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Hydrogen electrified railways based shunt hybrid filter

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ABSTRACT

This paper presents a proposal to keep the conventional railway system, by creating a secure external independent hydrogen station, with the integration of a parallel hybrid filter to isolate the propagation of harmonics, and the reduction of the current ripple. In modern applicactions hydrogen stations are one of the most important sources of sustainable energy; this has been considered one of the most significant sources of energy, as it has no pollution output. Most current research proposes to integrate the fuel cell into the railway, and this will make it face higher risks such as accidents and vibrations as well as the approach of the storage a system to different people. We research any aspect of the proposed method and we demonstrate the ffect of shunt hybrid filter (SHPF) uses in stopping the propagation of the harmonics to the hydrogen side.

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1. INTRODUCTION

Due to the chemical reaction conducted inside each cell, fuel cell power plants are a unit of electrical power generation units [1]. Fuel cell can survive for a long time, and its output technology and system are very good, and this is one of the most valuable features that make it more commonly used at present [2, 3]. The PEM is one of the most important alternative energy sources currently used in electric traction systems. Because of the exponential expansion of the cities and the large increase in population rates faced by most countries in the world today [4]. To minimize construction costs, the production of electric express train technologies, which are mostly powered by a single overhead line, has been important [5]. But this induces strong currents from the rail net's negative chain [6].

One of the main worries with the fast evolution of the railway electrification network is the harmonic currents produced by Power electronics devices flowing through the network pantograph on an electric rail [7-9]. One of the most effective solutions used to reduce these producing harmonics, especially from high loads, is the hybrid power filter, which includes two key features, the lack of cost and performance quality over the other two filter types (passive filter and active filter) [10-12]. The objective of this work is to study the proposal to keep the old railway architecture, with the construction of a external hydrogen generation zone, inserting a hybrid shunt filter to solve the harmonic pollution and ripple of the currents problems.

2. OVERVIEW OF FUEL CELLS

Total fuel cell classifications are (AFCs, PAFCs, PEMFCs, MCFCs and SOFCs) [13]. PEMFC technology should be the most commonly used according to a cost study [14-16]. The general PEMFC architecture is specified in Figure 1.

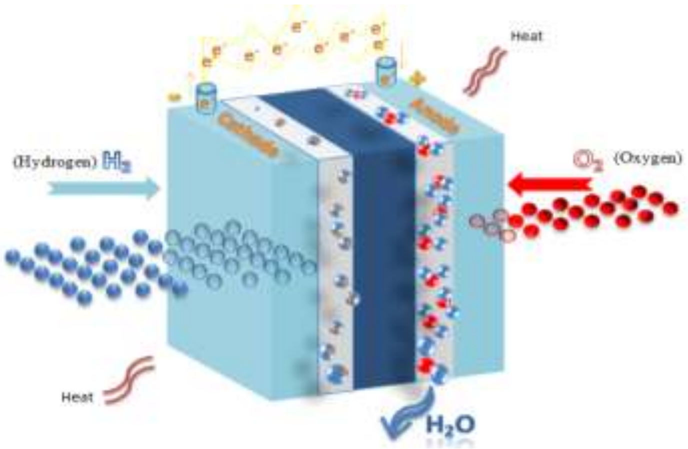

Figure 1. Schematic of PEM

3. CONVERTERS DC–DC

The voltage drop that PEMFCs emit needs to be raised to a normal supply voltage. As seen in Figure 2, all cell structures in series connected and interface the output with a power converter. You should also disable the DC/DC converter and control the inverter's modulation index to get a set output AC voltage [17, 18].

