International Journal of Engineering Sciences &Research Technology

(A Peer Reviewed Online Journal)

Impact Factor: 5.164

IJESRT

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

IJESRT
INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

QUALITY ANALYSIS OF HYBRID POWER SUPPLY (ELECTRICITY GRID-PHOTOVOLTAIC GENERATOR) OF WATER PUMPING SYSTEM DRIVEN BY INDUCTION MOTOR

Noma Talibi Soumaïla*[1], BoureimaSeibou[2], AdekunléAkim Salami[3] & Agbassou Guenoukpati[3]
[*1]Laboratory of Energy, Electronics, Electrotechnics, Automatics and Industrial Computing - AbdouMoumouni University, Niamey, Niger
[2]Mines, Industry and Geology school of Niamey-Niger
[3]Electrical Engineering Department, National Engineering School, University of Lome, Togo

DOI: 10.5281/zenodo.2668857

ABSTRACT
The availability of significant amount of solar energy in Sahelian countries can make the application of water pumping through photovoltaic generators very attractive solution for irrigation of agricultural land and drinking water supply to remote sites. This paper discusses the effect of harmonic currents on the energy efficiency of electromechanical equipment in a water pumping system. The electricity grid is already assumed to pollute upstream by non-linear loads in which the current is not proportional to the voltage applied. These harmonics do not produce active or reactive power, only losses by the Joule effect. The most important long-term effect is of a thermal nature, it results in the heating of the windings in electric motors, which leads to premature fatigue of the equipment, and thus to an ageing of the equipment. The photovoltaic generator, being an independent energy source, the main charge is the device under study. The quality of the electrical energy supplied provides more or less good performance for the electromechanical device. The results obtained showed that the supply of the motor pump by the photovoltaic generator via PWM inverter generates less harmonics compared to the electrical distribution network and allows an interesting improvement in efficiency.

KEYWORDS: Motor pump, Photovoltaic Generator, Efficiency, Harmonic.

1. INTRODUCTION
In recent years, there has been an increase in so-called non-linear loads on electricity grids related to computer equipment and power electronics. These loads contribute to the degradation of the supply voltage and can affect the proper operation of industrial equipment and processes. They generate disturbances, the main ones being voltage dips, harmonics and inter-harmonics [1].

To reduce or eliminate these disturbances and improve the quality of electrical power, various filtering systems have been developed and used, including passive filters. They eliminate current harmonics and also compensate reactive power. These traditional filtering systems have certain disadvantages such as: the appearance of resonance phenomena, additional costs, etc. [2]. An independent power source adapted to the electrical needs of an equipment could be a solution to harmonics caused by non-linear loads connected upstream to the electrical grid.

Solar energy is widely used to supply isolated or deserted areas (lighting, battery charging, pumping, etc.). The great advantage is that this source is inexhaustible, offers great safety of use and is clean (unpolluted) compared to the energy of the distribution network polluted by other non-linear loads[3].

The device under study is a variable flow water pumping system. The pumping system, including a hybrid power supply (electric grid - photovoltaic generator), a set of static converter (DC/AC), an asynchronous motor, a centrifugal pump and piping, is designed for small area irrigated areas[4]. After a theoretical study on the modelling of the power supply, the motor in the presence of harmonic pollution and the pump, we simulated

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

under Simulink/Matlab the power supply of the motor to the electrical grid and then by a photovoltaic generator. Finally, we set up a bench to carry out experimental measurements.

2. MATERIALS AND METHODS

a. Description of the experimental set-up

For experimental measurements, we have a measurement bench including:

- Computer equipped with Matlab software for simulation;
- Three-phase 380V/50Hz power supply between phases;
- Photovoltaic generator whose modules are interconnected in series and/or parallel to adapt the voltage supplied and the current required;

Table 1: Electrical characteristics of the photovoltaic module

Characteristics	Values
Standard irradiation G	1000w/m²
Standard temperature T	25°C
Maximum peak power	100 W
Maximum voltage	18.18 v
Maximum current	5.5 A
Open circuit voltage (V_{co})	21.8 V
Short-term current - circuit(I_{cc})	6.05 A
Number of cells in série(N_s)	36
Temperature coefficient (I_{cc})	0,065±0,015%

- Static converter (DC/AC),driven by PWM signals to obtain a quality voltage at the output;
- Induction motor, with a nominal power of 2.2 kW, a nominal current of 5.6 A and a nominal voltage between phases of 380 V. Table 2 shows the electrical parameters of the asynchronous motor;

Table 2: Electrical parameters of the asynchronous motor used in our study.

