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A Compensation Techniques Of Railway Power Conditioner For Railway Power System

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ABSTRACT

This paper provides an analysis of a three-phase dual active bridge (DAB) topology used as high-power-density dc–dc converter for railway applications. The three-phase DAB is analyzed concerning the current intervals, the output power, and soft switching region, including the impact of zero-voltage switching capacitors. Furthermore, two measures are proposed to achieve soft-switching in the entire operating range, being auxiliary inductors and a straightforward switching strategy called the burst mode. Optimal component values are calculated to minimize losses in the complete operating range and to assess which measure is best suited. A prototype with the specifications acquired from the application has been built, yielding an efficiency of 95.6% at a nominal output power of 80 kW. High-speed train traction power supply system causes serious negative current problem. In extension Railway power conditioner (RPC) is efficient in negative sequence compensation. A novel power quality collaboration compensation system and strategy based on RPC is proposed in this paper. The minimum capacity conducted is 1/3 smaller than traditional single station compensation. Simulation results have confirmed that the collaboration compensation system proposed can achieve a good performance at the negative sequence compensation with capacity and cost efficient.

INTRODUCTION:

Recent years, high-voltage, large-capacity Static Var Compensator, Active Power Filter and Static Compensator (STATCOM) have become focus on power quality compensation of electrified railway. However, these methods all need high-voltage transformers which increase cost. Active Power Filter is effective in suppressing harmonic currents in electrified railway but rarely used in negative sequence compensation. An active power quality compensator (APQC) with a impedance-matching balance transformer or a Scott transformer is this in to compensate negative-sequence current, harmonics and reactive current. Reference and put forward a proposal of Railway Power Conditioner

(RPC), RPC can make comprehensive compensation of negative sequence components, harmonics and reactive power. Reference carries a dual-loop control strategy in order to improve the control effect and performance of RPC. Taken into account the disturbance and variation of electrified railway environment, a recursive PI control based on fuzzy algorithm is adopted to realize a fast and smooth tracking to reference current. Reference raises a method of setting up two groups of thyristor control reactors (TCR) and two groups of thyristor control 3rd harmonic wave filter besides RPC. The RPC is used to transfer active power; the reactive power is supplied by the TCR and the filter. These works prove that RPC is a effective way to solve the power quality problems in railway system. Half-bridge-converter-based (RPC) (HBRPC) which consists of two half-bridge converters connected by two capacitors connected series. As compared with the traditional railway power conditioners (RPC), the HBRPC requires only a pair of power switch legs and two capacitors. The same function of RPC, this conditioner can reduce half of the power switches, which can make it with lower hardware complexity at lower cost. A double-loop control is this for HBRPC to keep the dc-link voltage stable and achieve the dynamic tracking of the current reference signals, while a balanced voltage control is this to eliminate the error of two capacitor voltages and maintain the normal operation of HBRPC.

II. NEED OF POWER CONDITIONING IN HIGH SPEED RAILWAY SYSTEM

With the rapid development of high-speed and high power railway system, power quality such as the negative sequence current and harmonic current caused by electric locomotives becomes more and more critical. High-speed locomotives which have a high power factor; however, they will generate a lot of harmonic currents in a broad spectral range. These NSC and harmonic currents would have much impact on the stable and economic operation of the grid, which can increase power losses of the traction system, reduce the life and reliability of the traction transformer, and lead to malfunctions of sensitive equipment. These adverse impacts threaten the safety of highspeed railway traction supply system. Therefore, it’s necessary to take measures to suppress negative current & Harmonic current The amount of negative-sequence currents depends on the topology of the traction power system, in particular, the type of traction transformers used. Typical transformers used include Scott transformers, Woodbridge transformers, threephase V/V transformers, impedance matching transformers, etc. Scott transformers, Woodbridge transformers are balanced transformers but three-phase v/v transformers are unbalanced. When balanced transformers are used, so no negative sequence current is injected into the public grid when two feeder sections consume the same power. However, for the traction systems with three-phase V/V transformers, the negative sequence current injected into the public grid is half of the positive- sequence current even when two feeder sections consume the same power. The problem with this topology is that a strategy to effectively compensate the negative-sequence and harmonic currents needs to be developed. Since most electric locomotives are single-phase rectifier load, random unwanted fluctuations are frequent, large amounts of harmonic & negative sequence current produced by the electric traction power supply system are injected into the power grid. As a result, grid voltage and current are asymmetrical and the harmonic content is increased, which lead problems including the overheat of motor rotor in power plant, the service life of transformer is reduce, the misoperation of relay protection device and, these issues have a great influence on the safe and stable operation of power system

