The impact of Naama's 12 MW Solar Project on the Algerian Southwestern Electricity Network

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ABSTRACT

In order to achieve a sustainable future and renewable energy targets, Algeria has launched special projects for clean energy, such as the Hassi Rmel solar thermal-gas hybrid power plant, the Kaberten wind farm in Adrar, and several small photovoltaic power plants. Besides, others are planned including, the Naama PV plant. The aim of this paper, is to present the impact of the expected photovoltaic power plant at the province of Naama on the southwestern network of Algeria. We have justified the choice of the installation of the power plant in this province by a detailed analysis of the various data e.g, the solar irradiation, the geographical position and the topology of the electrical network. The obtained results indicate that the installation of this plant would have a positive impact on the system by losses active a reduction of 6.994 MW and improving the voltage profile.

I. Introduction

Renewable energy plays a progressively important role in the energy supply of the industrializing and developing countries. Developing a renewable and clean energy has become a one of the most important to mitigate global warming and develop the economy. Which was discussed profoundly in the sustainable development framework at the Johannesburg Earth Summit in 2002 [1]. Like all countries in the world, Algeria has a very high electricity demand around 15210 MW and 26626 MW by 2030 [2].

In fact, despite the increase in electricity generation capacity of 300% between 2000 and 2017, it is necessary to satisfy the remaining consumption by installing new power plants with an additional production potential of 17210 MW by 2027. Adding to hydrocarbon resources, Algeria has a strong potential for renewable energy that has been the ambition to develop for the electricity production. Additionally, the different electricity production sources from renewable energies are considered as the top priority for reasons of diversification of energy supply for Algeria, protection of the environment, economic and social cohesion [3].

In this perspective, Algeria has adopted a new strategy based on:

- Satisfaction of demand and securing energy supply in the long term.
- Preservation of fossil resources.
- Development of alternative sources of energy and adoption of an energy mix for the medium-long term.

- Algeria's international commitments in tackling environmental issues (climate change) and, more generally, promoting sustainable development.
- Availability of big potential solar.

The Algerian Ministry of Energy and Mines are paving the way for Algeria to become a dynamic leader in green energy through a law that was adopted in 2011 and revised in February 2015, Placed as a national priority, by the President of the Republic, at the Select Council of Ministers in February 2016; consists of the realization of a global capacity of 22 000 MW for the national market and the realization of this program will achieve a share of renewable nearly 27% in terms of production and 37% in terms of installed capacity to the 2030 horizon.

This law was concretized by a strategy for implementing a program that consists of:

- Creation of a filial dedicated to Renewable Energies and conventional power plants of the Greater South Networks (SKTM: Sharikat Kahraba Takat Moutadjadida).
- Acquisition of technologies through the implementation of pilot projects and "school" projects and search for strategic partnership (Ghardaia and Kabertane power stations, Hassi Rmel, etc.).
- Investment in the human potential: establishment of RnE (Renewable energy) programs in Sonelgaz technical schools, training in the framework of the realized projects.
- Partnership between universities and research centers / companies like REDC (Renewable Energy Development Centre), RCSTE (The Research Center in Semi-conductors Technology for Energetic), etc.

Several sites with high solar potential are identified by a study of the Energy Ministry in collaboration with national institutions, such as REDC, WCA (Weather Center of Algeria), and RCAAG (Research Center in Astronomy Astrophysics and Geophysics). Through 21 provinces, eligible for the installation of solar power plants PV (Photovoltaic) and CSP (Concentrator solar plant), among these sites, we find the Naama province.

The prsent study consists of the installation of a PV power plant at the Naama province and its integration into the southwest network of Algeria. Moreover, in this study, we start with the brief presentation about photovoltaic energy and the solar field in Algeria, then overview of the different renewable energy projects installed locally. In addition, detailed study on the criterion of the choice of the Naama region summarized by the geographical position, the solar field, and its electrical network, which allows the integration of this kind of power station.
At the end of this study, a simulation was performed by the software PSAT (section IV), completed by a part of the analysis discussion of the results. Conclusions are presented in section V.

II. Solar in Algeria

II.1. Solar potential in Algeria

All over the word including Algeria, direct solar radiation is considered one of the most promising sources of energy. Moreover, Algeria has one of the largest solar deposits of the world. It's for many international experts, a potential site for the production of solar energy capable of contributing significantly to the coverage of global electricity needs in the coming decades.

