Comparison Study Between PV Inverters Available In The Palestinian Market

Primary Results

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***Abstract*—Our paper presents primary results of a comparison study between Chinese and German PV inverters having the same power class, topology and connection type but different prices. The selection of the inverters to be compared followed after analysis of a questionnaire addressing the most purchased PV inverters in the Palestinian market.**

Keywords— power system reliability ; PV inverters; PV market; renewable energy market in Palestine; renewable energy sources

I. Introduction

With increasing financial support for establishing renewable energy stations and sources starting from small individual stations of ca. 5 kW till very large scaled station of ca. 1 GW, an increase in the photovoltaic industry and market addressing small private customers can be observed worldwide. The Palestinian and Arab markets are not an exception. In the last 5 years, numerous of small and medium scaled respective companies have arisen in Palestine. The main business area of these companies are design , building and marketing of PV systems and components like solar modules and inverters.

Respective companies offer a wide range of PV components partially with the similar promised performances , power classes, efficiency , etc., but however with sometimes huge price gaps. Laity may trend to select the components of their system based on the attractive low price without considering reliability, efficiency and safety issues which as known could have an opposite economical effect on the customer in case of technically unreasonable decision.

As the inverters are the most expensive and sensitive component in the Photovoltaic system, we were motivated to start a project aims to provide customers and interested investors of/in photovoltaic systems a scientific based comparison study of PV inverters with the same category but with different manufacturers and price gap.

Analysis of the parameters and specifications that was studied and analyzed to be compared depended on: General inspections of the real devices, real measurements and studying the respective datasheets / manuals. Fig.1 shows both inverters under comparison mounted on for the study designed wall.

Fig.1: Inverters under Comparison (ABB left and OMNIK right) and Test Set-up

The in this paper presented results are considered to be primary comparison and evaluation results. Reliability and cycling tests for the most important internal devices and components are planned.

II. Inverters under Comparison

To select the inverters to be compared a questionnaire was designed addressing companies involved in renewable energy sector to find the specifications of the most popular PV inverters in Palestine . The questionnaire has shown that 69 % of the marketed inverters in the Palestinian market are On-Grid inverters. The rest 31% are Off-Grid type. Regarding the most popular power class of the by private customers purchased PV inverters in is 5 kW with 62,5% followed by 3 kW inverters with 37,5 %. As mentioned, the market for renewable energy sources offers a huge variety in components coming from different manufacturers and countries. Table I below summarizes the types and manufacturing country of the most by private persons purchased PV inverters based on the analysis of our questionnaire.

TABLE I: TYPES AND ORIGINS OF THE MOST MARKETED 5 kW ON-GRID INVERTERS IN THE PALESINEAN MARKET

Type	KACO	SMA	ABB	OMNIC	Others
Market share	4.5%	30%	30%	17.5%	18%
Origin	Germany	Germany	Germany	China	China, Taiwan and Israel

Based on these results we decided to select two inverters to be investigated and compared, the German ABB inverter and the Chinese OMNIK Inverter (see Fig.1).

More details about the inverters under comparison are shown in Table II.

TABLE II: SPECIFICATIONS OF THE INVERTERS UNDER COMPARISON

Model	**PVI-5000-TL-OUTD**	**Omniksol-5k-TL2**
Manufacturer	ABB	OMNIK New Energy Co.
Origin	Germany	China
Price [USD]	1300	1000
Power [kW]	5	5
Circuitry Topology	Transformerless, single phase	Transformerless, single phase
Number of DC inputs	2	2
Connection to Grid	On-Grid	On-Grid

III. COMPARISON CRITERIA AND RESULTS

A. Electrical Parameters

A.1 Efficiency

According to the datasheets, ABB inverter has a maximum efficiency (η_{max}) of 97%. The OMNIK inverter has a maximum efficiency (η_{max}) of 98,2 %, <u>however at a test input voltage of 360 V</u>.

Our self executed measurement for η_{max} resulted into a η_{max} = 96,07 % for the ABB inverter and 92,9 % for the OMNIK inverter. Table III summarizes the values of the efficiency for both inverters.

