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Integral Sliding Mode Control: A Review of Applications

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Abstract

Integral Sliding Mode Control (ISMC) has emerged as a robust and efficient method for handling nonlinear systems with uncertainty, turbulence and external disturbances. This study provides a detailed review of ISMC and its design foundations, design methods, practical application aspects and recent developments are included. ISMC design methodology is explored, to be extended with various design methods with different design methods. Recent advances in research, chatter reduction techniques, applications in specific areas, theoretical design advances, or comparative analysis with other control methods in addressing the challenges associated with ISMC are discussed in this study. Practical aspects of ISMC applications are discussed, including actuator saturation mitigation, robustness to model uncertainties, and sensor fusion techniques. Furthermore, various applications and case studies in various industries are presented to demonstrate ISMC efficiency and performance of complex problem solving. The effectiveness of these improvements are scrutinized, such as crime and the complexity of their controls. In addition, the study discusses the potential of ISMC in various applications and identifies promising future research directions in this policy topic. Finally, recent developments and possible future research directions in ISMC are outlined, highlighting topics such as ISMC with specialized systems, distributed ISMC, artificial intelligence, and emerging technologies such as the Internet; an integration will be emphasized.

Keywords: Integral sliding mode control, sliding mode control, radial basis functional neural networks

INTRODUCTION

Classical control techniques such as proportional integral derivative (PID) control often struggle with nonlinear systems and uncertainties. Sliding mode control (SMC) emerged as a powerful tool to control such systems, providing resistance to disturbance. ISMC eliminates the acquisition phase of SMC by ensuring that the system trajectory remains on the predetermined sliding surface from the beginning and greatly reduces distortion. This review work explores recent developments in ISMC system internally, analyzes its application in various industries, and compares its performance with other control techniques. ISMC allows the system to start with a sliding surface, which eliminates reach step and simplifies controller design into recent advances in research, focusing on gossip reduction techniques, applications in specific areas, theoretical design advances, or comparative analysis with another methods' implementation.

The challenges of ISMC, a control method that eliminates the reach phase and offers advantages over traditional sliding mode control is examined. This method aims to provide the system stability and reduce unwanted oscillations, ultimately enhancing control performance. In addition, the study explores the global SMC concept and challenges associated with super twisting and

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higher order ISMC design [1]. The ISMC design aims to reduce transient voltage drops, improve recovery time against load resistance variations, and reduce current total harmonic distortion (THD). Experimental results show that ISMC based on DPC system is more efficient and higher compared to the PI-based approach where the system consists of power control loops, voltage regulation loops, and voltage balancing loops; the power monitoring loop is equipped with an extended state observer (ESO), while voltage regulation loop radial basis to calculate load variation and maximize disturbance and rejection using Radial basis functional neural networks (RBFNN) [2]. The ISM based yaw moment control formulation, robustness of ISM control structure against discrete implementation, and experimental validation in two-wheeler electric vehicle includes simulation models of chassis, electric drivetrain, and vehicle communication bus. The effect of operating system dynamics on control system performance is investigated through simulation of ramp steer and step steer maneuvers. The main parameters, control actions, and experimental results associated with the ISM controller [3].

This application of integral sliding mode control for yaw control in four-wheel drive vehicles includes information on control structure, torque-vectoring controller, and comparison with other control methods such as PID with feedforward (PID FF) component. The study uses simulation in Carmaker to analyze performance, focusing on stability and chatter avoidance [4]. Full sliding mode method of direct torque control (DTC) of asynchronous motor drive, especially integral sliding mode direct torque control (ISMDTC) is proposed to ensures power, fast response and reduced ripple comparatively. It incorporates a sliding-mode supervisor for sensor less operation, maintaining accuracy and robustness at low speeds [5]. Research on control robotics focuses on integral sliding mode control (ISMC) for robustness against parameter uncertainty in bicycle mobile robots. Their work includes the development of a linear controller to stabilize sliding manifolds, flat-inclined with specific information about wheel and pendulum motion by calculating accurate statistics for control system efficiency and support research to advance control strategies for under activated systems especially in the case of mobile robotics [6].

