M Mosbah[1] / A Khattara[2] / M Becherif[3] / S. Arif[1]

Optimal PV Location Choice Considering Static and Dynamic Constraints

[1] LACoSERE Laboratory, Electrical Engineering Department, Amar Telidji University of Laghouat, Laghouat, Algeria, E-mail: mosbah.mustapha@gmail.com
[2] Laboratory of Energy Systems Modeling, University of Mohamed Kheider, Biskra, Algeria
[3] FCLAB Research Federation, FR CNRS 3539, FEMTO-ST/Energy Department, UMR CNRS 6174, University of Technology of Belfort-Montbeliard, 90010 Belfort Cedex, France

Abstract:
A new photovoltaic (PV) farm is proposed to be integrated in GHARDAIA bus distribution network (Gh-17 bus), this paper studies the optimal location of this PV farm in the distribution network. The study is done in IEEE-14 bus then it is validated in Gh-17 bus network, the constraints considered for the choice of the optimal location are the stability margin, power loss and critical clearing time (CCT) in case of line fault. The simulation results are given using the PSAT.

Keywords: critical clearing time, loading margin, optimal location, power loss, PV farm

DOI: 10.1515/ijeeps-2016-0141

1 Introduction

The electricity sector of most countries is constantly developing. Deregulation and privatization of the energy market have led to a complete restructuring of the electricity sector. The classic way is highly monopolized form in question. The opening of the market and technological development of means of production should be framed to meet the environmental requirements (*Kyoto Protocol*) and performance [1, 2]. A thought of more efficient means of production and bringing the production of consumption gives the idea of inserting Distributed Generation (DG) source at the power system to improve static and dynamic voltage stability standpoint network.Insertion of these sources needs to choose their location to optimize the operation of power system.

Many research works have been presented in literature those that clarifythe optimal insertion of DG sources in the power system [3].For example, the work cited in paper [4] describe multi-objective PSO based wind turbine generation unit and photovoltaic array placement, aim to reduce power loss and improvement voltage stability of radial distribution system. An hybrid method based on Tabu search and genetic algorithmshas been proposed in paper [5], in order to solve the model based simultaneous allocation of capacitor banks and DG source.A dynamic programming technique is used to determine the optimal location of DG, to improve the voltage stability and minimize network losses [6].

The DG influence on the bifurcation curve without considering reactive energy is discussed in reference [7].The voltage stability index changed by the influence of the DG size and their location using a nonlinear optimization technique to improve the voltage stability margin [8]. A multi-objective optimization of DG location and capacity is presented in [9] by minimizing the number of DG, power losses and maximizing the voltage stability margin. Reference [10] studies the photovoltaic introduction impact on voltage static stability in the distribution network using the continuation power flow method. The paper [11] presented the study of the introduction of more renewable energy sources, voltage stability, power losses and voltage profile, this problem is solving by multi-objective Pareto Frontier Differential Evolution (PFDE) algorithm. The work in [12] proposed a technique to determine the optimal configuration and optimal placement of DG in distribution network for reduction real power loss and voltage stability enhancement using cuckoo search algorithm.

The work [13] presented an approach which provides policy operator with a set of solutions for DG placement to optimize reliability and real power loss of the system. Another study proposed in [14] described the power forecast data method based wind turbine generators by considering wind power forecast error for optimal operation. In paper [15] presented a planning framework to find the sizes of minimum storage (power and energy) in several places in the distribution system to optimize of renewable distributed generation, specifically wind farms, while managing the congestion and voltage. In [16] proposed a new index to determine the

---

M Mosbah is the corresponding author.

optimal size and location of DG sources, in order to minimize active power losses and enhance voltage stability margin by considering the load variations.

An analytical approach in paper [17] has been used to optimize the size and location of solar photovoltaic, based on multiple location distributed generation in primary distribution system. The main aim of this paper includes power loss reduction and voltage profile improvement along with economic benefits. Another effective technique is proposed in [18] for optimal allocation of solar based distributed generation in the distribution power system by a Bat algorithm (BA), the objective functions is to power loss reduction of radial distribution system. A technique witch named Quasi-Oppositional Swine Influenza Model Based Optimization with Quarantine (QOSIMBO-Q) presented in [19] to solve a multi-objective function for optimal allocation and sizing of DGs in distribution systems. An efficient analytical (EA) method is proposed in paper [20] to optimize the installation of multiple distributed generations to reduce the power loss in distribution systems. A novel multi-objective function has been used in research [21] to determine the optimal sizing and placement of DGs using genetic algorithm and particle swarm optimization technique. A review paper [22] has presented certain methods that applied in optimum DG placement problem, which can aid the energy planners in deciding which objective and planning factors need more attention for optimum DG placement for a given location or in a given scenario.

Renewable energies are represented as the most desired modern sources, where solar energy is one of the major and most dominant in Algeria, namely photovoltaic solar panels that receive extended interest on their use, where multiple projects have been bet by Algerian energy Ministry, among of their objectives are 30 % of national production will be from renewable sources in 2030 [23, 24]. Different source types are interested in this program: solar thermal, solar photovoltaic, wind, geothermal and biomass. Algerian power system will profit from solar photovoltaic about 1,168 MW in 2020, while 20 MW will be injected into distribution network of GHARDAIA state [25, 26].

Our contribution will optimize the PV farm location, by considering static and dynamic constraints, the PV farm chosen is integrated in different buses of distribution part of IEEE-14 bus network, by considering stability margin, power losses and critical clearing time, in case of line fault witch given after each PV integration, and the optimal location, according to each obtained constraint, thus the optimal PV location considering all constraints cited is given. Finally the calculation method is validated in the choice of optimal PV farm in GHARDAIA distribution network (Gh-17 bus) considering the same static and dynamic constraints. In this work we have used a mathematical approximation to resolve the multi-objective problem. The simulation results obtained using PSAT *(Power System Analysis Toolbox)*.

2 Problem formulation

This work studies the optimal location of a PV source in the distribution network using the power flow calculation, considering static and dynamic voltage stability.