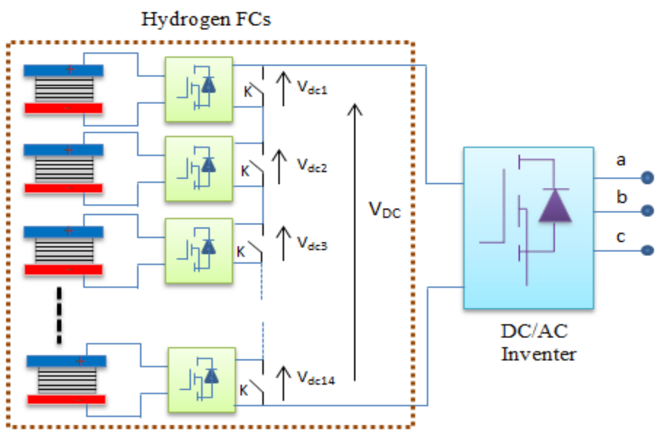

Figure 2. Model of hydrogen station

4. POWER QUALITY IN ELECTRIFIED RAILWAYS

Rail systems are classified into:

a) Low-voltage DC systems Medium-voltage low-frequency (15-25 Hz) AC systems.
b) Medium-voltage public-grid frequency (50/60 Hz) AC systems [7, 19].

Through the schematic diagram below, we notice that the system of driving current in a high-speed railway consists of two systems the control system and the driving system. In the control system, the pantograph collector provides the train with AC power. The driving system consists of the converter-inverter with the traction motor [20]. Figure 3 presents the traction drive system.

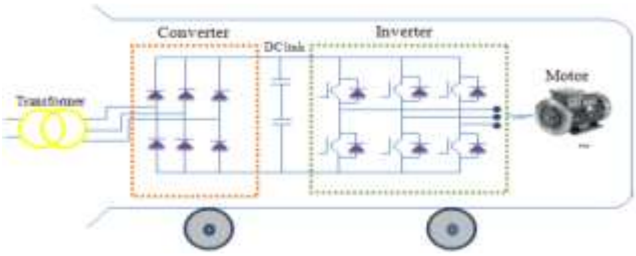

Figure 3. Schematic diagram of the traction drive system

5. HYBRID POWER FILTER

The experts made a mixture of the passive and the active filters with the improvement in load and the rise in the cost of active filter [21], and they developed the third form called hybrid filter. Hybrid filter can be divided into three topologies [22]:

a) Active power filter in series with passive shunt filter.
b) Active shunt power filter with passive shunt filter.
c) Active power filter series related to passive shunt filter [23].

We used the second topology of the hybrid filter for that analysis to account for reactive power and remove low-frequency harmonics and other harmonics [24]. Hybrid Power Filter controller: For this research, we use the theory of active and reactive instant power (P-Q) method as [25].

$$\begin{bmatrix} V_\alpha \\ V_\beta \end{bmatrix} = C_{32} \begin{bmatrix} V_{Sa} \\ V_{Sb} \\ V_{Sc} \end{bmatrix}, \begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} = C_{32} \begin{bmatrix} i_{Ca} \\ i_{Cb} \\ i_{Cc} \end{bmatrix} \quad (1)$$

$$\begin{aligned} i_\alpha &= \hat{i}_\alpha + \tilde{i}_\alpha \\ i_\beta &= \hat{i}_\beta + \tilde{i}_\beta \end{aligned} \quad (2)$$

$$\begin{bmatrix} \tilde{p} \\ \tilde{q} \end{bmatrix} = \begin{bmatrix} \hat{V}_\alpha & \hat{V}_\beta \\ -\hat{V}_\beta & \hat{V}_\alpha \end{bmatrix} \begin{bmatrix} \tilde{i}_\alpha \\ \tilde{i}_\beta \end{bmatrix} \quad (3)$$

$$\begin{bmatrix} \tilde{i}_\alpha \\ \tilde{i}_\beta \end{bmatrix} = \begin{bmatrix} \hat{V}_\alpha & \hat{V}_\beta \\ -\hat{V}_\beta & \hat{V}_\alpha \end{bmatrix}^{-1} \begin{bmatrix} \tilde{p} \\ \tilde{q} \end{bmatrix} \quad (4)$$

$$\begin{bmatrix} \hat{V}_\alpha & \hat{V}_\beta \\ -\hat{V}_\beta & \hat{V}_\alpha \end{bmatrix}^{-1} = \frac{1}{\hat{V}_\alpha^2 + \hat{V}_\beta^2} \begin{bmatrix} \hat{V}_\alpha & -\hat{V}_\beta \\ \hat{V}_\beta & \hat{V}_\alpha \end{bmatrix} \quad (5)$$

The reverse transformation of the Clark converts the load current into ABC coordinates in αβ, the command of the shunting active power filter as seen in Figure 4 [26, 27].

