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doi:10.15199/48.2023.06.47

Dynamic Stability Analysis with Real Data of Hybrid RES Integration in Southwest Algeria Power System Using Etap Software

***Abstract**. The power system is non-linear due to the constant change in loads, generators and operating conditions. In recent years, a substantial quantity of renewable energy sources (RES), has been integrated into the world power grid, which has provided alternatives to fossil fuels, especially since they are economical and environmentally friendly to the environment. But at the level of power system stability many concerns have been raised about its efficiency and its impact on its stability and reliability, so it is essential to investigate this impact. The simulation results demonstrated that the stability of the system is affected by this integration, particularly when conventional production plants predominate in the system.*

***Streszczenie.** System elektroenergetyczny jest nieliniowy ze względu na ciągłe zmiany obciążeń, generatorów i warunków pracy. W ostatnich latach znaczna ilość odnawialnych źródeł energii (OZE) została włączona do światowej sieci elektroenergetycznej, co stanowi alternatywę dla paliw kopalnych, zwłaszcza że są one ekonomiczne i przyjazne dla środowiska. Jednak na poziomie stabilności systemu elektroenergetycznego zgłoszono wiele obaw dotyczących jego wydajności i wpływu na jego stabilność i niezawodność, dlatego konieczne jest zbadanie tego wpływu. Wyniki symulacji wykazały, że integracja ta ma wpływ na stabilność systemu, zwłaszcza gdy w systemie dominują konwencjonalne zakłady produkcyjne. (**Dynamiczna analiza stabilności z rzeczywistymi danymi integracji hybrydowych OZE w systemie elektroenergetycznym południowo-zachodniej Algierii przy użyciu oprogramowania Etap**)*

Keywords: Dynamic Stability, transient stability, PV-Wind penetration, Etap.
Słowa kluczowe: Stabilność dynamiczna, stabilność przejściowa, penetracja PV-Wind, Etap.

Introduction

In recent years, the increase in electricity consumption has been strongly linked to the development of industry, transport and means of communication. The production of electrical energy in the world is based on exhaustible fossil fuels such as coal, natural gas, and uranium. The increasing demand for which is becoming greater than the supply, endangering the reserves of this energy for future generations without ignoring its negative impact on the environment, which threatens our health.

The global renewable energy generation capacity reached 3,064 GWH in 2021, and its growth rate was 9.1%. 88% of the rise in new renewable energy came from wind and solar power [1].

This growth results from the global electricity demand have reached an all-time high as the economy picks up again after the Covid-19 slowdown and drought in several places reduced hydropower supply [2] The integration of these renewable energy sources (RES) meets the rising energy demand, but in terms of power system stability, this comes with a number of concerns[3,4]. Therefore, it is necessary to study and analyze the impact of the integration of these renewable energies on the power system stability. Transient stability is the ability of the power system to maintain synchronism when subjected to a severe transient disturbance such as a fault in transmission facilities, loss of generation, or loss of a large load [5,6]. Many researchers presented the issue of the stability of the power system using diverse methodologies in terms of studying and analyzing its behavior under various operating conditions and its impact on power system reliability and stability. In this regard, works such as[6] Focused on analyzing the behavior of the power system at different types of fault on the IEEE-9 bus system when cleared Multiple contingencies before and after CCT. The Impact of grid-connected large-scale solar systems on electric power grids' dynamic voltage stability is also considered in[7] , stability of the IEEE 9 BUS system is observed under transient disturbances with and without penetration of PV in[8], whereas[9] reviews the impact that high penetration levels of wind energy on power systems. Authors in[10] investigated the effect of increasing the penetration levels of renewable energy sources on the grid capacity through load flow analysis based on line flow capacity constraints. Considering the decrease in total system inertia and regulatory capability, system operators are typically worried about the acceptable penetration limits for these renewable systems. The effect of wind penetration on frequency regulation is investigated in [11].

researchers in [13] investigates the effect of photovoltaic power plant integration on the stability of the power system. According to[14] the integration of wind power in-grid based on DFIG double-feed induction generator, shows higher improvement in voltage profile.

