1. Hocine GUENTRI[1], 2. Abdeldjalil DAHBI[2], 3. Tayeb ALLAOUI[3]

Department of Mechanic and Electromechanics, Institute of Science and Technologies, Abdelhafid Boussouf University Center of Mila, GE Laboratory Saida University, Algeria (1), Unité de Recherche en Energies Renouvelables en Milieu Saharien(URERMS), Centre de Développement des Energies renouvelables(CDER), 01000, Laboratory of sustainable Development and computing (L.D.D.I), Department of electrical engineering, Adrar university, Adrar, Algeria (2), Department of Electrical Engineering, Faculty of Applied Science, L2GEGI Laboratory, University of TIARET, Tiaret, Algeria (3)
ORCID: 1. 0000-0003-3720-1140; 2.xxxxx

doi:10.15199/48.2023.11.19

The impact of the power management technique on the transient stability of the electrical network

***Abstract**. Although renewable energies have socioeconomic and environmental aspects, their integration into electrical networks is always the fundamental issue for grid managers. Generally, this operation requires the control of all devices and converters. The integration approach must be accompanied by good power management across different sources to be optimal. Nonetheless, the scarcity of renewable energy sources has an impact on the stability of the electricity grid. This study is focused on renewable energy integration into the electricity network and rational management, as well as the impact of this later on the network's transient stability. This work has been performed using powerful and practical simulation software, ETAP 12.7. The obtained results show that power management influences transient stability, especially during peak hours.*

***Streszczenie.** Pomimo aspektów społeczno-ekonomicznych i środowiskowych energii odnawialnej, łatwość integracji energii odnawialnej w sieciach elektrycznych jest zawsze fundamentalną kwestią dla zarządców sieci. Generalnie operacja ta wymaga kontroli wszystkich urządzeń i konwerterów. Aby podejście integracyjne było optymalne, musi towarzyszyć dobre zarządzanie energią z różnych źródeł. Niemniej jednak ograniczenie odnawialnych źródeł energii wpływa na stabilność sieci elektroenergetycznej. Niniejsze opracowanie koncentruje się na integracji energii odnawialnej z siecią elektroenergetyczną i racjonalnym zarządzaniu, a także późniejszym wpływie tego na przejściową stabilność sieci. Ta praca została wykonana przy użyciu wydajnego i praktycznego oprogramowania symulacyjnego, jakim jest ETAP12.7. Uzyskane wyniki pokazują, że zarządzanie energią wpływa na stabilność przejściową, szczególnie w godzinach szczytu (**Wpływ techniki zarządzania energią na przejściową stabilność sieci elektroenergetycznej**)*

Keywords: Renewable energy, control, Power management, Transient stability, ETAP.
Słowa kluczowe: Energia odnawialna, kontrola, Zarządzanie energią, Stabilność przejściowa, ETAP.

Introduction

Since the invention of electricity by Thomas Edison, the producers' fundamental concern has been to satisfy the consumers' needs for electrical energy. Unfortunately, this satisfaction needs a production increase, the injection of new power generation plants, the realization of new electrical lines, and the addition of new transformer substations in the power grids. These investments influence not only the economy of the country but also the environment.

Government solutions have encouraged using isolated or integrated renewable energy sources like wind, solar PV, and others. This integration requires the use of several devices, such as devices based on power electronics like inverters, choppers, and rectifiers, protection devices such as circuit breakers and switchers, power management devices, load management devices, and communication devices. All these devices will facilitate this integration. Several studies have been done in the power management area, like in [1], [2], [3], [12], and [4]. All these studies and others have one goal, renewable energy integration facilitation. Unfortunately, despite the advantages of this integration, the latter will infect, disturb and degrade the quality of the electricity network, like disturbance of stability of frequency and voltage, deterioration of the level of voltage, and the infection of the power networks by harmonics. Several studies have been done in this field, like [5] Mkattiri et al. promote an approach to an impact study of distributed energy generation's integration into the urban HTA distribution network. Also, Nasiruzzaman et al. in [6] initiated a new area for complex system research to assess the stability of the power system. In [7], Shafiullah et al. develop a simulation model with power system simulation software PSS Sincal to investigate the potential adverse impact of large-scale renewable energy (RE) penetration into the Rockhampton power networks, Queensland, Australia. While Toma et al. [8] present the effect on voltage stability of renewable energy sources integration into the electricity grids.

