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MODELING THE SERVO MOTOR SPEED OPTIMIZATION UTILITY IN CONVENTIONAL APPROACH USING FUZZY LOGIC ALGORITHM

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ABSTRACT

In this research, the speed control of the servomotor will be optimized, with the application of intelligent agent Fuzzy Logic Controller (FLC).

The process is monitored by regulating the time voltage, torque, servomotor and angel, but a dominant role is played by servomechanism in optimization of the process. In the model the armature voltage is provided by selecting the controlled voltage source and a DC mode is selected for the same with a step signal as input the optima system condition the constrain by inputting the value, so the FLC will be design to maintain the steady state of the temperature.

The mechanical system is modelled to provide load torque to the DC motor model. The dynamic response of the DC motor (speed and armature current) is captured using scope with step change of armature voltage for different loads. An active optimization mechanism using fuzzy logic controls is presented in this work.

A model predictive control strategy based on fuzzy logic optimization is proposed, a servo motor driven constant which uses a servo motor, a constant pump, and a pressure sensor, a common motor, a constant pump, a pressure proportion valve, and a flow proportion valve were also articulated in the model based on the view of the high energy consumption and low response speed of the traditional hydraulic system for a machine. A MATLAB / SIMULINK was used to obtain the optimal specifications, which are firing angle and fast decision with Fuzzy controller depending on the variations of rotating speed and armature current with variations of load torque. Simulation results showed that this control method has good control precision and quick response.. Also the simulation results are tabulated and conclusions are drawn from the results.

***Keyword**: Optimization, Servo Speed, Feedback Control, Servo Motor, Variables*

1. INTRODUCTION

1.1 BACKGROUND OF STUDY

In this research, the optimization of servomotor speed control mechanism process will be done with the application of Fuzzy Logic Controller (FLC). The control motor with high torque capabilities is also known as Servomotor, it has the ability to control electrical devices with high precision. Unlike large scale industrial based motors.

The servo motors are utilized for precise speed and position control at high torques only but not for energy conversion. Their fundamental working principle is identical to that of other electromagnetic motors.. Servomotor ratings range from a fraction of watts to hundred watts, and it is electrical device that have ability to turn with high precision. They have high speed response because of low inertia.

The optimal system of operation FLC will be design to maintain this in the operation production line. The design FLC can also be applied to maintain any other optimal, an active optimization mechanism using fuzzy logic controls is presented in this work. Based on control theory, the fuzzy control system of the active suspension is proposed. The voltage, the angle position and the torque rate are considered for the operation the servomechanism is optimized in the mechanism process.. In view of the high energy consumption and low response speed of the traditional hydraulic system for an injection molding machine, a servo motor driven constant pump hydraulic system is designed for a high precision injection industry process, which uses a servo motor, a constant pump, and a pressure sensor, instead of a common motor, a constant pump, a pressure proportion valve, and a flow proportion valve. With the aid of software Matlab/simulink, a lot of simulation process is done. Simulation results indicate that the proposed active suspension system proves to be effective in the vibration isolation of the suspension system. With the aid of software FLC. A model predictive control strategy based on optimization is proposed to control this new hydraulic system in the injection cocking process. Simulation results showed that this control method has good control precision and quick response. These project shows that intelligent systems adopted significantly improve efficiency throughout the control of the process

2. RELATED WORKS

2.1. BACKGROUND AND RELATED WORKS

2.2 Dynamic Analysis of Pneumatic Actuators.

The analysis of the work was to control AC servo systems operation with pneumatic actuator for system command perfection in driving the system for motion control because of their favorable electrical and mechanical properties. Sorli M., Gastaldi L., Heras S. (2014)., This work presents an approach towards the control system tuning for the speed control of an AC servo motor. An approach towards speed control of servo motor in presence of system parameter variations is presented. Derivative based control system has been developed in order to create a stable and highly maneuverable system. Evaluate the system controller performance in simulation, a full range of system process was investigated for valve controller.

2.3 Auto-tuning DC motors

Auto- tuning dynamical system was used with Lyapunov optimization control Which he designed using a sliding-mode approach for DC motor by M. J. Neely, (2014),. Which ensure different forms of system stability? The state of a system at a particular time is often described by a multi-dimensional vector. System stability is achieved by taking control actions that make the Lyapunov function drift in the negative direction towards zero. Lyapunov drift is central to the study of optimal control in queueing networks. A typical goal of the work is to stabilize all network queues while optimizing some performance objective, such as minimizing average energy or maximizing average throughput. Minimizing the drift of a quadratic Lyapunov function leads to the backpressure routing algorithm for network stability, also called the max-weight algorithm which can automatically tune the controller parameters based on the gradient descent method. Finally, a field-programmable gate array (FPGA) chip is adopted to implement the proposed scheme for possible low-cost and high-performance industrial applications, and it is applied to a DC servomotor to show its effectiveness. To ensure the stability of the intelligent control system, a compensator usually should was designed. The most frequently used compensator is designed as a sliding-mode control, which results in substantial chattering in the control effort. To tackle this problem, the proposed gradient descent method, and the set compensator is utilized to eliminate approximation error based on the Lyapunov stability theorem through