2.1 Power flow analysis

The power flow analysis may be stated with some precisions. The formulation is based on mathematical and operational consideration of the power industry [27].

$$\begin{cases} P_i = \sum_{k=1}^{n} |V_i||V_k|\,(Gik\cos\theta ik + Bik\sin\theta ik) \\ Q_i = \sum_{k=1}^{n} |V_i||V_k|\,(Gik\sin\theta ik - Bik\cos\theta ik) \end{cases} \tag{1}$$

V_i, V_k, are voltage magnitude of bus i and k respectively, the G_{ik} is conductance, B_{ik} is susceptance, and θ_{ik} is the argument.

$$S_{ik} \leq S_{ikmax} \text{ for } i, k = 1 \ldots \ldots nl \tag{2}$$

$$P_{imin} \leq P_i \leq P_{imax} \text{ for } i = 1 \ldots \ldots ng \tag{3}$$

$$V_{imin} \leq V_i \leq V_{imax} \text{ for } i = 1 \ldots \ldots n \tag{4}$$

$$\sum_{i=1}^{ng} P_i - D - L = 0 \tag{5}$$

Where S_{ik} is apparent power flow of the line between buses i and j, D is the load demanded and L presents the transmission losses. P_{imin} and P_{imax} are the minimum and maximum generation output of i^{th} generator respectively, nl total number of lines, ng total number of generators and n is the number of network buses.

2.2 Objective function

The aim subject of this work is to seek the optimal PV location in a distribution network respecting the constraints of power flow equations and considering the static and dynamic voltage stability. In this work, three objective functions are considered:

2.2.1 Maximizing loading margin

Loading margin (λ) is the indication the most used in statique voltage stability evaluation, it's the distance between actual operating point and the point that causes the voltage collaps [28]. In this study we use continuation power flow to avaluate static behavior of the voltage. The main aime of this function is to maximize voltage stability margin by optimizing system variables. This function is formulated by the following eq. (7):

$$f_1 = Max\lambda \tag{6}$$

2.2.2 Minimizing active and reactive power losses

It presents the minimizing of active and reactive losses in the lines. The mathematical formulation of the objective function is expressed by eq. 7):

$$f_2 = \min \sum_{\text{j=1}}^{\text{j=nl}} (\sqrt{r_j^2 + x_j^2})\, i_j^2 \tag{7}$$

Where r_j and x_j are the line resistance and reactance respectively, i_j is the current flow in j^{th} line,

2.2.3 –Maximizing *critical clearing time*

The Critical Clearing Time (*CCT*) of removal fault is the maximum time t_c during fault which can last without compromising the system ability of equilibrium return. This time determined by the study of network dynamics during the transitional period. Another objective of *CCT* parameter is to determine protection devices time response during contingency. In this case, we use the Time Domain Simulation (TDS) method to evaluate voltage dynamic behavior. The main purpose of the objective function is to maximize the *CCT*. The mathematical formulation of this objective is expressed by eq. 8):

$$f_3 = MaxCCT \tag{8}$$

To take in consideration the three objective functions (7), (8) and (9), we have called a multi-objective optimiszation technic. In the litirature many thechnics have been proposed to resolve this function [28]. In this study we will use the weighted sum method.

The three objectives are weighted by coefficiens w_1, $w_{2,}$ et w_3, and sum to obtain a scaled mesure of each individual adaptation. The multi-objective mathematic formula is writen as folow:

$$F = \min(w_1(\sum_{\text{j=1}}^{\text{j=nl}} (\sqrt{r_j^2 + x_j^2})\, i_j^2) + w_2/\lambda + w_3/CCT) \tag{9}$$

Where w_1, w_2 and w_3 are three constants determined using a prior knowledge about the problem, these weights are fixed by the constraint of $\sum_1^3 w_i = 1$ and $w_i \varepsilon [0, 1]$ [28, 29].It should be noted that, $(\max \lambda)$ and $(\max CCT)$ are replaced in (10) by $(\min 1/\lambda)$ and $(\min 1/CCT)$ respectively.

3 Methods and simulation tools

In the present work, we have choosen PSAT (*Power System Analysis Toolbox)* as simulation tool developped under Matlab. PSAT is a software, simple, interesting, that include many research domains in the study and power system analysis. It can execute the following static and dynamic functions: PF function, OPF, CPF, SSSA and TDS functions [30]. In order to evaluate voltage static and dynamic behavior, we have two methods, such us, CPF method to determine loading margin (λ), and TDS method to determine critical clearing time (*CCT*) for fault ellimination.

3.1 Continuation power flow method

Voltage stability analyse is based on the voltage bifurcation curve (voltage collaps curve or PV curve). The tracing of those curves is based on continuous power flow method (*CPF*) implemented in PSAT software.

3.2 Time domain simulation method

Time domain simulation method is implemented by solving the state space differential equations of power system and then determines the *CCT*.

4 Characteristic of test network

The networks chosen in this work are the IEEE-14 bus and the Gh-17 bus (60 kV distribution network of GHARDAIA), the first is used to study the problem and the second is chosen to validate them. The Gh-17 bus network is located in the south of Algeria, this network is fed by a source of 240 MVA, with a step-down transformer of 220/60 kV.

The networks are modeled using the PSAT, the IEEE-14 bus network is generally known. The Figure 1 shows the GH-17 bus network topology, and its data are as follows: 17 buses, 10 lines, 8 transformers and 7 loads.

