ANALYSIS AND MINIMISATION OF NEGATIVE SEQUENCE CURRENTS IN HIGH-SPEED TRACTION SYSTEM WITH RAILWAY POWER CONDITIONER

Karthik K[1] and Panisetty Sreenivasulu[2]

[1] *Department of EEE, Annamacharya Institute of Technology and Sciences, India*

[2] *Department of EEE, Annamacharya Institute of Technology and Sciences, India*

***Abstract*— Analysis and Minimization of Negative Sequence Currents in High-Speed Traction System with Railway Power Conditioner is presented in this paper. The negative sequence currents are the major problems in high speed traction system. A Railway Power Conditioner system along with the traditional power quality arrangement is developed to minimize the negative sequence currents and it reduces the 1/3rd of conductor capacity compared to the conventional system. A MATLAB/Simulink model of traction system with developed converter is presented with the corresponding outputs to exhibits the greatness of the Railway Power Conditioner system along with the traditional power quality arrangement.**

***Keywords*—Compensation techniques, Negative sequence currents, Power quality, Railway Power Conditioner, Traction system**

1. INTRODUCTION

Railway transportation of people and cargo has many advantages compared with other modes of land/air transportation. This includes better control on schedule and travel time, lower exposure to risk factors such as heavy traffic and road accidents, more comfortable seating, contribution to environment and economy [1,2]. Another advantage of electrified railway system is that the energy is delivered to the train when needed, unlike the other modes of transportation (land, air, sea) where the source of energy must be carried by the vehicle for the duration of the journey.

The supply voltage of Railway Electrification System (RES) can be DC or AC of low voltage. The standard DC voltages vary between 600 V to 3000 V. The standard AC voltages vary between 11 kV and 25 kV, although older systems may have a voltage below that range. The frequencies found are 25, 50, and 60 Hz. Although other types of tractions are possible, among all electric railway traction appears superior in many respects.

In a conventional traction system trains are being fed by two adjacent phases through a single-phase transformer, as can be seen in Fig. 1. In order to equally load all three phases, the phase connection changes in every substation. With this supply system the currents on the grid side will be unbalanced at every single instant in time, due to the single-phase load characteristic.

The conventional system is simple, has a low investment cost, and the existing knowledge is large in this technology. However, when the expectations on the railway increase, regarding denser traffic and heavier loaded trains, certain improvements or even a complete redesign of the whole system is required [3-5]. It is no longer to have unpowered distances in the railway system. Moreover, the conventional system provides poor power quality in the grid. A modern railway system should preferably be able to maintain the voltage levels within given limits, mitigate harmonics from the traction equipment, and reduce the negative-sequence currents in the system. The amount of neutral zones should be reduced or avoided if possible.

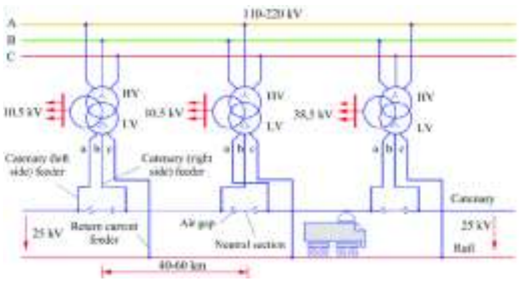


Fig. 1 Conventional railway feeding system

Under unbalanced situations, negative-sequence current will occur in the grid. The magnitude of these negative sequence currents depends on the degree of unbalance. The negative-sequence currents have a negative impact on the grid and apparatuses that operate in the grid. It will decrease the transmission capability, lower the output power from the transformer, and disturb rotating machines like motors and generators[6,7].

Negative-sequence currents in electrical machines such as in a motor or a generator will decrease their efficiency. The negative-sequence currents will create a magnetic flux in the rotor that opposes the direction of rotation of the rotor. A relative motion will occur between the magnetic flux and the rotor. This will cause rotor heating problems and may lead to insulation failure and mechanical problems [8-10]. Heating problems will demand extra cooling, and the efficiency of the machine will decrease accordingly. The positive sequence current will induce a magnetic flux in the same rotation as the rotor.