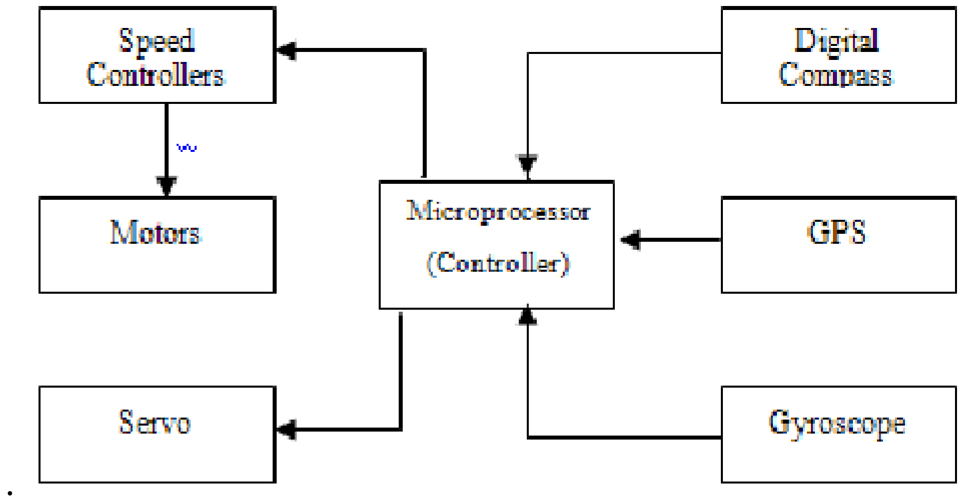

Figure 2.1 block of Lyapunov control system operation

The command of the diagram for work output sequential compensator not only can remove the chattering phenomena of conventional sliding-mode control completely, but also can guarantee the stability of the closed-loop system. Findings – The proposed system is applied to a DC servomotor on a FPGA chip. The hardware implementation of the ATPIDC scheme is developed in a real-time mode. Using the FPGA to implement, the ATPIDC system can achieve the characteristics of small size, fast execution speed and less memory. The experimental results verify the system stabilization, favorable tracking performance .

Dendrites receive input signals and, based on those inputs, fire an output signal via an axon. Or something like that. How the human brain actually works is an elaborate and complex mystery, one that we certainly are not going to attempt to tackle in rigorous

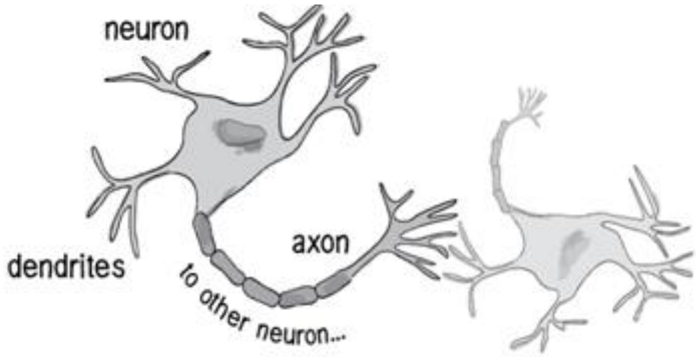

Figure 2.2 diagram of neural network

The good news is that developing engaging animated systems with code does not require scientific rigor or accuracy, which can simply be inspired by the idea of brain function.

3. METHODOLOGY

3.1: RESEARCH METHODOLOGY

Fuzzy logic application was to model a servomotor speed control for effective with perfect high precision for good output in control industry with aim to minimize cost and maximize profit and with the constrain programming of optimization system with various table and system behavior

3.2 SERVOMECHANISM IMPLEMENTATION SYSTEM AND REGULATING

A servo system mainly consists of three basic components a controlled device, a output sensor, a feedback system. This is an automatic **closed loop control system**. Here instead of controlling a device by applying the variable input signal, the device is controlled by a feedback signal generated by comparing output signal and reference input signal. When reference input signal or command signal is applied to the system, it is compared with output reference signal of the system produced by output sensor, and a third signal produced by a feedback system. This third signal acts as an input signal of controlled device through the flow chart bellow in figure. 3.1 below.

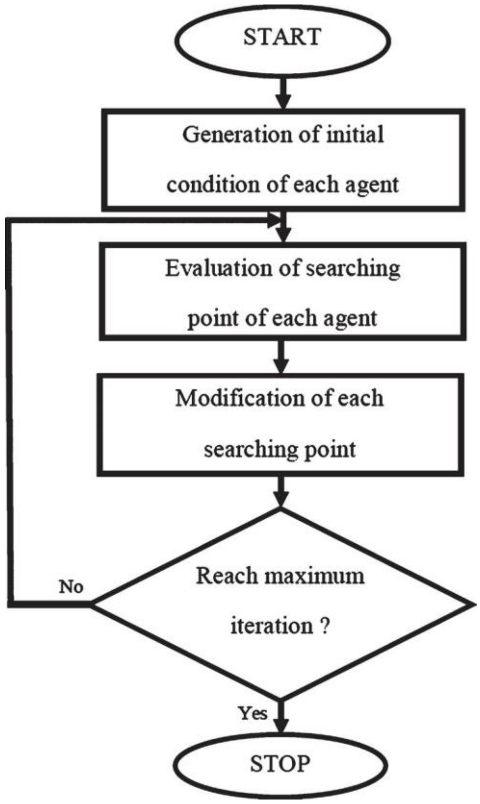

Figure 3.1 Flow graph of Servo system command control

This input signal to the device presents as long as there is a logical difference between reference input signal and the output signal of the system. After the device achieves its desired output, there will be no longer the logical difference between reference input signal and reference output signal of the system. Then, the third signal produced by comparing theses above said signals will not remain enough to operate the device further and to produce a further output of the system until the next reference input signal or command signal is applied to the system. Hence, the primary task of a servomechanism is to maintain the output of a system at the desired value in the presence of disturbances.

