A CAD SOFTWARE FOR TRACTION DRIVE SYSTEM OF HIGH SPEED TRAIN LED BY TOP-LEVEL TECHNOLOGY GOALS

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ABSTRACT

High Speed railway passenger transport of china developed rapidly in recent years. System integration is even more important. For this reason, a CAD software for Traction Drive System of High Speed Train is being developed based on researching on Traction curve, regenerative braking curve, the match of electrical and mechanical characteristics, calculation of electrical parameters, control method of motor and converter, arithmetic of running simulation etc. This paper provides a whole develop project of this CAD software, and presents the design ideas, the framework, the function and the modules. The application of this simulator aims at designing a traction drive system of High Speed train can be suitable for a certain line. This traction drive system must meet the technical requirements led by the top-level technology goals for the line. This CAD software has three main functions. First, design traction curve, regenerative braking curve and some electrical parameters of traction drive system according to the technical requirements. Second, run the High Speed train on the certain line. Speed curve, current and voltage curves of motor, temperature rise of motor and converter, running time, energy consumption can be got by the simulation. Third, decide whether the train's performance meet the technical requirements according to the simulation results, and improve the design.

KEYWORDS

High Speed train, traction drive system, CAD, simulation, top-level technology goals

INTRODUCTION

The development of the world High Speed train show that computer simulation is a very effective tool for the study of High Speed train. Costing lower cost and shorter time, it can provide reference data for the High Speed train's lines, operation plans, the signal design as well as performance of High Speed train (e.g. Wang *et al.* 2001; Wang *et al.* 2009). High Speed railway passenger transport of China developed rapidly in recent years. Now, China already has a large number of High Speed trains. And the related technologies are developing rapidly. Modelling and simulation of High Speed train is a key for specification, design, procurement and operation. (e.g. Wen *et al.* 1991; M *et al.* 1998). An excellent simulation software can make the research and development easier, more purpose and more economical. For this reason, our lab is developing a computer-aided design (CAD) software to support the design of High Speed trains.

GENERAL DESCRIPTION OF THE SOFTWARE

Scope and goal

There are three main tasks for this software. First, to design a performance qualified High Speed train is the initial goal. Then, the analysis of dynamic problems of train's operation is a very important task. Finally, testing and analysing some new design ideas is a necessary function.

This software is planned to be a software platform that contains design platform, research platform and display platform as a whole. First, this platform can be used to guide the design work. Design contents include performance of the whole train, traction system, braking system and other systems. Second, based on this platform and contact physical pantograph system and traction system, related research can be done. Such as

coordination and control between High Speed train and traction power supply systems， the relationship between contact-loss of pantograph and the performance of traction drive system, etc. Third, to better show the design results, a good display platform is needed. For instance, there is a 3D display mode to run the operation simulation.

Train and line model

Here, the High Speed train is modelled as two subsystems, power subsystem and electrical subsystem. Power subsystem reflects traction and braking ability. It includes traction and braking characteristics and some dynamic processes, such as composite brake. Electrical model is divided into two levels, basic and dynamic models. Basic model consists of capacity, efficiency, power factor, voltage RMS and current RMS of transformer, converter and traction motor. Only macroscopic quantities of traction drive system can be analyzed. Transformer, converter, traction motor and control process dynamic models are built. Dynamic model is constituted mainly by some equations of state. Here, the step length of calculation is 10^{-5}. Thus, the dynamic problems as harmonics can be analyzed.

Line model includes line conditions and power supply conditions. Line conditions consist of ramps, curves, marks and the kilometrage they correspond. Power supply conditions consist of supply mode and detailed parameters of power supply network.

Design ideas

Led by top-level technology goals of High Speed train, this software uses a top-down design. The top-level goals of High Speed train include speed, comfort, environmental protection and safety.

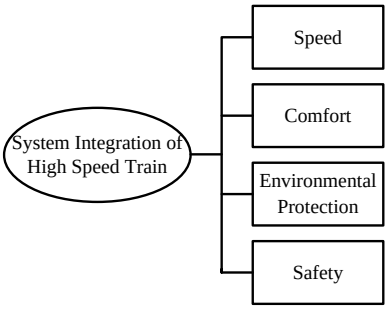

Figure 1 Top-level Goals of High Speed Train

At this stage, our software is carried out around the train's maximum operating speed. High Speed train can meet the requirements of speed and running time is our design target. Other top-level goals are involved, but not included in design, just being displayed.

