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Hybrid Power Quality Conditioner for Railway Application Using RLC Pair Circuit

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ABSTRACT

Hybrid Railway Power Quality (HPQC) is newly projected for its powerful reduction in DC link operation voltage while imparting similar strength great compensation in co-segment traction electricity supply compared to conventional railway power quality conditioner(RPC).nevertheless, reduction in HPQC operation voltage limits its electricity great compensation capability. For instance, the formerly proposed HPQC layout primarily based on minimal operation voltage beneath constant rated load has minimum strength quality reimbursement capability. Under realistic situations when load varies, the specified HPQC energetic and reactive repayment electricity also changes. The DC hyperlink operation voltage of HPQC may also therefore want to be stronger to growth its strength satisfactory reimbursement functionality. Therefore on this paper, the connection among DC hyperlink voltage of HPQC and its energy first-rate reimbursement functionality, as well as its barriers, are being analyzed. Model and investigational outcomes are also offered to verify the noted courting via investigations of machine performance below extraordinary loading conditions. The studies can offer a guideline for dedication of HPQC operation voltage when load varies.

Keywords: Hybrid railway power quality, Electricity and Voltage.

1. INTRODUCTION

WITH fast United States and city improvement around the arena, electric powered railway transportation has performed an essential role in economics and daily lives. This reasons excessive and increasing transportation demand. It is consequently critical that traction electricity supply is strong and can provide power with high strength supply typically suffers from diverse power fine issues which includes reactive electricity, gadget unbalance and harmonics, etc. [1][2][3].Concerning those power fine problems, the Institute of Electrical and Electronics Engineers (IEEE) and Standardization Administration of the people's Republic of China have released corresponding tolerance standards [4][5]. The idea of co-phase traction strength first seemed in [6] in yr 2009. Various power exceptional repayment techniques, which might be discussed in later sections, are consequently proposed. More details about hardware prototype and checking out results of co-section traction power supply may be discovered in [7]. The world's first co-phase traction power supply tool has already be applied and positioned into trial operation at MeiShan substation of the Chengdu-Kunming Railway in 2012 in china. More info are provided in [8] and [9]. Co-phase traction power supply system can balance 3 Segment traction energy, and at the equal time offer reactive electricity and harmonic compensation, Co-section traction strength is also one of the vital tasks supported by means of the National Science and Technology Pillar Program for the duration of the Eleventh Five-Year Plan Period of China. These show the significance of co-segment traction strength in railway improvement.

As discussed, electricity nice issues are top notch worries in traction strength deliver gadget. In order to obtain excessive electricity satisfactory that can satisfy the IEEE and different standards, numerous strength quality repayment strategies had been evolved [10] [11]. Conventionally, passive compensators are used, For example, shunt capacitive financial institution is used to provide reactive electricity reimbursement for inductive traction load [12]. However, it is able to simplest provide constant reimbursement potential and cannot provide dynamic performance.

Afterwards, compensator based on lively components are proposed. For instance, static var compensator (SVC) is used [13] [14], but it cannot compensate gadget unbalance hassle, and inject harmonics into the system. For machine unbalance trouble, although techniques such as installation of stability transformers or converting segment connection may be used, they can't provide whole and unified compensation. In contrast, compensators based totally on lively additives can provide higher dynamic performance, [15] [16] the railway power pleasant conditioner (RPC) is hence developed [17] [18].

It is widely adopted as a unified answer for reactive strength, device unbalance and harmonics in traction power deliver. specially, in Europe a few traction locomotives are electrified with 15kv ,164\3hz apart from system line frequency (usually of fifty Hz or 60 Hz) there are hence extra on-going researches on the improvement of energy digital traction transformer(PETT) for advanced performance and energy conditioning, particularly in Europe[19][20][21]. Field trying out of PETT Prototype has also been carried out with Swiss Federal Railways, and the machine performance is best and has proven improvements. However, similarly investigations of PETT are required while traction locomotives are immediately powered from gadget line software grid, like in china, in which 3 phase balancing is also concerned. Railway strength pleasant conditioner (RPC) can be more suitable beneath this situation.

2. HPQC

The HPQC is a power quality machine, which can keep these trade against the sags and swells. Usually sags and swells are related to isolated faults. A HPQC compensates for these voltage turbulence give that supply grid does not get detached entirely through breaker trips. It can replace both active and reactive power with the division system by varying the amplitude and phase angle of the converter voltage with respect to the line terminal voltage.

