SSRG International Journal of Electronics and Communication Engineering
ISSN: 2348-8549/ https://doi.org/10.14445/23488549/IJECE-V12I7P128

Volume 12 Issue 7, 360-377, July 2025

Original Article

Impact of an Innovative Approach in the Management of the Electricity Network in Cameroon

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Received: 15 May 2025 Revised: 16 June 2025 Accepted: 17 July 2025 Published: 31 July 2025

Abstract *- This paper highlights an innovative adaptive approach to optimize network topology and Distributed Generation (DG) placement with the objective of reducing power losses and optimizing voltage stability. The methodological approach proposes a metaheuristic algorithm inspired by the CUCKOO model for which the process of selecting the best solutions for successive iterations immediately integrates the convergence criteria (number of iterations, tolerance); this algorithm is tested respectively on the networks: IEEE-33, IEEE-69, and on the Northern Interconnected Networks (RIN) Cameroon; and this with 4 operating scenarios for each network with an estimation of convergence performance and a comparison with the current literature; the decentralized PV production used is permanent as a working hypothesis for the implementation. The results obtained for the case of the RIN Cameroon offer a reduction in power losses of 23.9647%, for a minimum voltage of 0.97762 PU. Thus, demonstrating the effectiveness and performance of the proposed method in optimizing the management of the reconfiguration of electrical networks. A comparison of its results with those of the literature allows us to recommend this work in particular for the development program of the Energy sector horizon 2030 (PDSE 20230) for Cameroon. And in general, for the reconfiguration of electrical networks.*

Keywords *- Management of electricity, Decentralized PV production, Adaptive Metaheuristic algorithm Cuckoo, PDSE 2030.*

1. Introduction

1.1. Context and Background

The exponential growth of the energy needs in the industrial sector requires a modernization of the electrical networks. These must be able to meet the different challenges of the demand in this sector. However, during the process of transporting this Energy, numerous losses are recorded; and multiple research in the current literature propose solutions [1-3]; decentralized hybrid productions effectively participate in the stability of the electrical networks with an optimal placement of photovoltaic power plants which are connected as reinforcements on the power lines [4-6]; this approach is therefore positioned as a modern solution with multiple advantages; therefore they also raise the problem of optimizing the management of multivariable systems. It will therefore be necessary to define an objective function and propose strategies for controlling its variables [7-9]; difficulties observed in the literature at this stage are therefore the subject of several works.

1.2. Motivations of the Study

The challenges of this research are multiple and varied. Among these, we have the optimal switching of power switches in opening and closing operating regimes without energy losses and electromagnetic compatibility problems. A poor implementation of an operation is likely to produce enormous losses in material goods and especially in human lives, without taking into account the inconvenience caused by power cuts, with its impact on economic and industrial development for countries that depend essentially on electrical energy.

The algorithm proposed in this work offers an optimization of the management of the northern network of Cameroon with several options in terms of balancing the voltage and power profile from the supporting photovoltaic power plants. Furthermore, this work will help consolidate and optimize the national development program for the electricity sector in Cameroon by 2030 by informing managers on how to build and optimize decentralized production to support power lines in the northern region of Cameroon, which also has a favorable climate for solar energy. Finally, this work also serves as a contribution to research for the optimization of multi-objective systems.

1.3. State of the Literature

Research [10-12] proposes an improved management of radial electrical networks based on a gravitational algorithm.

The objective is to optimize performance by reducing line losses by adjusting the architecture over time. The implementation required action on the poles or busbars where switching was performed. The objective function depends mainly on the system constraints for better estimating errors and uncertainties. Research [13-15] also proposes optimal management based on a hybrid algorithm in which the objective function depends on the state of the switches. A test is also carried out on a 69-node network for evaluation purposes. [16, 17, 1] Develop algorithms based on a second-order conical model, reducing the cost or value related to technical conditions. A significant improvement is therefore brought by the reconfiguration of the architecture in this case. Validations are carried out on a 33-node network. GAMS software is also used for implementation. [18, 19] Develop an algorithm for meter placement by limiting resistive losses and improving the accuracy of state estimation. [20, 21] Develop a methodological approach where the algorithm organizes the different switches by stages by assigning them specific missions according to the nature of the implementation network. Successive validations are carried out on the 33, 70 and 84 node networks, and several comparisons are made with other algorithms to show the added value of the method [22, 23]. An algorithm for optimal search of solutions related to the constraints of the objective function in 4 times or implementation sequences. The tests are carried out on electrical networks of 33 and 69 nodes. [24-26] propose an improved adaptive algorithm that 361inimizes line losses. It is called the imperialist algorithm. It also associates with its objective function all the conditions and constraints related to the system. A validation is also carried out on a test network of 33 and 69 nodes for two operating scenarios, highlighting decentralized photovoltaic production. [27] proposes an artificial intelligence algorithm with the notion of combinatorial optimization where an optimal path is established according to the system constraints. The validations are carried out on 33 and 119 nodes, and the results are compared with those obtained in the literature. [28] proposes an analysis of the literature on decentralized productions with a relation to the stabilization of the network in flow mode for an improvement of the overall performance. The validation and assessment criteria in this work are based on stability and efficiency during the online flow. In addition, a comparison of its results is made with the current literature according to the operating conditions of the networks. The work of [29] takes into account stress and imbalance conditions in production. This constitutes the permanent instability of the voltage and power profile. To address this, they develop FACTS systems. This work proposes an index method for the optimal estimation of power lines (UPFC). Based on the Modern Stability Assessment Index (MSAI), this method integrates the parameters and variables of transmission lines with respect to their previous indices. The methodological approach consists of identifying, by MSAI calculation, in normal operation and in the case of N-k contingency, the most critical line that can constitute the most appropriate location for the UPFC in order to improve the voltage profile and maximum load capacity, minimize power losses and dampen oscillations. Furthermore, an N-k contingency method based on Newton's continuous power flow is implemented in the study to refine and confirm the MSAI-based selection by a congestion analysis considering only possible cases of branch failures, with infeasible cases being negligible. Furthermore, a dynamic stability assessment is performed using time domain analysis and eigenvalue analysis to validate the appropriate location of the UPFC. The study was first validated with the IEEE-14 bus test system and concretely implemented within the Southern Interconnected Grid (SIG) to improve power quality in a generation/demand imbalance context. The study, which considered base, intermediate, and peak load scenarios, uses MATLAB. A comparative analysis shows that lines 5-6 are the most suitable for UPFC installation. The results obtained in normal operation show an average voltage of 0.931 p.u to 0.974, 0.982 and 0.973 p.u, respectively. The reduction rate of active losses is 18,553%, 14,361% and 19,616% respectively. The load point is improved from (1.383, 1.548, 1.803) p.u. to (1.544, 1.587, 2.513) p.u. Thus, the general objective of this work is to solve the problem of energy deficit linked to power losses on the RIN Cameroon with optimal placement of Distributed Generators (DG). And the specific objectives are as follows. Specific objective 1: Review the current literature on algorithms for reconfiguring electrical networks with limited power losses during flow, and especially with injections of decentralized production for voltage profiles. Specific objective 2: Propose a metaheuristic algorithm inspired by the CUCKOO model for which the process of selecting the best solutions for successive iterations immediately integrates the convergence criteria (number of iterations, tolerance); and carry out tests respectively on the networks: IEEE-33, IEEE-69, and on the RIN (Northern Interconnected Networks) Cameroon with distributed generations

1.4 Contributions

In this article, an optimization technique is proposed to improve the architecture or configuration of the networks with optimal positioning of photovoltaic power plants aimed at reducing power losses in lines while improving the stability of the electrical network. This is based on a metaheuristic algorithm inspired by the CUCKOO model, for which the process of selecting the best solutions for successive iterations immediately integrates the convergence criteria (number of iterations, tolerance); a validation is carried out on the 33, 69-node networks, but also on interconnected networks in northern Cameroon. This work provides solutions to the problems raised by the work of [12] On the parameterization of the constraints of its objective function and the necessary computing power, but also according to the convergence speeds for validation of the results.. for a better selection of implementation parameters; tests are carried out for a highly densified network of IEEE-69 nodes, a medium densified network of IEEE-33 nodes and a direct application on the RIN

–Cameroon; This complex variation of several categories of electrical networks allows not only to appreciate the robustness and flexibility of the algorithm according to the behavior of the loads but above all: (a) First, mastering the optimal switching of opening and closing modes of power switches without energy losses and without electromagnetic breakdown phenomena remains very complex in the experimental implementation of the solutions developed in the literature. For the case of the RIN-Cameroon distribution network. Hence the creation of the PDSE 2030 (Electricity Sector Development Program 2030); poor management of the distribution network can have major economic consequences and cause long-term power outages throughout the territory with real impacts on the lives of citizens; (b) second, the comparative study of this algorithm in this work offers a promising way to improve the reliability of the optimization constraints of metaheuristic algorithms which requires high computing power, especially when the number of nodes becomes large, because the margins of error also become larger; This algorithm therefore provides a better understanding of the optimal management of the reconfiguration of distribution networks with injections of Distributed Generators (DG) for the case of highly and moderately densified networks and in particular the case of the RIN-Cameroon; In addition, this study aims to show that the active power injected by distributed production contributes effectively to the stabilization of networks when their implementation is optimal. ; it is therefore important to continuously improve the strategies for placing production points according to the constraints of the objective function of the production network; (c) finally The comparative study of the algorithm developed in this work with those already available in the current literature offers the possibility of improving the sustainable development of electricity distribution networks with new advances, especially for developing countries like Cameroon where emergency industrialization requires high energy consumption; this work therefore also provides information of great importance for the academic community and in particular for political leaders with the ultimate aim of influencing political decisions as well as future research in the field of energy

