RPC coordinated control strategy with battery and flywheel energy storage

Shi Xiao1,Zhiqiang Zhang1,Peijin Yang2, Bin Li2, Zhihong Zhong2, Hu Sun2
1 CRRC Qingdao Sifang Co., Ltd., QingDao, China
2 Beijing Jiaotong University, Beijing, China

Abstract

This paper investigates the control strategy and parameter optimization of railway power conditioner and energy storage system based on the data collected in an actual substation. The coordinated control strategy of battery and flywheel energy storage device is proposed for the real-time data of railroad locomotive traction load. Through the new system of railroad power regulator and energy storage device to the actual working conditions of the simulation model to verify the strategy, the results show that the control strategy can be very good in the power quality management while the regenerative braking energy recycling, and on the arrival of the peak load at the same time can be maximized and effective reduction of the peak load, so that not only the power quality has been managed, but also to further improve the economic returns.

Keywords: Electrified railways, Railway power conditioners, Peak loads, Battery and flywheel energy storage devices, Regenerative braking.

1 Background

With the increase of operation mileage and many railroad loads put into the railroad sector, the amount of electricity costs faced by the railroad sector is also increasing, and it becomes particularly important to improve the economic operation of the system. As the traction load is characterized by random fluctuations, frequent movements and large load peaks, it not only brings a series of power quality problems, but also leads to a large amount of regenerative braking energy being fed back to the grid, resulting in a huge load impact. Following the principle of two-part tariff charging, the cost corresponding to the regenerative braking energy fed back to the grid is not reverse positively counted, and the large load peak and long duration directly lead to additional expenses. For the power grid, improving power quality, increasing the utilization rate of regenerative braking energy and improving the peak-to-valley difference of loads can effectively improve the utilization rate of the equipment, reduce the expenditure on electricity, reduce the investment in the system equipment, and make the power system operate stably, efficiently and economically. Therefore, how to improve power quality, increase regenerative braking energy utilization and reduce peak load in the system becomes especially critical.