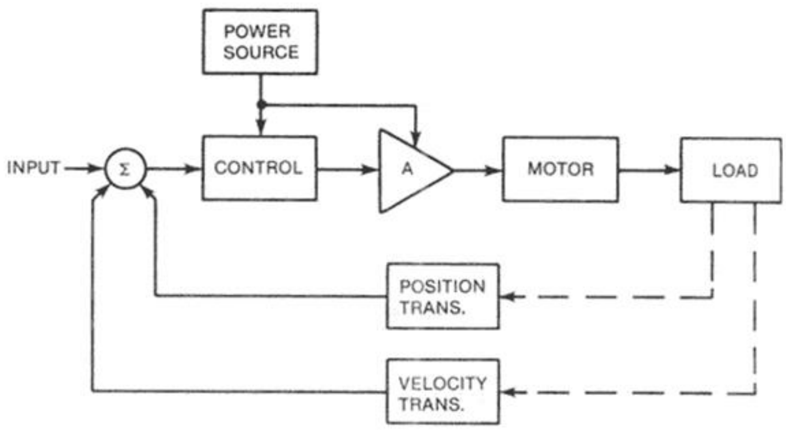

Figure 3. 2 Block diagram of servomotor initiation control

3.3 CONSTRAIN OPERATION OF SERVO MOTOR

A servo motor is basically a DC motor (in some special cases it is AC motor) along with some other special purpose components that make a DC motor a servo. In a servo unit, you will find a small DC motor, a potentiometer, gear arrangement and an intelligent circuitry. The intelligent circuitry along with the potentiometer makes the servo to rotate according to our wishes. As we know, a small DC motor will rotate with high speed but the torque generated by its rotation will not be enough to move even a light load. This is where the gear system inside a servomechanism comes into the picture. The gear mechanism will take high input speed of the motor (fast) and at the output, will get an output speed which is slower than original input speed but more practical and widely applicable. Say at initial position of servo motor shaft, the position of the potentiometer knob is such that there is no electrical signal generated at the output port of the potentiometer. This output port of the potentiometer is connected with one of the input terminals of the error detector amplifier. Now an electrical signal is given to another input terminal of the error detector amplifier. Now difference between these two signals, one comes from potentiometer and another comes from external source, will be amplified in the error detector amplifier and feeds the DC motor. This amplified error signal acts as the input power of the DC motor and the motor starts rotating in desired direction. As the motor shaft progresses the potentiometer knob also rotates as it is coupled with motor shaft with help of gear arrangement. As the position of the potentiometer knob changes there will be an electrical signal produced at the potentiometer port. As the angular position of the potentiometer knob progresses the output or feedback signal increases. After desired angular position of motor shaft the potentiometer knob is reaches at such position the electrical signal generated in the potentiometer becomes same as of external electrical signal given to amplifier. At this condition, there will be no output signal from the amplifier to the motor input as there is no difference between external applied signal and the signal generated at potentiometer. As the input signal to the motor is nil at that position, the motor stops rotating. This is how a simple conceptual servo motor works energized the valve for process command.