ISMC is used in an induction motor (IM) vector control system to control the stator current components and reject disturbances. The proposed controllers aim to increase the accuracy and stability of the regulator through integral sliding surfaces. It improved performance in terms of speed control, rotor flow control, and stator current monitoring compared to proportional integral (PI) controllers with ISMC regulators offering smoother control actions and better dynamics, and enables precise control of rotor flow for high-speed operation [7]. It focuses on digital applications of inverter systems, current control of grid-connected inverters using integral sliding mode control for improved dynamic performance, describes discrete sliding mode control systems including ISMC, resonance compensation and supervisor for grid-side current control. Furthermore, it discusses the importance of LCL filters in grid-connected inverters for harmonic attenuation and resonance suppression [8]. A robust method of nonlinear hybrid control to control the speed of a discrete DC motor (SEDCM) with Adaptive Backstepping Integral Sliding Mode Control (AB-ISMC) proposes to increase system performance by reducing chatter, improving settlement time, and reducing steady-state error. SEDCM parameters are comprehensive, and they study the importance of accurate modeling and control for complex system dynamics and different parameters [9]. The ISM controller closely monitors reference understeer characteristics, providing stability and resistance to unknown forces and disturbances. The high-level controller distributes the yaw moment between the wheels by considering drivetrain limits and friction coefficients. The design of the ISM controller incorporates parameter tuning for stabilization and synergy with the PID controller, ultimately increasing vehicle safety and performance during ramp and step steer maneuvers, and exhibiting improved cornering stability [10].

Through its basic principles, applications and explored utility, it is clear that ISMC offers a robust and effective method to solve the challenges posed by unrealistic nonlinear systems. Seamlessly integrating integral action with sliding mode control, ISMC exhibits enhanced performance, robustness and stability for a wide range of industrial applications.

BACKGROUND ON INTEGRAL SLIDING MODE CONTROL (ISMC)

CORE PRINCIPLES AND STRATEGIES

Sliding mode control (SMC) is a popular technique for nonlinear design because of its ability to handle uncertainties. However, SMC cannot guarantee any changes in the receiving category. Integral SMC addresses this issue by removing the received phase, ensuring no change in the overall response of the system. ISMC is a kind of global SMC and can be used for affine control nonlinear systems confusing and uncertain. It includes state vector, many nonlinear functions, control gain functions, control inputs, and unknown perturbations due to nonparametric uncertainties. Modification of integral sliding variables in ISMC is unnecessary and actually degrades the efficiency of sliding mode. ISMC can be considered as a kind of SMC general-purpose control (GSMC). Higher order ISMC designs with super twisting can lead to impossible stability conditions. A low-pass filtering solution can be used to reduce the chatter in ISMC without changing the integral sliding variable [1]. ISMC is a control strategy used in power transformers, especially three-stage neutral point clamped (NPC) transformers. It is designed to improve system efficiency by strengthening power management, energy management, and energy balancing objectives. The control system consists of three main components: power management loop, energy consumption planning loop, and energy balance loop (ESO) based ISMC strategy is applied. The voltage regulation loop uses radial basis function neural network (RBFNN) based adaptive integral sliding mode control (ISMC) strategy to control DC link voltage. A proportional integral (PI) control strategy is applied to the voltage balancing loop to achieve voltage balance between the two DC-link capacitors. The efficiency and superiority of the proposed ISMC-based control strategy for NPC converters are verified through experimental results [2].

ISMC is a technique used to control torque vectoring (TV) for fully electrified vehicles. It is based on the Integral Sliding Mode (ISM) design. The performance of the ISMC controller is evaluated under steady-state and transient conditions, including assessment of its performance degradation due to real-world application-related problems as an operational delay due to the drivetrain, signal disconnection, and vehicle communication bus. The possible issue of chatter and irregular control action, characteristic of sliding mode formulations, is addressed in the ISMC controller design. The ISMC controller is experimentally evaluated under an ideal electric vehicle demonstrator-shows significant performance enhancement [3]. The control strategy used in full electric vehicles with individual controlled motor drives provides vehicle safety and controlled performance. It is a control formulation based on vehicle yaw balance equation, allowing continuous operation of direct yaw control. ISMC makes it easier to usability, robustness, and tunability, which make it suitable for real vehicle applications. ISMC offers significant advantages over traditional control methods, such as combined feedforward and proportional integral-derivative (PID) controllers, with high tracking performance and disturbance rejection properties. Different operating conditions are developed for ISMC analysis, and gain is decided to improve the underlying controller performance [4].

