IRES Cyprus Project: Quantum Machine Learning for Monitoring PV Faults with an Emphasis on Detecting Soiled Panels

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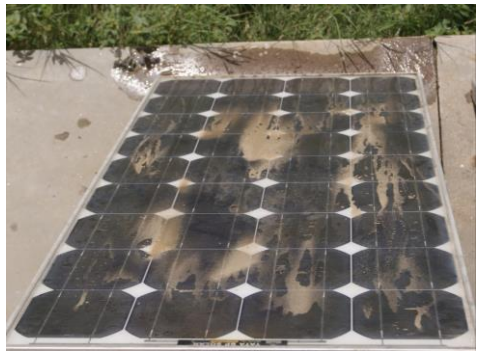
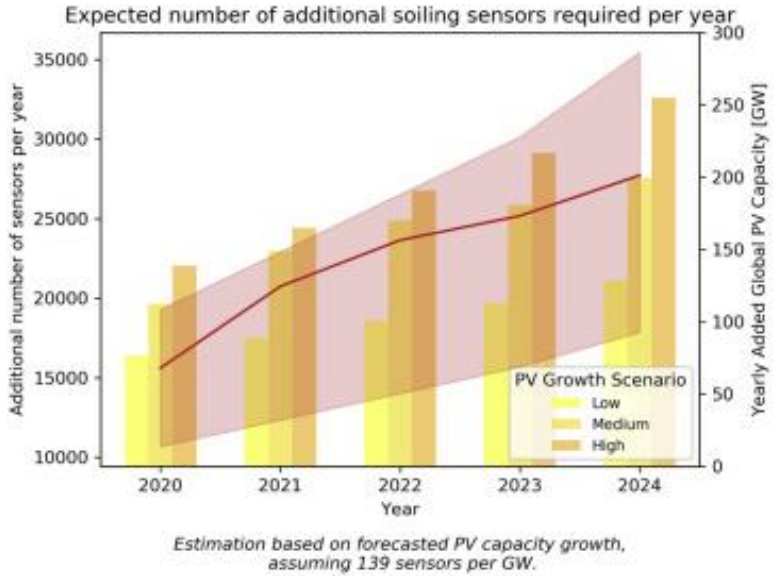
Presentation Agenda

- Problem Statement
- Previous Work
- Pre-training at ASU
- Classical ML Algorithms
- Quantum ML Algorithms
- Conclusions
- Reflection and Self Assessment
- References

Problem Addressed

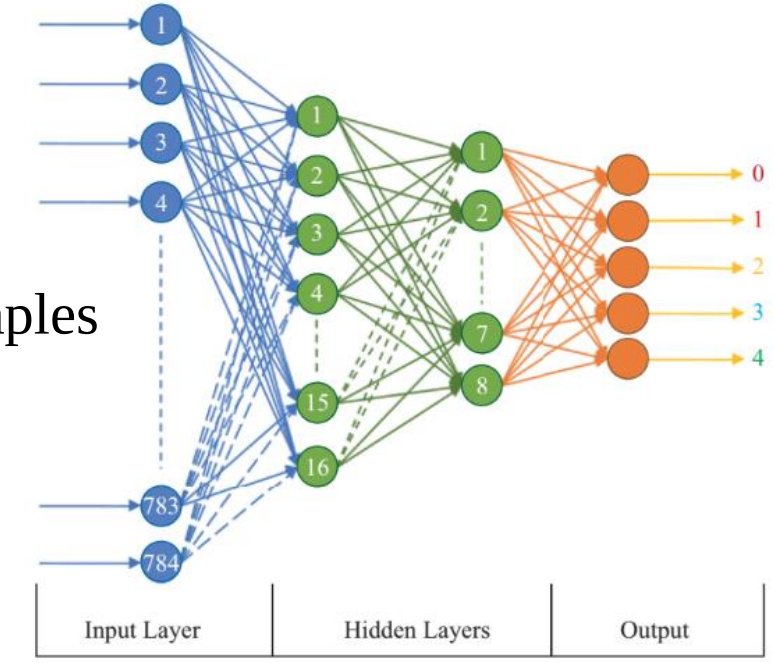
- Solar energy has risen as the leading sustainable and cost-effective replacement for fossil fuels
- Annual loss of soiling: 1.5%-6.2% depending on location
- This project aims to classify soiling faults by characterizing relevant features as inputs of the Machine Learning algorithm
  - Voltage
  - Current
  - Temperature
  - Irradiance