Configuration

The software will include seven components: input of general data, setting of top-level technology goals, design of traction drive system, braking system and bogie, comprehensive simulation, and the analysis of results. There is interface left for bogie and braking system, and they are the following works. Other parts have been completed or are being completed. The integrated framework of the software is shown in Figure 2.

(1) The general data includes the basic parameters of train and line. Here a train is defined, including its maximum operating speed, the proportion of motor car and trailer, weight of the axle and capacity. More detailed data of the train will be input in other components. The data of lines include line conditions and power supply mode. The detailed parameters of power supply network will be inputted in traction power supply module.
(2) Setting of top-level technology goals: define numerical value of the specific targets of top-level technology goals.
(3) Design of traction drive system: the main function module for train modelling. It includes the design of traction characteristics, analysis of braking characteristics, calculation of macroscopic parameters of the traction drive system, and establishment of dynamic model of the traction drive system. Also it includes search function of the relevant design features with a database.
(4) The Braking system will reflect physical processes of the composite brake.
(5) Design of bogie will be expanded later.

(6) Comprehensive simulation includes operation simulation, traction power supply simulation and temperature rise calculation. There will be interface left for other simulations. Then other commercial software can be linked up. The comprehensive simulation will be divided into basic and dynamic coupling simulation depending on whether dynamic model of the traction drive system will be called.
(7) The results analysis includes real-time display, recording and analysis reports of the results.

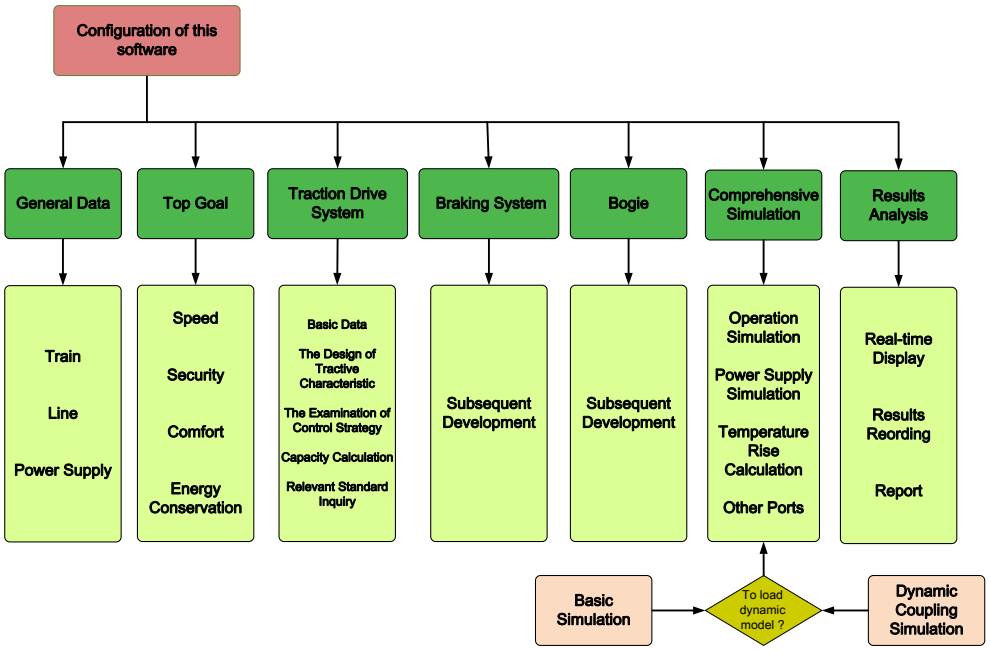

Figure 2 Configuration of this software

Current status

Now, the overall framework of this software has been determined. Train's dynamic model and traction power supply module are being developed. At present stage, the application of this software aims at designing a High Speed train can be suitable for a certain line. Based on the technical requirements of the certain line, model a High Speed train; determine the capacity of traction drive system; then evaluate and improve the design result with basic comprehensive simulation. Design of traction drive system around maximum operating speed is what the software can do now.

DESIGN AROUND MAXIMUM OPERATING SPEED

Design process

Suppose there is a High Speed railway between A and B cities. Line conditions are fixed. A High Speed train is needed for this line. Running time on this certain line is the only restriction. Then, running time and train speed are the top-level technology goals of the train for the line. The vendor or user must define the technical requirements of the High Speed train for its particular operation in order to request proposals. Such as maximum operating speed, acceleration, deceleration, failure rescue and so on. Our simulator is based on these technical requirements, around the running time, in other words train's operating speed, to start design. Model a train consist of traction and braking characteristics, the electrical parameters of traction drive system, etc. Then, to run the operation simulation with the train we have modelled on the certain line. Speed curve, current and voltage curves of motor, temperature rise of motor and converter, running time, energy consumption can be got by the simulation. According to the simulation results, to determine whether the performance meet the technical requirements. If not, back to the start, to modify the technical requirements or the model of the High Speed train. If yes, it is believed that the High Speed train designed could meet the technical requirements.

