Mohamed Niare, Fadaba Danioko, Mamadou Dansoko, Mamadou L. Doumbia, & Kante, B. S. (2025). Parallel active filter design for phase unbalanced problems resolution in 3-phase electrical grid. International Journal of Engineering Sciences & Research Technology, 14(5), 30-42. https://doi.org/10.29121/ijesrtp.v14.i5.2025.3 CC BY 4.0
IJESRT: 14(5), May, 2025 ISSN: 2277-9655

International Journal of Engineering Sciences & Research Technology

(A Peer Reviewed Online Journal)
Impact Factor: 5.164

IJESRT

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

IJESRT
INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

PARALLEL ACTIVE FILTER DESIGN FOR PHASE UNBALANCED PROBLEMS RESOLUTION IN 3-PHASE ELECTRICAL GRID

Mohamed NIARE[1], Fadaba DANIOKO[1,2], Mamadou DANSOKO[1], Mamadou L DOUMBIA[3], Boubacar S KANTE[1]
[1]Centre de Calcul de Modélisation et de Simulation, Faculté des Sciences and Techniques de Bamako, MALI
[2]Centre d'Intelligence Artificiel et de Robotique (CIAR) Bamako, Mali
[3]Université du Quebec à Trois-Rivières, CANADA

DOI: https://doi.org/10.29121/ijesrtp.v14.i5.2025.3

ABSTRACT
Energy quality is a very important in the electrical networks reliability, domestic and industrial equipment security. Indeed, all electrical network can be negatively impacted if the energy quality is poor. This poor quality is generally due to the phase unbalanced problems (cables and equipment warming, rotating machines stopping, equipment destruction, etc.). To solve this problematic, in this work, we first modeled the balanced three-phase network suppling three identical single-phase loads without filter using. Secondly, we modeled an unbalanced three-phase network, with a non-identical single-phase loads and a single-phase fault on phase 2 in two configurations; the three-phase unbalanced networks without filter and parallel active filter using. In this context, we propose an approach based on the SRF method (Synchronous Reference Frame) to solve the unbalanced electrical network phenomena by taking into account the harmonics attenuation generated by non-linear loads at the source side. Finally, we have designed and simulated the different model of balanced and unbalanced networks, with or without active power filter under the Matlab/Simulink environment. The obtained results show our model effectiveness with a net compensation of active energy and unbalanced harmonic distortion rate (THD<5%).

KEYWORDS: Parallel active filter, Unbalanced problem, 3-phase electrical grid, Harmonic distortion rate, SFR method.

1. INTRODUCTION
At to date, the electrical energy needs became more and more increasing, as well as the users requirements in terms of energy quality. One of these qualities concerns the balanced phase in electrical network, which is generally unbalanced. This imbalance can drive to the cables and electrical equipment overheating, sudden shutdown of rotating machines, equipment destruction, etc.

To solve this problem, several authors have proposed methods such as:
The authors of [1] propose an algorithm using reference currents under different conditions and based on the instantaneous powers theory which allows to detect and compensate harmonic currents. The obtained results showed that the proposed model allows the harmonics attenuation and a response time reduction for the reference currents computation. However, the proposed method is not applied to an unbalanced network.

In [2], the authors use an active power filter in order to study the operating regimes in three configurations: balanced, unbalanced with load and a single phase fault on the load side. The obtained results are satisfactory but do not include the current harmonics attenuation at the source.

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

The authors of [3] propose a three-phase parallel active power filter based on a two-level voltage converter controlled by the PQ algorithm to compensate the electrical networks harmonics. The obtained results are satisfactory in the harmonic compensation quality and power factor correction, except that they are not take into account the unbalanced systems in load and fault configuration.

In [4], the authors propose a parallel active filter which adapts to load variations. This filter is a PWM voltage inverter allowing to eliminate the harmonic currents generated by an uncontrolled three-phase rectifier bridge (nonlinear load). The obtained results showed that the harmonic distortion rate (THD) calculated after filtering is lower than 5%. A device is technically complex and generates economic costs linked to the PWM converter use. In addition, the considered network is not unbalanced and the current harmonics attenuation phenomena at the source side is not take into account.

The authors of [5] use a DSTATCOM to, filter the load currents harmonics, rectify the power factor and compensate the reactive power using two methods: SRF (Synchronous Reference Frame) and IRPT (Instantaneous Reactive Power Theory). Under these conditions, the obtained results show that the SRF method is better than IRPT method, it should be noted that this study does not take into account load faults and their fluctuation in network quality. Furthermore, it is not applied to an unbalanced network and is not take into account the current harmonics phenomena at the source.

