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IMPLEMENTATION OF HALF BRIDGE COMPENSATOR WITH AUTO TUNED DC LINK CAPACITOR FOR ELECTRIC TRACTION

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Abstract: Railway power conditioners have played a vital role in the railway industry for compensating negative sequence current (NSC), reactive power and current harmonics. Also, various power conditioners have been framed to ease its implementation and improve the power quality of the traction system. To nullify the power quality problem in railway power supply network, a railway static power conditioner (RPC) based on half-bridge converter is proposed. Compared with conventional Half-Bridge-Converter-Based Railway Static Power Conditioner, the proposed conditioner could keep the rating and cost of power quality conditioner reduced. Cooperative control strategies have been developed to achieve accurate tracking of reference signals.

***Index Terms* - Negative Sequence Current (NSC), Railway Static Power Conditioner (RPC), Half-Bridge-Converter-Based Railway Static Power Conditioner, Installed Capacity reduction.**

I. INTRODUCTION

A zap of railroad networks has been started in the mid-twentieth century [1]. The jolt was necessary in numerous nations as a result of its benefits, for example, lesser air tainting in contrast with the customary framework [2], weighty cargo burden and mass travel conveying capacity, high productivity, and most as of late less CO_2 age which assumes a significant part in air pollution [3]-[4]. From the very beginning of rail line charge, different power quality issues were huge issues for jolt defenders, scientists and numerous framework creators have been energetic about power quality upgrades in rail power conveyance frameworks [5]. Power quality (PQ) goals give the premise to accomplishing similarities between the highlights of the electric inventory framework and training end-user hardware [6].

Power quality can incorporate a wide area of limitations, like voltage fluctuations, voltage, and current unevenness, harmonics, and reactive power and the most difficult ones on account of rail route charge are responsive power, current sounds and negative grouping current (NSC) [7]. Two normal traditions to face power quality issues are planning a framework with fewer issues and greater adaptability or further developing the power quality all around the framework by the method for remuneration draws near traction substation [8]-[9]. Fig. 1.1 shows electric connection diagram of Modern Locomotive.

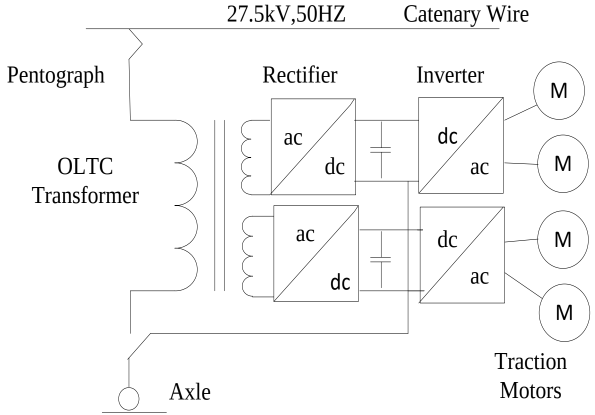

Fig. 1.1 Electric Connection Diagram of Modern Locomotive

II. PROPOSED WORK

Based on the exhaustive literature review, the inferences drawn out from the analysis of the literature and the scope of investigations, the investigator proposes the harmonic elimination and dc-link voltage stabilization in an RPC based on a Half Bridge compensator with a reduced number of switches.

III. PROBLEM FORMULATION

With the progression of the railroad transportation framework, the power quality issue has been taken into increasingly more consideration. The rail route traction load has the attributes of non-linear nature and low power factor (PF), which will outcome in the power quality issues of harmonic and reactive power. The rail line traction load is a single-phase load which will outcome in unbalanced three-phase flows in the public network. The unequal three-phase flows will prompt a negative sequence current (NSC) as per the even part study. The music part, reactive power, as well as the NSC, will massively influence the protected activity of the public network and the traction power supply framework. To alleviate these issues Railway Power conditioner is the key device. These devices feed compensating current to the rail route power framework organization.

This postulation expects to foster an RPC in view of a Half Bridge compensator with a decreased number of switches and limit the harmonic distortion in the rail route power traction system. In the context of the Half Bridge compensator, RPC is made up of two power-exchanging legs, two dc-link capacitors, and two switch legs connected by two capacitors in series. As a result, this power conditioner is made up of two half-bridge converters that are arranged in parallel. Both converters can be controlled with an upswing to deliver energy and discharge the dc-link capacitors, and one converter can be controlled with a correction to submerge energy and charge the capacitors. Once this is done, a dynamical energy equilibrium can be reached. By using a Half Bridge compensator, RPC can thereby transfer dynamic capacity to the electric traction power arms.
To design and analysis the RPC based on Half Bridge compensator and GA-based algorithm using MATLAB/SIMULINK™. To design an RPC based on a Half Bridge compensator with a reduced number of switches and the current controller and analyses the performance of the whole system. To develop GA-based NSC Compensation and harmonic elimination techniques to reduce the THD below the IEEE 519 standard. To compare the result with the latest literature.
The complete block diagram of the proposed work is shown in Fig.1.2. It consists of the railway supply system, traction transformer and compensator with single-phase nonlinear load. A V/V transformer steps down a 220-kV three-phase high voltage source to two single-phase power sources at a point of 27.5 kV voltage, as should be evident in Fig. 1.2. By means of result inductors and step-down transformers, the two converters of the proposed compensator are connected to the auxiliary power arms of the V/V traction transformer. The centre of two capacitors and the ground of two traction power arms are connected by a step-down transformer in the proposed compensator. Two dc-link capacitors, two power switch legs, and two capacitors connected in series between the two switch legs make up the proposed compensator.

