# Effect of Check Meter Quantity on Theft Detection in Distribution Networks with Rooftop PV and Net Metering

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## Abstract

The increasing demand for renewable energy has led to the rise of rooftop photovoltaics (PV) and net metering (NM). However, these technologies add a new dimension to energy theft detection, necessitating a more complex approach. This study aims to explore the effect of varying the number of check meters (CM) in distribution networks with rooftop PV and NM on theft detection algorithms, specifically for detecting meter tampering in households. The distribution network was modeled using the Ausgrid Dataset and the IEEE European Low Voltage Test Feeder on OpenDSS and Python. Several power flow simulations were conducted by varying levels of PV and NM penetration, and the number of houses connected per CM. The simulation data was then used to extract the following features: Gamma Deviance (GD), Log Cosh Loss (LCL), Percent Loss Error (PLE) and Poisson Deviance (PD). These were used as input to three machine learning algorithms: Support Vector Machine (SVM), Artificial Neural Networks (ANN), and Decision Tree (DT). The performance of each algorithm was measured through its accuracy. Then, Kendall's Tau correlation test was used to quantify the correlation between the theft detection accuracy and CM quantity. The results showed that LCL and PD exhibited a moderate to high correlation between theft detection accuracy and CM quantity at a 99% confidence level, and are more robust to varying levels of PV and NM penetration for all algorithms. This provides valuable insights into the development and implementation of theft detection systems which will not only reduce the risk of electricity theft but also further promote the transition to sustainable energy.

## Background

**Electricity theft** results in significant financial losses and power quality issues, so it must be prevented. One type of electricity theft attack is stored demand tampering wherein meter readings are manipulated to gain profit

**Net Metering (NM)** is an incentive mechanism used with rooftop photovoltaics (PV) that allows households to sell excess electricity generated to the distribution utility. It introduces new ways for consumers to tamper with meter readings as it allows pilferers to report higher generation values to gain profit.

**Check Meters (CM)** are devices used by distribution utilities to measure the supplied electricity to one or more consumers. Its readings do not change even if meter tampering occurs

**Machine Learning** algorithms have shown great potential in detecting electricity theft. It can be used to determine whether the difference between check meter and individual household readings is significant enough to be classified as theft.

**This project aims to study the effect of check meter quantity on the accuracy of theft detection in distribution networks with PV and NM**

## Methods

Household Data Acquisition and Cleaning

- Ausgrid Solar Home Data

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Power Flow Simulations

- IEEE European Low Voltage Test Feeder

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Benign and Malicious Dataset Creation

- Random multiplier from 0.1 to 0.8
- X = X * k for positive net consumption
- X = X - (|X| * k) for negative negative net consumption

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Feature Extraction and Labelling

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SVM Training | ANN Training | DT Training