The negative-sequence current also accepts the transmission lines. It flows in the transmission lines and does not perform any actual work. It cause additional power loss, and lower the transmission capability of the line. Transformers will also be accepted [11-13]. The negative-sequence current in the grid results in asymmetrical three-phase currents on the primary side of transformers. The rated output of a transformer will be limited by the largest current on the primary side, and thereby the output power will be lower. This leads to additional losses in a transformer and heating of the iron. The negative-sequence current may also disturb the relay protection in the grid [14-15]. The consequences in the grid from negative-sequence currents are severe and detrimental for most apparatus. The *amount of negative-sequence current* should, therefore, be reduced as much as possible.

The objective of this paper is to minimisation of Negative Sequence Currents in High-Speed Traction System with Railway Power Conditioner. A MATLAB/Simulink model of traction system with developed converter is presented with the corresponding outputs to exhibits the greatness of the Railway Power Conditioner system along with the traditional power quality arrangement.

2. TRANSPORTATION SYSTEM OF RAILWAYS

The two most common Electrification Power Supply Systems for High Speed Rail and Commuter Rail Lines are a 1 x 25 kV Systems and a 2 x 25 kV Systems. Both Systems receive power from High Voltage, 50 Hertz, 3 Phase Utility Circuits and both Systems provide 25kV, 50 Hertz, Single Phase Power to the Overhead Catenary System. 1 x 25 kV Systems utilizes Traction Power Supply Stations with Standard Power Supply Transformers which provide Power at 25Kv to the Overhead Contact System as shown in Figure 2.

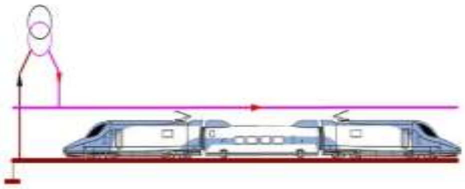


Fig. 2 lx25 kV system with Booster transformers.

The 2 x 25kV Systems utilize Traction Power Supply Stations, Switching Stations and Paralleling Stations with Autotransformers, which provide 25kV to the Overhead Contact System and -25kV along Track Negative Feeders as shown in Figure 3. To ensure that power is not lost to an entire Traction Power Supply System (TPSS) as a result of a single contingency occurrence both Systems utilize redundant Utility Power Supply Circuits and redundant HV Transformers.

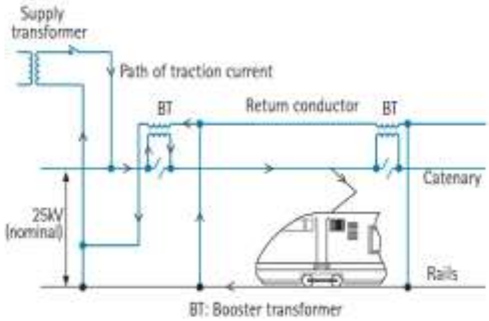


Fig. 3 2x25 kV system with Booster transformers

The advantage of the 2x25 system over the 1x25 system, especially for high speed trains is well documented. Among other, the New Haven-Boston line is electrified with a 2x25 kV system. Both systems use single phase AC provided by the three-phase power grid. In order to keep the power grid as balanced as possible, different sections of the RES are supplied from different phases of the grid.

2.1 RAILWAY ELECTRIFICATION SYSTEM

The RES is a subsystem of the overall railway system and cannot be designed in vacuum. Therefore, to specify the requirements of the RES, the starting point is the physical layout of the route, the location of the passenger stations, the topography of the track route including the curves to be encountered and their physical characteristics.

This information together with the required acceleration and speed of the train as a function of position along the track can be used, (using Newtonian mechanic), to determine the tractive effort requirement of the train as a function of position. Depending on the type of motor used, the motor drive, and efficiency, the electric power demand by the train as a function of position can be calculated using the tractive effort and speed (power = tractive effort x speed). Next, different operation scenarios are assumed starting with the number of trains per hour to run, in what station a train should stop, what are the speed limits at various lengths of the route, the required acceleration and deceleration, etc.