This power conditioner, therefore, comprises two half-bridge converters that are arranged sequentially. A correction may be used to manage one converter so that energy is stored and the dc-link capacitors are charged, and a reversal can be used to manage the other converter so that energy is delivered and the dc-link capacitors are discharged. At that moment, a dynamical energy equilibrium can be attained. As a result, the traction power arms can get dynamic capacity from the suggested compensator. The goals of moving active power from one power arm to the next, compensating NSC, and lowering harmonic currents would be achieved if the proposed compensator can use a suitable control method to change the output voltage and current of two half-bridge converters. When compared to RPC, the suggested compensator can eliminate a few switch legs, each of which has four power switches. In order to achieve a capacity similar to RPC, the suggested compensator can decrease the cost, equipment complexity, and power drawbacks. Furthermore, the suggested compensator's switch voltage stress would double while the same switching harmonics would be lowered by 50%, thereby increasing harmonic content. The proposed compensator can offer an alternative approach to controlling power quality in the rail route framework, which can extend the examination's focus despite a number of limitations.

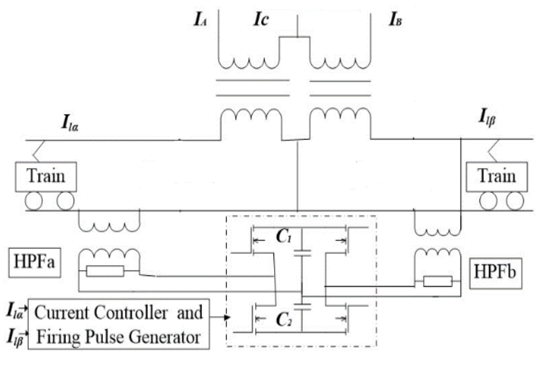

Fig. 1.2 Block Diagram of the Proposed Model

IV. METHODOLOGY

The proposed model of RPC based on the Half Bridge compensator will be implemented using the following steps:

- Design implementation of Railway electrical supply system for specific data sheet and draw the V and I characteristics of different phases.
- Design implementation of RPC based on Half Bridge compensator.
- Developing GA-NSC compensation-based optimized switching angles to fire the RPC based on Half Bridge compensator that replaces the conventional lookup table model.
- Validating the experimental results of the proposed RPC based on Half Bridge compensator with simulation results.
- Compare the proposed work results with another system investigated in the latest literature.

A. HARMONIC ELIMINATION

Several techniques have been discussed in the literature for stabilizing dc link voltage and eliminating the harmonic contents.

B. COMPENSATION PRINCIPLE

Large harmonic currents are being produced by the loads on locomotives. Because it is the most intense of all harmonic currents, the third and fifth harmonic components of current. As a result, the passive type of filter reduces the installed capacity of RPC based on the half-bridge compensator, suppressing the 3rd and 5th order harmonic currents. The harmonic active filter eliminates higher-order harmonics.

The suggested RPC based on the Half Bridge compensator sends the compensating current to the power arms of the traction system in order to reduce the negative sequence component of current. Following a thorough vector analysis, compensatory currents are generated.

Assume that the vital component of the current vector of α-phase traction power arm is I_α and the vital component of current vector of β-phase traction power arm is I_β. The three-phase currents on the high voltage side of the TSS transformer are displayed as follows:

$$\begin{Bmatrix} I_A = \frac{I_\alpha}{K_B} \\ I_B = \frac{I_\beta}{K_B} \\ I_C = \frac{-(I_\alpha + I_\beta)}{K_B} \end{Bmatrix} \quad (1.1)$$

where K_B is the transformation ratio of TSS transformer, and set the operator $a = e^{j120°}$, The following are the calculation equations for the positive sequence component of current (PSC) and negative sequence component of current (NSC). In Fig. 1.3 vector diagram of three phase voltage, traction power arm voltages and compensating current resultant calculation is displayed.