SVM Testing | ANN Testing | DT Testing

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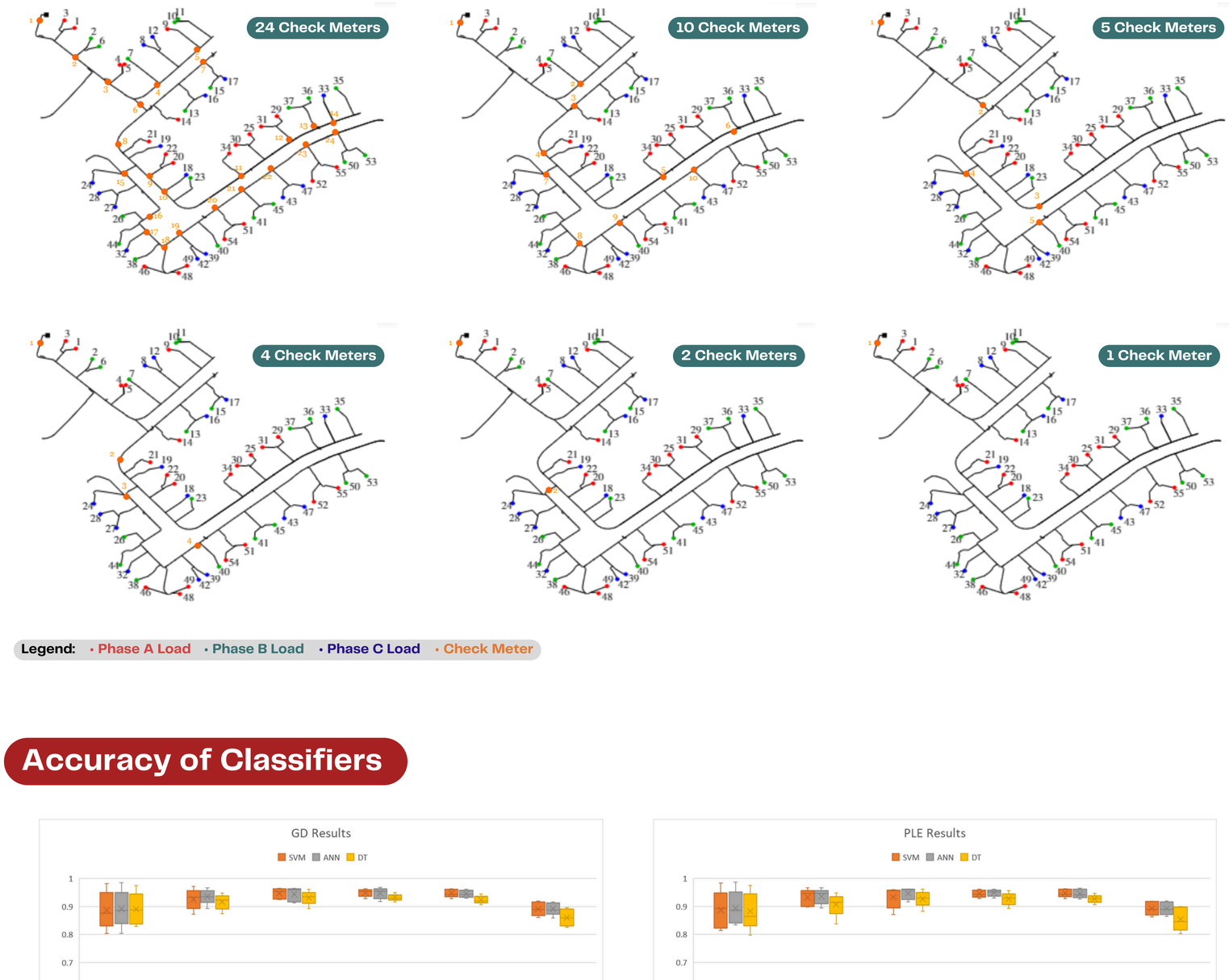
Performance Assessment

- Kendall's B-Tau Correlation Test

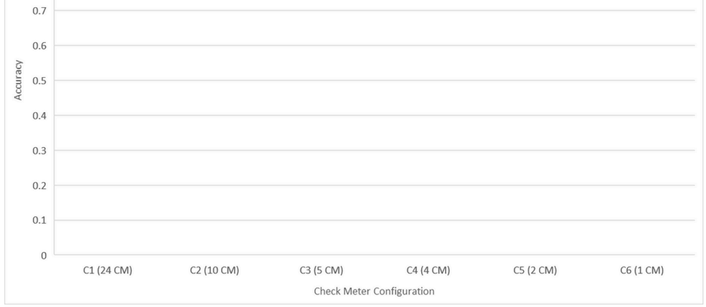
## Key Findings

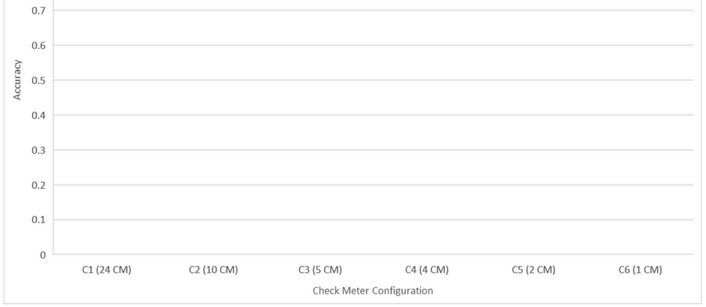
When Poisson Deviance or Log Coss Loss are used as features, the theft detection accuracy increases as the number of check meters in the network increases. On the other hand, theft detection accuracy and check meter quantity are not correlated when using Gamma Deviance or Percent Loss Error as features.