The literature divides energy management problem-solving into two dimensions: the first deals with the sizing of energy sources and determining their characteristics and performances. The second dimension treats the management strategy problem, which consists of finding the optimal power distribution supplied by the different energy sources [9], [10]. Furthermore, energy management uses breakers, switchers, and other control devices. The challenge is to control many small and distributed generation sources instead of commanding a few large plant generations without disturbing the stability of the whole system [11].

This paper is focused on the impact of energy management devices on the grid stability, such as breakers, switches, and power electronic devices.

1 Methodology

1.1 System model

The electrical network comprises the utility grid and wind power generation with a variable wind speed to provide 35kW. Also, a PV array with variable solar irradiance provides 0-40kW. The three sources supply the power for two-variable loads for 24 hours. The first are four (4) buildings with an average load of 51kW and a peak of around 132kW. The second is two pumps of water, one used to feed the houses with drinking water for three hours in the morning and three hours at night, and the other pump for watering agricultural land near the buildings for three hours in the morning and three hours in the afternoon. The two pumps have 38kW load demand, as shown in Figure 1.

A single-line diagram of the system used for simulation is shown in Figure 4 to investigate the power management and the transient stability in the ETAP 12.6 software. The system is composed of five buses with three levels of voltage. The utility grid is connected to the medium voltage (MV) 34.5V. Then it uses a transformer to obtain a voltage of 4.16kV to connect the wind farm generation power. After that, it uses another transformer to get a low voltage of 0.480kV. In the LV, the PV array and the two loads of buildings and pumps are connected.

The power management strategy is simple, based on controlling different sources of PV, wind power generation, and electrical grid utility to provide power for loads (buildings and pumps) during certain times of the day.

The power management technique is as follows, as shown in Figure 2.

If the power provided by the PV array and the wind power generation is greater than the power load demand of the buildings and pumps, both sources will supply the loads. If there is a surplus, it is consumed by the utility network.

Otherwise, both sources feed the loads, and the lack powered by the utility network.

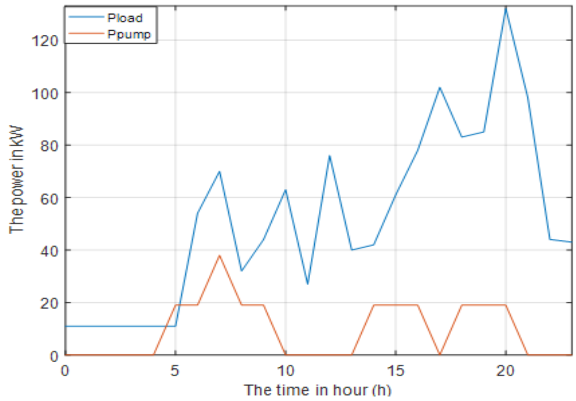

Fig.2. Power management strategy of the system.

