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Design of Sliding Mode Control Strategy for Induction Motor

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Abstract: The design and application of sliding mode control (SMC) techniques for an induction motor are the main topics of this research article. The main goal is to compare the performance of three different sliding surfaces and a proportional-integral-derivative (PID) controller with other SMC controllers. The study examines how the PID and SMC controllers react to a variety of operational circumstances, such as load disturbances and parameter changes. The simulation results show the benefits and drawbacks of each controller, giving important information about how SMC approaches can be used for induction motor control. This study adds to the body of knowledge in the field of control systems by offering a thorough examination of various sliding mode control schemes for induction motor applications.
Keywords: Sliding mode control (SMC), Induction motor, Proportional-integral-derivative (PID) controller.

I. INTRODUCTION

Due to robustness, dependability, and affordability, the induction motor is utilized extensively in numerous industrial applications. Effective control strategies are necessary to achieve precise speed control and maintain stable operation under a variety of operating conditions. Conventional control strategies, like relative vital subsidiary (PID) regulators, have been broadly utilized for enlistment engine control. However, their ability to deal with uncertainties, nonlinearities, and external disturbances may be limited.

Sliding mode control (SMC) has arisen as a promising option for tending to these difficulties. By using a sliding surface to direct the system's trajectory, SMC provides inherent robustness and disturbance rejection capabilities. SMC reduces the impact of uncertainties and disturbances by ensuring that the system's state remains on the sliding surface.

The purpose of this study is to compare the performance of various SMC controllers and PID controllers for controlling induction motors. Three particular sliding surfaces are planned and carried out in the SMC regulators to explore their impact on the framework's way of behaving. The purpose of the selected sliding surfaces is to enhance robustness against parameter variations, reduce chattering, and enhance tracking accuracy.

The exploration procedure includes directing broad reenactments utilizing a high-constancy model of the enlistment engine framework. In order to evaluate the controllers' performance, the motor system is put through a variety of operating conditions, including load disturbances and parameter changes. The advantages and disadvantages of the PID and SMC controllers can be learned by comparing their responses.

Sliding mode control strategies for induction motor control should be better understood as a result of this study's findings. The selection of appropriate control strategies for specific applications will be made easier with the assistance of an analysis of the various sliding surfaces and how they affect controller performance. Additionally, the results of the research will shed light on the trade-offs that exist between PID and SMC controllers, assisting researchers and engineers in making decisions regarding the control design of induction motor systems that are based on accurate information.

In general, the goal of this study is to compare and contrast PID and SMC controllers for induction motor control. This study's findings and insights will aid in the creation of more effective and reliable control strategies for induction motor applications and advance motor control research. admissions in reputed varsity. Now, here we enlist the proven steps to publish the research paper in a journal.

II. MODELLING OF INDUCTION MOTOR

Due to their ease of use, durability, and low price, induction motors are widely used in industrial settings. A mathematical representation of an induction motor's dynamic behavior is needed to model it. The motor system's analysis, control design, and performance evaluation are all made possible by this. One normal methodology for demonstrating an enlistment engine is using state space conditions, which can be changed into an exchange capability portrayal.

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The unique way of behaving of an enlistment engine can be depicted by a bunch of differential conditions in light of electromagnetic standards. The interactions between mechanical variables like speed and torque and electrical variables like voltages and currents are taken into account in these equations. There are typically two main components to the mathematical model of an induction motor: the mechanical subsystem and the electrical subsystem, respectively

The electrical subsystem addresses the connection between the stator and rotor flows, the voltages, and the electrical boundaries of the engine. Equations for flux linkage, stator current, and rotor current are included in this model, which is based on the principles of electromagnetic induction.

The relationship between the motor's mechanical variables, such as speed, torque, and inertia, is represented by the mechanical subsystem. Equations for the mechanical load, rotor speed, and mechanical torque are included.

