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A NEW RECTIFICATION METHODOLOGY OF RAILWAY POWER CONDITIONER CONSIDERING RAILWAY POWER SYSTEM

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ABSTRACT

The main aim of project is provides a new rectification methodology of railway power conditioner considering railway power system. In this project an investigation of a three phase dual active bridge is employed as high power density DC-DC converter for railway functions or operations. The three-phase dual active bridge is examined or determined concerning the current interruptions, the output power, and flexible switching sector, containing the impact of zero voltage switching capacitors. In addition, two quotas are proposed to achieve flexible-switching in the entire contriving space, actuality feathered inductors and a forthright switching procedure labeled the explosion mode. Optimal fundamental assessments are determined to reduce deficits in the complete performing range and to assess which part is best suited. Extremely fast train traction power supply system aims genuine negative order current issue. In the proposed extension Railway power conditioner is effortlessly in negative order current rectification. A unique power aspect collaboration compensation structure and plan of action based on RPC is proposed. The minimum capacity conducted is 1/3 smaller than traditional single station recommended. Simulation results have confirmed that the collaboration compensation system proposed can achieve a good performance at the negative order current rectification with capacity and without difficulty of cost.

KEY WORDS: RPC, Converter, Dual active bridge

I.INTRODUCTION

In conventional APUs, the galvanic isolation is often realized with low-frequency transformers, an example is shown in Fig. 1(a). These transformers are bulky and result in relatively large and heavy APUs. Especially for light rail vehicles, like trams and metros, this becomes a problem when the auxiliary power demand increases. Therefore, size and weight reduction of the APU is necessary to meet the auxiliary power demand within the capabilities of light rail vehicles. Most of the light rail transport systems are using a dc electrification system with common nominal voltages of 600 or 750V. Adding an isolated dc–dc converter is the preferable solution for reducing size and weight of the APU. By placing the isolated dc–dc converter between the input filter and the three-phase inverter, the bulky low-frequency transformer can be omitted, as can be seen in Fig. 1(b). This project focuses on the design of an isolated dc–dc converter for railway applications. With the rapid development of high speed railway in China, power quality has become a major concern for traction supply system. Compared with normal electrification railway locomotive load, high-speed locomotive load has some characteristics, such as big instantaneous power, high power factor, low harmonic components and high negative sequence component.

A large amount of negative current is injected into grid, which causes serious adverse impact on power system, such as increasing motor vibration and additional loss, reducing output ability of transformers. These adverse impacts threaten the safety of high-speed railway traction supply system and power system. Therefore, it's necessary to take measures to suppress negative current.

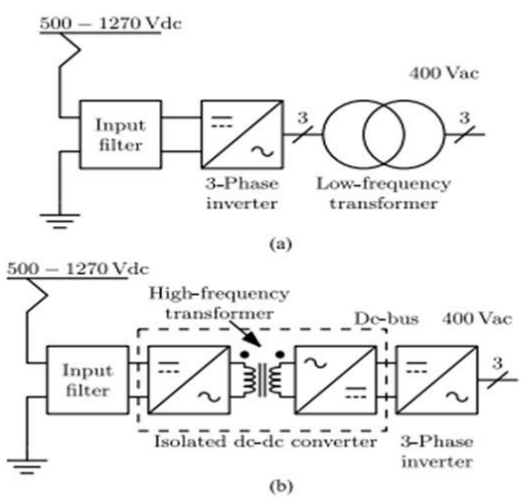

Fig 1 Simplified schematic of an APU. (a) Conventional APU. (b) Proposed APU.

II. STRUCTURE OF THE RPQC

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. 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. 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. An active power quality compensator with two single-phase inverters connected back-to-back (that is called the RPQC in this project) has been proposed. 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

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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.