The annual solar radiation in Algeria can reach a potential of 2000 kWh/m2 /year, and reaches 3900 hours (highlands and Sahara), as indicated in figure 1. The daily energy received on a horizontal surface in the order of 5 kWh/m^2 over most of the national territory, nearly 1700 kWh/m^2 / year in the North and 2263 KWh/m^2/year in the South of the country see table.1 [13].

Table 1. Solar potential in Algeria [7]

Region	Costal	Highlands	Sahara
Area %	4	10	86
Average duration of sunshine (hour/day)	2560	3000	3500
Average energy received (Kwh/m2/year)	1700	1900	2650

Furthermore,A small comparison between solar and natural gas, the Algerian solar potential is equivalent to a 37000 billion cubic meters, more than 8 times the country's natural gas reserves [5], [6].

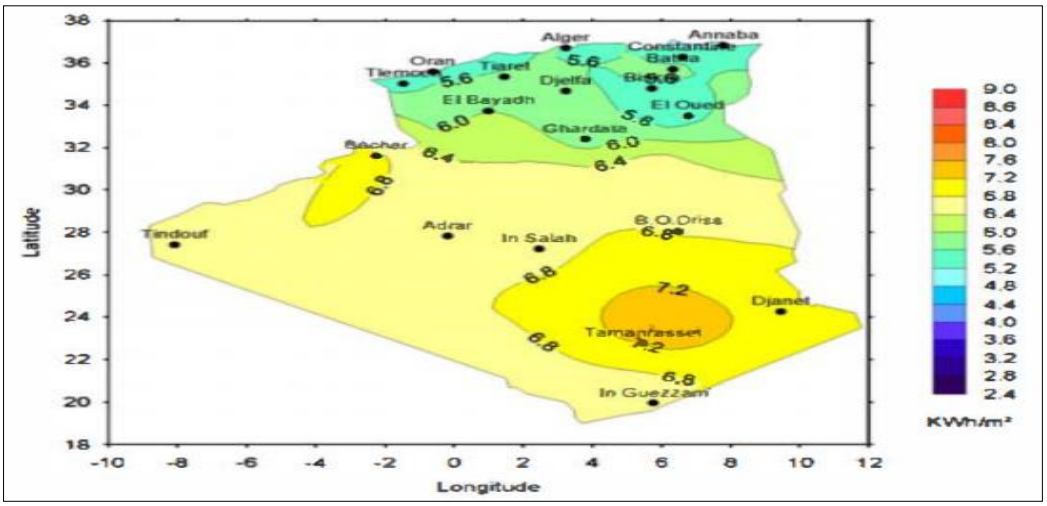

Figure 1. Mean annual global direct drradiation map (Period 2002-2011) [12].

II.2. Renewable energies program in Algeria

Through the national renewable energy integration program, Algeria intends to position itself as the major player in the production of electricity from the photovoltaic and wind sectors by integrating biomass, cogeneration, geothermal energy, and beyond 2021, solar thermal. These energy sectors will be the engines of sustainable economic development capable impel a new model of economic growth [7].
By 2030, 37% of installed capacity and 27% of electricity production for national consumption will be of renewable origin. Renewable Energy (RnE) projects for the production of electricity will be dedicated to the national market will be conducted in two stages:

- The first phase (2015-2020): This phase will see the realization of a power of 4000 MW, between photovoltaic and wind energy, as well as 500 MW, between biomass, cogeneration, and geothermal energy.
- The second phase (2021-2030): The development of the electrical interconnection between the North and the Sahara (Adrar). Will allow the installation of large renewable energy plants in the regions of In Salah, Adrar, Timimoun, and Béchar and their integration into the national energy system. By that time, solar thermal energy could be economically viable. The following table gives the cumulative capacities of the RnE program, by type and phase, over the period 2015 – 2030.

Table 1. RnE cumulative capacity, by type and phase

Installed power (MW)	1st phase 2015-2020	1nd phase 2021-2030	Total
Photovoltaic	3000	10750	13575
Wind	1010	4000	5010
Concentrator Solar	-	2000	2000
Cogeneration	150	250	400
Biomass	360	640	1000
Geothermal	5	10	15
Total	4525	17475	22000

III. Naama selection criterion

III.1. Geographical position

Naama is a province located in the center of the southwestern region, presents a crossroads position with the other provinces, 200 km from El bayadh, 200 km from Saida, and 300 km from Bechar. Also, bordering wilayas of Tlemcen and Sidi bel abbes, and in the border with Morocco see figure.2.

Figure 2. Location of Naama province [15].

