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# Experimental Analysis of Grid Connected to PV System According to DIN VDE 0126-1-1

S.Boulahchiche, S.Makhloufi, S.Semaoui, A.Hadj Arab, A.Djoudi Guerbi, K.Abdeladim
Centre de Développement des Energies Renouvelable
BP. 62, Route de l'Observatoire Bouzareah, 16340
Algiers, Algeria
*Corresponding author E-mail
*s.boulahchiche@cder.dz, s.makhloufi@cder.dz, s.semaoui@cder.dz, A.hadj Arab@cder.dz, a.djoudi@cder.dz, k.abdeladim@cder.dz*

***Abstract***— **This work presents tests of certain detection techniques; the degradation of the insulation resistance (IR) caused by the decrease of the IR, and the anti-islanding protection at the output of the inverters caused by the RLC load connected to the common connection point (PCC), according to the German DIN standard VDE 0126-1-1. A case study conducted on single-phase inverters without transformer type SMA and PCC, the first photovoltaic installation (maximum rated power of 3 kW) on an institutional building of the Renewable Energy Development Center (CDER), Algeria. The detection methods are invested on a sunny webbox, a sunny portal. And CHAUVIN ARNOUX equipment (C.A. 8335, C.A. 6116 N). The analysis provides a lot of valuable information about the German DIN VDE 0126-1-1**

***Keywords***— **Photovoltaic inverter; DIN VDE 0126-1-1; insulation resistance; anti-islanding protection**

## I. INTRODUCTION

Over the last ten years or so, a rapid development of distributed photovoltaic systems (PVs) technologies and the low PVs cost, encourage many utilities and governments to shift from conventional generations to more photovoltaic (PV) systems, affording electricity in many remote areas. In some areas, the increasing of PVs has already affected the local utilities' price policy and revenue. With continuous technical progress and cost reduction, it is expected that PVs will become one of the major energy sources in the future. When the PV cost is lower than the retail electricity price, electricity end users might prefer to use more PV energy instead of grid power [1, 2].

Since 2010, Algeria has confronted with socio-economic and industrial transformations, resulted in excessive improvement in level of living of population. These changes require more electrical energy; have forced government in 2011to modify expansion energy strategy, underpinned on renewable energies and PV in particular. This contributes decreasing dependency on fossil fuel helps preventing climate change, and promotes the emergence of national renewable energy industry. In 2015, Algeria revives the renewable energy program, which intends to place 22 GW capacity by the end of 2020, including 13575 MW of PV by 2030 [3]. To date, significant growth is seen in PV power plants connected to the public electricity distribution network, where 16 plants with a capacity of 195 MW are already operational and inject clean energy into the grid network. Currently, renewable energy represents a small fraction of the global energy mix, where 16 plants with a total capacity of 195 MW are already operational.

With the presence of photovoltaic (PV) distributed generation systems, a variety of challenges reported in the research. The islanding phenomenon that can arise several technical problems, such as interactions between PV system and the grid network. Therefore, behavior of inverters operating in islanding is very important and complicated task. There are various factors that influence the islanding operation of PVs, such as:

- Topology of photovoltaic inverters.
- Relationship between electricity generation and load.
- RLC load behavior.
- Initial conditions at the islanding time.
- Anti-islanding protection technology.
- Type of network with the presence of PV systems.

Anti-islanding methods are typically classified into two: passive and active methods [4-7]. Passive methods are monitoring of (under/over-frequency) and monitoring of (over/under-frequency). These methods observe the the voltage magnitude and the frequency on the common connection point (PCC) and de-energize and disconnect the inverter if the permissible operating thresholds are exceeded. However, these methods are not 100% reliable. Therefore, active methods that intentionally introduce disturbances to the inverter output and observe whether the parameters such as active methods are the method of variation of the active power, the method of variation of the reactive power, the impedance analysis method.