Many countries, including Algeria, seek to build their renewable energy capacities to preserve their fossil fuel resources and benefit from more exports, Total renewable energy capacity in Algeria increased to 686 MW at the end of December 2021, with 448 MW from PV power and 10 MW from wind power; grid-connected renewable energy capacity is approximately 448 MW [17].

Solar photovoltaic represents 92% of renewable energy in Algeria, excluding hydroelectricity, and 84% of the total solar photovoltaic energy is connected to the grid. The wind power plant project in the kaperten region (72 km north of Adrar, Algeria) is considered the first at the national level. This station offers alternative productions of About 10 MW of clean and renewable electricity integrated into the electricity grid to strengthen energy supply capacities in Adrar. It belongs to the experimental stage of The National Renewable Energies Program, which consists of achieving a 27% RES penetration into its existing national energy mix by 2030 [18].

The main contribution of this study is as follows:

- Examine the impact of integrating renewable energy sources (PV and Wind) into the distribution network.
- Investigate the response of the hybrid power system of the Kaberten region with actual data during various disturbance scenarios with different penetration levels.

Simulation studies are carried out with Etap software to Examine and compare the transient performance of a test power system with and without RES integration during different disturbance scenarios.

System configuration and description

The distribution network of the Kaberten region (72 km north of Adrar - Algeria) is an appropriate model for studying hybrid power systems because it combines conventional power plants with renewable energy sources. It contains two types of renewable energy sources, the first is a photovoltaic power plant, and the second is based on wind energy, with a capacity of 3 and 10 megawatts, respectively. The two distributed generations are connected to a 30 kV medium voltage distribution network, in addition to a conventional power plant with a capacity of 40 MW.

Six (6) loads are connected to the distribution network: AGRICUL, BENTALHA, ARRAIAN RAS, METARFA,

O. MAHMOUD, and TINLKIN; the values of these loads are 1.09 MVA, 4.20 MVA, 4.46 MVA, 2.90 MVA, 4.21 MVA, and 4.36 MVA, respectively, as recorded on 17 July 2021.

Six (6) feeders connect these loads to the network's main busbar, and the voltage is 30KV. The network is fed by a conventional power plant if a grid source is unavailable.

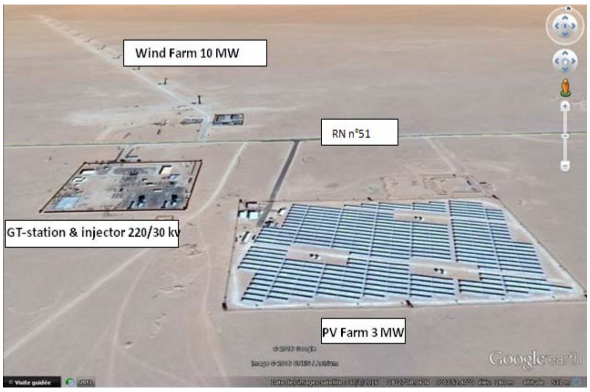

Fig.1. A satellite photo of the system under study

Wind farm specifications

The kaperten wind power plant (72 km north of Adrar - Algeria) comprises 12 wind turbines of type G52 850 KW. It is a Gamesa production, with a capacity of 0.85 megawatts each and a total production capacity of 10 MW. Each turbine has a step-up transformer (MT 690V/30 KV) which directly supplies its power to the 30 kV busbars and is equipped with a circuit breaker and other safety equipment. this project is the first of its kind in Algeria. The farm entered service in 2014 and is presently connected to the network electrical grid.

