A Comparison of Output Waveforms of Different Alternating Current Sources and Uninterruptible Power Supplies of Various Brands

Abdul Rauf Bhatti[1], Abdul Ghafoor Bhatti[2], Muhammad Amjad[3], Yasir Saleem[4], Prof. Dr. Tahir Izhar[5], Muhammad Faisal Hayat[6]

[1,2]Electrical Engineering Department, GC University, Allama Iqbal Road Faisalabad, Pakistan
[4,6]CSE Department, UET, L-90 Staff Colony UET, G.T. Road, Lahore,
[3]Electrical Engineering, Islamia University, Bahawalpur, Pakistan
[5]Electrical Engineering Department, UET, G.T. Road, Lahore,
[1]bhatti.abdulrauf@gmail.com, [4]ysaleem@gmail.com

Abstract: Electrical Energy is the lifeline of domestic, industrial, agricultural and approximately every field of life. Generally available appliances at domestic and industrial levels are of Alternating Current (AC) nature that is they operate on Alternating Current. This type of Current can graphically be shown by pure sinusoidal wave. All of the appliances are designed to operate on pure sine wave but most of the electrical energy sources, converters and various types of Uninterruptible Power Supply (UPS) available in the market give the output which is not of pure sinusoidal wave shape and contains harmonics and interharmonics. These harmonics can cause overheating of the devices and many other problems that ultimately damage the device/appliance or at least decrease the life of electrical gadgets. This research is going to evaluate the shapes of these waveforms, their harmonics and then to establish a hierarchy among the sources on the basis of characteristics of their resultant output waveforms. For the purpose mentioned above, a very high range digital oscilloscope with ultra zoom capabilities has been used. It will provide ease to suggest a new buyer of the energy source in setting priority amongst the available alternatives qualitatively.

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1. Introduction

Pure electrical energy is excessively essential for safe working and long life of all electrical and specially electronics appliances. At present, the world is attaining continuous availability of AC electrical energy through electrical power sources and electrical power converters, both locally made and of different international brands, but most of the companies are not taking care of the quality of electrical energy; rather they are concentrating on cheap rates due to the market competition. These low quality sources and converters produce output electrical waveform of impure sinusoidal shape although approximately all available appliances at domestic and industrial levels are designed to operate on Alternating Current having the shape of pure sinusoidal wave as shown in Fig. 1.

Habitually, the commercial power systems were aimed on the basis of preceding engineering practices and information [1]. The impure sinusoidal waveform of low quality power sources contains harmonics and interharmonics in their output waveforms. So, it is the dire need of today to design not only cheaper but also energy sources of very high quality. This will be possible only when a buyer of these products will be well aware of their distorted output waveforms and their drawbacks enabling them more conscious than before about the product quality. So, as a thumb rule, whenever a selection decision is to be made among different alternatives, select not only the cheapest but also a more reliable source [2].

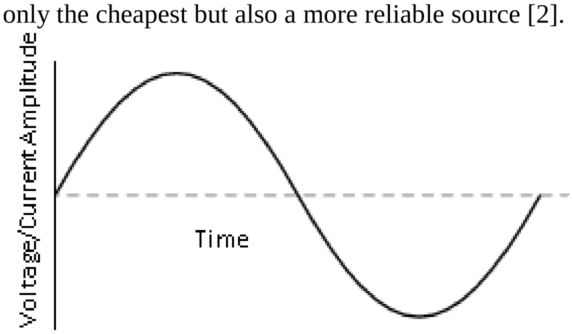


Fig. 1. Pure Sine Wave

Previously, a lot of research has been carried out on harmonics, interharmonics and their hazards but the research in this paper is an effort to give a common man an idea about the selection of the choice of energy source or converter on the basis of these hazards. The experiments were performed on physically and practically existing sources and converters locally made and of different national and international companies and are mentioned in the paper by the names as Brand 1, Brand 2, and Brand 3 and so on instead of real names of the companies. The actual record is kept with the authors. For this research, the authors used a very high range digital oscilloscope with ultra zoom capabilities and having different features required for the study of different aspects of output voltage. The UPS unit is a vital part of any computer system to promise constant stabilized voltage supply [3]. In any system linking power source, a distribution network and appliances, the characteristics of the system and user equipment interface are mutually dependent upon the design and operation of both [4]. Today's user has neither enough technical knowledge nor much time to check and evaluate every appliance but it's rather easy to choose the most suitable energy source or energy converter. This initial approach is a guide for advance research in this field to evaluate these sources and converters on the more technical basis which will become a complete guide for national and international manufacturers of these sources and converters. The comprehensive results of the research are briefly tabulated in Table 1. This work can be used for further R&D if we make deep analysis of sources and UPS on the basis of voltage regulation and efficiency respectively.

