank. Multiple valves can be connected in a parallel arrangement and system pressure is equal for all valves.

Computer-aided design (CAD) is the use of computer systems to aid in the creation, modification, analysis, or optimization of a design (*Narayan and Lalit, 2008*). CAD software is used to increase the productivity of the designer, improve the quality of design, improve communications through elaborate documentation, and to create a comprehensive database for manufacturing. CAD output is often in the form of electronic files for print, machining, or other manufacturing operations (Duggal and Vijay, 2000). CAD is used in many fields. Its use in designing electronic systems is known as Electronic Design Automation (EDA). In mechanical design it is known as mechanical design automation (MDA) which includes the process of creating a technical drawing with the use of computer software. CAD software for mechanical design uses either vector-based graphics to depict the objects of traditional drafting, or may also produce raster graphics showing the overall appearance of designed objects. However, it involves more than just shapes. As in the manual drafting of technical and engineering drawings, the output of CAD must convey information, such as materials, processes, dimensions, and tolerances, according to application-specific conventions. CAD may be used to design curves and figures in two-dimensional (2D) space; or curves, surfaces, and solids in three-dimensional (3D) space (Farin et al, 2002). CAD is an important industrial art extensively used in many applications including; automotive, shipbuilding, aerospace industries, industrial and architectural design, prosthetics, and many more. The modern ubiquity and power of computers means that even perfume bos and shampoo dispensers are designed using techniques unheard of by engineers of the 1960s. Because of its enormous economic importance, CAD has been a major driving force for research in computational geometry, computer graphics (both hardware and software), and discrete differential geometry (Pottman et al, 2007).

This research used a computer based approach viz CAD to design and model an optimized electro-hydraulic automatic control system

II. LITERATURE REVIEW

The mathematical model for the hydraulic System is made with the help of system characteristics and its behaviour. With the help of these mathematical models various hydraulic systems can be analysed by using software like MATLAB SIMULINK, SIMULATIONX etc. (Ing et al, 1975) Response time is the time gap between input and output commands. The description of the importance of dynamic analysis for calculating system response and importance of it for hydraulic systems. Were describes. A simple case study of servo control valve is taken and its response time is calculated.

(Pramodh and Joshi, 2002) studied the effect of non-linearities in the configuration design of Digital Auto Pilot (DAP) in launch vehicles. An electro hydraulic actuator model of a launch vehicle control system is considered for analysis of non-linearities. Various non-linear effects like saturation (in current and stroke limit), dead zone and coulomb friction are taken into account. DAP, which is an interface between the guidance system and control system, is designed to cater to the model (linear/ non-linear) adopted for the actuator. In the actuator alone case, without considering the total flight regime and vehicle model, the performance is found to be satisfactory for linear as well as non-linear actuator models. In the actuator–vehicle combination, when the simulation is carried out for the total flight regime considering the vehicle model, the performance of the linear / nonlinear actuator model is dependent on DAP configuration this study brings out the fact that the DAP configuration is specific to the actuator model, so that satisfactory performance of launch vehicle control system can be ensured only by choosing proper configuration for DAP, based on consideration of non-linearities in actuator model.

(Ashok Joshi, 2003) in his papers presented the effects of servo valve nonlinearity, actuation compliance and friction related nonlinearity on the dynamics of a flight control surface, during its deployment through an electro-hydraulic actuation system. Starting from the pilot command, a realistic model of the electro-hydraulic actuation system is evolved, which includes the command lags, servo valve nonlinearity, actuation chain compliance and friction nonlinearity. A realistic mathematical model for the control surface motion, under the action of the actuator forces and the aerodynamic and inertia forces is postulated, using subsonic incompressible aerodynamics.

(Papadopoulos, 2004) presented an optimal hydraulic component selection for electro hydraulic systems used in high performance servo tasks. Dynamic models of low complexity are proposed that describe the salient dynamics of basic electro hydraulic equipment. Rigid body equations of motion, the hydraulic dynamics and typical trajectory inputs are used in conjunction with optimization techniques, to yield an optimal hydraulic servo system design with respect to a number of criteria such as cost, weight or power. The optimization procedure employs component databases with real industrial data, resulting in realizable designs.

(Edson Roberto, 2004) studied the problem of experimental control of hydraulic actuators is considered. To deal with mechanical and hydraulic uncertainties a different controller is synthesized: a back stepping controller. Experimental results of both implementations are analysed in the context of practical difficulties, mainly the measurement of acceleration. These results illustrate the main features of these controllers when applied on a hydraulic actuator.

(Panagiotis, 2004) in his technical paper presented a model-based controller applied to a fully detailed model of an electro hydraulic servo system aiming at improving its position and force tracking performance. Fluid, servo valve, cylinder and load dynamics are taken into account. Simulation results show the strategy to be promising in controlling hydraulic servo actuators. It also compares its position tracking performance to that of a classical linear controller, using intensive simulations.

(Berndt, 2005) presented an interactive design and simulation platform for flight vehicle systems development. Its "connect-and-play" capability and adaptability enable "on-line" interaction between design and simulation during the integrated development. As a case study, the implementation of the proposed platform and an aircraft flight control system development example are demonstrated on an experimental test bed including a real time Systems simulator.

(Kexiangwei, 2006) developed a fluid power control unit using electro rheological fluids. Electro Rheological (ER) fluids can change their rheological properties when subjected to an electrical field. By using ER fluids as the working medium in fluid power systems, direct interface can be realized between electric signals and fluid power without the need for mechanical moving parts in fluid control unit. The pressure drop and flow rate can be directly controlled through the change of applied electric fields. This paper investigates the design and controllability of ER fluid power control system for large flows. The design criterion for an ER valve is proposed and four ER valves are manufactured based on this criterion. A fluid control unit consisting of an ER valves bridge circuit is constructed, the characteristics of which are theoretically and experimentally investigated. The results show that the ER fluid control units have better controllability for fluid power control.

(Anderson, 2008) in his paper presented a nonlinear dynamic model for an unconventional, commercially available electro hydraulic flow control servo valve is presented. The two stage valve differs from the conventional servo valve design in that: it uses a pressure control pilot stage; the boost stage uses two spools, instead of a single spool, to meter flow into and out of the valve separately; and it does not require a feedback wire and ball. Consequently, the valve is significantly less expensive. The proposed model captures the nonlinear and dynamic effects. The model has been coded in MATLAB/Simulink and experimentally validated.