All this is to determine where the trains are on the tracks at any instant of time. Having those snapshots, the engineer determines the power requirements at the different points on the tracks (where the trains are). This information provides the interface between the overall system and the RES (the power system providing electric energy to the trains).The specifications of the electrification system constitute a subset of the overall specifications, for example, voltage specifications are specified by international standards such as BS EN 50163 and IEC 60850.

These take into account the number of trains drawing current and their distance from the substation. For example: Nominal System Voltage (25.0 kV), Maximum Long Term Voltage (27.5 kV), Maximum Short Term Voltage (29.0 kV), Minimum Long Term Voltage (19.0 kV), Minimum Short Term Voltage (17.5 kV), Minimum Supply Voltage for Utility Circuits (115 kV at SS) among many others. The numbers in parenthesis are taken from the European Standard. However, this project deal with a sub-problem of the electrification system and the following paragraph is pertinent to the Load factor problem.

Designing an RES is done in several stages. In the first stage the following information is generated:

1. Locations and speeds of trains: This is based on design specification (speed, headway...), topography, and type of trains.
2. Power requirements: The power requirement of each train on each track and the location of each train is calculated using the speed and the traction effort. This calculation is usually done using software that takes the slope of the track, the acceleration of the train, etc., into consideration when using Newton's laws of motion.
3. Certain power system configuration and wire sizes are selected.

3. RAILWAY POWER CONDITIONER

Railway Power Conditioners (RPCs) were introduced by Japanese scholars in the 90s and has been in commercial operation in Shinkansen since the beginning of 2000. Similar devices have also been described in papers in other configuration or with added components that improve their performance. RPCs do not have a unique definition, but they are often referred to a conditioner placed after a special design transformer, such as a Scott or V/V-transformer, as shown in figure 4. Furthermore the conditioners often consist of two single phase AC/DC-converters connected back-to-back with a common DC-link. They are placed between the transformer secondary sides.

These devices enable active power flown between two sections of the catenary. During an upgrade of Shinkansen in 2002 several RPCs were installed in the railway system to obtain a balanced public grid. Later demonstration could show that balance were established between the phases but the RPC could also compensate for reactive power and keep the voltage levels within given requirements. As modern trains also tend to a larger extent use pulse width modulation (PWM) control the need of compensating reactive power is decreased while the need of active power transfer still exists.

The major advantage with this technology is that total balance can be achieved in the electrical grid. The major disadvantage is that this technology still requires neutral zones.

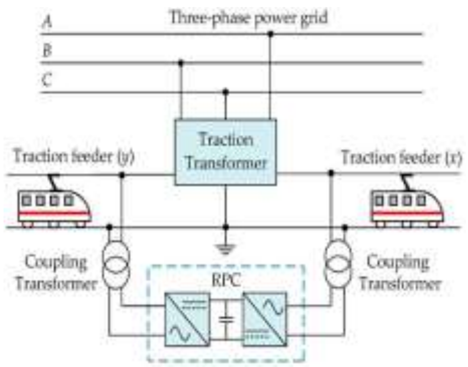


Fig. 4 Railway power conditioner connected to the grid via a step-down Transformer

The main purpose with an RPC is to Transfer active power between two electrical subsystems, Compensate reactive power on each side of the converters and the Mitigate harmonics.

4. METHODOLOGY OF THE PROPOSED SYSTEM

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. This causes serious adverse impact on power system, such as increasing motor vibration and additional loss, reducing output ability of transformers and causing relay protection disoperation. These adverse impacts threaten the safety of high-speed railway traction supply system and power system. Therefore, it is necessary to take measures to suppress negative current.