RAILWAY POWER QUALITY CONDITIONER

The AC electrified railway systems have the power quality problems such as the reactive power consumption and the load imbalance due to their inherent electrical characteristics of single-phase and nonlinear moving loads. Also the power electronics equipments in the AC electrified railway systems produce the large amount of harmonic currents. These power quality problems in the AC electrified railway systems have a bad effect on themselves as well as other electric systems connected together. Therefore a power quality compensator is required to maintain the proper power quality in the AC electrified railway systems. There are many researches on the power quality compensator for improving power quality in the AC electrified railway applications. Especially, a single-phase active power filter and a single-phase hybrid active power filter, being composed of a passive power filter and an active power filter, have been studied [1]. Most of the active power filters are connected in parallel with M-phase and T-phase secondary outputs of Scott transformer respectively. Although they can compensate the harmonic currents and the reactive power, the load imbalance cannot be compensated. A three-phase active power filter for power quality compensation has been proposed [2]. However, the three-phase active power filter installed at the three-phase mains requires the high-voltage rating. Another active power quality compensator, being composed of a three-phase inverter and a Scott transformer, has been studied [3]. An active power quality compensator with two single-phase inverters connected back-to-back (that is called the RPQC in this paper) has been proposed [4]. The RPQC requires no additional Scott transformer and can be operated at lower voltage level than the three-phase active power filter. In spite of these merits, there are few researches on the control of RPQC. A novel control algorithm based on SRF for the RPQC is proposed. The proposed RPQC control algorithm can properly compensate the harmonic currents, the reactive power, and the load imbalance. The effectiveness and the validity of the proposed control algorithm are demonstrated through the simulations.

Structure of the RPQC

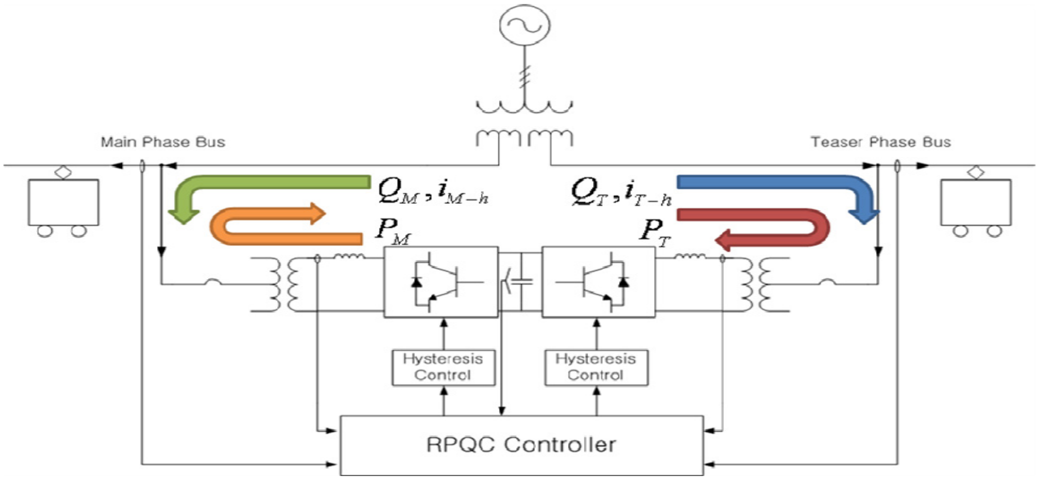


Fig. 1: Configuration of RPQC

Fig. 1 shows an AC electrified railway system adopting the RPQC. The RPQC consists of two single-phase inverters sharing a DC-link capacitor. Each of the single phase inverters is connected with M-phase and T-phase feeder of the Scott transformer.