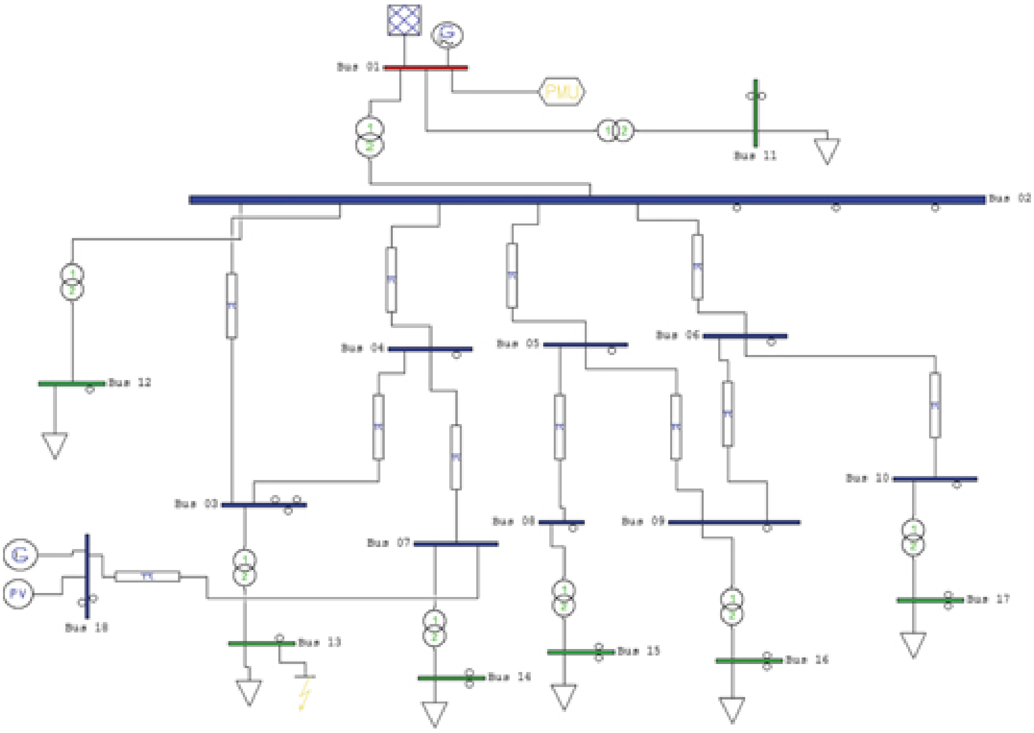

Figure 1: Gh-17 bus distribution network.

5 Simulation results

The study is done using IEEE-14 bus then applied in Gh-17 bus network. A PV farm of 20 MW is integrated in different bus of distribution part of cited networks, the loss, the stability margin λ and the critical clearing time during line fault are obtained after each integration. The type faults applied for this work are the three phases on ground ($z_f = 0$), where z_f is the impedance fault. The simulation results are given using PSAT.

Each PV integration to the power system is gone by the following steps.

Step 1- Initialize parameter. Input power system parameters and PV farm. **Step 2**- Select buses for PV locations, **Step 3**- PV integration in bus_i, **Step 4**- Run load flow, and calculate power loss (S_i), **Step 5**- Run continuation power flow routine, and calculate loading margin (λ_i), **Step 6**- Applied a line fault (three-phase short-circuit and grounded), **Step 7**- Run time domain simulation routine, and calculate critical clearing time (cct_i), **Step 8**- If the i=N go to step 9, if not return to step 3, **Step 9**- Calculate of multi-objective function (9 using mathematical approximation, **Step 10**- Give the optimal PV location.

The flow chart of optimal PV location is presented in Figure 2.

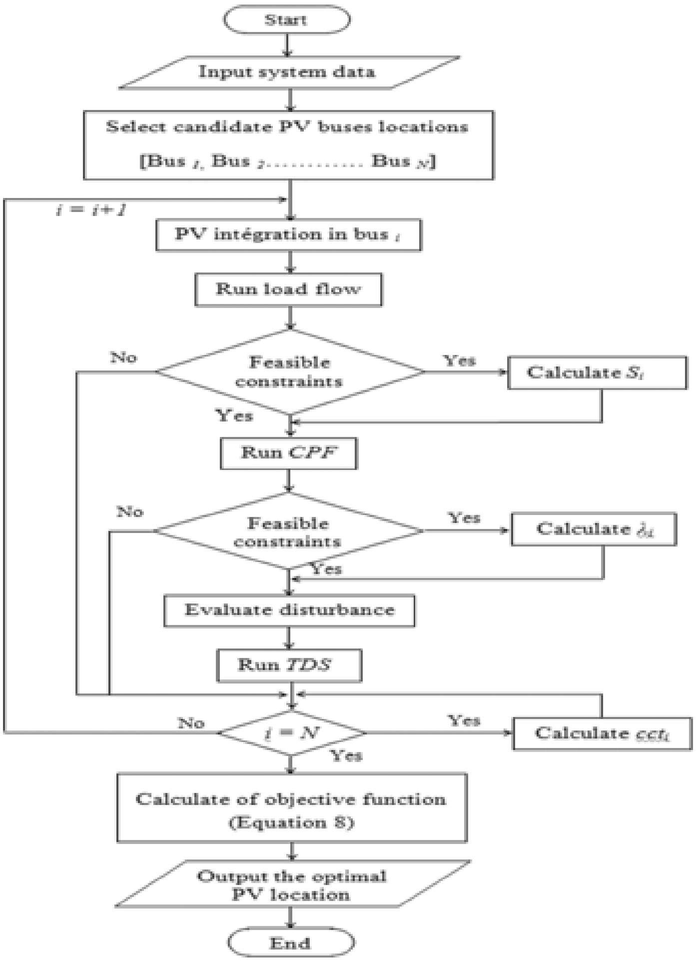

Figure 2: Flow chart of optimal PV location.

PV integration in IEEE-14 bus The PV farm of 20 MW is integrated in different buses of distribution part and the Table 1 summarizes the results. The faultis applied on bus 14.

Table 1: Sumulation results of IEEE-14 bus.

Bus	λ(pu)	Losses (pu) P	 Q	 S	CCT (s)
No PV	1.719	0.295	0.919	0.965	0.1
6	1.914	0.854	1.678	1.883	0.4
7	1.943	1.749	6.939	7.156	1.6
8	1.690	1.239	2.364	2.669	0.3
9	1.975	0.266	0.766	0.811	0.4
10	1.934	1.785	6.840	7.069	0.9
11	1.896	1.680	6.444	6.660	1.2
12	1.858	1.657	6.350	6.562	1.2
13	1.903	1.719	6.630	6.849	0.2
14	1.9001	1.695	6.478	6.696	NI

In the case PV installation in bus 14, we have noticed that the system is always steady, and whatever the duration of the contingency.

The results give that the optimal PV location according to the maximum stability margin and the minimum losses is the bus 9 where λ=1.975 and S_{loss}=0.811 pu respectively, but the optimal PV location according to the maximum CCT is the bus 7 where t=1.6 s, so the question is what is the optimal PV location according to all constraints cited above.

The Figure 3 shows the optimal location of PV farm for each constraint.