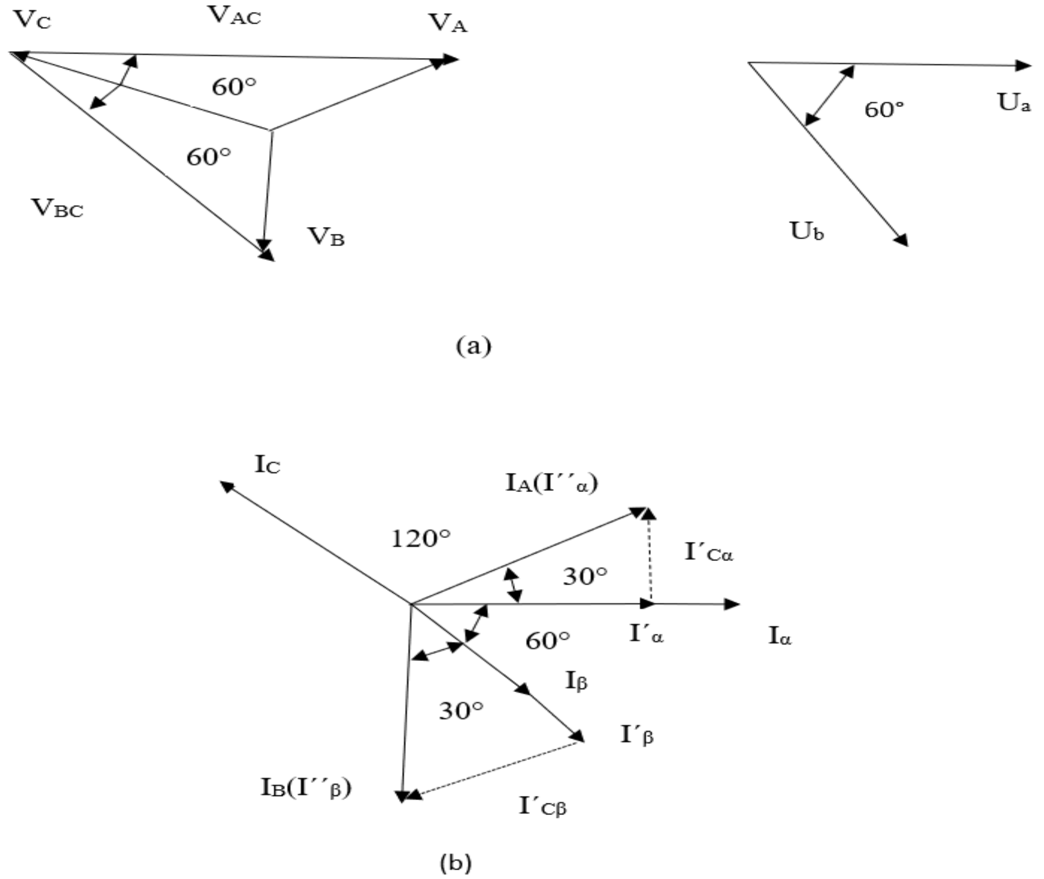

Fig. 1.3 Vector Diagram of (a) Three Phase Voltages and Traction Power Arms Voltage (b) Three Phase Currents and Compensating Currents

$$\begin{bmatrix} I^+ \\ I^- \end{bmatrix} = \frac{1}{3}\begin{bmatrix} 1 & a & a^2 \\ 1 & a^2 & a \end{bmatrix}\begin{bmatrix} I_A \\ I_B \\ I_C \end{bmatrix} = \frac{\sqrt{3}}{3K}\begin{bmatrix} e^{j\frac{\pi}{6}} & e^{j\frac{\pi}{6}} \\ e^{-j\frac{\pi}{6}} & e^{-j\frac{\pi}{2}} \end{bmatrix}\begin{bmatrix} I_\alpha \\ I_\beta \end{bmatrix} \quad (1.2)$$

$$\eta = \frac{I^-}{I^+} \times 100\% \qquad (1.3)$$

Where $I^+$and I^-stand for the PSC and NSC components of the three-phase currents, respectively, and is the imbalanced level of the three-phase currents. According to (1.2) and (1.3), the unbalanced level is 50 % when two traction system power arms have the same train loads and 100 % when only one traction power arm has a train load. As a result, there would be a large number of NSCs in the traction power supply system without a power correction mechanism.

Assuming the railway locomotive load uses a four-quadrant PWM rectification and has a a power factor of around one in order to build the NSC and harmonic current correction theory. Assume that the transformer's K_B ratio is equal to one to simplify the analysis.

The active current amplitudes of two traction power arms are I_α and I_β, respectively, before compensation; the phase traction power arm has current I_α, while the -phase traction power arm has current I_β. The compensator first moves from the light power supply arm to the heavy one half of the active current differential between the two traction power arms $(I_\alpha - I_\beta)/2$). The two traction power arms' currents are then corrected into $I_\alpha^{'}$ and $I_\beta^{'}$, respectively. The unbalanced level was 50 percent at this point because the current amplitudes of the two traction power arms are equal to $(I_\alpha + I_\beta)/2$) and the phase angle difference is π/3.

The proposed compensator once more adjusts a certain amount of capacitive reactive current $I_{C\alpha}^{'}$ on the three-phase traction power arm and a certain amount of inductive reactive current $I_{C\beta}^{'}$ on the three-phase traction power arm on the basis of the transfer of active power, which can cause the current of the three-phase power arm to lead the equivalent voltage by π/6 and the current of the three-phase traction power arm to lag behind the corresponding voltage by π/6. Two traction power currents were changed to be $I_\alpha^{''}$ and $I_\beta^{'}$, respectively, after the reactive power adjustment. At this point, the reactive current's amplitude might be estimated as

$$I_{C\alpha}^{'} = I_{C\beta}^{'} = \frac{\tan\frac{\pi}{6}(I_\alpha + I_\beta)}{2} \qquad (1.4)$$

After the compensation, the currents I_A and I_B. are separately in phase with the traction power arm current $I_\alpha^{'}$ and $I_\beta^{'}$, respectively, and their phase angle deference is 2π/3; then, C phase current I_C can be obtained as $I_C = -I_A - I_B$. The three-phase currents' power factors are now all equal to one, the NSC on the primary side is zero, and the compensation goal has thus been accomplished. For the traction structure of the Indian railway in any load condition, the compensation concept of transferring active power and separately compensating some specified reactive power is the same, and it may perfectly symmetrical the three-phase currents.