The RPQC controller is shown in Fig. 2 The DC-link voltage for the DC-link voltage regulation, the inverter currents for the current control, and the load currents for the harmonic extraction are required as the controller inputs. The RPQC can compensate not only the harmonic currents and reactive power, but also the load imbalance by exchanging the active power deviation between M-phase and T-phase feeders through the DC-link capacitor. shows an AC electrified railway system adopting the RPQC. The RPQC consists of two single-phase inverters sharing a DC-link capacitor. Each of the single phase inverters is connected with M-phase and T-phase feeder of the Scott transformer. The RPQC controller is shown in Fig. 2 The DC-link voltage for the DC-link voltage regulation, the inverter currents for the current control, and the load currents for the harmonic extraction are required as the controller inputs. The RPQC can compensate not only the harmonic currents and reactive power, but also the load imbalance by exchanging the active power deviation between M-phase and T-phase feeders through the DC-link capacitor.

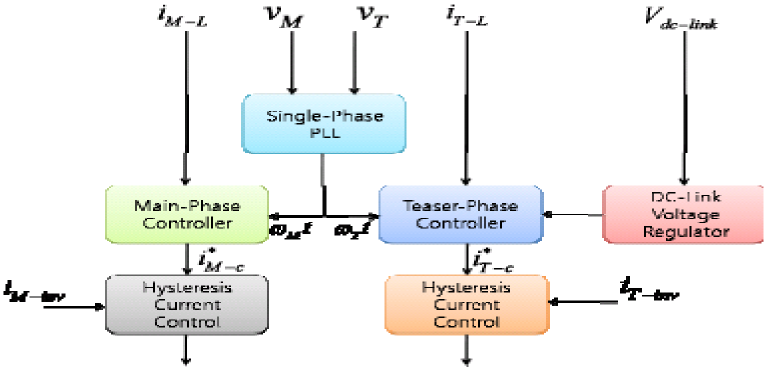


Fig. 2. RPQC controller.

Harmonic compensation

The load current of the M-phase feeder that means the current flowing into the locomotives is expressed as follows

$$i_{M-L} = I_{M-L}\cos(\omega t - \phi) \tag{1}$$

After transforming the load current in equation (1) into the SRF coordinate, the respective d-q components can be expressed as the following equations (2) and (3).

$$I_{M-Ld} = \overline{I}_{M-Ld} + \tilde{I}_{M-Ld} \tag{2}$$

$$I_{M-Lq} = \overline{I}_{M-Lq} + \tilde{I}_{M-Lq} \tag{3}$$

where, *M Ld I* − and *M Lq I* − are the DC values of the load current on the SRF. The DC values of the d-q axis are obtained by using the low pass filters. *M Ld I* − % and *M Lq I* − % are the AC values of the load current on the SRF, which means the harmonic contents of the load current. Therefore, when the d-q DC values are subtracted from the d-q load currents, the d-q harmonic currents to be compensated are obtained. Fig. 3 shows the method to extract the harmonic components from the load current.

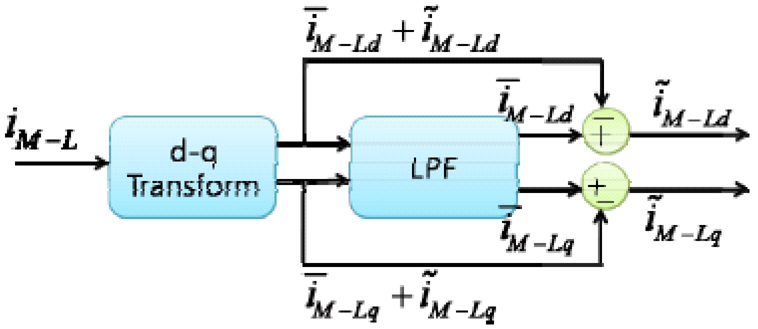


Fig 3: harmonic current extraction

Reactive power compensation

The M-phase voltage is represented as follows

$$v_{M-L}=V_{M-L}\cos\omega t \quad (4)$$

Through substituting equations (2) and (3) into equation (1), equation (5) can be derived as follows

$$\begin{aligned}i_{M-L}&=I_{M-Ld}\cos\omega t-I_{M-Lq}\sin\omega t\\&=I_{M-L}\cos\phi\cos\omega t+I_{M-L}\sin\phi\sin\omega t\end{aligned}$$

(5)

