Design of programmable electronic circuit for electrical power quality assessment and improvement

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This paper presents the efforts and the results of developing a new software codes and methodologies aimed to provide more flexible and efficient ways for assessing and improving the quality of power supply. The main objective of the introduced work is a construction of an automated generalized scheme that can be used for real time detection and identification of different types of power quality disturbances that produce sudden changes in the power quality levels. To achieve the goal, a programmable electronic circuit is designed and suggested for electrical power quality assessment and improvement. The designed electronic circuit depends mainly on the construction of hardware–software scheme that can be used for the distorted signals, supposed to be monitored at supply systems, to be automatically collected, transferred, and processed for further investigation and analysis processes.

يقدم هذا البحث طريقة جديده يمكن من خلالها القياس والكشف وتقييم جميع متغيرات جودة التغذيه الكهربيه بالاضافة الى وضع منهجيات وتوصيات فعليه يمكن من خلالها تحسين أداء منظومات توزيع القوى الكهربية. ولتحقيق هذا لغرض ، تم انشاء منظومة متكاملة(Hardware-software Scheme) يمكنها عمل محاكاة حقيقيه لجميع انواع الاضطرابات التى تقلل من جودة التغذية الكهربيه ، وعمل تحليلات كاملة ومفصلة لجميع انواع الاضطرابات المفترض وجودها بنظم توزيع القوى الكهربيه ، وأخيرا تم تقديم تقنيه مقترحه يمكن من خلالها الحد من تأثيرات الاضطرابات المختلفة التى تحدث تدنى لجودة التغذيه الكهربيه. وقد اعتمد التصميم المقترح على تصميم وأنشاء دائرة الكترونيه مبرمجه بالاضافه الى مجموعه من برامج الكمبيوتر المتقدمه والتى تم أنشاؤها خصيصا لهذا الغرض . وقد تم عمل عدة أختبارات لتقييم اداء الطريقه الجديده المقترحه لعمليات الكشف والتعريف بانواع الاضطرابات المختلفه وذلك من خلال حالات دراسيه متنوعه ومتعدده . وقد اظهرت النتائج التى تم الحصول عليها أن الطريقه المقترحه لها القدره على الكشف السريع والدقيق لمعظم انواع الاضطرابات ، كما ان لها القدره على تحسين اداء منظومات توزيع القوى وذلك بمعالجة وتقليل التأثيرات السلبيه الناتجه من وجود مسببات تدنى جودة التغذيه .

Keywords: Power quality disturbances, On-line power quality assessment, Power quality disturbance generator, And the decision-making system

1. Introduction

Quality of power is becoming a very important requirement in the new deregulated and restructured power systems. The importance is associated both with a need to have a “cleaner” power delivery due to a variety of sensitive loads and with a goal to provide a premium service to gain a competitive edge.

This paper proposes a method for automatic detection and analysis of voltage events in power systems. The proposed method estimates different categories of power quality disturbance signals using the design of a hardware device namely, Power Quality Disturbance Generator (PQDG), as shown in fig. 1. Such device, PQDG, is used to test the performance and the credibility of the linked software codes for detecting and analyzing the pre-defined distorted waveforms. For the achievement of the implementation of on-line automatic data transfer, a digital signal processor based system *(CIO-DAS08/JR-AO-DAC)* has been also used that is shown in fig. 2.

Several software program codes, using the applications of MatLab data acquisition toolbox, have been developed to *create* and *gather* data that can be classified as power quality events. Further programming codes are then executed for further processing and investigation of the distorted waveforms that gathered from real measuring fields or created as simulated test examples. The overall system is mainly to verify the purpose of this paper, which is the on-line monitoring and assessment the quality of power supply.

The performance of the suggested system is tested and verified through simulated and

Fig. 1. The constructed power quality disturbances generator.