In order to address such issue, there has been an increasing interest in researches. M. Bakhshi et al. proposed an islanding detection scheme based on adaptive identifier signal estimation method [8]. A novel anti islanding detection method for grid connected fuel cell power generation systems was presented in Ref [9]. G. Escobar et al. introduced a combined method for anti-islanding in PV inverters [10]. G. Xiaoqiang et al, give an Overview of anti-islanding US patents for grid-connected inverters [11]. V. Shashank et al. proposed data analytics and computational methods for anti-islanding of renewable energy based distributed generators in power grids [12].

The impetus for the presented article comes from the necessity to improve the performance of the first PVs connect to an institutional building at Renewable Energy Development Center (CDER) at the PCC. This work focuses on validation tests of pre-standard DIN VDE 0126-1-1 for the disconnection of transformers-free single-phase inverters, by studing two phenomena; the degradation of the resistance at the input of the inverter and the island detection for change of voltage imbalance

## II. Description of PVs and Monitoring System

This section describes the experimental PVs setup on CDER

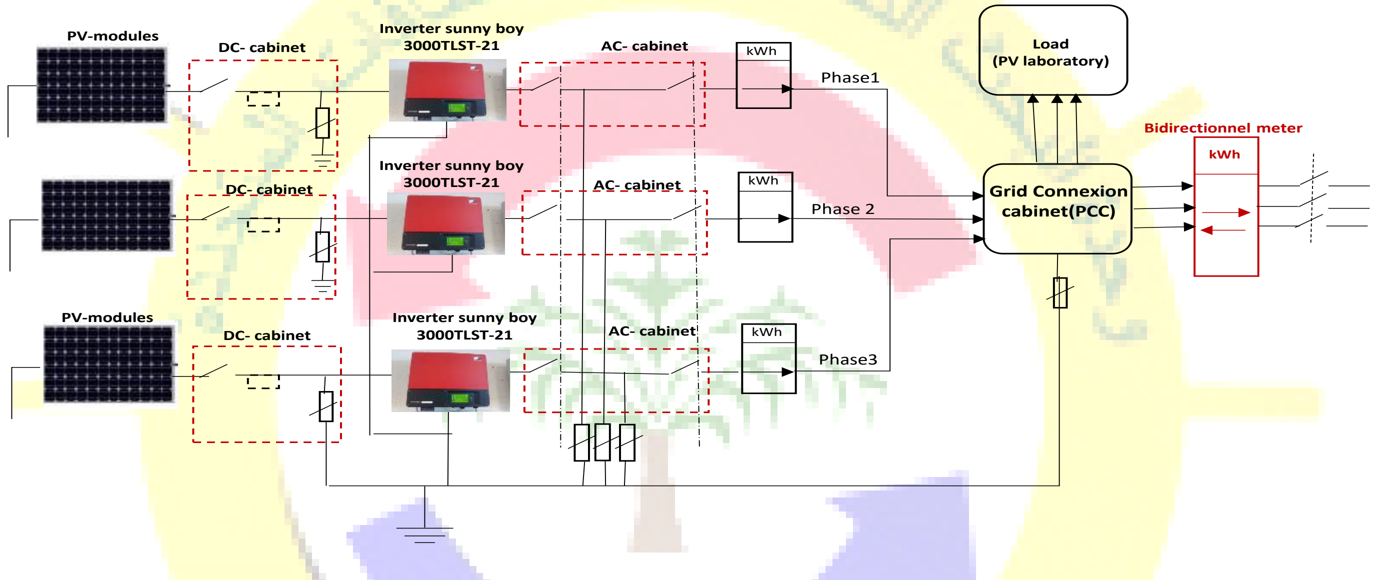


Figure.1 Electrical system diagram connected to CDER's building

### 1. *PV system description*

Fig. 1 shows the wiring diagram of the PV studied system. The PVs is made of 90 solar modules with an installed capacity of 10 kWp, covers a surface area of 70 m²; the modules are of type Isofoton with a rated power of 106 Wc and a rated voltage of 12 V. The PVs is divided into three fields of 30 modules gives an installed capacity of 3.18 kWp. Each PV field is structured in two parallel branches of 15 modules in series. The three identical fields are connected to the low voltage distributed grid through three single-phase inverters without transformer of the SMA type with a nominal power of 3 kW [13, 14].

