Modeling and Simulation of Platform Screen Door (PSD) System using MATLAB-SIMULINK

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***Abstract*— In this paper, electromechanical modeling of an industrial platform screen door (PSD) system has been developed. The system incorporates several sub-units such as PMSM, motor controller, inverter, and mechanical unit. Moreover, a newly designed motor control system based on real operation conditions is introduced. In addition, modeling procedures are described, and simulation results are presented. Furthermore, numerical simulation in accordance with specific velocity and position references are provided for verifying the effectiveness of the proposed modeling. Furthermore, the results show that the developed electromechanical model of PSD system is effective in managing the parameters that affect the actual operating state of the PSD sliding door system. These modelling and simulation will play an important role in increasing the PSD design capability for real applications.**

Keywords—platform screen door, sliding door, control, modeling, simulation, Simulink

I. INTRODUCTION

Platform Screen Door (PSD) system is a sliding barrier door installed on the sides of station platforms in many modern metro stations [1] and in many RBT (Rapid Bus Transit) stations [2]. PSD systems are called safety-critical systems, and they serve many functions, such as, optimization of station energy consumption, air quality control, suicide prevention and safety, especially by protecting passengers from access to train tracks [3].

The PSD system plays a role of not only providing barrier between platform and train truck but also safe boarding of the subway. Therefore, the PSD system for subway stations is rapidly spreading and being installed nowadays. In the last decade, research has investigated the effect of PSDs on environmental conditions of station [4-6], air leakage [7], energy consumption [8,9], dwell time [10], and emergency evacuation [11,12] and safety [13]. These studies include various research methods such as simulation, calculation, modeling and experimental. None of these studies are related to mathematical modelling and simulation of PSD itself. One of the very limited studies in the literature is the mechanical structure analysis and simulation studies of PSD based on the finite element method [14]. In this study, the authors have presented finite element simulation of PSD structure with theoretical references supported by experiment.

In the literature, several researchers have focused on the modeling and simulation studies using MATLAB/Simulink, which provides a single, integrated simulation environment to model and simulate, for the different concepts of railway sector. Computer simulations, including mathematical modeling, can be used to enhance understanding of mechanisms in various applications such as train vehicle dynamic [15], transient skin effect [16], pantograph arc location [17], and electric train modeling [18] for the railway sector. However, even though many researches have been carried out to model and simulate the train door system [19, 20], there is no published material modeling and simulating of overall PSDs as electromechanical system, including electrical control, motor, and mechanical sub-systems. In this work, entire PSDs system combined with the electromechanical model for the opening/closing function of the door is mathematically represented and implemented using the MATLAB/Simulink environment. The advantage of this study is that it provides component libraries and analysis tools for modeling and simulating electrical driving and controlling the PSD sliding door system. It offers models of electrical driving components, including PMSM motors, encoders, and electric drives, as well as mechanical load.

In the literature, there are some studies on the control, simulation and modeling of train door systems [19-21] and automatic sliding door systems [22-24]. In particular, more studies have been carried out on the simulation and electronic realization of sliding door systems. In these studies, the operational analysis was made by modeling the components consisting of sensors, control unit, motor driver, power supply, motor and door system in general. However, there are not many studies in the literature in terms of modeling and simulation for PSDs. Modeling and simulation of PSDs, which are an important component in terms of safety, especially in rail systems, is very important for the development of effective and efficient PSD systems. The block diagram below contains a block diagram that can be used for this. In this paper, PSDs were analyzed by creating a Matlab-Simulink model and simulation, and a study was conducted to use them in the development process by overlapping them with real PSD systems.

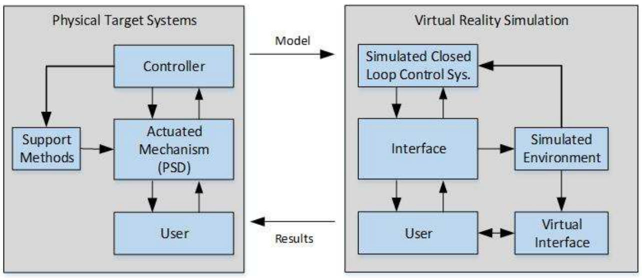

Fig. 1. Block diagrams of physical and simulated PSDs system

This paper aims to perform a computer simulation of the mathematical models of the passive (mechanical model and friction forces) and active models (driving and controlling sub-system) of a PSD sliding door system. To the best of our knowledge, this is the first report on the electromechanical modeling and simulation of PSD systems in a Matlab/Simulink environment.