Therefore, the single-phase instantaneous active power and reactive power can be described as equations (6) and (7).

$$\begin{aligned}p_M(t)&=v_{M-L}\cdot I_{M-Ld}\cos\omega t\\&=V_{M-Ld}\cos\omega t\cdot I_{M-Ld}\cos\omega t\\&=\frac{1}{2}V_{M-Ld}\cdot I_{M-Ld}\left[1+\cos(2\omega t)\right]\\&=V_{M-Lrms}\cdot I_{M-Lrms}\cos\phi\left[1+\cos(2\omega t)\right]\end{aligned} \quad (6)$$

$$\begin{aligned}q_M(t)&=v_{M-L}\cdot I_{M-Lq}\sin\omega t\\&=-V_{M-Ld}\cos\omega t\cdot I_{M-Lq}\sin\omega t\\&=-\frac{1}{2}V_{M-Ld}\cdot I_{M-Lq}\sin(2\omega t)\\&=V_{M-Lrms}\cdot I_{M-Lrms}\sin\phi\sin(2\omega t)\end{aligned} \quad (7)$$

where, V_{M-Lrms} and I_{M-Lrms} denote the RMS value of v_{M-L} and v_{M-L}, respectively. It is shown that the single phase instantaneous active power depends on the d-axis current value, while the instantaneous reactive power depends on the q-axis current value. The source current, i_{M-s} is made by the load current of M-phase, i_{M-L} and the inverter current, i_{M-inv}, as in equation (8)

$$i_{M-s}=i_{M-inv}+i_{M-L} \quad (8)$$

If the q-axis value of the source current becomes zero through the compensation of the q-axis current, the corresponding reactive power can be compensated. Fig. 4 shows the control blocks of reactive power compensation algorithm.

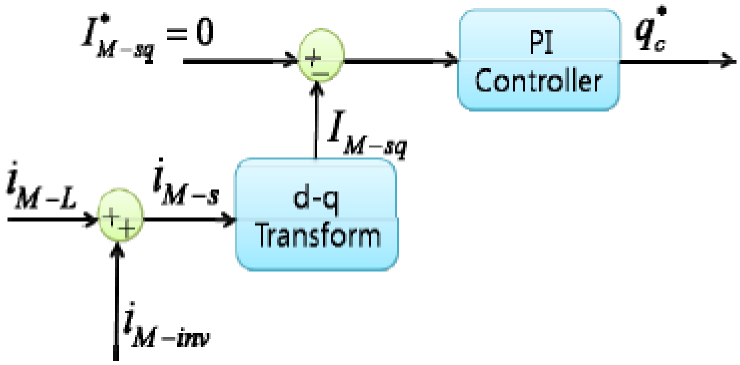


Fig. 4. Reactive power compensation algorithm.

Load imbalance compensation

It is shown in equation (6) that the single-phase instantaneous active power can be properly controlled by controlling the d-axis current. If the harmonic currents and the reactive power have been compensated by the proposed compensation algorithm, the load imbalance is provoked by a deviation between the active power load of the M-phase and that of the T-phase. For example, the load current of the M-phase is larger than the T-phase when the load of the Mphase is larger than T-phase, then the load imbalance problem is occurred. This results into that the d-axis current of the M-phase is larger than that of the T-phase. The d-axis values of the M-phase and the T-phase are equal to each other when three-phase balancing condition is considered. This load imbalance compensation can be achieved if the difference between the d-axis source currents of the Mphase and the T-phase is controlled to be zero. Fig. 5 shows the control blocks of load imbalance compensation algorithm.

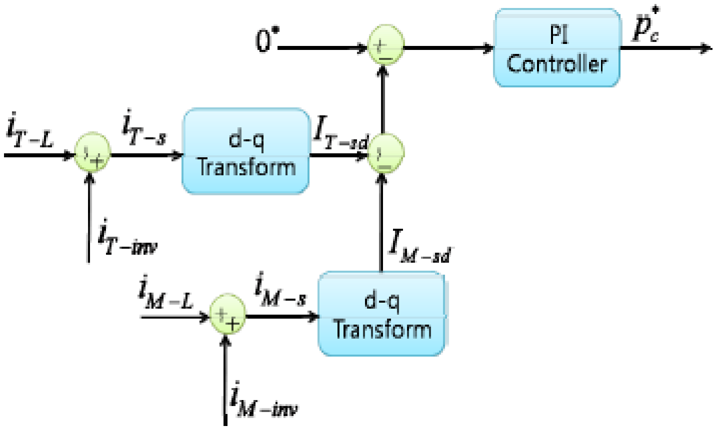


Fig. 5. Load imbalance compensation algorithm.