PV farm specifications

The kaberten photovoltaic farm (72 km north of Adrar - Algeria) consists of three 1 MW power subfields, for a total power output of 3 MW. Each sub-field divides into two connected fields, each of which is connected to a 1.25/0.630/0.630 MVA step-up three windings transformer through two 500 kW inverters. The transformer increases the generation voltage from 0.315 kV to 30 kV before injecting it into the 30 kV distribution network, Panels type is YL245P-29b made using polycrystalline silicon by YINGLI SOLAR. Inverters type is SG1000TS made by SUNGROW.

Conventional station specifications

The conventional power plant of kaberten (72 km north of Adrar - Algeria) consists of two gas turbine units with a capacity of 17 MW each. Connected to a three-winding step-up transformer (11.5KV, 11.5KV, 220KV). It injects its power into a 30 kV busbar through a 40 MVA step-down transformer, the latter creating the junction between the output of the conventional station and the injector from high voltage transmission line 220 kV (Adrar – Timimoun).

The equivalent single-line diagram of the Kaberten distribution grid was modeled using the Etap software, as presented in Fig. 2.

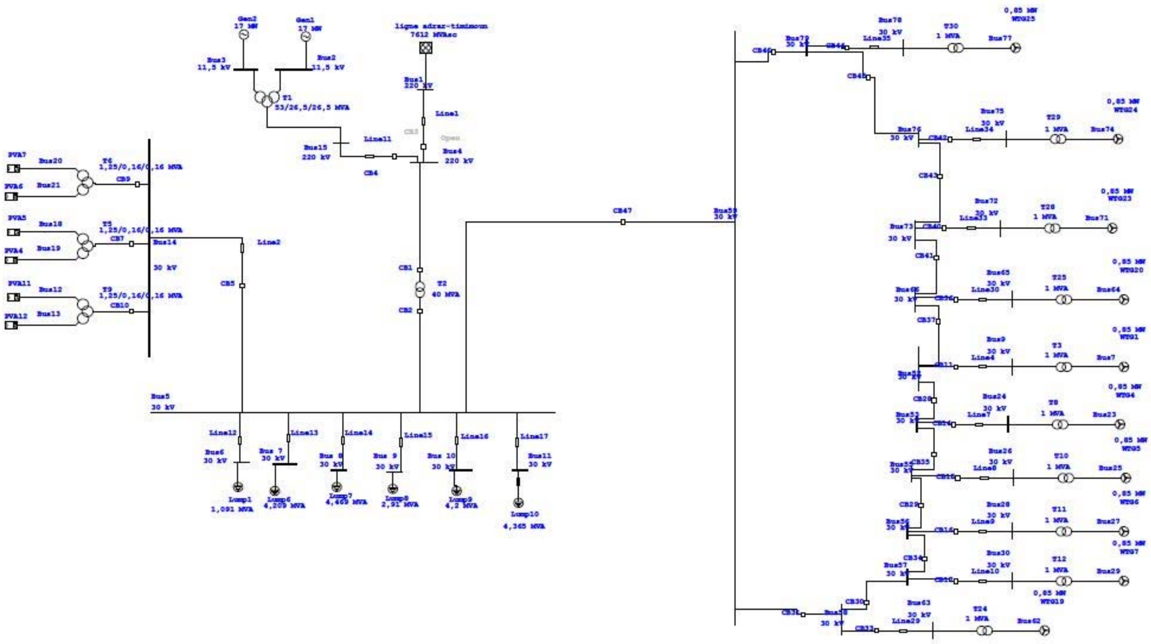

Fig.2. Single line diagram of Kaberten distribution grid model using the Etap software

Scenarios

Table 1. List of scenarios

Scenarios	Network feed by	Events
3-phase fault	Gas-turbine station	application of Disturbance with different levels of (RES) penetration
	power grid	
sudden disconnection of load	Gas-turbine station	
	power grid	
sudden loss of RES power	Gas-turbine station	
	power grid	

Results and discussion

All results are performed in ETAP, which is a grid modelling and simulation software utilized by power system engineers to evaluate the dynamics of the power system

Dynamic stability is the stability of a system during and after unexpected changes or disruptions caused by short circuits, loss of generators, sudden load changes, line tripping, or similar causes. The study of This type of stability depends on the system's initial condition operation and the disturbance's nature. Vast integration of renewable energy sources into the grid can cause oscillations that decrease with time. The main reason for these oscillations is the imbalance between the electrical and mechanical torques of the generators at a specified time.