CHARACTERISTICS	VALUES
Stator resistance Rs (Ω)	**2,5**
Rotor resistance Rr (Ω)	1,74
Cyclic inductance at stator Ls (H)	0,2530
Cyclic inductance at rotor Lr (H)	0,2530
Cyclic stator-rotor mutual cyclic inductanceMsr (H)	0,24
Moment of inertia J (kg.m²)	0,05

- Centrifugal pump, directly fixed on the motor shaft, representing the motor load. It allows water to be pumped from the lower basin to the upper basin (the castle) with a nominal flow rate of 110 l/min;
- DIRIS A40 from SOCOMEC, a multi-meter device for measuring electrical quantities. It can measure currents, voltages, powers (active, reactive and apparent), frequency, power factor and harmonics of high voltage and low voltage single-phase, two-phase or three-phase networks;
- Tektronix digital memory oscilloscope of the TDS1001B range characterized by a bandwidth of 40 MHz, a maximum sampling frequency of 2 G samples/s on 2 channels. It allows the start current and steady state current spectrum to be displayed on a monochromatic LCD display. The particular interest of this device is that it allows to store removable data via a USB port on the front panel;
- An AC 1050 current sensor allowing to observe, in real time, the pace as well as the current spectrum.
- A burket brand flow meter with 12-36V/0.7A characteristics to control the flow of water at the pump outlet.

The structure studied consists of two power sources (a photovoltaic generator and the power grid), two variable frequency DC/AC converters, electrical wiring, an asynchronous motor coupled to a centrifugal pump, as shown in Figure 1.

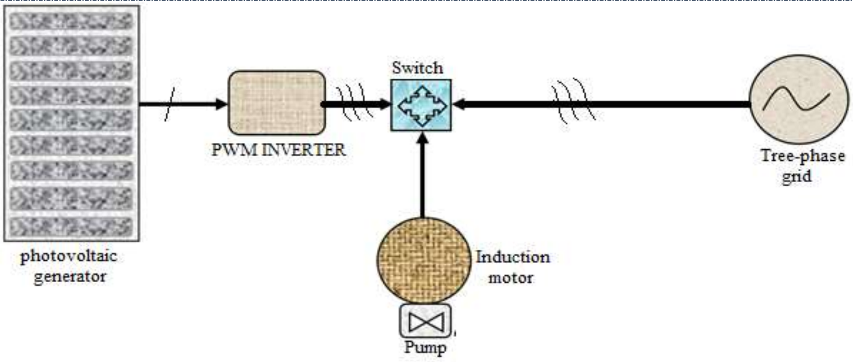


Figure 1: Overview of the device

b. Harmonic study

The harmonic rank **n** is the ratio of its frequency $\mathbf{f_n}$ to that of the fundamental, generally the industrial frequency 50Hz or 60Hz. As a matter of principle, the fundamental $\mathbf{f_1}$ has the rank **1**[5, 6].

$$n = \frac{f_n}{f_1} \qquad (1)$$

It is a histogram giving the amplitude of each harmonic as a function of the rank.