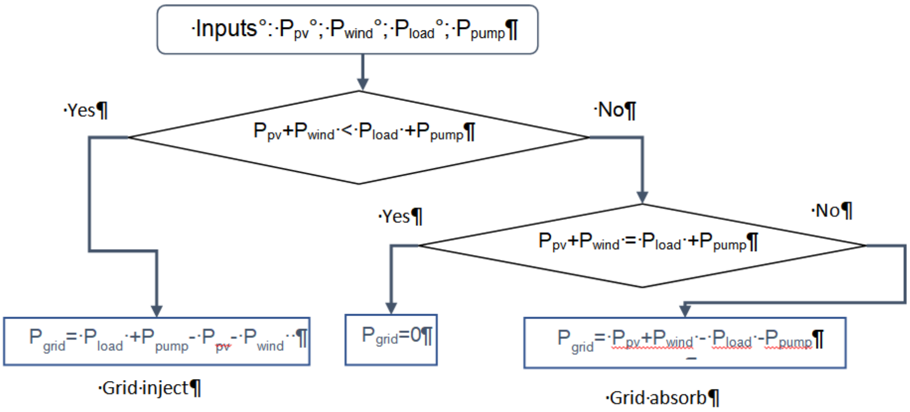

Fig.2. Power management strategy of the system.

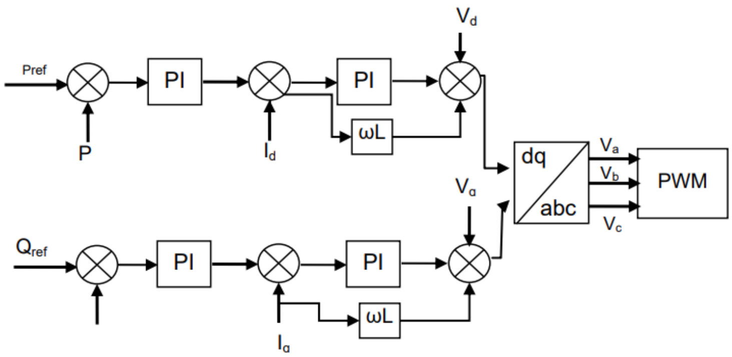

Fig.3. Power management strategy of the system.

1.2 Voltage transient stability

A combined electro-mechanical system makes up the power network. The machine's rotor angle oscillates due to a divergence in speed and power flows that occurs when lines are disrupted [13]. Transient stability analysis investigates the system following this disturbance and confirms whether the system becomes stable even after the perturbations are present. After a particular disturbance, the system must stabilize and return to its original state for the power system to operate as intended.

A microgrid stability controller imports and exports power energy with a complete control converter and electrical grid utility. When a microgrid is connected to the grid, DGs provide expert power to the microgrid. However, the variation in wind speed, solar sunshine, load variation, or other external factors that may cause output power fluctuation that further causes voltage fluctuation and flicker have a significant impact on the output power of DG systems based on renewable energy sources, such as photovoltaic generation or wind power [14]. Therefore, a microgrid stability controller is required to mitigate power fluctuation brought on by DGs in the microgrid and to adjust for power variance.

Different renewable energy sources work in a constant-current control mode to supply power to the distribution network. Microgrid stability controllers provide dynamic active and reactive power compensation to the microgrid to reduce the output power fluctuation of different renewable sources and the load, as shown in Figure 3 [15].

2 Results and simulation

After building the system model in ETAP 12.6, the most comprehensive platform for the design, simulation, analysis, operation, control, optimization, and automation of power systems, we can profit from this software by doing two simulations. The first is about the power management of the different sources. The second is the transient stability of the system that causes the power management and variation of the loads (buildings and pumps) in this system.

Fig.4. Single line diagram of the system in ETAP.