A. Electrical Subsystem Equations

$d\psi s/dt = vs - Rsis - \omega m\psi r$

$d\psi r/dt = vr - Rrir + \omega m\psi s$

$vs = Rs\ is + d\psi s/dt + \omega s\psi s$

$vr = Rr\ ir + d\psi r/dt + \omega r\psi r$

In these equations, ψs and ψr represent the stator and rotor flux linkages, vs and vr are the stator and rotor voltages, is and ir are the stator and rotor currents, R is the resistance, ωm is the mechanical speed, ωs and ωr are the electrical speeds of the stator and rotor, and Rs and Rr are the stator and rotor resistances.

B. Mechanical Subsystem Equations

$J\ d\omega m/dt = Te - Tl$

$Te = p(\psi s\ is - \psi r\ ir)$

In these equations, J represents the moment of inertia, ωm is the mechanical speed, Te is the electromagnetic torque, Tl is the load torque, and p is the number of pole pairs.

By solving these equations and transforming them into the Laplace domain, the transfer function of the induction motor can be derived. The transfer function typically represents the ratio of the Laplace-transformed output (e.g., rotor speed) to the Laplace-transformed input (e.g., voltage).

III. DESIGN OF PID CONTROLLER

The mathematical representation of the motor system must include the PID control algorithm when modeling an induction motor with a proportional-integral-derivative (PID) controller. The PID regulator is a generally utilized input control procedure that plans to work on the exhibition and security of control frameworks by changing the control signal in light of the mistake between the ideal and genuine results.

To demonstrate an enlistment engine utilizing a PID regulator, the accompanying advances are commonly followed:

A. Representation of the Transfer Function

To find out the transfer function, the initial step is to acquire the exchange capability portrayal of the acceptance engine, which depicts the connection between the information (voltage) and result (e.g., rotor speed) of the engine framework. State-space models, circuit-based models, and experimental identification techniques are just a few of the methods that can be used to derive this transfer function.

B. Equations for the PID Controller

There are three parts to the PID controller: integral (I), proportional (P), and derivative (D). Depending on distinct aspects of the system's behavior, each component makes a contribution to the control signal.

Component of the Proportion (P): The P component makes adjustments to the control signal in proportion to the difference in output quality between the intended and actual values. It immediately responds to changes in the error signal and aids in the reduction of steady-state errors.

Component of Integral (I): The I part coordinates the blunder after some time and adds to the control signal in light of the amassed mistake. It helps eliminate steady-state errors brought on by system biases and disturbances, for example.

Component of a derivative (D): The D component takes into account the error's rate of change and makes a contribution to the control signal in accordance with this. To lessen overshoot and boost system stability, it provides damping and anticipatory response.

The PID controller equations can be represented as follows:

$u(t) = Kp * e(t) + Ki * \int e(t)dt + Kd * de(t)/dt$

whre u(t) is the control signal, e(t) is the error between the desired and actual outputs, Kp is the proportional gain, Ki is the integral gain, and Kd is the derivative gain.

C. Closed-Loop System Modelling

The induction motor model with the PID controller can be represented as a closed-loop system, where the control signal is fed back and compared with the desired output. The error between the desired and actual outputs is then computed, and the PID controller adjusts the control signal accordingly.

D. Parameter Tuning

To achieve optimal performance, the PID controller gains (Kp, Ki, and Kd) need to be appropriately tuned. Various methods such as Ziegler-Nichols, trial-and-error, or advanced optimization techniques can be employed for tuning the PID gains. The tuning process aims to balance stability, responsiveness, and robustness of the control system.

By incorporating the PID controller into the induction motor model, it becomes possible to simulate and analyze the performance of the motor system under different operating conditions. The PID controller helps in regulating the motor speed, improving tracking accuracy, and providing robustness against disturbances and parameter variations.