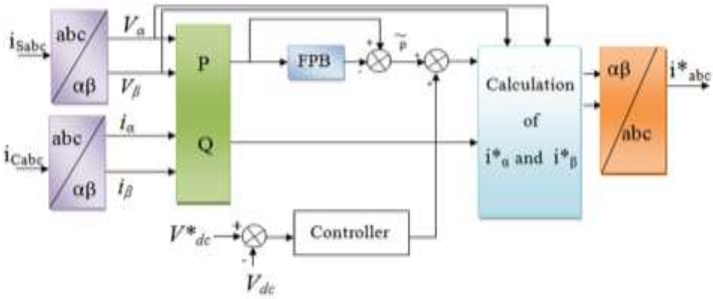

Figure 4. Active power filter parts control

6. SIMULATION RESULTS AND DISCUSSION

To keep old railway architecture, a hydrogen station is created using Matlab based thirty-two PEMFC cells associated in series, we present in Table 1 the parameters of each cell and in Table 2 we describe the specifications of the DC/DC converter of each one. The hydrogen station is connected to the electric railway system using a 26kV/600V three-phase transformer. The hybrid filter is shunted to the transformer as shown in Figure 5. Table 3 includes the parameters system of the proposed hybrid filter and Table 4 presents the railway parameters.

Table 1. Fuel cell nominal parameters

Stack power=50 Kw
Nominal Utilization:Hydrogen(H2) = 99.25%, Oxigen(O2) =59.3%

Table 2. Specifications of the DC/DC converter

Parameters	Value
DC bus voltage, Vdc, fs	1200V, 10kHz

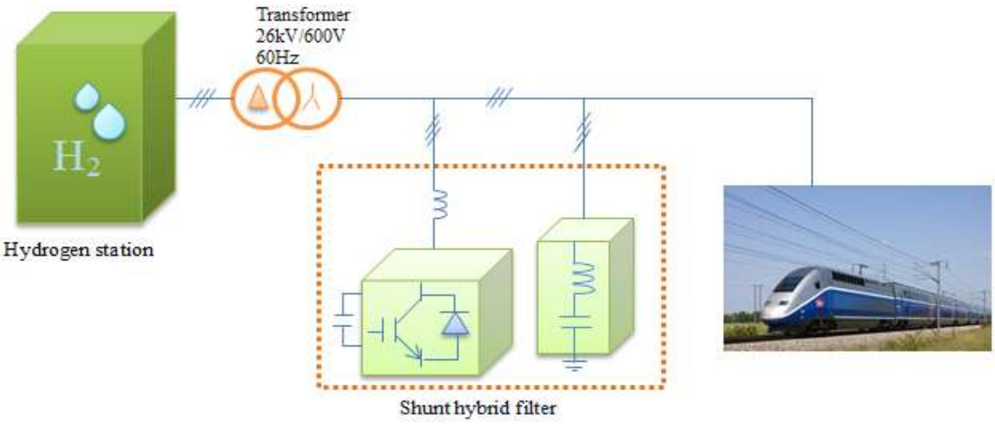

Figure 5. Studied system

Table 3. Hybrid power- filter specifying parameters

Passive power filter	250Hz 350Hz 550Hz (H11)
Active power filter	Vdc=770V, C=10µH, PWM switched frequency=10kHz

Table 4. Railway parameters

Parameters	Value
Electrical system	25kV, 60Hz,
Speed	192 km/h
Traction motor	3 phase asynchronous motor 3000rpm

Figure 6 explain the utilization of O_2 and H_2. Figure 7 presents the cell voltage (V) and current (A) and Figure 8 describe cell power (W). The utilization of DC-DC boost converters as depicted in Figure 9 is necessary to increase the voltage generated by the PEMFC.