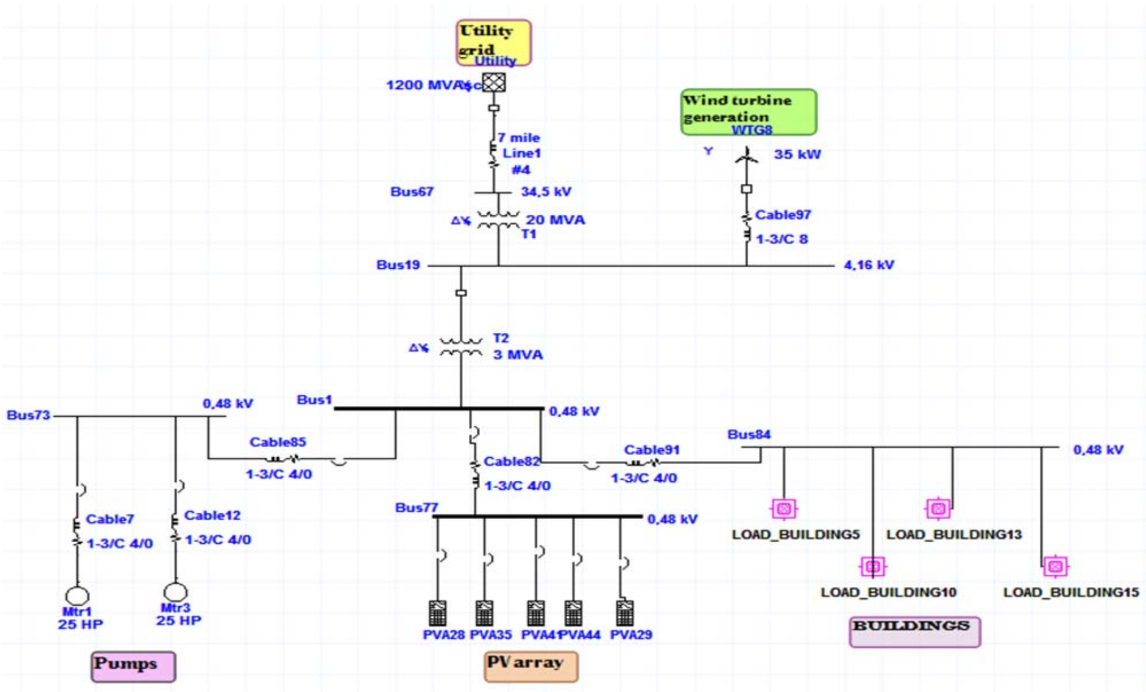

Fig.4. Single line diagram of the system in ETAP.

2.1 Power management simulation

After integrating the power management technique in our system in ETAP, we have Figure 5.

From 00:00 until 06:00: the night period, the residential load is at the minimum, it fixe around 11kW, the turbine wind generation provides power, and the utility network consumes the power surplus.

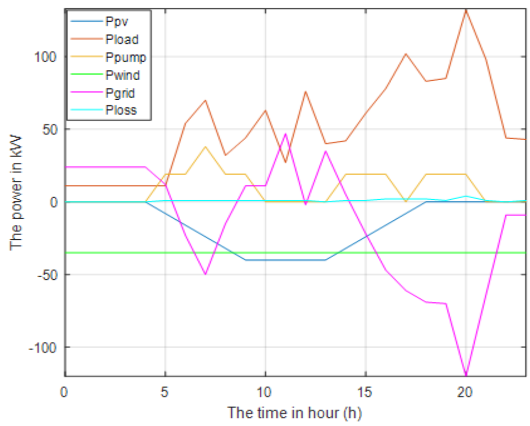

Fig.5. The daily power management of the system.

From 06:00 until 09:00: The beginning of the day, an increase in the buildings and pumps loads was observed, such as 70kW for the buildings and 19kW for the pumps. The two photovoltaic and wind power sources support the loads, and the utility network compensates for the power lack.

From 09:00 until 17:00, after the passage of the first peak time, the residential load decreases to 27kW at noon. At this period, the wind farm and photovoltaic sources support the load, while the utility network absorbs the power surplus.

From 17:00 until 22:00: the time of the peak hour of the day. The building load continues to increase, reaching a maximum value of 132kW. Both sources supply the load: the wind farm and the PV array. As usual, the utility network provides insufficiency.

From 22:00 until 24:00 (night period), the building load is minimal. During this period, the wind farm source supplied the building load, and the utility network consumed excess power.

During the rest of the day, we have 1520kW of electrical production mix distributed as follows, the PV with 360kW, the wind farm with 840kW, and the utility grid with 320kW. The total renewable energy product is 1200kW, and the utility network product is 320kW.