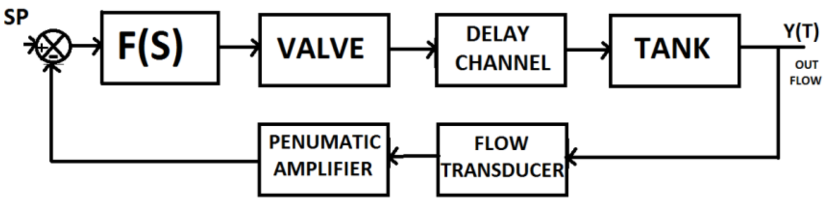

Figure 3.3 block diagram of servomotor valve control station

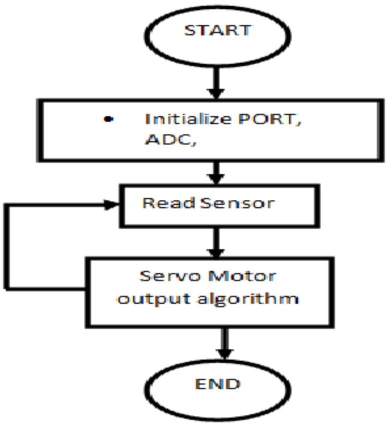

Fig 3.4 Flow graph of servomotor valve control algorithm

3.4 DC MOTOR SYNCHRONOUS

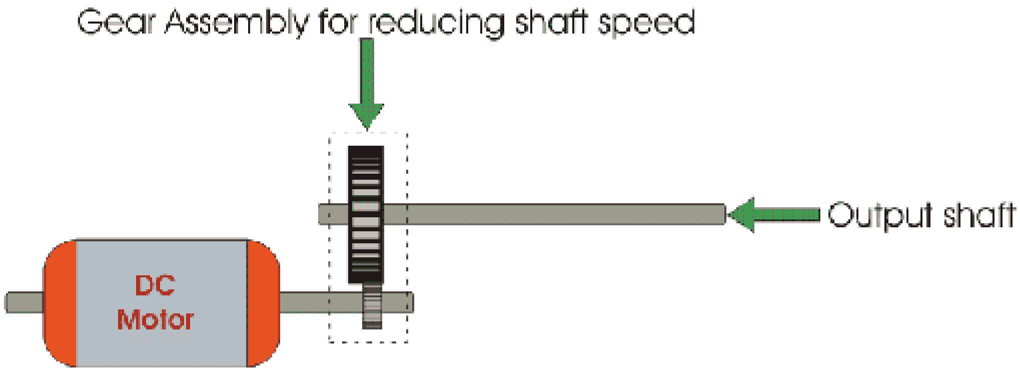

Fig 3.5 Block diagram of DC motor gear reducer

The voltage adjusting knob of a potentiometer is so arranged with the output shaft by means of another gear assembly, that during rotation of the shaft, the knob also rotates and creates an varying electrical potential according to the potentiometer.

This signal i.e. electrical potential is increased with angular movement of potentiometer knob along with the system shaft from 0° to 45°. This electrical potential or voltage is taken to the error detector feedback amplifier along with the input reference commends i.e. input signal voltage.

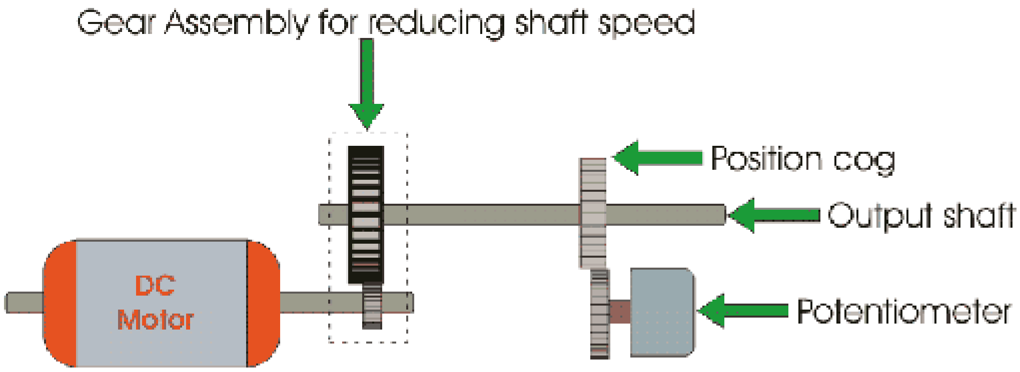

Fig 3.6 Diagram of DC motor voltage implementation

As the angle of rotation of the shaft increases from 0° to 45° the voltage from potentiometer increases. At 45° this voltage reaches to a value which is equal to the given input command voltage to the system. As at this position of the shaft, there is no difference between the signal voltage coming from the potentiometer and reference input voltage (command signal) to the system, the output voltage of the amplifier becomes zero.

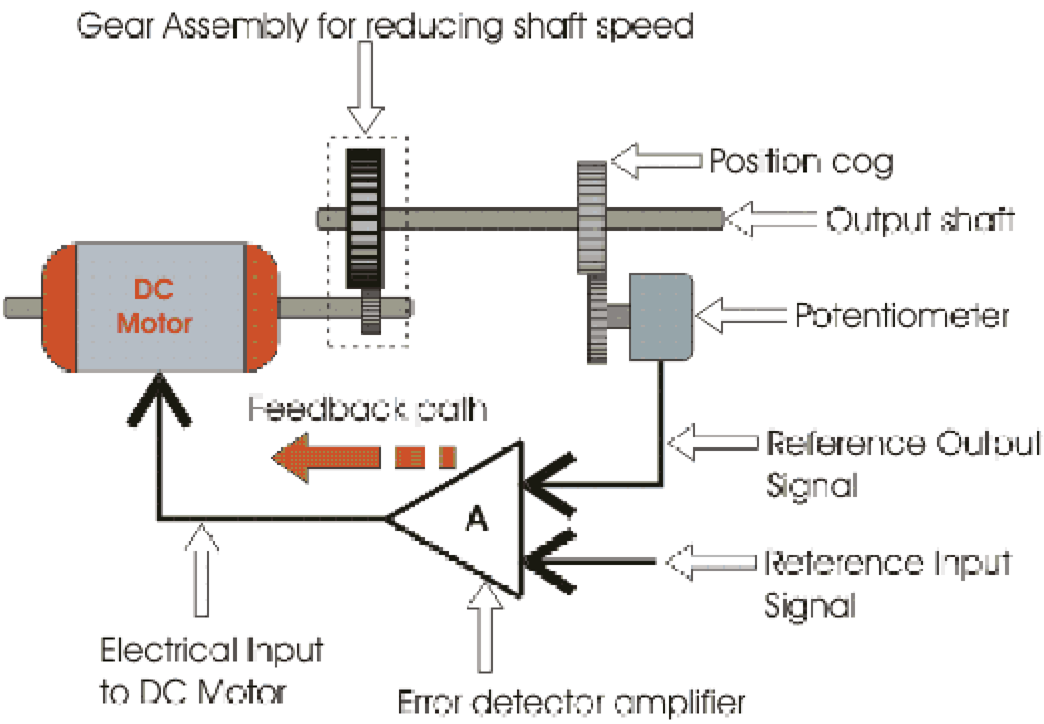

Fig 3.7 diagram of DC motor Speed controller system

As per the picture given above the output electrical voltage signal of the amplifier, acts as input voltage of the DC motor. Hence, the motor will stop rotating after the shaft rotates by 45°. The motor will be at this rest position until another command is given to the system for further movement of the shaft in the desired direction. From this example we can understand the most basic servo motor theory and how servo motor control is achieved.