2.1 Principle and Operation of HPQC

A HPQC (Distribution Static Compensator), which is schematically depicted in Figure 1, consists of a two-level Voltage Source Converter (VSC), a dc energy storage device, a coupling transformer connected in shunt to the division system through a coupling transformer. The VSC vary the dc voltage across the storage device into a set of three-phase ac output voltages. These voltages are in phase and coupled with the ac network through the reactance of the coupling transformer. Suitable regulation of the phase and magnitude of the HPQC output voltages allows efficient control of active and reactive power exchanges between the HPQC and the ac system. Such configuration allows the device to soak up or produce controllable active and reactive power.

The VSC connected in shunt with the ac system provides a multifunctional topology which can be used for up to three quite distinct purposes:

1. Voltage regulation and compensation of reactive power;
2. Correction of power factor; and
3. Elimination of current harmonics.

Here, such device is employed to provide continuous voltage regulation using an indirectly controlled converter.

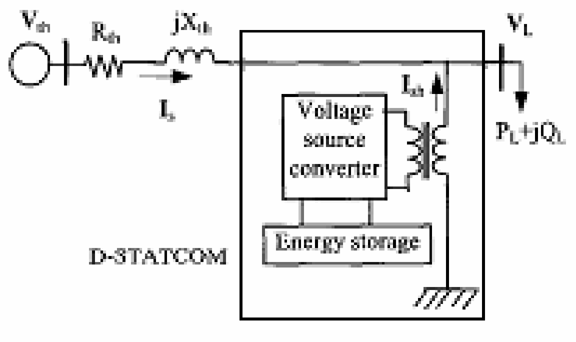


Fig.1. Schematic Diagram of a HPQC

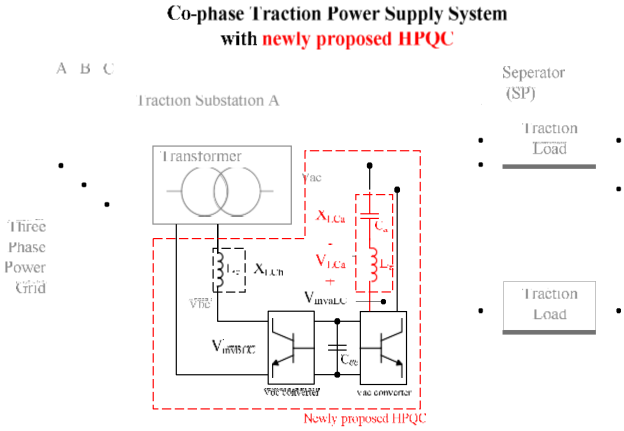
Figure.1 the shunt inserted current Ish corrects the voltage sag by regulating the voltage drop across the system impedance Zth. The value of Ish can be controlled by regulating the output voltage of the converter. The shunt inserted current Ish can be written as,

$$Ish = IL - Is = IL - (Vth - VL)/ Zth \quad \text{------ 1}$$

It may be mentioned that the successfulness of the HPQC in booster voltage sag depends on the value of Zth or fault level of the load bus. When the shunt injected current Ish is kept in quadrature with VL, the desired voltage correction can be achieved without injecting any active power into the system. On the other hand, when the value of Ish is reduced, the same voltage rectification can be achieved with minimum apparent power inoculation into the network.

3. EXISTING SYSTEM

3.1 Circuit Diagram



Co-phase traction power supply system with proposed capacitive

Hybrid railway energy exceptional conditioner (HPQC) in fig. four is as a result proposed and developed, Different from conventional RPC, the Vac segment converter in HPQC is attached to the PCC thru capacitive coupled impedance, the capacitive coupled impedance. The capacitive coupled capacitance can help to provide assist voltage at some point of reactive energy compensation so that the DC hyperlink voltage can be decreased. The device rating and value of HPQC can hence be reduced.

The concept of HPQC is first proposed in [22] yr 2012. More information and derivations of system parameter layout can be observed in [23] and [24]. A brief evaluate of voltage reduction mechanism in HPQC is likewise blanketed within the subsequent phase. However, the HPQC is designed based totally on the standards of minimal operation voltage requirement below constant rated load. Under minimal operation voltage, the HPQC can offer first-class compensation overall performance handiest at the designed fixed rated load. The HPQC electricity exceptional compensation capability is by some means limited with the aid of discount in operation voltage. The operation voltage of strength compensators can be more desirable to provide exceptional performance for wider range of loadings [25][26]. Therefore, below sensible situations when traction load varies, the desired energetic and reactive reimbursement strength from HPQC additionally modifications, the DC link voltage of HPQC may additionally then want to be increased. However, the HPQC DC link voltage requirement isn't without delay proportional and does no longer vary linearly with load versions. Furthermore, load versions encompass both variations in load strength factor and capability. Therefore, it is important and worth to research the relationship between HPQC DC hyperlink voltage and its power quality compensation functionality in co-phase traction energy.