III.2. Solar irradiation

This location is characterized by its solar potential, which is very favourable. See the figure and table below: [8]

Table 3. Annual average of the global irradiation received on a horizontal surface, 1992-2002 period

Sites	Atitude	SS0	Gh
Adrar	279	9.40	6020
Ain Sefra	1058	9.07	5868
Bechar	809	9.36	6096
El bayadh	1341	8.38	5576
Ghardaia	468	9.36	5892
Mecheria	1149	8.37	5460
Naama	1166	8.51	5555

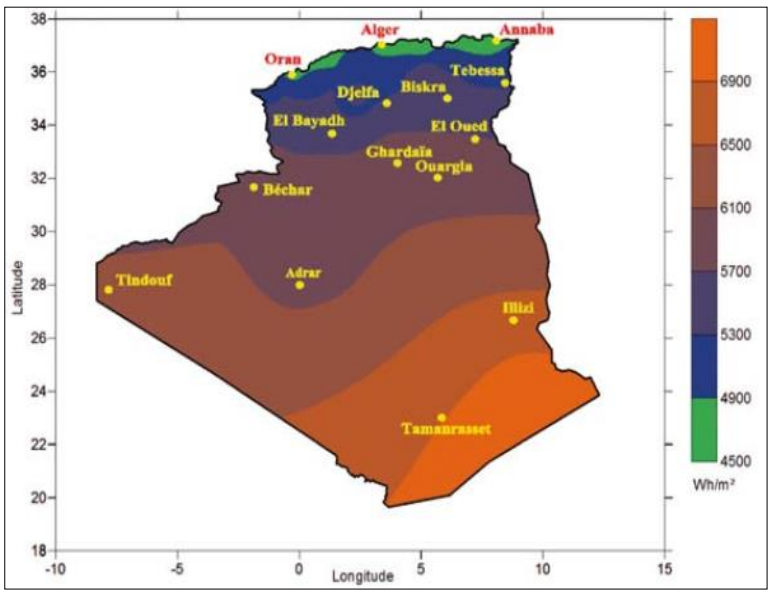

Figure 3. Annual average of the global irradiation received on a horizontal surface, 1992-2002 period [8].

According to the results published by the Centre for Development of Renewable Energy (CDRE) [8]- [14], we can conclude that the three points of the NAAMA region, which are Ain Safra, Mecheria, and Naama present close and favorable data for the installation of a photovoltaic power plant .

III.3. Topology of the electrical network

The province of Naama is connected to Saida province via a line 220 Kv with a length of 200Km, and connected to Bechar province via two lines, the first is a 220 kV line with 300 km length, and the second is a 400 kV line operated in 220 kV of the same distance. Another 60 Kv line that links Mecheria to El Biodh Sidi Sheikh and afterward Elbayadh province. Besides, this province has a natural gas power plant of 400 Mw, which is near the city of Mecheria [11].

Also, this province will be connected via two 400Kv lines that are in realization, the first connected to the Terga power plant via the Sidi Ali Boussidi substation, and the second line connected to Oued El Abtal to Mascara, as shown in Figure 4. In addition to all these electrical investments a new combined cycle power plant that is under construction with a capacity of 1163 MW, located in Touifza, not far from Naama, a carefully selected site to meet the criteria necessary for this kind of installations, including the proximity to the national road 6 and national road 22, as well as the railway [9], [10].

All these electrical investments make this province a favourable and targeted region for the integration of a photovoltaic power plant to cover not only the local demand but also satisfy the need of the neighbouring provinces and injecting the surplus of the electrical production through the 400Kv lines outside (the other provinces or the export abroad).