C. IDENTIFICATION OF NSC AND HARMONIC REFERENCE SIGNALS

The proposed compensator's NSC and harmonic reference signal are obtained using the momentary power detection approach, as demonstrated by the analysis of the compensation guideline above. The unit traction supply voltages of two traction arms are $V_\alpha(t) = \sin(wt - \frac{\pi}{6})$ and $V_\beta(t) = \sin(wt - \frac{\pi}{2})$ correspondingly, assuming that the A-phase unit voltage is $V_A(t) = \sin wt$, Assuming two power arms' load currents are $i_{l\alpha}(t)$ and $i_{l\beta}(t)$, the Fourier series representation of these currents is as follows:

$$\begin{Bmatrix} i_{l\alpha}(t) = I_{\alpha p}\sin(wt) + I_{\alpha q}\cos(wt) + \sum_{n=2}^{\infty} I_{\alpha n}\sin(nwt + \varphi_{\alpha n}) \\ i_{l\beta}(t) = I_{\beta p}\sin(wt) + I_{\beta q}\cos(wt) + \sum_{n=2}^{\infty} I_{\beta n}\sin(nwt + \varphi_{\beta n}) \end{Bmatrix} \qquad (1.5)$$

Where $I_{\alpha p}$ and $I_{\beta p}$ are two different load currents' fundamental active components, $I_{\alpha q}$ and $I_{\beta q}$ are their respective reactive components, and $I_{\alpha n}\sin(nwt + \varphi_{\alpha n})$and $I_{\beta n}\sin(nwt + \varphi_{\beta n})$ are their respective nth harmonic components. According to the identification guideline shown in Fig. 3(b), the synchronous signals are multiplied by each of the two traction power arms' heap flows, and at that point, a total i_{mp} proposes that the power size of the two traction power arms may be obtained by adding together. The low-pass filter may then be used to separate the dc component I_{mp} from i_{mp}, suggesting the usual dynamic current abundance of two traction power flows as shown in the following example.

$$I_{mp} = \frac{1}{2}(I_{\alpha p} + I_{\beta p}). \qquad (1.6)$$

The analysis of the compensation guideline revealed that the following are the predicted target currents of two power arms:

$$\begin{Bmatrix} i_\alpha(t) = I_{mp}\sin\left(wt - \frac{\pi}{6}\right) + I_{mp}\tan\frac{\pi}{6}\cos\left(wt - \frac{\pi}{6}\right) \\ i_\beta(t) = I_{mp}\sin\left(wt - \frac{\pi}{2}\right) - I_{mp}\tan\frac{\pi}{6}\cos\left(wt - \frac{\pi}{2}\right) \end{Bmatrix} \qquad (1.7)$$

One may comprehend the rationale behind NSC and harmonic current compensation, however, if the suggested compensator can compensate a specified measure of flows to convert the flows $i_{l\alpha}(t)$ and $i_{l\beta}(t)$ of the two power arms into $i_\alpha(t)$ and $i_\beta(t)$, respectively. The two converters of the proposed compensator's compensation reference signals can be established in the following ways:

$$\begin{Bmatrix} i_{C\alpha}^*(t) = i_\alpha(t) - i_{l\alpha}(t) \\ i_{C\beta}^*(t) = i_\beta(t) - i_{l\beta}(t) \end{Bmatrix} \qquad (1.8)$$

The resultant flows of the proposed compensator can completely follow the given harmonic currents and fundamental by suitable control technique simulated in Fig.1.6. This would accomplish the remuneration for harmonic flows and NSC extraordinarily further develop the power quality of the electrified rail route.

D.DESIGNING THE TUNED DC-LINK PARAMETERS

The DC-link voltage is commonly fixed with a PI-controller, but it must be built properly to have a rapid response time and minimum voltage ripple. Using a weighted multi-objective evolutionary algorithm, the optimal PI-controller, DC-link voltage level, and DC-link capacitor properties are attained (GA). The goal function is shown in (1.9), where the ripple is defined as (1.10)

$$O.F. = rms(ripple) + 0.1 \times (Max\ (V_{DC}) - Min\ (V_{DC})) \qquad (1.9)$$

ripple = $V_{DC} - V_{ref}$ (1.10)

The extreme disparity between the desired and optimal DC-link voltage is constrained by GA optimization. As a result, it encourages quick action because a smaller gap between expected and actual DC-link voltage will result in a speedier action.

In addition, the difference between the greatest and lowest values of the DC-link voltage should be kept at an appropriate value given the likelihood of high or low voltage difficulties for switches, which is to be recalled for the objective capability with the weight of 0.1. The hefty 0.1 is due to the standardisation of the capability, which causes the second term of the objective capability (i.e., the difference between the maximum and lowest worth of DC-link voltage) to be almost double times as large as the first term. The function of the PI-transfer regulator is shown in equation (4.7), with the GA-planned coefficients.

$$T_{PI} = K_P\left(1 + \frac{1}{s}K_I\right) \quad (1.11)$$

V. FLOW CHART

- Start the design of MATLAB/SIMULINK™ Model of Railway electrical Supply System and Locomotives
- Design MATLAB/SIMULINK Model of RPC based on half-bridge compensator
- Check the value of inductance and capacitance appropriate or not?
- Check the value of dc-link voltage less than equal to 2.6 %?
- Check the value of THD less than equal to 5 %?
- If not Modify firing angle using optimization technique.
- Do this process until dc-link voltages and THD value reached to its stabilised value.