In the reference [6], the authors study the robustness and the dynamic performance of an active filter compared to a passive filter under the frequency and load variation conditions without consider the voltage, which explains that the unbalance phenomena is not taken into account.

In [7], the authors use the instantaneous power method and the synchronous detection method to improve the network quality under the nonlinear loads influence. The obtained results from the parallel active filter which is based on the hysteresis control of the inverter are satisfactory, except that the network considered is not unbalanced.

The authors of [8] make a comparative study between a new approach proposed FVM (Filter Multi-Variable) and the SRF method to compensate the harmonics currents in a network including several loads. For this, they use two current inverters to inject current harmonics at the connection points. Although the results are satisfactory with a THD conforming to the standard, this method generates some technical-economic problems resulting to the two inverters use and does not take into account the nonlinear loads effect on the currents at the source side.

In [9], the authors propose a real-time control technique using an active power filter to improve the quality of an unbalanced network subjected to fluctuating non-linear loads. They use two STF filters, one to process line voltage and the other to separate fundamental current and harmonics. The results obtained are satisfactory with a THD conforming to the standard; however, they do not take into account the current harmonics at the level of the source.

The authors of [10] use instantaneous power theory to propose an active power filter to attenuate current harmonics at the source. The obtained results are satisfactory with an acceptable THD, moreover, it should be noted that the electrical network considered in this study is not unbalanced.

Recent works have been focused on this phase unbalanced problematic [11-19]. In these works, some authors use intelligent techniques which require a lot of parameters adjustment, this fact makes their experimental validation difficult. Other authors combine at least two techniques, this implies the technical and economic complexity increase of the system.

None of the studies propose an active filter to solve the unbalanced electrical network problem while taking into account the harmonics attenuation generated by nonlinear loads at the source. In addition, the challenge is to develop only efficient method but also a less complex system. For these reasons, we propose a parallel active filter using SFR method to solve the unbalanced problem in 3-phase electrical grid.

The rest of this article is organized as follows: the section 2 describes the methodology part, the simulation results and discussion are presented in section 3 and some concluding remarks are made in section 4.

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

2. PROPOSED METHODOLOGY

The approach used is the SRF method which exploits successively Concordia and Park transformations to reach hree phase line currents to Park dq line current. This allow to transform the fundamental current component into a continuous component and the harmonic current components in AC components. This aptitude offers eliminates the DC current component elimination by using a simple low-pass filter. In this condition, the Concordia inverse transformation allows to provide the reference currents.

SRF Method

Matlab/ Simulink

1st transformation from three-phase to two-phase (Concordia)

2nd transformation into dq (Concordia - Park)

Transform the fundamental component into continuous and the harmonic component into alternative, Continuous component

Concordia inverse transformation to obtain reference currents

Fig.1. Proposed methodology

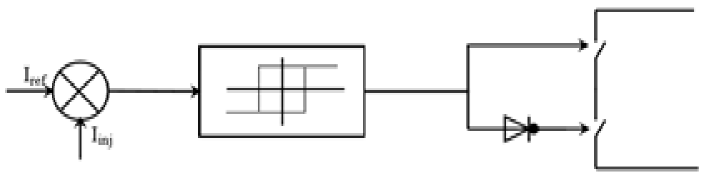

Fig. 2: Filter currents control by hysteresis [1]

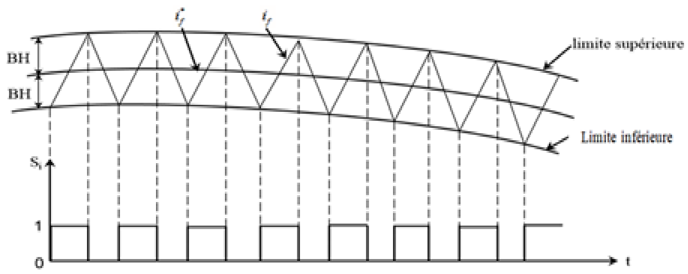

Fig. 3: Switches control by hysteresis [1]

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

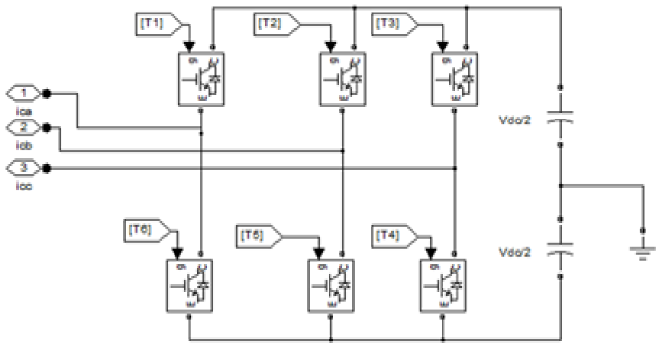

Fig.4 : The voltage inverter

-First transformation or transformation of Concordia: to switch load currents from three-phase to two-phase.