Through Figure 6, we can see that the rate of electricity production during a day of PV is 23.68%, while the wind farm produces 55.26%, the rest supplied by the utility network, which is 21.05%. Globally, renewable energy produces 79% of total production, while the utility network produces only 21%.

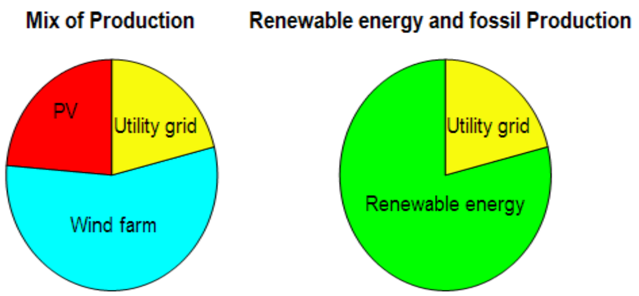

Fig.6. The Electrical production during one day.

2.1 Transient stability simulation

In this sub-section, we study the influence of power management on the transient stability of the system. We use the same electrical network as the above drawing in the ETAP software. After the insertion of the parameters of the electrical grid, we run the transient stability simulation. We obtained the results as follows:

We observe that the bus voltage of the wind turbine generator varies between 99.2% and 100%, as shown in Figure 7.

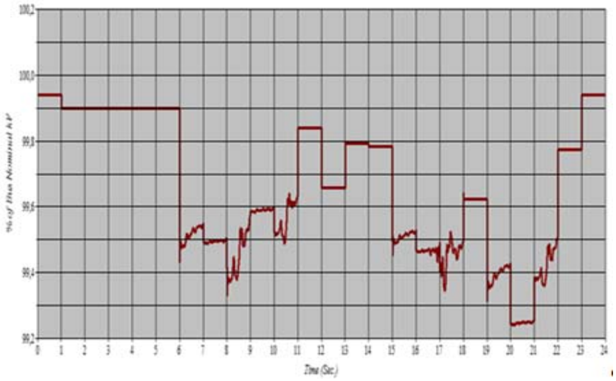

Fig.7. The Bus voltage of the wind turbine generator.

We observe that the voltage of bus 1 varies between 98.4% and 100%, as shown in Figure 8.

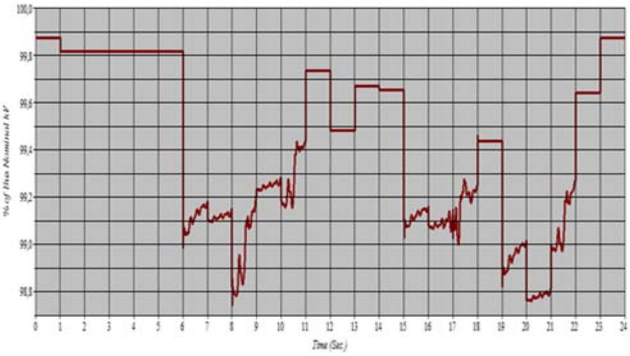

Fig.8. The Bus voltage of the bus 1.

The voltage of the bus pump is between 97% and 100%. Precisely during the peak demand of the morning at 08:00 am and the evening at 8:00 pm, see Figure 9.

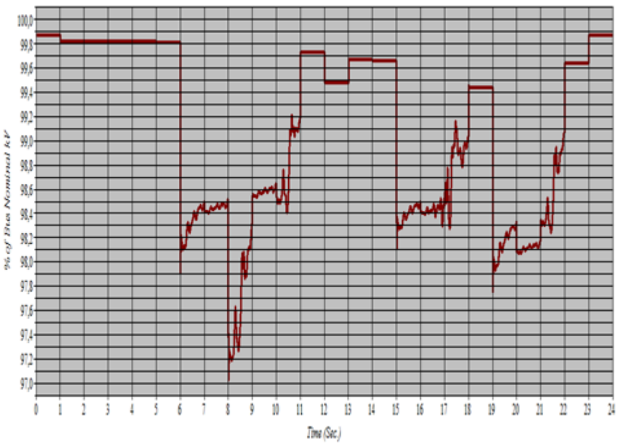

Fig.9. The Bus voltage of the bus pumps.

