IMPACT OF PHOTOVOLTAIC INTEGRATION IN THE DISTRIBUTION NETWORK ON TIME DELAY OF ELEMENT PROTECTIONS

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Abstract. *The integration of renewable energy to distribution networks is very increased in those last years, the Algerian government starts in this topic by integration of photovoltaic panels PV to Oued Nechou distribution network. This paper studies the impact of PV integration in Oued Nechou network on line fault time delay. The problem is studied before on IEEE-14 bus network then it is applied on Oued Nechou network. The simulation results are obtained before and after PV integration and are compared. The comparison is done on time delay, power loss and speed of return stable before line fault disappearing. The aim of this study is the evaluation of PV exploitation in Oued Nechou network and the choice of element protections parameters. The networks chosen in this study are modeled and simulated using the PSAT.*

Keywords. ***PV integration; line fault time delay; element protection; distribution network***

1. Introduction

The choice of protection elements in the power systems is very importance due to its influence on the stability; and the integration of photovoltaic panels to the power system take importance thanks to its cleanly; but they provoke several problems in protection. In paper [1] considering instantaneous voltage and instantaneous current are considered function in periodic time, think of it in terms of periodic function space to define the inner product and norm, Hilbert space based power theory is proposed. Real power, reactive power and apparent power in Hilbert space based theory are defined.

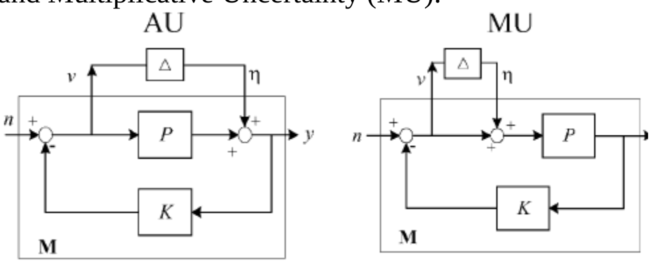
***The paper was first presented at ICREGA 2016.**

This proposed Hilbert space based power theory provide a novel view for the protection, islanding detection and control of grid connected PV power generation system; The protection's setting values set according to the Technical rules for photovoltaic power station connected to Power Grid for State Grid Corporation of China, may bring adverse influence to stable operation of the PV station connected to isolated grid with small capacity. The inverter's protection setting of the PV station connected to isolated gird is studied with PSASP software [2]. The simulation results of [2] shows that the frequency protection's setting values of the inverters should be adjusted according to the actual frequency characteristics and operation requirements of Ali grid to improve the operational stability and power supply reliability. A proposes a new online overvoltage prevention (OOP) control strategy to maintain PV terminal voltages within specified range while maximizing the PV energy yields is proposed in [3]. The proposed method is based on a precise active power limit prediction using the dynamic Thevenin equivalent. The active power output of PV array can be modulated in real time such that the voltage at a point of interconnection (POI) is always maintained within a specified range without triggering overvoltage protection. Simulation results using the IEEE 33-bus single-phase test system and IEEE 34-bus three-phase system have validated the effectiveness and accuracy of the proposed control method. The challenges to overcurrent protection devices OCPD in a PV array brought are examined in [4] by unique faults: One is a fault that occurs under low-irradiance conditions, and the other is a fault that occurs at night and evolves during “night-to-day” transition. In both circumstances, the faults might remain hidden in the PV system, no matter how irradiance changes afterward. These unique faults may subsequently lead to unexpected safety hazards, reduced system efficiency, and reduced reliability. A small-scale experimental PV system has been developed to further validate the conclusions. The analysis of the time delay impact to wide-area power system control is addressed in [5] by a robust supervisory power system stabilizer SPSS design.

This paper studies the influence of PV integration in network on line fault time delay.

2. Problem Formulation

The details is shown in [5], The small gain theorem is used here to derive robust stability conditions for the two most common descriptions of uncertainty shown in Fig. bellow: Additive Uncertainty (AU) and Multiplicative Uncertainty (MU).