1.5. Article Organization

In the rest of the article, in section 2, a formulation of the problem is clearly stated with details of the objective function of the system. This section will also make it possible to better describe the steps of the method developed; in section 3 an in-depth modeling of the mathematical models of the network parameters or variables is carried out with additional details on networks: IEEE-69; IEEE-33, RIN Cameroon with an announcement of the operating scenarios of our networks; in section 4 a detailed presentation of the results obtained for the different operating scenarios is carried out. An analysis of the convergences of the summaries of the results is also proposed in this part with a validation and comparison with the results available in the current literature; finally in section 5 a conclusion is proposed with a reminder of the general objective of the work, the main contributions proposed, the recommendations and perspectives of the study for sustainable development also applicable within the framework of energy policy in Cameroon for horizon 2030

2. Development of the Problem

In this work, the objective function translates the evolution of the system parameters over time by integrating all the constraints necessary for the optimal development of the flow on the electrical network. Mathematical models of power flows and variations in conditions at the voltage and current levels are therefore developed.

2.1. Objective Functions

The robustness and stability after the reconfiguration of the architectures of electrical distribution networks with optimal placement of Distributed Generation (DG) helps effectively reduce online power losses during flow; the expression of losses is therefore defined by:

$$P_{loss,i} = R_{i;i+1} * I_i^2 = R_{i;i+1} * \left(\frac{P_i^2+Q_i^2}{V_i^2}\right) \quad (1)$$

The function in this method is linked to the evolution of the power on the electric line:

$$P_{loss,T} = \sum_{i=1}^{Nbr} P_{loss,i} = \sum_{i=1}^{nbr} R_{i,i+1} * I_i^2 = \sum_{i=1}^{nbr} R_{i,i+1} * \left(\frac{P_i^2+Q_i^2}{V_i^2}\right) \quad (2)$$

Figure 1 shows the evolution of nodes on part of the network.

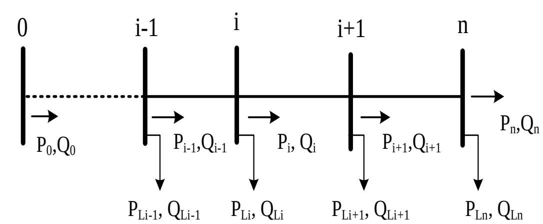

Fig. 1 spatial distribution of nodes

The constraints linked to the objective function are functions of:

2.1.1. Voltage

The evolution of the voltage range is within an interval for better execution:

$V_{min} \leq V_i \leq V_{max}$ (with Vmin = 0.91) (3)

2.1.2. The Current

Since the value of the current is most often high in comparison with the voltage, it is necessary to also set a range of evolution:

$$0 \leq I_i \leq I_{max} \quad (4)$$

In addition, the load is considered as invariable and on the power of the PV generators distributed on a:

$0 \leq P_{DG,i} \leq P_{DGmax}$ (Maximum power available is 2,000 KW).

2.2. Flowchart Method Proposed

Figure 2: Below shows the diagram for the method proposed in this article; or (a) represents the general process and (b) the developed steps of Cuckoo Adaptive Search; each of its steps determines the quality of the optimization of the reconfiguration.

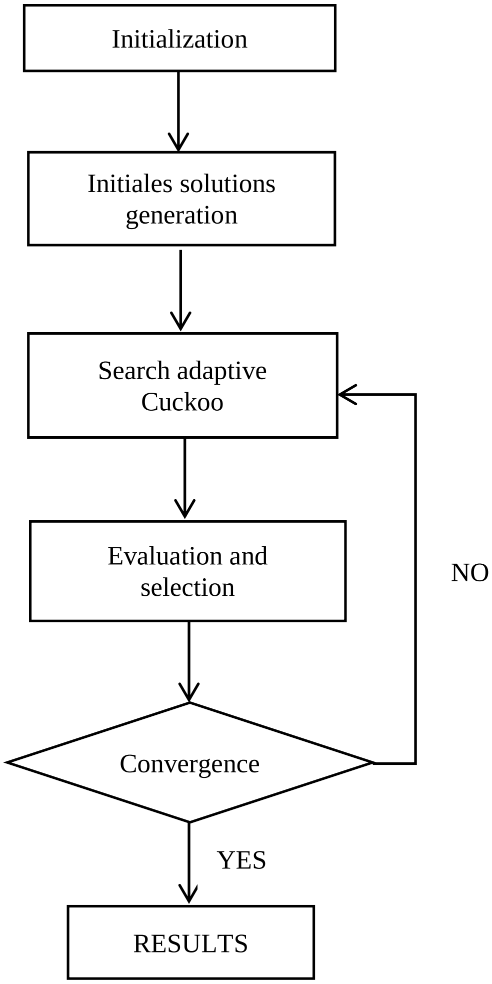

Fig. 2(a) Flow chart method proposed

The first step for this method is initialization. This involves defining:

- Network parameters (number of nodes, number of lines, requested loads)
- Distributed generator parameters (Power, location)
- The parameters of the Cuckoo algorithm (number of agents, probability of abandonment, exploration factor, exploitation factor).

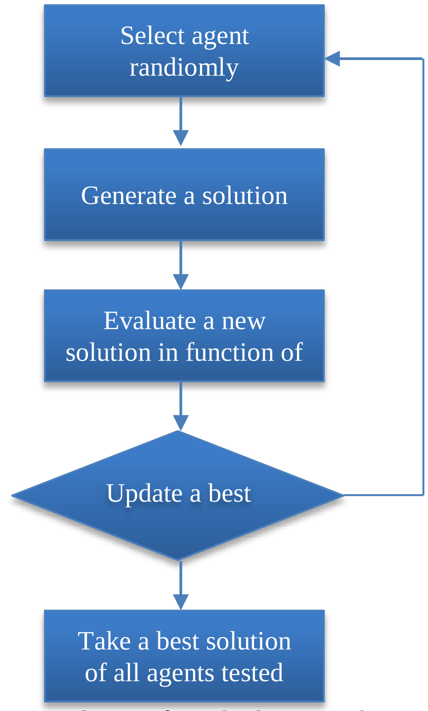

Fig. 2 (b) Step of search adaptive Cuckoo

The number of agents or elements depends on the size of the network, the complexity of the electrical network, the available computing power, and the desired calculation time for the IEEE.33 network, we chose 50 agents according to the optimization conditions by the CUCKOO 2020 algorithm and the Probability of abandonment is given by:

$$P_a = 0{,}1 + \left(0{,}4 * \left(\frac{n}{N}\right)\right) * \left(1 - \left(\frac{P}{C}\right)\right) \quad (5)$$

Where: n: number of iterations

The N size of the search space (which corresponds to the number of nodes in the network).

The exploration factor (α) varies between 0 and 1. A high value of α means that agents have a high probability of moving. The exploitation factor (β) controls the search intensity in the CUCKOO algorithm.

Step (2): Generation of initial solutions. Here we show the initial configuration of the network and the initial solutions depending on the objective (voltage profile, lost power, cost, etc.). Step (3) of the adaptive cuckoo algorithm in this flowchart is defined by the equation:

$$X_{new} = X_{old} + \alpha(X_{best} - X_{old}) + \beta(X_{rand} - X_{old}) \quad (6)$$

Step (4) Evaluation and Selection allows you to re-evaluate the solutions based on the objective and select the best solutions for the next iteration.

Step (5) of Convergence consists of checking whether the convergence criteria are achieved (number of iterations, tolerance). If not, return to step 3 of the method flowchart.

Step (6) Results display the optimal network reconfiguration and distributed generation results. Table 1 presents the methodological algorithm developed for the proposed method.