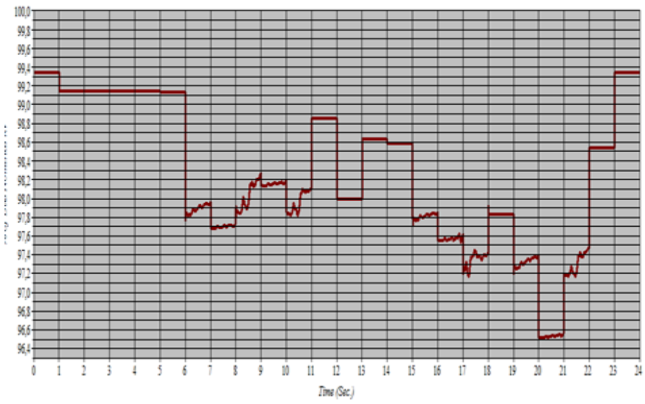

Fig.10. The Bus voltage of the bus buildings.

Concerning the PV node, it is in the general stable because the variation of the voltage is minimal, it is between 98.8% and 100% see Figure 11.

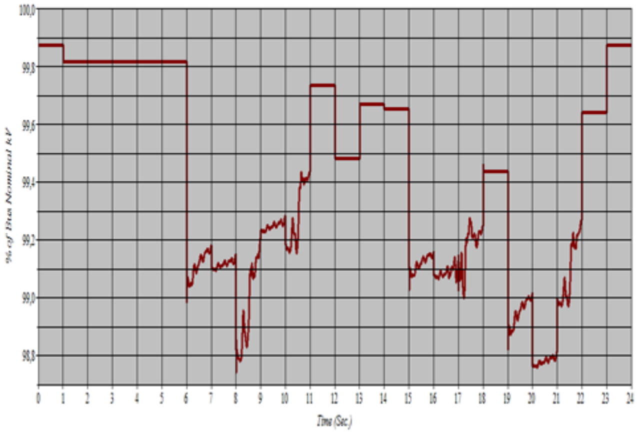

Fig.11. The Bus voltage of the bus PV.

The voltage of the bus building is the under-voltage in the system is between 96.4% and 100%. This bus is infected by the immense demand for active power during the peak demand time. Like during the morning at 08:00 am and during the night at 8:00 pm, as shown in Figure 10.

For the water pumps, work two times a day. First, we have two starting a day for the first pump at 06:00 am and 07:00 pm. At these times, the reactive power increases until 150kVAR and decreases until 90kVAR, as shown in Figure 12. Also, active power arrives at 45kW at the start for the same reasons. After this time, the active power decreases until the nominal value, which is 19kW, as shown in figure13.

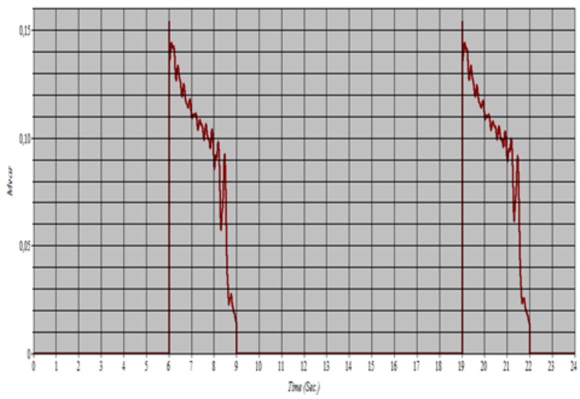

Fig.12. The Pump 1 reactive power.