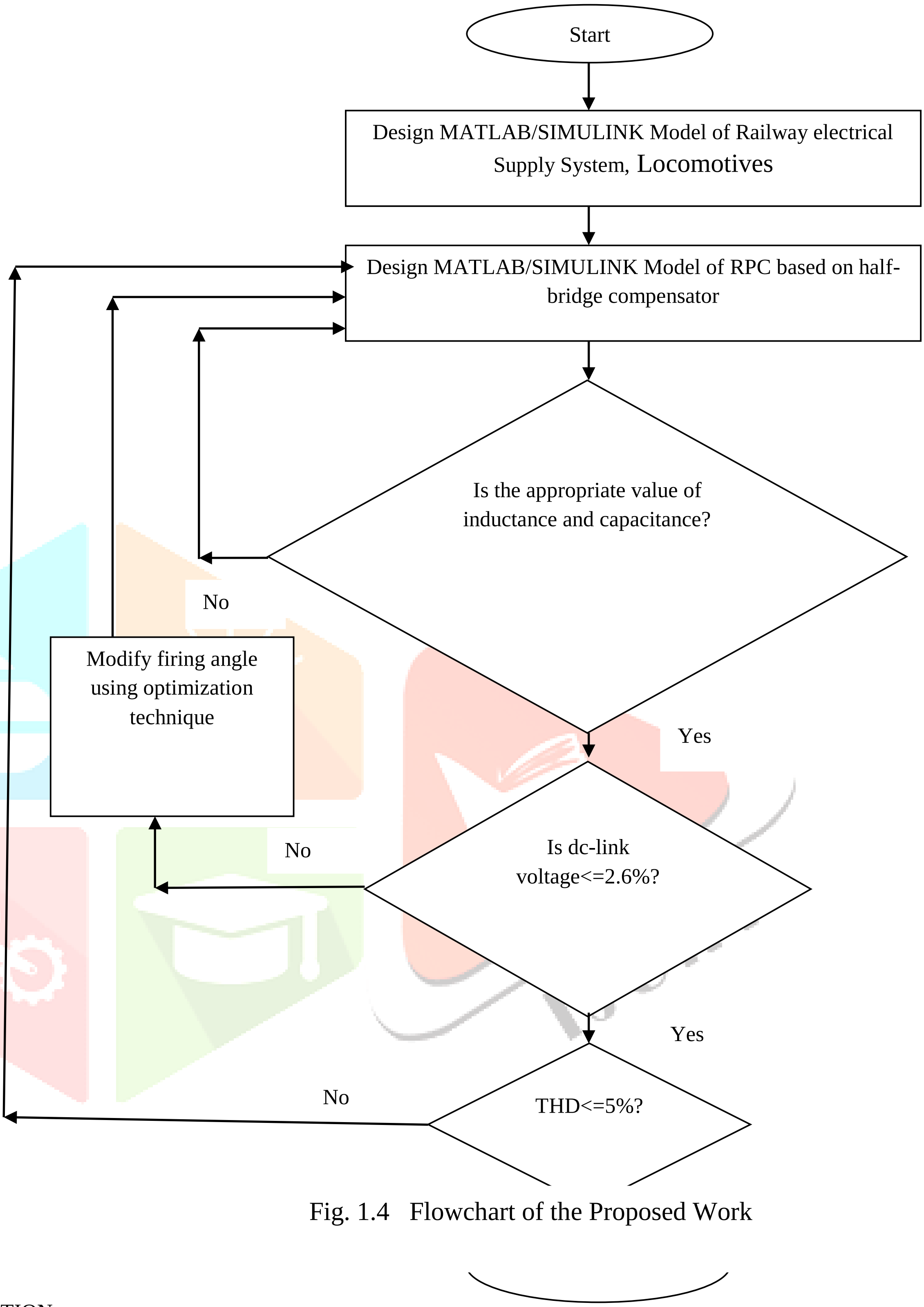

Fig. 1.4 Flowchart of the Proposed Work

VI. SYSTEM SIMULATION

Dynamic simulation is a very important step in the design and optimization of any system. For power systems, the dynamic simulation is approved to observe the instantaneous and timely behaviour of the system under study. This is to see the dynamic behaviour of the system and the power quality voltage stability and load variation effects. The proposed Compensator model is simulated in MATLAB/SIMULINK™ Tool under various electrical conditions. The schematic model of the proposed Compensator is made in MATLAB/SIMULINK™ in Fig.1.5

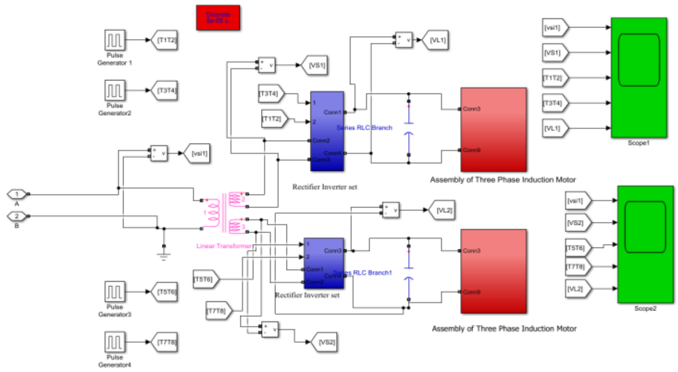

Fig. 1.5 Locomotive Model

Fig.1.5 shows the complete simulation of the Indian locomotive. in this first power is given to the online tap changer transformer. Power is converted to dc with the help of rectifier blocks. Rectifier unit feed the power to dc series motor unit or to inverter operated three phase induction motor unit.