(Rowland et al, 2009) this paper describes about modular design approach for modelling of large and complex hydraulic systems. Using this creation and analysis of large hydraulic models can be avoided. It will reduce run time, editing and results can be manages easily. Each complex model is divided into small systems and each system was modelled using standard pressure and flow source models as boundary conditions. Later subsystem could be linked together the boundary condition models removed and the desired analyses completed. For accurate simulation of landing gear model interaction between hydraulic and mechanical systems is required. This allows better modelling of both gear deployment time and pressure time history in hydraulic system.

(Krus, 2012) this paper describes about use of computer simulation for optimization. Optimizing total number of parameters of all components in a system is too large to be handled by numerical computation. A new approach is adopted here by introducing performance parameters which uniquely define the components. In aircraft design it is very important that system is optimized with respect to different aspects such as performance and weight. Using an optimization strategy and a simulation model of the system, it is possible to use a computer to optimize the system globally once the system layout is established.

III. DESIGN

Simulation Based Virtual Prototyping Methodology (SBVPM)

This research presents a Simulation Based Virtual Prototyping Methodology for the design and verification of embedded systems deployed in the industrial process control and monitoring. The targeted applications are industrial device such as sensor, actuators and close-loop controllers used to interact with physical processes in the field level of industrial automation systems. This methodology provides multidisciplinary team members with enhanced modelling and simulation capabilities in order to identify and solve design problems during early development stages. It also provides supporting modelling guidelines and a problem-oriented verification approach which can be applied in different development stages. The Simulation Based Virtual prototype described in this work (in this context for monitoring and control of industrial processes) provide a pragmatic solution for emulating the behaviour of hardware prototypes and experimental setups. The underlying simulation models used can be described in varying granularities according to the development stage, and using different modelling formalisms and simulation tools. This research, demonstrates that virtual prototypes can help increase the confidence in the correctness of a design thanks to a deeper understanding of the complex interactions between hardware systems/ signal processing components and software applications in an embedded setup and the physical processes they interact with.

Generally, the performance characteristics of various sections of the model intended for a simulation study can be developed using different simulation platforms such as Proteus ISIS 8.0, and SIMULINK in this context. The goal of this research approach is to enable the use of overall system simulation approaches throughout the development process of a system for industrial devices and to provide a supporting methodology for it. This work is intended to provide multidisciplinary design team members with enhanced verification capabilities to identify and solve design problems during early development stages. This is possible by coupling the execution of different simulators (listed above), each one responsible for obtaining the behaviour of part of a system. The combined execution of simulators can help increase the understanding of interdependencies between different system components. This eventually helps increase the confidence in the correctness of a design, thereby reducing risks in a project and leading to hardware prototypes and experimental setups that are built right the first time. Basically, the model can be reconfigured and experimented with through simulation in order to achieve its best performance objectives. Besides, if the operation of the model can be clearly studied, hence, the properties concerning the behaviour of the actual system or its subsystem can be inferred. Based on the above stated advantages of modelling and simulation as well as the formal model characterization approaches, this research adopts these on a general note as our approach for the brewery operation optimization. There are some basic concepts taken into consideration while implementing the **SBVPM** approach.

a) Virtual Prototypes

Virtual prototypes are system level simulation models that emulate (mimic) the behaviour of hardware prototypes. A useful definition provided by Synopsys is the following: “Virtual prototypes are fast, fully functional software models of systems under development executing unmodified production code and providing a higher debugging/analysis efficiency.” (www.synopsis.com/system/virtual)

Virtual prototypes are composed of system level models of processing elements and peripherals, such as memories, buses, interrupt controllers, etc. In particular, processing elements are models of software programmable components, such as traditional microcontrollers and DSPs, and hardware programmable components, such as customized Field Programmable Graphic Array (FPGA) processing elements. Communication and computation components are taken into account; altogether culminating in a full simulation of a complete proposed embedded system for industrial process monitoring and control on a host computer. Virtual platforms can be used in most stages of a design. For instance, in early design stages, virtual platforms are used as executable specification models that capture both hardware and software requirements in a high abstraction. Due to their high abstraction, they can be made available in very little time and can serve as golden reference models for further development and refinement stages. They are especially useful in the following cases: software-driven verification and software development. Software-driven verification is equivalent to software-in-the-loop testing, where production code can be verified inside a virtual platform along with a simulated environment. This facilitates the verification process without the need of real hardware prototypes and experimental setups. Virtual platforms are also very useful for software development. Initial software applications and drivers can be developed and tested using virtual platforms. This allows the identification of software bugs and communication bottlenecks, which might be too complicated to find in real prototypes. Aside from the previously stated verification benefits, virtual prototypes enable many other testing capabilities such as software performance optimization, software centric power analysis and fault injection.

b) Processor models

Processor models are system level descriptions of processing elements, such as Digital Signal Processors (DSPs) and microcontrollers, used in embedded systems. They are responsible for the simulation of binary code compiled for particular processor architectures and for their communication with other components inside a virtual platform. As any other system level model, processor models are composed of structural and behavioural descriptions. Structural descriptions contain architectural details of a processor such as functional units, pipelines, caches, registers, counters, input/ output (I/Os), etc. Behavioural descriptions correspond to a software application that is loaded into the system model. There are two approaches to structural and behavioural descriptions; analytical and simulation approaches. Analytical approaches obtain timing information of a processor model by performing a formal analysis of pessimistic corner cases on the system level model (Schnerr et al, 2009). Such information is vital in systems with hard real-time constraints, e.g. an Automatic Breaking System (ABS) application in the automotive domain. The second approach to the timing estimation is via simulation. Simulation cannot ensure the complete coverage of corner cases, but it is adequate for verifying the functionality of a virtual prototype and for obtaining approximate timing information from it, something which is not possible by analytical approaches. For this research, emphasis is laid on simulation based approach. The behaviour and timing information of a processor model is dictated by an Instruction Set Simulator (ISS). In this research work, the ISS is used to perform binary translation of a software application complied for a specific microprocessor or DSP instruction set and to execute it in a host computer. Instructions set simulators are classified into two main categories according to how the binary translation process is done: interpreters and binary code translators. Proteus Isis 8.0 effectively characterizes this framework and as such would be used in this research work for the emulation for the industrial process control of the hydraulic actuator of a mash filter machine in a brewery.