2. Harmonics

The electrical power system has been growing in complexity at a rapid rate in the last few decades [5]. System is becoming more and more polluted due to the intense use of power electronics converters and of low quality power sources which is a major cause of harmonics and interharmonics. Harmonics are the integral multiple of fundamental frequency that is 50 Hz in our case. The voltage driving the current through the load circuit is expressed in terms of frequency and amplitude. If load impedance does not change, the frequency of the current will be the same as that of the voltage. In a linear load (a resistor, capacitor or inductor), current and voltage will be of the same frequency. Provided that the characteristics of the load components do not change, the frequency component of the current will also remain unchanged. When we put up with non-linear loads like switching power supplies, saturated transformers, capacitors which charge to the peak of supply voltage, converters and UPS used in diverse fields change the frequency of current [6]. This changing current results in complex waveform which is due to harmonic and interharmonic components. Fig. 1 shows pure sine wave having only fundamental frequency, but Table 1 shows the wave shapes of different sources which are not identical to the wave shown in Fig. 1 except that of Water and Power Development Authority (WAPDA) source at Sr. No. 11 in Table 1. It means all the sources, except that of WAPDA, generate output voltage which contains harmonics or interharmonics apparent in the column named as "Types of contents" in Table 1.

The Effects of Harmonics:

Power system problems associated with harmonics are not common but it is probable for a number of unwanted effects to occur [7]. Harmonic distortion at high levels can become the basis of such effects as the increased transformer, capacitor, motor or generator heating, improper operation of electronic gadgets specially which relies on voltage zero crossing detection or is sensitive to wave form, wrong readings on meters, the wrong operation of protective relays, intervention with telephone circuits, etc. [7].

Elimination of Harmonics:

Companies can solve the troubles of harmonics inside their operations through numerous techniques [8]. These can be eliminated or at least minimized using isolating transformers, using shunt and series filters and by the increasing number of pulses by rectifiers using 12-pulse rectifier or even higher pulse rectifier for better results etc.

Interharmonics:

Interharmonics are voltages or currents having frequency which is non-integral multiple of the fundamental supply frequency [9]. Interharmonics are present in the power systems which have recently appeared as more significant due to the extensive exercise of power electronic systems. The order of interharmonics is the ratio of the interharmonic frequency to the fundamental frequency. If its value is less than unity, the frequency is also referred to as a subharmonic frequency.

The Effects of Interharmonics:

The most common effects of the existence of interharmonics are variations in root mean square (rms) voltage magnitude and flicker, thermal effects, low-frequency oscillations in mechanical systems, turbulence in fluorescent lamps and electronic equipment operation [9]. In practice, the operation of any equipment that is synchronized with respect to the supply voltage zero-crossing or crest voltage can be disturbed. Telecommunication interference, acoustic trouble and saturation of current transformers (CT) may be the results of interharmonics.

Elimination of Interharmonics:

Presently, there is no limit for the existence of harmonics that are non-integer multiples of the power frequency [10]. The interharmonics generated by some types of nonlinear loads limit the effectiveness of classical passive filter compensation, so active compensation must be incorporated for elimination of interharmonics [11].

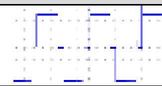
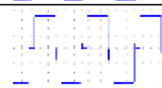
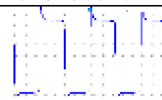
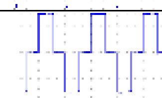
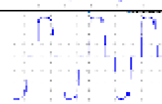
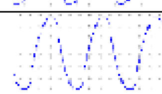
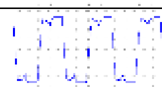
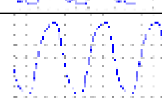
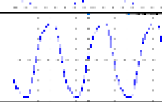
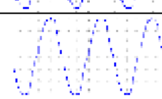
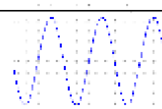
3. Material and Methods

As mentioned earlier, this paper is the outcome of practical work on different types of local made, nationally and internationally branded electrical power sources, converters and complete UPS using a very advance oscilloscope and measuring devices along with deep study of harmonics and inteharmonics related material. First of all, the output waveforms of different electrical power sources with complete information regarding their parameters have been plotted using digital high resolution and highly zoom capability oscilloscope. Their wave shapes are then categorized on the basis of frequencies. The summary of these results is presented in the Table 1.