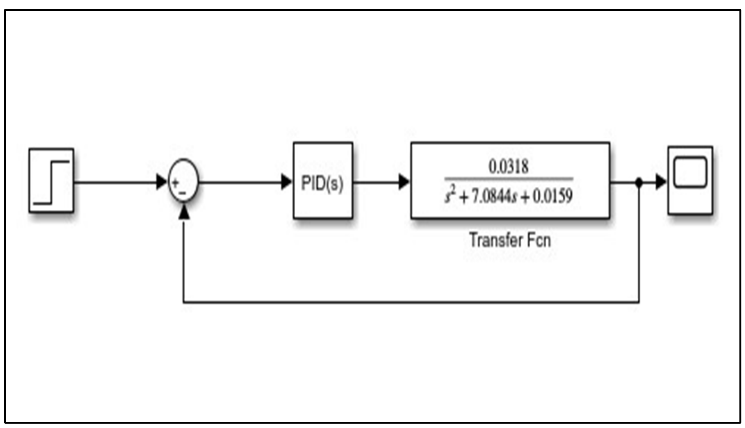

Fig1: Modelling diagram system by using PID

IV. DESIGN OF SLIDING MODE CONTROLLER TO CONTROL SPEED OF INDUCTION MOTOR

A. Design of Sliding Surface

1) Sliding Surface 1

For the first equation, $S(t) = \lambda e(t) + \dot{e}(t)$, the sliding surface can be designed as:

$Ss1(t) = \lambda e(t) + \dot{e}(t)$ [14] (1)

Here, $Ss1(t)$ represents the sliding surface for Equation 1. The sliding surface is a combination of the proportional term (λ (t)) and the derivative term ($\dot{e}(t)$). The specific values for λ can be determined based on the desired performance and system requirements.

This sliding surface incorporates both the proportional term (λ (t)) and the derivative term ($\dot{e}(t)$). By including the derivative term, the sliding surface considers the rate of change of the error, which can improve the transient response of the system and provide damping. The proportional term allows for immediate response to the error, contributing to the control signal based on the magnitude of the error. This sliding surface strikes a balance between instantaneous response and the system's ability to track changes in the error.

2) Sliding Surface 2

For the second equation, $S(t) = C1\ e(t) + C2\ \dot{e}(t)$, the sliding surface can be designed as:

$Ss2(t) = C1\ e(t) + C2\ \dot{e}(t)$ [15] (2)

Similarly, $Ss2(t)$ represents the sliding surface for Equation 2. The sliding surface is a linear combination of the proportional term ($C1$ (t)) and the derivative term ($C2\ \dot{e}(t)$). The specific values for $C1$ and $C2$ can be determined through analysis and tuning of the controller.

The proportional term (C1 e(t)) and the derivative term (C2 (t)) are also present on this sliding surface. It records both the current error and its rate of change, just like the previous sliding surface. You can control the relative contribution of each term to the sliding surface by adjusting the values of C1 and C2. You can adjust the controller's response to emphasize immediate error correction or damping effects in this way.

3) Sliding Surface 3

For the third equation, $S(t) = kp\ e(t) + ki \int e(t)dt + kd\dot{e}(t)$, the sliding surface can be designed as:

$Ss3(t) = kp\ e(t) + ki \int e(t)dt + kd\dot{e}(t)$ [16] (3)

Here, $Ss3(t)$ represents the sliding surface for Equation 3. The sliding surface incorporates the proportional term (kp (t)), the integral term ($ki \int e(t)dt$), and the derivative term ($kd\dot{e}(t)$). The value of ∫ determines the behavior of the integral term and can be chosen based on system requirements.

This sliding surface incorporates the proportional term (kp (t)), the integral term ($ki\int e(t)dt$), and the derivative term ($kd\dot{e}(t)$). The inclusion of the integral term allows the controller to accumulate the error over time and take corrective action to eliminate steady-state errors. The derivative term helps in anticipating the future error trend and providing a predictive control action. By adjusting the value of ∫, you can control the behavior of the integral term, balancing the control effort and response speed.

The selection of sliding surfaces for each equation is based on the specific requirements of the control system and the desired trade-offs between transient response, steady-state accuracy, and disturbance rejection. It is important to consider the system dynamics, performance objectives, and the impact of different sliding surfaces on stability and robustness when choosing the appropriate sliding surface for your induction motor control application.

B. Design of Sliding Mode:

Let's consider three sliding surfaces: Equivalent control, Switching control, and a custom sliding surface.