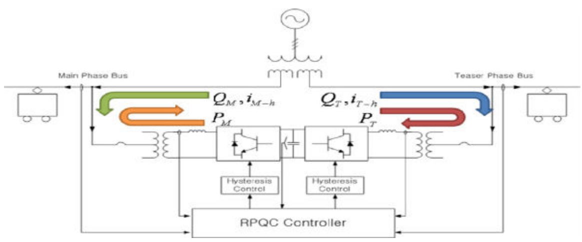

Fig.2: Configuration of RPQC

Fig 2.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. 3. 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. 3.2 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.

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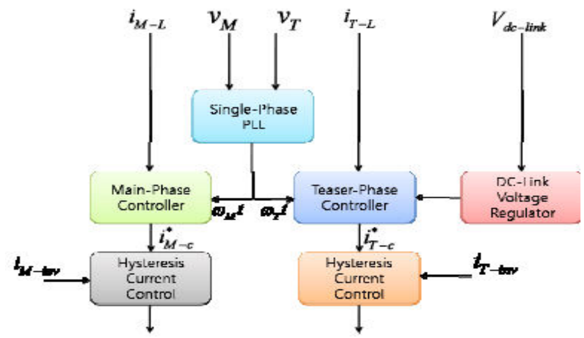

Fig.3. RPQC controller.

III.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. 4 shows the control blocks of DC-link voltage regulation algorithm.

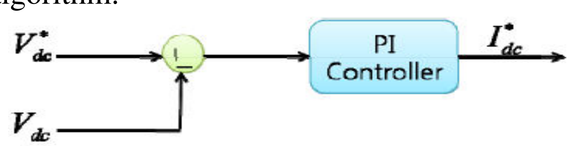

Fig.4. DC-link voltage regulation algorithm.

IV. OVERALL RPQC CONTROLLER

Fig.5. 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 project, 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

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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.

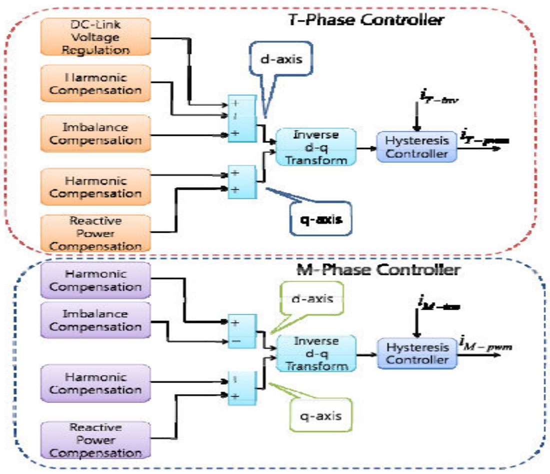

Fig.5. Control block diagram of overall RPQC controller.

V. THREE-PHASE DAB DC–DC CONVERTER

The three-phase DAB, shown in Fig.6, consists of two three-phase bridges coupled with a three-phase transformer connected in Y–Y. The bridges are operated in six-step mode at a constant frequency. By applying a phase shift between the input and Output Bridge, the power flow can be controlled. Because the converter is symmetrical from input to output, bidirectional power flow is possible. The transformer leakage inductances are used as current transfer elements and, therefore, not considered as parasitic. If the magnetizing inductance Lm is neglected, an equivalent circuit can be used for analysis. In this circuit, only the total leakage inductance Ls seen from the primary side is connected between the phase legs from the input and output bridge. The corresponding idealized waveforms are shown in Fig.