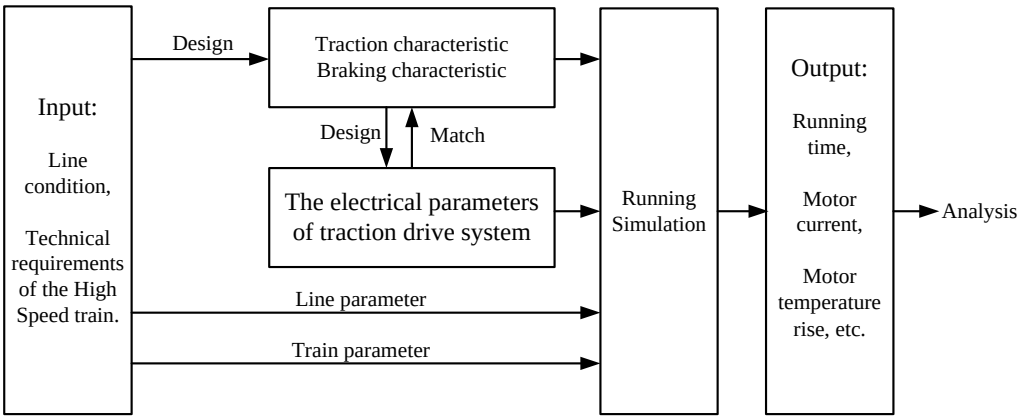

Figure 3 Design process

Features and results of each module

We can set a new line, edit the parameters of an existing line and delete an existing line in the module "input of general data". Lines for operation simulation have been defined in this module. A High Speed train will be defined for a certain line in the module "input of general data". And its maximum operating speed, the proportion of motor car and trailer, weight of the axle and capacity will be given out. Then, its detailed data for design will be set in the module "basic data" of "traction drive system". Data setting is the source of follow-up design. When the design conditions have been identified, design of traction characteristics, analysis of braking characteristics, calculation of macroscopic parameters of the traction drive system, operation simulation and thermal calculation will be achieved.

(1) Basic data of a train defined in this software consist of acceleration, deceleration, efficiency of traction drive system, resistance function, adhesion function, inertial coefficient, etc. All the trains in the database can be referenced in later design.

(2) The design of traction characteristics function: Select a train. The simulator will output maximum traction curve according to the speed, weight, the remaining acceleration and some other parameters. And the current curve of the traction motor will be given out. Based on this designed traction curve, the simulator can calculate the average acceleration, acceleration distance and acceleration time from start to maximum speed with maximum traction. According to these indicators, users can determine the reasonableness of the traction curve. The following figure is the traction characteristics of a train designed by this software that maximum operating speed of it is 380km/h.