$M = -(1+PK)^{-1}k$ $\quad$ $M = -PK(1+PK)^{-1}k = -T_0$

For these two cases, the small gain theorem guarantees the stability of the perturbed loop provided that M is stable (i.e, K stabilizes P) and the following inequalities are satisfied, at every frequency:

1) AU

$$\|(1+PK)^{-1}k\|_\infty \leq \|\Delta\|_\infty^{-1} \quad (1)$$

2) MU

$$\|(1+PK)^{-1}Pk\|_\infty \leq \|\Delta\|_\infty^{-1} \quad (2)$$

If the time delay uncertainty expressed in AU, the block Δ has the form

$$\Delta = P_0 e^{-ts} - P_0 e^{-t_0 s} \quad (3)$$

If expressed in MU, the uncertainty is in a simple form of an exponential function

$$\Delta = \frac{P_0 e^{-ts} - P_0 e^{-t_0 s}}{P_0 e^{-t_0 s}} = e^{-(t-t_0)s} \quad (4)$$

For a time-delay uncertainty, AU will depend on the nominal system operating conditions while MU will not. In this paper, MU is used to model the uncertainty for its simplification and direct relation with complementary sensitivity function. Then the criterion of the closed-loop system robust stability to time delay uncertainty is

$$\|T_0\|_\infty < \|1 - e^{-T_{dm}s}\|_\infty^{-1} \quad (5)$$

While T_0 is the complementary output sensitivity transfer function/matrix and T_{dm} is the largest time delay uncertainty.

3. Characteristic of Test Network

The networks chosen in this work are the IEEE-14 bus and the Oued Nechou-14 bus, the first is used for study the problem and the second is chosen for validate the results obtained. The Oued Nechou network is placed in the south of Algeria, this network is fed by one conventional source and one photovoltaic PV farm, the second is new and it becomes on service in 2014 [6].

The networks are modeled using the PSAT (power system analysis toolbox), the IEEE-14 bus network is generally known [7-11], the model of Oued Nechou network is resumed in fig.1 to 3 bus network. The table below gives the characteristics of Oued Nechou network.

TABLE I. BUS DATA OF OUED NECHOU NETWORK

Bus	V (pu)	phase (rad)	Pgen (pu)	Qgen (pu)	Pload (pu)	Qload (pu)
Bus 1	1	0	0.06563	0.04316	0	0
Bus 2	0.99685	-0.00482	0	0	0.07176	0.05382
Bus 3	0.99759	-0.00514	0	0	0	0
Bus 4	0.99775	-0.00519	0	0	0	0
Bus 5	0.99777	-0.0052	0	0	0	0
Bus 6	0.99779	-0.00521	0	0	0.0004	0.0003
Bus 7	0.99756	-0.00518	0	0	0.0004	0.0003
Bus 8	0.99769	-0.00518	0	0	0.00012	9,00E-05
Bus 9	0.99781	-0.00521	0	0	0.0008	0.0006
Bus 10	0.99778	-0.0052	0	0	0.0008	0.0006
Bus 11	0.99756	-0.00513	0	0	0.0016	0.0012
Bus 12	0.99763	-0.00515	0	0	0.00092	0.00069
Bus 13	0.99891	-0.00547	0	0	0	0
Bus PV	1	-0.00465	0.0112	0.01494	0	0

The figure below gives the model of oued Nechou network (note that this is not the model simulated)

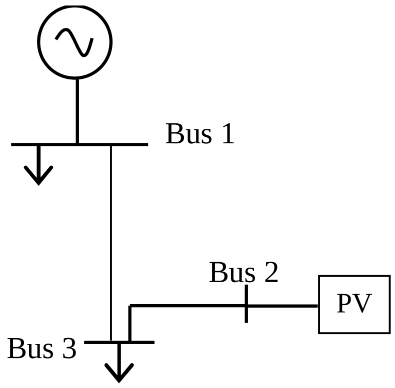


Fig 1. Resume of Oued Nechou network model.

4. Simulation Results

The networks are modeled and simulated using PSAT. Two cases of study are considered for each network, before PV integration and after, the objects of these simulations are the comparison of time delay and losses for the two cases, and determination of element protections characteristic before PV integration.

Note that the line fault applied in these simulation is the same in resistance value (0 Ω).

A. 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 where the voltage is most drop (bus 2); after that the line fault time delay was increased before each simulation and the voltage curves was obtaining until it had diverged. The time delay was increased by 10 ms.

The simulation results give that the line fault time delay for the IEEE-14 bus network before PV integration is 300 ms, and the losses are 94951 kVA.

The figure below shows the voltage in bus where the line fault is applied before PV integration.