### 2. *Inverter Sunny boy 3000TLST-21*

The inverters are SMA type Sunny Boy 3000TLST-21. The PV inverter is a single phase inverter without transformer with a rated power of 3 kW. Such type of installation causes a galvanic isolation between the public network and the PV array.

Moreover, the transformers can cause power losses up to 2 %, due to the metal core feature. Transformer less inverters therefore performs better than that occupied with transformer, which can rise up to 50 % to 70% smaller and inexpensive to produce energy [14-18]. Table 1 shows the inverter specifications, under rate conditions.

### 3. *Sunny Webbox*

Sunny web box is a central communication interface connected to the PVs, linked with a computer via a cable. It collects all the data of installed devices, allowing continuous monitoring of the PV system. All recorded data are held at the disposal of the operator by the sunny web box via an internet connection or a GSM modem [14].

In the presented work, data of the Web-box and the sunny portal for monitoring the variation of the RI and detection parameters anti-seizure protection according to DIN VDE 0126-1-1 have used.

TABLE I. Inverter specifications under rate conditions

| | Symbol | Parameter | Value |
|---|---|---|---|
| Input | PDC | Nominal Power | 3200 W |
| | IDC | The max input current | 15 A |
| | VDC | Input Voltage max | 750 Hz |
| | VDC | Input Voltage Min | 125 V |
| Output | PAC | | 3000 W |
| | cosØ | Factor of nominal power | 1:00 AM |
| | f | The frequency | 50 Hz |
| | V | Rated mains voltage | 230 V |
| | ɳ | Efficiency | 96% |

### 4. *CHAUVIN ARNOUX Equipment's*

The equipment to be studied from our test are CA 8335 and CA 6116N which offer excellent measurement stability according to international standards (IEC 60364-6, NF C 15-100, VDE 100, FD C 16-600, etc. .) and the various neutral systems (TT, TN, IT). The CA 8335 network analyzer is connected to the common connection point (PCC) by four MN 93 (200 A) current sensors and five voltage sensors to visualize the impact of the loads on the inverter composting. (Voltage, harmonic), and the grid controller CA 6116 is connected to the output of the inverter to measure the impedance at the moment of disconnection of the inverter.

### 5. *Inverter efficiency*

Fig.2 shows the variation of the inverter efficiency with inplane output power inverter. At low radiation level, the inverter efficiency appears somewhat disturbed, as the radiation level is less than 200W/m². Beyond 300 W/m2, it stabilizes around 96%.

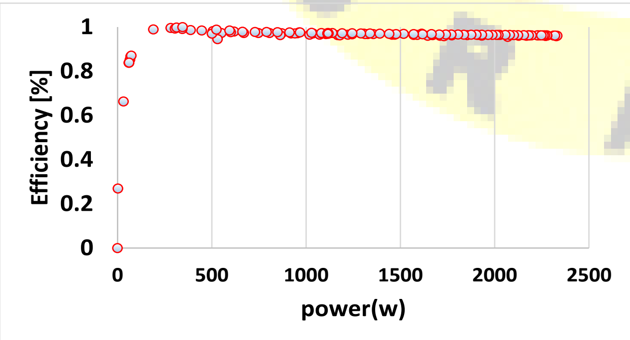


Figure. 2 Inverter efficiency against solar radiation

The main goal of DIN VDE 0126-1-1 is to provide a test procedure to evaluate the reliability of the disconnection prevention inverters due to detection the degradation of the insulation resistance at the input of the inverter, and detection of the monitoring between the PV system and the distributed grid [19].