Many methods and power quality compensators are studied in order to solve the issue of power quality. The traditional methods adopted to suppress negative sequence current are as follows:

(1) Connect unbalanced load to different supply terminals.
(2) Adopt phase sequence rotation to make unbalanced load distributed to each sequence reasonably.
(3) Connect unbalanced load to higher voltage level supply terminals.
(4) Use balanced transformers such as Scott transformer and impedance balance transformer. These methods have some effects on reducing degree of unbalance, but they are lack of flexibility and can't adjust dynamically.

Recent years, high-voltage, large-capacity Static Var Compensator (SVC), Active Power Filter (APF) 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. APF 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 proposed in to compensate negative-sequence current, harmonics and reactive current.

Railway Power Conditioner (RPC), can make comprehensive compensation of negative sequence components, harmonics and reactive power. It 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 proportional-integral control based on fuzzy algorithm is adopted to realize a fast and smooth tracking to reference current. From this paper, 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.

RPC is used to transfer active power; the reactive power is supplied by the TCR and the filter. These works prove that RPC is an effective way to solve the power quality problems in railway system. But the compensator capacity is still too big to make RPC into practice. To reduce the high compensator capacity, this project puts forward a new railway negative unbalance compensation system based on the thought of multiple RPC collaboration compensation. This method realizes a minimum compensation capacity which is strictly proved, which reduces 1/3 capacity compared with traditional single station RPC compensation method. The simulation results have verified the correctness of the method proposed in this theory.

Vol 11, Issue 6,June/2020
ISSN NO:0377-9254

4.1 RPC STRUCTURE AND ANALYSIS OF COMPENSATION PRINCIPLE

The structure of RPC is shown in Figure 5. Three phase 220kV voltage is stepped down into two single-phase power supply voltage at the rank of 27.5kV by V/V transformer. RPC is made of back-to-back voltage source converters and a common dc capacitor, which can provide stable dc-link voltage. Two converters are connected to secondary arms of V/V transformer by step down transformer. Two converters can transfer active power from one power supply arm to another, supply reactive power and suppressing harmonic currents.

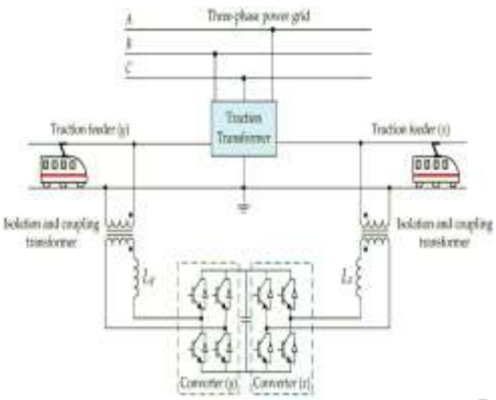


Fig. 5 Traction power system with a three-phase V/V transformer and a RPC

The single phase sequence rotation is widely adopted in traction power supply system is discussed in this system and also a 3 stations collaboration compensation system in upcoming sections.

4.2 SINGLE RPC COMPENSATION

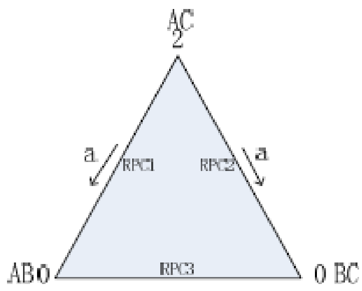
Based on the compensation strategy of RPC, when there is a maximum capacity in one of the traction feeder arms, RPC transfers active power from one traction feeder arm to another. And then compensates reactive power to both traction feeder arms based on Steinmetz theory. So the compensation capacity of single RPC is given in Eq. (1)

$$S = \sqrt{\left(\frac{1}{2}\right)^2 + \left(\frac{1}{2\sqrt{3}}\right)^2}\,\frac{X}{2} \qquad (1)$$