2 RPC Coordinated Control Strategy with Battery and Flywheel Energy Storage

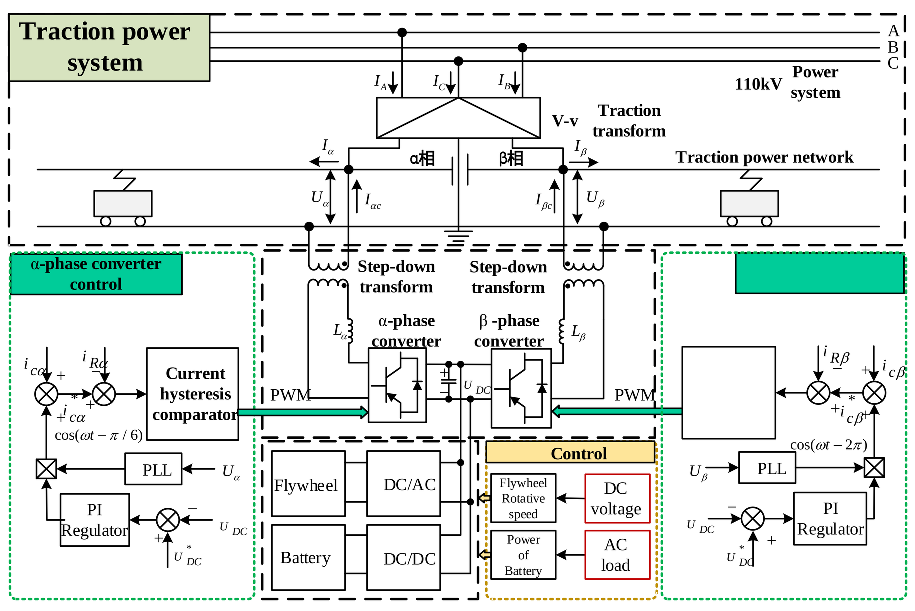

Fig. 1 RPC topology with battery and flywheel energy storage device

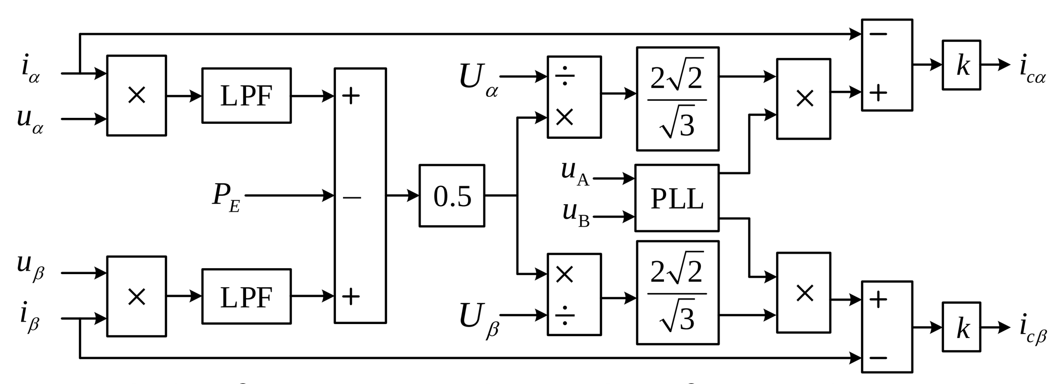

Fig.2 Reference current instruction of new RPC

The RPC can be operated stably after using the command current extraction method and the double-loop control strategy shown in the above figure, but it is also particularly critical to adopt which control strategy for the energy storage system.