The amplitude is given in relative value with respect to the fundamental at a specified point

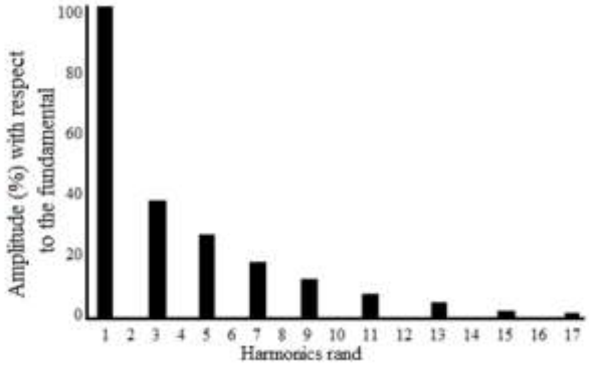


Figure 2. Spectral representation

c. The Harmonic Distortion Rate

Different criteria are defined to characterize this type of disturbance. The THD (Total Harmonic Distortion) and power factor are the most commonly used to quantify respectively the harmonic disturbances and the reactive power consumption [7]. The THD represents the ratio of the rms value of harmonics to the rms value of the fundamental [8, 9, 10]. It is defined by the relationship (2):

$$THD = \sqrt{\Sigma_h^{\infty} \frac{X_h^2}{X_1^2}} * 100\% \qquad (2)$$

With X_1 the rms value of the fundamental current (or voltage) and X_h the rms values of the different harmonics of the current (or voltage). In general, the harmonics taken into account in a power grid are less than 2500 Hz, which corresponds to the low-frequency disturbance range in the sense of standardization. Higher frequency harmonics are strongly attenuated by the skin effect and the presence of line inductances. In addition, the vast majority of harmonic generating devices have an emission spectrum of less than 2500Hz, which is why the range of harmonic studies generally extends from 100 to 2500Hz, i.e. ranks 2 to 50, [11, 12].

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

The TDH represents the ratio of the rms value of harmonics to the maximum value of the current called by the load [13]. It is defined by the relationship (3):

$$THD = \sqrt{\sum_h^{\infty} \frac{I_h^2}{I_L^2}} * 100\% \quad (3)$$

d. The power factor

For a sinusoidal signal, the power factor is given by the ratio between the active power P and the apparent power S. Generators, transformers, transmission lines and the control and measuring devices are designed for the nominal voltage and current. A low power factor value results in improper use of this equipment. In the case of harmonics, the power factor is degraded [7, 9]. An additional power appears called the deforming power (D) given by the relationship (4):

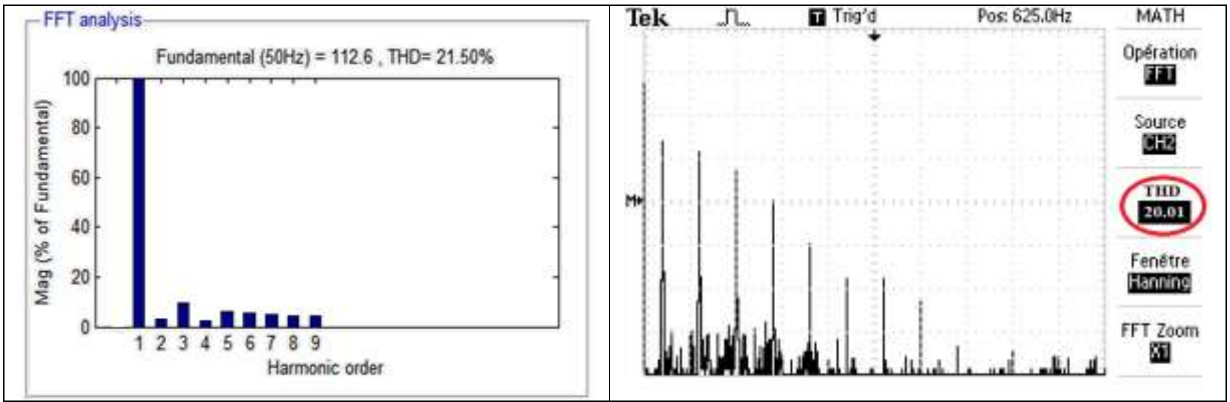
$$D = 3V_1 \sqrt{\sum_{h=2}^{50} I_h^2} \quad (4)$$

$$F.P = \frac{P}{\sqrt{P^2 + Q^2 + D^2}} \quad (5)$$

After modeling, simulation is necessary step before any practical implementation. Simulink is an extension of MATLAB software used for the simulation of linear and non-linear dynamic systems. In Simulink, mathematical models are represented by block diagrams. They highlight the structure of the system and allow to visualize the interactions between the different internal and external quantities. A particular distinction is made between feedback, reciprocal couplings, non-linearities, etc. In this paper, we used Simulink after mathematical modeling to simulate our study device.

