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Power Quality Issues in Railway Electrification

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Abstract— This paper presents a perspective on power quality issues through railway electrification development and the necessity of power quality and system requirements for appropriate power quality. It has been a major problem in railway networks because of their special characteristics. The most important systems affected by railway electrification are upstream power supply networks railroad signaling and communication, and telecommunication systems. The most important problem is, in the case of three-phase systems, the imbalance of current because a railway load is nowadays always a single-phase load which causes a negative-sequence component (NSC) current equal to the positive-sequence component (PSC). In a high-speed train application, the modularized traction converter produces the significant harmonic currents caused from the switching behavior of a power converter. . One way to minimize the interference is to design the secondary windings of a power transformer decoupled magnetically as possible.

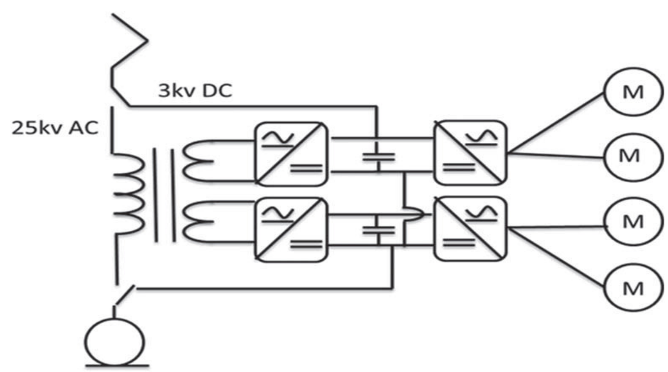
Keywords— Power quality, negative-sequence component, Harmonic current, modularized traction Behavior

INTRODUCTION

Power quality determines the fitness of electric power to consumer devices. Synchronization of the voltage frequency and phase allows electrical systems to function in their intended manner without significant loss of performance or life. Power quality can be referred to a wide area of parameters, such as voltage fluctuations, voltage and current imbalance, harmonics, reactive power, etc., among which the most problematic ones in case of the railway industry are current NSC, current harmonics, and reactive power. Compensation methods throughout electric railway development are classified based on basic concepts. This low quality of power may harm the power system and cause the adjacent loads to malfunction. There is a co phase system which has been highlighted in this paper. The three-phase to single-phase converter-based substation is adopted in this system, which can transfer active power from three-phase grid to singlephase catenary and compensate reactive power and harmonics of the locomotives. The power quality issues through electric railway development are overviewed as follows:

System Imbalance

System imbalance is the most serious problem in electric railway power quality because most trains are single phase and a single-phase load produces a current NSC as much as a PSC.[1] A new traction power supply system adopting single-phase traction transformer and active power flow controller (PFC) is proposed. In the new system, the power quality problems caused by single-phase traction load are solved in grid side and the continuous power can be provided to electric trains without neutral sections in traction side. The mathematic model of the new system is built and the compensation currents of PFC are calculated.



Voltage Problems

The most frequent problems of voltages are associated with their magnitudes. The major problem is unbalanced currents produce unbalanced voltages. Traction motors and other related loads in trains are designed to function properly with reduced voltage amplitude by 24% or increased amplitudes by 10% than the nominal voltage of electric railroad drives

Arcing

The interaction between the pantograph/catenary of overhead systems or between brushes and the third or fourth rail causes arcs because of dynamic latitudinal tolerance between the wheels and rail. Arcs will occur, which can distort voltages and currents and produce a transient dc component in the ac systems causing a breakdown of dielectrics.

HAZARDS OF POWER QUALITY PROBLEMS

1) Impacts on Signaling and Communication :
In the presence of harmonics, communication signals may be affected by harmonic frequencies. Traffic operation has a significant impact on energy consumption in metro lines and thus it is important to analyze strategies to minimize it. In lines equipped with Automatic Train Operation systems (ATO), traffic regulation system selects one ATO speed profile on line among a preprogrammed set of optimized speed profiles.

2) Malfunction of the Protective System:
Protection relays may operate incorrectly in the presence of harmonics and NSCs of currents and voltages. Traction load injects a large amount of harmonics and NSCs, resulting in the malfunction of the protective system.

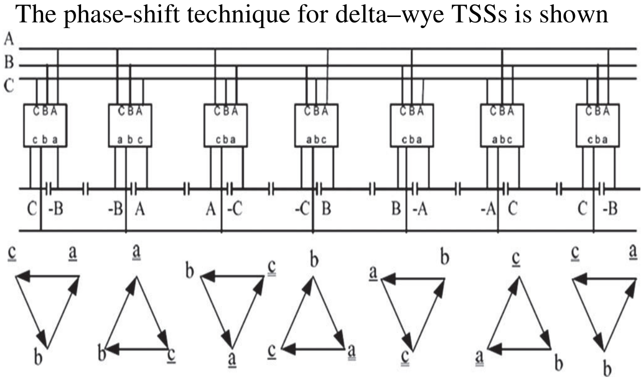
3) Incorrect Operation of Transmission Line Control Systems:
Voltage and current sampling is based on the fundamental components of either voltage or current. Every control system in the transmission line would not work appropriately because traction loads inject large amounts of harmonics and NSC current into the transmission lines.