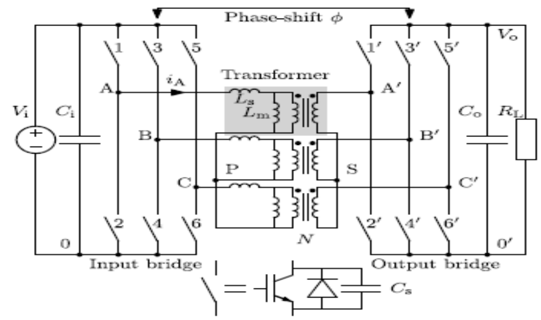

Fig.6.Three Phase Dual Active Bridge

A. Analysis

To analyze the soft-switching region, the current of phase A is defined for the first six intervals as depicted in Fig. The current i_A in the different intervals is given in (3) for phase shifts of $0 \leq \varphi \leq \pi 3$.For phase shifts of $\pi 3 \leq \varphi \leq$ 2 3 , a second set of equations, not given here, is utilized for further analysis of the soft-switching region. The magnetizing inductance Lm of the transformer is neglected in the analysis. Furthermore, the angular frequency is defined as $\omega = 2\pi fs$, with f_s the switching frequency in Hertz. The transformer's leakage inductance is indicated with Ls and the input and output voltage is defined as Vi and Vo, respectively. The reflected output voltage is given by $V_0' = V_0 N$ with N the turn's ratio of the transformer.

Because the phase current is symmetric, the current $i_A(0)$ can be found by solving the set of equations, assuming steady-state Fig. Three-phase DAB. (a) Topology. (b) Idealized waveforms, gating signals can be found in [1]. Condition $i_A(0) = -i_A(0)$. These results in

$$i_A(0) = \frac{1}{3WL_S}\left[\frac{2\pi}{3}(V_0' - V_i) - V_0'\emptyset\right] \quad (1)$$

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B. Output Power

Under the assumption of a lossless converter, the output power Po can be found with $P_o = P_i = \frac{3}{\pi}\int_0^{\pi} v_{AP}(\theta) i_{AP}(\theta) d\theta (2)$

$$i_A(0) = \begin{cases} i_A(0)+\frac{V_i+V'_0}{3\omega L_S}\theta & \forall\ 0\le\theta\le\emptyset \quad \text{:interval 1} \\ i_A(\emptyset)+\frac{V_i-V'_0}{3\omega L_S}(\theta-\emptyset) & \forall\ \emptyset\le\theta\le\frac{\pi}{3} \quad \text{:interval 2} \\ i_A\left(\frac{\pi}{3}\right)+\frac{2V_i-V'_0}{3\omega L_S}\left(\theta-\frac{\pi}{3}\right) & \forall\ \frac{\pi}{3}\le\theta\le\frac{\pi}{3}+\emptyset \quad \text{:interval 3} \\ i_A\left(\frac{\pi}{3}+\emptyset\right)+\frac{2V_i-2V'_0}{3\omega L_S}\left(\theta-\frac{\pi}{3}-\emptyset\right) & \forall\ \frac{\pi}{3}+\emptyset\le\theta\le\frac{2\pi}{3} \quad \text{:interval 4} \\ i_A\left(\frac{2\pi}{3}\right)+\frac{V_i-2V'_0}{3\omega L_S}\left(\theta-\frac{2\pi}{3}\right) & \forall\ \frac{2\pi}{3}\le\theta\le\frac{2\pi}{3}+\emptyset \quad \text{:interval 5} \\ i_A\left(\frac{2\pi}{3}+\emptyset\right)+\frac{V_i-V'_0}{3\omega L_S}\left(\theta-\frac{2\pi}{3}-\emptyset\right) & \forall\ \frac{2\pi}{3}+\emptyset\le\theta\le\pi \quad \text{:interval 6} \end{cases}$$

Finally, the expression of the output power for $0\le\varphi\le\frac{2\pi}{3}$ is

$$P_o = \begin{cases} \frac{V_i V'_0}{\omega L_S}\emptyset\left[\frac{2}{3}-\frac{\emptyset}{2\pi}\right] & \text{for } 0\le\emptyset\le\frac{\pi}{3} \\ \frac{V_i V'_0}{\omega L_S}\left[\emptyset-\frac{\emptyset^2}{\pi}-\frac{\pi}{18}\right] & \text{for } \frac{\pi}{3}\le\emptyset\le\frac{2\pi}{3} \end{cases}$$

C. Soft-Switching Region

Minimizing the switching losses is the key to achieve a high switching frequency. The turn-on losses are of main interest because excessive losses in the switch and the anti parallel diode can arise when the anti parallel diodes experience the reverse recovery process. The input bridge faces this problem when $i_A(0) > 0$. Therefore, the current has to fulfill $i_A(0) \le 0$ to ensure soft-switching in the input bridge. During the switching transient, the current i_A is considered constant.