DC-link voltage regulation

The DC-link voltage regulator has a role in compensating power losses of the RPQC as well as the voltage regulation. Fig. 6 shows the control blocks of DC-link voltage regulation algorithm.

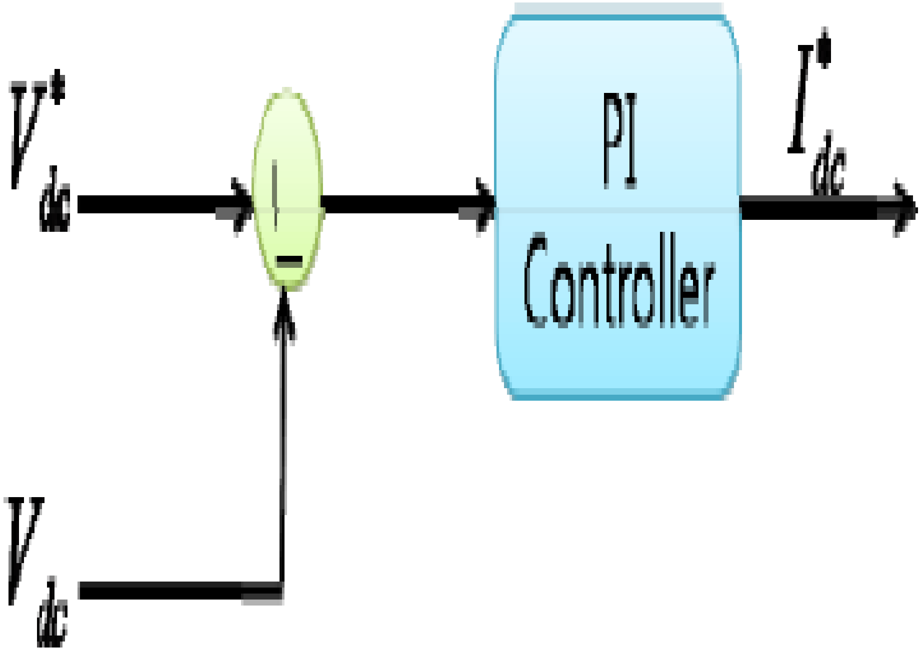


Fig. 6. DC-link voltage regulation algorithm.

Overall RPQC controller

Fig. 7 shows the structure of overall RPQC control scheme. M-phase controller and T-phase controller are fundamentally on the same structure together. However, in this paper, the T-phase controller involves the DC-link voltage regulation loop, and the sign of load imbalance compensation loop of the M-phase and the T-phase controller is opposite because the reference direction of power flow is on the T-phase. The DC-link voltage regulation and the load imbalance compensation are achieved on the d-axis and the reactive power compensation is performed on the q-axis. The harmonic currents compensation is performed on both of the d-q axis. Hysteresis current control is employed for the inverter current control.

