451-23-barragan

Power Quality Analysis of Photovoltaic Systems

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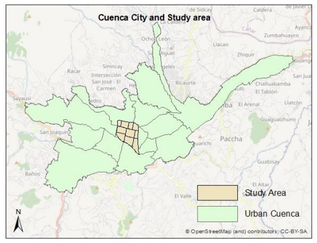
ABSTRACT

This research analyzes the quality of electricity generated by photovoltaic systems connected to the power grid in Cuenca, Ecuador. The study reviewed literature and regulations related to power quality in Ecuador, the US, and Europe to establish regulatory parameters and acceptable limits. The findings indicate that there are generally no power quality issues, except for momentary current imbalances. However, one case showed violations of voltage parameters, voltage unbalance, current unbalance, and flicker. The study recommends that individual harmonic distortion and frequency be added to the quality standards in Ecuador.

INTRODUCTION



Voltage fluctuations and harmonic distortions are common issues in photovoltaic (PV) electrical systems, which can lead to failures in electrical equipment and associated problems. In Ecuador, there have been efforts to promote renewable energy, particularly photovoltaic energy, with regulations and plans in place to support its development.

However, with an increasing number of grid-connected PV systems, there is a need to evaluate the safety and reliability of the power supply they provide. This study analyzes monitored data on the power quality of small residential or institutional PV systems in Cuenca, Ecuador, and compares the results with local regulations and international standards to assess their adequacy in ensuring acceptable power quality.

METHODOLOGY

Data from five PV systems are analyzed to assess the impact of PV connection on power quality in the distribution grid, compared to the permissible parameters set in current regulations. The study considers current and updated standards and regulations in the electrical sector, including national, American, and European standards, and analyzes key parameters such as voltage, current, unbalance, frequency, flicker, and harmonics.

The PV systems were installed and connected to the Cuenca distribution company, and power quality measurements were taken using equipment installed for a one-week period. The results were then compared with local, American, and European standards.

Table provides the main characteristics of each system evaluated:

Characteristics of the evaluated PV systems

Name	Power (kW)	Topology	Consumption (kW)	Plant Factor (%)
Poliéecnica Salesiana University	12,65	Three-phase four-wire	11,38	18,20
Azuay University	69	Three-phase four-wire	30,59	15,96
Cuenca University	15	Three-phase four-wire	0,96	5,23
Residential system 1	2	Two-phase three-wire	0,38	19,11
Residential system 2	1,34	Two-phase three-wire	0,012	10,14

For more details, please visit:

REFERENCE STANDARDS

National Standards:

- ARCERNNR 001/2021: State guidelines for regulating small size self-consumption systems connected to the grid and distribution companies for net-metering purposes.
- ARCERNNR 002/20: Defines limits on quality indexes for electric energy commercialization and distribution, and processes for registration, measurement, and evaluation.

American Standards:

- IEEE 519: Defines limits on harmonics in voltage and current waveforms for reliable power system operation.
- IEEE 1159: Describes the effects of electromagnetic phenomena on power circuits and analyzes power quality monitoring equipment.
- IEEE 1250: Assesses power quality limits, factors influencing system performance, and mitigation measures.

European Standards:

- EN 50160: Corrects low-voltage electrical operation installations at a common coupling point, applicable to any electrical system including PV systems interconnected with the power grid.
- IEC 61000-2-2: Provides comprehensive guidance for compatibility levels for each power quality parameter in public low-voltage power supply systems.
- IEC 61000-2-4: Divided into three classes to protect power supplies with high sensitivity to disturbances, connection points to the public grid, and internal connection of industrial facilities affected by short fluctuating loads.

RESULTS AND CONCLUSION

- The results of 5 case studies provide valuable information on compliance of PV systems with electrical parameters established by national and international standards
- Analyzed parameters include voltage, voltage unbalance, current unbalance, flicker, individual and total harmonic distortion, and frequency variation
- PV systems can achieve high levels of compliance with established parameters, especially in voltage and harmonic distortion
- All evaluated systems achieved 99.90% or higher compliance with voltage parameter
- All evaluated systems achieved 100% compliance with individual and total harmonic distortion parameters
- Some challenges and limitations include significant unbalance levels in some systems that can affect performance and efficiency
- Sources of current unbalance can be related to unbalance of loads, short circuits, or null generation of PV system due to lack of irradiation availability
- Flicker parameter also a limitation, with some systems exhibiting compliance levels lower than 99%
- Results highlight need for identifying causes of current unbalance and implementing corrective measures to improve system performance and need for further analysis and corrective actions for systems exhibiting lower compliance levels in flicker parameter.