## III. DIN VDE 0126-1-1 TEST DESCRIPTION

To validate test objective of DIN VDE 0126-1-1 of our installed inverter Sunny boy 3000TLST-21 (German products), a standard of automatic disconnection between the PV system and the public low voltage network. The abbreviation DIN stands for German standardization body (Deutsches Intitut für Normung), ie the characteristics of the inverters making them suitable for the decoupling protection function, the decoupling protection which makes it possible in particular to eliminate any risk of Electrocution in case of power failure for the staff involved in case of network default or PV generator risk in the absence of galvanic isolation [14]. Several methods for islanding detection have been tested. They can be classified into two main categories:

- Passive methods, which are based only on monitoring local measurements at the point of connection. PCC: over / under voltage, over / under frequency [17-19].
- Active methods which intentionally introduce disturbance into the grid in order to amplify the quantities deviation from the nominal values (the harmonic current, the impedance and the degradation of the energy quality at the PCC) [8-17-19],

According to the problems observed of our system, we will be monitored according to the standard the detection of degradation.

TABLE.II IR Thresholds and voltage of SMA Inverter

| Parameter | Symbol | Value | Disconnection time (ms) |
|---|---|---|---|
| voltage range | VAC | 180-280 V | 0.2 |
| frequency | f | 45-55 Hz | 0.2 |
| Impedance | Z | 1 Ω | 0.2 |
| Monitoring of the nsulation resistance | Riso | > 625 kΩ | 0.2 |

### 1. *Insulation resistance*

PV systems with transformer-less inverter are not galvanically insulated, the insulation resistance (Riso) becomes small due to the larger surface area of the generator, parallel installation of many photovoltaic panels, and insulation defects exists in different DC elements (generator, junction box, wiring) as only one short circuit can cause material and material damage [6, 20-22].when the inverter is a central element. It monitors the insulation resistance of the entire PV system, according to DIN VDE 0126-1-1, standard for safety reasons which indicates that the prescribed Riso value depends on the maximum input voltage of the inverter [22]. Where, Riso> 1 k Ω /V, but at least 500 k Ω.

*2. Anti-Islanding Protection*

The inverters use in our PV system is a SMA type made in German. In this country, the control of the separation of the upstream network (islanding) of the inverters for a PV installation is defined by the standar DIN VDE 0126 a first version date. This standard specifies the criteria that must lead to decoupling of PV installations in order to ensure the safety of material and people. These disconnection criteria relate to the network [8-14]. The correlation between the variation of the active power, reactive power, the frequency variation, and the tension thresholds and frequency compute the following models:

$$\Delta P = P_{load} - P_{pv} \quad (1)$$

$$\Delta Q = Q_{load} - Q_{pv} \quad (2)$$

$$P_{load} = \frac{V_0^2}{R} = P_{in} \quad (3)$$

$$\left(1-\left(\frac{V}{V_{\max}}\right)^2\right) \le \frac{\Delta P}{P_{load}} \le \left(1-\left(\frac{V}{V_{\min}}\right)^2\right) \quad (4)$$

$$Q_f\left(1-\left(\frac{f}{f_{\min}}\right)^2\right) \le \frac{\Delta Q}{Q_{load}} \le \left(1-\left(\frac{f}{f_{\max}}\right)^2\right) \quad (5)$$