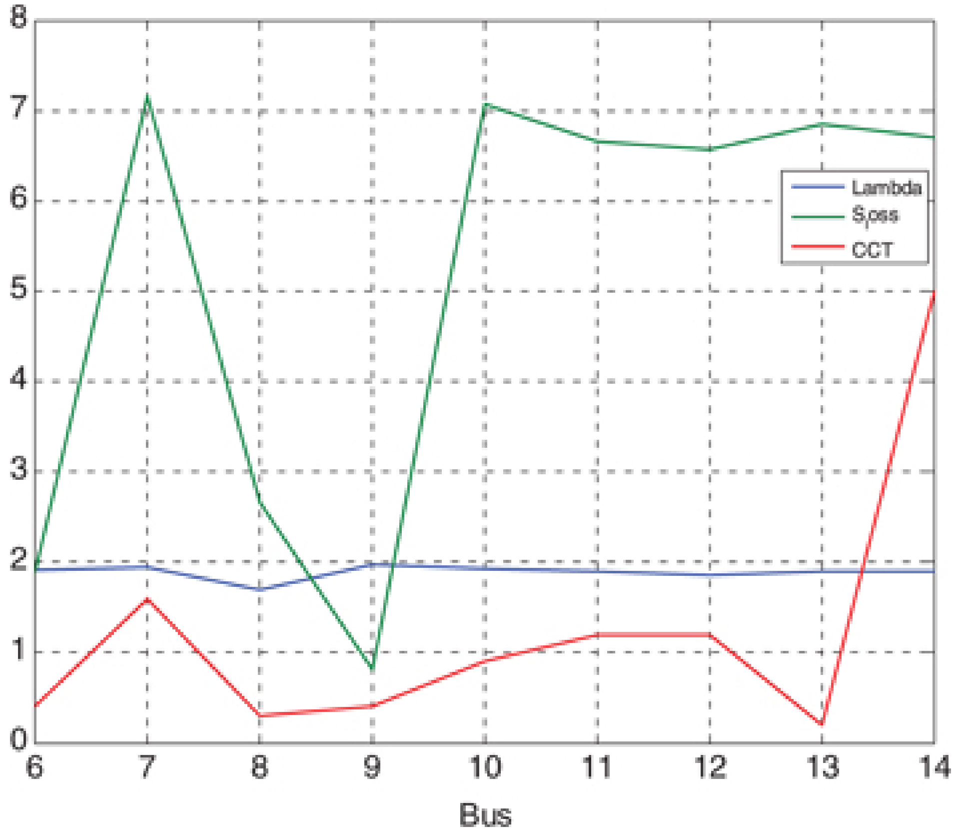

Figure 3: Optimal PV location for each constraint.

A new program is developed using eq. 9 to calculate the optimal PV location according to maximum stability margin, minimum power losses and maximum *CCT*.

The Figure 4 shows the optimal PV farm location in respect to all constraints cited above.

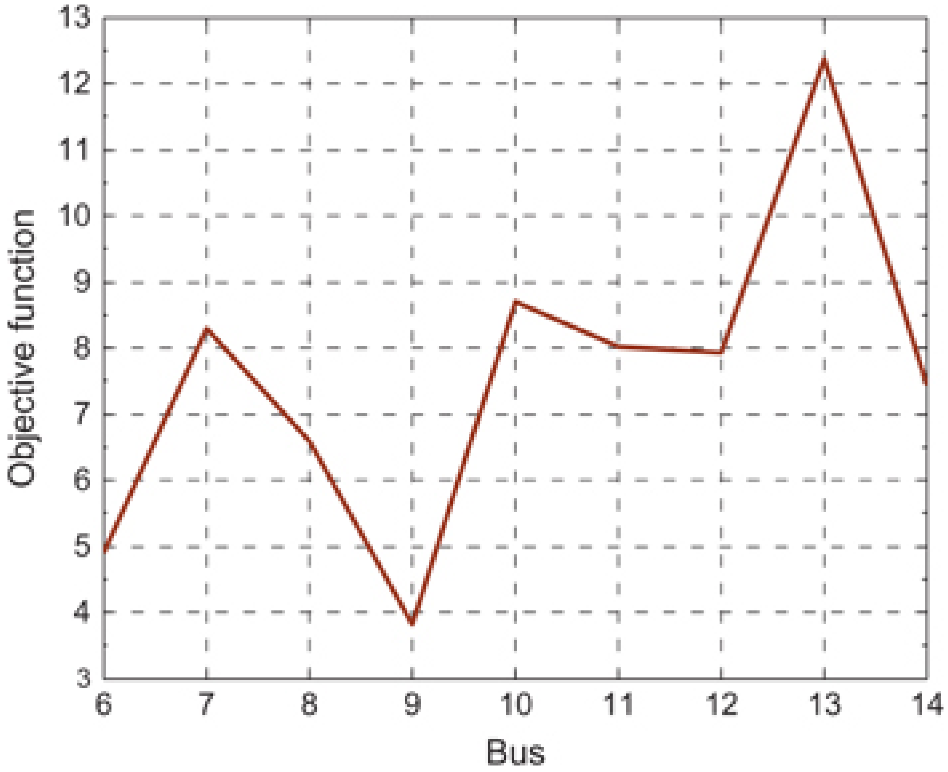

Figure 4: Optimal PV farm location.

In the case where weighted factors are considered have the same value w_1=w_2=w_3=1/3, optimal PV farm location is in bus 9, indicated by Figure 4.

PV integration in Gh-17 bus The PV farm of 20 MW is integrated in buses of distribution part and the Table 2 summarizes the results.

Table 2: Sumulation results of Gh-17 bus.

Bus	λ (pu)	Losses (pu) P	 Q	 S	CCT (s)
No PV	1.335	0.035	0.218	0.220	0.7
2	1.660	0.113	0.348	0.366	1.99
3	1.637	0.019	0.163	0.164	0.5
4	1.684	0.029	0.197	0.199	3.1
5	1.654	0.068	0.288	0.296	3.1
6	1.584	0.040	0.230	0.234	3
7	1.552	0.029	0.194	0.197	5
8	1.377	0.034	0.213	0.216	1.6
9	1.586	0.039	0.228	0.232	2.9
10	1.445	0.036	0.218	0.221	1.87

The results give that the optimal PV location according to the maximum stability margin is the bus 4 where λ=1.684 and according to the minimum losses is bus 3 where S_{loss}=0.164 pu respectively, but the optimal PV location according to the maximum CCT is the bus 7 where t=5 s, so the question is what is the optimal PV location according to all constraints cited above.

Figure 5 shows the optimal PV farm location for each constraint.