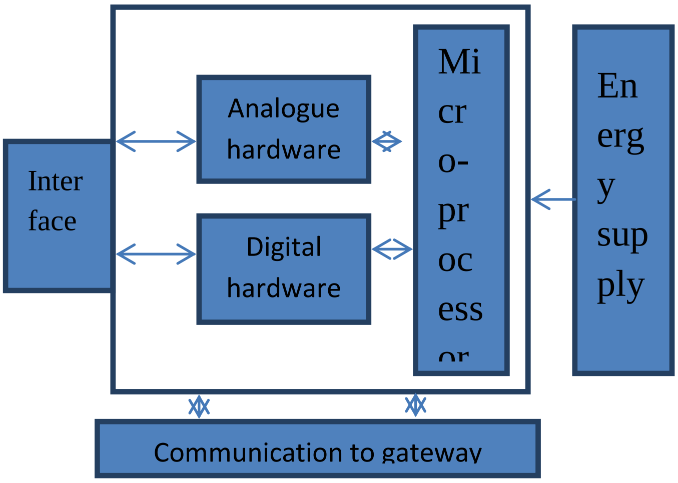


Fig 2 Structure of embedded control for automation of mash filter

3.3 Embedded Systems for devices used in Industrial Process Control of Mash Filter

Fig 3 effectively summarizes the structure for the embedded system base control for automation of the mash filter machine. Each level of an industrial automation system relies on different underlying technologies. They are selected according to requirements such as processing power, memory, communication data rates and real-time behaviour. For instance, in the station level, tasks are highly data oriented. Large amounts of information, generated by the control and field levels, need to be stored, transferred and monitored. The underlying technologies are typically general purpose, such as PCs, data servers and high bandwidth networks. In the case of the control level, multiple industrial processes, sometimes strictly dependent on each other, need to be carefully orchestrated and synchronized. This requires the execution of multiple control cycles with real-time processing and communication constraints. The underlying technologies are industrial computers relying on powerful processor architectures, as well as various types of industrial networks. Lastly, in the field level, highly specialized sensing, manipulation and local control tasks need to be performed. Real-time processing and communication constraints apply here as well. The underlying technologies are embedded systems with strict limitations regarding their processing and communication capabilities, memory and power consumption.

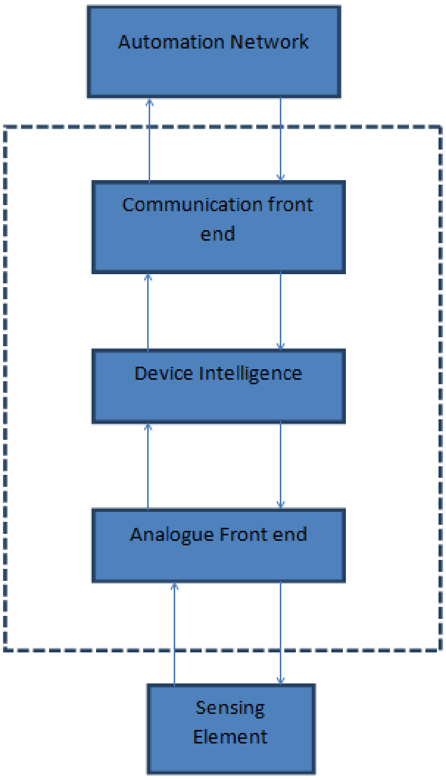


Figure 3 Basic structure and functionality of an industrial measurement device.

Fig 3 makes a functional description of the measurement / data acquisition section of the automated system. It relies on three main components for its operation: an analogue front-end, a device intelligence module and a communication front-end. The analogue front-end is responsible for interacting with transducers and other sensing/actuating elements. It performs function such as signal adaption, filtering and quantization. The device intelligence is responsible for the execution of measurement tasks and for performing data analysis on acquired data sets. It may also be responsible for the execution of communication stacks.

It should be noted that this research work goes beyond just trying to fully automate the hydraulic actuator of the mash filter machine, it also tries to integrate Proportional integral derivative tuning in controlling the servo –mechanism that controls the hydraulic actuator while shortening the time response for general optimization of the system

3.4 Design Approaches for Industrial Devices

Figure 4 illustrates the initial stages of the design of embedded systems for industrial process control and monitoring. A similar design flow is followed in most applications where embedded systems are used to interact with physical processes. It starts with the definition of the system specifications and ends with the creation of a hardware prototype and an experimental setup. Further steps in the design include integration and testing phases.