$$Q_f = R\sqrt{C/L} = 1 \quad (6)$$

Riso insulation resistance, kΩ

$P_{load}$ active power load

$P_{pv}$ PV's active power

$Q_{load}$ reactive power load

$Q_{pv}$ PV's reactive power

$\Delta$P active power unbalance

$\Delta$Q reactive power unbalance

$P_{max}$ and $P_{min}$ active power thresholds

$f_{max}$ and $f_{min}$ frequency thresholds

$Q_{max}$ and $Q_{min}$ active power thresholds

$V_{ne}$ neutral ground voltage

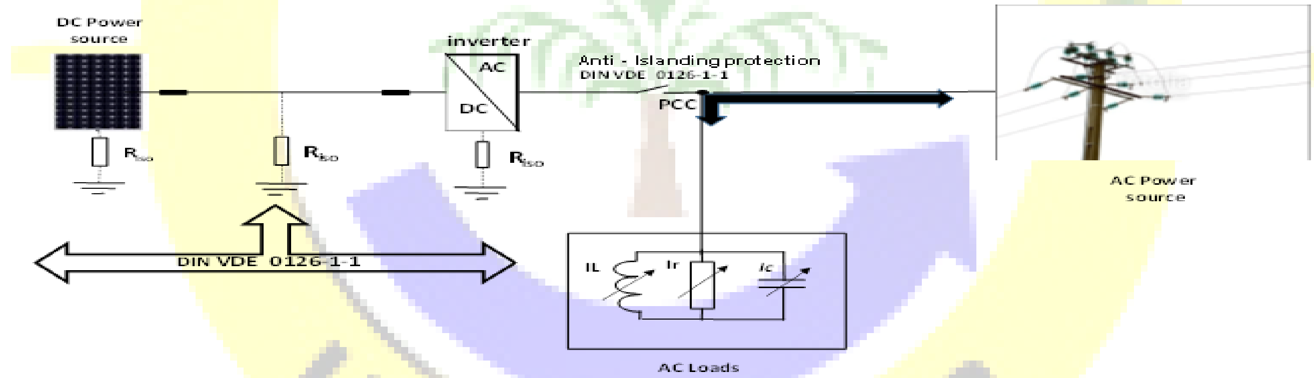


Figure.3 The Servility of the PV System According to DIN VDE 0126-1-1

## IV. RESULTS AND DISCUSSION

In order to analyze the power quality, an Experimental study on the protection of PV systems between the stability of the distribution network and protection in the absence of galvanic isolation is investigated. The given measure of the different days according to the factors influencing phenomena study are taken for the analysis.

*1. Insulation resistance*

Figure 4 illustrates the behavior of the inverter with respect to the variation of weather conditions (irradiation, rain) in a rainy day of March 15, 2017, and shows the disconnection of the inverter due to the degradation of the resistance of the inverter. Insulation according to DIN VDE 0126-1-1 in less than 0.2s which reaches less than 300 kΩ for about four hours as shown in figure 5.

2. Voltage Drop

Figure 06 shows the daily peak voltage at the PCC. For all PCCs and for a nominal voltage of about 230 V, the maximum and minimum voltages are 180 V and 280 V respectively. According to DIN VDE 0126-1-1, some exceed the operating limit of the voltage that has been affected by the load consumption of the PCC detected on the inverter.

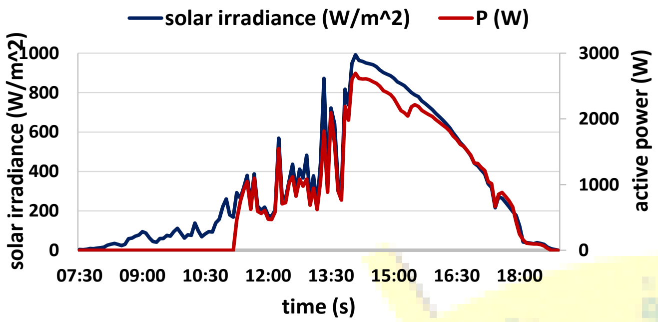


Figure.4 impact the degradation of the insulation resistance on the performance of the inverte

