CHAPTER 2 LITERATURE REVIEW

The chapter discusses various literature review related to automotive power window in the field of Mathematical modeling, Simulation, hardware development, control system, algorithm development, Software in the loop testing and Hardware in the loop testing techniques.

2. 1 Detailed Literature Survey

The section presents the several design aspects, reviews, surveys about mathematical modeling, motor model, software in the loop testing, hardware in the loop testing and control algorithms which have been used in modeling and validation of power window system time to time. The detailed survey from some research papers is presented.

Prawoto, Y et al. [5] discussed the common failures of the power window mechanism and explains manufacturing process and another finding is since gear is coupled to the linkages and generally stall torque is higher in magnitude leads to cracks on the linkage and finally with respect to time failure of the system. This paper outlines simplified manufacturing process and common failures of the mechanism.

Sameer M. Prabhu et al. [14] This paper outlines the conceptualization and implementation process of the electromechanical system using a model-based design and development approach in combination with modern tools. Another key finding is embedded systems development process through mathematical modeling and auto code techniques from conceptualization to implementation stage.

M.A. Dehghani et al. [16] This paper proposes hardware in the loop simulation testbed using airborne seekers (an onboard visual tracking system) as a relative measurement sensor in the leader-follower formation flight. The

projected system explains uncertainties in the camera processing delay and various measurement noises.

Binglin Li et al.[17] The paper analyzed the prerequisites of smart windows in savvy structures, joined with PLC high unwavering quality, propelled control innovation and touch screen's interface, simple and adaptable setup programming. The detailed design of intelligent window control system with respect to working principle, software program, hardware development and its control algorithm are discussed.

A. Ebner et al.[18] authors explains a hybrid PID (Proportional-Integral-Derivative) controller for battery management system. Also explains particle swarm optimization (PSO) established control arrangement for Battery Management System to minimize energy consumption. For high-quality solution, author explains fast tuning feature of optimum PID controller.

Yingjie Zhang et al.[19] Paper explains how to solve the risk of safety effectively in power window system with improved pinch detection algorithm is used. Another finding is different estimation techniques are proposed in the development of anti-pinch based power window control techniques. Smart Anti-pinch technique (Hall effect Vs Current measurement).

Sarhadi, Pouria et al.[20] In the paper, an adaptive reference novel model controller is proposed for an autonomous underwater vehicle (AUV) with anti-windup compensator (MRAC AW). Parametric uncertainties and input saturations are most common practical problems in the development of control techniques for autonomous vehicles. Hardware in the loop based design and development of a novel adaptive control technique with dynamic anti-windup is discussed.

Li Hongqiang, et al.[21] Research paper explains model-based design of power window system with respect to error detection of the anti-pinch system. This study also explains Electronic Control Units (ECU) design and development of Body Control System of EV i.e. Electric Vehicles. The research work is

classified into two domains: The model based design and analysis of fault detection for anti-pinch window and CANopen application layer protocol.

Xiaogang Yu et al. [22] The study introduces anti-pinch window control system design using different methods of LMI-based designing for robust error recognition using a H_∞ filter. The research proposes pinch torque rate recognition algorithm constructed on H_∞ filter. Based on MATLAB simulation, the results show that fault occurrence after 70 milliseconds whenever algorithm detects faults. In addition to that the proposed algorithm, simulation model is having very high sensitivity to handle fault and strong robustness to uncertainties.

Dietmar Winkler et al.[23] Paper illustrates object-oriented modeling language using Modelica for the hybrid electric vehicle. Also explains test bench system simulation (real-time) in linking with a Hardware-in-the-Loop (HIL) testing. The paper also explains micro hybrid architecture associated with hybrid electric vehicle. Article also explains the offline simulations techniques used for early stage development process known as MIL(model in the loop) simulations. For electronic control unit (ECU) development it is a model of the function for its operation.

BOUSCAYROL, Alain et al. [24] Paper explains Software-in-the-loop simulation as well as Hardware-in-the-Loop simulation of the electromechanical system. Explain the significance of hardware-in-the-loop (HIL) and simulation in different vehicle applications.

Ari Hentunen et al.[25] A versatile full-scale HIL verification environment for HIL simulations of heavy-duty hybrid electric vehicles and work, machines were presented. Author also explains for rapid control prototyping model-based software development tools and hardware are used to implement control algorithms and other vehicle controller software as well as to control other test equipment.

R. A. Hanifah et al. [26] The article explains study on simulation for PSO-PID and PID for the development in term of current consumption and power

consumption of DC motor. The result of research article shows development in control of current and motor power is smooth with PSO-PID controller.