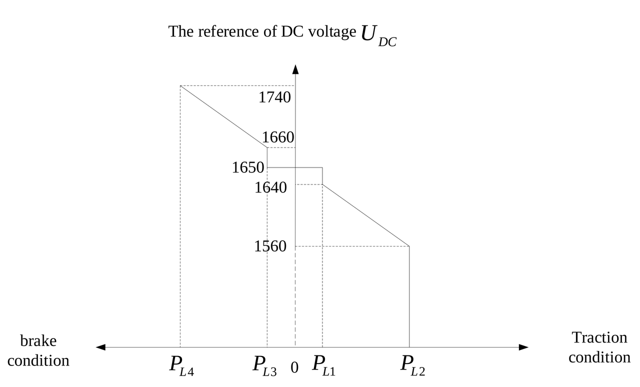

Fig.3 Voltage stability value curve of middle dc link

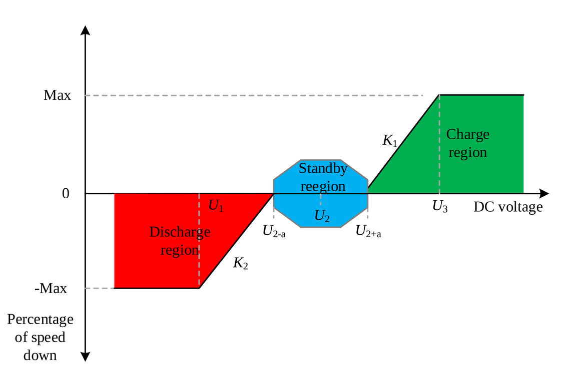

Fig.4 Speed control strategy

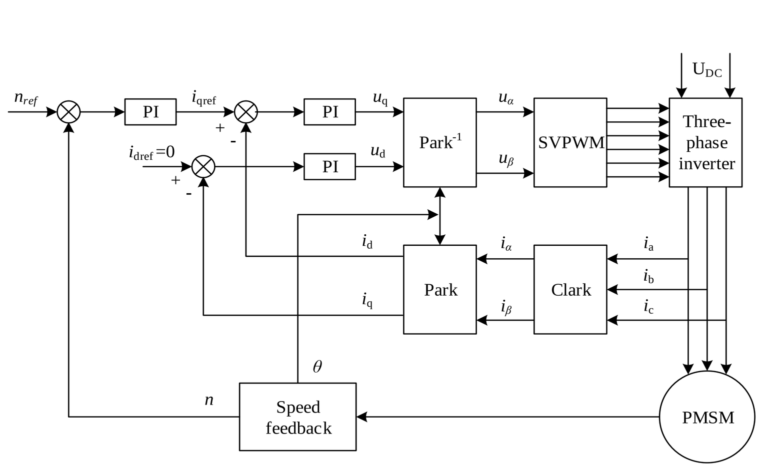

Fig.5 Control strategy of flywheel energy storage device

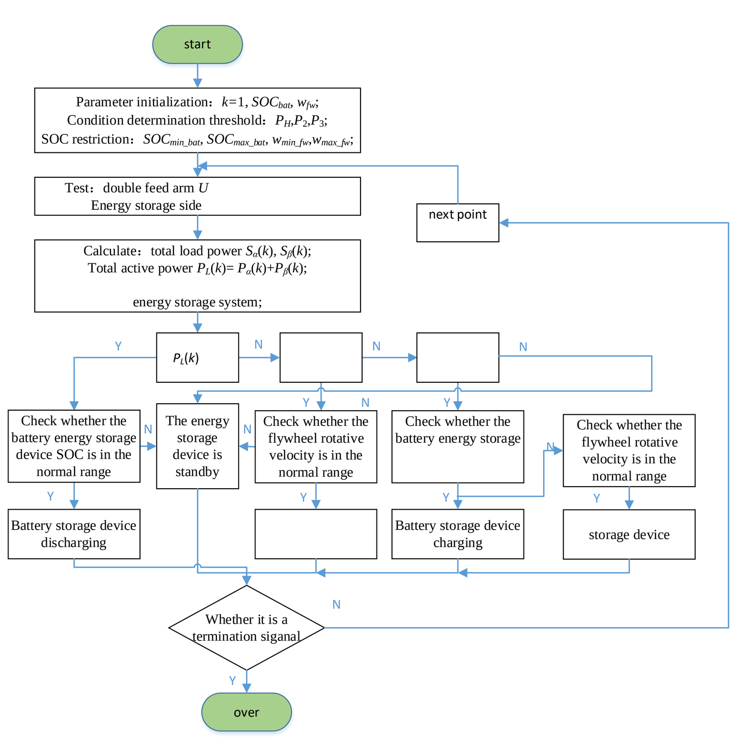

Fig.6 Upper load detection condition determination flow II

3 Simulation results and analysis

In order to verify the RPC coordinated control strategy with battery and flywheel energy storage, the feasibility of each control strategy and the effectiveness of the corresponding energy management strategy, the simulation adopts the data of a certain substation in Hebei Province on the day of the peak in a certain month, and utilizes MATLAB to carry out the RPC simulation of the entire traction power supply system and the RPC simulation of the energy storage system with batteries and flywheel.

(1) Battery charging and discharging

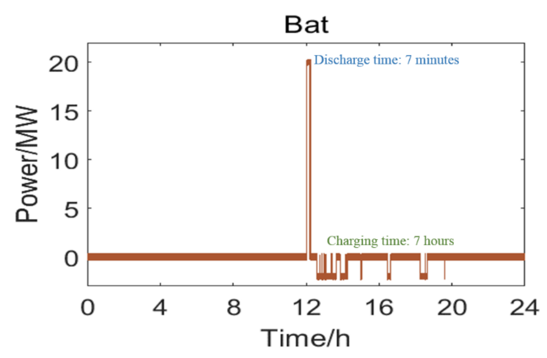

Fig.7 The working condition of the battery energy storage device in the peak-clipping area

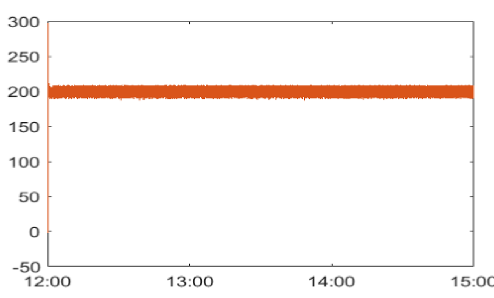

Fig.8 Flywheel working condition Ⅰ

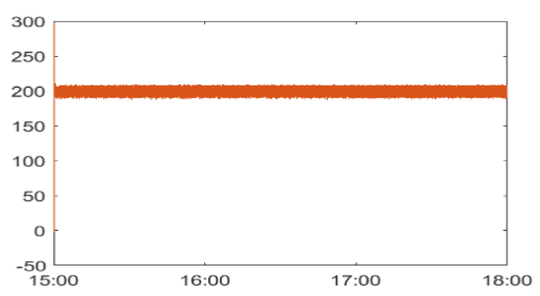

Fig.9 Flywheel working condition II

The flywheel has been reduced to its lowest speed before the battery is discharged, and the flywheel maintains its speed unchanged throughout the battery charging and discharging intervals, during which time the flywheel does not perform regenerative braking energy utilization.