II. PLATFORM SCREEN DOOR SYSTEM ARCHITECTURE

PSD system has similar mechanical and electrical structures as the train passenger access system [19]. It includes several sub-systems such as the driving unit, carrying unit, control unit, and door leaf. A schematic drawing of the full-height PSD sliding door system is depicted in Fig. 2.

Fig. 2. Schematic drawing of PSD door system

Each unit has special components in order to fulfill the related tasks. Detail architecture structure of the PSD system is given in Fig. 3.

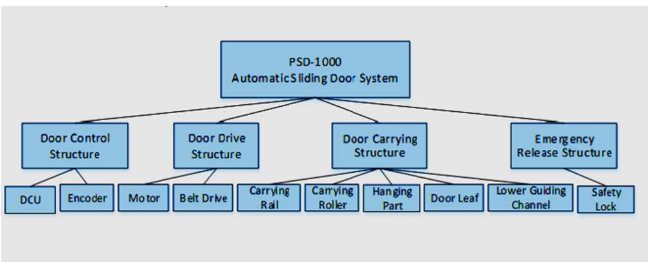

Fig. 3. The architecture of the PSD system

III. BASIC SIMULINK MODEL OF THE PSD SYSTEM

This section will describe in more detail several components and sub-blocks. The proposed model allows the user interactively view effects such as control and driving performance and mechanical load and friction levels in a single simulation environment, as shown in Fig.4.

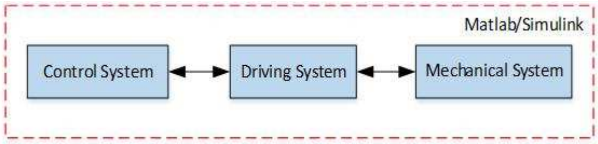

Fig. 4. Single Matlab/Simulink environment for simulating PSD system

The basic components of a PSD sliding door system can be classified into three groups: control system (controller and encoder), driving system (PMSM, inverter), and mechanical system, including door weight, all friction losses, and belt-drive. All blocks are integrated into Simulink modeling via Simulink blocks or mathematical functions.

PSD sliding door system is usually a driven PMSM motor. PMSM and its driver block, which is controlled by the controller and encoder for easy speed feedback, comprise the driving system. For the complete open/close cycle of the PSD sliding door system, the electrical and mechanical systems are coupled, as shown in Fig.5.

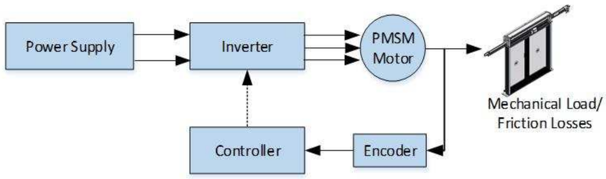

Fig. 5. General Structure of PSD system, including electrical and mechanical Systems

Fig.6 shows the overall PSD sliding door electromechanical model and its input-output system via Matlab/Simulink under the constant load. The applied model is selected from ready-to-use modules available in the Simulink library and is designed to fit PMSM for this study [25].

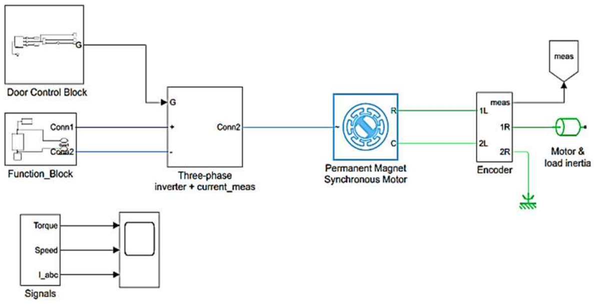

Fig. 6. Simulink model of PSD system including inputs and outputs

The door control block, whose main task is to control the motor, is configured to receive the inputs from encoders such as motor rotational speed and torque. Fig.7 shows the inside of the door control block. The entire system can be modeled in the same diagram using blocks from the electric drives library and Simulink libraries. The PI controller structure is used with these blocks because of its simple structure and fast system response.