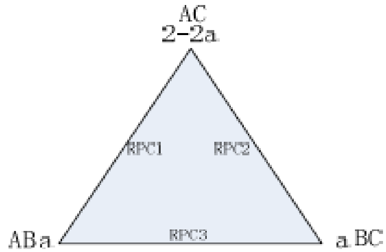
S=0.28 X

4.3. THREE STATIONS COMPENSATION

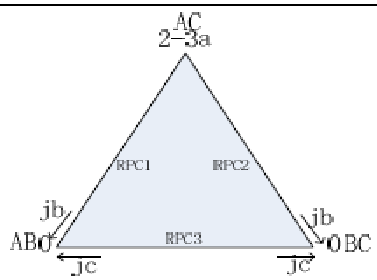
The simple model of 3 stations structure is shown in Figure 6. Since RPC could transfer a quantity of active power and compensate reactive power, a triangle is applied to illustrate the principle of collaboration compensation: apexes of the triangle are regarded as active load in Phase-AC, Phase-BC and Phase- AB, and edges of the triangle are regarded as three railway power conditioners. The arrows mean the delivery of active power (real part) and compensation of reactive power (imaginary part). There are three steps to compensate. Firstly, transfer a quantity of active power. Secondly, separate the network into two parts: a balanced network and an unbalanced network. And last, make compensation to the unbalanced network based on the Steinmetz theory.



(a) Active power delivery



(b) Three phase power after active power delivery



(c) Reactive power compensation

Fig. 6 simple model of three stations structure

According to the Steinmetz theory, fully compensation should satisfy the relationship of b+c

Vol 11, Issue 6,June/2020
ISSN NO:0377-9254

$\geq\frac{2-3a}{\sqrt{3}}$ The capacity of three RPC is $\sqrt{a^2+b^2}$,$\sqrt{a^2+b^2}$, c separately. The installed capacity will be the maximum of the three RPC capacities above. So we can obtain the minimum installed capacity when $\sqrt{a^2+b^2}=c$

The results can be conducted that a=1/3, b = 1/3√3 and the minimum capacity is S_{min} = $\sqrt{a^2+b^2}$ = c= 2/3√3. This is a fully compensation but the station where RPC2 installed is capacitive. To avoid this condition, RPC1 supply inductive reactive power with the value of *b*, and RPC2 supply capacitive reactive power with the value of *b*, too. So the capacitive condition is avoided and the system keeps balance at the same time. Working condition of three stations is shown in Figure 7. The ellipses stand for different traction feeder arms, the squares stand for RPC which connect to traction feeder arms. The arrows stand for active power transfer and reactive power compensation.

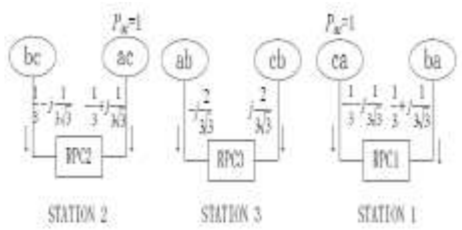


Fig. 7 working condition of three stations which supply active power and reactive power

Three stations collaboration compensation minimum capacity is given in Eq. (2)

$$S_3=\sqrt{\left(\frac{1}{3}\right)^2+\left(\frac{1}{3\sqrt{3}}\right)^2}\frac{X}{2} \qquad (2)$$

$$S_3=\frac{2}{3\sqrt{3}}\frac{X}{2}=0.19\text{X}$$

This is the 2/3 of the capacity of single RPC compensation. Table 1 shows the compensation capacity of the two strategies.

Table 1. Comparison of single and three stations collaboration compensation

Compensation type	**RPC Formula**	**RPC Capacity**
Single stations compensation	$S=\sqrt{\left(\frac{1}{2}\right)^2+\left(\frac{1}{2\sqrt{3}}\right)^2}$	S= 0.28 X $\frac{X}{2}$
Three stations collaboration compensation	$S_3=\sqrt{\left(\frac{1}{3}\right)^2+\left(\frac{1}{3\sqrt{3}}\right)^2}$	S= 0.19X $\frac{X}{2}$

It can be proved that this installed capacity (0.19*X*) can satisfy any condition when *Y′* varying from 0 to 2. If there is *N* stations connect to one 220kV bus, *N* may be 3*n*, 3*n*+1 or 3*n*+2 (*n*=0,1,2…). When *N*=3*n*, it means there are n sets of 3-stations compensation. When *N*=3*n*+1, it means there are n sets of 3-stations compensation and a single station compensation. When *N*=3*n*+2, it means there are *n* sets of 3- stations compensation and single station compensation.