Whenever the term electric motor or electrical generator is used, I tend to think that the speed of rotation of these machines is totally controlled only by the applied voltage and frequency of the source current. But the speed of rotation of an electrical machine can be controlled precisely also by implementing the concept of drive. The main advantage of this concept is, the motion control is easily optimized with the help of drive. In very simple words, the systems which control the motion of the electrical machines are known as electrical drives. A typical drive system is assembled with a electric motor (may be several) and a sophisticated control system that controls the rotation of the motor shaft. But now this is model with Fuzzy logic controller FLC, this control can be done easily with the help of software. So, the controlling becomes more and more accurate and this concept of drive also provides the ease of use. This drive system is widely used in large number of industrial and domestic applications like factories, transportation systems, textile mills, fans, pumps, motors, robots etc. Drives are employed as prime movers for diesel or petrol engines, gas or steam turbines, hydraulic motors and electric motors.

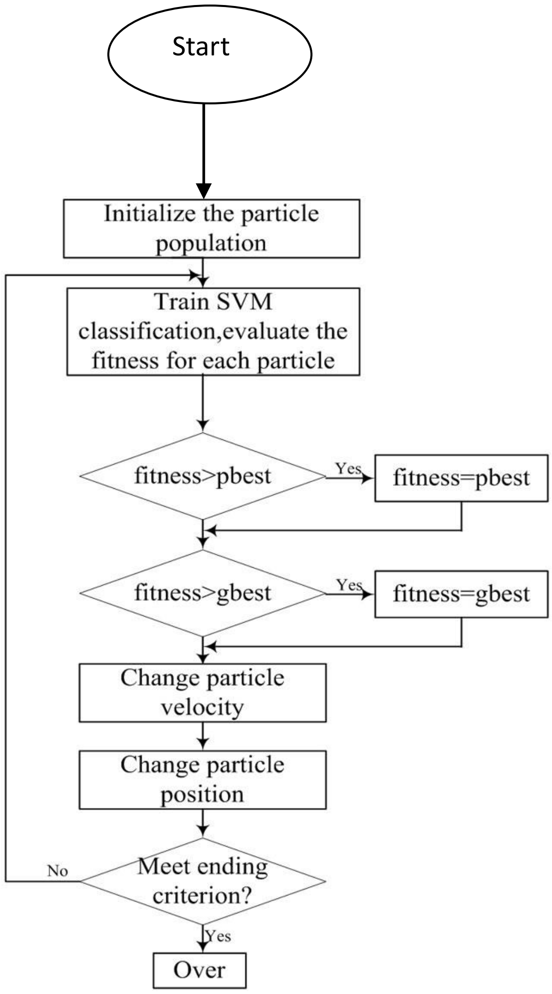

Fig 3.8 flow chart of motor sizing control

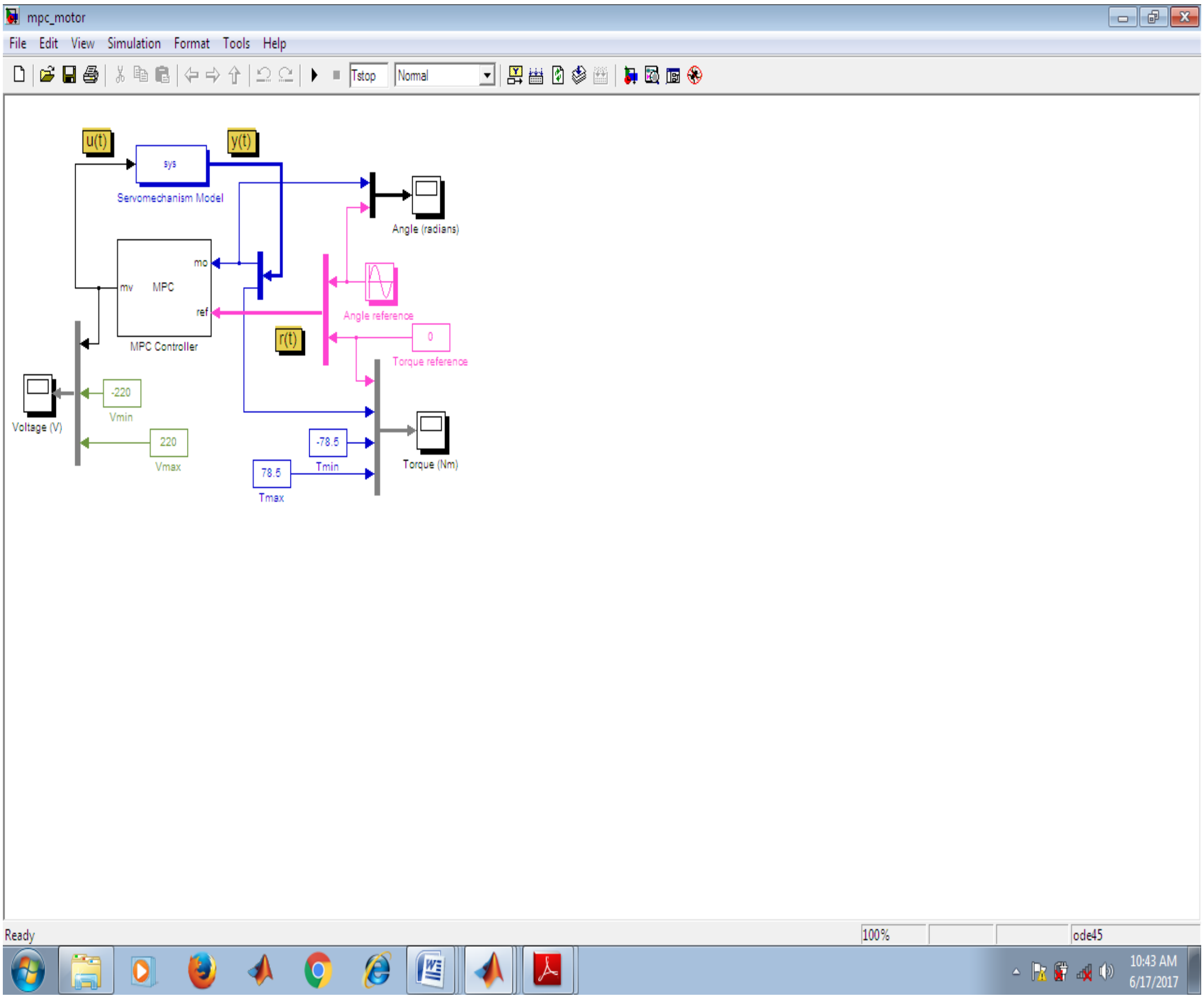

Figure 3.9 Matlab Model of the Servo Motor speed control optimization

The DC servo motor is part of a larger system that contains the control electronics (H-Bridge) and a disk attached to the motor shaft. The overall model is shown in figure 3.9, where the Input Signal (V) is the voltage signal applied to the H-bridge circuit, and the Output Signal (deg) is the angular position of the motor shaft

A first-principles model of the DC motor within the DC servo motor subsystem was developed. And a Sim Power Systems was used to model the electrical components and Sim Driveline to model the mechanical components of the motor. The figure 3.9 shows the content of the servo motor subsystem.