3. RESULTS AND DISCUSSION

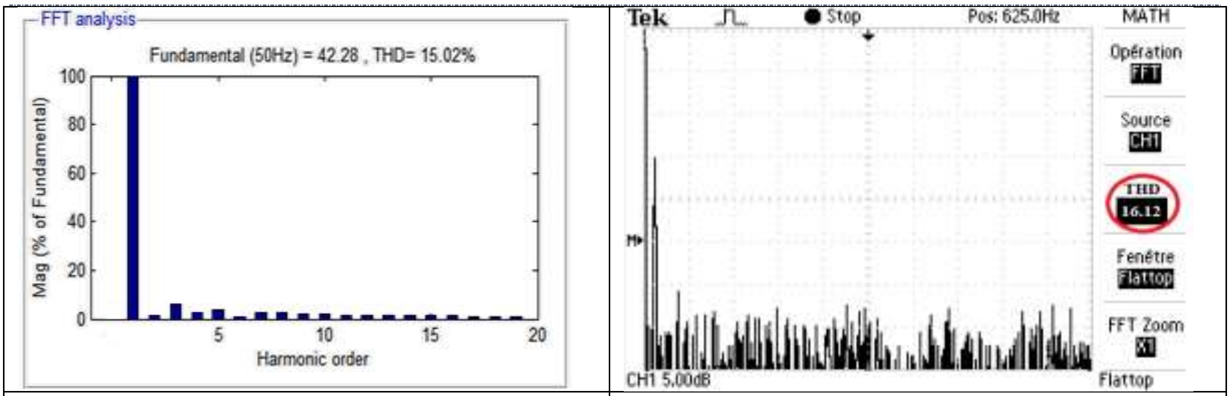
Figures 5 and 6 represent the harmonic current spectra of the two types of power supplies under study. The numerical values are summarized in tables for analysis.