5. SIMULATION RESULTS AND DISCUSSION

The proposed system is designed and implemeted in MATLAB/Simulink model for analyses of single and and three stations collaboration compensation in following sections.

5.1 SINGLE RPC COMPENSATION

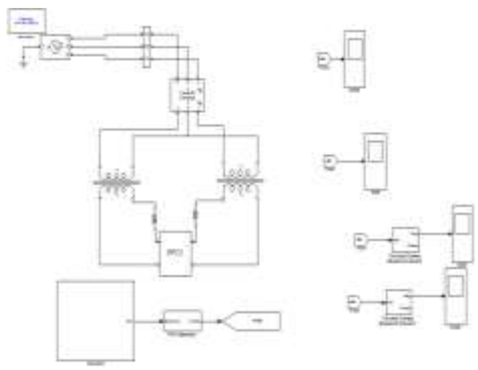


Fig. 8 Simulink model of Single RPC compensation

Fig. 8 shows the simulink model of single station RPC compensation method, The simulation parameters are as follows: three phase voltage of the system is 220kV; the frequency is 50Hz; the ratio of V/V transformer is 8:1; the ratio of step down transformer is 40:1; the capacitor of RPC at DC side is 100000μF, and the value of L_1 and L_2 is 3mH and 2mH respectively.

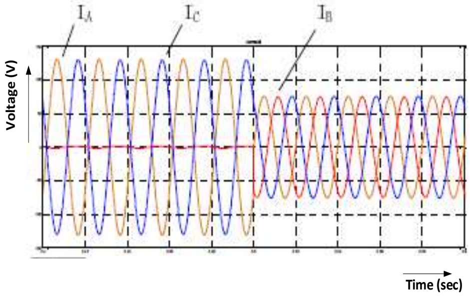


Fig. 9 Positive and negative sequence of currents under compensation results

The a-phase load was switch on at 0s, the compensation system ran at 0.5s. The simulation schematic diagram is shown in Fig. 9. Similarly the comensation method is analysed in the three station system with the RPC compensation technique.

5.2 THREE STATIONS RPC COMPENSATION

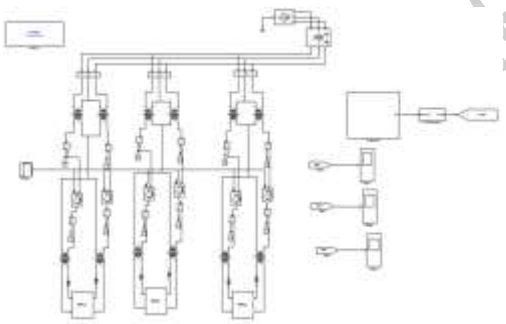


Fig. 10 Simulink model of three RPC compensation

Fig. 10 shows the simulink model of three station RPC compensation method, The simulation parameters are as follows: three phase voltage of the system is 220kV; the frequency is 50Hz; the ratio of V/V transformer is 8:1; the ratio of step down transformer is 40:1; the capacitor of RPC at DC side is 100000μF, and the value of L_1 and L_2 is 3mH and 2mH respectively.

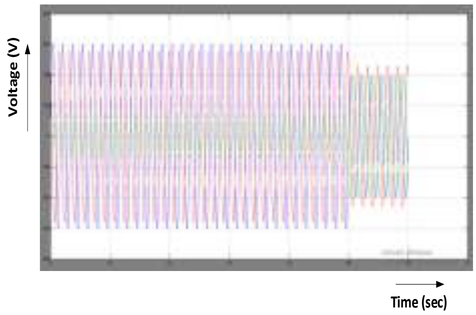


Fig. 11 Current of tractive transformer high voltage side (Y=0)

Figure 11 shows the waveform before and after compensation when the maximum locomotive load appears at the Phase-AC at the condition of Y=0. The situation before compensation is almost the same as single station compensation, except for that the load is twice as much as single station locomotive load. With the use of compensator, the unbalance level was changed from 100% to 1%.