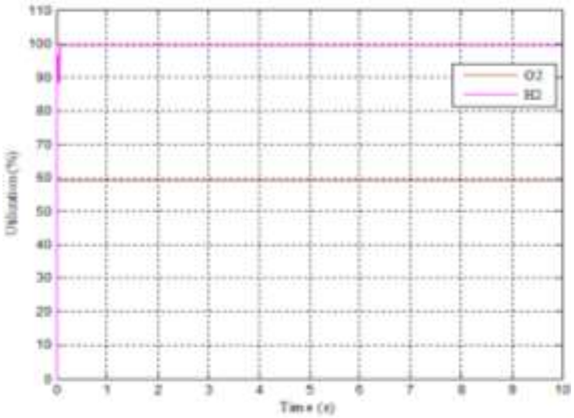

Figure 6. Utilization of O_2 and H_2

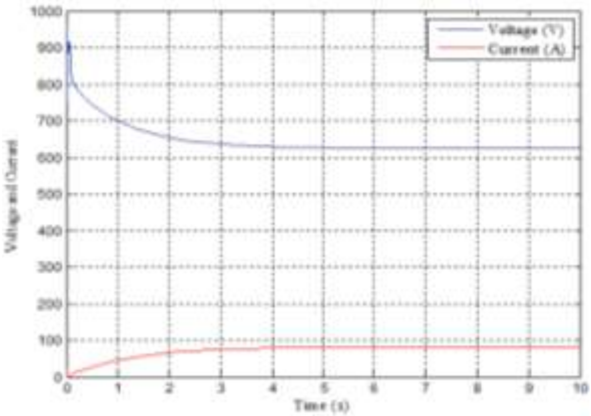

Figure 7. Output voltage and current of PEMFC

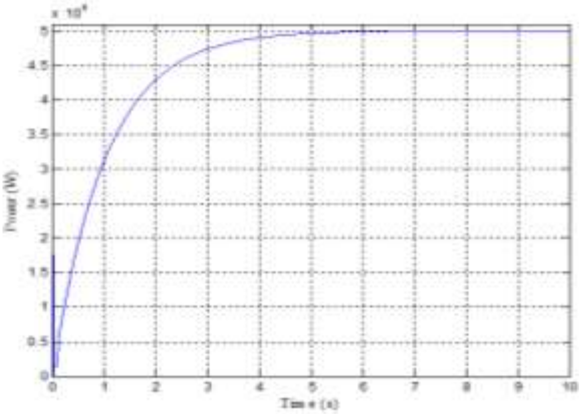

Figure 8. Power of PEMFC

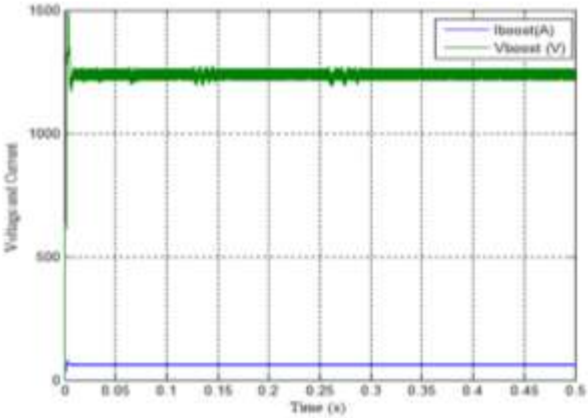

Figure 9. Output voltage and current of a cell DC-DC converter

The voltage of thirty-two cells together and the output of central inverter which is a format is presented in Figure 10. Through an LC filter and a 26kV/600V the hydrogen station governs the railway however, the speed of the railways observed in Figure 11, we can also see in Figure 12 that the current is non-sinusoidal and enables the transmission of a THD=28.48%; that could affect the hydrogen station as defined in Figure 13.