ISMC control technique is used in induction motor drives for direct torque and flow control. It combines integral sliding-mode control with a speed sensor-less sliding-mode monitor. The ISMC is threaded in a stator-flow reference frame and requires no current regulators. It optimizes rotor speed without stator flow, torque and provides estimates values. ISMC controls the robustness of the sliding controller and reduces steady state chatter. It provides similar performance to the more complex second-order sliding mode control (SMC) but with easier implementation. ISMC ensures high accuracy and robustness in low-speed operation and parameter deviations throughout the entire operating range of the induction motor drive. A comparison with conventional direct torque control (DTC) has been made to demonstrate its effectiveness [5]. It is suitable for inefficient system control because there is additional freedom in control when sliding mode is reached the stage then process is changed. The sliding surface is designed to handle uncertainty and is defined by projection vector and nominal control. The adjustment term is used to nullify the effects of congruent uncertainties and reduce the effects of incongruent uncertainties [6].

This control method is used for induction motor (IM) stator current in the field of industrial control systems. Developing a d-q synchronous reference frame using indirect field-oriented control (FOC) method to provide and accuracy of regulators. The position of each loop is expressed by Lyapunov method, which ensures asymmetric tracking of stator currents. Compared with traditional ISMC and PI regulators, the proposed controllers now provide flexible control actions with good dynamics. ISMC also enables precise control of the rotor flow, so that the motor can drive speeds above the rated value using the rotor flow attenuation method [7]. This control scheme for eliminating the negative effects of parameter changes and distorted network conditions in a grid-connected inverter. It is based on the concept of sliding-mode control, which aims to affect and control the system conditions upon sliding previously defined surface. The integral sliding back function is used to eliminate the steady state error and can be discretized in discrete time domain. ISMC is known for high monitoring performance, robustness and good harmonic compensation ability. Chattering phenomenon, which current-induces harmonics and increases power losses can be eliminated by using a quasi-sliding mode method [8].

ISMC blends the benefits of integral and sliding mode control. It effectively handles systems exhibiting nonlinear behaviors. ISMC finds applications in industries like robotics, aerospace, and power systems. It utilizes a mobile component to address external interference, making the system robust despite uncertainties. Additionally, ISMC employs optimization techniques to dynamically adjust control parameters. These adaptations, coupled with structural alterations, enhance its resilience to uncertainties [9]. The ISMC algorithm manages all electric vehicles with torque vectoring capabilities. It relies on sliding mode control, guiding the system's state towards a predefined "sliding surface". ISMC excels in this context due to its simplicity and resilience to model uncertainties. With only two adjustable parameters and no need for a state observer, ISMC is user-friendly. It leverages common industry standards, yet achieves accuracy and reliability even without them. By incorporating a suitable filter function for the discontinuous control process, ISMC effectively reduces noise and vibrations during reference tracking [10].

The basic principle of ISMC revolves around sliding surface design that achieves and rides the system state, ensuring desired system behavior. Unlike traditional sliding mode control, ISMC eliminates reaching phase, simplifies controller design and it gives system trajectory from origin on sliding surface. It demonstrates the ability to eliminate defects, ensuring accurate monitoring of the desired system results. With this basic understanding of the principles of ISMC, we can delve into its applications in various industrial fields in.

METHODOLOGIES USED IN VARIOUS FIELDS

In modification of integral sliding variables in ISMC proves unnecessary because it degrades the performance of sliding phase. ISMC is a kind of global sliding mode control (SMC). It is suggested that a high-order ISMC design with super twisting involves a stability condition that may be infeasible in theory. An effective solution to reduce chatter in ISMC without compromising tracking accuracy, extended to uncertainty in control gain functions. ISMC design to simplify depiction in class of perturbed-uncertain affine-in-control nonlinear systems is presented [1]. ISMC based direct power control (DPC) scheme for three-layer NPC converters is discussed here. The ISMC algorithm consists of an ESO based ISMC algorithm for a power monitoring loop, a RBFNN based adaptive ISMC algorithm for a voltage regulation loop, and a proportional-integral (PI). ESO is used in the power control loop to reduce the effect of uncertainty. RBFNN is used in voltage regulation loops to calculate load changes and feed the system; the ability to reject violence is effective. Adaptive rules are used in the controller to reduce power chatter, which helps to reduce the current coherent distortion. PI control strategy is used in the voltage balancing loop to achieve voltage balance only in a DC-link between two capacitors [2].