a. Power grid simulation

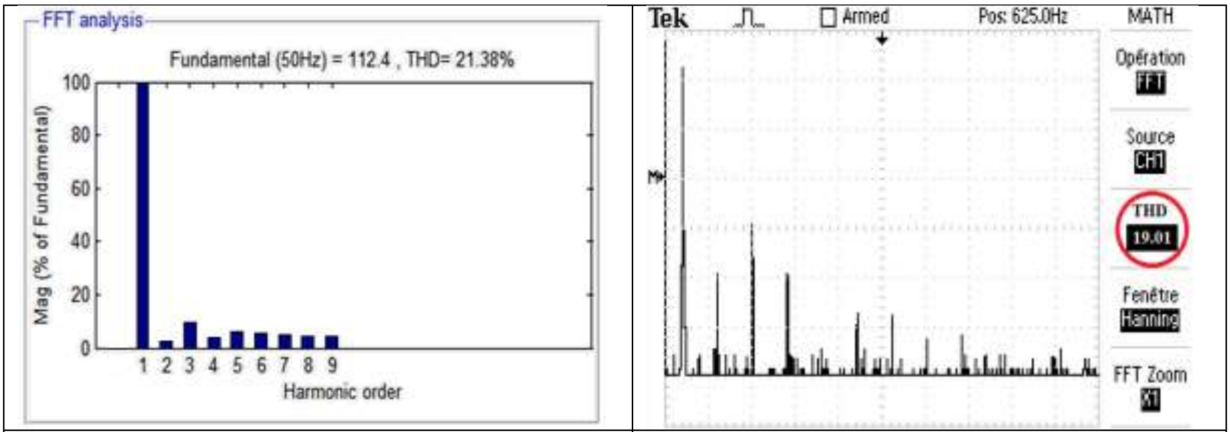
b. power grid experimentation

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

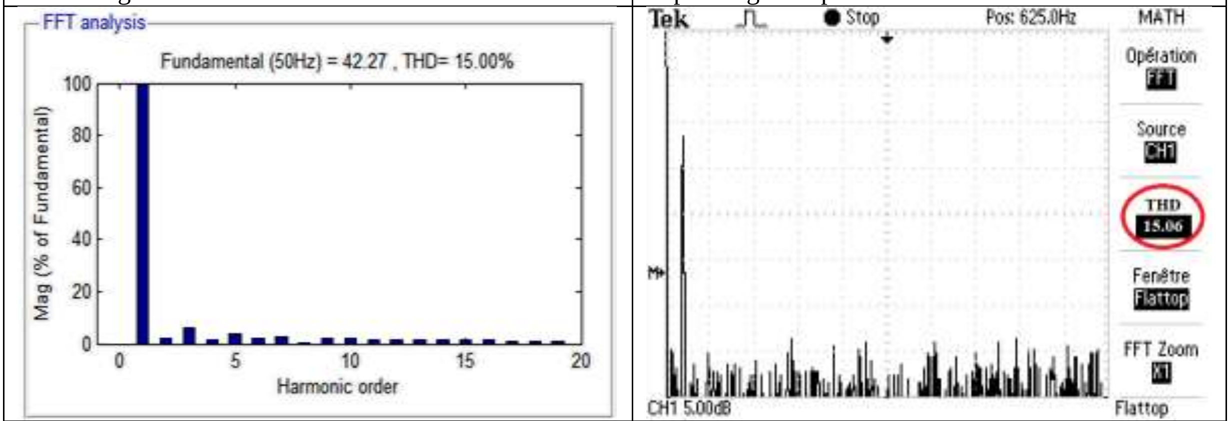


c. PV generator simulation | d. PV generator experimentation

Figure 5. Steady state current spectra over-load



a. Power grid simulation | b. power grid experimentation



c. PV generator simulation | d. PV generator experimentation

Figure 6. Steady state current spectra under load

Table 1: Simulation and experimental surveys of harmonic levels

	Simulation		Experimentation	
	Network connection	PV generator and PWM inverter	Direct connection	PV generator and PWM inverter
Empty	21.50%	15.02%	20.01%	16.02%
Load	21.38%	15.00%	19.01%	15.06%

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

Table 2: Experimental surveys of electrical and mechanical paramete

		Stator current (A)	Power absorbed			Power factor	Pumped water flow rate (l/s)
			Active (kW)	Reactive (kVAR)	Apparent (KVA)		
Direct network	Empty	1.75	0.92	0.64	1.12	0.62	-
	Load	3.8	1.52	2.15	2.63	0.70	1.80
PV generator and PWM inverter	Empty	1.45	0.70	0.66	0.96	0.74	-
	Load	3.5	2.02	1.09	2.30	0.88	2.45

Table 3: Experimental surveys of electrical and mechanical parameters with same flow rate

	Stator current (A)	Power absorbed			Power factor	Pumped water flow rate (l/s)
		Active (kW)	Reactive (kVAR)	Apparent (KVA)		
Direct network	3.80	1.87	1.90	2.61	0.71	1.50
PV generator and PWM inverter	2.70	1.66	1.3	2.10	0.79	1.50

Table 4: Experimental surveys of electrical and mechanical parameters with same stator current

	Stator current (A)	Power absorbed			Power factor	Pumped water flow rate (l/s)
		Active (kW)	Reactive (kVAR)	Apparent KVA)		
Direct network	3.05	1.38	1.45	2.00	0.7	1.32
PV generator and PWM inverter	3.05	1.62	1.17	2.00	0.81	1.63

Figures 5 and 6 show a significant increase in current spectrum peaks when the motor is idle. These peaks are very important in the case of the power supply to the grid compared to the photovoltaic generator. This is due to pollution upstream of the network by non-linear loads. Under load, there is a slight decrease in peaks because the motor is rated for operation. Table 1 confirms this variation in the harmonic levels generated in the engine.