The preceding research suggests and simulates a power compensator in light of the half-bridge construction, as illustrated in Fig. 1.6. A transformer steps down a 220-kV three-phase high voltage source into two single-phase power sources at a position of 27.5 kV. The two converters of the proposed compensator are connected to the auxiliary power arms of the traction transformer via output inductors and step-down transformers. In the suggested compensator, a step-down transformer connects the centre of two capacitors and the ground of two traction power arms. The recommended compensator consists of two dc interface capacitors, two power switch legs, and two capacitors in series linked across the two switch legs. This power conditioner essentially comprises two half-bridge converters that are arranged in a row. The management of one converter allows for energy storage and dc-link capacitor charging, while the management of the other converter allows for energy delivery and dc-link capacitor discharging. A dynamical energy equilibrium can be reached at that moment. This allows the proposed compensator to transmit dynamic capacity to the traction power arms.

If the suggested compensator could find an appropriate control strategy to modify the output voltage and current of two half-bridge converters, it would succeed in transferring active power from one power arm to the next, compensating NSC, and suppressing harmonic currents. In contrast to RPC, the geographic region of the suggested compensator can cut down on a few switch legs, including four power switches. For the objective of achieving a comparable RPC capability, the suggested compensator can lower cost, equipment complexity, and power misfortunes. The identical exchanging frequency would decrease to half but the switch voltage stress suggested compensator would double, which might enhance harmonic content. The suggested compensator could offer a different approach to managing the quality of the power in the traction system.

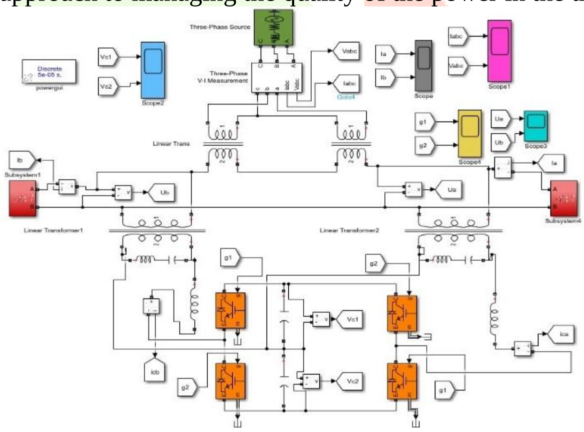

Fig. 1.6 Schematic Model of Traction Substation along with Compensator

VII. SIMULATION RESULTS AND ANALYSIS

Simulations are done by modelling the system in MATLAB/SIMULINK™. The running time of the schematic model is about 0.4 seconds and the results observed as waveforms are shown in Fig 6.1 to Fig 6.18. All the waveforms are drawn taking the x-axis as time in seconds and y-axis units are shown on the up-right side of all waveforms.

To segregate the impact of power conditioners in railway traction systems, we have considered two different case studies as follows:

Case-I: Operational parameters such as FFT analysis, voltage and current without the power compensator.

Case-II: Operational parameters such as FFT analysis, voltage and current with the power compensator.

Table 1 Simulation Cases

Case-I	Before compensation
Case-II	After compensation

WAG-9 is a locomotive engine which is completely based on dc series motor drives, Basically, in both the arm the loading condition is varying with respect to incoming and outgoing trains.

In the instance of the WAG-9 Locomotive, I_a and I_b in Fig. 1.7 stand for the loco-1 and loco-2 traction power currents. As illustrated in Fig. 1.8, three-phase voltage waveforms are given, which are balanced in nature. Before compensation, two traction power currents are insufficient, and uneven, and three phase currents are unbalanced, which contain a lot of negative sequence currents and harmonic currents.

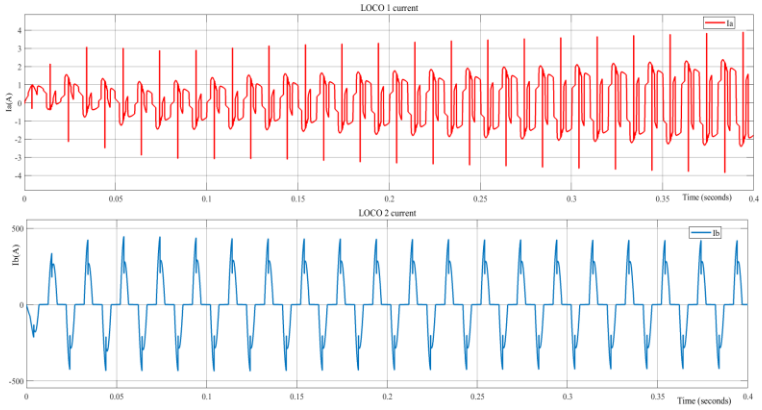

Fig. 1.7 Waveform of Traction Power Currents of WAG-9 Before Compensation

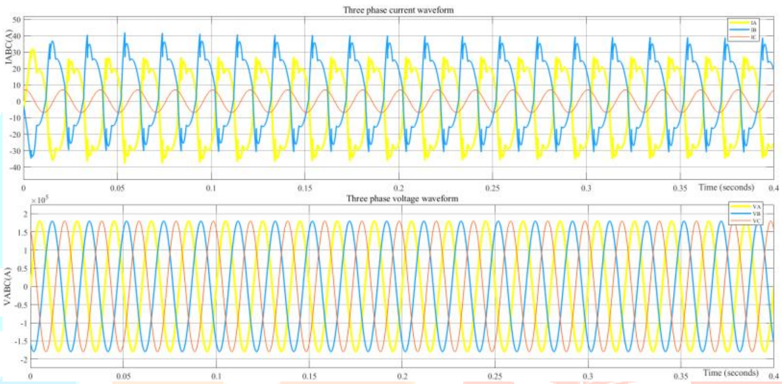

Fig. 1.8 Waveform of Three Phase Currents and Voltage before Compensation in Case of WAG-9 Locomotive

In Fig. 1.9, I_a and I_b denote the loco-1 and loco-2 traction power currents. After adding compensation circuit, two traction power currents are stable and settle to their rated value after 0.4 sec.