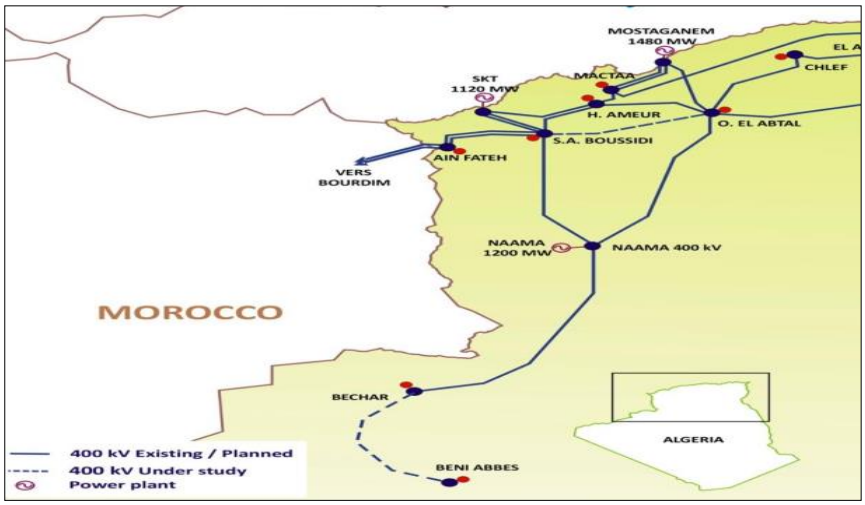

Figure 4. 400Kv power grid in western Algeria [4].

IV. Simulation and results

IV.1. Presentation of the southwest network of Algeria

In this study, the southwest network presented by (10) nodes, in which a 400 MW gas power plant located at Mecheria province of Naama, and the Saida province is supplied by three lines 220 Kv, one from Tiaret power plant and the other lines from Terga power plant via Sidi Ali Boussidi substation.

The Naama province is connected by three 220 Kv lines, two lines with Bechar province, and the other with the Saida province. El Bayadh province is powered by two lines 60 Kv, the first from the department of Saida and the second from Mecheria via Elbiodh Sidi Chikh. Finally, Ain Sefra is powered by a line 60 Kv from Naama.

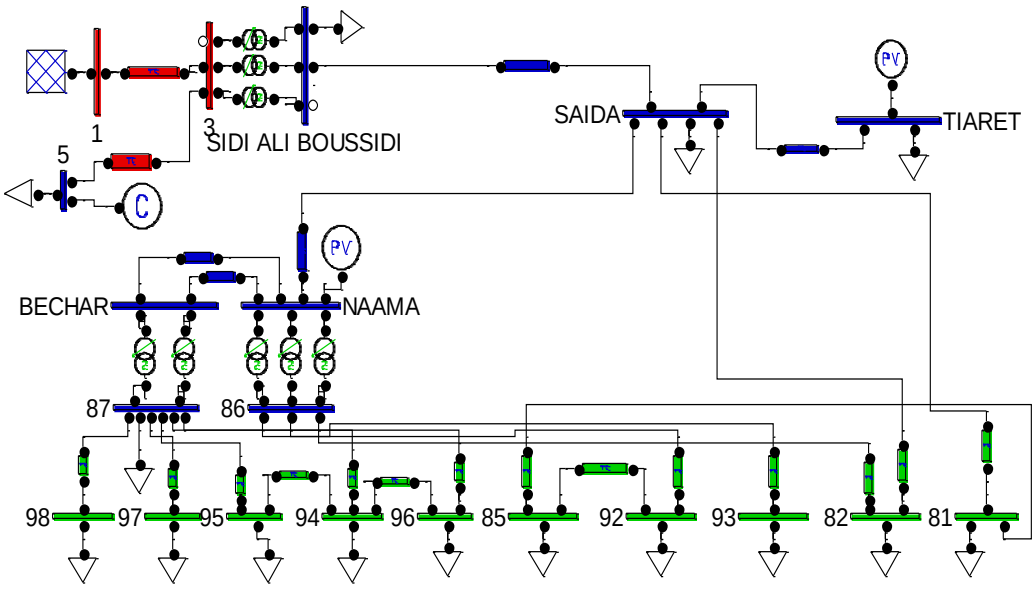

Figure 5. Southwest Algerian network without PV plant insertion.

IV.2. Simulation

The simulations are carried out using the Power System Analysis Toolbox (PSAT), which is a Matlab toolbox for electric power system analysis and simulation, After inserted the Southwest Algerian network into the PSAT software as shown in the figure.5, we simulate to calculate the power flow, we choose Newton Raphson's method (set in the parameters of this software) with an uncertainty of 10-3, The power flow converged after ten (10) iterations. The tables below show the results obtained.