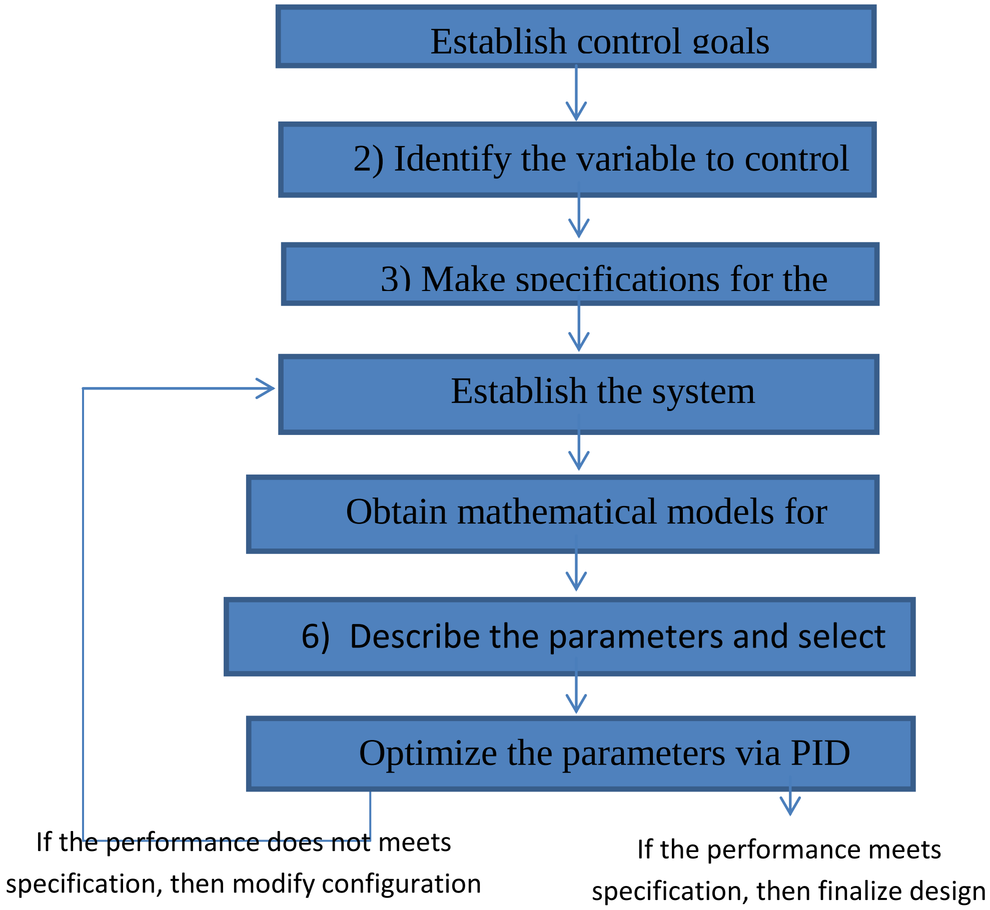


Figure 4: Design flow of embedded systems

System specifications are based on functional and non-functional requirements. Functional requirements describe the particular measurement or control principles that need to be implemented in an embedded system, as well as boundary conditions for its operation. Non-functional requirements include things like operation temperature range, safety considerations, robustness considerations, the desired power consumption, footprint and cost, etc. Algorithmic models are derived from functional system specifications. They are behavioural models described using formalisms such as mathematical equations or transfer functions. Within the algorithmic modelling stage, measurement and control algorithms, which will be later executed in an embedded system, are verified and validated together with plant models. Commercial modelling and simulation tools for dynamic systems such as MATLAB /Simulink are commonly used during this stage. Once enough knowledge of a systems' behaviour has been gathered during the algorithm modelling phase, a complete paradigm shift occurs.

3.5 Tools Used in Simulation Design

- SIMULINK
- Proteus 8.0 Isis

3.5.1 MATLAB SIMULINK

This research work makes use of MATLAB SIMULINK modelling tools for modelling some sections of the servo valve and the hydraulic actuators. It is also used for the characterization of the PID control process. It primarily interface is a block set diagramming tool with its customizable set of block libraries which offers tight integration with the rest of the MATLAB environment and can either drive MATLAB or be scripted from it.

3.5.2 Proteus 8.0 Isis

This is the primary simulator used in this project. It gives a platform whereby components at the gate level are logically connected together so as to achieve a real time virtual prototype. The logical components can be characterized to emulate various stages of the design. Proteus Isis is used to develop a virtual prototype model that can descriptively visualize the proposed system. This platform monitors the responses of the simulation model to evaluate if the model is behaving in the intended manner. It has tool boxes from which electronic, solid state or logical components can be brought together and logically connected to give us the desired results.

3.6 Mathematical Characterization of Hydraulic System

Mathematical formulations are developed for various components of the hydraulic system in this research. Mathematical formulation involves the representation of the hydraulic system components in the form of equations. These mathematical schemes help in representing the hydraulics system components in Simulink Software. This mathematical formulation is done by considering the component properties such as flow properties, functional properties, characteristics of the component (like electrical characteristics etc.).

3.7 Modelling of Servo Controller

The error amplifier continuously monitors the input reference signal (U_r) and compares it against the actuator position (U_p) measured by a displacement transducer to yield an error signal (U_e).

$$U_e = U_r – U_p \qquad (3.1)$$

The error is manipulated by the servo controller according to a pre-defined control law to generate a command signal (Uv) to drive the hydraulic flow control valve. Most conventional electro-hydraulic servo-systems use a PID form of control, occasionally enhanced with velocity feedback. The processing of the error signal in such a controller is a function of the proportional, integral, and derivative gain compensation settings according to the control law

$$U_v(t) = K_p U_e(t) + K_i \int Uedt + K_d (dUe /dt) \qquad (3.2)$$

Where K_p, K_i, and K_d are the PID constants, U_e is the error signal and Uv is the controller output. Eqn. 3.10 can further be simplified;

$$u(t) = K_p e(t) + K_i \int e(t) + K_d \frac{d}{dt} e(t) \qquad (3.3)$$

$$U(s) = (K_p + K_i \frac{1}{s} + K_d s)\, E(s) \qquad (3.4)$$

$$Gc(s) = \frac{U(s)}{E(s)} = K_p + K_i \frac{1}{s} + K_d s \qquad (3.5)SS$$

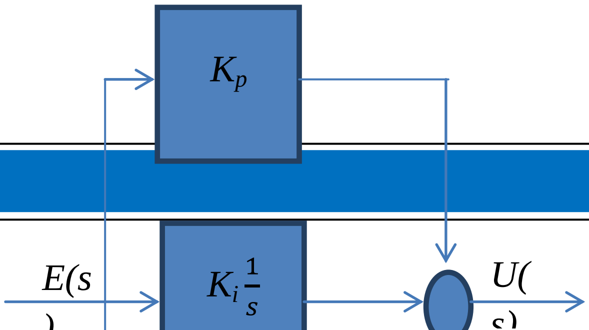


Fig 5 Block representation of PID

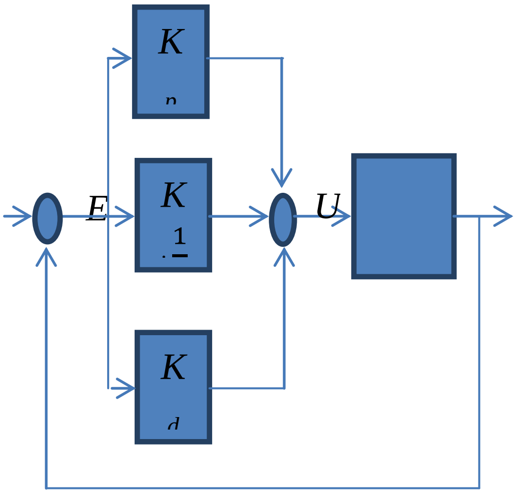


Fig 6 Block representation of PID integrated in a feedback control system

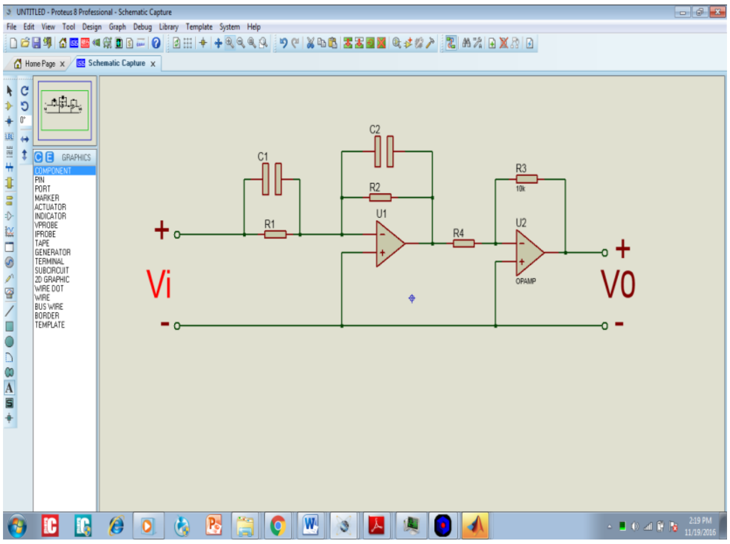


Fig 7 circuit diagram representation of PID

3.10 Control Loops

An important part of industrial automation is the feedback loops which are executed in real-time to give production processes desired behaviour. The control loops handle disturbances and ensure stable product quality. Figure below shows an overview of a simple feedback loop. The input to the controller is the control error, e(t), which is the difference between the desired (reference/set-point) process state, $y_{sp}(t)$, and the measured process state, y(t) is

$$e(t) = y_{sp}(t) - y(t) \qquad (3.6)$$

The output of the controller is the manipulated variable (control signal), u(t).