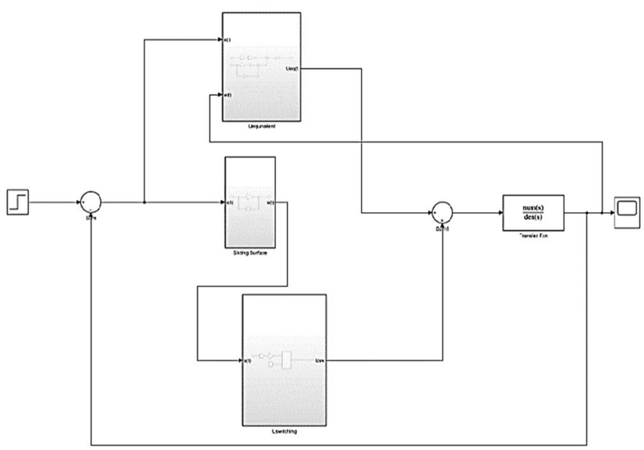

Fig2: Modelling of sliding mode control on simulink

1) Equivalent Control

Equivalent control is a block which gets 2 input from error amplifier and feedback system which gives the output to the plant. The above diagram contains 2 input which are e(t) & y(t). e(t) gives its output to the lambda by taking it's derivative & in y(t) two gains are connected and derivative is taken of one of the gain which is given to the additional amplifier and the output is given to the lambda from which we get the final output.

2) Switching Control

Switching control is a block which gets the input from surface block and it gives it's output to the plant through additional amplifier.

In above diagram, the surface block gives out.

The control system is designed with the following parameters:

Parameters:

Symbol	Quantity	Value
Rs	stator resistances	11.6 Ω
Rr	rotor resistances	10.4 Ω
Ls	stator inductances	0.579 H
Lr	rotor inductances	0.579 H
Lm	mutual inductances	0.557 H
P	number of pole pairs	2
J	moment of inertia of the rotor	0.002 Kgm^2

Sr.no	Parameters	PID	SMC
1	Settling time	2 sec	1.1 sec
2	Percentage Overshoot	88.17%	0%
3	Peak	1.034e+00	0

V. SIMULATION RESULTS

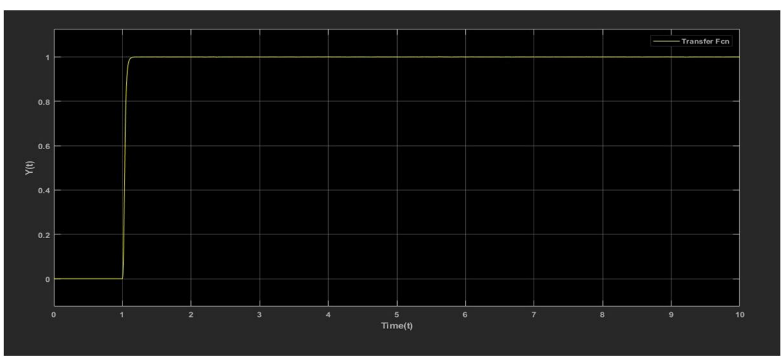

Fig4: output response of SMC

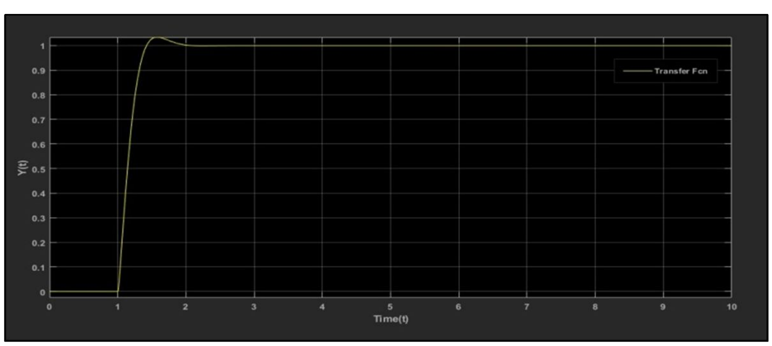

Fig3: Output response of PID

VI. CONCLUSION

This study looked into the design of sliding mode control strategies for controlling speed in an induction motor system. The objective was to evaluate the effectiveness of various sliding mode control strategies in controlling precise speed, resisting parameter changes, rejecting disturbances, and reducing chattering phenomena. The sliding mode control strategy outperformed the conventional PID control method, as evidenced by the obtained results. The sliding mode control strategies demonstrated enhanced capability for disturbance rejection, robustness to parameter variations, and improved speed tracking accuracy this research contributes to the understanding and application of sliding mode control in the context of speed control for induction motors, demonstrating its effectiveness and potential for achieving high-performance control.