Table 1. Algorithmic evolution

STEP 1. INITIALIZATION			
Setting		**value**	
Number of agents		N	
Number of iterations		MaxIter	
Exploration factor		(α)	
Operating factor		(β)	
Probability of abandonment		(p_a)	
Number of nodes		N_nodes	
Numbers of lines		N_rows	
Capacities of DGs		P_DG	
Number of DGs		N_DG	
STEP 2. GENERATIONS OF AGENTS			
Agent	**Network setup**	**Location of DGs**	**Purpose of the function**
1	x_1	y_1	$f(x_1,y_1)$
2	x_2	y_2	f(x2, y_2)
….	…	…	…
N	x_n	y_n	$f(x_n,y_n)$
STEP 3. AGENT EVALUATIONS			
Agent	**Load loss**	**Voltage**	**Purpose of the function**
1	P_loss(x1,y1)	V(x1,y1)	F(x1,y1)
2	P_loss(x2,y2)	V(x2,y2)	F(x2,y2)
….	….	…	…
N	P_loss(Xn, Yn)	V(xN,yN)	F(xN,yN)
STEP 4. SELECTION OF THE BEST AGENTS			
Agent	Network setup	**Location of DGs**	Purpose of the function
Best agent	x_best	y_best	f(x_best,y_best)
STEP 5. UPDATE AGENTS			
Agent	Network setup	**Location of DGs**	Purpose of the function
1	x1_new	y1_new	f(x1_new,y1_new)
2	x2_new	y2_new	f(x2_new, y2_new)
….	…	…	…
N	xn_new	yn_new	f(xn_new,yn_new)
STEP 6. VERIFICATION CONVERGENCE			
Condition		Value	
Number of iterations		MaxIter	
Value of the objective function		F(x_best,y_best)$\leq\varepsilon$	

3. Applications on Distribution Network Architectures

3.1. 69-Bus Test System

The work [30, 31] proposes the technical values necessary for the study of the IEEE-69-bus network, and the simulation hypotheses are as follows:

- Voltage profile for a normal network
- Voltage profile for a normal network with distributed source placement
- Voltage profile for a reconfigured network
- Voltage profile for a reconfigured network with optimal distributed source placement

Figure 3: Presents scenario 1 for a single-line architecture of the 69-node IEEE network for normal operation.

Figure 4 shows scenario 2 for a Voltage Profile for a normal network with distributed source placement. It is also important to note that the distributed generation in this case is permanent and in 3 poles.

Figure 5: Illustrates the case of scenario 3 for the voltage profile for a reconfigured IEEE 69-node network; it highlights the impact of the algorithm in the reconfiguration of the network.

Figure 6: Shows scenario 4 for the voltage profile for a reconfigured IEEE 69-node network with optimal distributed source placement

3.2. Bus Test System 33

Figure 7 shows the Scenario 1 voltage profile for a normal 33-node IEEE network.

Figure 8 shows scenario 2 for the Voltage Profile of a normal 33-node IEEE network with optimal distributed source placement; The distributed sources are arranged at three points.

Figure 9 illustrates scenario 3. This is the voltage profile for a reconfigured 33-node IEEE network.

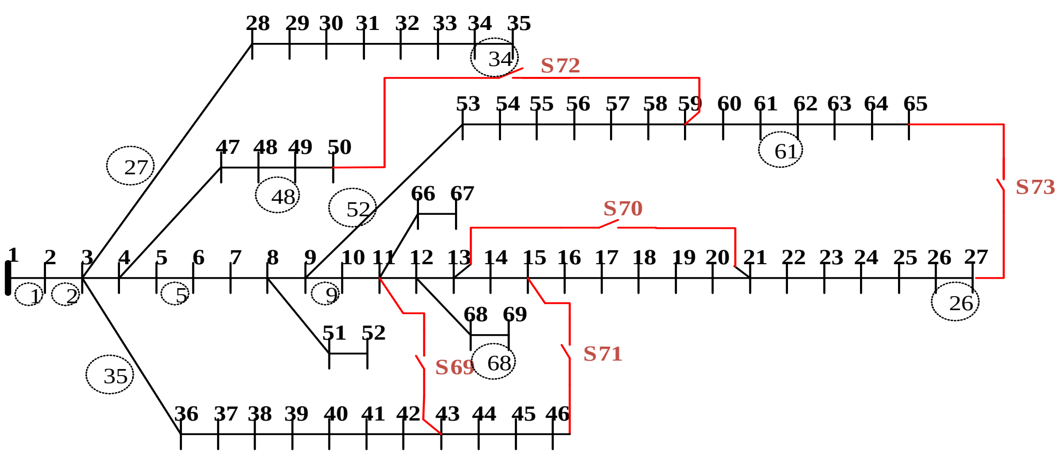

Fig. 3 Architecture of the 69-node IEEE

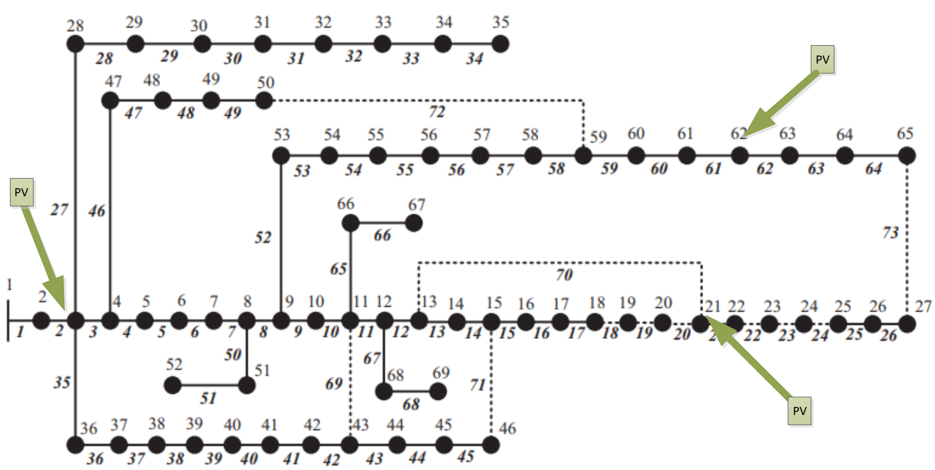

Fig. 4 Scenario 2 for a Voltage Profile for a normal IEEE 69-node network with distributed source placement

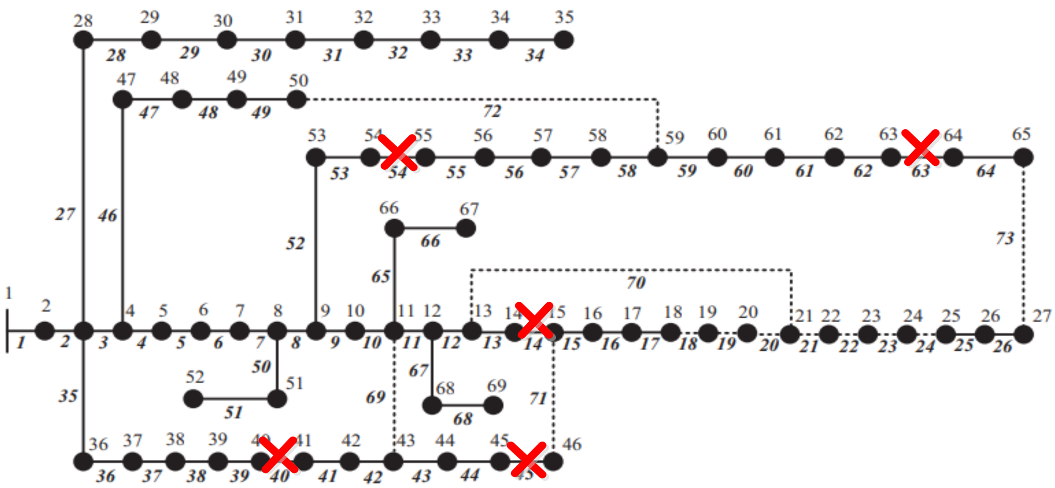

Fig. 5 Scenario 3 for a voltage profile for a reconfigured IEEE 69-node network

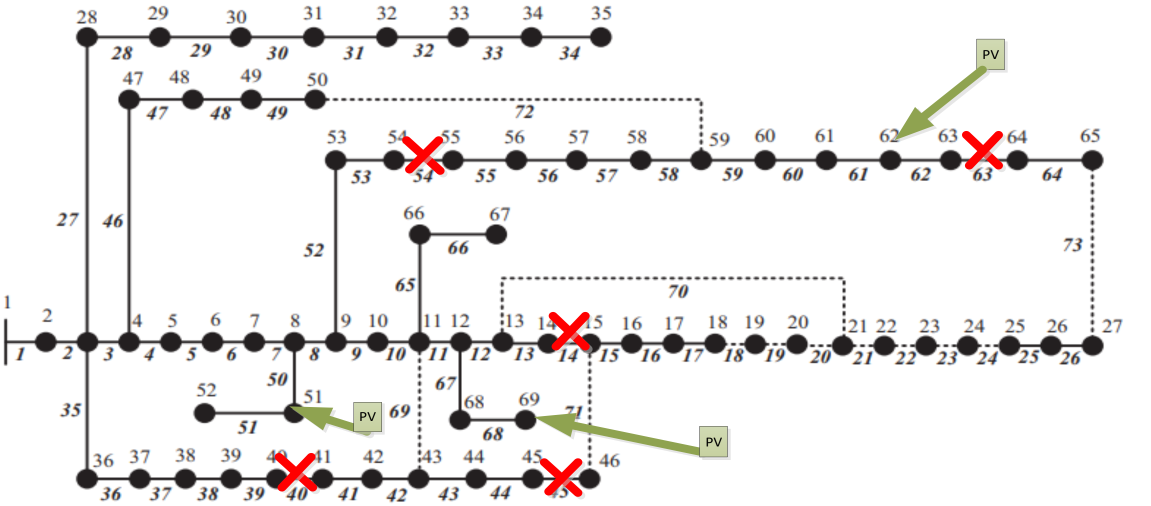

Fig. 6 Scenario 4 of the voltage profile for a reconfigured IEEE 69-node network with optimal distributed source placement