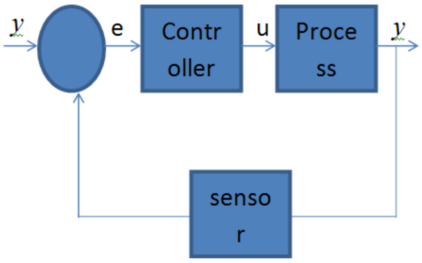


Figure 8: A feedback loop where a controller is used to control the process by considering the control error

The PID controller is by far the most commonly used controller in industry. A basic PID controller in continuous time is described by

$$u(t) = K\left(e(t) + \frac{1}{Ti}\int_0^1 e(\tau)d\tau - T_d\frac{dyf(t)}{dt}\right) \qquad (3.7)$$

where u(t) is the control signal, e(t) is the control error, y f (t) is the filtered process value, K is the controller gain, Ti is the integral time, and Td is the derivative time.

A PID implementation must consider many aspects to ensure good behaviour under all circumstances. In particular for the work described later, physical limits of signals need to be considered. If the physical limits for the control signal are not considered, there is integrator windup (Åström and Hägglund, 2006) when the control signal saturates. The integrator, and thus the desired control signal, continues to grow even though the real control signal is saturated and cannot be increased further. When the set-point is reached and the integral terms starts to decrease, it takes a long time before the desired control signal is in the allowed range again. This causes a large process value overshoot which is not desirable. The solution to integrator windup is known as anti-windup and involves adjusting the integral part according to the actually actuated control signal. This means that the control signal limitation is considered and that this knowledge is used to make sure the control signal does not grow outside the control signal range.

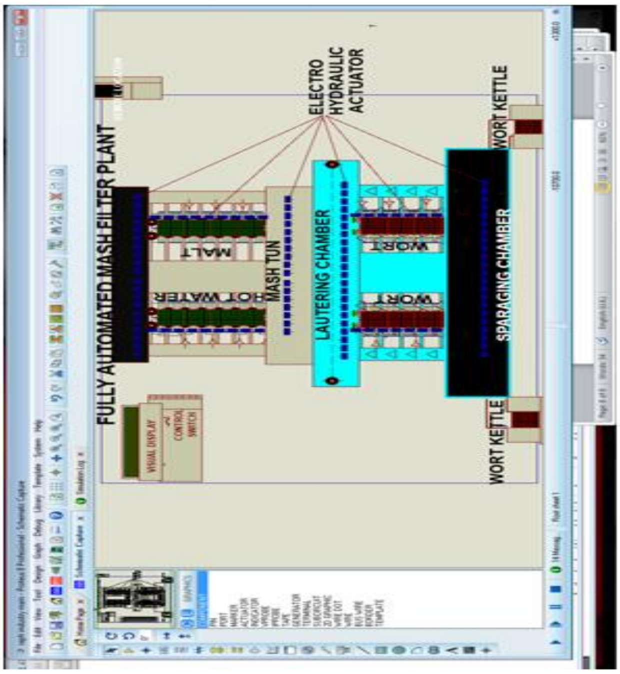


Figure 9 Snapshot capture of a section of the distribution section yet been initialized Proteus 7.8.

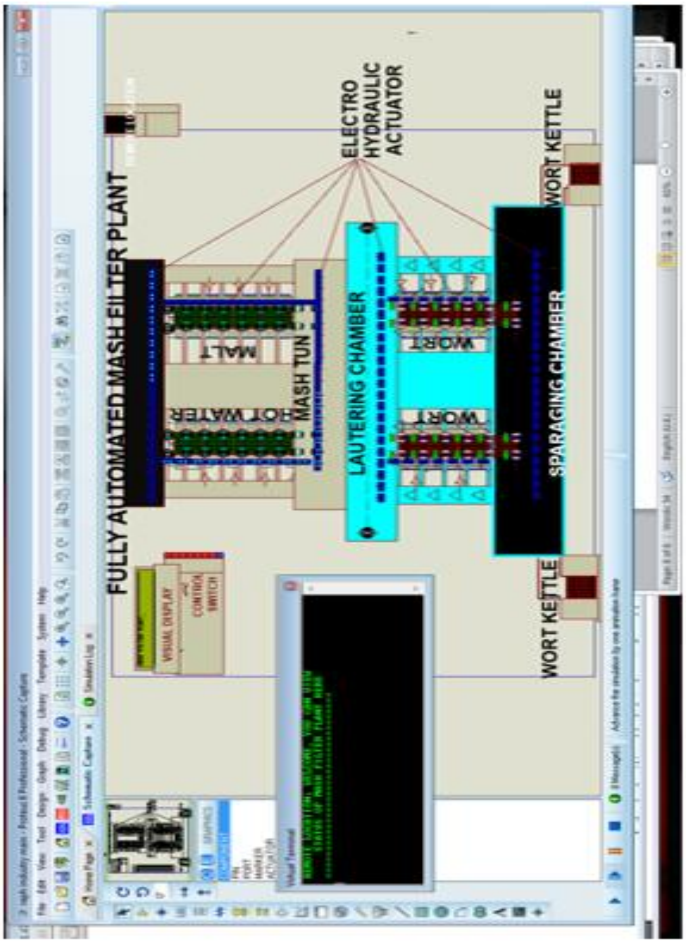


Figure 10 Snapshot capture of the system when it has just been initialized Proteus 7.8 with welcome messages

