

Article

# Design, Implementation, and Evaluation of Open Power Quality

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**Abstract:** Modern electrical grids are transitioning from a centralized generation architecture to an architecture which must accommodate distributed, intermittent generation. This transition also means that the formerly sharp distinction between energy producers (i.e. utility companies) and consumers (residences, businesses, etc) are blurring: residences can now both produce and consume energy, making energy policy more complex. The Open Power Quality (OPQ) project began in 2013 with the goal of designing and implementing a low cost, distributed power quality sensor network in order to provide make useful information about electrical grids available to producers, consumers, and policy makers. Since then, we have designed low cost hardware devices that monitor power quality and low-cost cloud-based software services that can economically analyze the data and detect a variety of anomalies. In 2019, we performed a pilot study where 15 OPQ hardware devices were deployed across the University of Hawaii microgrid for three months. Results of the pilot study provide evidence that OPQ provides a variety of useful monitoring services and that the system could be scaled to service larger geographic regions. We conclude that OPQ provides a new and useful approach to power quality monitoring.

**Keywords:** Power Quality, Open Source, Renewable Energy, Grid Stability

## 1. Introduction

The introduction should briefly place the study in a broad context and highlight why it is important. It should define the purpose of the work and its significance. The current state of the research field should be reviewed carefully and key publications cited. Please highlight controversial and diverging hypotheses when necessary. Finally, briefly mention the main aim of the work and highlight the principal conclusions. As far as possible, please keep the introduction comprehensible to scientists outside your particular field of research. Citing a journal paper [1]. And now citing a book reference [2]. Please use the command [1] for the following MDPI journals, which use author-date citation: Administrative Sciences, Arts, Econometrics, Economies, Genealogy, Humanities, IJFS, JRFM, Languages, Laws, Religions, Risks, Social Sciences.

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This section may be divided by subheadings. It should provide a concise and precise description of the experimental results, their interpretation as well as the experimental conclusions that can be drawn.

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## 2.1. Subsection

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Bulleted lists look like this:

- First bullet
- Second bullet
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Numbered lists can be added as follows:

1. First item
2. Second item
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All figures and tables should be cited in the main text as Figure 1, Table 1, etc.



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Text

Text

**Table 1.** This is a table caption. Tables should be placed in the main text near to the first time they are cited.

Title 1	Title 2	Title 3
entry 1	data	data
entry 2	data	data

Text

Text

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This is an example of an equation:

$$a + b = c \quad (1)$$

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The text continues here. Proofs must be formatted as follows:

**Proof of Theorem 1.** Text of the proof. Note that the phrase ‘of Theorem 1’ is optional if it is clear which theorem is being referred to. □

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### 3. Discussion

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### 4. Materials and Methods

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Interventionary studies involving animals or humans, and other studies require ethical approval must list the authority that provided approval and the corresponding ethical approval code.

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### 6. Patents

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### Abbreviations

The following abbreviations are used in this manuscript:

MDPI Multidisciplinary Digital Publishing Institute

DOAJ Directory of open access journals

TLA Three letter acronym

LD linear dichroism

## Appendix A

### Appendix A.1

The appendix is an optional section that can contain details and data supplemental to the main text. For example, explanations of experimental details that would disrupt the flow of the main text, but nonetheless remain crucial to understanding and reproducing the research shown; figures of replicates for experiments of which representative data is shown in the main text can be added here if brief, or as Supplementary data. Mathematical proofs of results not central to the paper can be added as an appendix.

## Appendix B

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## References

1. Author1, T. The title of the cited article. *Journal Abbreviation* **2008**, *10*, 142–149.
2. Author2, L. The title of the cited contribution. In *The Book Title*; Editor1, F., Editor2, A., Eds.; Publishing House: City, Country, 2007; pp. 32–58.

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