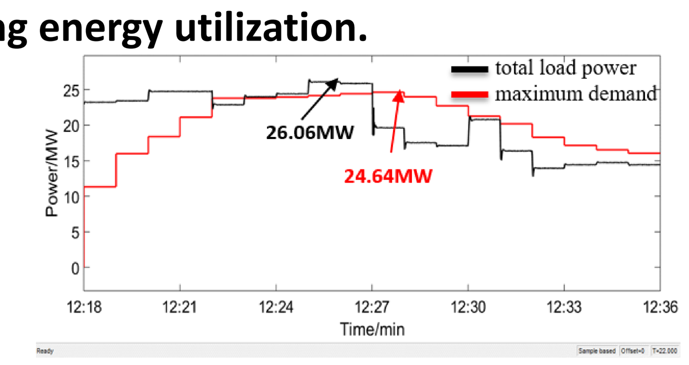

Fig.10 Total active power and maximum demand before load of energy storage device

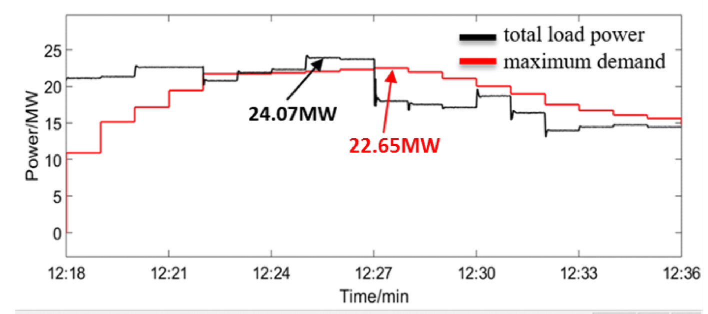

Fig. 11 Fig.3-5 Total active power and maximum demand after load of energy storage device

(2) Flywheel charging and discharging

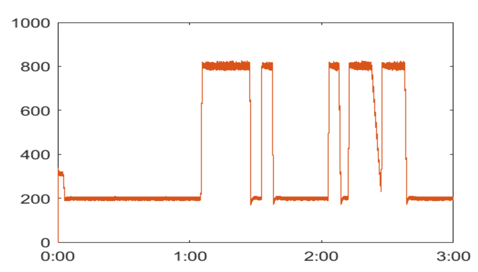

Fig.12 Flywheel working condition III

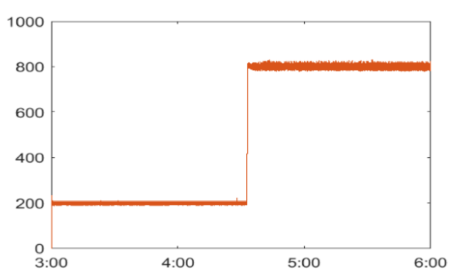

Fig.13 Flywheel working condition IV

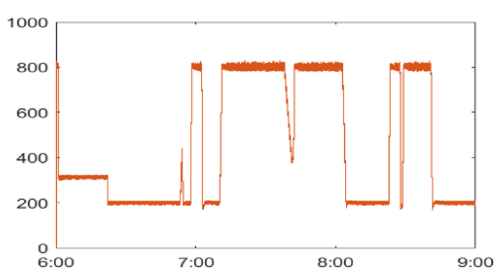

Fig.14 Flywheel working condition V

As shown in the figure above, the flywheel energy storage device is charged and discharged a total of 31 times, which allows for effective regenerative braking energy utilization.