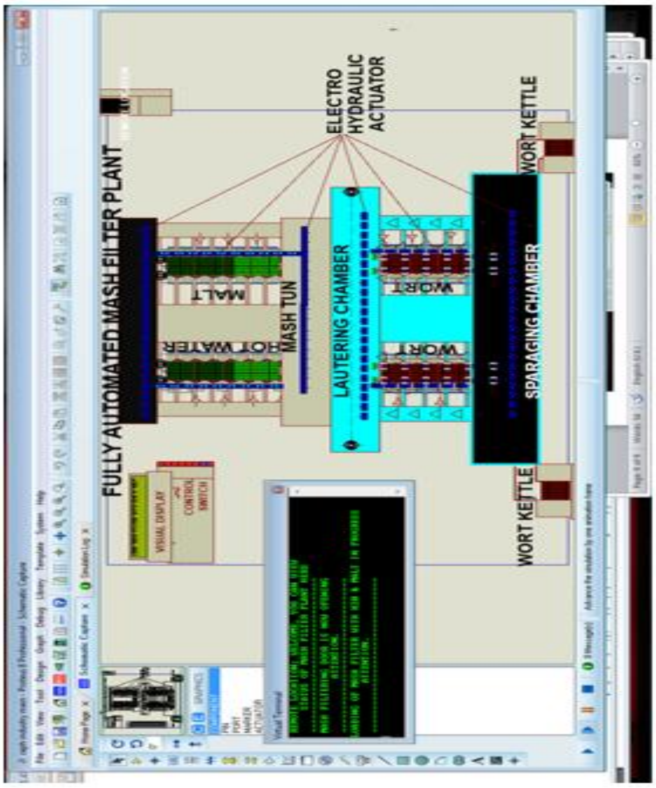


Figure 11 Snapshot capture of the system when malt and hot water are mixed in mash filter

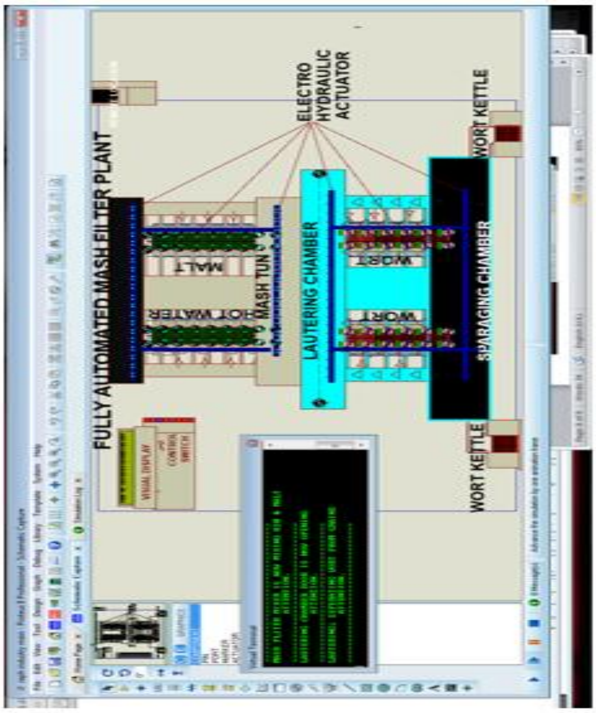


Figure 12 Snapshot capture of the system toward end of a mash filter cycle

Simulation Based Implementation of the in MATLAB

As discussed in the methodology of this research work, the mathematical equations for PID control and closed loop feedback control are used in the characterization of the processor for the central node in the industrial process control set up. The signal for the characterization of the waveform of interest is obtained by simulating the PID mathematical equations in MATLAB. So, the variation in disturbances can be controlled by controlling the parameters of the signals.