The DC motor model shows a relationship from current to torque (the green line on the left). The torque causes the shaft of the motor to spin and i have a relationship between this spinning to the Back EMF (electromotive force). The rest of the parameters include a shaft inertia, viscous friction (damping), armature resistance, and armature inductance.

4. SIMULATION

4.1 PARAMETERS FOR SIMULATION

4.2 SERVOMOTOR PARAMETERS

For armature- controlled servomotors (220V, 3KW), the closed loop transfer function can be written as:

$$H(s) = K_t / (R_a J S^2 + (K_b K_t + R_a B) S + K_t) \quad 4.1$$

Where:

Ra: resistance of armature of motor.

Kt: torque constant of motor.

Kb: back e.m.f. constant of motor.

Jm: inertia of motor rotor.

JL: inertia of additional inertia disc.

Bm: viscous friction coefficient of motor shaft.

BL: viscous friction coefficient of load shaft.

In order to verify the effectiveness of the used controller, the simulations are performed with Matlab/Simulink. The Transfer function of the servo system is defined in equation 4.1 and the system parameters are listed in Table 4.1.

Table 4.1: Parameters of the Servo-Motor

Parameter	Value
Servo-motor	220V
Potentiometer sensitivity (Kp)	5.093 V/rad
Signal amplifier gain (Ka)	1
Back emf constant (K)	$15x10^{-3}$ V/rad/s
Armature Resistance (R)	2W
Armature Inductance (Lr)	1mH
Motor Torque Constant (Kr)	$15x10^{-3}$N-m/A
Combined moment of inertia motor shaft & load referred to the motor shaft side (Jm)	$42.6x10^{-6}$Kg-m^2
Viscous damping coefficient of the motor referred to the motor shaft side *(Dm)*	$47.3x10^{-6}$ Nm/rad/s

4.3 SIMULATION RESULT

In the model the DC motor field excitation is provided with constant DC source and the armature voltage is provided by selecting the controlled voltage source and a DC mode is selected for the same with a step signal as input. The mechanical system is modelled to provide load torque to the DC motor model. The dynamic response of the DC motor (speed and armature current) is captured using scope with step change of armature voltage for different loads. Also the simulation results are tabulated and conclusions are drawn from the results.

MATLAB / SIMULINK was used to obtain the optimal specifications, which are firing angle and fast decision with Fuzzy controller depending on the variations of rotating speed and armature current with variations of load torque.