In this paper, the relationship between HPQC DC link operation voltage and its repayment functionality is analyzed and discussed a good way to provide a guiding principle for willpower of HPQC DC link voltage whilst load varies. In segment 1, a brief advent of research background and motivation is blanketed. In phase II, the HPQC control algorithm and design based on minimal operation voltage at rated load is reviewed. The relationship between HPQC reimbursement functionality and DC link voltage, as well as their boundaries, are then analyzed and mentioned in phase III. In segment IV, simulation verifications and experimental consequences received from hardware prototype are supplied. Finally, a conclusion is given in section V.

3.2 Simulation Diagram

A complete track of diagram and control of co-phase traction power with planned HPQC in model certification .The boundary settings in the simulation are select based on ordinary realistic traction power supply system. The three phase power grid is of 110 kV, 50 Hz and is malformed into two single phase outputs via V/V substation transformer. The V/V transformer is composed of two single phase transformers (31.5 MVA 110 kV/27.5 kV, 31.5 MVA 110 kV/13.75 kV), with V/V connections. One phase of substation output, Vac phase, is connected to locomotive loadings; whereas another phase, Vbc phase, is unloaded. The power quality conditioner, HPQC, is then connected across the Vac and Vbc phase in order to give power quality reimbursement from secondary side to the three phase primary source grid. Notice that the locomotive voltage is 27.5 kV, which is a bit higher than 25 kV, in order to concession the voltage drop caused by inductive traction load. The electronic switches used in the back-to-back converter of proposed HPQC are insulated-gate bipolar transistors (IGBT) for its high power submission. The calculation of required reimbursement power is achieved according to (1) based on instantaneous pq theory.

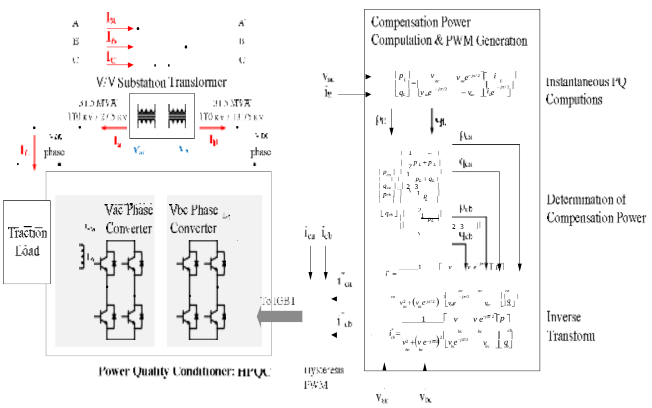


Fig.2. Detailed circuit schematic and control of co-phase traction power supply with newly proposed HPQC

The compensation current location is then obtained by performing inverse transform. The compensation current location is lastly compared with the real compensation current to produce pulse width modulation (PWM) signals for IGBT switches in Railway HPQC using linear-operated hysteresis PWM method in [30]. In the model, the HPQC direct algorithm is completed according to (1), and is designed based on minimum operation voltage requirement at preset rated load of power factor 0.85 and capacity 15 MVA (denoted as 1 p.u.). The traction load is then changed from 0.1 to 2 p.u. (0.1 p.u. step size), each with deviation of load power factor 0 to 1 (0.1 step size). The Vac phase coupled impedance is designed and the coupled LC branch is designed at the 5th load harmonics. As the order in the assessment, the value of HPQC function voltage rating used is 0.66. The corresponding DC link voltage is then 25.7 kV. The source power factor and current unbalance is being monitored. The simulated three phase source power factor and current unbalance (%) below different load setting obtained. Details of the data in the model can be found in appendix. With acceptable HPQC compensation, the source power factor is harmony and the current unbalance is 0%. The HPQC can give satisfactory compensation presentation within a range of loadings

4. PROPOSED SYSTEM

4.1 Block Diagram

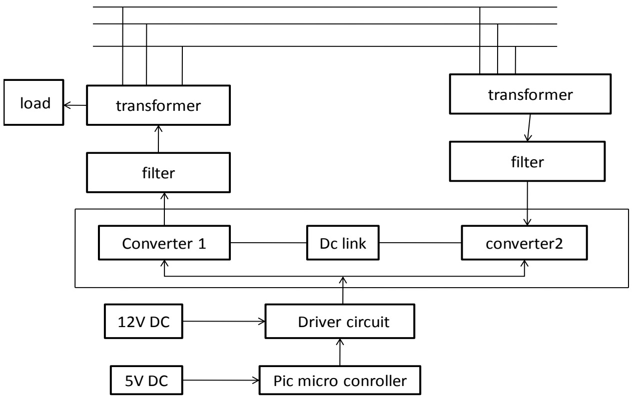


Fig.3. Block diagram

A three phase supply is given to the transformer. Transformer step up the voltage and it is given to the active power filter to filters the harmonics and boost the voltage. This boost voltage is given to the HPQC circuit. It basically composed of back to back converter with a common dc link. DC link used to store the energy.