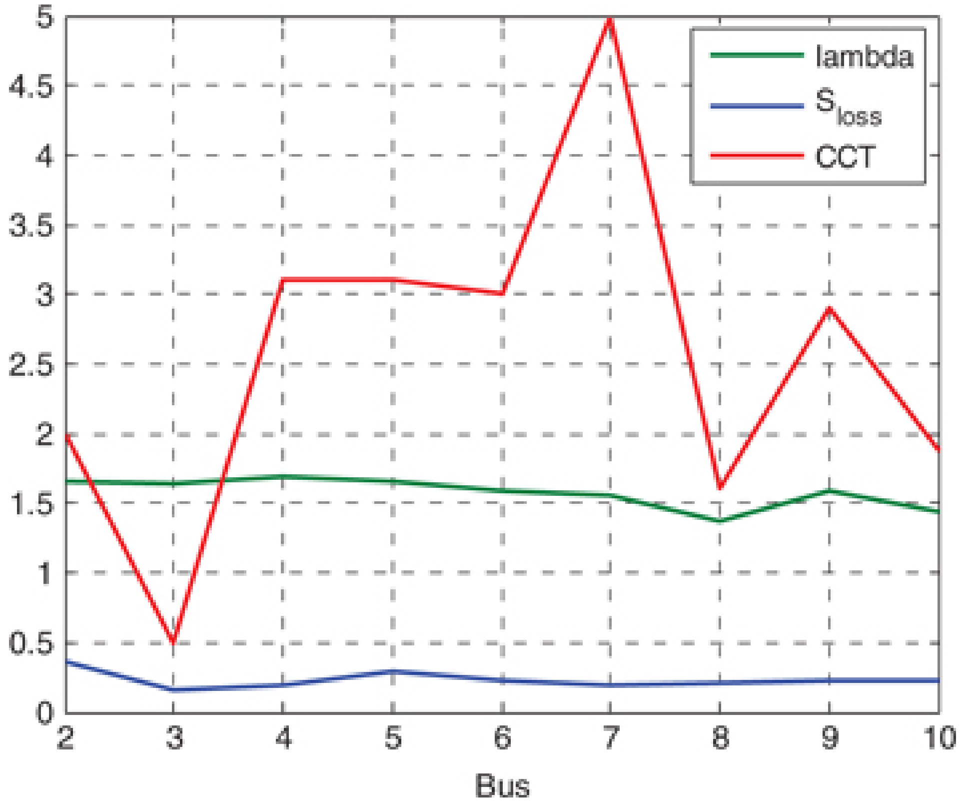

Figure 5: Optimal PV location in Gh-17 bus for each constraint.

A new program is developed using eq. 9 to calculate the optimal PV location according to maximum stability margin, minimum power loss and maximum CCT.

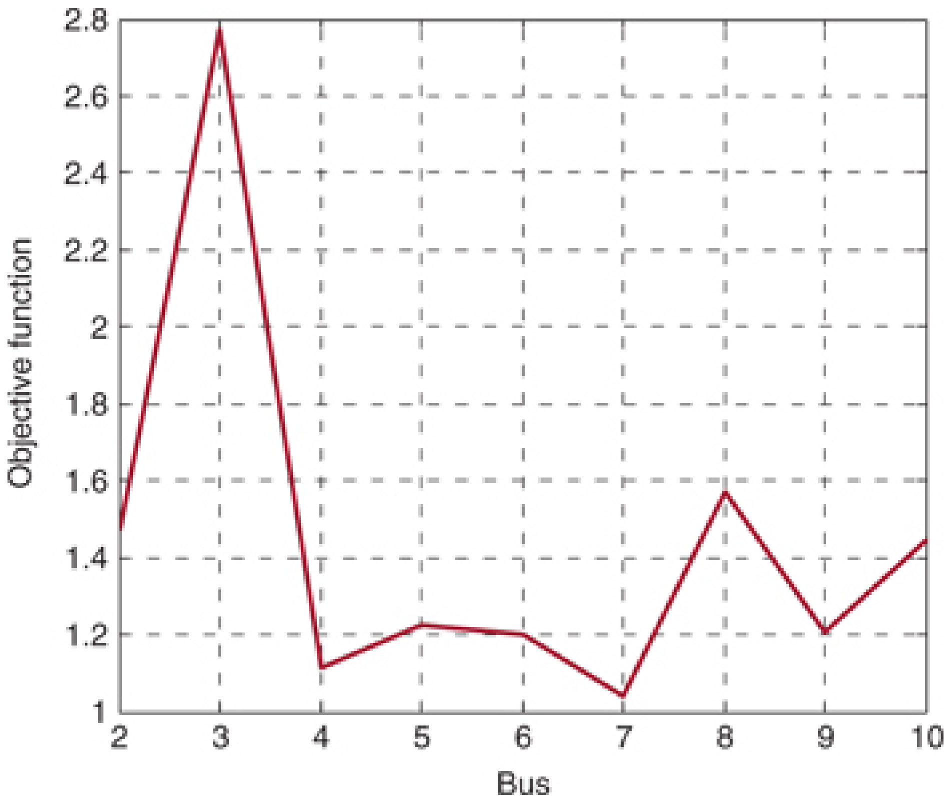

Figure 6: Optimal PV farm location.

In the case where weighted factors are considered have the same value w_1=w_2=w_3=1/3, optimal placement of PV form is in the bus 7.

It convince to mention that fault clearing time interval is between 100 and 150 ms, and which considered as values to be not exceed in Algerian 60 kV network systems [31]. For that, the optimal weighted factors are: w_1=0.4, w_2=0.4, w_3=0.2, thus the optimal PV location is in bus 4.

Table 3 presents the set of simulation results obtained for mono-objective and multi-objective cases. Table 4 presents upper and lower limits of different parameters system.

Table 3: Sumulation results the single and multi-objective of 14-bus and Gh-17 bus.

System	Variables	Variables		Without PV	With PV Single objective			Multi-objective
		Min	Max	Parameters	Max (λ)	Min loss	Max CCT	
14 bus	PV location	**	**	**	Bus 9	Bus 9	Bus 7	Bus 9
	Active losses (pu)	**	**	0.29464	0.266	0.266	1.749	0.266
	Reactive losses (pu)	**	**	0.91909	0.766	0.766	6.939	0.766
	Apparent losses (pu)	**	**	0.965	0.811	0.811	7.156	0.811
	Loading parameter λ (pu)	**	**	1.7188	1.975	1.975	1.943	1.975
	CCT (s)	**	**	0.1	0.4	0.4	1.6	0.4
Gh-17 bus	PV location	**	**	**	bus 4	bus 3	bus 7	bus 7
	Active losses (pu)	**	**	0.035	0.029	0.019	0.029	0.029

Reactive losses (pu)	**	**	0.218	0.197	0.163	0.194	0.194
Apparent losses (pu)	**	**	0.220	0.199	0.164	0.197	0.197
Loading parameter λ (pu)	**	**	1.335	1.684	1.637	1.552	1.552
CCT (s)	**	**	1.5	3.1	0.5	5	5

Table 4: Upper and lower limits of different parameters system 14-bus and Gh-17 bus.