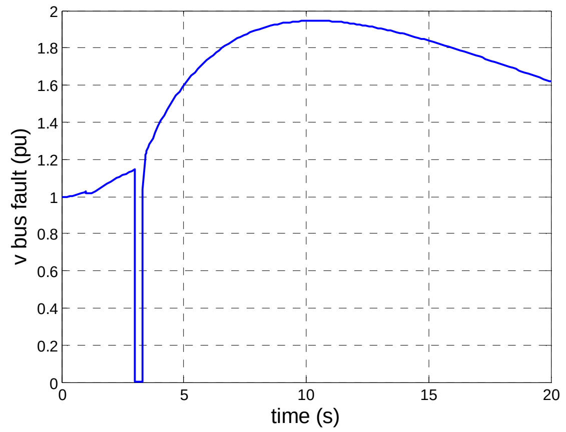


Fig 2. Voltage in bus fault before PV integration in IEEE-14 network

Fig 2 shows that a voltage deep is appeared during line fault but it return to its value gently when the line fault is disappeared.

The figure below shows the voltage in the sources in the case of line fault before PV integration.

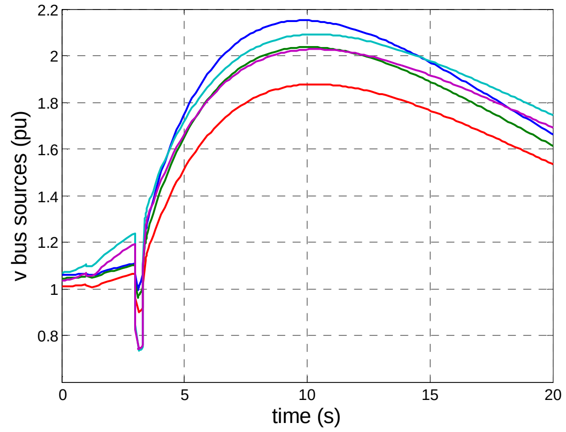


Fig 3. Voltage in bus source before PV integration in IEEE-14 network

It is shown in Fig 3 that when the line fault is applied a voltage deep appears in source buses, but it return gently to its value when the line fault time delay is ended.

Note that the line fault time delay in this case is critical (300 ms), where if it increased just by 10 ms the voltage curve will diverge.

B. 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 part A is applied on the network and in the same location; the line fault time delay was increased before each simulation and the voltage curves was obtaining until it had diverged. The time delay was increased by 10 ms also.

The simulation results give that the line fault time delay for the IEEE-14 bus network after PV integration is 1600 ms, and the losses are 85812 kVA.

The figure below shows the voltage in bus where the line fault is applied after PV integration.

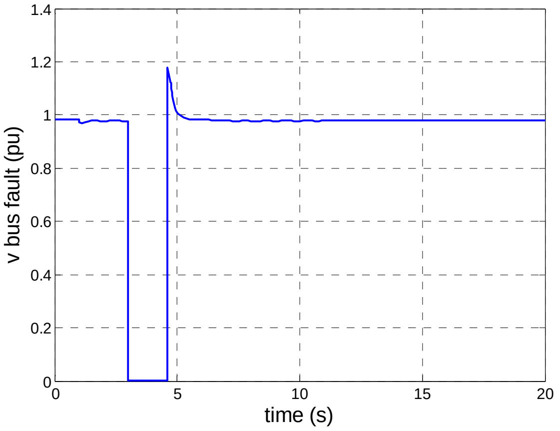


Fig 4. Voltage in bus fault after PV integration in IEEE-14 network

It is observed in Fig 4 that a voltage deep appeared during line fault but it disappeared quickly although the line fault time delay is larger than part A.

The figure below shows the voltage in bus where the PV is installed.

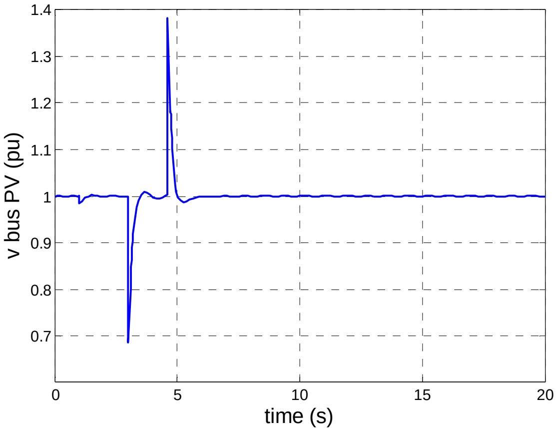


Fig 5. Voltage in bus PV after PV integration in IEEE-14 network

The figure below shows the voltage sources in the case of line fault after PV integration.