$$\begin{bmatrix} i_\alpha \\ i_\beta \\ i_0 \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & \frac{-1}{2} & \frac{-1}{2} \\ 0 & \frac{\sqrt{3}}{2} & \frac{-\sqrt{3}}{2} \\ \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \end{bmatrix} \begin{bmatrix} I_{la} \\ I_{lb} \\ I_{lc} \end{bmatrix}$$

-Second transformation or transformation in the dq referential: to switch the fundamental component to DC and the harmonic component to AC.

$$\begin{bmatrix} i_d \\ i_q \\ i_0 \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} \cos(\theta) & \cos(\theta - \frac{2\pi}{3}) & \cos(\theta + \frac{2\pi}{3}) \\ -\sin(\theta) & -\sin(\theta - \frac{2\pi}{3}) & -\sin(\theta + \frac{2\pi}{3}) \\ \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \end{bmatrix} \begin{bmatrix} I_{la} \\ I_{lb} \\ I_{lc} \end{bmatrix}$$

-Inverse transformation: to find the reference currents.

$$\begin{bmatrix} I_{refa} \\ I_{refb} \\ I_{refc} \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & 0 \\ \frac{-1}{2} & \frac{\sqrt{3}}{2} \\ \frac{-1}{2} & \frac{-\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix}$$

The algorithm for identifying the reference currents by the Synchronous Reference Frame (SRF in English) using the Matlab/Simulink software is shown schematically in the figure below.

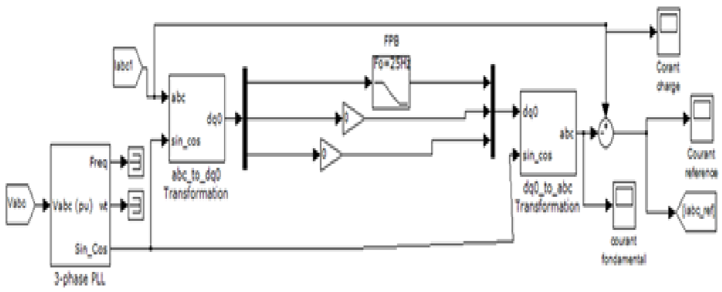

Fig. 5: Principle of identification of harmonics by the SRF method

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

Schematic diagram of APF is given by the figure below.

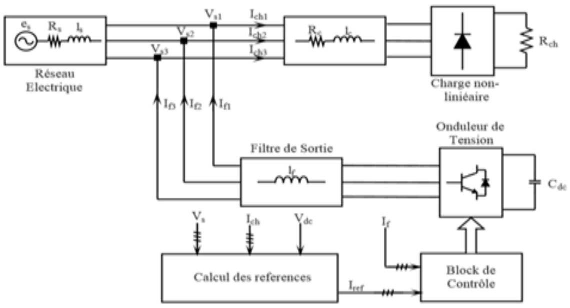

Fig. 6: Network set, APF, polluting load [2]

SIMULATION RESULTS AND DISCUSSION

Description of the three-phase electrical network without active power filter:
-Balanced system without APF:

Table 1: Simulation parameter

V_{s_eff} (V)	f (Hz)	r_S (mΩ)	L_s (µH)	r_C (mΩ)	L_C (µH)	r_{dl123} (Ω)	L_{dl123} (mH)
240	50	3,63	14,12	12,87	105,98	5	30

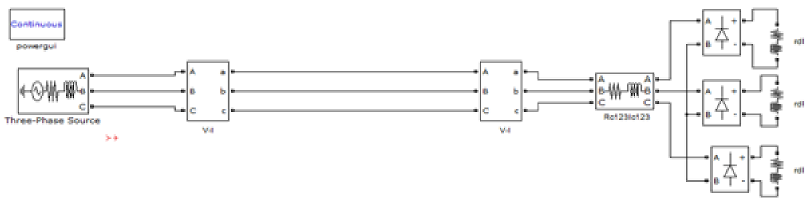

Fig. 7: Balanced electrical network without APF

Voltage on the source side is sinusoidal and balanced.