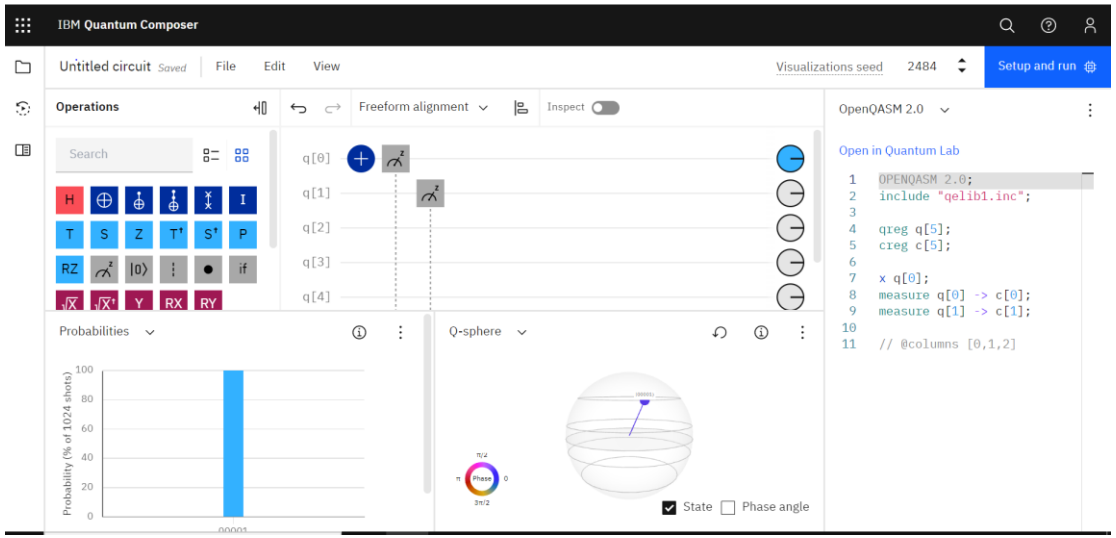
Previous Work

- Soiling faults result in irradiance as per STC and lower measured power
- Requirements for fault detection algorithms:
  - Accurately classify array's condition
  - Adaptable to different configurations
  - Recognize fault type from small number of training examples
  - Based off prior knowledge of PV array behavior
  - Capable of reacting to "unknown unknowns"

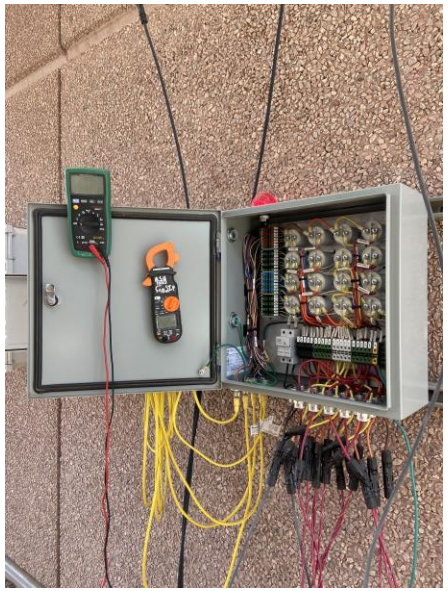


S. Rao, S. Katoch, V. Narayanaswamy, G. Muniraju, C. Tepedelenlioglu, A. Spanias, P. Turaga, R. Ayyanar, and D. Srinivasan, "Machine learning for solar array monitoring, optimization, and Control," *Synthesis Lectures on Power Electronics*, vol. 7, no. 1, pp. 1–91, 2020.