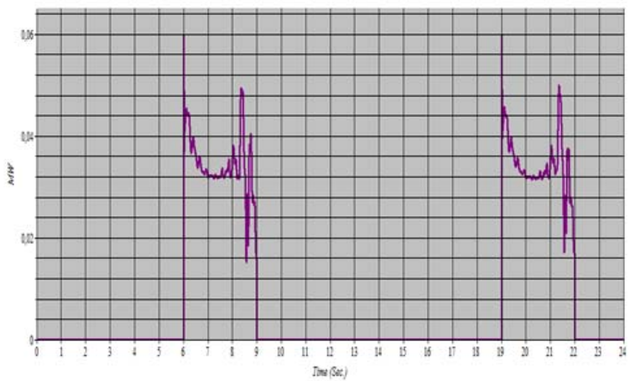

Fig.13. The Pump 1 active power.

For the second pump, the same thing happens because both pumps have the same parameters, as shown in Figures 14 and 15. Both pumps are operational between

10:00 am and 11:00 am, and the active power decreases to 38kW. Also, one of the pumps is at the starting time when the other is operational. Despite this, the power rest stable.

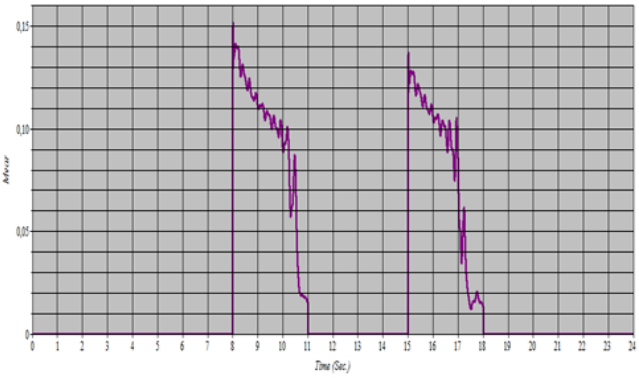

Fig.14. The Pump 2 reactive power.

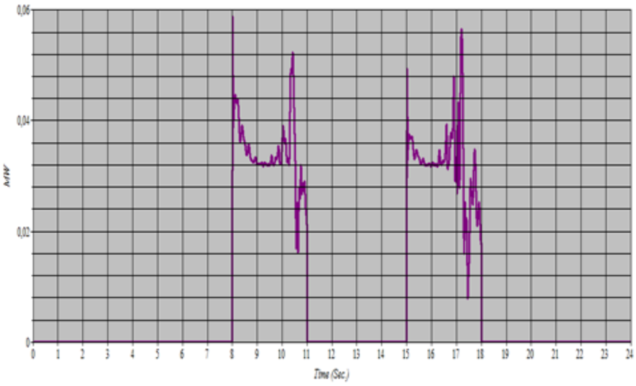

Fig.15. The Pump 2 active power.

3 Conclusion

This paper has studied the impact of power management on transient stability. Starting with a simulation of the power management system integration according to the production cost of each source as well as the priority of renewable energy use. The results of this first phase are reflected in the production cost reduction and the integration of renewable energies promotion.

The second phase studied the influence of power management on the transient stability of the studied system. The ETAP 12.7 simulation tool used the inserted system data (different sources and loads). In conclusion, power management immensely influences transient stability, especially during peak hours when the power demand is very high. This results from the control function that is based on the use of switches and breakers.

To improve the transient stability of an electrical power system during control and power management. It is necessary to reduce the impact of switches and breakers on power management and control. Also, it is imperative to use more efficient control.

***Authors**: H. Guentri is with Abdelhafid Boussouf University Center of Mila, GE Laboratory Saida University, Algeria, D. Abdeldjallil is with the Développement des Energies renouvelables(CDER), 01000, Laboratory of sustainable Development and computing (L.D.D.I), Department of electrical engineering, Adrar university, Adrar, Algeria, and T. Allaoui is with the Electrical Department of Electrical Engineering, Faculty of Applied Science, L2GEGI Laboratory, University of TIARET, Tiaret, Algeria.*
E-mail : hguentri2005@centre-univ-mila.dz, dahbi_j@yahoo.fr, allaoui_tb@yahoo.fr.
The correspondence author:
Email: hguentri2005@centre-univ-mila.de
Department of Mechanic and Electromechanics, Institute of Science and Technologies, Abdelhafid Boussouf University Center of Mila, GE Laboratory Saida University, Algeria.