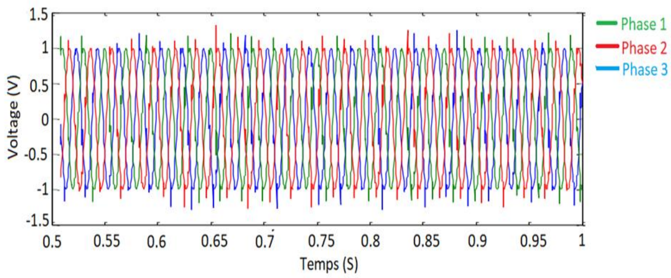

Fig. 8: Source side voltage

The current absorbed by the nonlinear load is shown in the following figure;

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

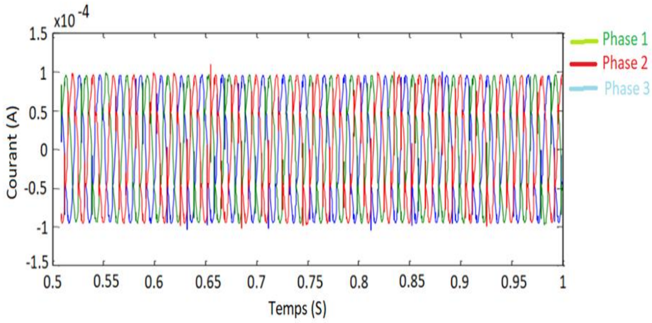

Fig. 9: Load current

Non-linear loads generate current harmonics at each phase.
-Unbalanced system without APF:
1st case: single-phase load imbalance:

Table 2: Simulation parameter.

$V_{s\ eff}$ (V)	f (Hz)	r_S (mΩ)	L_s (µH)	r_C (mΩ)	L_C (µH)
240	50	3,63	14,12	12,87	105,98
r_{dl1} (Ω)	L_{dl1} (mH)	r_{dl2} (Ω)	L_{dl2} (mH)	r_{dl3} (Ω)	L_{dl3} (mH)
0,2	1	0,79	4,8	0,3	4

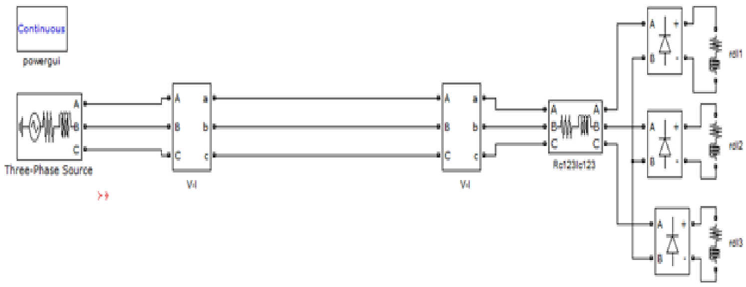

Fig. 10: Unbalanced electrical network, single-phase without APF

The source side voltage is sinusoidal and balanced:

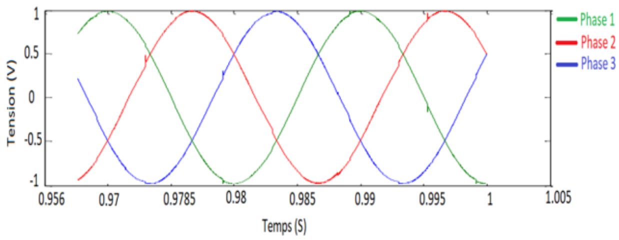

Fig. 11: Source side voltage

On the other hand, the load currents are unbalanced.

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

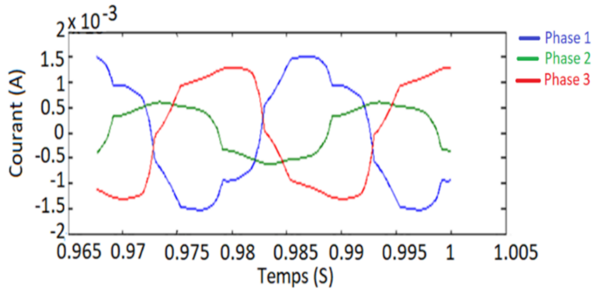

Fig. 12 : Load current.

2nd case: single-phase fault of phase 02:

Table 3: Simulation parameter

$V_{s\ eff}$ (V)	f (Hz)	r_S (mΩ)	L_s (µH)	r_C (mΩ)
250	50	3,63	14,12	12,87
L_C (µH)	r_{dl1} (Ω)	L_{dl1} (mH)	r_{dl3} (Ω)	L_{dl3} (mH)
105,98	5	30	5	30

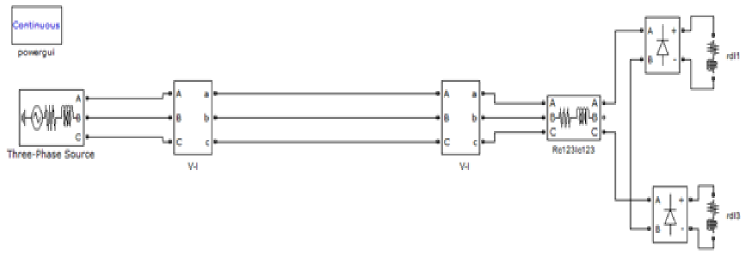

Fig. 13: Electrical network unbalance, phase fault 02

The voltages on the source side form a balanced sinusoidal signal:

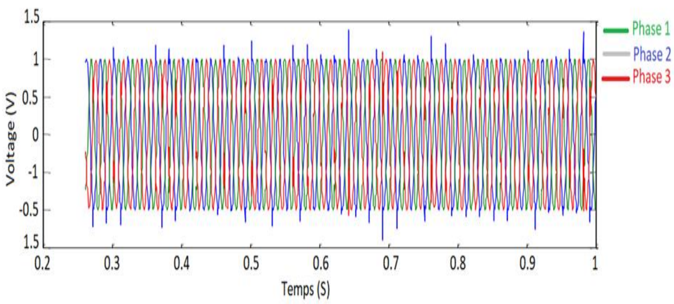

Fig. 14: Source side voltage

On the other hand, the charge current is unbalanced:

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

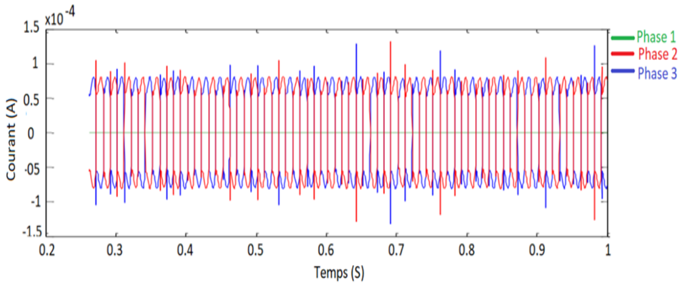

Fig. 15: Load current

We notice that the FFTs of phase one and three are identical and that we have no results for phase two, this is due to the fact of the single phase fault on this phase.

Table 4: The THD of source currents before filtering

Phase	Balanced electrical network	Unbalanced electrical network, Load different phase	Electrical network unbalance, phase fault 02
THD phase 1	09,67 %	17,45 %	31,79 %
THD phase 2	10,31 %	20,23 %	No value
THD phase 3	10,90 %	20, 21 %	31,79 %

Description of the three-phase electrical network with active power filter
After having described our electrical network connected to three non-linear single-phase loads, we will mount our active filter in parallel between the source and the single-phase non-linear load.

Table 5: APF simulation parameters

L_f (µH)	C_{dc} (mF)	V_{dc} (V)
200	8	700

-Balanced electrical network:

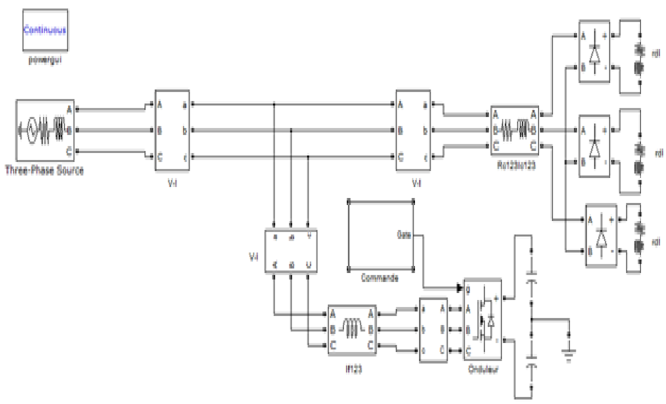

Fig. 16: Balanced electrical network with APF

Current on the source side is sinusoidal on the other hand; current on the load side is of the following form:

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

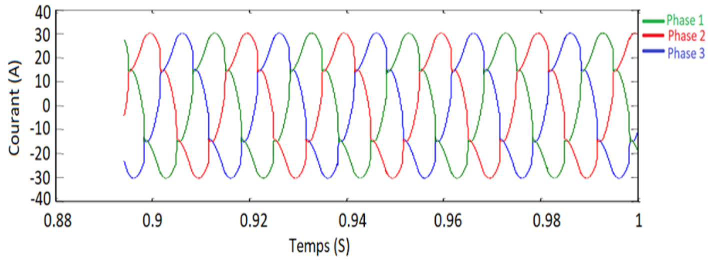

Fig. 17: Unbalanced load current, identical single-phase load

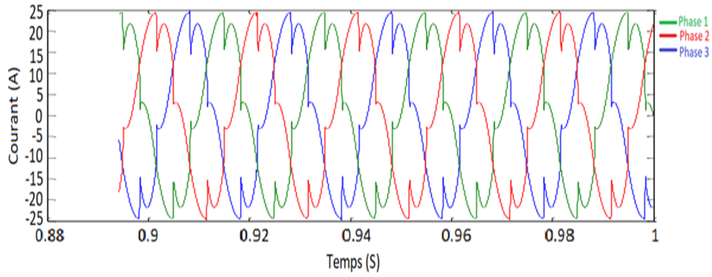

Fig. 18: Filter current injected into the network

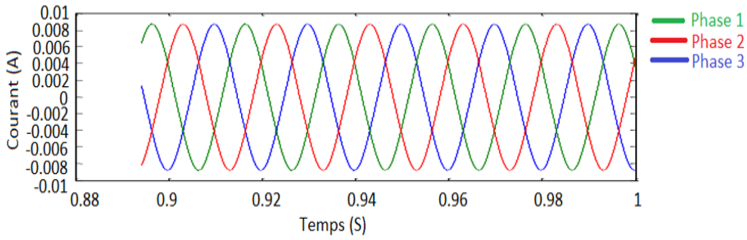

Fig. 19: Source current compensated

The load current harmonics of each have been compensated.
The reactive energy has been compensated so as to obtain the sinusoidal shape of the current.

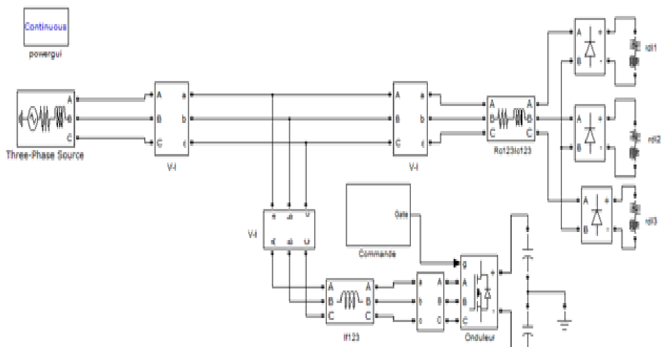

Fig. 20: Unbalanced electrical network, single-phase.

Current on the source side is sinusoidal on the other hand; current on the load side is of the following form:

[Niare at *al.*, 14(5): May, 2025]
IC™ Value: 3.00

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

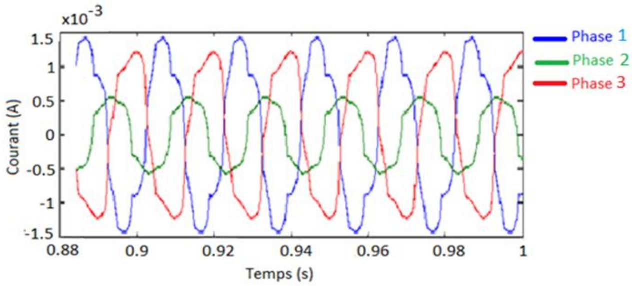

Fig. 21: Unbalanced load current, single-phase load not identical

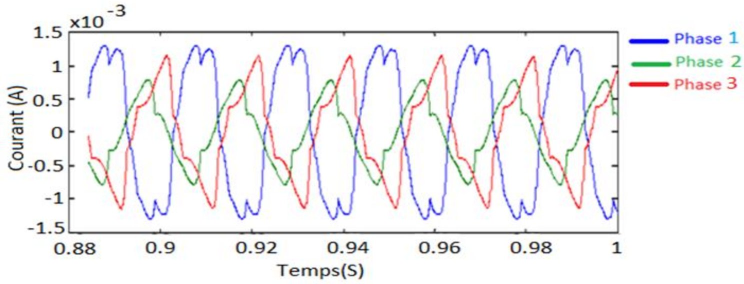

Fig. 22: Filter current injected into the network

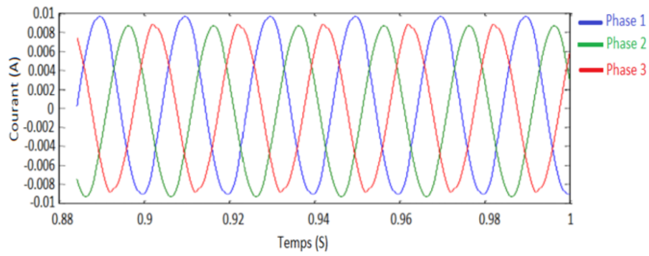

Fig. 23: Source current compensated

The load current harmonics of each phase have been compensated.
We also notice that the current imbalance has been corrected (THD <5%)
The energy compensated therefore the shape of the current became sinusoidal again.
- Single-phase unbalanced electrical network, phase 02 fault:

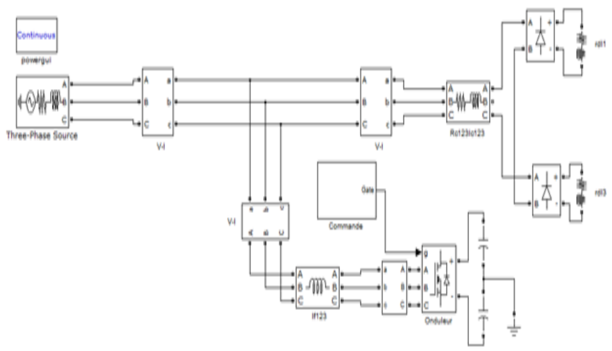

Fig. 24: Unbalanced electrical network, phase 02 fault with APF.

Current on the source side is sinusoidal on the other hand; current on the load side is of the following form:

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

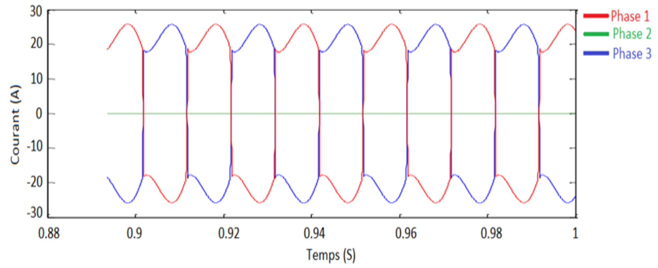

Fig. 25: Load current for the electrical network in the absence of phase 02.

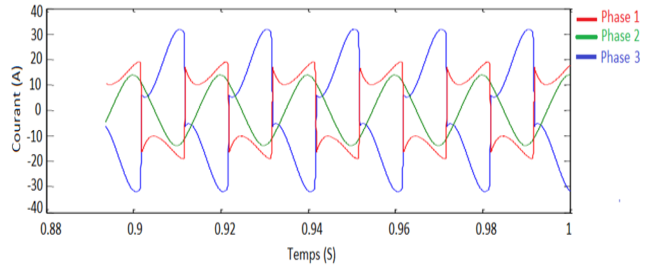

Fig. 26: Filter current injected into the network

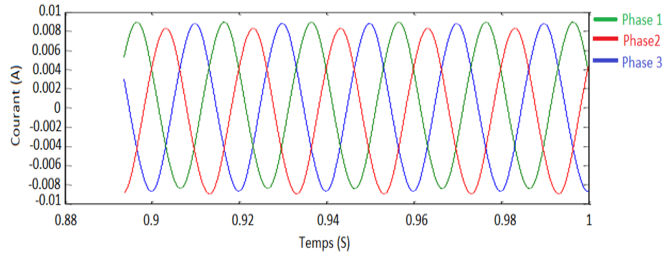

Fig. 27: Source current compensated

The load current harmonics of each phase have been compensated.
We also notice that the current imbalance has been corrected (THD <5%)
The energy compensated therefore the shape of the current became sinusoidal again.

Table 6: The source current THD after filtering

Phase	Balanced electrical network	Unbalanced electrical network, Load different phase	Electrical network unbalance, phase fault 02
THD phase 1	2,21 %	2,98 %	2,34 %
THD phase 2	2,21 %	2,00 %	2,14 %
THD phase 3	2,21 %	2,16 %	2,00 %

3. CONCLUSION:

In this paper, we have proposed a parallel active filter based on SFR method in order to improve the unbalanced electrical network quality. This proposed method is applied on electrical network in balanced and unbalanced configuration with line and loads faults. The filtered system is designed in Matlab/Simulink environment in order to study his behavior. The obtained results show that the proposed parallel active filter allow to strongly attenuate the generated harmonics by the nonlinear loads at the source side with the harmonic distortion rate whose the value is lower than 5% (THD<5%). In addition, they allow to compensate reactive energy and to maintain constant

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

the condenser voltage. This fact implies the implementation simplicity of proposed method compared to methods which regulate DC bus voltage to the condenser boundary. In the future, it will be interesting to see how the hybrid filter (parallel and series) or the UPQC (Unified Power Quality Controller) can be improve the unbalanced electrical network quality.