System	Generator	P_{min}(pu)	P_{max}(pu)	Q_{min}(pu)	Q_{max}(pu)	V_{min}(pu)	V_{max}(pu)
14 bus	G 1	0	3.324	-9.9	9.9	0.8	1.2
	G 2	0	1.4	-0.4	0.5	0.8	1.2
	G 3	0	0	-0.06	0.24	0.8	1.2
	G 4	0	0	0	0.4	0.8	1.2
	G 5	0	0	-0.06	0.24	0.8	1.2
Gh-17 bus	G 1	0	2.4	-0.6	0.6	0.95	1.05

5.1 Before PV integration in IEEE-14 bus network

The IEEE-14 bus network is modeled and simulated before PV integration, the voltages in different buses are obtained, a line fault is applied on the bus 14.

The dynamic simulation results give that the critical clearing time for the IEEE-14 bus network before PV integration is 100 ms.

The Figure 7 shows the voltage before PV integration.

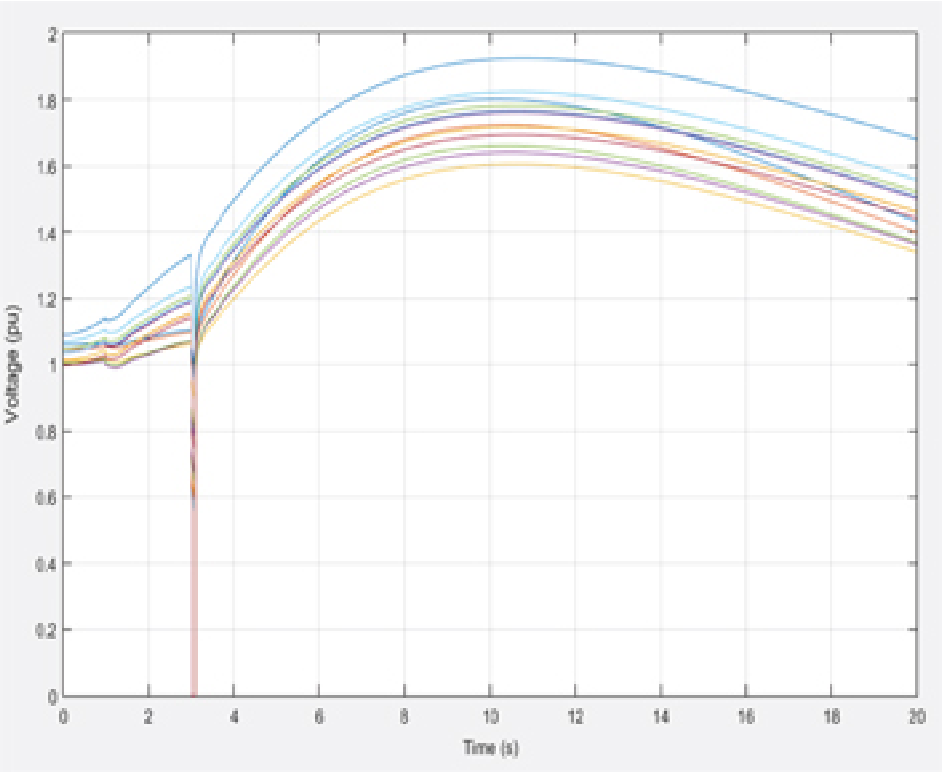

Figure 7: Bus voltage before PV integration in 14 bus.

5.2 After PV integration in IEEE-14 bus network

A PV farm is integrated in the IEEE-14 network, and the same line fault considered in previous part is applied on the network and in the same location.

The simulation results give that the critical clearing time for the IEEE-14 bus network after PV integration in optimal location (bus 9) is 400 ms.

The Figure 8 shows the voltage after PV integration.

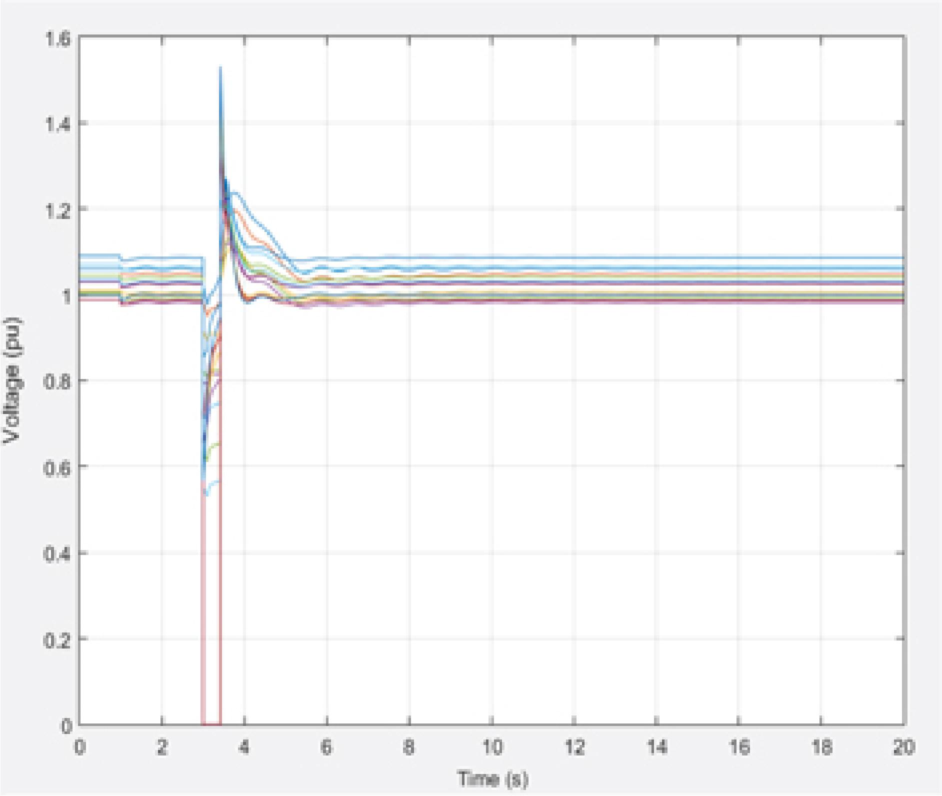

Figure 8: Bus voltage after PV integration in 14 bus.