When a gas turbine station is used to supply the distribution network, the first turbine is operated in swing mode and the second in voltage control mode. Accordingly, checking the rotor angle of the second turbine. Provides crucial details about the station's synchronization with the grid.

In transient stability studies, the disturbance is typically in the order of 3–5 seconds following a disturbance [19] however, the simulation length in this study is 20 seconds in order to obtain a comprehensive view of the system's behavior under various transient circumstances. Accordingly, the test distribution network is subjected to three distinct transitory conditions for this research, including:

- Fault On the Network Main Busbar
- Sudden Disconnection of Load
- Sudden Loss of RES (PV-Wind) Power.

For each of the three scenarios, the results show the voltage and frequency in the main busbar, as well as the generator rotor angle, under different levels of renewable energy penetration into the grid in the following order:

- Basic condition: without RES
- With the integration of half (50%) of the photovoltaic plant's actual capacity (P=1.5 MW)
- With the integration of the photovoltaic plant's full capacity (100%) (P=3 MW)
- With the integration of half (50%) of the actual capacity of the wind power plant (P=5 MW)
- With the full integration of the wind power plant (100%) (P=10 MW)
- With hybrid integration of the full real capacity (100%) of the two stations (P_{pv}=3 MW, Pwind=10 MW).

The Newton-Raphson method was chosen for the initial load flow.

Three-phase fault on the main busbar

In this scenario, a three-phase-to-ground fault is applied to the network's main busbar at 1 s for five cycles (50 Hz system). A three-phase fault is a typical example of a study of transient stability disturbances of the power systems.

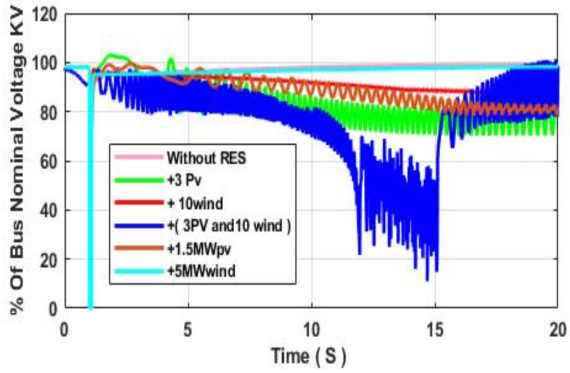

Fig.3. Voltage magnitude variations (network feed by gas-turbine station)

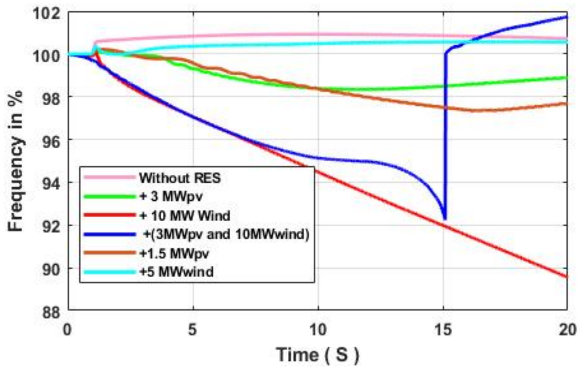

Fig.4. Frequency variations (network feed by gas-turbine station)