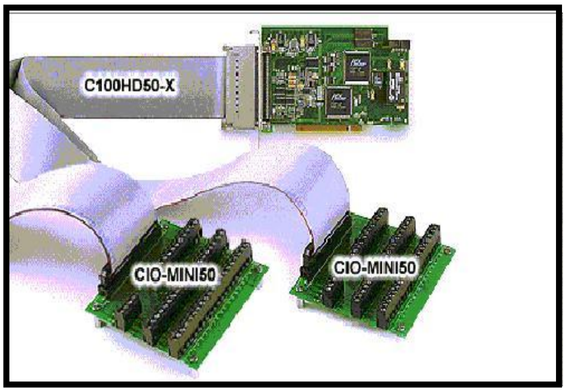

Fig. 2. The data acquisition card and 37-pin analog connector

real case studies. The obtained results reveal that, the suggested system, detects accurately most of the power quality disturbance events, introduces new indicative factors (new power quality indices) estimating the performance of any supply system, and suggests a reliable Decision Making System (feed back correction signals) for disturbance mitigation.

2. Historical background

The importance of power quality was primarily concerned with the fluctuations in voltage levels such as surges and sags. In addition, utilities have been assessed service quality using sustained interruption indices such as System Average Interruption Frequency Index (SAIFI) and Customer Average Interruption Duration Index (CAIDI). Today, many electricity consumers are adversely affected by inadequate supply systems due to the accelerated increase in sensitivity of end–use equipment. As a result of these and other quality concerns, many utilities indicating several indices and implementing different methods and methodologies to assess quality levels for both supply side and load side [1-4]. The objective of such methodologies is to construct a reliable power quality assessment scheme that would be a guide for utilities to satisfy customer needs and for the customers to ensure that the quality of supply is within the compatibility levels provided by their equipment.

In recent years, power quality phenomena have been investigated directly from actual recorded disturbance waveforms using widely available power monitor equipment. These disturbance recordings are stored as three-phase voltage and current time-series, which bring wealth information about the characteristics of the associated power quality events [5-7].

This paper introduces a new concept of advanced power quality assessment and improvement. The introduced system is implemented using the applications of powerful software (*MatLab6.5 tool box)* and a digital signal processor based hardware data acquisition system. The suggested scheme is mainly to construct a system for real time detection and identification of different types of power quality disturbances that produce a sudden change in the power quality levels.

3. Basic description of the proposed method

The basic model of the proposed method is shown in fig. 3.

The construction of the proposed system mainly depends on three processes; the monitoring process, the data acquisition process, and the decision making system algorithm. In the monitoring process, the status of the quality of power supply is picked from a real field using suitable measuring instruments for further investigations and analysis. Then, the captured signals are re-manipulated by suitable devices such as transducers or signal-conditioning devices to

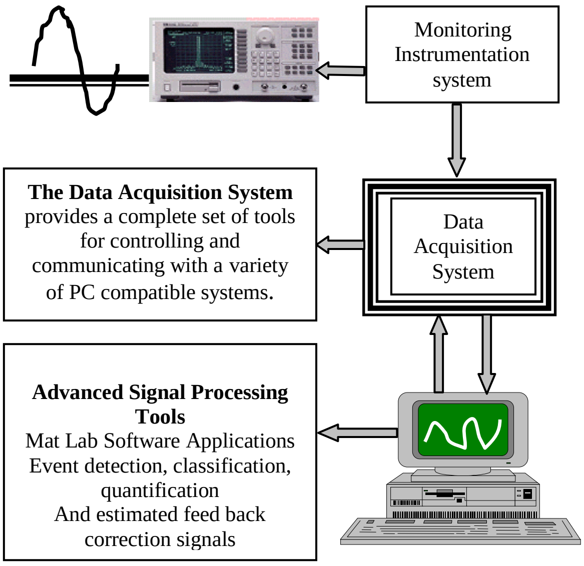

Fig. 3. General Schematic Diagram for the suggested on-line power quality assessment.

step down the voltage level to be compatible with the Digital Signal Processor devices.

In the data acquisition process, a data acquisition card is used and linked to the monitored signals and transfers it to a more applicable format which is the digital format. Once the signal being in a digital form, signal processing tools and different computer software applications can be implemented.

Finally, for the decision system, a set of software codes were used to analyze the distorted signals. The developed software is acting as on-line and automatically scheme that can, directly, deal with the digital waveform. The software codes are used to detect, classify, and quantify all power quality disturbance phenomena supposed to be found in the distorting signals. Moreover, feedback correction signals are suggested to enhance the performance of the supply system.