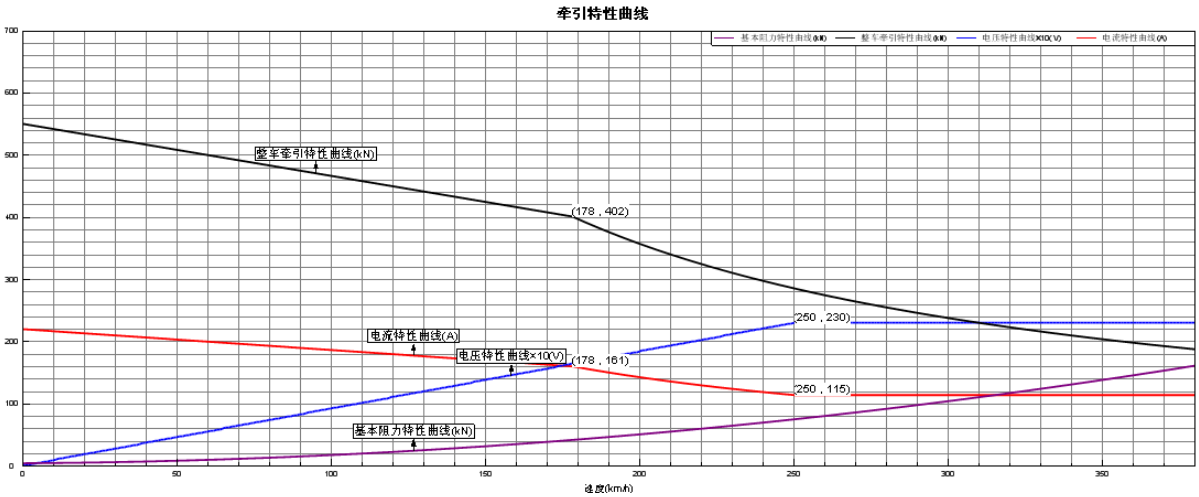

Figure 4 Traction characteristics of a 380km/h train designed by this software

(3) The analysis of braking characteristics function: Select a train. The simulator will output a series braking force curves according to the speed, deceleration and some other parameters. Based on these braking characteristics curves, the simulator can calculate braking distance and braking time. According to these indicators, users can determine the reasonableness of these braking curves. The following figure is the regenerative braking curve of a train designed by this software that maximum operating speed of it is 380km/h.

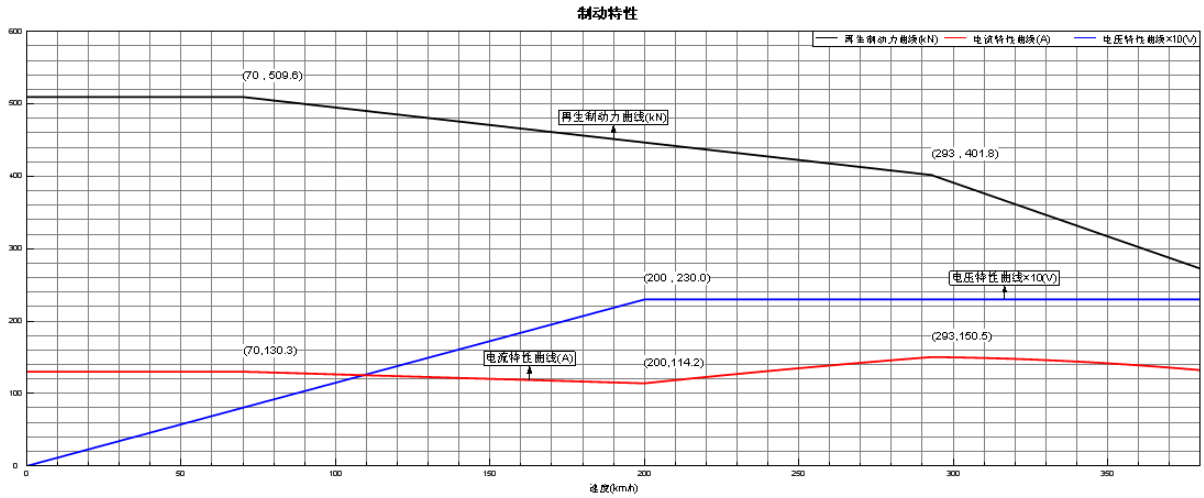

Figure 5 Regenerative braking curve of a 380km/h train designed by this software

(4) Calculation of electrical capacity function: Select a train. Match the machine performance and transmission capacity according to the designed traction and braking characteristics. If the traction or braking characteristics curves are unreasonable, redesign them.

(5) Operation simulation function: Select a line, a train designed for it and the simulation mode. Run the operation simulation. The simulator will give out simulation results. It can be determine that whether the train meets the technical requirements according to the simulation results. If not, back to the start, to modify the technical requirements or the model of the High Speed train.

Select a line and a train with 380km/h speed rating, the simulation mode with minimum operation time. Run the simulation. Part of the speed curve, current curve of motor, and temperature rise of IGBT are showed in Figure 6.