4. Results and Discussions

The abridged results of research performed on different UPS, Converters and electrical generators of various brands are shown in Table 1.

Table 1. A Comparison of different types of UPS, power converters and AC Sources

Sr. No.	Brand Name	Source Type	Model	Rating	Wave shape	Frequency (Hz)	Type of the contents
01.	Brand 1	Power Inverter	A-1	600W		81.32	interharmonic
02.	Brand 1	Power Inverter	A-2	1kW		178.6	interharmonic
03.	Brand 2	UPS	Nil (Local)	600W		50.25	interharmonic
04.	Brand 3	UPS	B-1	600W		100.00	2nd harmonic
05.	Brand 3	UPS	B-2	600W		476.20	interharmonic
06.	Brand 4	Gas Generator	Nil (Local)	750kW		48.36	subharmonic
07.	Brand 5	UPS	Nil (Local)	750W		52.08	interharmonic
08.	Brand 6	Petrol Generator	C-1	5kW		49.75	subharmonic
09.	Brand 6	Gas Generator	C-2	5kW		48.54	subharmonic
10.	Brand 7	UPS	F-1	2.5kW		70.42	interharmonic
11.	WAPDA	Hydel Turbine Generator	Standard	Depends upon requirement		50.00	No harmonic

To elaborate the results as tabulated above, some of the output waveforms for more understanding with detailed information are shown in the graphs below.

The simplified waveform of Fig. 2 is also shown at Sr. No. 09 as Brand 6 in Table 1.

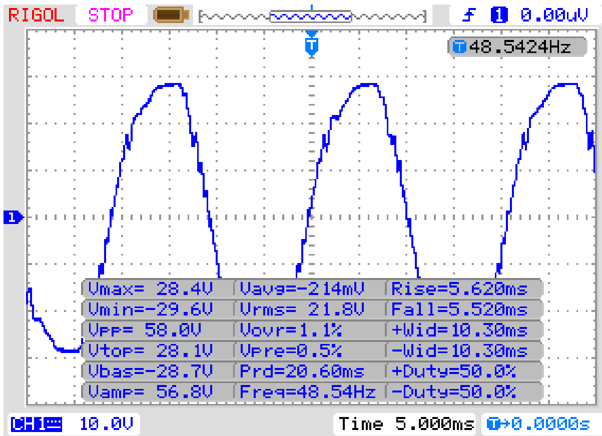


Fig. 2. Output Waveform of Gas Generator

Fig. 2 shows the output waveform of a gas generator containing subharmonics, a type of interharmonics. This is a little bit better waveform as this is not more deviated from standard pure sine wave like that of WAPDA which is shown in Fig. 3 below.

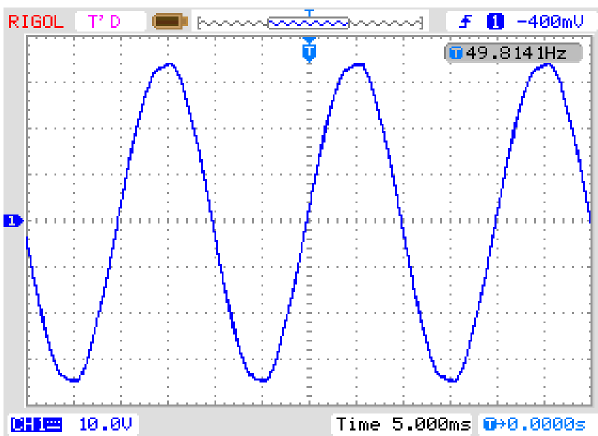


Fig. 3. Output Waveform of WAPDA Power Source

From Fig. 3 it is obvious that WAPDA generated electrical power has approximately pure sine wave like that in Fig. 1. It also has the frequency of 49.814 Hz which can be rounded to 50 Hz. During experiments, WAPDA supply at some locations was found having exactly 50 Hz frequency containing no content of harmonics and interharmonics. The resultant output for petrol generator is shown in Fig. 4 which is better than that of the gas generator but deviating more from sine wave than waveform of the WAPDA source. Most computer systems are linked to the main supply by on-line static UPS units to assure uninterrupted stabilized voltage supply autonomous of mains interruptions [3]. Fig. 5 shows output waveform of the international company made UPS also shown at Sr. No. 4 as Brand 3 in Table 1. In its detailed information it can be clearly seen that output has 100 Hz frequency as encircled in Fig. 5 that is it contains 2nd harmonic, also having very distorted waveform deviated from that of ideal one.