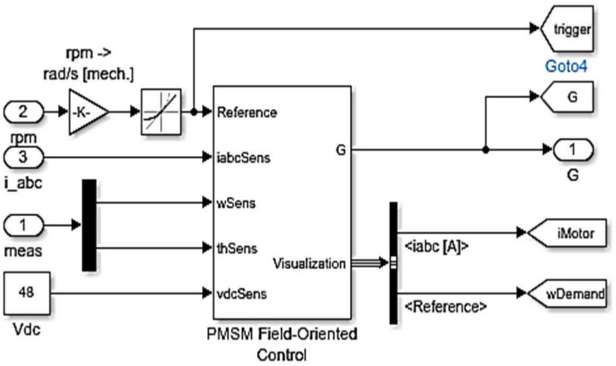

Fig. 7. Door Control (PMSM motor control) model

PMSM motor inverter sub-system Simulink model is illustrated in Fig. 8. The figure contains the power switches (IGBT-Insulated-Gate Bipolar Transistor) components with serial triggering for three motor phases in order to provide the required current to drive the motor. The electric drive library is used for modeling these blocks.

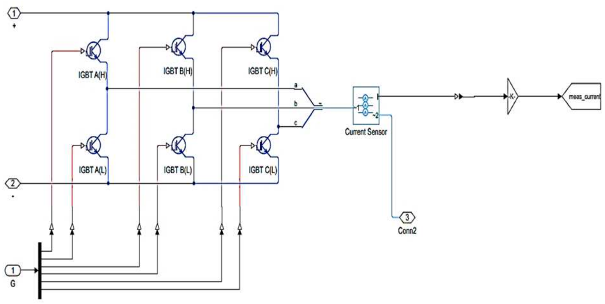

Fig. 8. Three-Phase PMSM motor Inverter model

Fig. 9 presents encoder blocks for providing a feedback signal to control the motor. These blocks perform feedback to the motor controller by converting the constant load and mechanical torque to the electrical system with sensor structures.

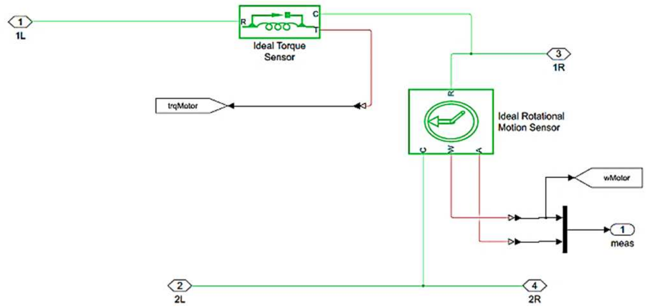

Fig. 9. Encoder Simulink model

In order to visualize the output in the Scope block, motor torque, motor speed, and motor current values can be selected and transformed, as shown in detail in Fig. 10

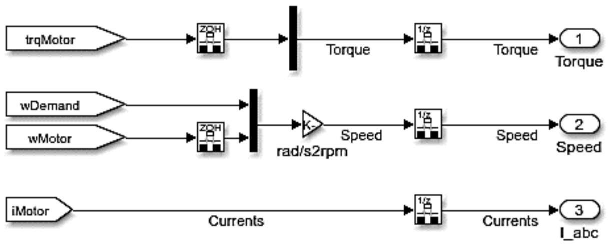

Fig. 10. Motor Output parameters (torque, speed, and current)

IV. SIMULATION RESULTS AND DISCUSSIONS

This section introduces some simulation performances of the PSD model by using the scope to see various characteristics with time.

For PMSM modeling, related motor parameters are given in Table 1. This PMSM motor is used in the commercial ALPSD-1000 system produced by Albayrak [1].

TABLE I. PMSM MOTOR PARAMETERS

Symbol	Name	Value
V_{rs}	Rated Speed	300 rpm
T_{rs}	Rated Torque	5 Nm
P	Number of Poles	10
J	Motor Inertia	21.63x$10^{-4}kgm^2$
L_d	d-axis Inductance	1.07 mH
L_q	q-axis Inductance	1.15 mH
R_s	Stator Resistance	0.2 Ohm

This study assumes that the mechanical load of the PMSM motor is constant and only consists of the three components: door leaf, rail, and lower guiding channel. In the simulation, the effects of these three components were added together to obtain a single mechanical load value and entered into the model as the load inertia of 0.03 kgm^2.