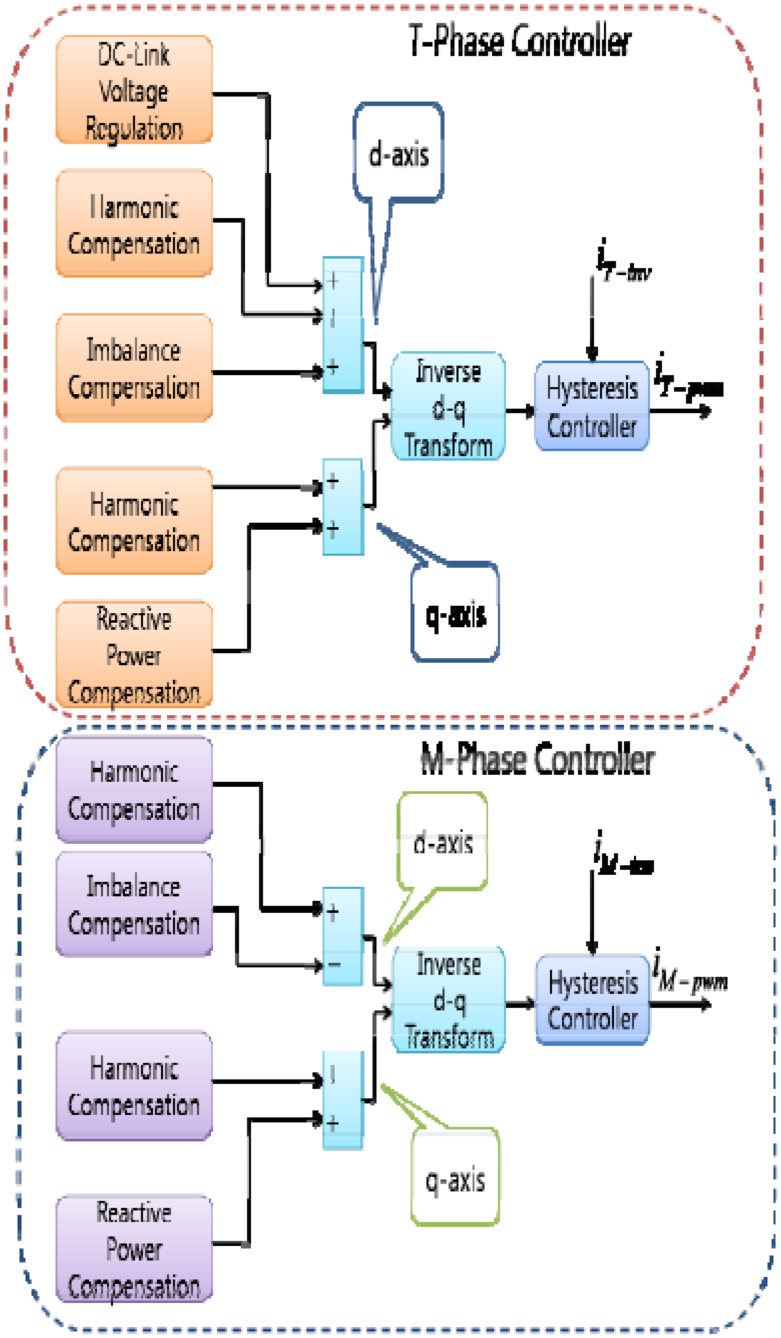
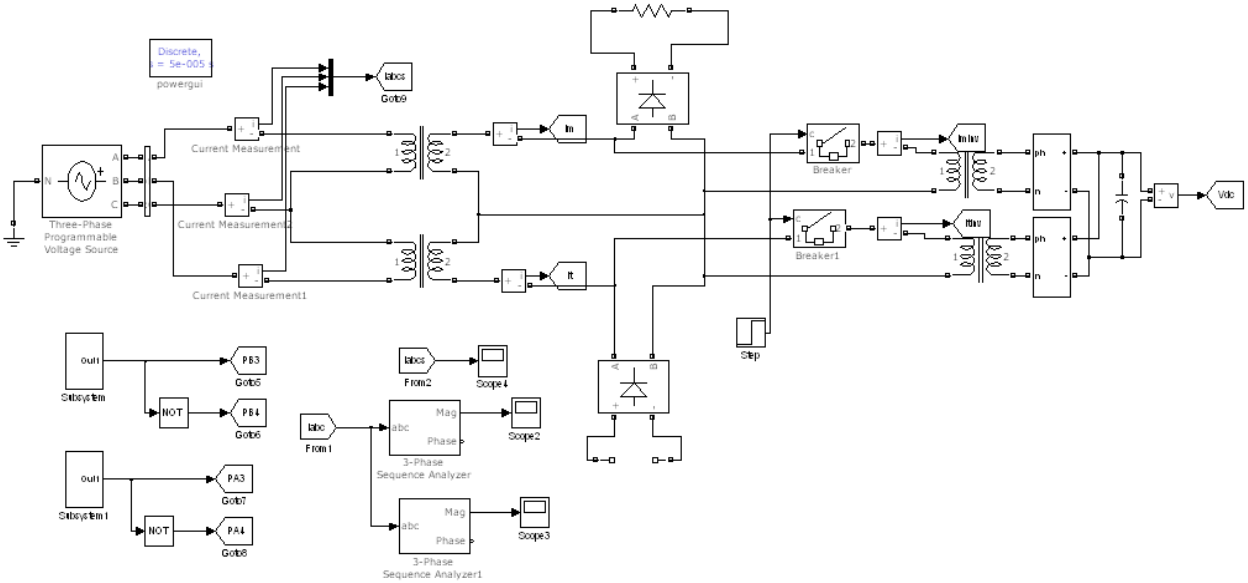
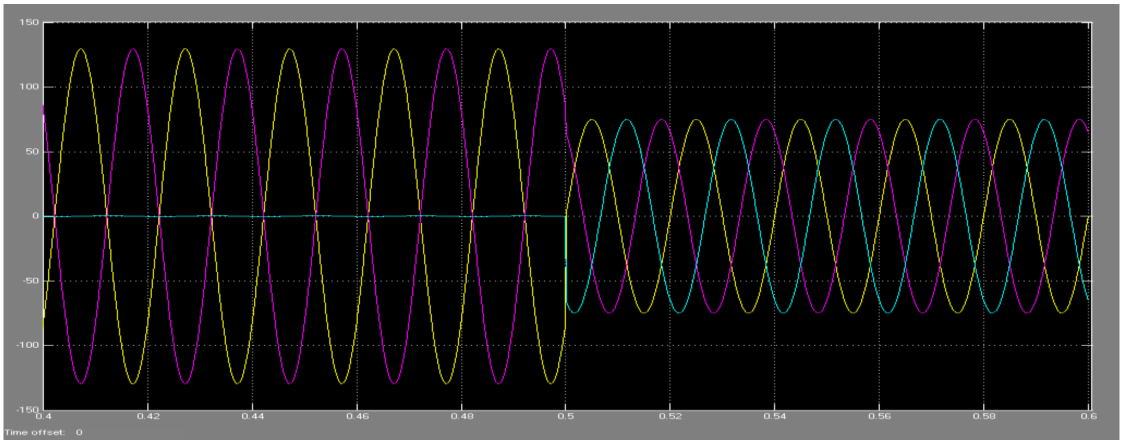