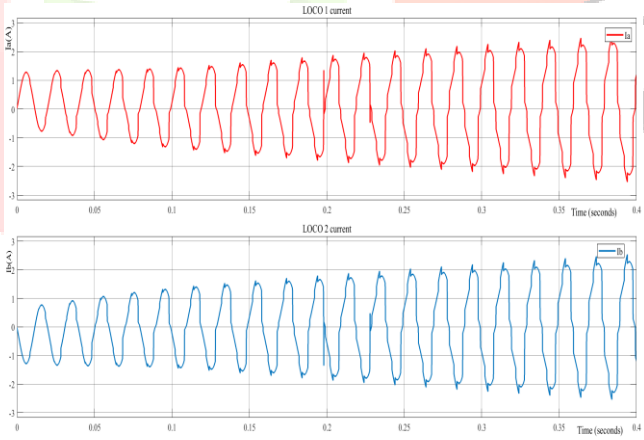

Fig. 1.9 Waveform of Traction Power Currents After Compensation in Case of WAG-9 Locomotive

Currents in three phases are balanced as shown in Fig. 1.10, and harmonic currents and NSC are reduced to a significant value with both the locomotive types after adding a compensator to the traction system. In Fig. 1.10 three-phase voltage waveforms are shown which are balanced in nature with WAG-9 type locomotive.

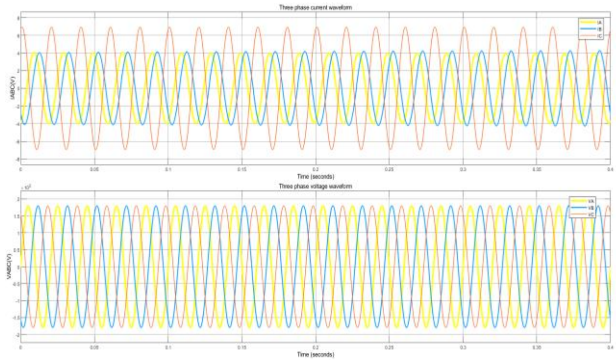

Fig. 1.10 Waveform of Three Phase Currents and Voltage After Compensation in Case of WAG-9 Locomotive

In Fig. 1.11, V_{c1} and V_{c2} are dc-link capacitor voltages. Before adding a compensation circuit both voltages are unbalanced. At starting a sudden peak appears because charging of the capacitor. After two cycles the dc link capacitor voltage varies sinusoidally between desired values V_{p-p} of 800 V.

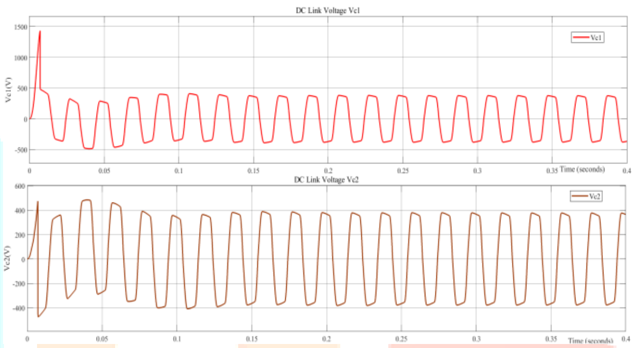

Fig. 1.11 Waveform of Two dc Link Capacitors in Case of WAG-9 Locomotive

In Fig. 1.12, the FFT bar diagram of three phase currents before compensation in the case of the WAG-9 locomotive is shown. This FFT bar diagram shows that the dc component is 1.24%. whereas 2nd, 4th and 6th harmonics have strengths of 3.24 %,1.81 % and 0.98 %. the 3rd and 5th harmonics have strengths of 4.36 % and 0.53 % respectively.

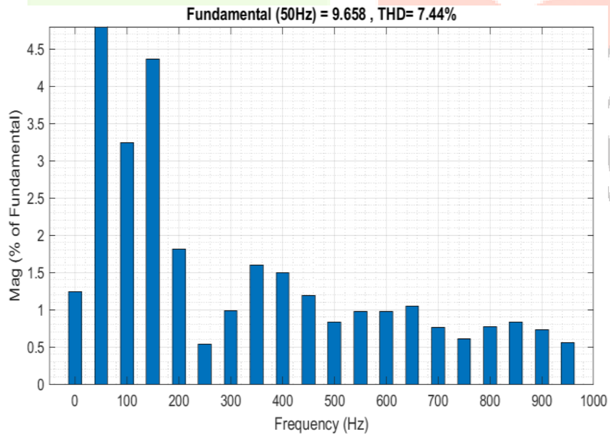

Fig. 1.12 FFT Bar Diagram of Three Phase Currents Before Compensation in Case of WAG-9 Locomotive

In Fig. 1.13, the FFT bar diagram of three-phase voltages before compensation in the case of the WAG-9 locomotive is shown. This diagram gives clear information about the value of different harmonic components is very less as compared to the fundamental frequency.