The development and implementation of yaw moment controller is based on Integral Sliding Mode (ISM). This controller aims to combine robustness, ease of assembly, and simple practical application for electric vehicles. The effect of operating system voltage, input/output signal delay, and disconnection on control system performance over the four-wheel-drive sport utility-electric vehicle model are described. Different techniques, such as ramp-steer and step-steer sequence, were developed to investigate the response of the controller under various conditions. It also compares the ISM controller with other feedback control structures for vehicle yaw moment control, including second-order sliding mode formulas which include control allocation algorithms. Detailed simulation models of chassis, electrical drivetrain, and vehicle communication bus were developed to evaluate ISM controller performance. Accurate system planning is required for planning sliding mode controllers to eliminate chatter and ensure proper control [3]. The performance analysis of the control structure is carried out by vehicle dynamics modeling using Carmaker model. The model considers spring and upsprung mass dynamics, suspension elastic dynamics, tire modeling and Pacejka Magic Formula. It includes comparison of the proposed ISM controller with PID FF controller combined with basic vehicle without any controller. Performance specifications are tested under uncertainty and disturbance under nominal conditions [4].

The implementation of integral sliding-mode direct torque control (ISMDTC) for induction motor drive mode of control is designed in the stator current reference frame without the current regulators. It incorporates a sliding mode monitor without a speed sensor for stator flow and torque estimation. ISMDTC looks robust, reduces confusion, and provides easy implementation compared to traditional methods. Simulations were performed using MATLAB and SIMULINK software tools to demonstrate the efficiency of the ISMDTC. The system parameters were recorded, and a sensor less sliding-mode observer was adopted for accurate estimation. The Lyapunov method was used to investigate the stability of the displacements. Furthermore, the SMO algorithm was used to eliminate the rotor speed optimization and improve the accuracy of the calculation in sensor less low-speed operation [5]. The methods include the design method starting from 2 WMR dynamic model introduced to establish the system behavior. ISMC design is elaborated, describing control system of monitoring under activated 2 WMR system and setpoint control, then comprehensive simulation investigation to validate effectiveness of proposed controller is carried out, after which ISMC is practically applied on real platform to monitor its performance in the ground state [6]. An advanced control method for the electric current in an induction motor, is known as ISMC. The ISMC technique operates within a rotating reference frame and utilizes an indirect field-oriented control (FOC) approach to enhance accuracy. Stability analysis is performed using Lyapunov's function method, which ensures the stability of controllers that include an integral component on the sliding surface. The proposed control methods are validated through simulations and experiments involving a commercial induction motor. The experimental setup consists of a DS1103 card, a high-performance real-time interface, and a PC running dSControl software for observation and validation. MATLAB/Simulink and dSControl software are employed for control and monitoring purposes, interfacing with the real-time system [7].

The current control scheme of LCL-filtered grid-connected inverter is based on discrete integral sliding mode control (ISMC) and resonance compensation. The proposed scheme consists of three control loops: cascaded and grid-side current control and capacitor voltage multi loop structure is used for control, and inverter-side current control. An active damping method is used to prevent the resonance caused by the LCL filter, which is achieved through an inverter-side feedback control loop. Island mode grid-connected on mode Seamless transfer operation is possible in f capacitor voltage control loop. Proposed current controller combines robustness of ISMC with high tracking performance and good harmonic compensation capability of resonance control (RC) system [8]. An adaptive backward step integral sliding mode control (AB-ISMC) method for speed control of multiple input and multiple output separately excited DC motor (SEDCM). AB-ISMC Technical Adaptive combine back-phase gain (AB) with integral sliding mode control (ISMC) to increase system robustness. Optimization rules are used to account for unknown parameters and load disturbances, which are then incorporated into controller design. Lyapunov stability criteria are used to verify the stability of the system. Simulation parametric uncertainties load disturbance F is performed to demonstrate the efficiency of the proposed AB-ISMC to track the reference velocity. The control performance of the proposed method is so compared with feedback linearization (FBL), conventional sliding mode control (SMC), and without optimization rule and AB control rules to analyze the tracking performance and robustness of performance of the system [9].