Table 4. The power without insertion

	Active power (MW)
Total production	542.95
Total load	516.22
Total losses	26.734

Table 5. Nodal voltages without insertion

Nodes	Voltage (pu)
Terga 400Kv	1.025
Sidi Ali Boussidi 220kV	1.025
Sidi Ali Boussidi 400kV	1.0223
Saida 220kV	1.0301
Naama 220kV	1.00
Naama 60kV	1.0301
Bechar 220kV	1.0228
Bechar 60kV	1.042
Bechar1 60kV	0.99528
Bechar2 60kV	1.0003
Bechar3 60kV	1.0101
El Bayadh 60kV	1.0045
El Biodh Sidi Chikh 60kV	0.67535
Bogtob 60kV	1.0237
Mecheria 60kV	0.60444
Beni Ounif 60kV	1.0076
Ain Safra 60kV	1.0075

IV.3. Problematic of the southwest Algerian network

From the results of the power flow obtained previously, we can deduce the following observations:

1. The network has a problem with a slight voltage drop at the following nodes: El Biodh Sidi Chikh 60Kv and Mecheria 60Kv.
2. The network suffers from the losses active power problem, which reaches up to 26.734Mw, which represents 4.92% of the total production above the acceptable norm.

To benefit from solar weather conditions in the Naama region, we propose to install a photovoltaic plant of 12 MW in Mecheria, Naama, and Ain Safra, and comparing the results to choose the optimal location.

IV.4. The insertion of the PV plant at Naama, Mecheria or Ain Safra

The calculations of the power flow after the insertion of the photovoltaic power plant at the node of Mecheria, Naama, or Ain Safra. As shown in Figure 6, are shown in the tables below.
Table 6 below shows the different powers of the Southwest Algerian network with the insertion of the PV plant in Mecheria, Naama, or Ain Safra.

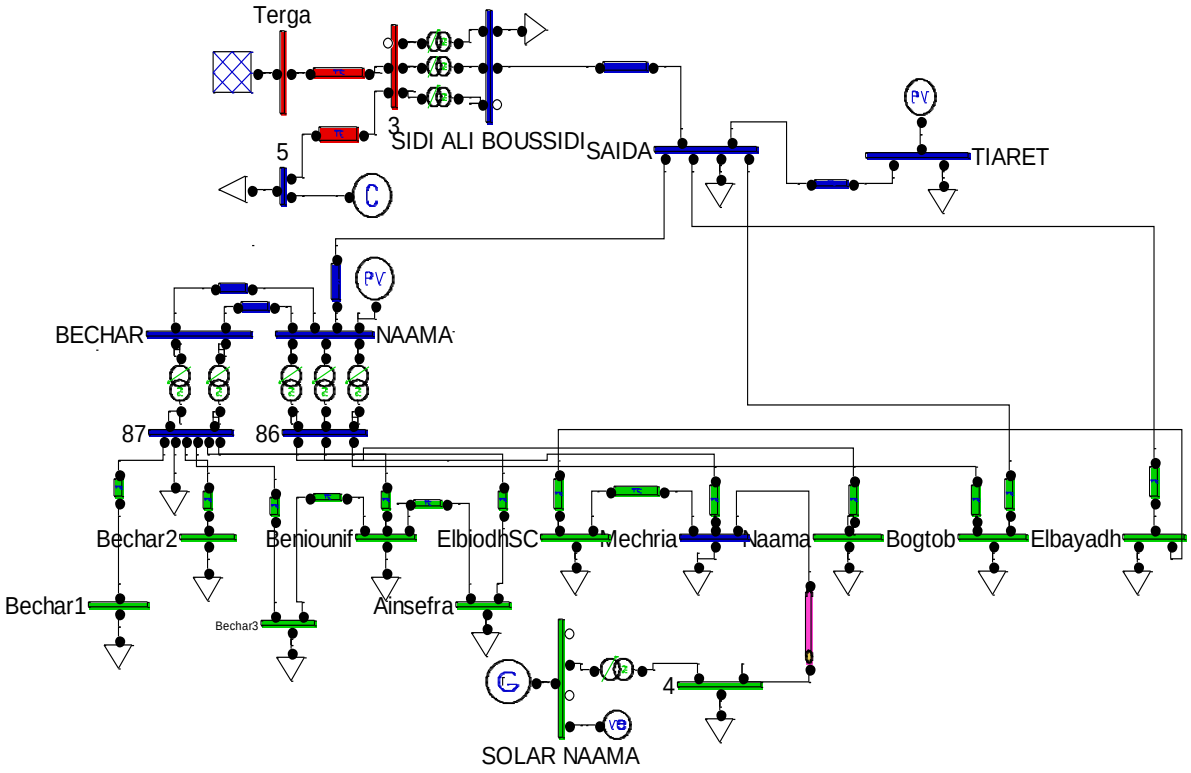

Figure 6. Southwest Algerian network with PV plant insertion at Naama.