4) Decreased Utilization Factor*:*
Since the traction load is a large single-phase load, it results in high current NSCs, which will flow in only two phases, and it decreases the utilization factor of the transmission line.
The Multipurpose Balance transformer features high material utilization factor, reduced harmonic filter cost, improved input power factor, and provision of a symmetrical two-phase voltage for traction load and a balanced three-phase voltage for use in railway substations

POWER QUALITY IMPROVEMENT METHODS

Configuration-Based Classification

The phase-shift technique for delta–wye TSSs is shown



As single-phase-fed trains were developed, the phase-shift method was applied to traction systems, in which three adjacent TSSs connect between two different phases of the upstream network, compensating the fundamental NSC of the overall system[9]

An equipment-based and configuration-based compensation methods employed to form the co phase circuit as shown in fig2. This approach minimizes all main power quality problems. The co phase system is now an immature technology for which some improvements are studied by researchers. In this method, the return circuit (i.e., running rails) is connected to one phase of the three-phase power supply system, and the contact wire is fed by two other phases through an active power compensator (APC) as shown in Fig. 2(b), which divides power between phases to have symmetrical currents in the primary side, having the ability to compensate imbalance current, harmonics, and reactive power simultaneously. [2] An additional advantage of the co phase system is the absence of section isolators in TSSs. This is an important aspect for high-speed trains because section isolators limit the speed profile of the train. It can be a strong point for high-speed lines. Co phase traction power system has high potential to be power supply for high-speed railway. However, the dc operation voltage of conventional power quality compensation device within, such as railway power quality conditioner, is high and may limit its application and development. This HPQC minimizes the dc-link voltage and harmonic currents at PCC.

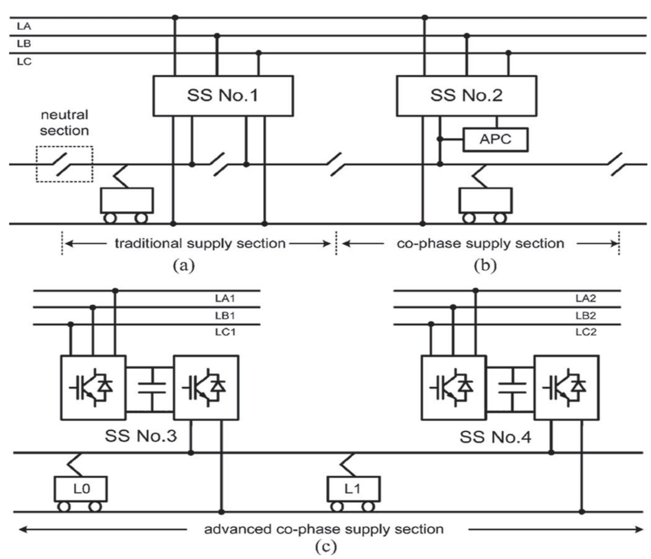


Fig2 Advanced cophase system compared with cophase system andtraditional supply system[1]

LATER TRENDS AND FURTHER DEVELOPMENTS IN RAILWAY COMPENSATION SCHEMES

In the concept of railway APCs, an improvement of APQC is used. An advanced cophase supply system as can be seen in Fig. 2(c) is developed, in which a three-phase converter shares its dc link with a single-phase converter (see Fig. 3). The voltage frequency, amplitude, and phase of each section are set equal to that of adjacent sections, so they can be connected directly; therefore, in this method, there would be no need to section isolators, resulting in no limits on the speed profile forced by section isolators and no arcs in the section passage.

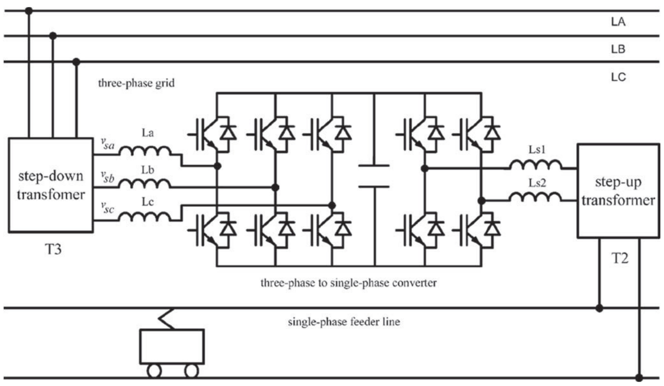


Fig.3 Detailed configuration of advanced cophase supply system[2]

Another method is Phase-Shifted Scott transformer type SVC was installed in front of Scott connection transformer to improve the voltage fluctuation which is caused by High Speed Railway (HSR) Systems. [6] [7].

This HPQC minimizes the dc-link voltage and harmonic currents at PCC. It is shown that the combination leads to reduction in dc voltage operation, reducing the total size of the compensator[8]

CONCLUSION

This paper has reviewed power quality problems of electric railway propulsion, including their supply networks, and possible methods to suppress power quality problems. The strategies for improving power quality have been classified based on important concepts. With respect to the progress from the phase-shift method to the cophase system, there is a tradeoff between cost and quality. The SVC is the first active method to compensate NSCs and reactive power, but in turn, it increases the amount and amplitudes of harmonics within a network. The advanced cophase traction power supply system is an ideal promotion of the established two-phase traction system. The three-phase to single-phase converter is one kind configurations of the advanced co-phase system, which transfers active power from grid to catenary and compensates reactive and harmonic current of locomotives

FUTURE WORK

It is necessary to optimize the power quality using types of power quality compensation techniques such as co phase. A hybrid railway power conditioner (HRPC) is proposed for the co-phase traction power supply system. The HRPC operates at a lower DC bus voltage compared to RPC.

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