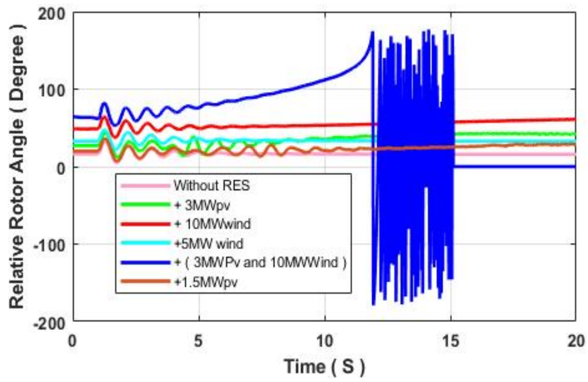

Fig.5. The rotor angle of generator 2

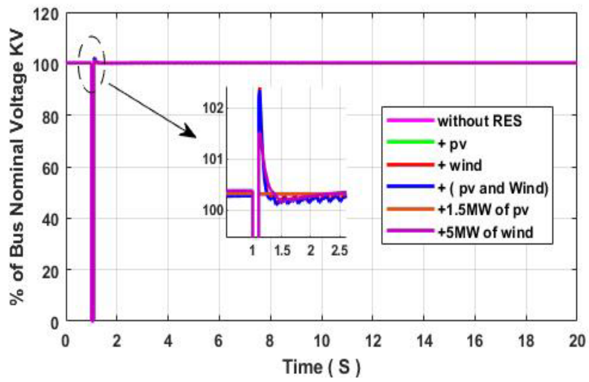

Fig.6. Voltage magnitude variations (network feed by power grid)

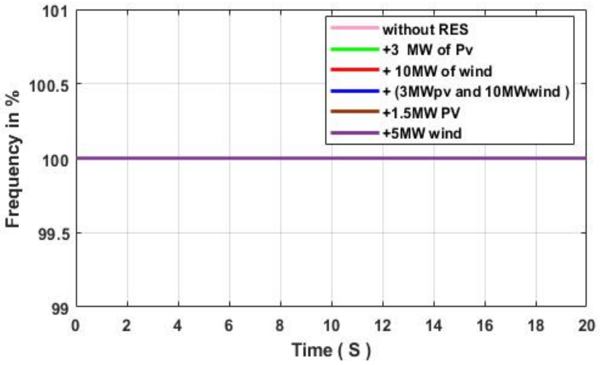

Fig.7. Frequency variations (network feed by power grid)

-Fig.3 shows voltage magnitude variations of the main bus, (network feed by gas-turbine station):

In the base case with no RES power penetration at t=1s, the bus voltage magnitude drops to zero value and remains zero until the fault is cleared at t=1.100 s, then it gradually returns to its value in a steady state. This indicates that the system is dynamically stable.

In the case of PV penetration, 100% of the actual capacity of the PV station, the fluctuation is higher than in the case of 50%, In the case of wind energy reaching 100% of the wind power plant's actual capacity, the voltage rises to a value of 97.59% and it then begins to decrease to a value of 93.46% with small amplitude oscillations.

Substantial variations are observed in the case of a 100% integration of RES power (10 MW of wind and 03MW of solar), with a significant reduction of up to 40% before it increases to a value of 87.32%, with relatively large oscillations.

-Fig.4 shows Frequency variations: In the base case without RES penetration, at t= 1s, the frequency rises and stabilizes at 100.9% of the fundamental frequency (50 Hz). An increase in frequency is shown in the scenario of a 50% penetration of wind power. It stabilizes at 100.5% of fundamental frequency in the steady state.

-Fig.5 shows the relative rotor angle of generator 2: There is an increase in the value of the rotor angle proportional to the value of the increase in the penetration of RES (PV or wind) in the system, we observe a large rise at rotor angle until 12 s, then the generator loses synchronism.

-Fig.6 In this case (network feed by power grid), the voltage is minimally changed, as it quickly returns to a steady state following fault elimination, with an overshoot in the case of wind integration.

-Fig.7 we can observe that the frequency has not been affected by the different penetration of renewables into the grid

When a short circuit occurs in the network, a large demand for reactive energy occurs, directly affecting the network's voltage stability. Conventional synchronous generators can compensate using their rotor excitation systems. In contrast, PV energy has no inertia because it does not involve any moving parts in the power generation process. And The inertia of wind turbines is negligible compared to the system's inertia. A grid source is a huge reserve of energy that can compensate for any fluctuation in the grid, including variations in power generation (solar or wind turbines) caused by rapid weather changes.