Table 4.2: Servomotor Torque

Time (s)	**Torque (Nm)**
0	0
0.1000	-14.8965
0.2000	-43.1728
0.3000	-64.4573
0.4000	-71.8871
0.5000	-77.6626
0.6000	-78.5398
0.7000	-63.4604
0.8000	-36.0709

0.9000	-9.0312
1.0000	5.4925
1.1000	2.4564
1.2000	-14.2548
1.3000	-34.7543
1.4000	-48.6584
1.5000	-50.1342
1.6000	-40.1031
1.7000	-24.9071
1.8000	-12.5412
1.9000	-8.5867
2.0000	-13.8414
2.1000	-24.5644
2.2000	-34.8738
2.3000	-39.8607
2.4000	-37.8239
2.5000	-30.6677
2.6000	-22.5107
2.7000	-15.4837
2.8000	-10.2307
2.9000	-7.5190
3.0000	-7.3817
3.1000	-8.8302
3.2000	-10.3254
3.3000	-10.5396
3.4000	-8.9482
3.5000	-5.9693
3.6000	-2.6357
3.7000	-0.0157
3.8000	1.3061
3.9000	1.4469
4.0000	1.0772
4.1000	1.0250
4.2000	1.8565
4.3000	3.6381
4.4000	5.9699
4.5000	8.2398
4.6000	9.9460
4.7000	10.9240
4.8000	11.3816
4.9000	11.7497
5.0000	12.4459
5.1000	13.6746
5.2000	15.3571
5.3000	17.2066
5.4000	18.8936
5.5000	20.2100
5.6000	21.1537
5.7000	21.9023
5.8000	22.7038
5.9000	20.9359
6.0000	13.5919
6.1000	1.5099
6.2000	-11.0957
6.3000	-19.3193
6.4000	-20.3166
6.5000	-14.6400
6.6000	-5.6904
6.7000	2.1749
6.8000	5.7700
6.9000	4.3804
7.0000	-0.2742
7.1000	-5.2172
7.2000	-7.8113
7.3000	-6.9609
7.4000	-3.4069
7.5000	0.8957
7.6000	3.8875
7.7000	4.4053
7.8000	2.6114
7.9000	-0.2695

8.0000	-2.6816
8.1000	-3.5233
8.2000	-2.6038
8.3000	-0.6016
8.4000	1.3834
8.5000	2.4150
8.6000	2.1430
8.7000	0.8861
8.8000	-0.6150
8.9000	-1.6100
9.0000	-1.6975
9.1000	-0.9655
9.2000	0.1207
9.3000	0.9938
9.4000	1.2692
9.5000	0.9015
9.6000	0.1578
9.7000	-0.5542
9.8000	-0.9005
9.9000	-0.7687
10.0000	-0.2901
10.1000	0.2580
10.2000	0.6049
10.3000	0.6143
10.4000	0.3303
10.5000	-0.0702
10.6000	-0.3798
10.7000	-0.4644
10.8000	-0.3160
10.9000	-0.0385
11.0000	0.2175
11.1000	0.3334
11.2000	0.2741
11.3000	0.0929
11.4000	-0.1065
11.5000	-0.2267
11.6000	-0.2218
11.7000	-0.1121
11.8000	0.0352
11.9000	0.1446
12.0000	0.1696
12.1000	0.1103
12.2000	0.0071
12.3000	-0.0848
12.4000	-0.1231
12.5000	-0.0974
12.6000	-0.0290
12.7000	0.0433
12.8000	0.0847
12.9000	0.0799
13.0000	0.0377
13.1000	-0.0163
13.2000	-0.0549
13.3000	-0.0618
13.4000	-0.0383
13.5000	-0.0000
13.6000	0.0328
13.7000	0.0453
13.8000	0.0345
13.9000	0.0088
14.0000	-0.0174
14.1000	-0.0316
14.2000	-0.0287
14.3000	-0.0126
14.4000	0.0072
14.5000	0.0207
14.6000	0.0225
14.7000	0.0132
14.8000	-0.0009
14.9000	-0.0126
15.0000	-0.0167

15.1000	-0.0122
15.2000	-0.0025
15.3000	0.0069
15.4000	0.0117
15.5000	0.0103
15.6000	0.0041
15.7000	-0.0031
15.8000	-0.0078
15.9000	-0.0081
16.0000	-0.0046
16.1000	0.0007
16.2000	0.0049
16.3000	0.0061
16.4000	0.0043
16.5000	0.0007
16.6000	-0.0027
16.7000	-0.0044
16.8000	-0.0037
16.9000	-0.0013
17.0000	0.0013
17.1000	0.0029
17.2000	0.0029
17.3000	0.0016
17.4000	-0.0004
17.5000	-0.0019
17.6000	-0.0022
17.7000	-0.0015
17.8000	-0.0002
17.9000	0.0011
18.0000	0.0016
18.1000	0.0013
18.2000	0.0004
18.3000	-0.0005
18.4000	-0.0011
18.5000	-0.0011
18.6000	-0.0005
18.7000	0.0002
18.8000	0.0007
18.9000	0.0008
19.0000	0.0005
19.1000	0.0000
19.2000	-0.0004
19.3000	-0.0006
19.4000	-0.0005
19.5000	-0.0001
19.6000	0.0002
19.7000	0.0004
19.8000	0.0004
19.9000	0.0002