4. Test system

The proposed method has been tested and verified using a test system namely, Power Quality Disturbance Generator (PQDG),as shown in fig.1.

The designed Power Quality Disturbance Generator has the ability to generate real distorted waveforms correlated to the most common disturbance events supposed to be present in the distribution networks such as harmonics, sags, swells, and complete interruptions. Such device is used to test the performance and the credibility of the linked software system for detecting and analyzing the pre-defined distorted waveforms supposed to be monitored from real supply systems.

5. Simulation and experimental results

The proposed advanced method for power quality assessment is implemented and verified through the examination of detailed case studies. In the case studies, the new developed software program codes were used to investigate different simulated as well as real test signals that undergo different types of disturbance events.

Different types of time domain disturbance signals were simulated using the PQDG as test examples in order to test and verify the performance of the suggested software programming codes. The test signals supposed to be distorted with different categories of disturbance events. The following example is used to *test* the performance of the suggested complete hardware-software structure shown in fig. 4 as an on-line electrical power quality assessment system.

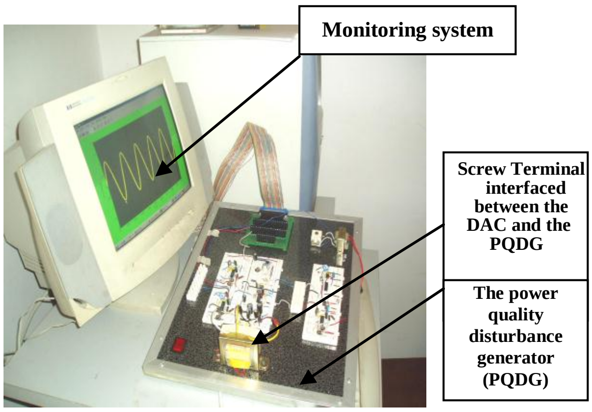

Fig. 4. Complete on-line structure.

The main purpose of this experimental example is to verify that the performance of the suggested system is acting as a complete on-line power quality assessment system. The mission has been executed as follows:

1. A typical distorted signal is generated using the PQDG, which is used to simulate the distorted signals supposed to be monitored at the supply system.
2. The data acquisition system succeeded in acquiring the status of the supply systems (simulated disturbance signals) from its raw format to the computer frame for further processing and analysis should be maintained.
3. The methodology of the suggested software algorithms is then applied to investigate the quality of power supply that indicated by the simulated test signal. The software is implemented to detect, classify, and quantify all power quality disturbance events that exists and disturbs the test signal. Moreover, recommendation actions should be stated for correction and mitigation purpose.

A generalized disturbance signal is generated using the PQDG and successfully acquired and monitored using the data acquisition system (DAS). The generated signal is used to test the performance of the suggested system. The test signal, shown in fig. 5, includes harmonic disturbance as well as root mean square (RMS) voltage disturbance phenomena (Complete Interruption Event).

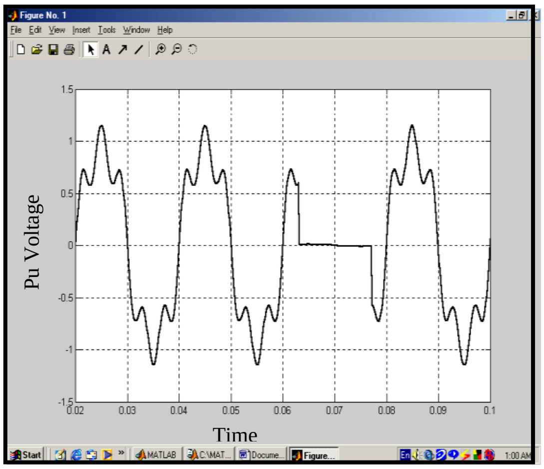

Fig. 5. Generated test signal for investigation.

The programming software codes are applied to the test signal and an output electrical power quality datasheets are obtained from the following main analyze/investigate processes:

5.1. Detection process

Two stages of detection process are applied to the test signal, harmonic detection process and RMS variation detection process. The detection process is mainly used to detect and extract all disturbance events supposed to be included in the test signal. The output from the harmonic detection process is well represented by fig. 6 and table 1.