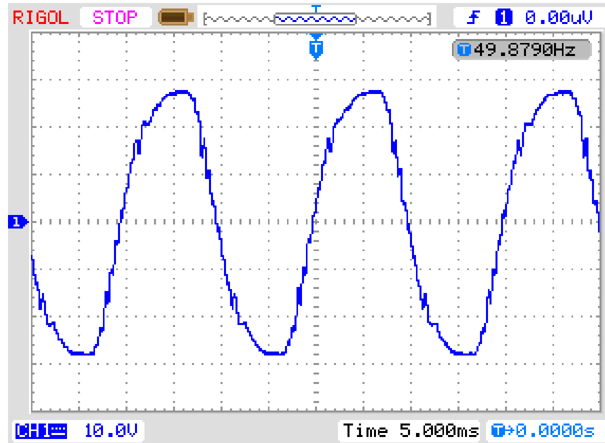


Fig. 4. Output Waveform of Petrol Generator

A second UPS of the same brand and of even same rating shown at Sr. No. 5 in the Table 1 has output waveform having 476.20 Hz frequency which indicates the low quality standard of electrical sources.

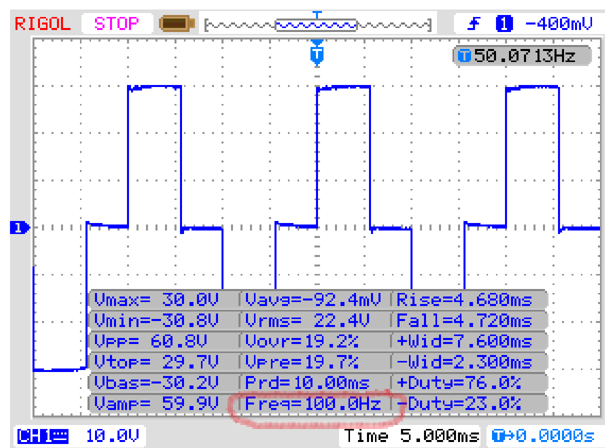


Fig. 5. Output Waveform of UPS

Power electronic converters generate characteristic harmonics, non-characteristic harmonics and interharmonics [12]. Fig. 6 also shown at Sr. No. 2 as Brand 1 in Table 1 shows the output waveform of a power converter having the frequency of 178.6 Hz again made of an international company, means it also contains interharmonics, but from Table 1, it is obvious that a power converter of the same company with different rating at Sr. No. 1 has 81.32 Hz output frequency which again clearly reveals the low quality products having still not up to the mark level of standard instead of a very advanced era of electronics engineering.