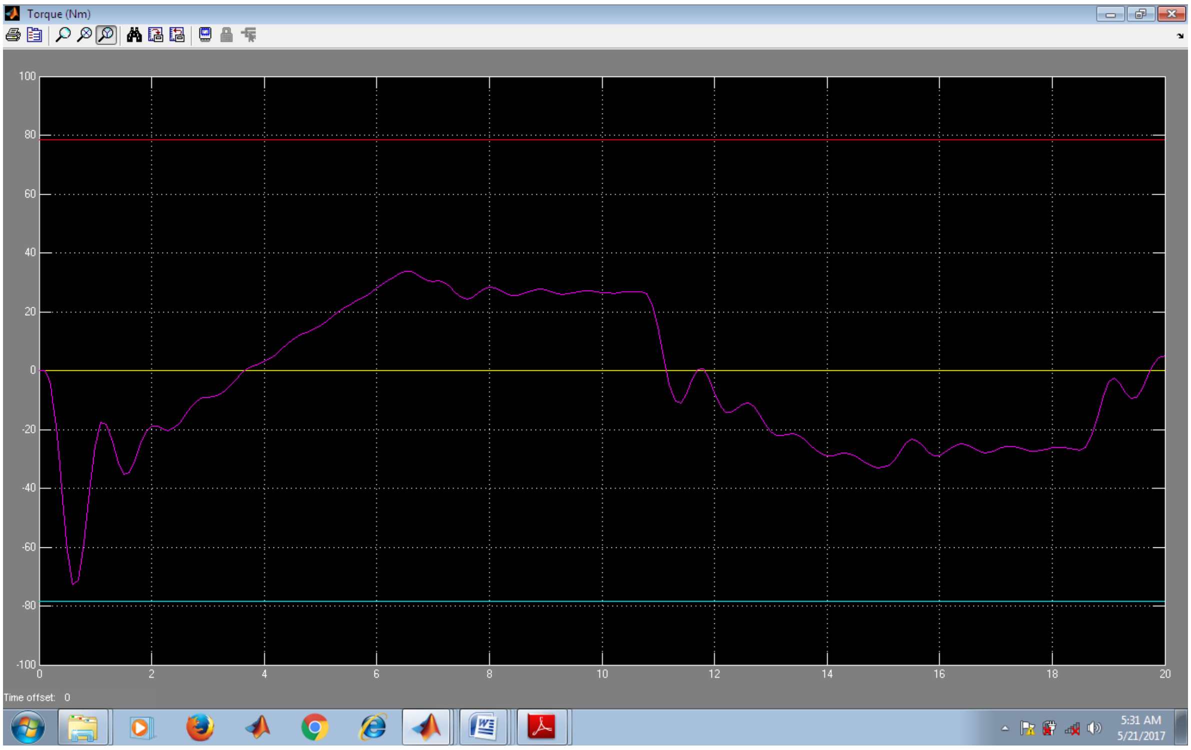

Fig. 4.1: Servomotor Torque

Figure 4.1 depicts that the motor speeds drops significantly as the load torque changes and also varies with the change in armature voltage. In order to compensate for the drop in the speed due to change in load torque, the armature voltage needs to be gradually increased to bring the motor back to desired speed.

In order to overcome the Non-linearity of DC motor response the conventional approach is to implement a linear controller with P+I strategy where the integral action is used to incrementally adjust the armature voltage to bring the motor speed to desired level and remove any steady state error as depicted in figure 4.1.

However, a fixed PI controller tuning at low load may not be suitable for higher load and vice versa in slow speed applications with variable load torque such as in case of breweries.

In view of these challenges, the performance of PI controller alone is sub-optimal. It is recommended to overcome the shortcomings of conventional PI controller by implementing the Fuzzy logic based PI controller where the gain of PI controller gets adjusted continuously based on dynamic response of the DC motor.

The results of the present study are meant to constitute a starting point for ongoing studies on identification of non-linearity in DC motor based electromechanical systems and adaptive and Fuzzy control applications for nonlinear systems.

4.4 DISCUSSIONS

In this research work, a fuzzy controller is proposed in order to improve the performance of the servo system. The proposed controller incorporates the advantages of PID control which can eliminate the steady-state error, and the advantages of fuzzy logic such as simple design, no need of an accurate mathematical model and some adaptability to nonlinearity and time-variation. The Fuzzy controller accepts the error (e) as inputs, while the parameters torque, angle, voltage as outputs. Control rules of the controller are established based on experience so that self-regulation of the values of PID parameters is achieved.

Following observations and conclusions can be drawn from the results of the simulations:

1. The response of motor speed and armature voltage is non-linear for 1.5-2 sec after the step change due to moment of interia and friction effects

2. The maximum motor speed drops in response to the increase in load torque and also the dynamic response gets sluggish even for the same VA.

5. CONCLUSION AND RECOMMENDATION

5.1 SUMMARY

It is observed that using the superposition of different consequent active at particular region of domain, for the same combinations of antecedents, performance of FLC is improved considerably in terms of settling time and overshoot. The combination of two sets of rules with same antecedents but different consequent reduces the settling time and overshoot.

However, is seen that the fuzzy controller preserves the desired response, even in the presence of load disturbance and varying contra1 environments. This ensures the controller's robustness. The choice of rules and membership functions has considerable effect on fuzzy controller performance, e.g., rise time, settling time, overshoot etc.

5.2 CONTRIBUTIONS TO KNOWLEDGE/RECOMMENDATION

This research work has contributed immensely in expanding the scope of knowledge of the reader in the areas of servomotor optimization using fuzzy logic controller. It is recommended that more research work be carried out in this field using other methods like neuro fuzzy

5.3 Conclusion

A fuzzy logic based controller for a DC servomotor has been studied. The results have been compared to the conventional controller. The design of the fuzzy logic controller has been explained and the performance was evaluated by simulation. The simulation results indicate that FLC provides the best performance in comparison with PI controller.

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