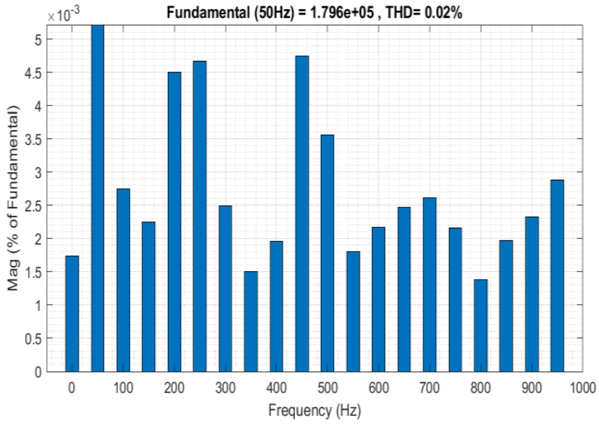

Fig. 1.13 FFT Bar Diagram of Three-Phase Voltages Before Compensation in Case of WAG-9 Locomotive

In Fig. 1.14, the FFT bar diagram of three phase currents after compensation in the case of the WAG-9 locomotive is shown. This FFT bar diagram shows that the dc component is 9.06 %. whereas 2nd, 4th and 6th harmonics have strengths of 1.75 %,0.90 % and 0.38 %. the 3rd and 5th harmonics have strengths of 0.52 % and 0.59 % respectively.

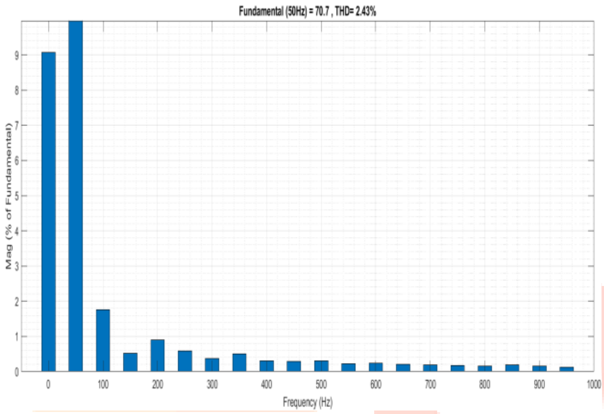

Fig. 1.14 FFT Bar diagram of Three Phase Currents After Compensation in Case of WAG-9 Locomotive

In Fig. 1.15, the FFT bar diagram of three-phase voltages after compensation in the case of the WAG-9 locomotive is shown. This diagram gives clear information about the value of the different harmonic components is very less as compared to the fundamental frequency.

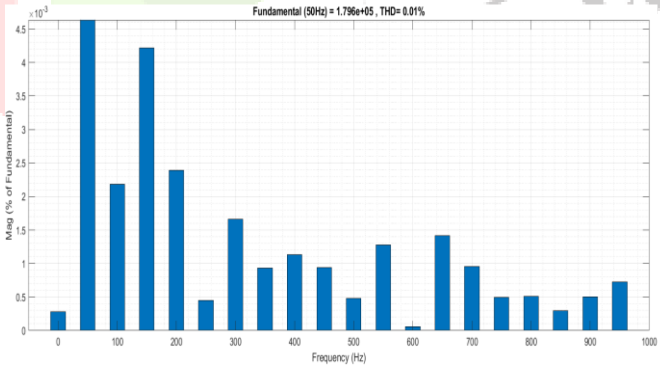

Fig. 1.15 FFT Bar Diagram of Three-Phase Voltages After Compensation in Case of WAG-9 Locomotive

THD Comparison of WAG-9 Locomotive in these studies is depicted in table 2. the value of total harmonic distortion of three-phase current was reduced from 7.44 % to 2.43 % after compensation.

Table 2 THD Comparison of WAG-9 Locomotive

Quantity	Before compensation	After compensation
I_{ABC}	7.44 %	2.43 %
V_{ABC}	0.02 %	0.01 %

As the proposed compensator is placed into the framework, it can adjust the particular fundamental part and harmonic parts of flows to understand the Negative Sequence Current compensation and harmonic current concealment. Then, at that point, the three-phase flows are balanced almost after compensation, and the Negative Sequence Current is generally decreased to focus on the consistent state. Before remuneration, two capacitor voltages are unequal (V_{C1} = 321 V and V_{C2} = 484 V), as displayed in Fig.1.11 in the case of WAG-9 locomotives. Subsequent to placing into the proposed compensator, the Balanced Voltage regulator is embraced to regulate the voltages of two capacitors using dc links. After some time of fluctuation, two capacitor voltages finally reach a constant state of about 350 V. As a result, this control method may comprehend the voltage equilibrium of two capacitors and maintain the compensator's consistent and routine operation.

The particular harmonic flows are extraordinarily decreased by the remuneration of the proposed compensator. The two traction power arm flows drop from 7.44 % to 2.43 % on account of WAG 9 Locomotive burdens. As indicated by the exploratory outcomes, the proposed compensator, by carrying out the proposed control technique, can effectively compensate NSC and harmonic flows, enormously further developing the power quality of the great speed rail route traction system.

CONCLUSION

The best power quality of the high-speed rail route traction framework, which is built on two half-bridge converters, has been suggested by a far-reaching compensator. When compared to the Railway Power Conditioner, the number of force switches is reduced, lowering the cost, equipment complexity, and power losses in the process. To eliminate voltage lop-sidedness and lessen the unequal impact on framework execution, a balanced voltage management has been presented, taking into account the dc-connect voltage equilibrium of two capacitors. Finally, replication and research findings have confirmed that the suggested framework has a positive impact on negative sequence. Harmonic current concealment and current pay. In spite of the fact that the half-bridge compensator has a few drawbacks, the proposed compensator represents a cunning effort to address the robustness of the railroad traction framework.

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