An integral sliding mode algorithm for the yaw rate control of a torque-vectoring fully electric vehicle with individually controlled motor drives presented. The control scheme and integral sliding mode formulation is derived from the yaw equilibrium equation of the vehicle. The simulation results are used to evaluate controller performance against baseline vehicle performance during ramp steer and step steer maneuvers. The model of the car is used within the automaker, where the spring and non-cracking mass of motion, suspension Erasto-gate science, the Pacejka magic formula is also verified by Lommel certified test results; and in any case, the mass moments of inertia and the efficiency of the drivetrain components are considered in the model. The battery model includes temperature effects and responses to emergency energy demands. The torque distribution in the four wheels is done by an algorithm based on simple rules at the higher level of the yaw rate controller [10].

We emphasize that changing different access methods can speed up the system's response to an application requirement. Additionally, control rule design is key to achieving optimal application performance. ISMC can be effective in a variety of industrial applications if control parameters are carefully selected and factors such as how quickly the system changes and the need for maintenance are considered. By providing clear reporting and following strict scientific methods, researchers empower the advancement of knowledge within their respective areas of study. This allows for more foundation for future research endeavors.

MATHEMATICAL FORMULATIONS FOR ISMC DESIGN AND ANALYSIS

To fully understand the real-life applications discussed in this review, it is important to understand the mathematical principles underlying Intelligent Structure Motion Control (ISMC) design and analysis. These mathematical simulations help us understand how ISMC manages non-linear systems.

System dynamics is usually represented by differential equations describing the state dynamics of the system. These equations can be linear or nonlinear depending on system complexity, here the general representation is:

$$\dot{x}(t) = f(\dot{x}(t), u(t)) \tag{1}$$

- x(t) is the state vector of the system at time t.
- ẋ(t) is the time derivative of the state vector, representing the rate of change of the states.
- f(x(t), u(t)) is a vector-valued function representing the system dynamics. It depends on the current state (x(t)) and the control input (u(t)).

The tracking error (e(t)) is defined as the difference between the desired state (reference) trajectory (x_d(t)) and the actual system state (x(t)):

$$e(t) = x_{d(t)} - x(t) \tag{2}$$

The core concept of ISMC revolves around the sliding surface (s(t)), a function designed based on the tracking error and its derivatives. The system trajectory is driven to reach and remain on the sliding surface (s(t)=0). The specific design of the sliding surface function (s(t)) depends on the desired system behavior and dynamics.

$$s(t) = g(e(t), e(t), \dot{\ldots}.) = \theta \tag{3}$$

- g(e(t), ė(t), ...) is a function of the tracking error (e(t)), its derivative (ė(t)), and potentially higher-order derivatives depending on the design choice.

The control law in ISMC incorporates the equivalent control (u_eq(t)) and an integral term of the tracking error to eliminate steady-state error. This is the key advantage of ISMC over traditional sliding mode control. Here is a general form of the control law (Eq. (4)):

$$u(t) = u\_eq(t) + k\_i \int e(t)\, dt \tag{4}$$

- K_i is the integral gain, a design parameter that determines the convergence rate and robustness of the control system.

Here, in Eq. (5), the integral sliding variable, denoted as s0(e), is a key component in ISMC for achieving invariance in the entire system response. It is calculated as the integral of the tracking error e, multiplied by a gain matrix [LT 1]. The integral sliding variable plays a crucial role in ensuring the stability and performance of the sliding mode control system [1].

$$s(t) \ = \ s_0(e) \ + \ z(t) \tag{5}$$

Eq. (6) describes the relationship between the sliding variable (s) and the estimated disturbance (-hd) in an integral sliding mode control (ISMC) system. The equation shows that the sliding variable is the control gain function (ks and a), system dynamics (fa(x) and fb(x)), the control input is affected by disturbances estimated by different terms such as (u1). The analysis of Eq. (6) shows that a considered large disturbance can cause large amplitudes in the left-hand side of the equation, which can affect the performance of the sliding mode control system [1].

$$\ddot{h}(x,t) = fa(x) + fb(x)(f\ (x) + g(x)u0 + d(t)) + \dot{d}(t) + fb(x)g(x)u1 \leq \bar{h}d \tag{6}$$

Eq. (7) describes the dynamic response of the power tracking error (e) in terms of time. It provides an exponential decay model for the power tracking error, where the decay rate is determined by the parameter x1, L (inductance), and the square of the voltage amplitude (vab^{2k1t}) [2].

$$e = e(0)e^{(-\frac{x1}{2L}\left|\left|v_{\alpha\beta}\right|\right|2k1t)} \tag{7}$$