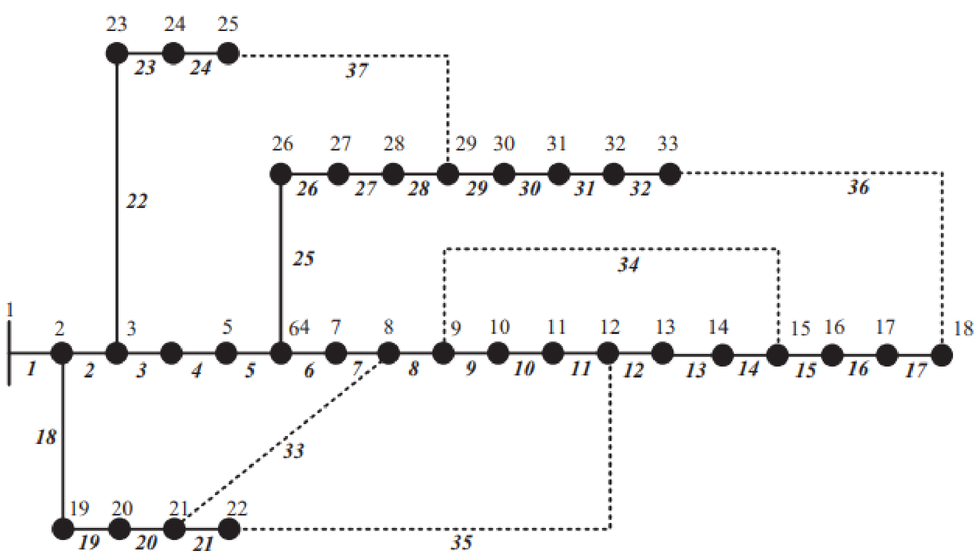

Fig. 7 Voltage profile for a normal 33-node IEEE network

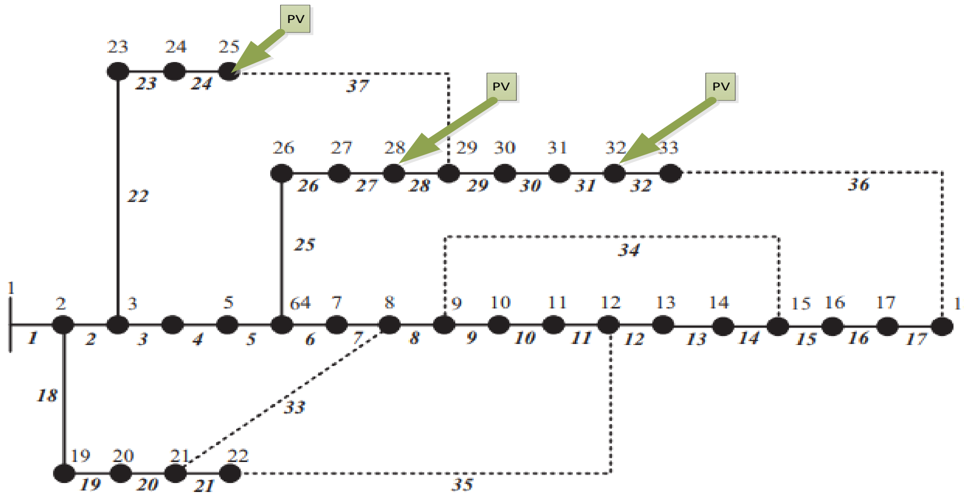

Fig. 8 Voltage profile for a normal 33-node IEEE network with optimal distributed source placement

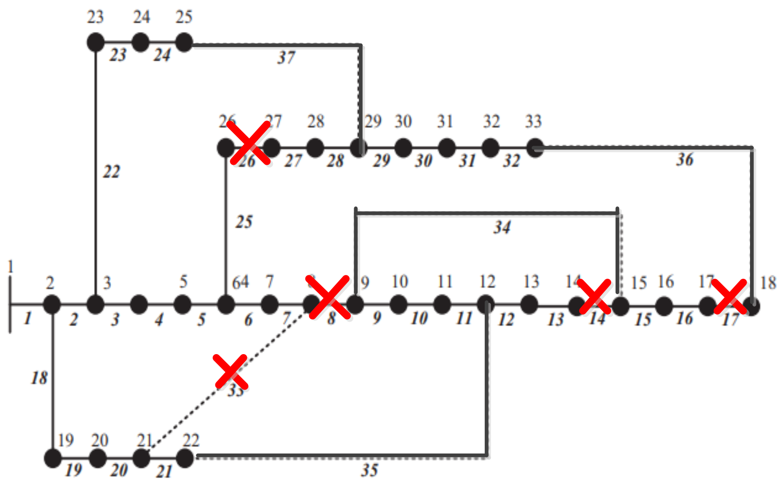

Fig. 9 Voltage profile for a reconfigured 33-node IEEE network

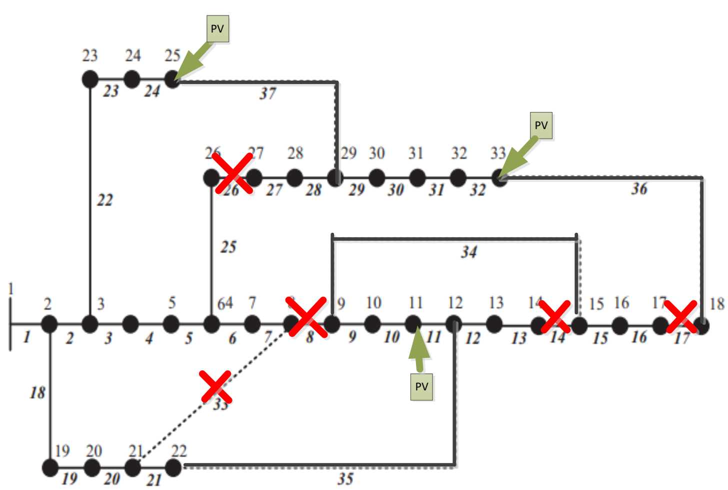

Fig. 10 Voltage profile for a reconfigured IEEE 33-node network with optimal distributed source placement

Figure 10 shows voltage scenario 4 for a reconfigured IEEE 33-node network with optimal three-point distributed source placement.

3.3. RIN – Cameroon

(RIN) Cameroon is geographically identifiable by a latitude of 9.170 and a longitude of 13.250. A better illustration is made in Figure 11. The meta-heuristic algorithm is inspired by the CUCKOO model, for which the process of selecting the best solutions for successive iterations immediately integrates the convergence criteria (number of iterations, tolerance). The proposal in this article is directly applied to a practical case on the interconnected network of North Cameroon. In order to evaluate and compare the performance of the method. The RIN in its architecture has 20 buses. The technical details of the RIS-Cameroon are given in Tables 3 and 4. Figure 12 illustrates the diagram of the RIN –Cameroon -2030.

Table 4 specifically presents the quantitative parameters of the different RIN–Cameroon buses for a better analysis of the performance of our algorithm in this article.