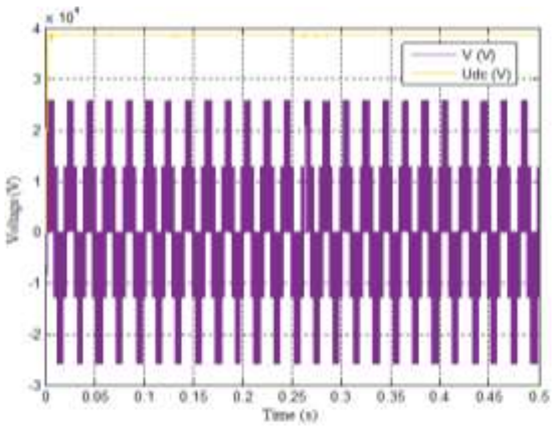

Figure 10. Inverter waveform generation of hydrogen station

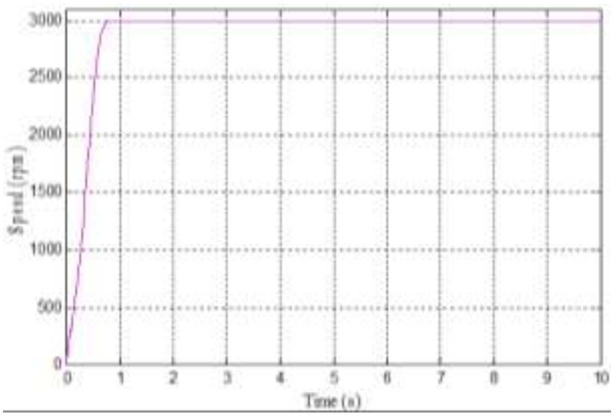

Figure 11. Railway speed

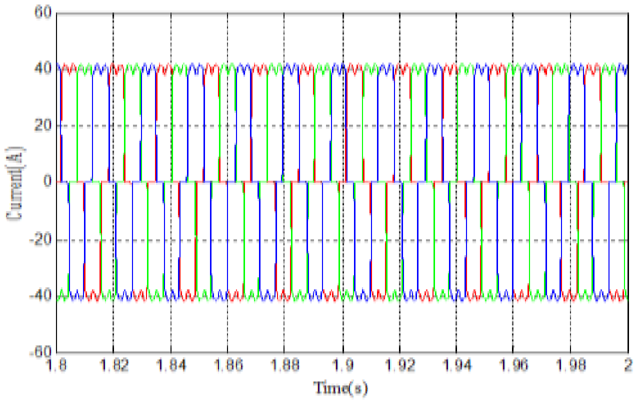

Figure 12. Current waveform without hybrid filter compensation

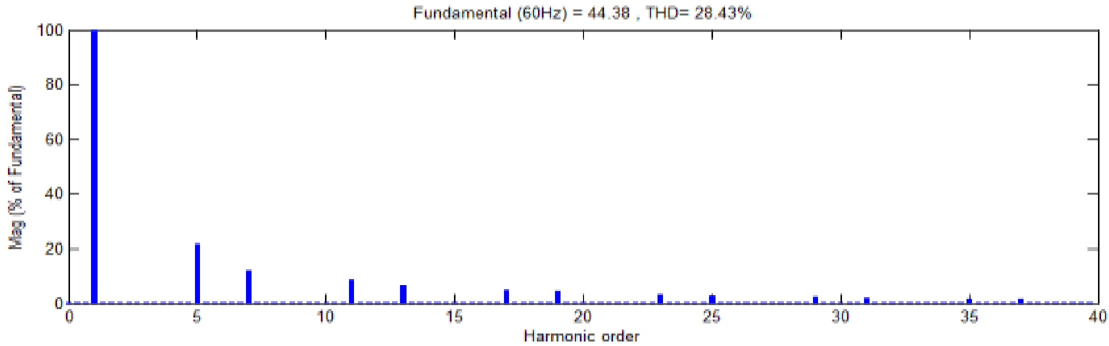

Figure 13. Harmonic spectrum analysis results of the pantograph before filtration

The supply current after compensation is almost the sinusoidal form which is the addition of the injected current of power hybrid filter with the load current the Figure 14 presents the hybrid current injected, the current waveform after compensation is shown in Figure 15. Figure 16 depicts the frequency range of harmonies analysis results after filtration. From a result obtained it can be observed that the THD of the currentis decreased by approximately 2.18% and we may say that the need for hybrid power filters to prevents the distribution of harmonic current generated by the electric traction system.