Block diagram of the proposed integral sliding mode control (ISMC)-based direct power control (DPC) strategy for a three-level neutral-point clamped (NPC) converter as shown in Figure 1. This shows the control structure and control loops involved in the system. The block diagram shows the power monitoring loops, voltage regulation loops, and voltage balancing loops, which are required to achieve the desired NPC converter Extended state observer (ESO) performance to reduce parameter uncertainty in ISMC-based DPC strategy, radial for calculating load fluctuations. The basic applications include a neural network (RBFNN), and a proportional integral (PI) control strategy for voltage balancing. Figure 1 provides a visual representation of the proposed control strategy, focusing on connections between the control loops [2].

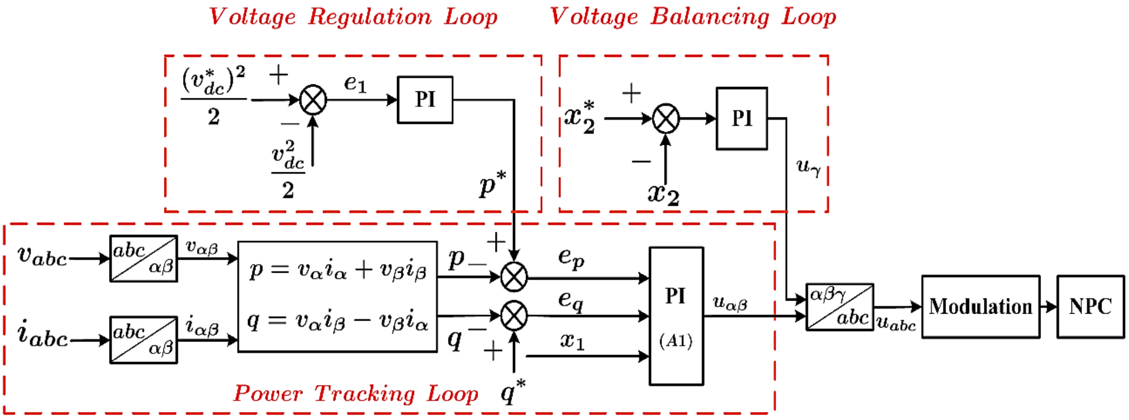

Figure 1. Control structure of PI based DPC.

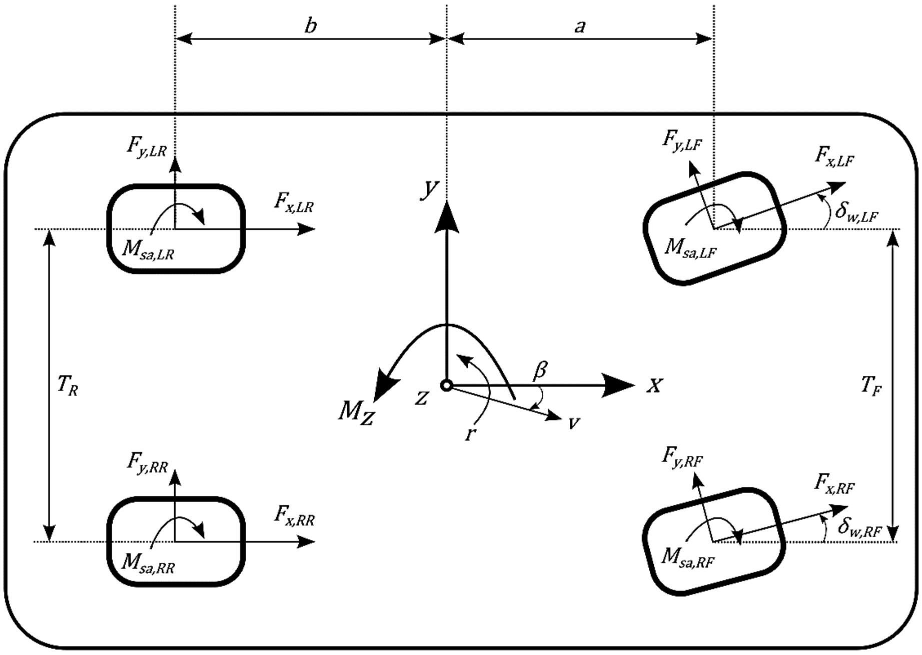

Figure 2. Top view of the car.