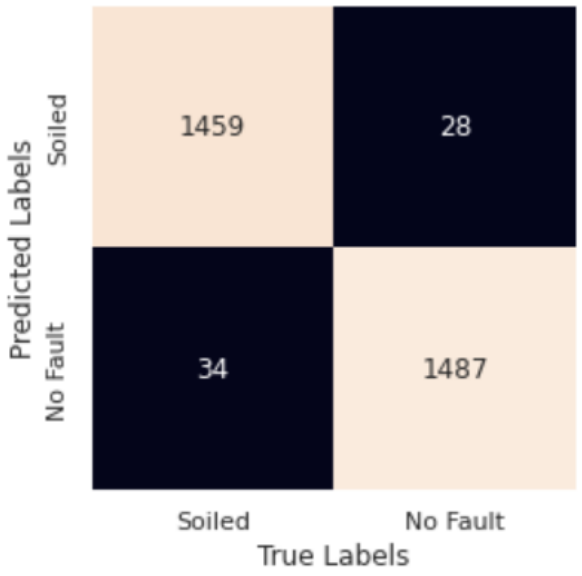
Pre-Training at ASU



- Introduced to:
  - Signals and Sensors
  - Java
  - Python
  - Google Colab
  - IBM Quantum Composer
- Visited solar array facility
- Pre-processed data;
  - normalization, one-hot encoding, train/validation/test split)

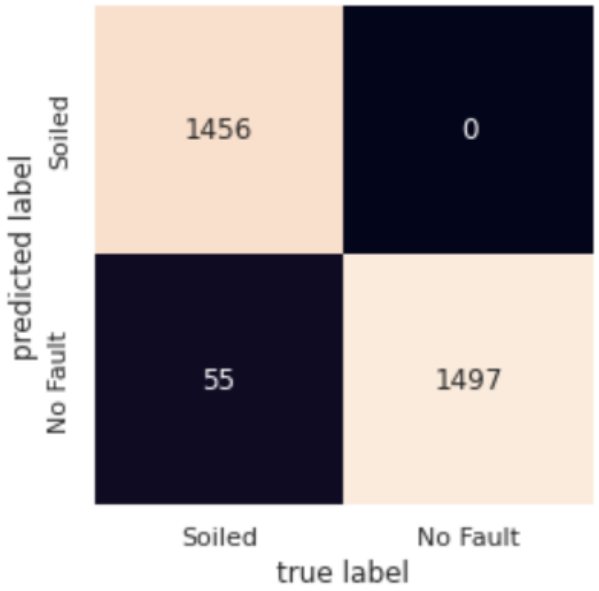


Classical Machine Learning Algorithms



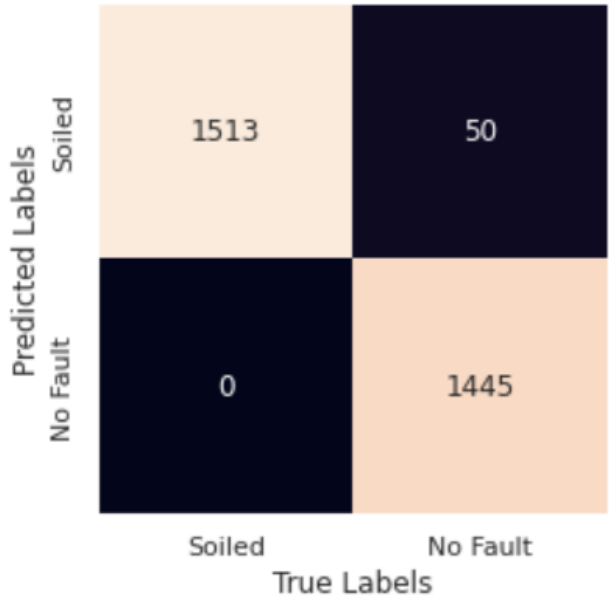
Logistic Regression

- ‘saga’ solver
- 5000 max iterations
- 97.94% accaccuracy



Support Vector Machine

- ‘linear’ kernel
- 5000 max iterations
- Held break ties as true
- 98.17% accuracy