Figure 12 is the waveform when between $0 \leq Y \leq 0.66$, Y appears at Phase AB. Compensator was put into operation at 0.5s. The unbalance level was reduced from 71% to 7%.

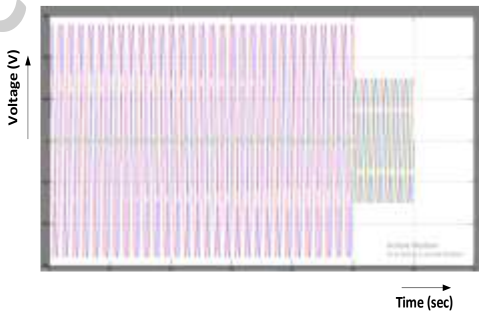


Fig. 12 Current of tractive transformer high voltage side (O<Y<0.66)

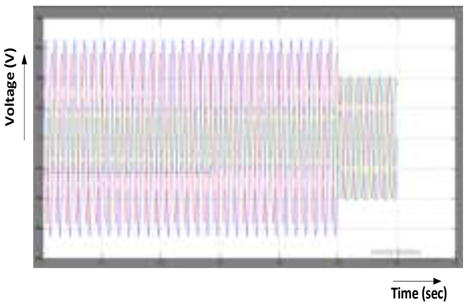


Fig. 13 Current of tractive transformer high voltage side (0.66<Y<1)

Vol 11, Issue 6,June/2020
ISSN NO:0377-9254

Figure 13 shows the waveform between the limits of $0.66 \leq Y \leq 1$. The unbalance level was reduced from 60% to 2%. It can be seen from the simulation that there is a serious unbalanced condition before the compensation. The collaboration compensation network is effective in reducing the negative current(the unbalance level is reduced below 8%). The error may come from the loss of power electronic components and isolation transformers.

The conventional system is simple, cheap and there is a large knowledge base in this technology, but it creates poor power quality in the grid. In practice the feeding from the single-phase transformers will be alternating between the phases in the grid. This is done to equalize the average load between the phases. However, the stochastic behavior of the train load will make it impossible to have equal loading on all phases with single-phase transformers. This may disturb other customers in the grid and lower the over-all performance of the power system. The power quality may even get worse with trains running at higher speeds or trains with a heavier load. To obtain a better power quality, compensation must be implemented either on the grid-side or at the railway-side.

The RPC can serve as a power compensator on the railway-side to symmetrize the grid currents. This device contains converters with switching devices that will create harmonics. To obtain a better performance more studies must be carried out to investigate its output harmonics, the losses and the ratings of an RPC. To determine if this is a competitive solution for the railway traction system, further studies must be performed. The system must be investigated in terms of harmonics and in what way the harmonic distortion from both the converters and the traction equipment on the trains can be reduced.

The RPC-system could also be compared with other compensation systems, such as the STATCOM. The comparison could include both cost and performance. In this study only the basic operation of the RPC has been investigated. The behaviour of this system could be further analyzed under fault conditions. It is also interesting to understand if the system can provide further support to the electrical grid, during the time that no train load is present.

6. CONCLUSION

This study has shown that railway power conditioners (RPCs) can mitigate unbalances in the grid, as they reduce the degree of current unbalance significantly. In a conventional system, the unbalance factor can be nearly 100 %, when the train is the only load served by the grid. In the system with a V/V-transformer and a connected RPC, the unbalance factor for the same conditions decreased to about 0.45 %. The RPC could hence fulfill its purpose. The proposed system is designed in MATLAB/Simulink environment and analysed in single station compensation and three stations compensation methods and obtain results are compared and tabulated.