TABLE III: OFFICIAL AND MEASURED MAX. EFFECIENCY OF BOTH INVERTERS

Inverter	ABB	OMNIK
η_{max} - Datasheet	97%	98.2% (at V_{DC}= 360V)
η_{max} - Measured	96.07%	92.9% (at V_{DC}= 206V)

The max. efficiency (η_{max}) was calculated according to equation (1) below:

$$\eta max = {PAC,max}/{PDC,max} \qquad (1)$$

Where $P_{AC,max}$ was measured using VEGA-78 measuring device and $P_{DC,max}$ *was calculated* according to equation (2):

$$P_{DC,max} = V_{DC} \cdot I_{DC} \qquad (2)$$

Where $V_{DC} = 206\ V$ and $I_{DC} = 15\ A$ for both inverters

As we notice the ABB manufacturer doesn't link the in the datasheet provided efficiency with specified input voltage. Our efficiency measurement of the ABB inverter agrees widely with that provided in the datasheet despite that our measurement followed at ca. 57 % of the rated input voltage.

The manufacturer of OMNIK inverter links its provided efficiency values with the rated input voltage (360 V). Furthermore, a remarkable difference of ca. 6% between the provided and measured efficiency can be observed.

This leads to the assumption that the efficiency of the ABB inverter of ca. 96% shows a stable behavior and is valid among a wide range of input voltages which can be considered as a plus point for it compared to that of the OMNIK inverter.

A.2 Total Harmonic Distortion (THD)

To evaluate the quality of the output signals of the inverters, the Total Current Harmonic Distortion (THDi) is usually used [1].

Our Measurement of the THDi followed by the previously mentioned VEGA-78 where a DC voltage source was used as input power source. TABLE IV shows the in the datasheet provided and the measured THDi .

TABLE IV: OFFICIAL AND MEASURED CURRENT TOTAL DISTORTION (THDi)

Inverter	ABB	OMNIK
THDi - Datasheet	< 3.5 %	<2%
THDi - Measured	4.85%	5.46 %

Again a remarkable difference between the in the data sheet provided and measured THDi of the OMNIK inverter can be observed. However and to make reliable statements regarding this issue further investigations and measurements are necessary. Especially measurements by replacing the DC voltage source by real solar panels to obviate any influence of the type of the input voltage source on the THDi .

B. Protection and Safety

Compared to other electrical power sources, PV systems have specific requirements and considerations regarding safety and protection. This is due firstly to the involvement of DC and AC levels in one system and secondly to the harsh environmental operation areas of PV systems.

Modern PV inverters undertake important protection duties beside their main purpose, namely converting DC input voltages to grid and customer conform AC voltages. Therefore, protection performances of PV inverters play very important role in evaluation and reliability of today PV inverters.

B.1 Leakage Current Protection

Leakage currents (or ground faults) in electrical installations and devices are usually cleared by Residual Current Devices (RCD). RCDs detect the unbalance between entering and leaving electrical current in electrical system, which is a sign for leakage faults, and interrupt the electrical current within specified time[2]. According to the type of the leakage current they react to, RCDs are categorized mainly in 3 types:

- Type AC which detects only AC leakage currents and is cheapest and simplest choice
- Type A which detects AC and pulsed DC leakage currents
- Type B which detects AC, pulsed DC and smooth DC leakage currents (All-Current-Sensitive RCD).

According to German standard VDE 0126-1-1 and international standard IEC 62109-2, transformerless inverters must have a Residual Current Monitoring Unit (RCMU) on the DC side with three tripping levels and times depending on the increasing rate of the leakage current.

Both inverters under comparison have such unit. However, the ABB product manual contains detailed information about the specifications and location of its RCMU. At the same time, OMNIK manufacturer gives only general description about his RCMU. It is for example not clear where the RCMU is integrated (DC or AC side), at which kind of current does it react and how are its time and fault current limits. Therefore no statements can be done about its agreement with the respective standards and whether an external RCD on the AC side is required or not .