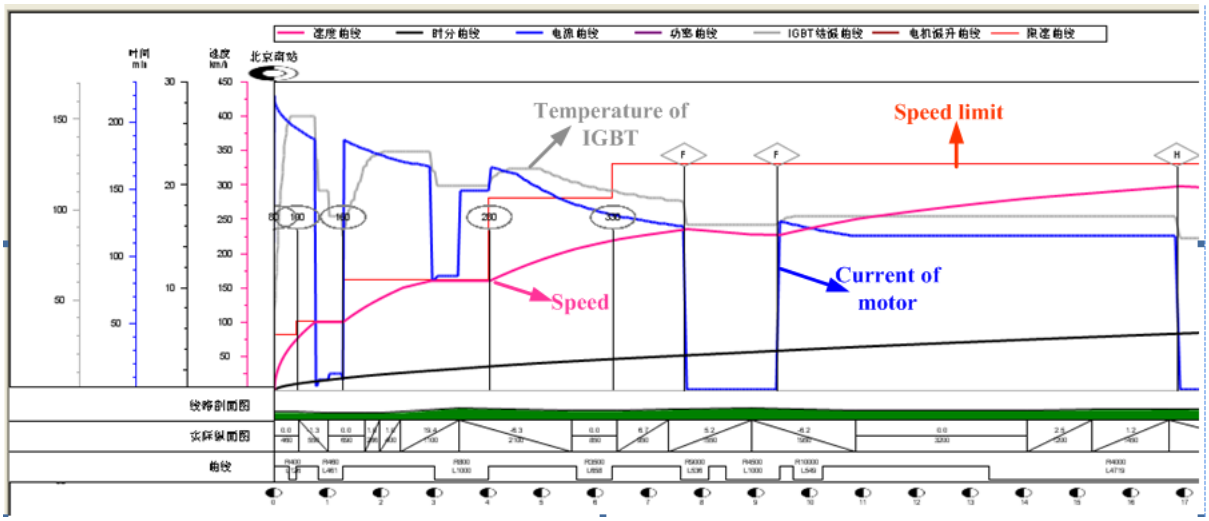

Figure 6 Simulation results

(6) Thermal calculation function: Thermal design of electrical equipment is very complicated, so this module separately. This module can be used to guide the thermal design of power converters. Its function includes temperature rise calculations and simulation of temperature rise. Temperature rise calculations consist of loss calculation, calculation of temperature-current curve, calculation of junction temperature fluctuation. And each calculation contains several contents. The following figure is an example of temperature rise calculations. Simulation of temperature rise is to obtain real-time temperature of converter in operation simulation.

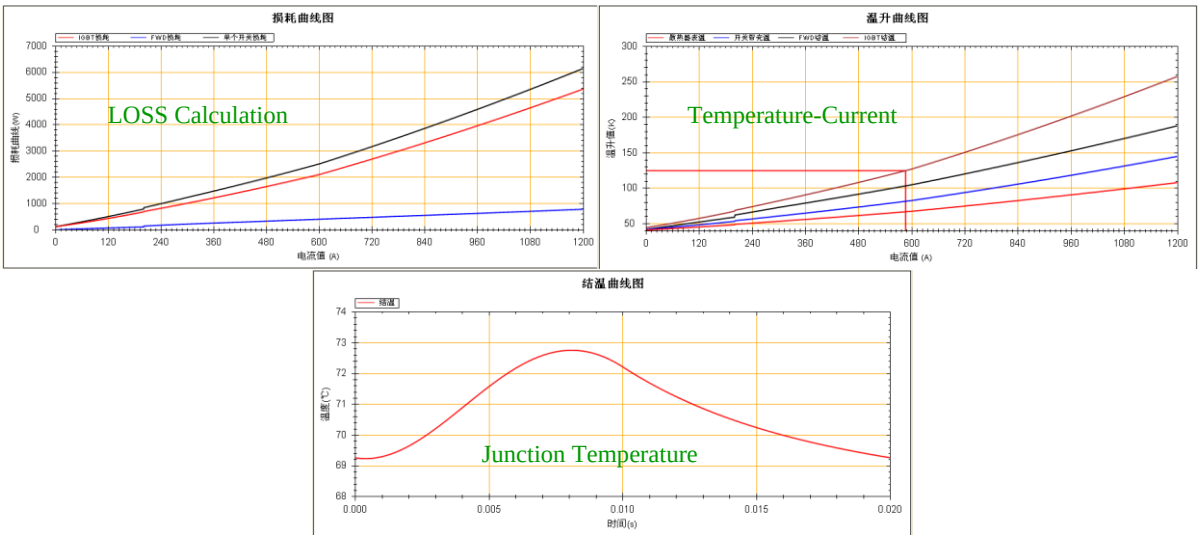

Figure 7 An example of temperature rise calculations.

CONCLUSIONS AND OUTLOOK

Currently, completed functions of this software include “data setting”, “the design of traction characteristics”, “operation simulation” and “thermal calculation” have a strong usability. “The design of braking characteristics” needs further improvement. Other parts will be gradually completed. This software will be more useful, practical and accurate. Cooperation unit has given appreciation to this software, and been satisfied with its progress and been full of hope for its prospect.

The development of this CAD software is based on theoretical research, and theoretical research will be expanded and deepened with this software. It is our goal, but also the significance of the development of this software. Developing the software, physical platforms are being built in our laboratory at the same time. This platform will be able to simulate most of the electrical process of High Speed train operation. Based on this platform, we can deepen the theoretical study. And we can make the train model more practical and accurate.

ACKNOWLEDGMENTS

This work is supported by a grant from National Key Technology Support Program (2009BAG12A01-F15-1).

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