Rewriting (1) to the required constraint gives the phase shift for ensuring soft turn-on of the switches in the input bridge, this is found to

$$\emptyset_i \ge \frac{2\pi(V'_o - V_i)}{3V'_o} \quad (5)$$

for i_A $(\varphi) \ge 0$. Using (3) and (1) gives the required phase shift to ensure soft turn-on of the switches in the output bridge, resulting i

$$\emptyset_o \ge \frac{2\pi(V_i - V'_o)}{3V_i} \quad (6)$$

D. Extension of the Soft-Switching Region

Auxiliary power converters for railway applications have to be able to operate from no-load to full-load conditions over the whole input voltage range. This means that the converter has to operate outside the soft-switching region. Therefore, two methods to extend the soft-switching operation of the converter have been investigated.

1) Auxiliary Inductors: The first method is based on adding reactive currents to fully charge or discharge the ZVS capacitors during the switching transient. The reactive currents are injected with three star-connected auxiliary inductors per bridge, as can be seen in Fig. 4(a). This has the same effect as the magnetizing inductances of the transformers, which are also connected in star. However, separate auxiliary inductors are preferred to have more design flexibility. The peak current, injected by the auxiliary inductors during the switching transient, is calculated from the voltage waveforms shown in Fig. For the input bridge, the peak current is calculated as

$$\hat{i}_{a-i} = \frac{2\pi V_i}{9\omega L_{a-i}} \quad (11)$$

and for the output bridge as

$$\hat{i}_{a-0} = \frac{2\pi V_0}{9\omega L_{a-o} N} \quad (12)$$

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Next, the soft-switching constraints from (7) and (8) can be extended to

$$i_A(0) + \frac{2C_sV_i}{t_b} - \frac{2\pi V_i}{9\omega L_{a-i}} \geq 0$$

and for the output bridge to

$$i_A(\emptyset) + \frac{2C_sV_o}{t_bN} - \frac{2\pi V_0}{9\omega L_{a-i}N} \geq 0$$

Then, the soft-switching region can be calculated with the minimum phase shift for the input bridge

$$\emptyset_i \geq \frac{2\pi(V_O' - V_i)}{3V_0'} + \frac{2C_SV_i}{V_0't_b}3\omega L_s - \frac{2\pi V_iL_s}{3V_0'L_{a-i}} \qquad (15)$$

and for the output bridge

$$\emptyset_0 \geq \frac{2\pi(V_i - V_O')}{3V_i} + \frac{2C_SV_0}{V_it_bN}3\omega L_s - \frac{2\pi V_0L_s}{3V_iL_{a-0}N} \qquad (16)$$

As shown with (15) and (16), the auxiliary inductance decreases the required phase-shift for operating in a soft-switching manner. To achieve soft-switching in the whole operating range, (15) and (16) should be solved for zero phase-shift, i.e., no-load condition. The corresponding values are shown in Fig. 4(b). For relatively low- and high-input voltages, the required values for La−i and La−o are low and, therefore, also causing high reactive currents. The use of auxiliary inductors presents a clear disadvantage due to the reduced efficiency and power density.

2) Burst Mode: The second method does not use any extra components but relies on a straightforward switching strategy. When the required output power Po is lower than the minimum load for soft switching, the converter switches from continuous mode to burst mode. In the burst mode, the converter operates with an output power P_b high enough to enable soft-switching. An example of the burst mode with the corresponding waveforms is shown in Fig. 5(a). The average output power is defined as