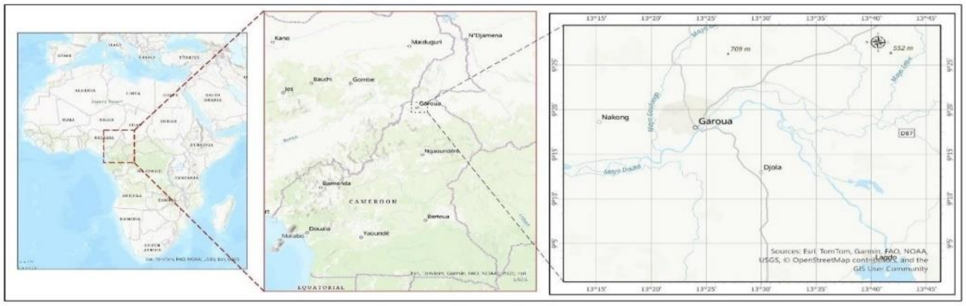

Fig. 11 Study area

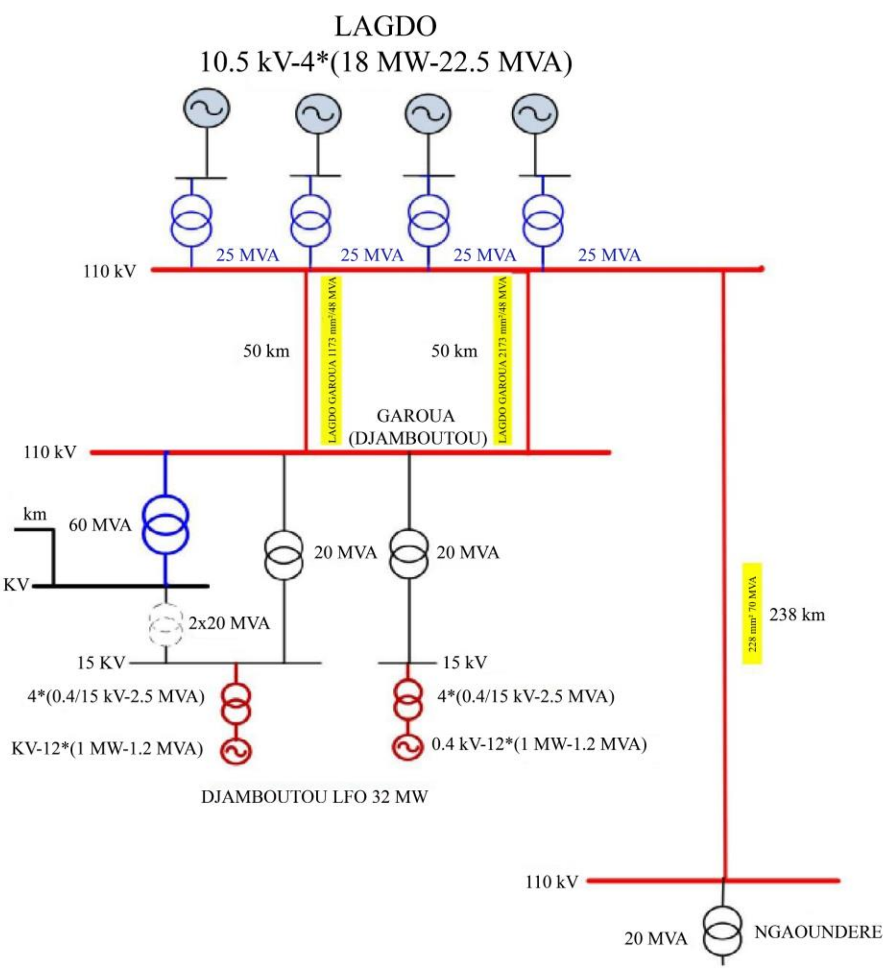

Fig. 12 PDSE 2030 (RIN –CAMEROON)

4. Results and Discussion

The simulation hypotheses below are tested with the algorithms on our test networks: a) voltage profile for a normal network, b) Voltage profile for a normal network with distributed source placement, c) voltage profile for a reconfigured network, d) voltage profile for a reconfigured network with optimal distributed source placement.

4.1. IEEE-69 Network Results

Figures 13 and 14, respectively, present the comparison of the voltage profile of the IEEE-69 networks and their convergence in the four scenarios or operating modes;

Table 2 provides a summary of the results of fluctuations or variations in the quantities of the IEEE-69 networks according to the operating scenarios:

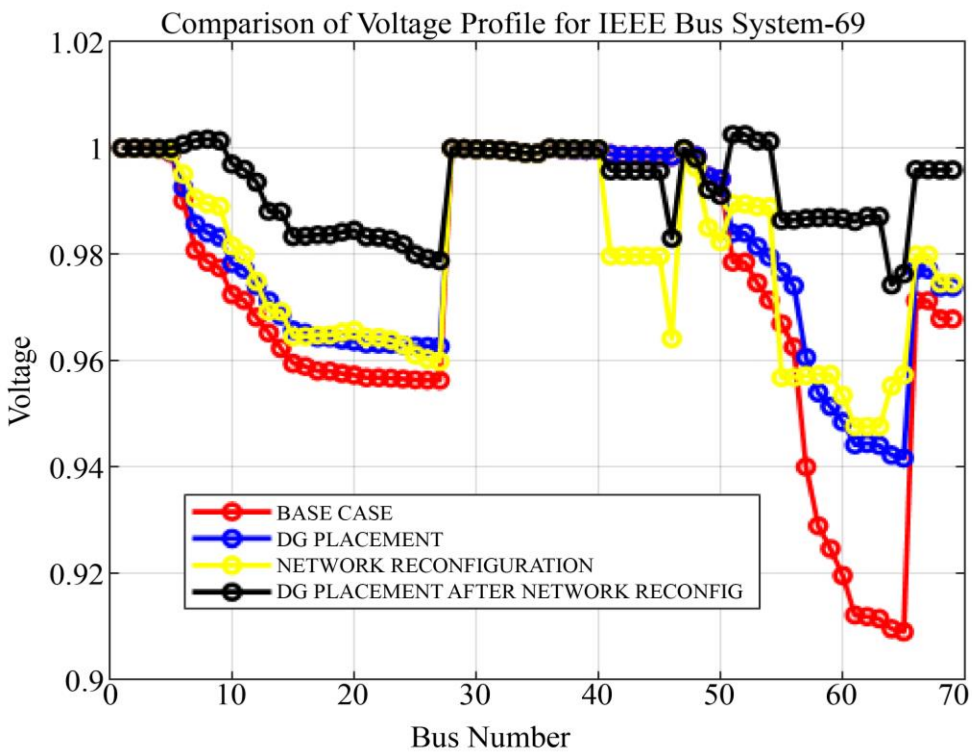

Fig. 13 Comparison of the voltage profile of IEEE-69 networks for operating modes

Table 2. IEEE-69 network summary results

Parameters	Base Case	DG placement	Network reconfiguration	DG placement after reconfiguration
Total active power loss	224.9606	107.4494	123.8158	28.6871
Total reactive power loss	102.147	52.0437	99.7633	21.9682
Switch number	69,70,71,72,73	69,70,71,72,73	54,63,45,14,40	54,63,45,14,40
Optimal DG location	-	2,62,21	-	69,62,51
Optimal DG size P (KW)	-	10,677,10	-	484 126,2967 126,2967
Optimal DG size Q (Kvar)	-	4.843221 327,8861 4,8432	-	234,4119 613,7798 613,7798
Total DG	-	697	-	3018,5993
Voltage Minimum	0.90901	0.94167	0.94761	0.97426

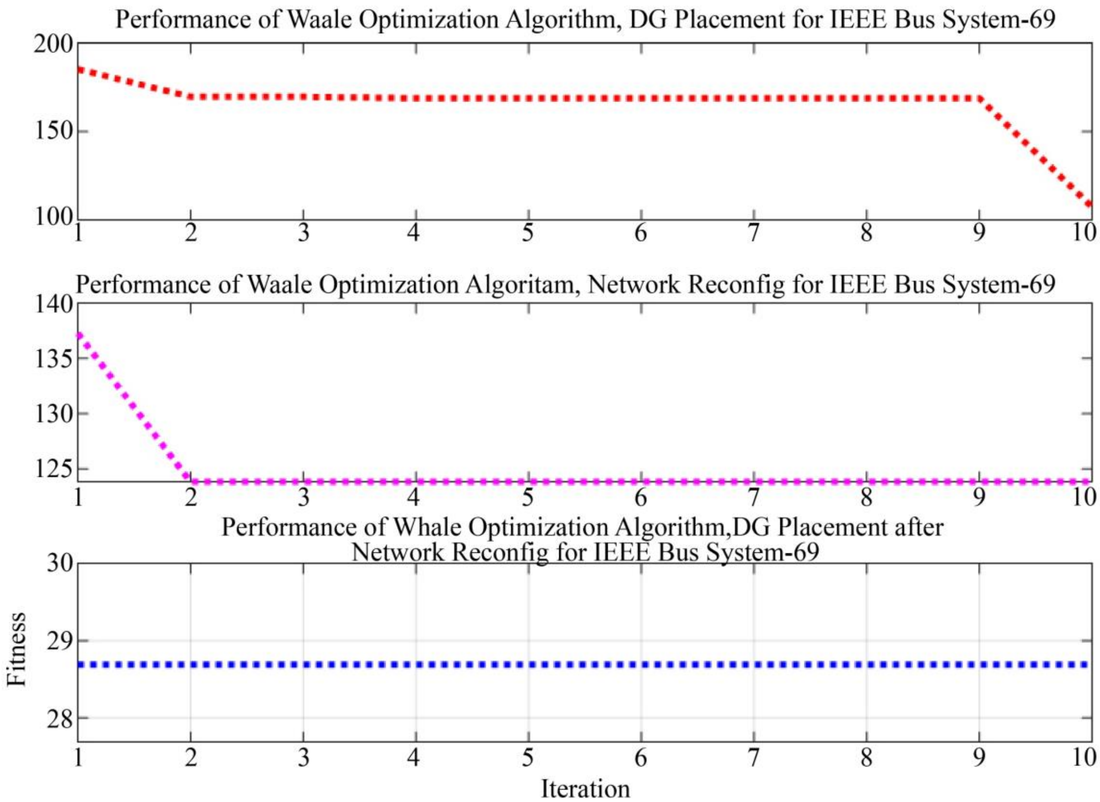

Fig. 14 Convergence performance of the proposed adaptive algorithm on IEEE-69 networks