Sudden disconnection of load

In this scenario, the largest load connected in the system (ARAIAN RAS 4.46MVA) is suddenly disconnected, And the system's behavior is evaluated using various renewable energy penetration scenarios.

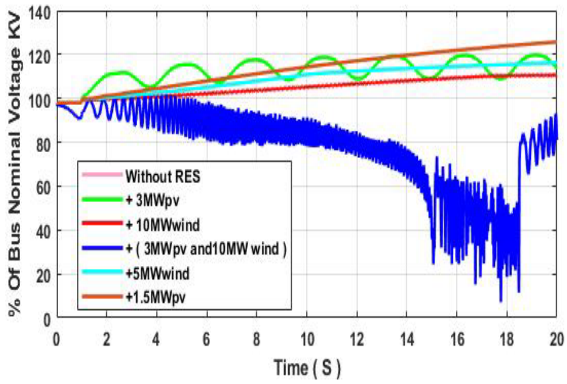

Fig.8. Voltage magnitude variations (network feed by gas-turbine station)

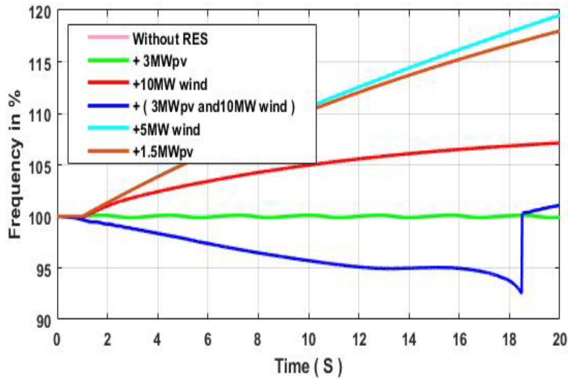

Fig.9. Frequency variations (network feed by gas-turbine station)

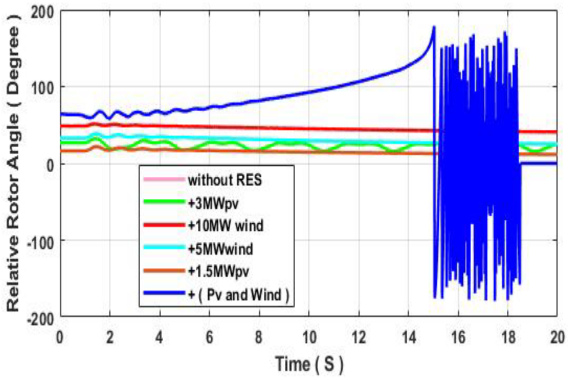

Fig.10. The rotor angle of generator 2

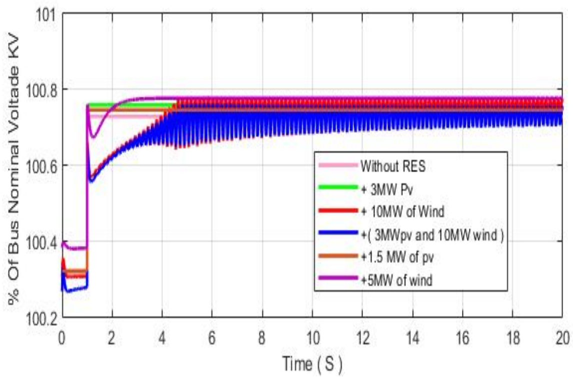

Fig.11. voltage magnitude variations (network feed by power grid)