(3) Improvement of three-phase current imbalance

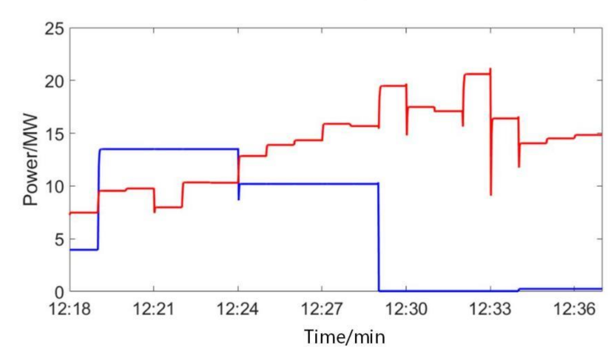

Fig.15 Both sides of the load before power quality control

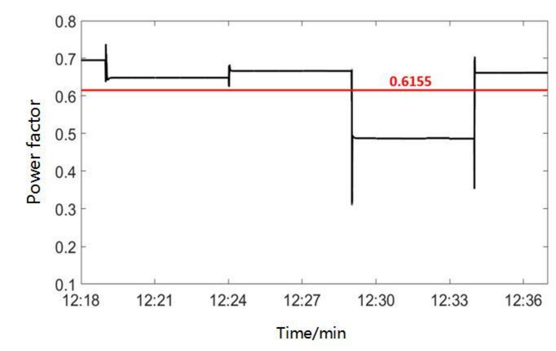

Fig.16 Power factor before power quality control

At this time both sides of the bridge arm load active power values are large, is the maximum demand value appears in the period, as shown in Figure 3-15 for the power factor at this time, the power factor varies between 0.7 and 0.5, the average power factor is only 0.6155, and the load changes in both sides of the bridge arm is large at 12:29 when the power factor fluctuates significantly.

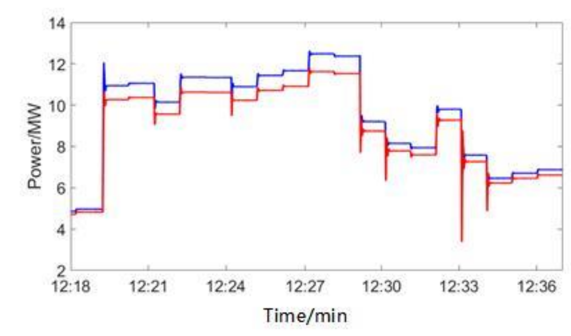

Fig.6 Both sides of the load before power quality control

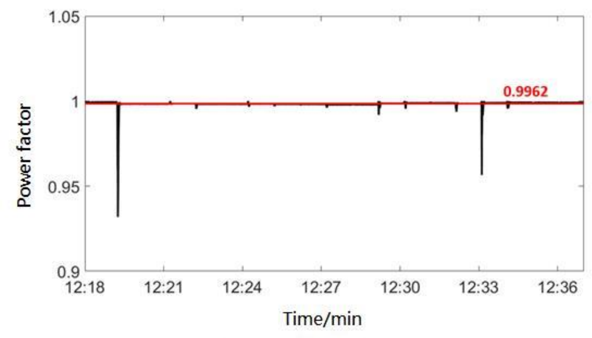

Fig.7 Power factor before power quality control

The battery energy storage device has been in the discharging condition during the period, when both sides of the bridge arm in addition to balancing the active energy also utilized the regenerative braking energy stored in the battery for peak clipping. Meanwhile, we can see that compared with the power factor before adding the new RPC compensation device is basically 1, the average power factor reaches 0.9962, which is a great improvement, so the addition of the battery and flywheel storage system in the RPC intermediate DC link can be a very good power quality management.

4 Summary and Outlook

In this paper, according to the actual situation of traction substation, with the premise of ensuring the safe and stable operation of the overall system, suitable control strategies are proposed for RPC compensation device, battery energy storage device, flywheel energy storage device, and finally RPC compensation system with battery and flywheel energy storage is formed, and the results of the coordinated work of each device are analyzed, which verifies the feasibility of the system for the quality of power, regenerative braking energy utilization of the storage part, storage part, peak clipping control, RPC power transfer regenerative braking energy utilization, and RPC power transfer regenerative braking energy utilization. The feasibility of the system for power quality, regenerative braking energy utilization in part of energy storage, peak clipping control, and regenerative braking energy utilization in RPC power transfer is verified.