The VSC vary the dc voltage across the storage device into a set of three-phase ac output voltages. These voltages are in phase and coupled with the ac network through the reactance of the coupling transformer. Suitable regulation of the phase and magnitude of the HPQC output voltages allows efficient control of active and reactive power exchanges between the HPQC and the ac system. 5v dc supply is given to the PIC micro controller to generate PWM and then PWM pulse is given to the driver circuit. Driver circuit trigger the firing pulse to the VSC. The VSC compensate the active and reactive power. Again filter boost the voltage sufficient with sinusoidal waveform voltage to the locomotive

4.2 Simulation Diagram

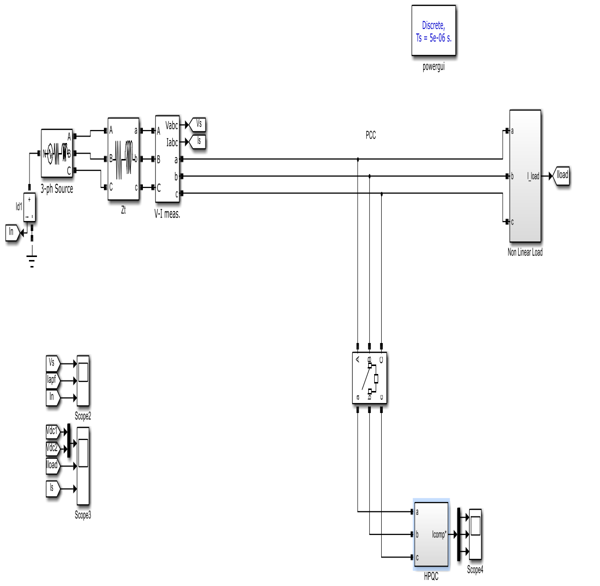


Fig.4. Simulink model

4.3 HPQC Diagram

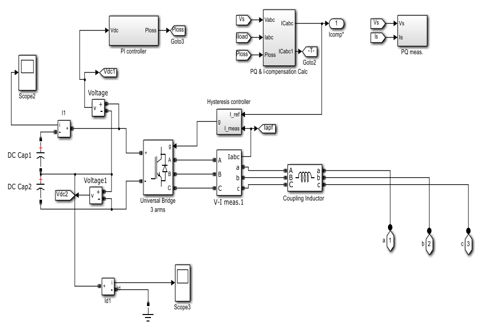


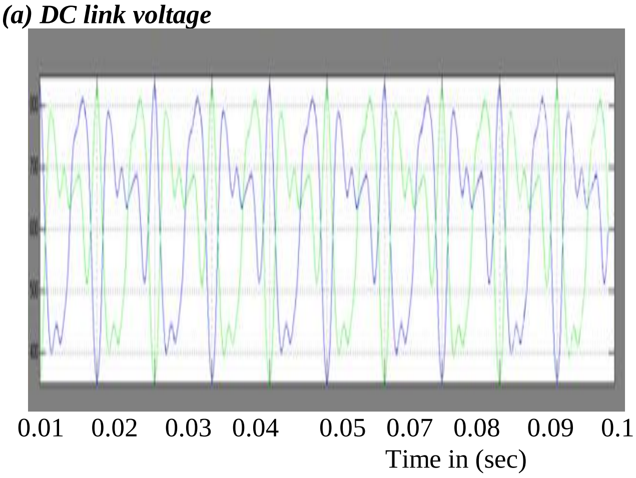
Fig.5. HPQC diagram

A typical construction of railway power quality conditioner is shown in fig .4. A three phase supply 110 kv, 50 HZ is given to the line impedance to filters the harmonics. Compensated harmonics is given to the V&I measurement. Due to nonlinear load harmonics created in distribution line so that we are using HPQC to compensate the harmonics.