According to the above mentioned German and international standards, an external class B RCD must be installed on the AC side of transformerless inverters. The cheaper classes A/AC can be used in transformerless inverters <u>only</u> if the manufacturer guarantees that his inverter does not inject DC fault currents in the AC side. ABB recommends to install an external A/AC RCD on the AC side and the required guarantee can be found in the product manual [3]. However no recommendations or instructions of the required leakage current protection on the AC side can be found for the OMNIK inverter [4].

B.2 Overvoltage Protection

Overvoltages at the inputs and outputs of a PV inverter with destroying consequences especially for the sensitive electronic components. Main source for overvoltages is the inductive effect of lightning stroke and current. To protect electrical equipment and installations from overvoltages, varistors are usually used [5].

Thank the in the product manual provided topographic diagram of the ABB inverter and as shown in Fig.2, it was easy to identify the overvoltage protection measures used. The diagram shows that each of the two inputs of the ABB inverter is overvoltage protected by two varistors combined with a fuse (totally 4 varistors). One varistor is connected between plus pole and minus pole (VAR11) and another one is connected between plus pole and ground (VAR12) to eliminate the possible high voltage between the short circuited plus and minus pole (in case of response of VAR11) and the ground. The output of the ABB inverter is overvoltage protected by using two varistors however with gas discharge tube.

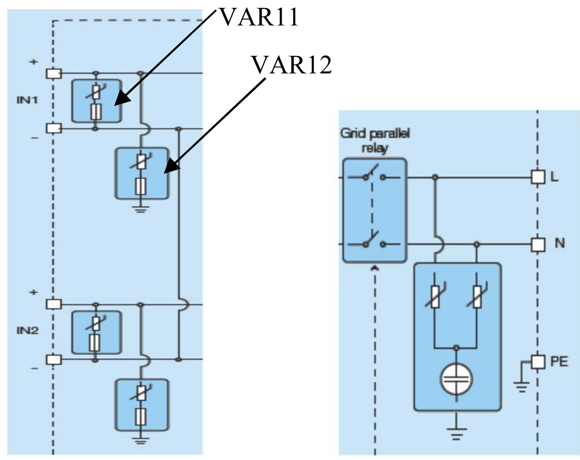

Fig.2: Overvoltage Protection of ABB Inverter at the Inputs (left) and Output (right) [3]

No data or information about the overvoltage protection measures in OMNIK inverter are provided either in the product manual neither in the website of the manufacturer.

C. Mechanical Parameters

C.1 Dimension and Required Safety Distance

The dimensions of the ABB inverter are (H $_X$ W) = 810 mm X 325 mm. This results into a net area of **263. 25 mm^2.**

The OMNIK inverter has clear smaller dimensions with (H $_X$ W) = 352 mm X 421 mm. Its area is then **148.192 mm^2 .**

It is obvious that the ABB inverter is almost 77% larger than the OMNIK inverter. <u>However</u> considering the by the manufacturers required vertical and horizontal safety clearance for better heat dissipation and as shown in Fig. 3, we find that the ABB inverter needs an occupation area of ca. 609 mm^2

where the OMNIK inverter needs an occupational area of ca. 618 mm^2.

That means the ABB inverter has a clear advantage compared to the OMNIK inverter regarding the required occupation area in case of installation of multi inverters.

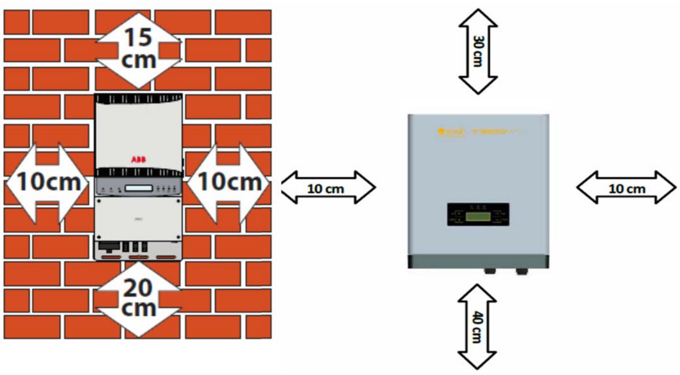

Fig.3: Required Clearance Distances for ABB Inverter (left) and OMNIK Inverter (right) [3],[4]

C.2 Cooling

ABB inverter depends 100% on natural convection for cooling its components using the advantage of the larger scaled heat sink. OMNIK inverter and possibly due to the smaller heat sink depends on combination between natural convection and electrical fan for cooling (see Fig.4).