Table 6. The powers after insertion of the PV plant at Mecheria, Naama or Ain Safra

Active power (MW)	Mecheria	Naama	Ain Safra
Total fossil production	527.989	533.36	530.713
Solar PV plant production	08.071	09.08	11.267
Total load	516.32	516.32	516.32
Total losses	19.74	26.12	13.66

Table 7 below presents the different nodal voltages of the Southwest Algerian network with the insertion of the PV plant in Mecheria, Naama, or Ain Safra.

Table 7. Nodal voltages without insertion

Nodes	Mecheria	Naama	Ain Safra
Terga 400Kv	1.025	1.025	1.025
Sidi Ali Boussidi 220kV	1.0626	1.0624	4.0625
Sidi Ali Boussidi 400kV	1.0226	1.0224	1.0224
Saida 220kV	1.0301	1.0308	1.0309
Naama 220kV	1.00	1.00	1.00
Naama 60kV	1.0308	1.0302	1.0302
Bechar 220kV	1.0228	1.0228	1.0202
Bechar 60kV	1.0228	1.0142	1.0106
Bechar1 60kV	0.99528	0.99528	0.99162
Bechar2 60kV	1.0003	1.0003	0.99662
Bechar3 60kV	1.0101	1.0101	1.0061
El Bayadh 60kV	1.0181	1.0053	1.0055
El Biodh Sidi Chikh 60kV	0.87125	0.67895	0.67952
Bogtob 60kV	1.0259	1.0246	1.0248
Mecheria 60kV	0.89849	0.60981	0.61063
Beni Ounif 60kV	1.0076	1.0076	1.0015
Ain Safra 60kV	1.0075	1.0075	1.0007

IV.5. Results and interpretation

According to the results obtained in Tables 8 and 9. The ideal location for the installation of the photovoltaic power plant is that of Mecheria. We noticed that the total losses of the system decreased from 26.734 MW to 19.74 MW, i.e. a reduction of 6.994 MW.

Also, the voltage quality was improved at El Biodh Sidi chikh60Kv node from 0.67535 to 0.87125pu and Mecheria node from 0.60444 to 0.89849pu.

Table 8. The powers after insertion of the PV plant at Mecheria, Naama or Ain Safra

Active power (MW)	Before insertion	Mecheria	Naama	Ain Safra
Total fossil production	542.95	527.989	533.36	530.713
Solar PV plant production	0.00	08.071	09.08	11.267
Total load	516.22	516.32	516.32	516.32
Total losses	26.734	19.74	26.12	13.66

Table 9. Nodal voltages without insertion

Nodes	Before insertion	Mecheria	Naama	Ain Safra
Terga 400Kv	1.025	1.025	1.025	1.025
Sidi Ali Boussidi 220kV	1.025	1.0626	1.0624	4.0625
Sidi Ali Boussidi 400kV	1.0223	1.0226	1.0224	1.0224
Saida 220kV	1.0301	1.0301	1.0308	1.0309
Naama 220kV	1.00	1.00	1.00	1.00
Naama 60kV	1.0301	1.0308	1.0302	1.0302
Bechar 220kV	1.0228	1.0228	1.0228	1.0202
Bechar 60kV	1.0142	1.0228	1.0142	1.0106
Bechar1 60kV	0.99528	0.99528	0.99528	0.99162
Bechar2 60kV	1.0003	1.0003	1.0003	0.99662
Bechar3 60kV	1.0101	1.0101	1.0101	1.0061
El Bayadh 60kV	1.0045	1.0181	1.0053	1.0055
El Biodh Sidi Chikh 60kV	0.67535	0.87125	0.67895	0.67952
Bogtob 60kV	1.0237	1.0259	1.0246	1.0248
Mecheria 60kV	0.60444	0.89849	0.60981	0.61063
Beni Ounif 60kV	1.0076	1.0076	1.0076	1.0015
Ain Safra 60kV	1.0075	1.0075	1.0075	1.0007

V. Conclusion

In this study, we discussed the installation of a photovoltaic solar power plant with a capacity of 12 MW at Naama wilaya. Through which, we have justified the choice of the installation of the power plant in this province by a detailed analysis of the various data such as, solar irradiation, the geographical position and the topology of the electrical network. The use of the simulation on the PSAT software allowed us to prove that the installation of this power plant in this region improves the quality of the electricity network, by reducing the active losses and the stability of the voltages within the admissible limits. Also, a comparison of the location of this plant was made between the three points Naama, Ain sefra and Mecheria, we find that Mecheria has the best location of this plant.

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