Table 3. Data1 PDSE 2030

Number	Nodes	Arrival	Line -L	Type of line	Line capacity in F ∗ 10 –	Voltage in pu	Resistance of the line in pu (1) et (2)	Reactance of the line in pu (9)	Susceptance in S
1	1	6	50	SL	0.5956	0.49	0.0049	0.0029	0
2	1	5	238	ML	2.38	1.00	0.0231	0.0163	0.0008
3	8	19	201	ML	2.412	0.49	0.0195	0.0117	0.0008
4	15	5	38	SL	0.38	1.00	0.0039	0.0026	0
5	11	10	20	SL	0.2	1.00	0.0019	0.0014	0
6	10	9	30	SL	0.36	0.49	0.0029	0.0021	0
7	13	14	30	SL	0.36	0.40	0.0029	0.0017	0
8	14	4	155	ML	1.55	1.00	0.0150	0.0106	0.0005
9	3	4	11	SL	0.11	1.00	0.0011	0.0008	0
10	3	11	56	SL	0.56	1.00	0.0054	0.0038	0
11	9	8	180	ML	0.18	1.00	0.0175	0.0123	0.001
12	8	7	56	SL	0.56	1.00	0.0054	0.0038	0
13	8	18	42	SL	0.42	1.00	0.0041	0.0029	0
14	12	13	10	SL	0.1	1.00	0.0010	0.0007	0
15	2	7	50	SL	0.6	0.49	0.0049	0.0034	0
16	16	17	201	ML	2.412	0.4	0.0129	0.0138	0.0008
17	19	20	260	LL	3.12	0.4	0.0252	0.0178	0.001
18	3	14	220	ML	2.2	1.00	0.0214	0.0151	0.0007
19	8	9	180	ML	1.8	1.00	0.0175	0.0123	0.0006
20	2	19	50	SL	0.5	1.00	0.0005	0.0034	0

An identification of the results obtained in relation to the literature by making a direct comparison with them after analysis is developed in this section; similarly [12] obtains 63.4 KW of power losses for a percentage of 71.81% under the same operating conditions; finally in this work with three distributed generation poles we obtained losses of 28.68KW and a percentage of 21.96% and values of 40.31 KW in losses for two distributed generation poles; Table 5: Provides a positioning of the results obtained in relation to the literature by making a direct comparison with them; after analysis it should be noted that the results obtained in this work are the best than several results available in the literature;

Table 4 specifically presents the quantitative parameters of the different RIN–Cameroon buses for a better analysis of the performance of our algorithm in this article.

Table 4. Data 2 PDSE 2030

Number	Node	Arrival	Angle in radian (15)	Power at source start in MW	Reactive source power at the start in MVar	Active power of the load at the end of the line in MW	Reactive power of the load at the end of the line in Mvar
1	1	6	0	72	34.9	25.34	12.7
2	1	5	1.5708	0	0	0	0
3	8	19	1.5708	0	0	33.5	16.5
4	15	5	1.5708	0	0	32	16
5	11	10	1.5708	70	33.9	0	0
6	10	9	1.5708	84	40.68	0	0
7	13	14	1.5708	0	0	0	0
8	14	4	1.5708	145	70.22	16	9
9	3	4	1.5708	0	0	0	0
10	3	11	1.5708	60	29.06	0	0
11	9	8	1.5708	83	40.2	25.34	12.7
12	8	7	1.5708	0	0	25.34	12.7
13	8	18	1.5708	0	0	100	0
14	12	13	1.5708	29	14.05	45	22
15	2	7	1.5708	0	0	0	0
16	16	17	1.5708	0	0	33.5	16.5
17	19	20	1.5708	0	0	150	0
18	3	14	1.5708	0	0	0	0
19	8	9	1.5708	0	0	0	0
20	2	19	1.5708	0	0	0	0

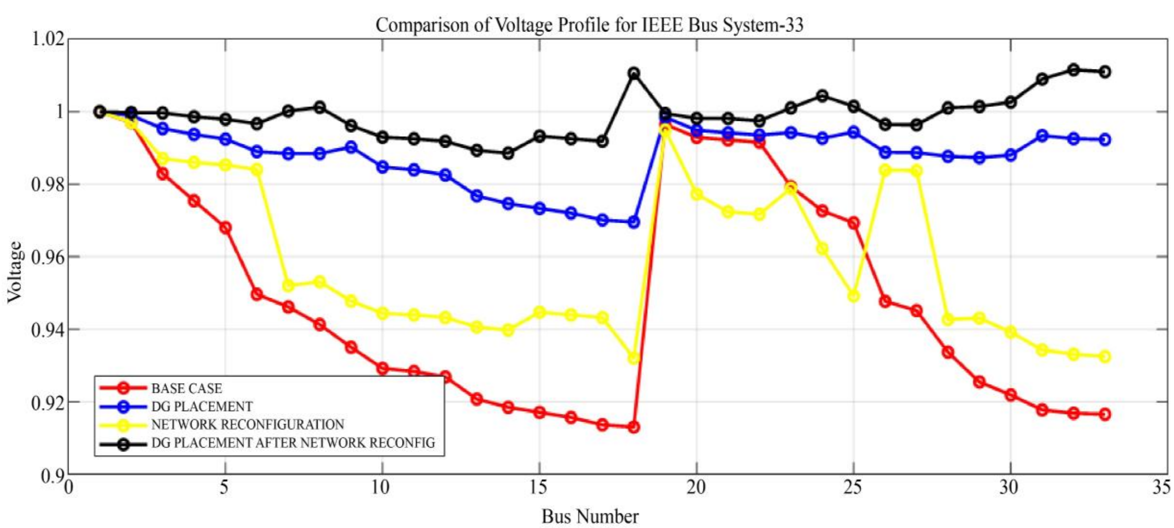

Fig. 15 Comparison of the voltage profile of IEEE-33 networks for operating modes

Table 5. Validations for IEEE-69 BUS

Placement	REF	DG installation Size (kVA/P.F)	nodes	Power-L Value (kW)	Percentage
1 DG	Without DG	-	-	224.94	-
	[10]	1900/1	61	83.31	62.96
	[2]	1794/1	61	83.42	62.91
	[15].	2000/1	61	83.8	62.74
	[2]	1873.32/1	61	83.22	63.01
	[20]	2300/1	61	89.4	60.3
	[17]	13378/1	61	83.8	62.74
	[16]	18196/1	61	83.323	62.95
	[12]	840.5/1	64	63.4	71.81
	In this work	2000/1	61	65.32	61
2 DG	[9]	1777/1 555/1	61 11	71.79	68.08
	[15].	600/1 2100/1	22 61	600/1 2100/1	66
	[2]	1781.2/1 530.5/1	61 17	71.67	68.11
	[15].	1000/1 2400/1	17 61	82.9	63.1
	[20]	700/1 2100/1	14 62	78.8	64.97
	[16]	519.71/1 1732/1	17 61	71.78	68.09
	[18]	538/1 1700/1	16 61	70.750	68.547
	[12]	1015/1 1015/1	63 64	43.98	80.45
	In this work	2000/1	61	40,31	45.70
3 DG	In this work	2000/1	62	28,6871	21,9682

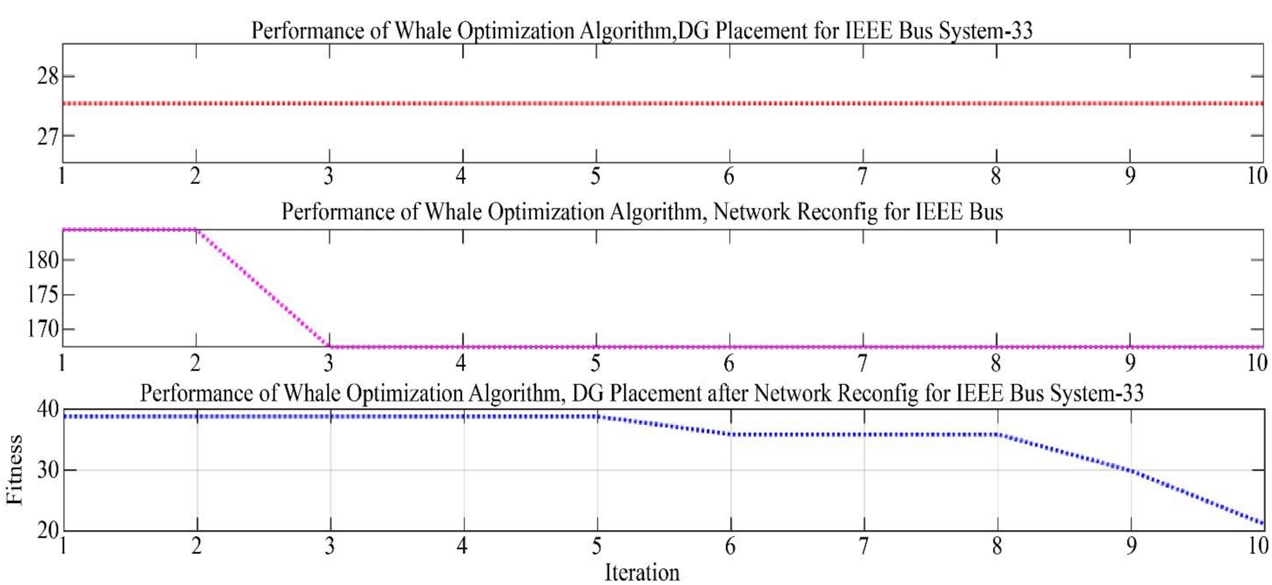

Fig. 16 Convergence performance of the proposed adaptive algorithm on IEEE-33 networks

4.2. IEEE-33 Network Results

Figures 15 and 16, respectively, present the comparison of the voltage profile of the IEEE-33 network and its convergence in the four scenarios or operating modes.