Xiaobin Ning et al.[27] explains dynamics simulation of regenerative braking in terms of feasibility of energy efficiency is studied in the research article. In the paper, modeling, and simulation of the electro-hydraulic regenerative braking system using AMESim is used. The main objective of this paper is to evaluate and establish recovery of hydraulic brake energy in electric bus. After evaluation report feasibility analysis of regenerative braking system is done.

Wahyu Kunto Wibowo et al.[28] Paper illustrates the load current based anti-pinch arrangement was proposed to make enhancements for control window framework. In this article Hall, IC current sensor is used for making anti-pinch system. A current sensor senses current flowing in the load circuit which is driving DC motor and the appropriate value is identified for threshold identification.

Levi Lucio et al.[29] This report is to illustrate the Model-Based Development of a simple automotive control system. Development of the software based system to control a power window system. In the report, author introduced model driven engineering technology for software development. Automotive power window software development is achieved using model driven engineering.

Junyeon Hwang et al.[30] In the paper, an LKAS (Lane Keeping Assistance System) the controller is designed in order to provide convenient lane keeping and to reduce driver workload. The proposed Lane Keeping Assistance System is constructed and evaluated using HIL simulator. Using camera images authors detected lane marker and simulated in Matlab/Simulink and carsim.

Yoann Nauel et al.[31] Paper explains a straightforward IP control execution has been intended for Induction machine drive frameworks in which IP filters are included an arrangement with the PI control reference esteems. Adjustable speed drives for induction machine are proposed for high-performance

applications. It is applicable to electric vehicle drive-trains for low-cost, maintenance-free operation and robustness system.

Christian R. Kelber et al.[32] Research articles explain validation techniques using Hardware-In-the-Loop testing for self-propelled agricultural machine. Also explain embedded electronics development using modern tool for the new self-propelled agricultural machine. Hardware-In-the-Loop (HIL) systems not only improve software validation coverage, but also guarantee that neither operator nor machine will be put in a risky situation during the field validation phase.

Martin Dendaluce et al.[33] The paper demonstrate, after a presentation into significant vehicle innovation angles concentrating on multi-engine powertrains, presents the advancement of a Torque Vectoring calculation and its usage, including race track testing comes about with vehicle furnished with Motors in Wheel.

Xiaoling He et al.[34] Paper explains in the hybrid electric vehicle (HEV) for special power control strategy using mathematical model and simulation is explained. A mathematical modeling of powertrain (parallel configuration) of HEV.is explained.

Jorge Varela Barreras et al.[35] Paper explains well-designed investigation of a BMS; basic LIB models are normally utilized as a part of hardware in loop simulation. The article illustrates state-of-the-art BMS system using hardware in the loop simulation of battery management system.

Casoli Paolo et al.[36] The algorithm has been developed for the in-cylinder processes simulation through the use of a variable time step in order to retain 1 degree CA during continuous variation in engine RPM.

Madhukar et al. [37] In this paper, authors explain Model-Based Testing of the miniaturized scale micro hybrid controller has been clarified utilizing dSPACE simulator. Also explains dSPACE based hardware in loop testing for Stop-Start controller to illustrate Functional tests and diagnosis procedure.

Vahid Izadi et al.[38] In the paper, a model for response wheels was portrayed by their general structure. Conditions administering on inner segments of the response wheel were exhibited.

A. Palladino et al.[39] Paper illustrates hardware-in-the-loop (HIL) simulation methodology for innovative controller approaches and diagnostic purposes on the inline vehicle networking protocol controller area network (CAN) controller which is tested easily on real-time platform to reduce efforts and time required for the testing phase.

Lu Yi et al.[40] In the paper, a rule-based energy supervision policy is used. In demand to verify the reliability and real-time performance of the advanced energy management strategy, the driver-in-loop's hardware-in-loop simulation platform is built.

Mehmed Yuksel et al.[41] Research article illustrates diverse test system is exhibited for testing a power prepare of this automated vehicle in HIL, as indicated by the genuine heterogeneous driving character of an electric vehicle.

S. H. Kim et al. [42] Paper suggests different regulation satisfying identical low-cost anti-pinch power window control system. Also explains anti-pinch based system motor speed and torque is calculated using hall sensors which are installed in a motor arrangement.

Sollmann, Matthias et al.[43] The article portrays the innovation and the utilization of material (pressure sensitive) hostile to squeeze frameworks and a non-touch (nearness detecting) framework which chips away at the premise of ultrasound. These frameworks are intended to be utilized as an additional option or notwithstanding circuitous, motor controlled against anti-pinch frameworks systems.