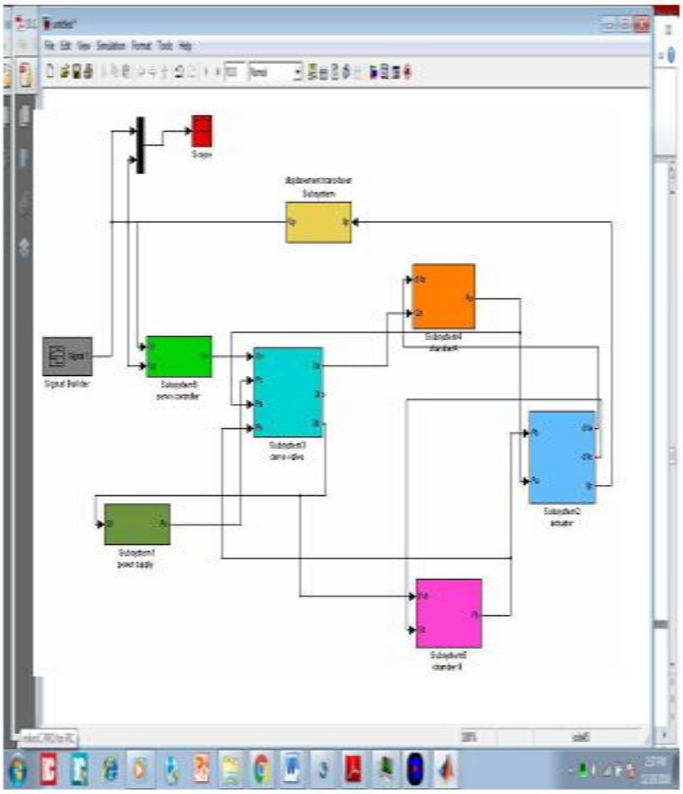


Fig 13 Simulink Model of Top level Hydraulic System

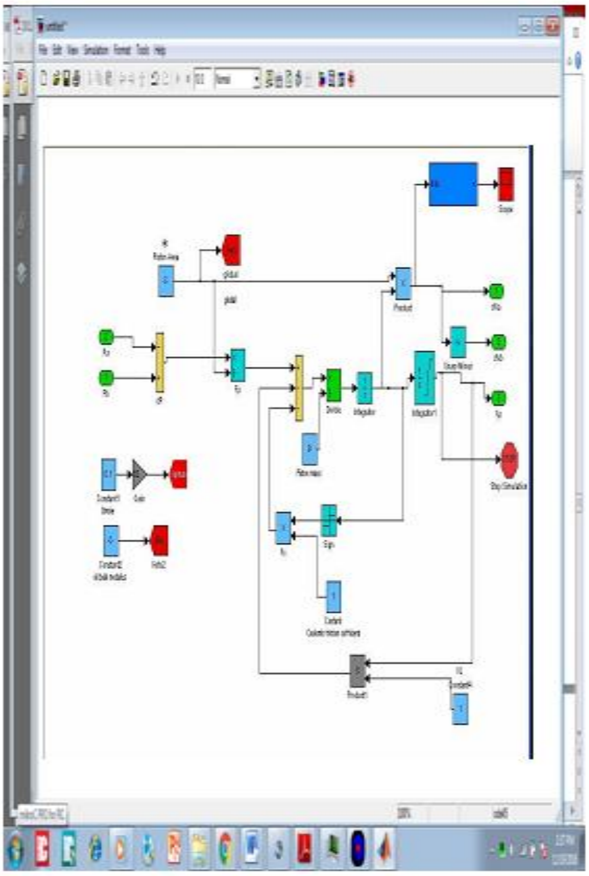
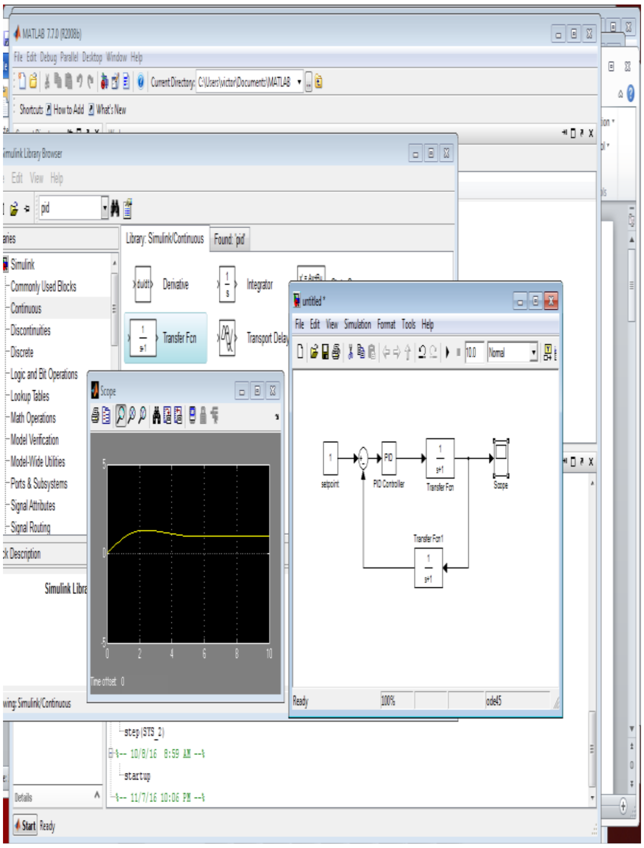


Figure 14 Simulink Model of Hydraulic Actuator



```
step(SYS_2)
%-- 10/8/16  8:59 AM --%
startup
%-- 11/7/16 10:06 PM --%
```

Fig 15 Schematic snapshot of the PID optimization in SIMULINK of the central node processor

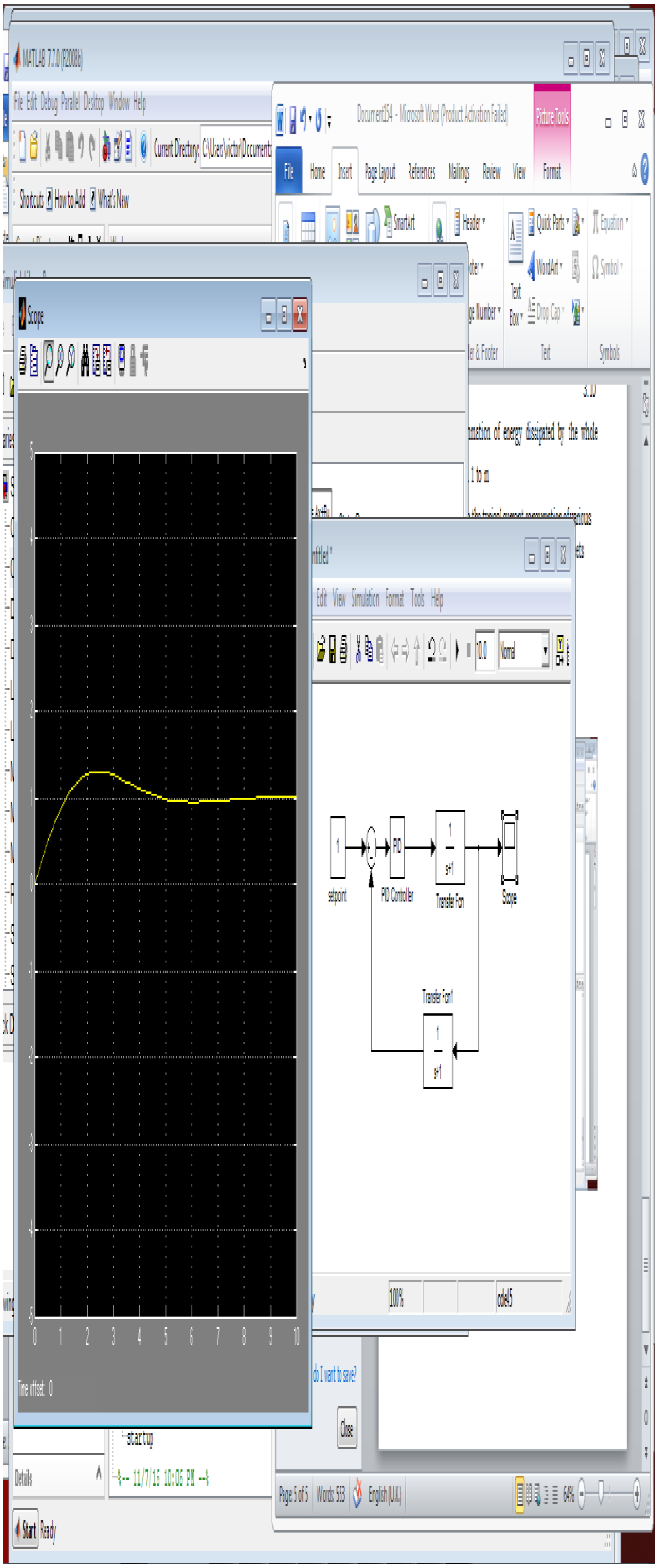


Fig 16 Schematic snapshot of the PID optimization in SIMULINK showing overshoot and steady response of the central node processor

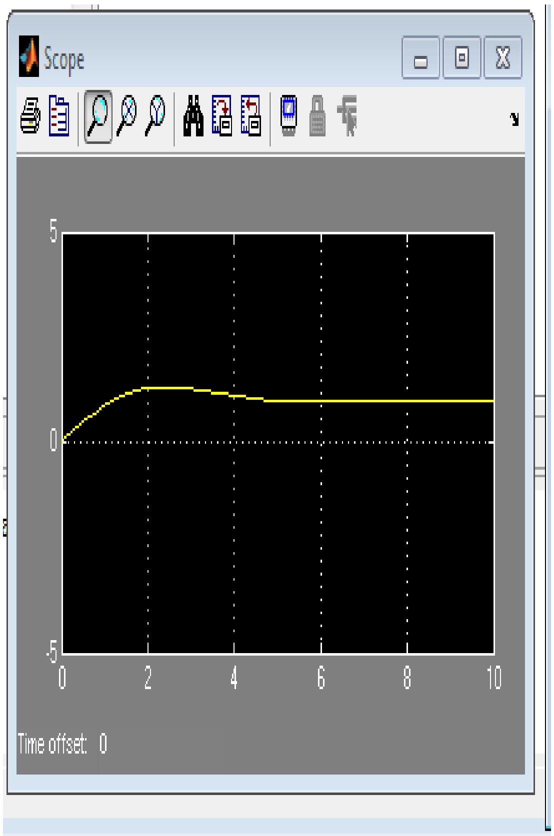


Fig 17 represents the graph showing the response of the processor when the processor is tuned with PID control.