REFERENCES

[1] Yan L., Xinshou T., Chao L., Yuanyuan S., Lisheng L., Linli Z., Yong S., Jianxiu L., Study on voltage control in distribution network with renewable energy integration, *Proc. of the IEEE Conference on Energy Internet and Energy System Integration*, EI 2017, Beijin, China
[2] Shahid A., Smart Grid Integration of Renewable Energy Systems, *Proc. of the IEEE Conference on 7th International Conference on Renewable Energy Research and Applications, ICRERA 2018*, Paris, France.
[3] Kaczorowska Dominika.,Przemysław J., Łukasz J., Jacek R., Vishnu S., Power flow control algorithm in a microgrid with energy storage, *Przegląd Elektrotechniczny*, 97 (2021), nr 7, 116-119
[4] Gozde H., Cengiz M T., Integration of renewable energy sources into turkey electric energy network general problems and solution proposals, *Proc. Of the 5th International Conference on Electrical and Electronic Engineering, ICEEE 2018,* Istanboul, Turkey.
[5] Mekattiri S., Saad A., Analysis of the impact of the integration of renewable energies on HTA distribution networks in Morocco, *Proc. Of the 19th IEEE Mediterranean Electrotechnical Conference, MELECON 2018,* Merrakech, Morocco.
[6] Mougay A., Khatir M., Flitti M., Zidi S. A., Ganoune A., Energy management for a new power system configuration of base transceiver station (BTS) destined to remote and isolated areas, *Przegląd Elektrotechniczny*, 97 (2021), nr 8, 1-8
[7] Shafiullah G., Impacts of renewable energy integration into the high voltage (HV) networks, *Proc. Of the 4th International Conference on the Development in the in Renewable Energy Technology, ICDRET 2016,* Dhaka, Bengladesh.
[8] Toma R., Gavrillas M., The impact on voltage stability of the integration of renewable energy sources into the electricity grids, *Proc. Of the International Conference and Exposition on Electrical and Power Engineering, EPE 2014,* Iasi, Romania.
[9] Stamenic M., Tanasic N., Simonovic T., Nikolic A., Energy management system for energy efficiency improvement in the industrial sector of the republic of Serbia, *In Proceedings of the 4th International Symposium on Environmental Friendly Energies and Applications, EFEA 2016.* Belgrade, Serbia.
[10] Menniti D., Pinarelli A., Sorrentino N., Vizza P., Burgio A., Brusco G., Motta M., A Real-Life Application of an Efficient Energy Management Method for a Local Energy System in Presence of Energy Storage Systems, *In Proceedings of the IEEE International Conference on Environment and Electrical Engineering and IEEE Industrial and Commercial Power Systems Europe, EEEIC / I&CPS Europe 2018,* Palermo, Italy.
[11] Rezkalla M., Heussen K., Marennelli M., Hu J., Bindner H. W., Identification of Requirements for Distribution Management Systems in the Smart Grid Context, *In Proceedings of the 50th International Universities Power Engineering Conference, UPEC 2015*. Stoke on Trent, UK.
[12] Mmary E B., Marungsri B., Integration of Renewable Energy Distributed Generation and Battery Energy Storage in Radial Power Distribution System, *International Energy Journal*, 78 (2019), nr 19, 27-36
[13] Thakar A., Pala M., Modelling and Transient Stability Analysis of Microgrid, *2019 IEEE 5th International Conference for Convergence in Technology (I2CT 2019),* 1-5, doi: 10.1109/I2CT45611.2019.9033873.
[14] Minxiao H., Xiaoling S., Shaobo L., Zhengkui Z., Transient analysis and control for microgrid stability controller, *2013 IEEE Grenoble Conference, 2013,* pp. 1-6, doi: 10.1109/PTC.2013.6652175.