$$< p_0 > \frac{n}{m}P_b, \qquad \forall\ 1 \leq n \leq m$$

VI.SIMULATION RESULTS

A) EXISTING RESULTS

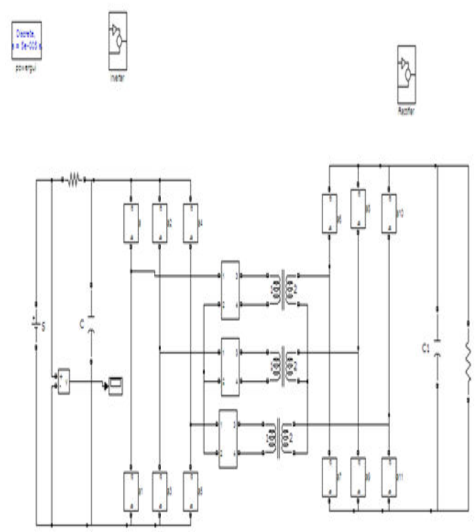

Fig.7.Three Phase Dual Active Bride

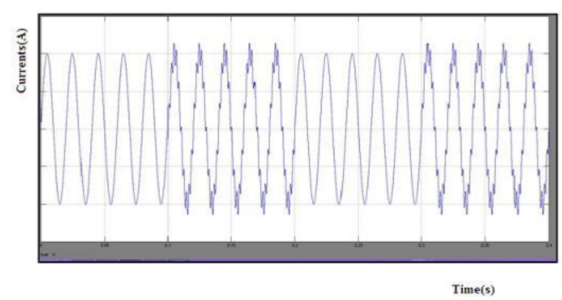

Fig.8.It Indicates Bridge Currents

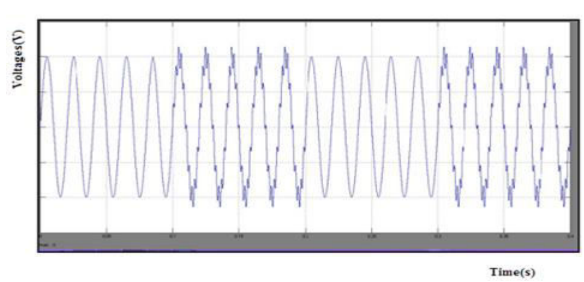

Fig.9.It Indicates Bridge Voltages

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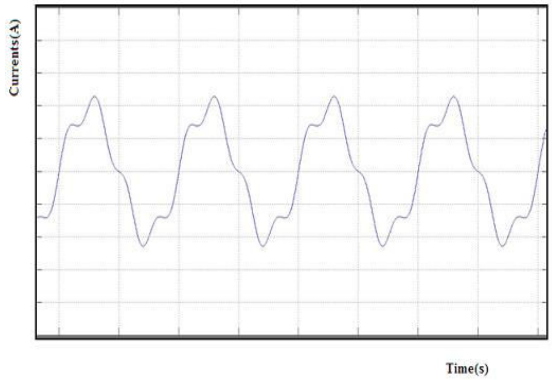
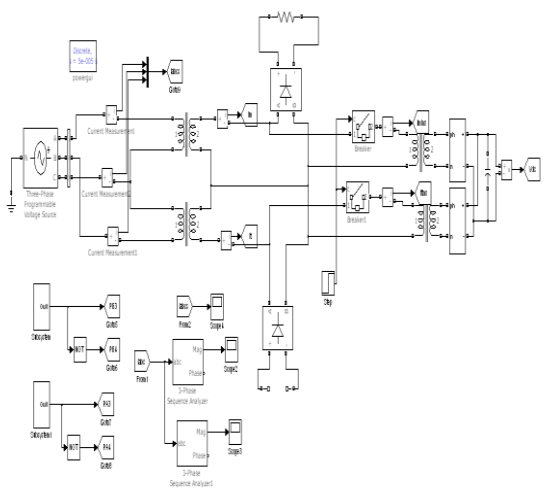