Wahyu, KW et al.[44] Control on revising the Federal motor vehicle security standard went for limiting the probability of death or damage from the incidental activity of power window frameworks.

Anthony M. Phillips et al. [45] A hybrid vehicle controller comprising of a state machine joined with dynamic control yields was displayed as the Vehicle System Control for the parallel hybrid electric vehicle. The state machine part of the VSC is used to manage the working method of the vehicle while the dynamic control calculations which part of algorithm serve to give smooth changes between states and accomplish the coveted vehicle reaction inside each state.

Zhang Xiaowei et al.[46] The paper explains, in a hybrid vehicle for controller design hardware in loop simulation (HILS) techniques are adopted. For the controller design which is used in a hybrid electric vehicle (HEV) the simulation results exactly match the HIL real-time simulation results. Both SIL and HIL exactly display the behavior of the vehicle and help in reducing the cost of vehicle controller as well as project development cycle.

Bruno Ando et al.[47] The paper proposes an instructive device made up of an easy to understand interface controlling exploratory boards. It fundamentally comprises of a variety of optical detecting sensors associated with appropriate conditioning circuits, which are interfaced to a virtual instrument by methods for an information procurement framework (DACs)

Doebelin, Ernest O Manik, Dhanesh N[48] This book discusses a comprehensive coverage of measurement systems, feedback systems, open loop control and closed loop control techniques.

Syed-Ahmad, N et al.[49] 1. In the article, DC motor model is simulated and implemented with respect to adaptive speed control. Different compensation techniques for load torque instabilities which diverge the dc motor speed. The methodology has three benefits: In the unit, circle locates closed-loop poles, Higher disturbance rejection is achieved as desired by the system and controller for the DC satisfies the system requirement without dead-beat.

Fang, J., et al. [50] The paper exhibits an effective technique for adjusting the attractive compass without the previously mentioned conventional necessities. The technique depends on the way that the mistaken model of the attractive

compass is an ellipsoid, and an imperative slightest square strategy is received to gauge the parameters of an ellipsoid by pivoting the attractive compass in different (arbitrary) introductions.

Hara, Y., et al. [51] The present invention relates to a digital processing for smoothly transmitting and receiving signals in wireless communications. Different calibration methods in communication technology.

Ramos, P.M et al. [52] The paper exhibits a technique to align current and voltage sensors exceptionally devoted to controlling quality estimations which can essentially diminish the distortion presented by the sensors.

Song, Y et al. [53] Decision tree approach is a regularly utilized data mining strategy for setting up classification frameworks in light of various covariates or for creating expectation calculations for an objective variable. Utilizing the training dataset for the development of decision tree classifier and implementing dataset to adopt the appropriate tree size required to attain the optimum ending prototype.

Muralidharan, V et al. [54] Paper explains vibration based methods is extensively used to convey condition monitoring tasks to the system. For the fault monitoring and condition monitoring the Decision tree classifier and machine learning based networks are used as the classification algorithm.

Freund, Y et al. [55] The paper explains an alternating decision tree algorithm (ADTree) is a machine learning methodology. It sums up decision trees and has associations with boosting. Decision tree nodes which are an integral part of An ADTree algorithm consists of decision nodes, which stipulate a establish condition and prediction nodes.

Lomax, S et al.[56] The previous decade has seen a huge enthusiasm on the issue of inciting decision trees that assess expenses of misclassification and expenses of obtaining the highlights utilized for decision making.

Naoki Abe Et al. [57] In this paper, the author presents a technique for binary classification algorithm which is multi-class cost-touchy learning algorithm

utilizing any paired arrangement calculation. The main idea of the algorithm is to deliver thee objectives: increasing data space, iterative weighting and gradient enhancing with stochastic groups

ZJ Bolton et al.[58] The task of a power window, sun rooftop or convertible top is ceased or hindered when a man is identified close to the vehicle keeping in mind the end goal to keep the individual from being harmed by the conclusion of with power window and sun rooftop. A motor, operatively coupled to move the window, sunroof or convertible top between open and closed positions responsive to a signal received by the motor from a motor controller.

Cao Xuwang et al. [59] Paper explains the usage of in vehicle networking protocol CAN bus topology for the system development is extended and network handling of the system is augmented. With help of L298 and LMD 18200 motor driver circuit different class of vehicle for different types and sizes of power windows. A different sensor like rain sensor, smoke sensor required to achieve automatic control for the windows.

2. 2 Literature Review Summary

In this section, all the referred article, patents, research paper, automotive electrical and electronics system and books are classified into following technology which are represented in Figure 2-1.