Fig. 7. Control block diagram of overall RPQC controller

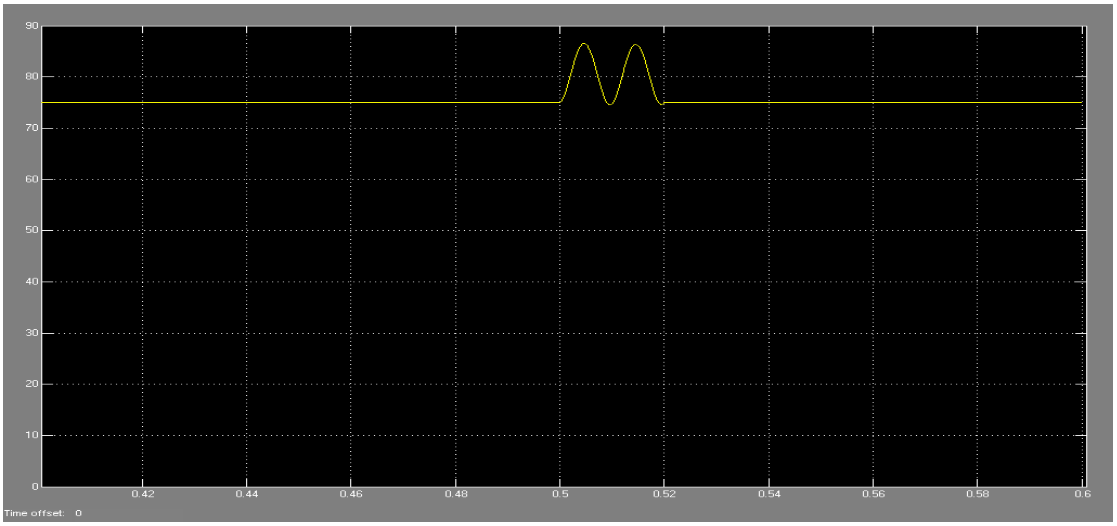
SIMULATION RESULTS:

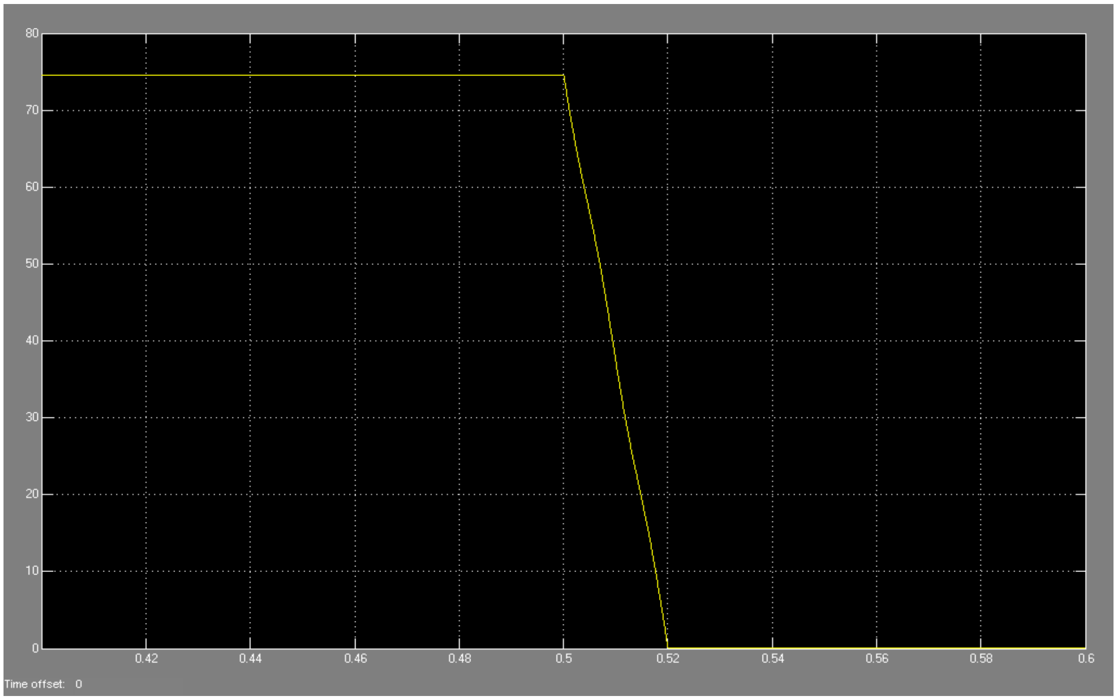
Single RPC





(a) Current of tractive transformer high voltage side





(b) Positive sequence and negative sequence current

Figure 7. Compensation result under the condition of single station

CONCLUSION:

The DAB phase topology has been selected for use in the APU due to preferred properties relating to the operation of lifting buck-boost, low-voltage device, small filters, high utilization of the transformer and switching losses low. Subsequently, soft switching region is analyzed, including the effect of ZVS capacitors. auxiliary inductors and switching strategy burst mode: In addition, two methods for extending the soft-switching region are presented. It comprises a combination of burst mode And auxiliary inductors, the optimum values of the components are calculated to minimize losses. As a result of analysis, it is found that the auxiliary inductors are not necessary to use burst mode. Experimental results show good agreement forms of wave action with the idealized model. In addition, the efficiencies of the burst and continuous mode with a measured performance of 95.6% at maximum output power at nominal conditions are presented. Furthermore, the use of capacitors ZVS shows approximately 40% reduction of the total loss, allowing power exceeding the rated output and maintaining good efficiency. The prototype was tested thoroughly throughout the operating range, including operation in burst mode with an input voltage of 500 to 900V. Burst mode is useful for extending the operating range in a soft switching mode. The operation during burst mode shows an efficiency slightly lower than that of continuous operation. The proposed system proposes a new compensation system the quality of energy that consists of several rail power conditioners. The proposed system can be used to offset the negative sequence current on the high-speed electrified railway. minimum capacity installed is 2/3 of traditional compensation capacity of one station is performed. a new compensation strategy simulation results show that the compensation proposed collaboration conditioners rail power is effective arises. You can reduce the ability of compensation and has good performance offsetting negative sequence current.

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