REFERENCES

[1] Xu, Q., Ma, F., He, Z., Chen, Y., Guerrero, J. M., Luo, A., ... & Yue, Y. (2016). Analysis and comparison of modular railway power conditioner for high-speed railway traction system. *IEEE Transactions on Power Electronics*, *32*(8), 6031-6048.

[2] Zhang, D., Zhang, Z., Wang, W., & Yang, Y. (2015). Negative sequence current optimizing control based on railway static power conditioner in V/v traction power supply system. *IEEE Transactions on Power Electronics*, *31*(1), 200-212.

[3] Kokatam Triveni, Shaik Fayaz, Vinsent Sireesha, S Jaswanth, Kumar K, “A Short Review on High Voltage Gain DC-DC Power Converters for Low Voltage Renewable Energy Sources” JASC: Journal of Applied Science and Computations, Vol. 6(4) (2019), pp. 3565-36574.

[4] Lao, K. W., Wong, M. C., Dai, N., Wong, C. K., & Lam, C. S. (2014). A systematic approach to hybrid railway power conditioner design with harmonic compensation for high-speed railway. *IEEE Transactions on industrial electronics*, *62*(2), 930-942.

[5] Lao, K. W., Wong, M. C., Dai, N. Y., Wong, C. K., & Lam, C. S. (2015). Analysis of DC-link operation voltage of a hybrid railway power quality conditioner and its PQ compensation capability in high-speed cophase traction power supply. *IEEE Transactions on Power Electronics*, *31*(2), 1643-1656.

[6] Roudsari, H. M., Jalilian, A., & Jamali, S. (2018). Flexible fractional compensating mode

for railway static power conditioner in a V/v traction power supply system. *IEEE Transactions on Industrial Electronics*, *65*(10), 7963-7974.

[7] Rajasekharachari, K., G. Balasundaram, and K. Kumar. "Implementation of a Battery Storage System of An Individual Active Power Control Based on A Cascaded Multilevel PWM Converter." International Journal of Innovative Research in Science, Engineering, and Technology. 2.7 (2013).

[8] Langerudy, A. T., & Mariscotti, A. (2016, April). Tuning of a railway power quality conditioner. In *2016 18th Mediterranean Electrotechnical Conference (MELECON)* (pp. 1-7). IEEE.

[9] Chen, Y., Chen, M., Tian, Z., Liu, Y., & Hillmansen, S. (2019). VU limit pre-assessment for high-speed railway considering a grid connection scheme. *IET Generation, Transmission & Distribution*, *13*(7), 1121-1131.

[10] Roudsari, H. M., Jalilian, A., & Jamali, S. (2018, May). Half-bridge power quality conditioner for railway traction distribution system based on a new balancing transformer. In *2018 Electrical Power Distribution Conference (EPDC)* (pp. 1-7). IEEE.

[11] T. Jahnavi, and Kumar K, "A New Power Control Strategy in Micro grid Integrated with Solid State Transformer" International Journal of Research, Vol. 7 (2018), pp. 393-400.

[12] Rajasekharachari K., K. Shalini, Kumar. K and SR Divya, "Advanced Five Level-Five Phase Cascaded Multilevel Inverter with SVPWM Algorithm"." International Journal of Electrical Engineering & Technology (IJEET), 4.4 (2013): 144-158.

[13] Kumar, K., S. V. Sivanagaraju, and K. Rajasekharachari. "Single Stage AC-DC Step up Converter Using Boost and Buck-boost Converters." International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering, 2.9 (2013): 4245-4252.

[14] Sivanagaraju, S. V., K. Kumar, and K. Rajasekharachari. "Performance Comparison of Variable Speed Induction Machine Wind Generation System with and Without Fuzzy Logic Controller." International Journal of Innovative Research and Development, 2.7 (2013).

[15] Dr. M. Vishnuvardhan, power quality improvement analysis by using different control techniques, Journal of Engineering Sciences, Pp :20-31, DOI: 10.15433. JES.2020. V11I02. 43P.4