Fig. 6 indicates that all harmonic contents are well detected and extracted from the test signal and become suffering only RMS voltage variation disturbance phenomena. Table1 indicates a comparison between harmonic contents that are extracted from the test signal using the proposed software and those known previously and used to generate the distorted signal.

The second stage of the detection process is the RMS voltage variation detection process. In such stage, the designed software code succeeded in detecting the start and the end points of each disturbance event as

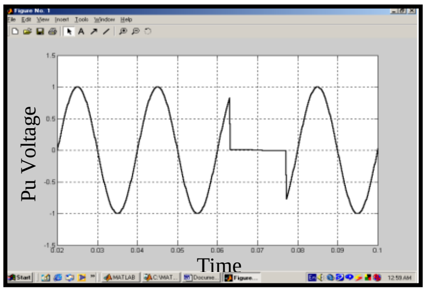

Fig. 6. Harmonic detection process, the test signal after harmonic detection / filtering process.

Table 1
The harmonic detection spreadsheet

Harmonic detection spreadsheet			
Generated		Detected	
Fund.	1.0	Fund	1.0
3rd	0.1	3rd	0,098
5th	0.25	5th	0.245

shown in fig. 7. Moreover a complement, namely pattern recognition diagram, is used for event classification where the magnitude as well as the duration of the detected event are specified, as shown in fig. 8.

As indicated, fig. 8 shows the result from the RMS voltage variation detection process. An RMS disturbance event was detected and marked by the (•) points, which are signed in the test signal. The (•) points indicate sudden undesirable changes in the RMS voltage variation and determine the start and the end points for each disturbance event detected during the detection process. While fig. 9 indicates a complete loss of RMS which indicate an interruption event.

5.2. Mitigation process

Power quality supply that represented by the supply waveforms is supposed to be ideal where there are no disturbance phenomena in the distribution network. Once a disturbance event is generated due to the existence of disturbing loads, the quality of power supply begins to be distorted and the voltage supply waveform starts violating from

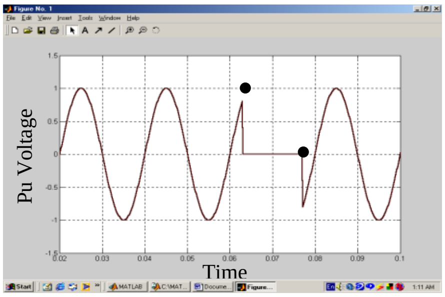

Fig. 7. Detection of start and end points of Rms voltage disturbance events.

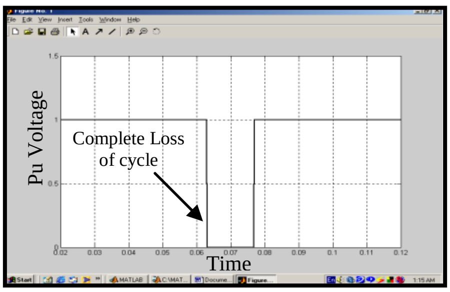

Fig. 8. Pattern recognition diagram.

the ideal waveform. The basic idea of the mitigation technique is that, how to formulate a compensation signal that can work against the disturbance signal. The addition of such compensation signal should act to cancel the effect of the disturbance signal so that the status of the quality of power supply returns

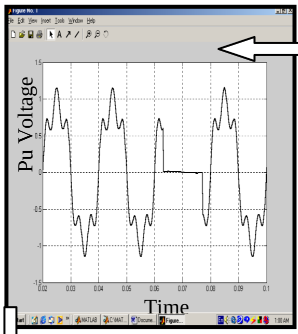

Fig. 9. Distorted signal under investigation

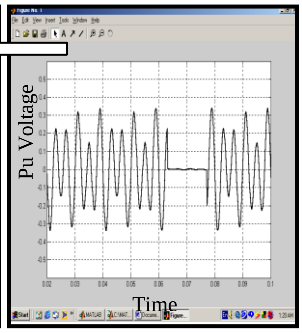

Fig. 10. Harmonic cancellation signal.