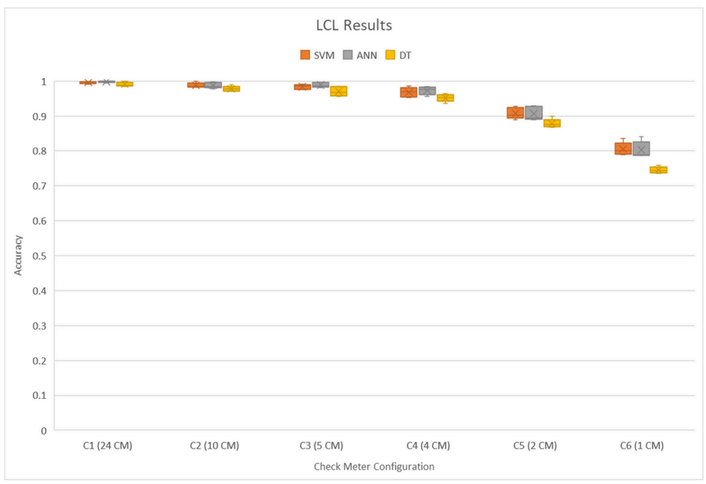
## Check Meter Placements

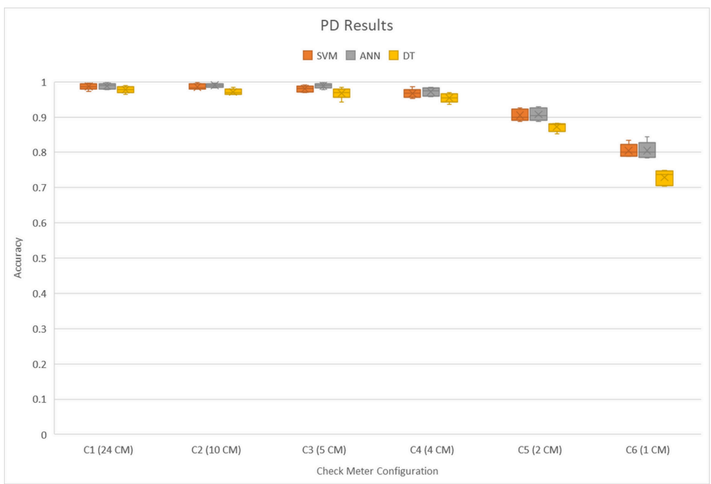



## Accuracy of Classifiers




## Correlation of Theft Detection Accuracy and Check Meter Quantity

**Magnitude and sign of tau corresponds to the nature of correlation when p<0.01**

**SVM**

| Feature | tau | p |
|---|---|---|
| GD | 0.007 | 0.957 |
| PLE | 0.015 | 0.913 |
| LCL | 0.829 | <0.001 |
| PD | 0.755 | <0.001 |

**ANN**

| Feature | tau | p |
|---|---|---|
| GD | 0.065 | 0.637 |
| PLE | 0.057 | 0.676 |
| LCL | 0.831 | <0.001 |
| PD | 0.714 | <0.001 |

**DT**

| Feature | tau | p |
|---|---|---|
| GD | 0.135 | 0.327 |
| PLE | 0.065 | 0.637 |
| LCL | 0.859 | <0.001 |
| PD | 0.756 | <0.001 |

**Main References**

R. M. P. Maala, A. M. B. Rebamba and A. E. D. Tio, "Classification-Based Electricity Theft Detection on Households with Photovoltaic Generation and Net Metering," TENCON 2023 - 2023 IEEE Region 10 Conference (TENCON), Chiang Mai, Thailand, 2023, pp. 1094-1099

C. Lavilla, M. Osorio, and Z. Restituto, "Effect of Net Metering and Rooftop Photovoltaics on Electricity Theft Detection," Capstone Project, EEEI, University of the Philippines, Diliman, 2021.

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