At no-load start, the motor is too inductive. It consumes a lot of reactive power (0.64 KVAR with the electricity grid and 0.66 KVAR for the photovoltaic generator) leading to a decrease in power factor resulting in more energy losses. Under load, there is a significant reduction in reactive power due to the rated operation of the motor. The photovoltaic generator has a very significant improvement in power factor compared to the electricity grid. This reduces maintenance and increases the lifetime of the installation. With an absorbed power of less than 2.3 VAR when using the photovoltaic generator compared to 2.63 VAR for the electricity grid, a slightly higher water flow rate is observed in the first case. PWM significantly improves the performance of the inverter voltage, thus avoiding the deficiencies of conventional filtering methods. These are essentially the cancellation of low-ranking harmonics and the minimization of the current distortion rate. The currents flowing in the phases of the machine in established state then have properties closer to the sinusoid, thus improving the efficiency of the installation. This phenomenon has been demonstrated in other articles[13]. The power supply to the motor pump by the photovoltaic generator is more promising than that of the electricity distribution network, in terms of energy efficiency and harmonic current pollution, and therefore good electromechanical conversion efficiency.

4. CONCLUSION

In this article, our work focused on the analysis of the harmonics of the supply of a pumping system by the electrical distribution network or by photovoltaic generator. It focused more particularly on the analysis of the motor pump's performance in the presence of harmonics.

After having presented an analytical study on the supply of polluted electrical energy, we simulated the model of the engine powered by the grid and then by the photovoltaic generator. The results of measurements of the electrical parameters show that starting the motor from the grid already polluted upstream by other non-linear sources is more reactive than in the case of the photovoltaic generator, with a higher power factor for the latter.
An important remark in these results is the low current harmonics compared to grid feeding, which is explained by the consumption of clean (unpolluted) energy.

REFERENCES

[1] Patrick ESPEL and André POLETAEFF, "Power qualityanalysis: measurement of distortedsignals", Laboratoire national de métrologie et d'essais (LNE), REVUE FRANÇAISE DE MÉTROLOGIE, Volume 27, Issue 3, 2011.
[2] CHENNAI Salim, Study, Modeling & Control of Active Filters: Contribution of Artificial Intelligence Techniques, PhD thesis from Mohamed Khider University –Biskra, 2013.
[3] A. MOUSSI, A. SAADI, Comparative study between the techniques of optimization of the systems of photovoltaic pumping, 1, November, pp. 73-79, 2001.
[4] A. BETKA, A. MOUSSI, Maximum efficiency of an asynchronous motor powered by a photovoltaic source, n°02, pp. 151-162, 2003.
[5] Yue MA, Zhu Ling, An analysis and simulation of shunt hybrid active power filter, Proceeding ofInternational Conference on Electrical Machines and Systems, Seoul Korea, pp. 90-93, 2007.
[6] DzondeNaoussi Serge Raoul, Implementation of neuromemitic networks on FPGA target: Application to the integration of an active filtering system ", PhD thesis in electrical engineering, University of Stasbourg, (France),2011.
[7] Amaia Lopez De Heredia Bermeo, Advanced control systems for systems dedicated to improving energy quality: from low voltage to rising voltage, PhD thesis, Institut National Polytechnique de Grenoble, 14 November, 2006.
[8] Tony Hoevenaars, Kurt LeDoux, Matt, Interpreting IEEE Std 519 and Meeting its Harmonic Limits in VFD Applications", Copyright Material IEEE Paper No15. PCIC, 2003.
[9] Djeghloud Hind, Active Power Filtering, PhD Thesis in Electrical Engineering, University of Constantine, Algeria, 2007.
[10] R.P. Mukund, Wind and solar Power Systems, Ph.D, P.e U.S merchant Marine Academy, KingsPoint, New York, CRC Press LLC, 1999.
[11] C. Collombet, J. M. Lupin and J. Schonek, Harmonic Disturbances in Polluted Networks, and their Treatment, Merlin Guerin N°152, 1999.
[12] M. A. E. Alali, Contribution to the study of active compensators in low-voltage electricity networks:Automation of electrical power systems, PhD thesis, Université Louis Pasteur, Strasbourg I, (2002).
[13] A. Boumaaraf, and all, a new concept of the PWM control for the photovoltaic pumping system, Revue. Energies. Renewable. Vol. 5 pp: 139-147, 2002.