Artificial Neural Networks

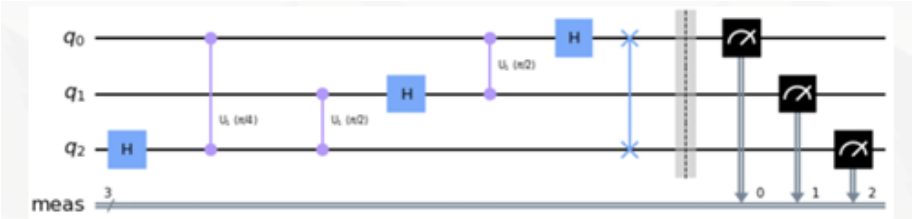
- ‘adam’ solver
- 100 max iterations
- 1 layer
- 250 hidden nodes
- 98.34% accuracy

Quantum Machine Learning Algorithm

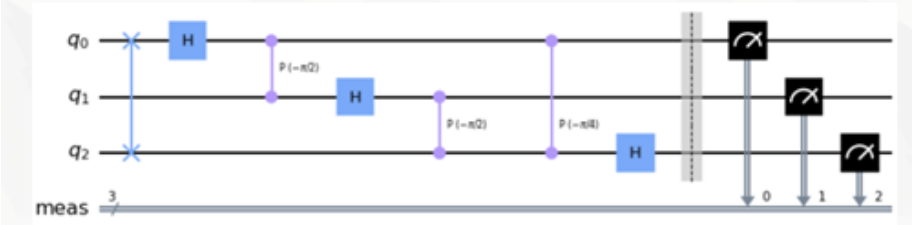
- Received training on IBM Qiskit
- Began programming a quantum neural network
- Preliminary results need improvement

Next Steps:

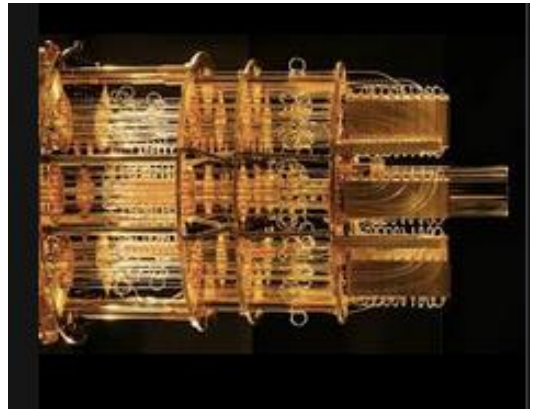
- Coding quantum logistic regression
- Optimizing quantum neural network
- Complete and finalize IEEE Summary