A positioning of the results obtained in this work on an IEEE-33 network in relation to the literature is carried out by making a direct comparison with them; after analysis, it should be noted that the results obtained in this work are better than several results available in the literature. Like [23], which obtained a loss of around 109.12 KW for a percentage of 48.28% with a Distributed Generation pole (DG); in the same logic, [12] obtained losses of 107.12 KW for a percentage of 49.23% and finally [22] obtained under the same conditions 47.38% for losses of 111.02 KW. And with three poles of generations distributed in this work with the same working conditions we obtain losses of 70KW with a percentage of 55%: Table 6 provides a positioning of the results obtained in this work on an IEEE-33 network in relation to the literature by making a direct comparison with them; after analyzing it should be noted that the results obtained in this work are better than several results available in the literature

4.3. RIN Results – Cameroon

Figure 17 represents the voltage profile of RIN-Cameroon before and after reconfiguration, and Table 7 offers a summary of the parameters or values before and after reconfiguration of the network.

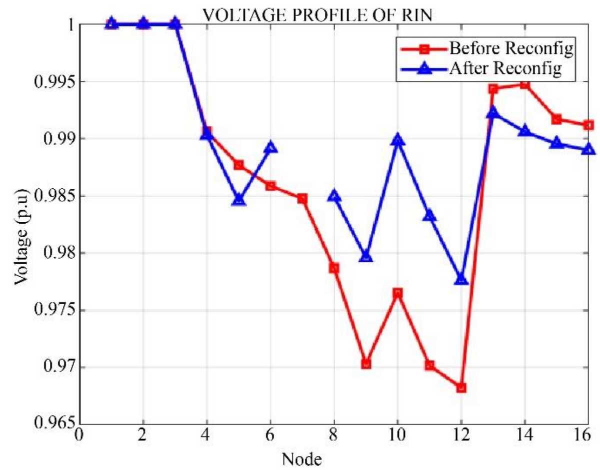

Fig. 17 Voltage estimation

Figure 18 represents the Distributed Generation (DG) in 3 poles respectively: nodes 4,8, and 16 with the aim of stabilizing the voltage profile of the RIN-Cameroon distribution network; by limiting power losses during network operation; this optimization in Distributed Generation (DG) placement.

Table 6. Validations for IEEE-33 BUS

placement	REF	DG installation		Power -L	
		Size (kVA/P.F)	Bus	Value (kW)	Percentage
	Without DG	-	-	211	-
1 DG	[23]	9700/1	7	109.12	48.28
	[1]	1190/1	30	116.7	44.69
	[22]	2590/1	6	111.02	47.38
	[3]	2590/1	6	111.03	47.37
	[12]	5020/1	7	107.12	49.23
	In this work	2000/1	6	98.69	40.51
2 DG	[1]	1013/1 612/1	30 14	96.9	54.08
	[22]	851.6/1 1157.5/1	13 30	87.17	58.69
	[6]	850/1 1160/1	13 30	87.17	58.68
	[12]	172/1 1050.4/1	14 62	76.4	63.79
3 DG	In this work	2000/1	30	70	55

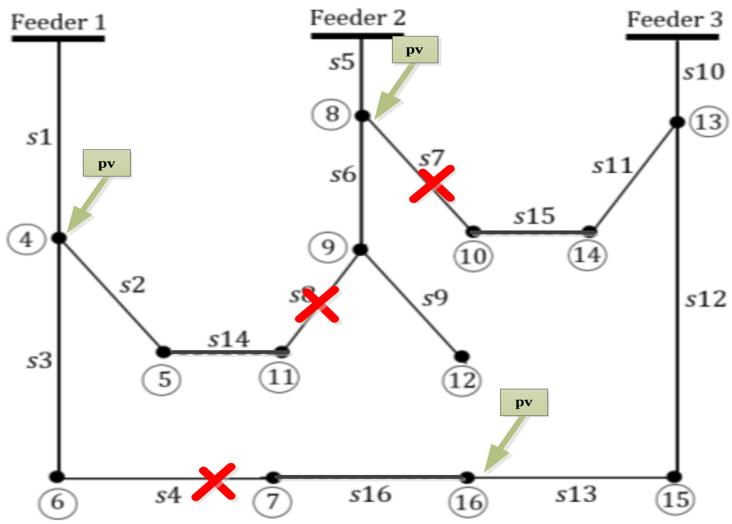

Fig. 18 RIN and reconfiguration

Table 7. Summary of the results of RIN-Cameroon before and after reconfiguration

Simulation Results		
	Before	After
Switches	14 15 16	4 8 16
Power loss	514.0293 kw	390.844 kw
Power loss reduction	-	23.9647
Minimum voltage	0.96824 pu	0.97762 pu
Elapsed time is 1.776475 seconds.		

Table 7 presents the particular case of RIN Cameroon with the metaheuristic algorithm inspired by the CUCKOO model; with a reduction in line losses of 23.9647 KW; and a variable voltage includes between 0.96824 pu and 0.97762 pu; with three generation points distributed at the level of nodes 4,8,16 after reconfiguration; These strategic results could also allow Cameroon to determine precisely where to build distributed or decentralized production plants with the aim of stabilizing the RIN network and optimizing its energy management; simulation time is 1.776475 seconds.

4.4. Discussion

The work of [17] develops the cukco model, which is also applied to an electrical network. However, in this model, the first step consists of using a set of available solutions to sort the best solutions in the second step. On the other hand, in our approach, the constraints linked to the variables of the objective function are immediately required and taken into account for the validation of a solution in the first step. This saves time and computing power by selecting only the optimal solutions according to the type of optimization in force. Moreover, after the transmission of the solutions, no initially selected solution is abandoned. It is just implemented in accordance with the convergence constraints of the parameters of the objective function, by evaluating the optimal path each time. This allows for better results and facilitates implementation when the network is very dense with several nodes. This approach is therefore fundamental in terms of the implementation principle compared to the work of [30], where the convergence speeds are not presented for a better analysis of the weaknesses of the implementation. However, in comparison with this article, the convergence speeds are clearly highlighted. Finally, in the work of [17], the authors record losses of 139KW for a density of 33 nodes and 98.58 KW for a density of 69 nodes. In comparison with the approach we propose, the losses are realized at 70KW for 33 nodes. And 28.6871 KW for 69 NODES, which also confirms a clear improvement in network management.

Finally, the mixture of operational decision and prevention or prediction becomes possible and also constitutes the novelty of the approach. Because taking an optimal decision or solution allows one to plan the future in the same space-time, this is a multi-objective approach. The success of this approach depends essentially on the behaviour of the variables of the objective function and their constraints.

On the other hand, this work is also an application of a real case, that of the interconnected network north of Cameroon (RIN) and will significantly contribute to the optimization of the national program of the electricity sector's horizon 2030 (PDSE 2030). It will offer political decision-makers a relevant evaluation tool for decisions that will produce sustainable development in the long term.

5. Conclusion

The objective of this work was to develop a metaheuristic algorithm inspired by the CUCKOO model for which the process of selecting the best solutions for successive iterations immediately integrates the convergence criteria (number of iterations, tolerance); the validation was done on the IEEE-33, IEEE-69 networks, and on the RIN (Northern Interconnected Networks) of Cameroon; the main contributions of this article were: (i) the development of an adaptive metaheuristic optimizer algorithm with fewer variables than other models and easier to implement with better performances; (ii) An analysis and a case study of the Northern Interconnected Networks (RIN) of Cameroon with permanent distributed production of PV systems in operating hypothesis with the aim of making recommendations for the optimization of Cameroon's energy policy by 2030; (iii) an analysis and positioning in relation to the current literature is carried out on the basis of certain performance criteria which offer a reduction in power losses of 23.9647%, for a minimum voltage of 0.97762 Pu; with a lost power of 514.0293 Kw before reconfiguration and 390.884KW after reconfiguration for a time of 1.776475 seconds.

The results obtained in this work will be able to optimize the objectives of the national program of the electricity sector in Cameroon by 2030 for the northern region by precisely designating the points requiring the construction of photovoltaic power plants but especially on how to balance the voltage profile and the powers available online during the flow. It is also a step forward for the optimization of multivariable systems having variables with constraints linked with a direct application on electrical networks for the sustainable development of the electrical energy sector. This study's prospects require considering additional scenarios for the intensities as a percentage of the power demanded by the loads during the operation of the line to control the function linking supply and demand optimally.

Acknowledgments

We are grateful to the Laboratory of Modeling Materials and Methods of the National Higher Polytechnics and the Department of Electrical Engineering, Higher Normal School of Technical Education (ENSET) University of Douala, for providing the necessary facilities and support.

Author Contributions

"The authors confirm contribution to the paper as follows: study conception and design: Leger Nguewa Chuembou; Felix Paune, data collection; analysis and interpretation of results; draft manuscript preparation: Luc Vivien Assiene Mouodo.

All authors reviewed the results and approved the final version of the manuscript".

Nomenclature/Abbreviations.

