

## Article

# Quantifying the Economic Impact of Supply Voltage Magnitude on Consumers

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**Abstract:** Increasing penetration of distributed energy resources is manifesting as voltage regulation challenges in many LV networks. Appropriate regulation of supply voltage magnitude is essential to ensure efficacy and efficiency in the operation of electricity supply networks and consumer equipment. While the theoretical impacts of supply voltage magnitude on the performance of consumer equipment, which include additional energy consumption and decreased equipment lifespan as voltage magnitude increases, are relatively well known, this has not been translated into quantitative impacts. This paper applies the outcomes of previous impact of supply voltage magnitude studies by the authors, in conjunction with domestic load models, to develop algorithms to estimate the quantitative impacts of supply voltage magnitude on consumers. The paper then applies these algorithms to calculate quantitative economic impacts that can be associated with the magnitude of the supply voltage. The outcomes of this research suggest that the per-annum impact of supply voltage magnitude on consumer equipment loss of life is potentially an order of magnitude greater than the resultant increased energy consumption based on case studies using Australian data.

**Keywords:** voltage; economic impact; power quality; supply voltage magnitude



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## 1. Introduction

Magnitude of the supply voltage is the most fundamental power quality (PQ) parameter and perhaps the most overlooked in terms of assessment of impact. For optimal performance, voltage magnitudes must be maintained within a range suitable for the operation and resilience of equipment. Voltage magnitudes that are too low (undervoltage) or too high (overvoltage) may result in equipment not operating as intended, a reduction in equipment lifespan, or—in extreme cases—catastrophic failure. While there are many qualitative sources, e.g., [1,2], that describe the impact of supply voltage on consumer appliances, there is no comprehensive body of literature that provides a quantitative assessment of the impact of sustained steady-state voltage magnitudes on consumers. This may be due to voltage levels historically being kept close to the nominal voltage in many jurisdictions or because few extensive measurement campaigns have been undertaken in LV networks. However, in recent times, voltage regulation and the magnitude of supply voltage in LV networks have received particular attention due to the widespread installation of smart revenue meters and the proliferation of rooftop solar photovoltaic (PV) generators. Rooftop solar PV generators can lead to increases in LV voltage magnitudes, also known as ‘voltage rise’ [3,4]. In addition, due to connection requirements and for their own protection, solar PV inverters will generally disconnect from the network if the sustained voltage magnitude rises above a threshold. While disconnection of solar PV inverters is a highly visible consequence of voltage magnitude excursions (through alerts to owners), studies have shown that the actual economic impact from loss of solar PV generation is likely marginal for the average consumer [5]. However, the studies have not taken into account the cost of

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