Electrical fans and similar to all electrical devices are exposed to failure and require maintenance. Failures of the electrical fan means reduction of the cooling efficiency and financial drawback due to dropout of the system and disconnection from the grid for possible maintenance.

Fig.4: Cooling Systems of the ABB Inverter (left) and OMNIK Inverter (right)

Depending only on the natural convection and without any usage of devices that presents a source of failure could be considered as a plus point for the ABB inverter.

D. Other Comparison Criteria

D.1 Types and Brands of the Internal Integrated Components

Hence many manufacturers of electronic and electrical components conduct published reliability and life-time estimation tests for their products, it could be very helpful to know the origins, types and brands of the in the inverters integrated electronic and electrical components especially that of the used power electronics switches.

ABB has no information included in its manual about the brands of the in its inverter integrated components. On inquiry, ABB has also officially apologized from providing us this information.

OMNIK product manual contains a detailed key component list. The list includes 15 key components with brands from United States, Germany and Japan exclusively. The most electro –thermally stressed components, namely the power IGBTs, come from the German company INFINEON. INFINEON is one of the leading companies in production and developing of power electronics devices and systems. The company executes continually thermal and power cycling tests on its products with published results [6], [7].

No doubt that the transparency in providing the brands and origins of the components of the OMNIK inverter represents a plus point for its inverter and products.

D2 Provided Data and Instructions and After-Sell-Service

Both manufacturers have web sites with downable product manuals, instruction, certificates etc. Interaction sides to send questions and inquiries are also available.

The product manual of the ABB inverter contains detailed information and instructions about the product itself and helpful general instructions for installations and behavior of PV systems. All these information and instructions are compacted in one document.

The user manual of the OMNIK inverter is not so extensive. Many important information for the customer and technicians like internal topographic circuit and protection measures are missing or to be found in further downable documents.

The ABB company responses to our inquires and requests sent via the on its web site included portal. Unfortunately no response to inquiries from the OMNIK company was received.

IV. CONCLUSION

A German ABB and a Chinese OMNIK 5 kW, tranformerless, single phase, grid tied PV inverters were investigated under the same conditions.

The ABB inverter has shown advantages in the stability and high constancy in the efficiency and quality of the sinusoidal output current at different input electrical values. OMNIK inverter has shown obvious differences between the measured and in the data sheet provided efficiency and THDi. However it is important to mention that our measurements followed at values below the rated ones and this issue should be more intensively investigated.

Depending the ABB inverter on only the natural convection for cooling allows the elimination of possible failure source namely electrical fans. OMNIK inverters has integrated electrical fan as support for natural convection. A failure of the fan would lead to reduced cooling efficiency and/or disconnection from the grid for maintenance.

The detailed information and instructions provided by the ABB company allow customers and professionals to evaluate important specifications and measures of the ABB inverter and whether they fit with the respective national and international standards or not. Important information, especially regarding protection measures are missing in the used manual of OMNIK inverter.

A noticeable plus point of the OMNIK inverter is the transparency in providing customers the brands of the in its inverter integrated electronic devices. Considering the notable names of the manufacturers that OMNIK deals with left a positive indicator for high reliable internal electrical and electronic devices. Incomprehensibly, the German ABB stays closed regarding any information about the brands of the internal components of its inverter.

The presented results can be considered as primary results based on general external observations, measurements and manual analysis. Cycling tests for several internal components are necessary for reliability evaluation and life-time estimation. Measurements must be also accomplished under similar real life operation conditions. Especially using solar modules as source for input voltage.

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