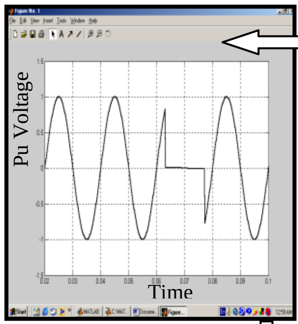

Fig. 11. Distorted signal still need compensation

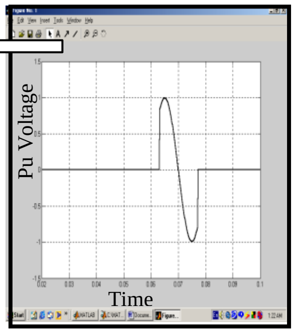

Fig.12. RMS Voltage Disturbance Correction signal

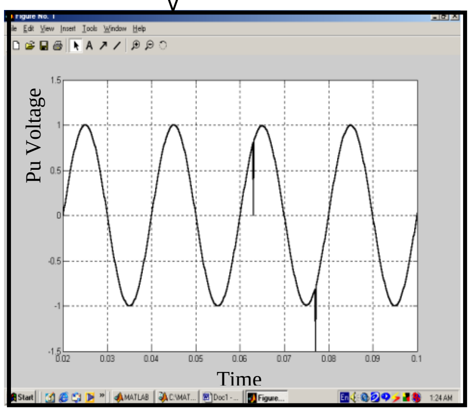

Fig. 13. Back to nature (almost pure sine) before melted by the disturbance events.

back again innocent/clean as it was before disturbance phenomena has presented in the distribution network.

Two types of correction signals are generated, the harmonic compensation signal, and RMS voltage variation compensation signal. Harmonic compensation signal should be injected so as to cancel harmonics that already presented and detected in the system. For example, a harmonic content characterized by 0.2 pu magnitude and with angle in-phase with the fundamental waveform, may be compensated by injecting a harmonic signal characterized by the same magnitude *but* acts out-of phase with the fundamental waveform. On the other hand, RMS voltage variation compensation signal should act to restore or damp the loss or the rise of voltage level that sensed and detected in the supply waveform.

For the given test example, two correction signals are generated for correction purposes, harmonic compensation signal, and RMS voltage variation correction signal. The complete process is well illustrated with aid of the figs. 9 to 13.

6. Conclusions

From the study the following conclusions can be derived:

- A generalized methodology has been suggested to assess and improve electrical power quality. The objective of the proposed work, the structure of software programs and hardware devices being used in each stage, and how they all correlate into the final goal of this paper are discussed.
- Good estimation and pattern recognition of the different power quality disturbances.
- Construct a powerful analysis algorithm for the Decision Making System in order to enhance the performance of the quality of power supply.

References

[1] M. Kezunovic, "Advanced Assessment of the Power Quality Events," 9th International Conference on Harmonics and Quality of Power, Orlando, October (2000).

[2] O. Poisson, P. Rioual and M. Meunier, "New Signal Processing Tools Applied to Power Quality Analysis," IEEE Trans. On Power Delivery, Vol. 14, pp. 561-566 (1999).

[3] E. Styvaktakis, M.H.J. Bollen and I.Y.H. GU, 2001, "Expert system for Voltage Dip Classification and Analysis," IEEE Power Engineering Society Summer Meeting, pp. 671-676.

[4] A. Moussa, M. Elgammal, E.N. Abdallah, and A. Abouelseoud, “A New Methodology for On-Line Power Quality Assessment, “IEEE Conference, The International Conference on Renewable Energy and Power quality”, ICREPQ’04, Barcelona - Spain, 31 March –2 April (2004).

[5] O. Poisson, P. Rioual and M. Meunier, "State of the Art in the Classification of Power Quality Events, An Overview," http://www.s2.chalmers.se/~flores/project/ paper_1.pdf

[6] Julio BARROS, Enrioue PEREZ, Alberto PIGAZO, “Real Time System For Identification of Power Quality Distribution,“ 17th International Conference On Electricity Distribution, CIRED, Barcelona-Spain, Session. 2, Paper (29) May (2003).

[7] M. Wang, G. I. Rowe, and A. V. Mamishev, “Real-Time Power Quality Waveform Recognition With A Programmable Digital Signal Processor”. www.ee. washington. edu/research/seal/pubfiles/34.pdf

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