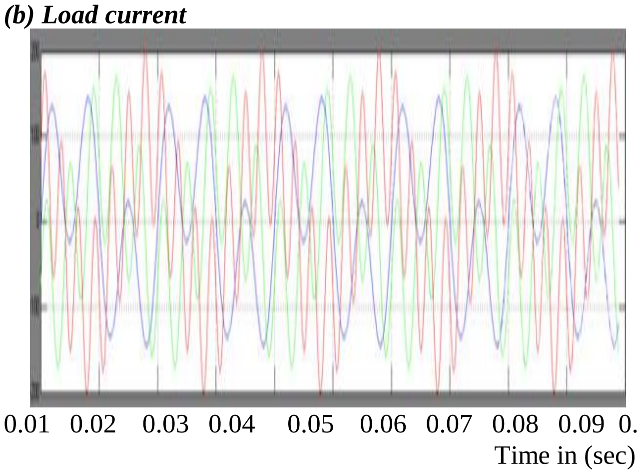
Fig.5. DC link connected to the universal bridge for storage purpose. During the insufficient power supply storage device give the power to universal bridge through distribution line. Measured voltage and current is given to the pi controller. It compare the actual and reference voltage to find the error value. PQ and current block measure the loss and voltage. By using Clarke inverse transform eliminate the zero sequence and three phase supply is transformed into two phase supply because hysteresis controller allow two phase supply only. Hysteresis controller having upper and lower limit to compare the actual and reference current. Current exceed the upper limit lower leg is on. Actual current exceed the lower limit upper leg is on. Hysteresis controller used to giving triggering pulse to the voltage source converter. The universal bridge eliminate the harmonics, real and reactive, unbalance current after that it give the sinusoidal waveform of voltage/current. Furthermore, voltage/current is given to the measurement block it measure the voltage. Measured voltage is given to the coupled inductor to boost the current due to that we can compensate the harmonics, unbalance current and improve the efficiency by using RLC pair circuit. Model and investigational outcomes are also offered to verify the noted courting via investigations of machine performance below extraordinary loading conditions.

4.4 Simulation Output

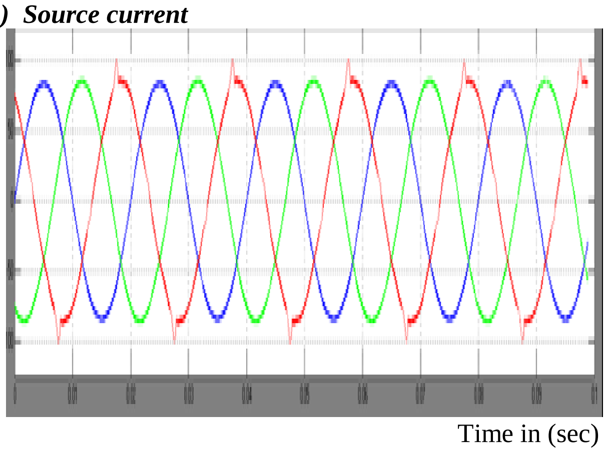
(a) DC link voltage



(b) Load current



(c) Source current



The (a)(b)(c) with respect to dc link voltage, load current and source current. It shows the compensated harmonics and improved efficiency.

5. CONCLUSION

In this paper, the connection between HPQC DC link voltage and its power value reimbursement capacity in co-phase traction power is being evaluated and argued. Co-phase traction power has high possible to be power supply system. However, the function voltage need of conventional inductive coupled RPC surrounded by the system is high due to its high power need to control power flow. This leads to higher cost and device ratings. The capacitive coupled HPQC is therefore newly presented for reduction of function voltage while giving similar performance at rated load. Nevertheless, reduction in HPQC function voltage limits its power quality reimbursement capacity. Therefore, it is important to find the connection between HPQC DC function voltage and the corresponding power quality compensation capacity so as to give a guideline for the propose of HPQC. It is found that when HPQC operates with minimum voltage under preset rated load, the HPQC can only give minimum compensation capacity. Below realistic conditions when load varies, the HPQC function voltage may be improved so that HPQC can give satisfactory compensation presentation for a range of loading conditions. The limitation of these conditions and limit are also inspected. The followings can be accomplished from the evaluation.

When HPQC DC link voltage rise, the power quality compensation capacity also gets bigger; When HPQC DC link voltage rise to over minimum value, the range of loading situation which is suitable for compensation presentation can be afford always include rated situation;

With a assured HPQC DC link voltage, there is a superior limit of load power factor; when the load factor obtain ahead of this limit, HPQC cannot give reasonable compensation; Based on these, the HPQC DC link function voltage may be chosen based on the loading situation (possible range of load capacity rating and power factor).

Lastly, MATLAB model are performed and investigational results are obtained from a laboratory-scaled hardware prototype to verify the evaluation. The study gives a preliminary guideline for HPQC boundary selection when greater power quality compensation capacity is preferred. For practical purpose, it would be preferable if the power quality compensation capacity can be freely changed under a specific function voltage, and this worth further evaluation and attention.

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