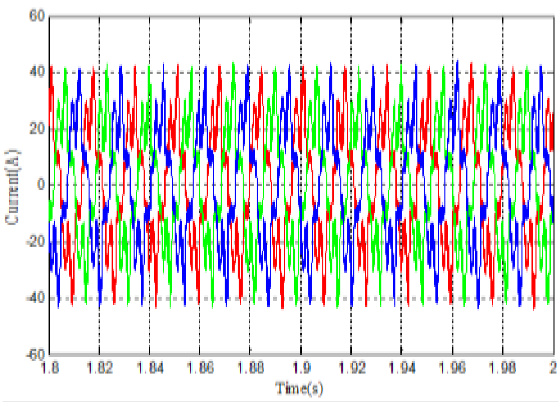

Figure 14. Current injected from hybrid filter compensation

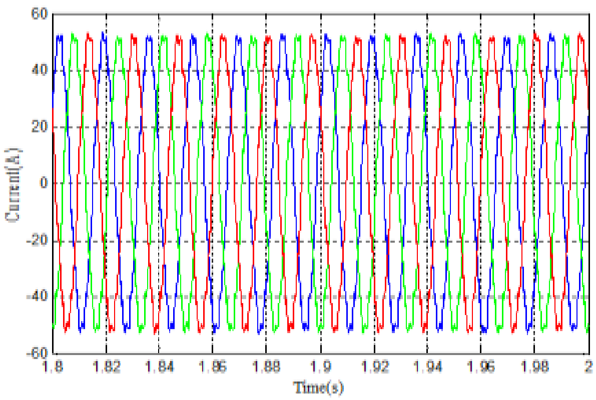

Figure 15. Current waveform with hybrid filter compensation

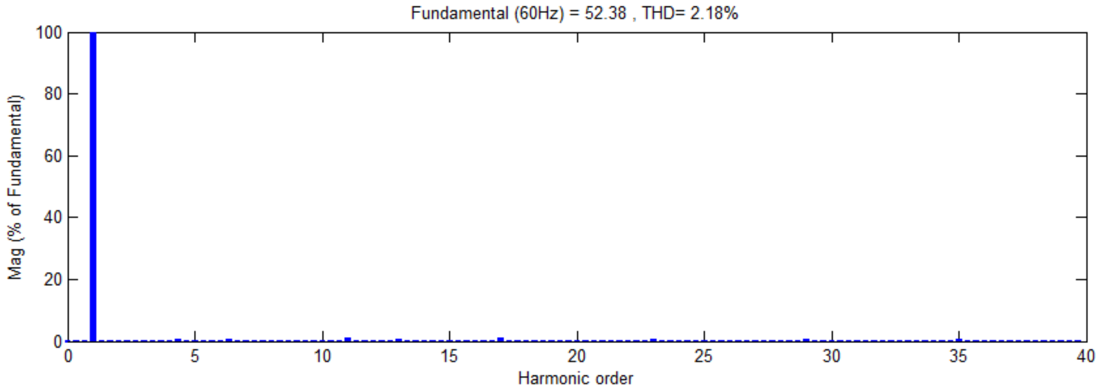

Figure 16. Harmonic spectrum analysis results of the pantograph after filtration

7. CONCLUSION

This paper describes first the proposition of an electrical railway governed with external hydrogen station. In this solution, that we can keep the old architecture of railways and use a type of renewable energy sources like hydrogen. The harmonics caused by electric railway systems can cause great problems in power systems such as the malfunction of electrical devices, and the reduction of the effective lifetime of fuel cells. From this we conclude that the hybrid power-filter has a high ability to inhibit or eliminate the transmission of harmonics towards the network, So in this experiment, the transmission of the harmonic emission to the hydrogen station is stopped.

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