5.3 Before PV integration in Gh-17 bus network

The simulation results gives that the critical clearing time for the 17-Gh bus network before PV integration is 700 ms.

The Figure 9 shows the voltage before PV integration.

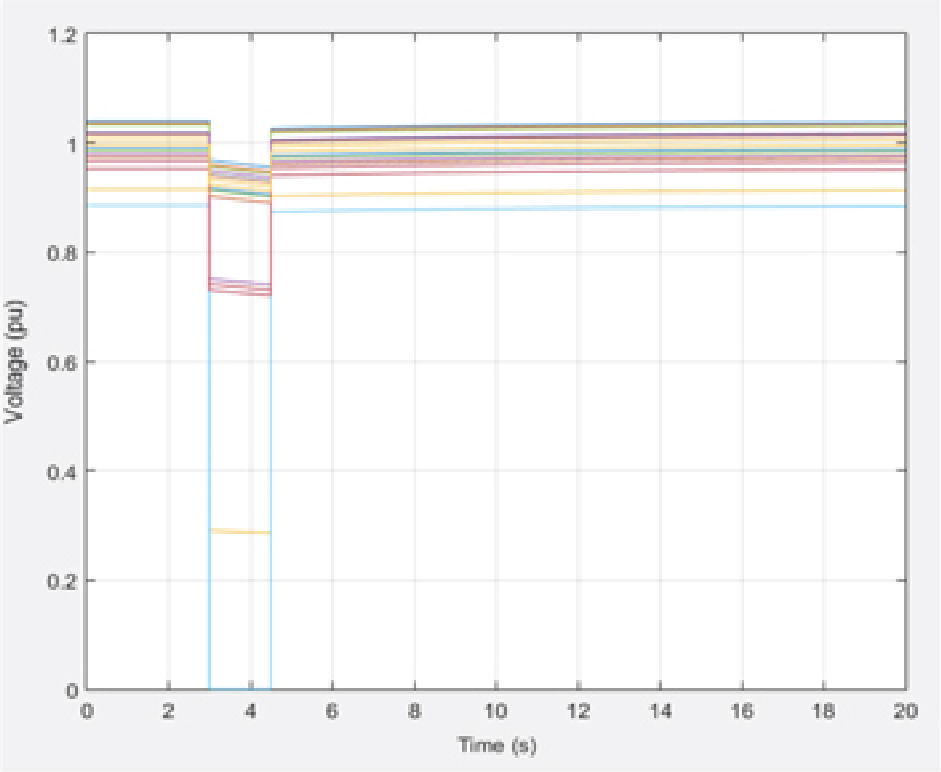

Figure 9: Bus voltage before PV integration in Gh-17 bus.

5.4 After PV integration in in Gh-17 bus network

The simulation results give that the critical clearing time for the 17-Gh bus network after PV integration in optimal location (bus 4) is 3100 ms.

The Figure 10 shows the voltage before after PV integration.

.

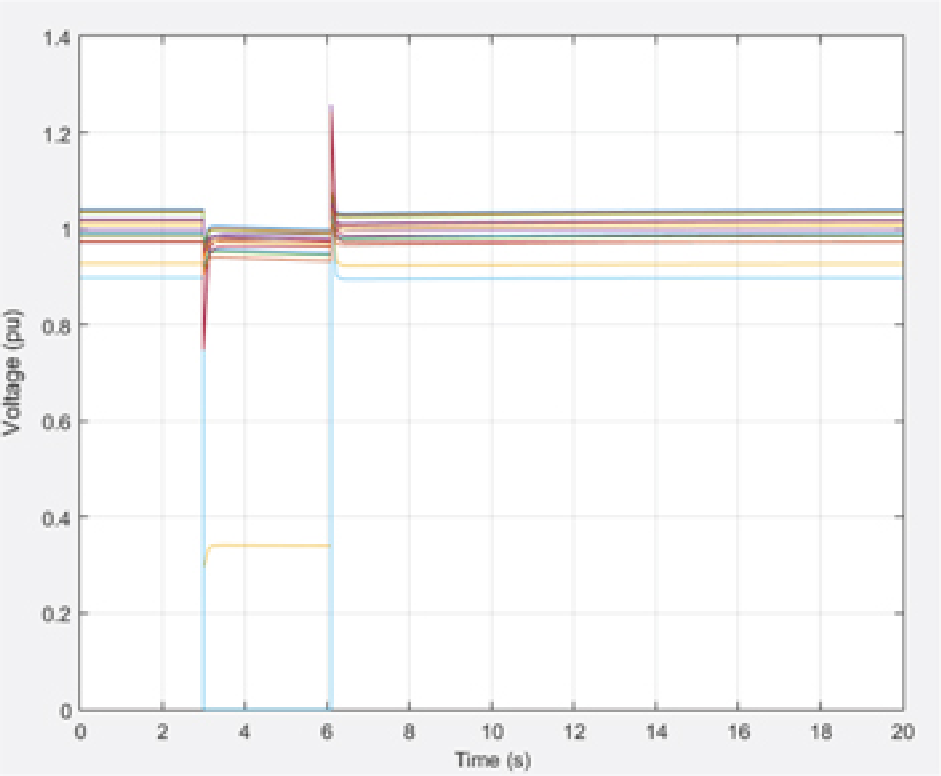

Figure 10: Bus voltage after PV integration in Gh-17 bus.

The simulation results of 17-Gh bus network shows that the integration of PV farm changes some network characteristics.

6 Conclusion

In this paper, a simple approach based on the aggregation of static (losses and static stability margin) and dynamic (critical clearing time of a contingency) constraints for the PV farm optimal location in a distribution network has been validated on IEEE 14 bus system model. Then, an application on a real network of GHARDAIA southern Algeria (Gh-17 bus) was conducted. The *CPF* technique for static voltage behavior evaluation to determine the loading margin is used. For evaluate the dynamic voltage and determine the *CCT* parameter the *TDS* method is used. According to the analysis, the integration of PV farm affects behavior static and dynamic voltage. The problem of choosing PV location was discussed, as well as their influence on active and reactive power losses. The proposed multi-objective optimization based on weighted sum method that has been solved by a mathematical approximation.