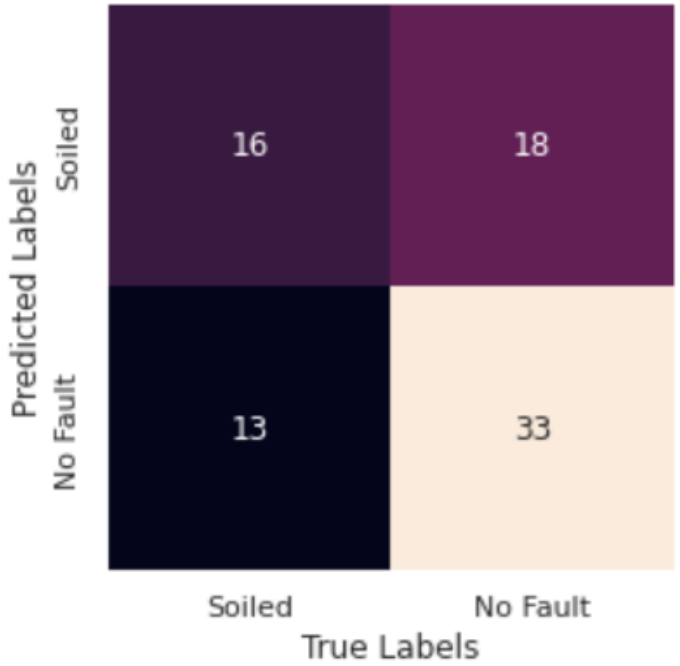
Quantum Fourier transform for 3 qubits



Quantum Inverse Fourier transform for 3 qubits

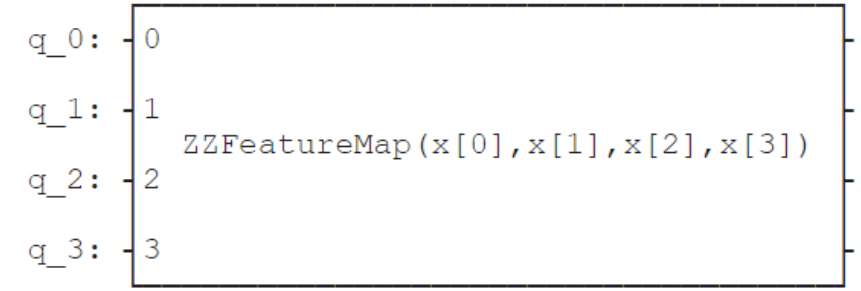


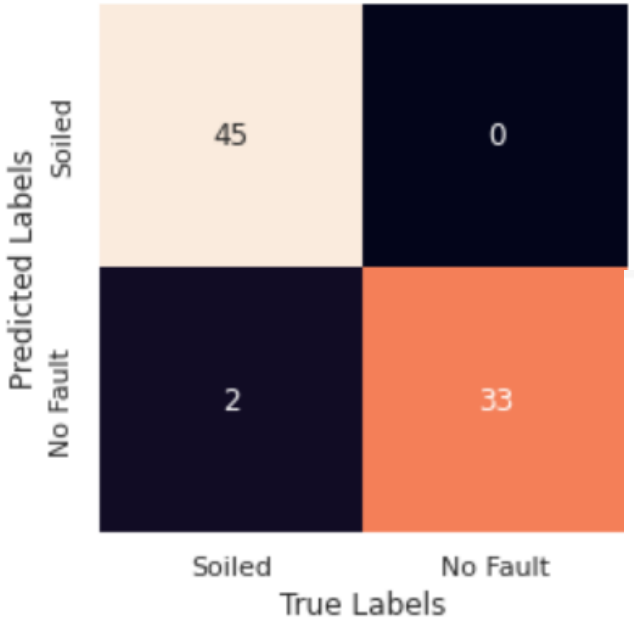
Quantum Machine Learning Algorithms

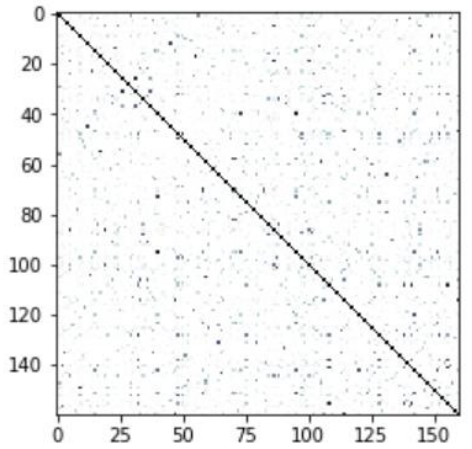


Quantum Neural Network

- 61.3% accuracy
- 4 layers, 50 epochs, learning rate of 0.01





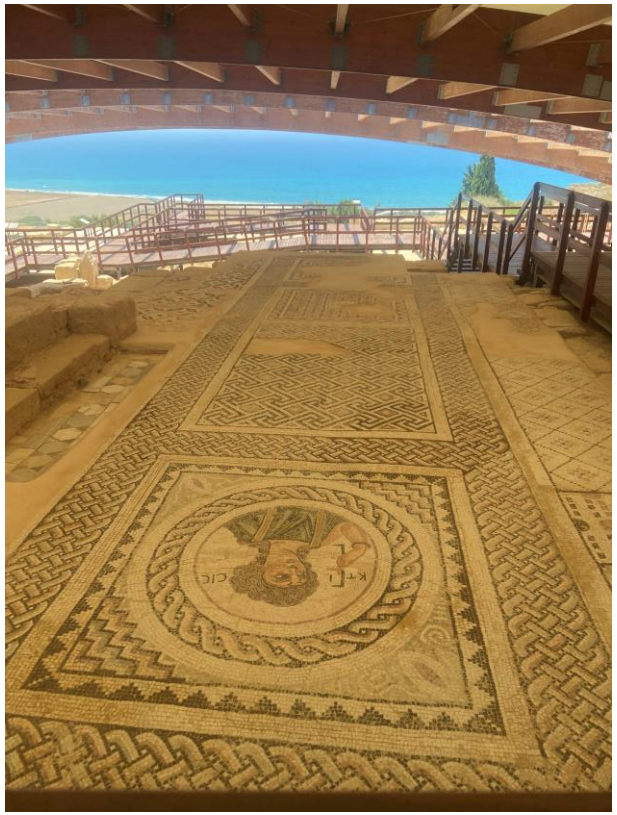


Quantum Support Vector Machine

- 97.5% accuracy

Conclusions

- International collaboration
- Research Operations
- Basics of PV Fault Detection
- Quantum Computing Intro
- Machine Learning Algorithms
- Quantum Machine Learning
- Technical Paper Writing
- Presentation to International Audiences
- Cyprus Cultural Exposition
- KIOS Research Projects



Reflection and Self Assessment

References

[1] N. Kannan and D. Vakeesan, “Solar Energy for future world: - A Review,” *Renewable and Sustainable Energy Reviews*, vol. 62, pp. 1092–1105, Sep. 2016.

[2] V. V. Tyagi, N. A. A. Rahim, N. A. Rahim, and J. A. L. Selvaraj, “Progress in solar PV technology: Research and achievement,” *Renewable and Sustainable Energy Reviews*, vol. 20, pp. 443–461, Sep. 2013.