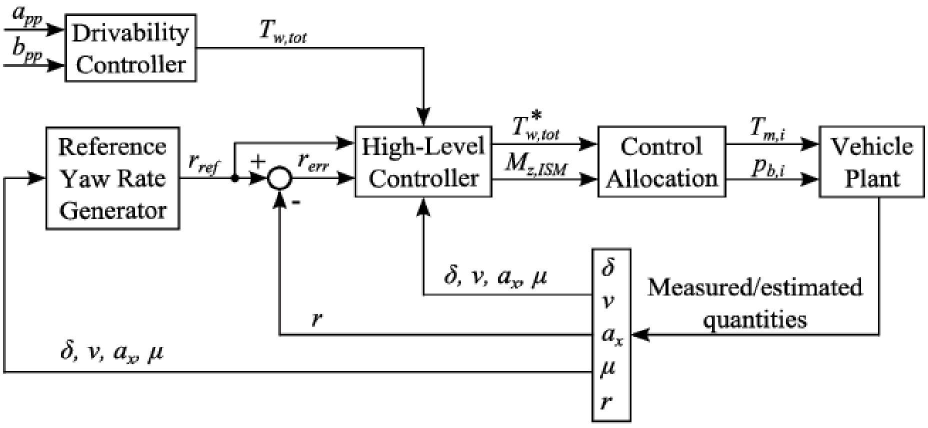

Figure 3. Schematic of the overall control structure.

Table 1. Main vehicle parameters.

Symbol	Description	Value
J_z	Yaw moment of inertia	2995 kgm^2
a	Front semi-wheel base	1.05 m
b	Rear semi-wheel base	1.59 m
T_f	Front track width	1.63 m
T_r	Rear track width	1.64 m

Figure 2 represents the top view of the car. It shows the various components and parameters of the vehicle, including front and rear half-wheel bases (a and b), front and rear track widths (Tf and Tr), and yaw moment of inertia (Jz). The main parameters of the vehicle, such as yawing moment of inertia and half-wheel edges are listed in Table 1 [10].

Figure 3 in the provided sources illustrates the overall control structure for torque-vectoring in fully electric vehicles. The high-level controller compares the reference yaw rate with the actual vehicle yaw rate to produce a yaw rate error, which is used to compute the reference yaw moment and overall wheel torque. The torque distribution is achieved through a simple rule-based algorithm, although optimization-based methods are also possible [10].

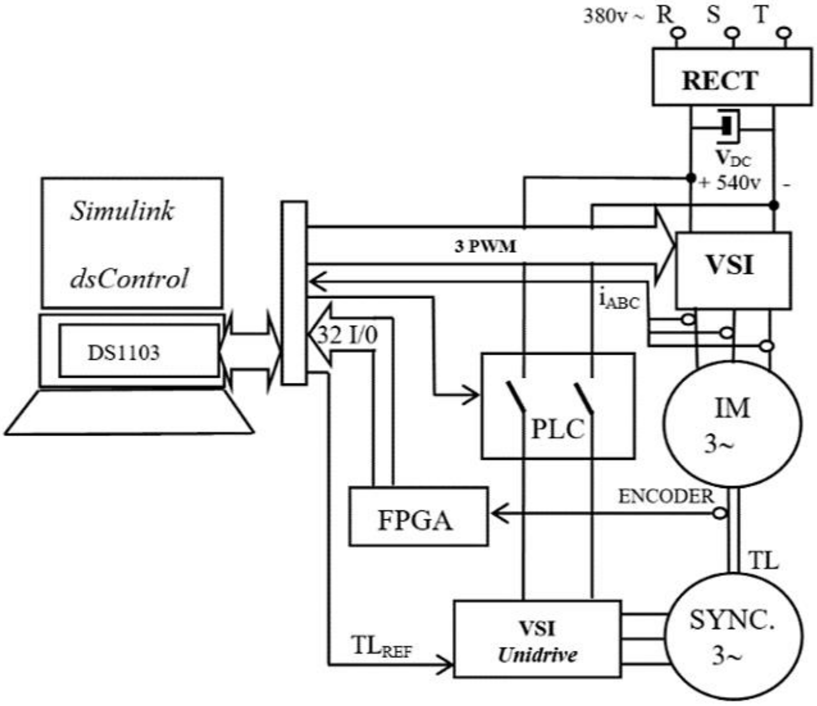

Figure 4. The Blocks diagram of the IM experimental platform.