The obtained results using PSAT are very satisfactory and extremely encouraging.

In the perspective of this work, the use of optimization methods can lead to a better optimization of network operation.

References

1. Nanda G, Yamgar S, Srivastava SC, Singh SN, Gupta P, Paul D, Shrestha Ram M. Implications of carbon tax on generation expansion plan & GHG emission: a case study on Indian power sector. Int J Emerg Electr Power Syst 2005;3(1):Article 1045.
2. Varabuntoonvit V, Sadamichi Y, Kato S, Mungcharoen T. Life cycle inventory data development for greenhouse gas emissions of Thailand's electricity grid generation systems. Int J Emerg Electr Power Syst 2008;9(1):Article 6.
3. Georgilakis PS, Hatziargyriou ND. Optimal distributed generation placement in power distribution networks: models, methods, and future research. IEEE Trans Power Syst 2013;28:3420–3428.
4. Kayal P, Chanda CK. Placement of wind and solar based DGs in distribution system for power loss minimization and voltage stability improvement. Electr Power Energy Syst 2013;53:795–809.
5. Pereira BR, Martins da Costa GRM, Contreras J, Mantovani JRS. Optimal distributed generation and reactive power allocation in electrical distribution systems. IEEE Trans Sustainable Energy 2016;7:975–984.
6. Murty VV. Optimal placement of DG in radial distribution systems based on new voltage stability index under load growth. Electr Power Energy Syst 2013;53:450–467.
7. Hedayati H, Nabaviniaki SA, Akbarimajd A. A method for placement of DG units in distribution networks. IEEE Trans Power Delivery 2008;23:1620–1628.
8. Al Abri RS, El-Saadany Ehab F, Atwa YM. Optimal placement and sizing method to improve the voltage stability margin in a distribution system using distributed generation. IEEE Trans Power Syst 2013;28:326–334.
9. Esmaili M, et al. Placement of minimum distributed generation units observing power losses and voltage stability with network constraints. IET Gener Transm Distrib 2013;7:813–821.
10. Aly MM, Abdel-Akher M, Ziadi Z, Senjyu T. Assessment of reactive power contribution of photovoltaic energy systems on voltage profile and stability of distribution systems. Int J Electr Power Energy Syst 2014;61:665–672.
11. Moradi MH, Reza Tousi SM, Abedini M. Multi-objective PFDE algorithm for solving the optimal siting and sizing problem of multiple DG sources. Int J Electr Power Energy Syst 2014;56:117–126.
12. Nguyen TT, Truong AV, Phung TA. A novel method based on adaptive cuckoo search for optimal network reconfiguration and distributed generation allocation in distribution network. Int J Electr Power Energy Syst 2016;78:801–815.
13. Battu NR, Abhyankar AR, Senroy N. DG planning with amalgamation of operational and reliability considerations. Int J Emerg Electr Power Syst 2016;17:131–141.
14. Ogimi K, Kamiyama S, Palmer M, Yona A, Senju T, Funabashi T. Optimal operation planning of wind farm installed BESS using wind power forecast data of wind turbine generators considering forecast error. Int J Emerg Electr Power Syst 2013;14:207–218.
15. Douak M, Settou N. Estimation of hydrogen production using wind energy in Algeria. Energy Proc 2015;74:981–990.
16. Poornazaryan B, Karimyan P, Gharehpetian GB, Abedi M. Optimal allocation and sizing of DG units considering voltage stability, losses and load variations. Int J Electr Power Energy Syst 2016;79:42–52.
17. Majid J, Sharique AA. Optimal sizing and location of SPV (solar photovoltaic) based MLDG (multiple location distributed generator) in distribution system for loss reduction, voltage profile improvement with economical benefits. Energy 2016;103:231–239.
18. Sudabattula SK, Kowsalya M. Optimal allocation of solar based distributed generators in distribution system using Bat algorithm. Perspect Sci 2016;8:270–272.
19. Sharma S, Bhattacharjee S, Bhattacharya A. Quasi-Oppositional Swine Influenza Model Based Optimization with Quarantine for optimal allocation of DG in radial distribution network. Electr Power Energy Syst 2016;74:348–373.

20. Mahmoud K, Yorino N, Ahmed A. Optimal distributed generation allocation in distribution systems for loss minimization. IEEE Trans Power Syst 2016;31:960–969.
21. Bohre AK, Agnihotri G, Dubey M. Optimal sizing and sitting of DG with load models using soft computing techniques in practical distribution system. IET Gener Transm Distrib 2016;10:2606–2621.
22. Sultana U, Khairuddin AB, Aman MM, Mokhtar AS, Zareen N. A review of optimum DG placement based on minimization of power losses and voltage stability enhancement of distribution system. Renewable Sustainable Energy Rev 2016;63:363–378.
23. Alnaser SW. Optimal sizing and control of energy storage in wind power-rich distribution networks. IEEE Trans Power Syst 2016;31:2004–2013.
24. Sonelgaz Group Company. Ministry of Energy and Mines. Renewable energy and energy efficiency program. 2013 Available at: http//www. mem-algeria.org.
25. Saidur R, Islam MR, Rahim NA, Solangi KH. A review on global wind energy policy. Renewable Sustainable Energy Rev 2010;14:1744–1762.
26. Mosbah M, Kobbi M. Introduction of the renewable energy and SDC Experience. 1st Conference of Heads of Districts Engineers Electrical Company of Distribution Electricity and the Gas Centre, Blida Technical School, 2015.
27. Miranda V, Hang PS. Economic dispatch model with fuzzy wind constraints and attitudes of dispatchers. IEEE Trans Power Syst 2005;20:2143–2145.
28. Mosbah M, Hellal A, Mohammedi RD, Arif S. Genetic algorithms based optimal load shedding with transient stability constraints. 2014 International Conference on Electrical Sciences and Technologies in Maghreb (CISTEM) 2014;1–6.
29. Mohammedi RD, Hellal A, Arif S, Mosbah M. Optimal DG placement and sizing in radial distribution systems using NSGA-II for power loss minimization and voltage stability enhancement. Int Rev Electr Eng 2013;8:1806.
30. Milano F. PSAT Version 1.3.4 © 2002–2005. Software and documentation 2005 http://thunderbox.uwaterloo.ca/ fmilano.
31. Electricity and Gas Algeria Company. Technical guide for protection of Algerian power systems. Electr Tech Dir 2006.