[3] M. R. Maghami, H. Hizam, C. Gomes, M. A. Radzi, M. I. Rezadad, and S. Hajighorbani, “Power loss due to soiling on Solar Panel: A Review,” *Renewable and Sustainable Energy Reviews*, vol. 59, pp. 1307–1316, Jan. 2016.

[4] S. Rao, S. Katoch, and V. Narayanaswamy, *Machine learning for solar array monitoring, optimization, and Control*. San Rafael, CA: Morgan & Claypool Publishers, 2020.

[5] J. A. Dhanraj, A. Mostafaeipour, K. Velmurugan, K. Techato, P. K. Chaurasiya, J. M. Solomon, A. Gopalan, and K. Phoungthong, “An effective evaluation on fault detection in solar panels,” *Energies*, vol. 14, no. 22, p. 7770, 2021

[6] A. C. Chang, “Machine and deep learning,” *Intelligence-Based Medicine*, pp. 67–140, 2020.

[7] “Applications of support vector machine (SVM) learning in cancer genomics,” *Cancer Genomics & Proteomics*, vol. 15, no. 1, 2018.

[8] R. Gholami and N. Fakhari, “Support Vector Machine: Principles, parameters, and applications,” *Handbook of Neural Computation*, pp. 515–535, 2017.

[9] S. Dreiseitl and L. Ohno-Machado, “Logistic regression and Artificial Neural Network Classification models: A methodology review,” *Journal of Biomedical Informatics*, vol. 35, no. 5-6, pp. 352–359, 2002.