Fig.10.It Indicates Currents as Phase C

B) EXTESNSION RESULTS



Fig, 11. SINGLE PHASE RPQC

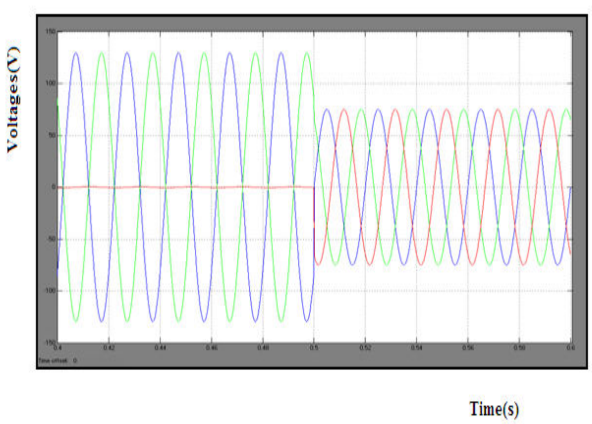


Fig.12.Current of tractive transformer high voltage side

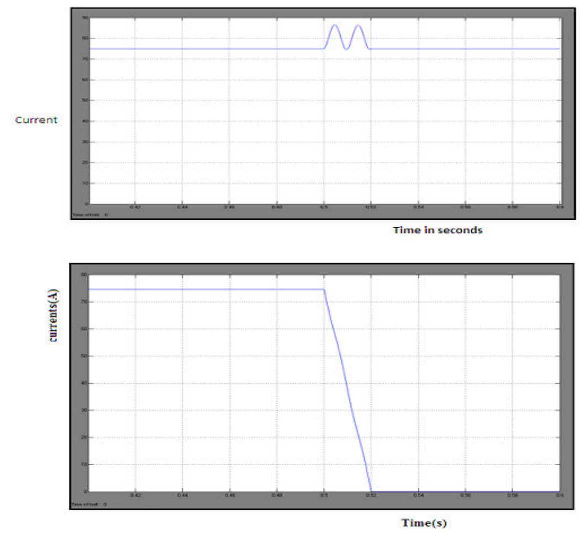


Fig.13. Compensation result under the condition of single station

THREE PHASE RPC CURRENTS

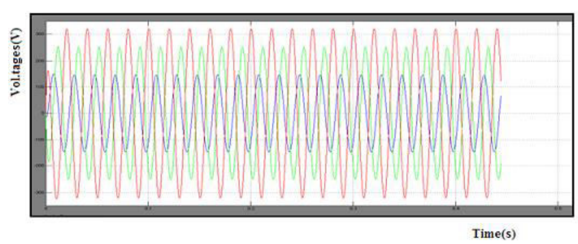


Fig.14.It indicates the three phase RPC Currents

CONCLUSION&FUTURE SCOPE

The three-phase DAB topology has been selected for application in the APU because of the preferred properties concerning buck–boost operation, low device stress, small filters, high transformer utilization and low-switching losses. Subsequently, the soft-switching region is analyzed, including the effect of ZVS capacitors. Furthermore, two methods are presented to extend the soft-switching region: auxiliary inductors and a burst-mode switching strategy. Comprising a combination of the burst mode and auxiliary inductors, optimal component values are calculated to minimize the losses. As a result of the analysis, it is found that auxiliary inductors are not necessary with the use of the burst mode. Simulation results show good agreement of measured waveforms with the idealized model. Furthermore, efficiencies of the burst and continuous mode with a measured efficiency of 95.6% at maximum output power at nominal conditions are presented. Also, the use of ZVS capacitors shows about 40% reduction of the total loss, enabling an output power above nominal and still preserving a good efficiency. The burst mode proves to be useful to extend the operating range in a soft-switching manner. Operation during burst mode shows slightly lower efficiencies compared to continuous operation.

The proposed system proposes a new power quality compensation system which is composed of several railway power conditioners. The proposed system can be used to compensate negative sequence current in high speed electrified railway. A minimum installed capacity is conducted which is 2/3 of the traditional single station compensation capacity. A new compensation strategy is raised Simulation results show that the proposed collaboration compensation of railway power conditioners is effective. It can reduce compensation capacity and has a good performance at negative sequence current compensation.

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