Figure 4 shows a block diagram of the experimental platform for paper-based IM. The platform consists of a DS1103 card, a real-time interface connected to a PC, and various components such as an inverter, a motor, a power block, and so on. The DS1103 card contains uP PPC from Motorola, DSP for SVPWM generation, DA channels, and AD channels. dSControl software is used to monitor signals and conversion during actual testing and compare with Simulink counterpart. Power section is DC bus, inverters for controlling motors, and a capacitor bank [7].

The data presented provided valuable insights into the use of ISMC to control systems such as robot manipulators, industrial processes, etc. This data visually demonstrated how ISMC addresses specific control challenges' role in any application, in addition to obtaining fast monitoring response, reducing disturbances and maintaining desired system output; of system dynamics, sliding surface design, and mathematical framework proposed for control law formulation gave reasonable foundation on the basic principles governing ISMC. Moving forward, further research may seek to combine ISMC with intelligent strategies or develop application-specific design strategies to drive business up and expanding its operations in emerging areas.

DISCUSSION AND FUTURE DIRECTIONS

The proposed chatter reduction solutions need to be validated by using experiments to evaluate their effectiveness in real-world applications. The stability of higher order ISMC configurations with super twisting should be analyzed in detail in order to determine its feasibility in principle and possible modifications to improve its performance. Future research should focus on developing advanced techniques for ISMC that overcome the limitations of conventional sliding mode control and provide better performance in the presence of uncertainty. The use of sliding mode observers (SMOs) to estimate the state vector in systems with only partial measurements could be further explored to enhance the utility of the ISMC. Applications of the proposed control system to other power transmission and energy conversion systems should be investigated to ensure efficiency and effectiveness. Explore the potential of combining advanced optimization algorithms or machine learning methods to further improve the control strategy's performance and robustness. Comparative analysis with other existing control methods to verify the efficiency and superiority of the proposed system is emphasized.

Further optimization and tuning of ISM controller parameters to enhance its performance over a wide range of driving conditions and vehicle dynamics presented. Expanding testing studies in real-world driving conditions and road conditions to prove controller robustness and effectiveness in applications in the workplace. To extend the certification of the ISM controller to electric vehicles, such as passenger cars, commercial vehicles, or electric race cars, in order to ensure suitability and performance on different platforms. Investigating the impact of the ISM controller on energy efficiency in electric vehicles and strategies to optimize torque distribution for improved range and battery consumption. Future research will focus on investigating the effect of measurement noise on the ISM controller response. Understanding how measurement noise affects controller performance will be important for real world applications. Ongoing research aims to increase controller robustness by investigating integral sliding mode of concurrent yaw rate and sideslip control. Profitability decision strategies to improve controller performance under a wide range of operating conditions will also be explored. Find advanced control techniques such as second sliding mode control, internal model control, model predictive control, linear quadratic regulation, and optimal control for improved vehicle performance. Control System Performance country integrated statistical methods to improve robustness, especially in the absence of a state estimator. Focus on optimizing wheel torque distribution in all-electric vehicles with multiple drivetrains to improve stability, and control. Consider adding technologies and processes, which dramatically improve power management stability and overall performance. Investigate control strategies that will improve vehicle stability by considering factors such as tire force distribution and uncertain operating conditions.

CONCLUSION

This review work examines the various applications of Integral Sliding Mode Control (ISMC) in engineering fields. ISMC is a control technique suitable for nonlinear systems, and its advantages include eliminating steady-state errors. Its effectiveness has been demonstrated in applications such as controlling movements in robot manipulators, and optimizing industrial processes. In each case, ISMC addresses specific control challenges, proving its robustness and flexibility. Studying specific examples and mathematical equations helped us better grasp how ISMC works and its fundamental ideas. While acknowledging ISMC's limits, such as possible chattering and design constraints, the discussion explored potential future research paths. These include reducing chattering, creating design methods specific to applications, combining ISMC with advanced control techniques, and using ISMC in emerging areas. In summary, ISMC has proven to be a powerful and effective control method for systems with complex behaviors. Its successful application in diverse engineering fields and its potential for future advancements make ISMC a valuable resource for researchers and control engineers. As ongoing research focuses on addressing limitations and expanding its capabilities, ISMC is expected to continue playing a significant role in the precise and dependable control of complex systems in the years to come.

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