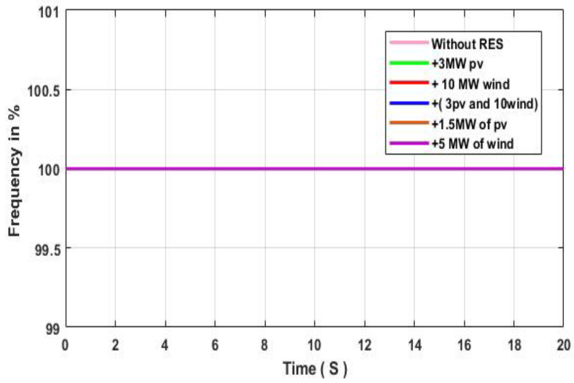

Fig.12. Frequency variations (network feed by power grid)

-Fig.8 shows the variations of the main bus voltage magnitude (network feed by gas-turbine station), When wind power is incorporated, the system is more stable,
-Fig.9 shows the variations of frequency in the main bus: The frequency is stable in the case of integration of the photovoltaic plant's full capacity
-Fig.10 in the case of integration a 100% of hybrid RES, we observe a large rise at rotor angle until 15 s, then the generator loses synchronism.
-Fig.11 shows that the system was affected more by the complete integration of the solar and wind plants.
-Fig.12 Clearly, the frequency was not affected in all cases.

Sudden loss of RES (pv-wind) power

This scenario simulates abrupt climate changes in reality that have an impact on the performance of renewable energy plants. It involves the sudden loss of various quantities of electricity produced by RES. Various separation scenarios are used to analyze the system's behavior. In order to investigate how these operational conditions, impact the system's stability.

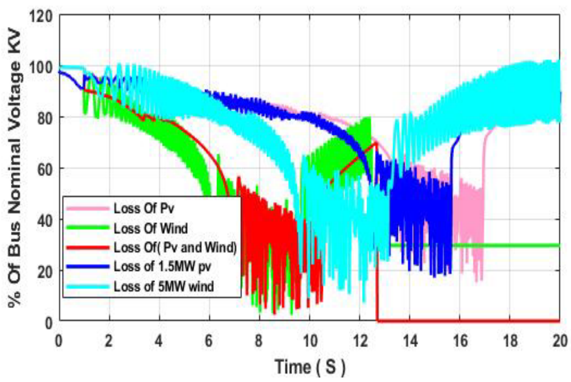

Fig.13. Voltage magnitude variations (network feed by gas-turbine station)

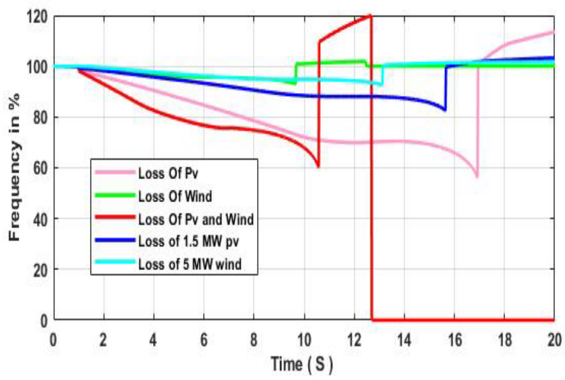

Fig.14. Frequency variations (network feed by gas-turbine station)