IEEE 33-bus: The Institute of Electrical and Electronics Engineering designed a test system with 33 Nodes.
IEEE 69-bus: The Institute of Electrical and Electronics Engineering designed a test system with 69 Nodes.
RIN: Northern Interconnected Networks
RIS: Northern Interconnected
DG: Distributed generation
PSO: Particle swarm optimization
PPSO: Pyramid particle swarm optimization method
EPSO: evolutionary particle swarm optimization
BPSO: Binary particle swarm optimization algorithm
HAS: Harmony Search Algorithm
PL: Power loss
P_{DG}: Generators' real power bounds
EP: Evolutionary Programming
SL: Short Line
ML: Medium Line
LL: Long Line

References

[1] Ketfi Nadhir, Djabali Chabane, and Bouktir Tarek "Firefly Algorithm for Optimal Allocation and Sizing of Distributed Generation in Radial Distribution System for Loss Minimization," *2013 International Conference on Control, Decision and Information Technologies (CoDIT)*, Hammamet, Tunisia, pp. 231-235, 2013. [CrossRef] [Google Scholar] [Publisher Link]

[2] Ayman Awad et al., "Developing a Hybrid Optimization Algorithm for Optimal Allocation of Renewable DGs in Distribution Network," *Clean Technologies*, vol. 3, no. 2, pp. 409-423, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[3] Ramadoni Syahputra, Indah Soesanti, and Mochamad Ashari, "Performance Enhancement of Distribution Network with DG Integration Using Modified PSO Algorithm," *Journal of Electrical Systems*, vol. 12, no. 1, 2016. [Google Scholar] [Publisher Link]

[4] Bipul Kumar Talukdar, "Electrical Distribution System (An Overview)," *International Journal of Advance Research and Innovative Ideas In Education*, vol. 5, no. 4, pp. 22-33, 2019. [Google Scholar] [Publisher Link]

[5] Rudresh B. Magadum, and Tejaswi M. Timsani, "Minimization of Power Loss in Distribution Networks by Different Techniques," *International Journal of Scientific & Engineering Research*, vol. 3, no. 5, pp. 1-5, 2012. [Google Scholar]

[6] A.V. Sudhakara Reddy, and M. Damodar Reddy, "Optimization of Network Reconfiguration by Using Particle Swarm Optimization," *2016 IEEE 1st International Conference on Power Electronics, Intelligent Control and Energy Systems (ICPEICES)*, Delhi, India, pp. 1-6, 2016. [CrossRef] [Google Scholar] [Publisher Link]

[7] Pedro Antmann, "*Reducing Technical and Non-Technical Losses in the Power Sector*," The World Bank Group, vol. 1, 2009. [Google Scholar] [Publisher Link]

[8] Kola Sampangi Sambaiah, and T. Jayabarathi "Optimal Modeling and Allocation of Mixed Wind and Solar Generation Systems in Electric Distribution Networks," *IETE Journal of Research*, vol. 68, no. 6, pp. 4129-4141, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[9] T.N. Shukla et al., "Optimal Sizing of Distributed Generation Placed on Radial Distribution Systems," *Electric Power Components and Systems*, vol. 38, no. 3, pp. 260-274, 2010. [CrossRef] [Google Scholar] [Publisher Link]

[10] Fahad S. Abu-Mouti, and M.E. El-Hawary, "Optimal Distributed Generation Allocation and Sizing in Distribution Systems via Artificial Bee Colony Algorithm," *IEEE Transactions on Power Delivery*, vol. 26, no. 4, pp. 2090-2101, 2011. [CrossRef] [Google Scholar] [Publisher Link]

[11] Ahmed Fathy et al., "Robust Approach Based Chimp Optimization Algorithm for Minimizing Power Loss of Electrical Distribution Networks via Allocating Distributed Generators," *Sustainable Energy Technologies and Assessments*, vol. 47, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[12] F. Fissou Amigue et al., "Optimal Integration of Photovoltaic Power into the Electricity Network using Slime Mould Algorithms: Application to the Interconnected Grid in North Cameroon," *Energy Reports*, vol. 7, pp. 6292-6307, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[13] Boyu Qin et al., "Impact of System Inherent Characteristics on Initial-Stage Short-Circuit Current of MMC-Based MTDC Transmission Systems," *IEEE Transactions on Power Systems*, vol. 37, no. 5, pp. 3913-3922, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[14] Hengyi Li et al., "Data-driven Optimal Scheduling for Underground Space based Integrated Hydrogen Energy System," *IET Renewable Power Generation*, vol. 16, no. 12, pp. 2521-2531, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[15] W.S. Tan et al., "Allocation and Sizing of DG using Cuckoo Search Algorithm," *2012 IEEE International Conference on Power and Energy (PECon)*, Kota Kinabalu, Malaysia, pp. 133-138, 2012. [CrossRef] [Google Scholar] [Publisher Link]

[16] Juan Andrés Martín García, and Antonio José Gil Mena, "Optimal Distributed Generation Location and Size Using a Modified Teaching–Learning based Optimization Algorithm," *International Journal of Electrical Power & Energy Systems*, vol. 50, pp. 65-75, 2013. [CrossRef] [Google Scholar] [Publisher Link]

[17] Thuan Thanh Nguyen, "Electric Distribution Network Reconfiguration for Power Loss Reduction based On Runner Root Algorithm," *International Journal of Electrical and Computer Engineering*, vol. 10, no. 5, pp. 5016-5024, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[18] A. Mohamed Imran, and M. Kowsalya, "A New Power System Reconfiguration Scheme for Power Loss Minimization and Voltage Profile Enhancement using Fireworks Algorithm," *International Journal of Electrical Power & Energy Systems*, vol. 62, pp. 312-322, 2014. [CrossRef] [Google Scholar] [Publisher Link]

[19] Ling Ai Wong et al., "Optimal Placement and Sizing of Battery Energy Storage System for Losses Reduction using Whale Optimization Algorithm," *Journal of Energy Storage*, vol. 26, 2019. [CrossRef] [Google Scholar] [Publisher Link]

[20] Jun Xiao et al., "Determination of the Optimal Installation Site and Capacity of Battery Energy Storage System in Distribution Network Integrated with Distributed Generation," *IET Generation, Transmission & Distribution*, vol. 10, no. 3, pp. 601-607, 2016. [CrossRef] [Google Scholar] [Publisher Link]

[21] Hao Xiao et al., "Bi-level Planning for Integrated Energy Systems Incorporating Demand Response and Energy Storage Under Uncertain Environments using Novel Metamodel," *CSEE Journal of Power and Energy Systems*, vol. 4, no. 2, pp. 155-167, 2018. [CrossRef] [Google Scholar] [Publisher Link]

[22] Anurag Das, and Laxmi Srivastava, "Optimal Placement and Sizing of Distributed Generation Units for Power Loss Reduction using Moth-Flame Optimization Algorithm," *2017 International Conference on Intelligent Computing, Instrumentation and Control Technologies (ICICICT)*, Kerala, India, pp. 1576-1581, 2017. [CrossRef] [Google Scholar] [Publisher Link]

[23] Fissou Filbert Amigue et al., "Optimal Placement and Sizing of Distributed Energy Generation in an Electrical Network using the Hybrid Algorithm of Bee Colonies and Newton Raphson," *Journal of Power and Energy Engineering*, vol. 8, no. 6, pp. 9-21, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[24] Dariush Shirmohammadi, and H. Wayne Hong, "Reconfiguration of Electric Distribution Networks for Resistive Line Loses Reduction," *IEEE Power Engineering Review*, vol. 9, no. 4, pp. 111-112, 1989. [CrossRef] [Google Scholar] [Publisher Link]

[25] Mostafa Sedighizadeh et al., "A New Optimal Operation Framework for Balanced Microgrids Considering Reconfiguration and Generation Scheduling Simultaneously," *International Transactions on Electrical Energy Systems*, vol. 30, no. 4, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[26] Antonio A.M. Raposo, Anselmo B. Rodrigues, and Maria da Guia da Silva, "Robust Meter Placement for State Estimation Considering Distribution Network Reconfiguration for Annual Energy Loss Reduction," *Electric Power Systems Research*, vol. 182, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[27] Y. Mohamed Shuaib, "Optimal Reconfiguration in Radial Distribution System using Gravitational Search Algorithm," *Electric Power Components and Systems*, vol. 42, no. 7, pp. 703-715, 2014. [CrossRef] [Google Scholar] [Publisher Link]

[28] Gholamreza Memarzadeh, Mohammadreza Arabzadeh, and Farshid Keynia, "A New Optimal Allocation of DGs in Distribution Networks by using Coot Bird Optimization Method," *Energy Informatics*, vol. 6, pp. 1-18, 20223. [CrossRef] [Google Scholar] [Publisher Link]

[29] Seyed Hasan Mirhoseini et al., "A New Improved Adaptive Imperialist Competitive Algorithm to Solve the Reconfiguration Problem of Distribution Systems for Loss Reduction and Voltage Profile Improvement," *International Journal of Electrical Power & Energy Systems*, vol. 55, pp. 128-143, 2014. [CrossRef] [Google Scholar] [Publisher Link]

[30] Thuan Thanh Nguyen, and Anh Viet Truong, "Distribution Network Reconfiguration for Power Loss Minimization and Voltage Profile Improvement using Cuckoo Search Algorithm," *International Journal of Electrical Power & Energy Systems*, vol. 68, pp. 233-242, 2015. [CrossRef] [Google Scholar] [Publisher Link]

[31] Neeraj Kanwar et al., "Simultaneous Allocation of Distributed Energy Resource using Improved Particle Swarm Optimization," *Applied Energy*, vol. 185, pp. 1684-1693, 2017. [CrossRef] [Google Scholar] [Publisher Link]