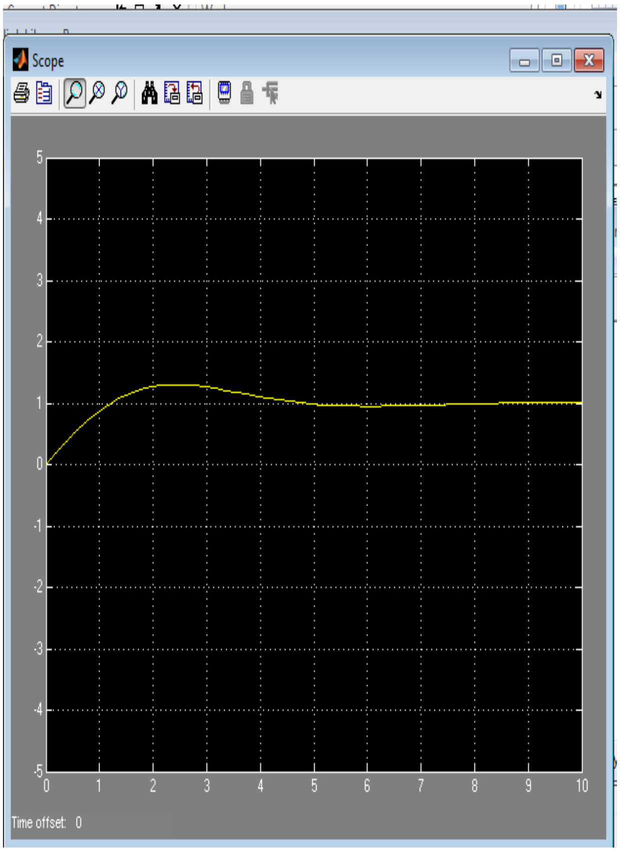


Fig 4.13 displays the steady state response of the electro hydraulic actuator. It is seen from the graph that the actuator attains stability after 5 seconds

IV. CONCLUSION

We have designed, developed, simulated and fully automated an optimized Computer Aided Control Scheme for improved operations of a mash filter machine in an industrial brewery set up. This system if fully implemented would effectively cater for the problems discovered while trying to automate industrial process control on an industrial brewery set up and minimize human intervention to the barest minimum. The above automation system, which is functionally based on PROTEUS ISIS, SIMULINK set up can be used in procedures for developing software tools and techniques to solve other problems in an industrial set up. It will help the control and protection engineers to have a clear picture of the operation of the industry even if they are in a remote location.

REFERENCES

[1]. Salgado, Graham C. Goodwin, Stefan F. Graebe, Mario E. (2001). *Control System Design*. Upper Saddle River, N. J.: Prentice Hall. p. 21. ISBN 0139586539.

[2]. Joshi, A. and Pramodh, Modelling and Simulation of Launch Vehicle Digital Autopilot, AIAA Paper No. 4696, Proc. Of .Modeling and Simulation Technologies Conference, Monterey, CA, USA, 6-8 August 2002

[3]. E. Papadopoulos, a systematic methodology for optimal component selection of Electro hydraulic servo systems International journal of fluid power, volume 5 number 3,November 2004 page 31-39.

[4]. Edson Roberto, design and experimental evaluation of position controllers for hydraulic actuators: back stepping and LQR-2DOF controllers International journal of fluid power, volume 5, number 3, November 2004 page 41-53.

[5]. Kexiangwei, Fluid Power Control Unit Using Electro rheological Fluids, International journal of fluid power, volume 5, number 3, November 2006, Page 61-69.

[6]. Holger Berndt, Interactive Design and Simulation Platform for Flight Vehicle Systems Development, IEEE Transactions on Control Systems Technology, Vol. 12, No. 2,March 2004, pp. 250–262.

[7]. Joshi, A. and Jayan, P.G., Modelling and Simulation of Aircraft Hydraulic System, AIAA Paper No. AIAA-2002-4611, Proc. of Modelling and Simulation Technologies Conference, Monterey, CA, USA, 6-8 August 2002.

[8]. Randall T. Anderson Mathematical Modeling of a Two Spool Flow Control Servovalve Using a Pressure Control Pilot, ASME journal, volume 124, September 2004. Ashok joshi ,Modelling of Flight Control Hydraulic Actuators Considering Real System Effects,journal of AIAA , volume 132, march 2003, pp. 123-140.

[9]. Peter Rowland, M. Longvitt modular design approach for modeling of large and complex hydraulic systems ,International journal of fluid power, volume 12, number 4,August 2005, pp 134-152.

[10]. Sreeraj P.N, simulation work for typical aircraft’s steering system and wheel brake system, journal of AIAA, volume 121, November2001, pp. 153-172.

[11]. Panagiotis **,** detailed model of an electro hydraulic servo system International journal of fluid power, volume 5, number 2,september 2004, pp 121-138.

[12]. Ing T.Hong, Dynamic analysis for calculating hydraulic system response, Moog Technical Bulletin132, November 1975.

[13]. Paul J.Heney, challenges in aircraft hydraulic system, Moog Technical Bulletin142, August 1978.

[14]. Ming Yuan –Tsuei, application of computer programs for system design and analysis, International journal of fluid power, volume 7, number 4, September 2005, pp.143-158. .

[15]. P.Krus, A.Jansson, computer simulation for optimization of hydraulic components, International journal of fluid power, volume 12, number 4, November2005, pp162-183.

Obieribie Vincent Oluchukwu. "Computer Aided Modelling and Design of Automatic Control System for Industrial Based Electro-Hydraulic Actuator in Mash Filter Machines." American Journal of Engineering Research (AJER) 6.7 (2017): 191-206.