- Mathematical modeling
- Software in the loop testing
- Calibration Tool and Techniques
- Hardware in the loop testing
- Decision tree algorithm
- Measurement and Instrumentation

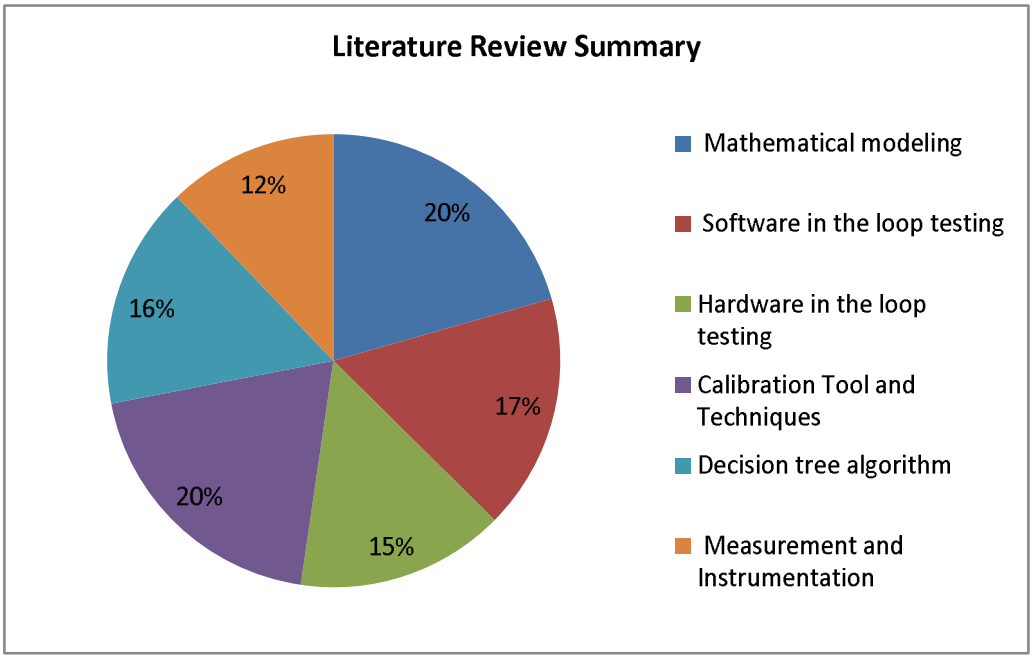

Figure 2-1 Detailed literature review summary chart

2. 3 Research Gaps

The section introduces automotive power system, covering model-based development, simulation model, hardware circuit, software in loop testing, Processor in loop testing and hardware in loop testing tools and technique for development of the system. As per literature survey and conventional power window product description in automobile following research, gap is identified:

1. A smart sensor based power window is required in all types of vehicles.

2. Anti-pinch or current sensor based system is required to avoid fatigue during power window upward and downward movements.

3. Advanced motor control algorithm is required for initial control of the system. Since DC motor rotor having ring gear and cross arm power window mechanism having pinion gear which gets coupled during on state and lifting happen in power window system, due to coupling of ring and pinion gear arrangement leads to cracks on the linkage, which further breakdown of the lifting mechanism of power window system.

4. Algorithm design for identifying valid or invalid force acting on the window and accordingly power window upward movement is restricted.

2. 4 Problem Statement

The various factors which influence the design of power window system are discussed. Also, model-based development using Matlab/Simulink and dSPACE tool (using ACE 1104) is examined which help to resolve the system development.

The automotive power window system has several mechanical and electrical components which are liable to uncontrolled variations. The characteristics of electrical or mechanical components should always lie within an acceptable limit. These part attributes drive the framework behavior and are identified with execution measurements by proper function. To fulfill the system performance, model-based design approaches satisfies performance requirements and make it robust against uncontrolled variations.

Model-based design approach and hardware in loop (HIL) technique based automotive power window fulfills performance constraints. It is accomplished by suitable sets of values through current sensor, flexi force sensor and with help of decision tree classifier design algorithm for the component characteristics (system parameters as a possible outcome) to bound the execution attributes as desired. The problem statement of the research work is given as **"Mathematical Modeling and Modern Control Based Validation of Automotive Smart Power Window"**

2. 5 Objectives

Based on problem statement and literature gaps identified, the objectives of the research are as follows

1. Formulate mathematical model based power window system.
2. Develop and analyze the control algorithm for smart power window application.
3. Validate the control algorithm response output on the power window hardware system.