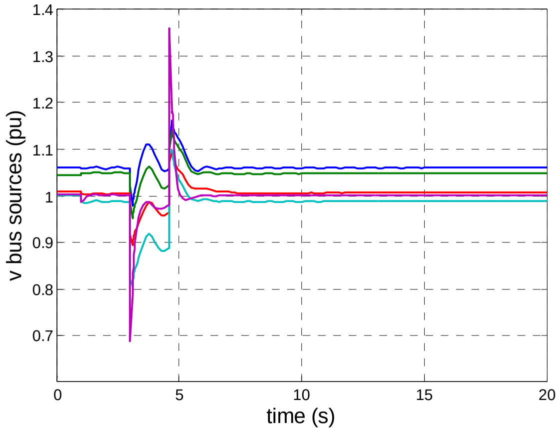


Fig 6. Voltage in bus source after PV integration IEEE-14 network

Note that the line fault time delay in this case is critical (1600 ms), where if it increased just by 10 ms the voltage curve will diverge, i.e. the network will be instable.

The simulation result of IEEE-14 bus network shows that the integration of PV farm to the grid change some network characteristics.

The time delay after PV integration was extended. And the energy loss was reduced.

The return to steady state after the integration of pv farm is faster than before.

C. Before PV integration in Oued nechou network

The Oued Nechou network is modeled with no PV panels, and the line fault is applied on the network; the line fault time delay was increased before each simulation and the voltage curves was obtaining until it had diverged. The time delay was increased by 10 ms.

The simulation results gives that the line fault time delay for the Oued Nechou network before PV integration is 400 ms, and the losses are 68 kVA.

The figure below shows the voltage in bus where the line fault is applied before PV integration.

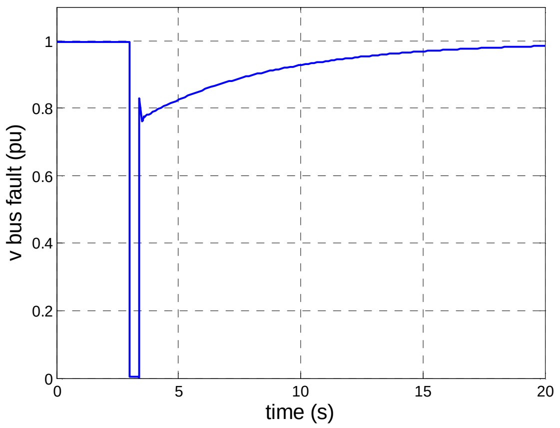


Fig 7. Voltage in bus fault before PV intefration

Fig 7 shows that a voltage deep is appeared during line fault but it return to its value gently when the line fault is disappeared.

The figure below shows the voltage in the source in the case of line fault before PV integration.

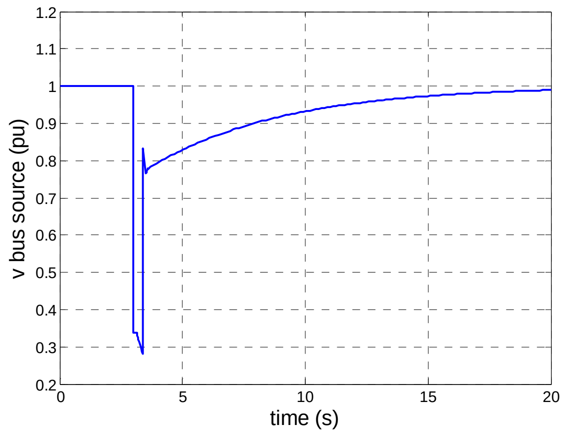


Fig 8. Voltage in bus source before PV integration

It is shown in Fig 8 that when the line fault is applied a voltage deep appears in source bus, but it return gently to its value when the line fault time delay is ended.

Note that the line fault time delay in this case is critical (400 ms), where if it increased just by 10 ms the voltage curve will diverge.

D. After PV integration in Oued nehou network

The Oued Nechou network is modeled with PV panels in this case, and the same line fault considered in part C is applied on the network and in the same location; the line fault time delay was increased before each simulation and the voltage curves was obtaining until it had diverged. The time delay was increased by 10 ms also.