PSD sliding door system designed with PI controller in Simulink works in 3.5 s opening and closing time interval which is commonly used in application conditions for metro operation. Opening/closing states of the PSDs system and the relevant time intervals are given in Table 2 in detail. Since these time intervals are very important in order to calculate the dwell time in stations, time intervals for opening and closing of PSD are determined according to actual operating condition [10]. For the sake of running the simulation in reasonable time, shorter opened and closed time intervals than their actual values were chosen.

TABLE II. OPENING/CLOSING TIME INTERVALS OF PSD SYSTEM

Status	Time interval (sec.)
Opening	3.5
Opened	0.5
Closing	3.5
Closed	0.5

Fig.11 shows the change in demand and model output sliding door linear speed over time. Positive values of speed correspond the opening direction of the PSDs, whereas negative values point out the reverse one which means the closing direction. It is seen that there is no significant margin of error between the demanded and model response speeds. The compatibility of the selected PMSM motor parameters and the controller structure in the Simulink model can be determined by these curves. It can be seen that the PMSM motor and controller structure in the PSD model are compatible with each other because the two curves follow each other almost at any time.

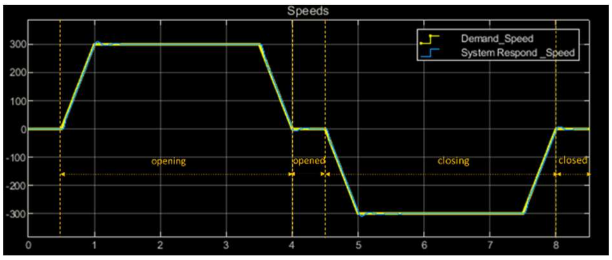

Fig. 11. Speed vs. time graph for PMSM motor

During the simulation, the model should work so that it can follow the speed curve of the PSDs system given in Fig.11, and the simulation should generate a torque suitable for this door's linear movement. A change of PMSM motor output torque over the time is given in Fig.12. It is seen that the torque data in the PMSM motor catalog and the data obtained in the simulation output are compatible. In addition, for the mechanical load value used in the model, it can be said that the torque value at the simulation output is also compatible with the torque values that occur in the real operating condition.

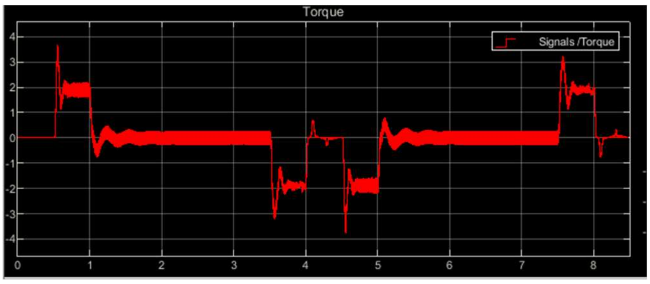

Fig. 12. Motor output torque vs. time graph

Fig.13 represents a three-phase motor current for the same opening/closing time interval of the PSD system. It appears that the currents are initially non-sinusoidal and become sinusoidal when the motor reaches the PI controller command speed in steady state. The simulation result was observed to be compatible with electrical motor phase current values measured from commercial ALPSD-1000 PSDs system produced by Albayrak.

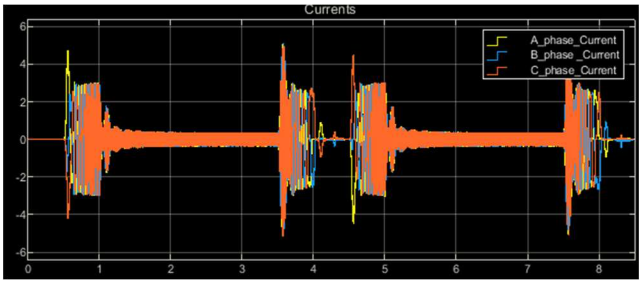

Fig. 13. Three-phase PMSM motor current vs. time graph

V. CONCLUSIONS

This paper shows a simulation model for the open/close function of the PSD sliding door system in Matlab/Simulink, which gives the advantages of using a single modeling environment. The modeling procedures of the electromechanical system are described, and simulation results are presented. The interaction between the control and driving system components and the door mechanical components were modeled with MATLAB/Simulink.

The developed model can provide the actual working conditions of the PSD sliding door system in a simulation environment. Furthermore, the results show that the proposed control and driving system is effective in managing the parameters that affect the actual operating state of the PSD sliding door system.

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