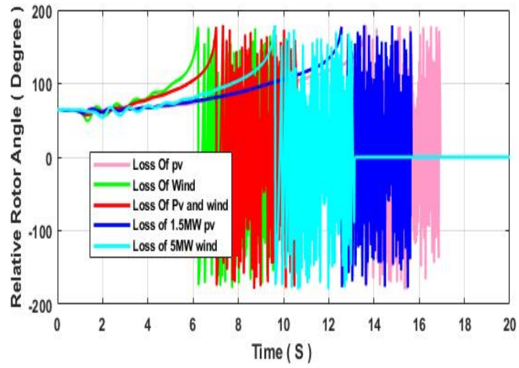

Fig.15. The rotor angle of generator 2

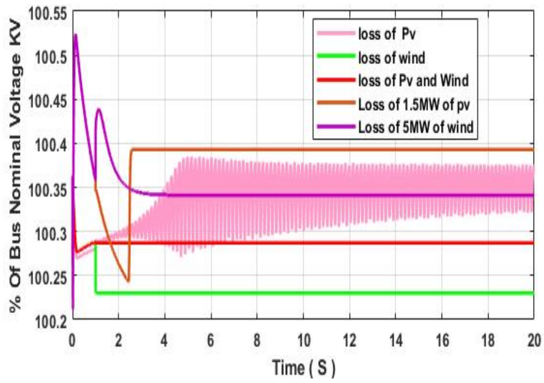

Fig.16. Voltage magnitude variations (network feed by power grid)

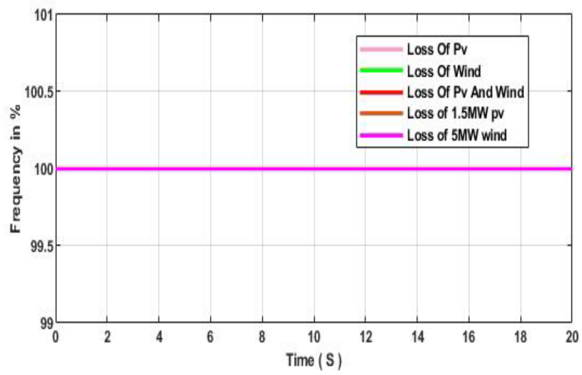

Fig.17. Frequency variations (network feed by power grid)

-Fig.13 In the case of the simultaneous loss of all RES in the system, the voltage drops to low values and fluctuates until 12 s before reaching zero.
-Fig.14 In this case, we note that in the simultaneous of the simultaneous loss of all renewable energy sources in the system, the voltage drops to low values and fluctuates until 11 s, before reaching zero.
-Fig.15 In all cases, we note that the value of the initial angle is 65 degrees, which is a large value (Any disruption to the network has the capacity to turn the system unstable) We observe that the generator loses synchronization, but at different times.
-Fig.16 we observe the voltage magnitude variation -In the case of losing 50 % of the solar plant, the voltage amplitude increases slightly in the main bus. In the case of complete loss of the solar power plant, the voltage amplitude rises slightly, with oscillation gradually decreasing with time.
-Fig.17, we observe that the frequency is unaffected by different scenarios

When all the renewable energy sources on the grid (solar and wind) are lost, with a total capacity of 13 MW (65%) of the capacity of the loads connected to the grid, there is a significant difference between the electrical energy required by the loads and the mechanical energy entering the generator. This is the reason for the fluctuation.
-When we lose part of the renewable energy sources from the grid, it is still penetrated by the rest of the part; therefore, the system's inertia is low and cannot sustain the disturbance.

Conclusion

This paper discusses the results of an investigation into the dynamic behavior of power system stability integrated with hybrid RES (pv-wind) in the kaberten region (Southwest Algeria). in three scenarios: three-phase fault, sudden disconnection of load, and sudden loss of RES. In different levels of RES penetration.

By analyzing the main bus frequency and voltage responses, as well as the rotor angle change during these contingencies, we conclude that the dynamic behavior of these renewable energy sources, caused by the associated system disturbance, affects the system's stability. The results indicated that integrating renewable energy sources (solar and wind) into the kaberten region's distribution network negatively impacts the network's performance during transient conditions when the conventional power station feeds the network due to the diminishing inertia of the system.

As a big energy store that may compensate for grid imbalances, the effect is less severe when a power grid supplies the system. So, Strengthening and expanding the transmission network is among the best technical solutions to improve the integration of renewable energy with high levels of penetration for a highly reliable and flexible power system. Also, the output of renewable energy plants depends on variable weather. Therefore, network operators must equip these stations with intelligent weather forecasting systems to provide timely alerts and prevent the sudden loss of these stations. The stability improvement of the system using a facts device (Flexible Alternating Current Transmission System) will be studied in future work.

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