The simulation results gives that the line fault time delay for the Oued Nechou network after PV integration is 320 ms, and the losses are 56,98 kVA.

The figure below shows the voltage in bus where the line fault is applied after PV integration.

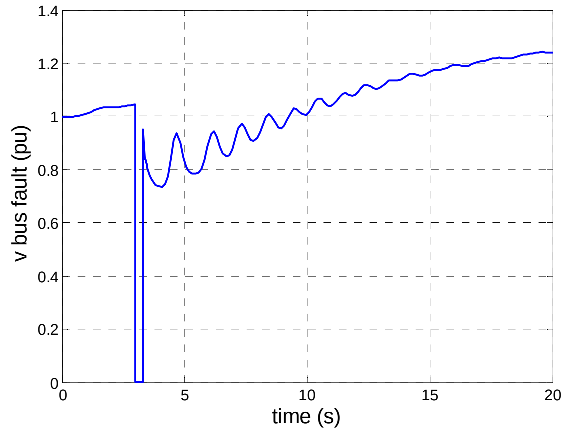


Fig 9. Voltage in bus fault after PV integration

It is observed in Fig 9 that a voltage deep was appeared during line fault but it disappeared quickly.

The figure below shows the voltage in bus where the PV farm was integrated.

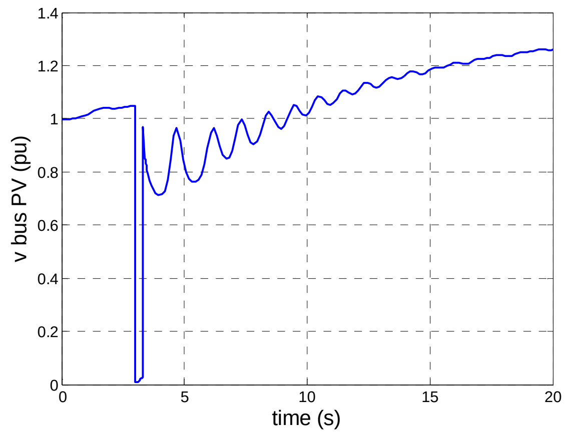


Fig 10. Voltage in bus PV after PV integration

The figure below shows the voltage source in the case of line fault after PV integration.

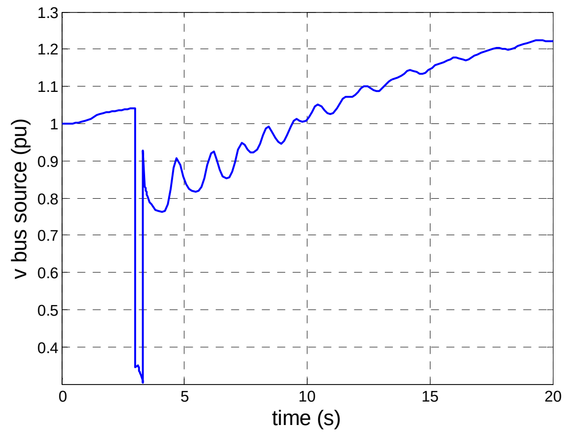


Fig 11. Voltage in bus source after PV integration

Note that the line fault time delay in this case is critical (320 ms), where if it increased just by 10 ms the voltage curve will diverge, i.e. the network will be instable.

E. Comparison

The table below resumes the simulation results given before and after PV integration.

TABLE II. RESULTS GIVEN BEFORE AND AFTER PV INTEGRATION

	no PV	with PV
Time delay (ms)	400	320
Fault duration for instability (ms)	410	330
Power losses (kVA)	68	56,98
Return stable	gently	quickly

The simulation results of Oued Nechou network shows that the integration of PV farm change some network characteristics.

The time delay after PV integration is changed by 120 ms. And the power loss for energy distribution is decreased.

The desperation of voltage deep is faster with panel integration than before although the time delay is increased.

This paper advices to change the characteristic of element protections for better exploitation of Oued Nechou distribution network.

5. Conclusion

This paper had studied the impact of integration of photovoltaic panels to the network on the time delay. The simulation results showed that the integration of PV farm influences the line fault time delay, and reduces the power loss during power distribution.

The time to return the network stable in case of line fault after PV integration is faster than before.

Authors propose to change the characteristic of protection elements after PV integration for better exploitation of network.

The networks modeled in this paper are the IEEE-14 bus for studying the problem and the Oued Nechou for validating the results, the simulation was done using the PSAT.

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