REFERENCES

1. Boussaid "Filtrage actif des harmoniques dans les réseaux électriques. Contribution à l'amélioration de l'énergie électrique" Thèse à la faculté de science et de technologie, Algerie, 2017.
2. S. OTHMAN "Modélisation et Commande à base d'une représentation par Réseau de Pétri d'un Filtre Actif Parallèle avec un Onduleur Multicellulaire Série " These, Université de Gabès, Tunisie, 2021.
3. A. Morsli, A. Tlemçani, M.S. Boucherit and N. Ould Cherchalit, " Dépollution des réseaux électriques basse tension utilisant un filtre actif parallèle à deux niveaux contrôlé par algorithme PQ" Acta Electrotehnica, vol. 53, n° 2, pp105-111, 2012,
4. L. Zellouma, S. Saad, N. Debbache and A. Omeiri, " Etude de l'auto-adaptivité du filtre actif parallèle aux variations de charge" Revue synthèse, n° 17, Janvier 2008, Annaba, Algérie.
5. S. Gairola and M. Chamoli , " SRF And IRPT Methods of DSTATCOM for Combined Harmonics Elimination and Reactive Power Compensation" International Journal of Engineering Research & Technology, Vol. 7 Issue 07, pp 254-260, 2018
6. A. J. Mahdi and B. A. Fadheel "Study the Robustness Active Filter for a Three Phase Power Rectifier Considering Line Frequency and Load Variations" Journal of Babylon University/Engineering Sciences, n° 1, Vol. 26,pp 141-154, 2018.
7. R. Boubakeur "Contribution à l'amélioration des performances d'un filter actif parallèle de puissance par l'utilisation d'un convertisseur multicellulaire".These, Université FERHAT ABBAS -SETIFI , Algerie, 2021
8. L. Benyettou, "Comparative Study Entered New Approach FMV and Control SRF for Active Compensation of Harmonic Currents in Shunt Active Power Filter". International Journal of Robotics and Automatique, vo 7, N° 2, pp 119-128, 2018.
9. S. Biricik, S. Redif, Ö. C. Özerdem, S. K. Khadem, M. Basu "Real-Time Control of Shunt Active Power Filter under Distorted Grid Voltage and Unbalanced Load Condition using Self Tuning Filter" Institution of Engineering and Technology,vol 7,issue 7;pp 1895-1905,2014
10. K. J. S. Khan and S. Chunduri "MITIGATION OF CURRENT HARMONICS USING SHUNT ACTIVE POWER FILTER" International Journal of Advances in Engineering & Technology, Vol. 8 Issue 04, pp 646-662 Aug., 2015.
11. Conghuan Yang, Oingtao Zhang and Zhiyi Zhao. , "Filtering characteristics of parallel-connected fixed capacitors in LCC-HVDC considering the variations of system strength". Sec. Sustainable Energy Systems Volume 12 – 2024.
12. Ismail Ghadbane, Khaled Belhouchet, Assam Zorig. "Series active filter using seven level packed U cell converter for power quality enhancement". Studies in Engineering and Exact Sciences, Curitiba, Vol. 5 No. 01 , 2024
13. Shubhang Bandyopadhyay, Tathagata Rout and Harsh Vardhan Rathi. "Design of Multilevel Inverter based Active Filter for Harmonic Elimination & Frequency Regulation". International Journal for Research in Applied Science & Engineering Technology, Volume 11, Issue 4, 2023.
14. D. Ravichandran1 and N. Muruganantham. "Effect Of Filter Current Reduction On Hybrid Shunt Active Filters In Three phase Four Wire Network With Unbalanced Linear And Non-Linear Loads". Journal of Applied Science and Engineering, Vol. 26, No 1, pp 79-90 , 2022
15. Yusef Asadi, Mohsen Eskandari, Milad Mansouri,, Sajjad Chaharmahali, Mohammad H. Moradi and Mohammad Sajjad Tahriri. " Adaptive Neural network for a stabilizing shunt active power filter in distorted weak grids " Applied Sciences, Volume 12, Issue 16 , 2022
16. A. K. Dubey, J. P. Mishra and A. Kumar, "Modified CCF Based Shunt Active Power Filter Operation With Dead-Band Elimination for Effective Harmonic and Unbalance Compensation in 3-Phase 3-Wire System," in *IEEE Transactions on Power Delivery*, vol. 37, no. 3, pp. 2131-2142, June 2022.
17. Y. Hoon, M. A. A. M. Zainuri, A. S. Al-Ogaili, A. N. Al-Masri and J. Teh, "Active Power Filtering Under Unbalanced and Distorted Grid Conditions Using Modular Fundamental Element Detection Technique," in *IEEE Access*, vol. 9, pp. 107502-107518, 2021.

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

18. Al-Gahtani, S.F.; Nelms, R.M. "Performance of a Shunt Active Power Filter for Unbalanced Conditions Using Only Current Measurements". *Energies*, Volume *14*, Issue 02 , 2021.
19. A. Ojo, K. Awodele, A. Sebitosi and M. Mzulwini, "Application of Active Power Filters for Distribution Network Performance Enhancement," *2020 International SAUPEC/RobMech/PRASA Conference*, Cape Town, South Africa, 2020.