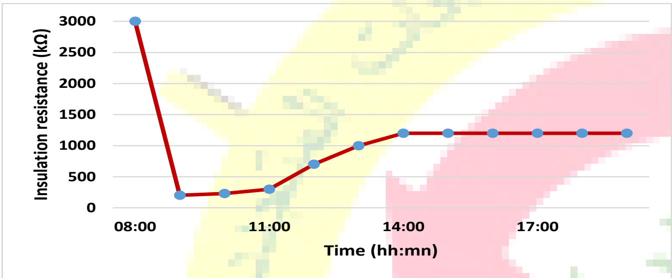


Figure.5 impact the weather condition on the value of the insulation resistance

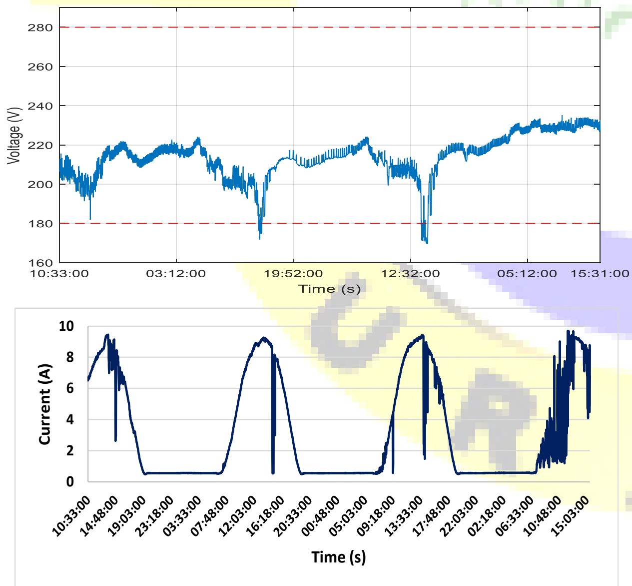


Figure.6 Detecting Anti-Islanding Protection Due To Voltage Drop

3. The Impedance to the PCC

Figure 7 shows the evolution of the PV system when the PCC equivalent impedance of 30/01/2018 which is suddenly increased by 1.6 Ω where (R = 1.675 Ω) and (L = 0.1 mH); which can be classified as an islanding situation, as a result, the monitoring system disconnects the converter from the network in less than 0.2 s. The reasons for this disconnection are related to the number of loads and harmonic pollution in this phase, as shown in Table.3.TABLE 3. Load influences on the harmonic distortion rate at PCC

TABLE 3. Load influences on the harmonic distortion rate at PCC

| THD | Value |
|---|---|
| $THD_v$ | 3.80 % |
| THDi | 67.30 % |

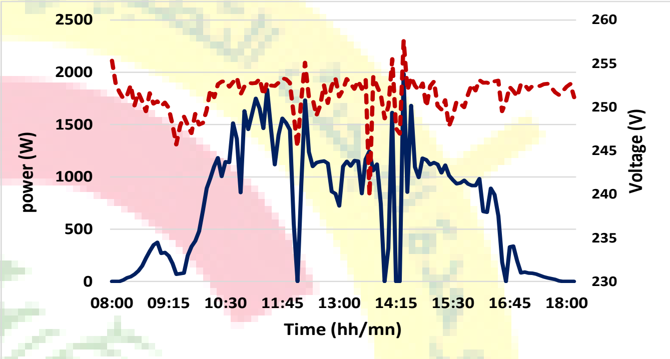


Figure.7 Detecting Anti-Islanding Protection due to Increase in Impedance

## I. CONCLUSIONS

In recent years, the energy efficiency and the ensuring a continuity of service have the most important elements on which the interests of research are examined. For this reason, the current issue for the renewable electricity is the protection of the PV systems between the stability of the DC and AC side (anti-islanding protection), and the protection in the absence of the galvanic isolation quoted DC (degradation insulation resistance). In this context, the inverters use the first network-connected PV system in Algeria (CDER) type SMA which are shown a model of protection performance. In this work, a detailed experimental study on voltage monitoring, frequency, impedance, insulation resistance, and earth faults according to DIN VDE 0126-1-1 standard is presented.

The experimental results make it possible to claim the main DIN VDE 0126-1-1 standard, where several conclusions are made

- The large area of the PV systems and the presence of fault on the entire DC side of the inverter influence the degradation of the insulation resistance under poor metrological conditions.

- The influence of the variation of several load parameters on anti-islanding performance on the PCC. These parameters (load distribution, power factor, and harmonic distortion rate) can positively or negatively affect the performance of this type of protection
- The harmonics of the current injected by the loads are transmitted to the PCC, which generally has a higher impedance than the grid. The interaction of the harmonic currents and the impedance of the network generates a harmonic voltage
- Influences the current harmonics generated by the non-linear loads connected to the PCC on the increase of the impedances and the detection of the anti-islanding protection by the active method, but of a value greater than one Ω which has reached a value 1

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