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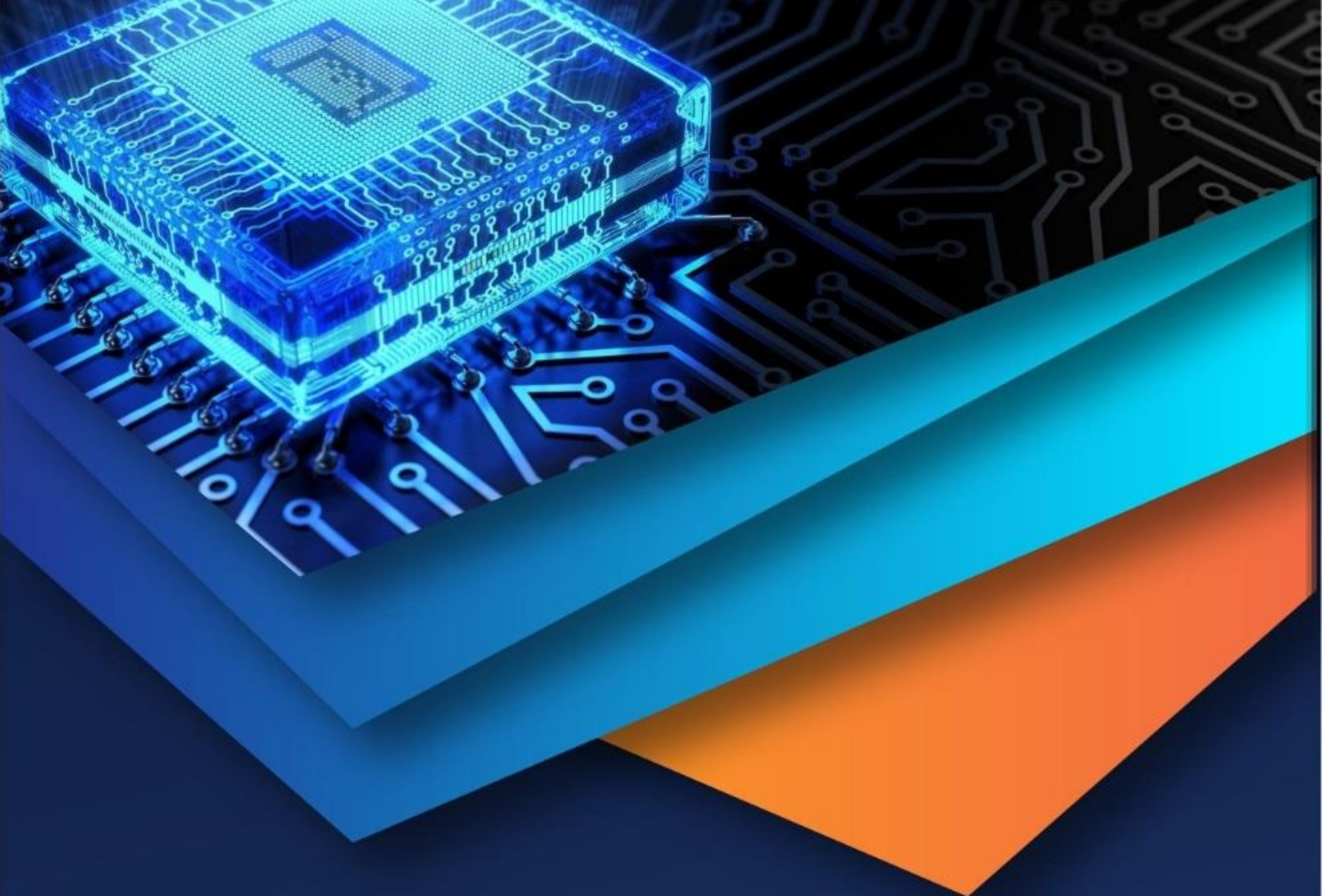

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