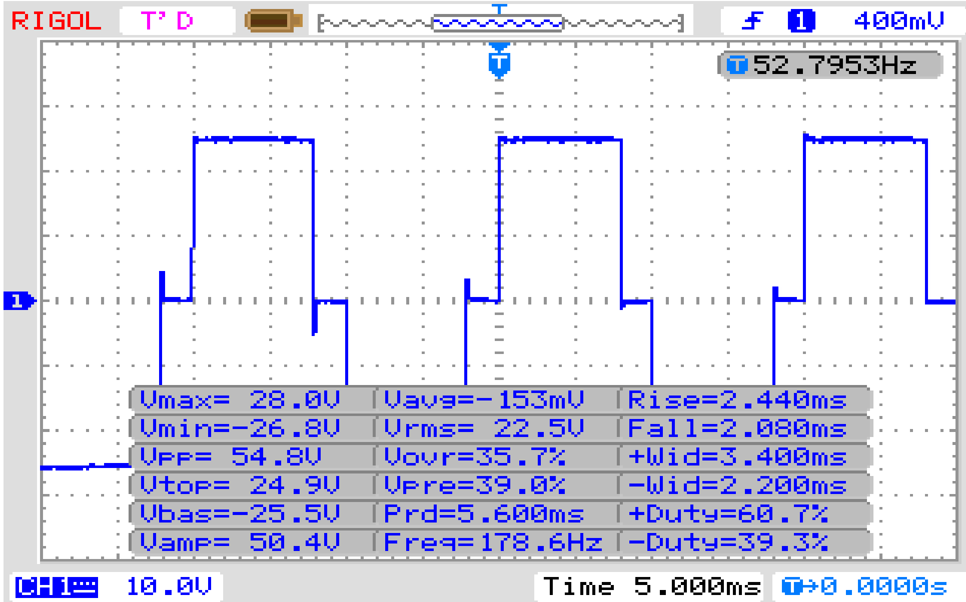


Fig. 6. Output Waveform of Power Inverter

Table 1 shows the results of 11 different power sources, power converters and UPS of different local, national and international companies and research was done on even more than the shown in the Table 1, but to avoid surplus details and for simplicity of the paper only few of the samples have been discussed just sufficient to replicate investigation.

From above discussion and waveforms of power sources, UPS and power inverters of different brands, it is obvious that more safe and suitable electrical energy source is of WAPDA in this research, 2nd preference goes to Brand 7, very costly UPS if affordable, 3rd for Brand 6 Petrol Generator then Brand 6 Gas Generator and rest should be avoided or should be kept in minimum use. More precisely, when we talk about UPS Brand 7 is best and in case of generators Brand 6 petrol generator is the best one. Moreover wave shapes and frequencies of power inverters are poorly deviated from those of WAPDA or any other ideal sine wave, so it is recommended to abandon the use of such inverters. This research is very useful for further R&D if we use the available data and get some more parameters like no load and full load voltage in the case of UPS and converters and input and output powers in the case of generators for the calculations of voltage regulation and efficiency respectively. The output waveforms and their frequencies obtained in this research are also very helpful for the designer of harmonic filters to design active and passive filters for different brands given in the Table 1.

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References

1. Abdul Rauf Bhatti, Abdul Ghafoor Bhatti, Rehan Liaqat, Saima Noreen, Erum Rehman. To check the reliability of different power sources and busbar schemes using etap. *Proceedings of 1st International Conference on Energy and Environment* 1, pp. 132-138 (2011).
2. Rehan Liaqat, Abdul Rauf Bhatti, H.T.Hassan. Management and Conservation of Electrical Energy in Industrial Units. *Proceedings of International Conference on Power Generation and Renewable Energy Technologies* 1, pp. 351-355 (2010).
3. El-Bakry, M.A., Aly, A.E.-M.M., Khalil, H.S., Shehata, S.A. An UPS with proper crest factor and efficiency for computer loads. *Proceedings of the 32nd Intersociety IEEE*, pp. 1726 - 1731 (1997).
4. Bizjak, B., Planinsic, P. Increasing power quality in systems with limited power sources. *47th International Symposium, IEEE*

transaction, doi: 10.06.05, pp. 401 - 404 (2005).
5. Kumar, V.S., Kannan, P.S., Sudhakar, T.D., Kumar, B.A. Harmonics and Interharmonics in the Distribution System of an Educational Institution - A Case Study. *International Conference on Power System Technology, IEEE transaction*, pp. 150 - 154 (2004).
6. Allen-Bradley. *Harmonics, What are Harmonics? Can they impact AC Drive Sales?* Rockwell Automation. United States (2007)
7. Robert G. Ellis, P. Eng. *POWER SYSTEM HARMONICS, A Reference Guide to Causes, Effects and Corrective Measures*. Rockwell International Corporation. Printed in Canada (2001).
8. Ontario Hydro. *Harmonics, The Energy Management Series*, Cos Phi Inc., Goderich, Ontario.
9. Zbigniew Hanzelka & Andrzej Bien. *Power Quality Application Guide*. Copper Development Association IEE Endorsed Provider, Brussels, Belgium (2004).
10. S. Mark Halpin, Vikas Singhvi. Limits for Interharmonics in the 1–100- Hz Range Based on Lamp Flicker Considerations. *IEEE Transactions on power delivery*, vol. 22, No. **1,** pp. 270 - 276 (2007).
11. D. Basic, V.S. Ramsden, P.K. Muttik. Hybrid filter control system with adaptive filters for selective elimination of harmonics and interharmonics. *Electric Power Applications, IEE Proceedings*, Vol. 147, Issue: 4. pp. 295 – 303 (2002).
12. Kus, Vaclav, Peroutka, Zdenek, Drabek, Pavel. Non-characteristic harmonics and interharmonics of power electronic converters. *18th International Conference on Electricity Distribution, IEEE transaction*, pp. 1-5 (2005).

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