



CAREER: Cyber Physical Solution for High Penetration Renewables in Smart Grid

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Project Overview

- An adaptive, resilient, efficient and effective integration of large amounts of renewable energy into the utility grid.
- Developing technologies for efficient and intelligent on-demand sharing of solar generation with conventional power generation in the grid.
- Synergistic renewable energy integration with novel computational tools for forecasting and intelligent load sharing with distributed energy storage.
- The study collects real-time Photovoltaic (PV) data from the plant, conducts high-end modeling, analysis and visualization on various datasets to understand, predict and mitigate the system instabilities and fluctuations triggered by PV intermittencies.
- The main goal of this project is to reduce carbon footprint and make the system stable under expected high penetration of renewable sources and unanticipated intermittencies.

Step-size Optimization of New Straight Line Approximation-based MPPT Algorithm for Photovoltaic Systems

- This study proposes a straight-line approximation-based maximum power point tracking (MPPT) algorithm using open circuit voltage of Photovoltaic (PV) module.
- This employs an iterative based optimization technique for determining the optimum step-size to extract maximum energy from PV-module.
- It extracts more energy at optimized step size and at other different step sizes during fast and slow varying global horizontal irradiance (GHI) parameter.
- The algorithm generates 14.4% more energy than the P&O for smooth irradiance at the optimized step size of 0.003.
- Algorithm generates 9.5% more energy for fluctuating irradiance at the optimized step size of 0.3.

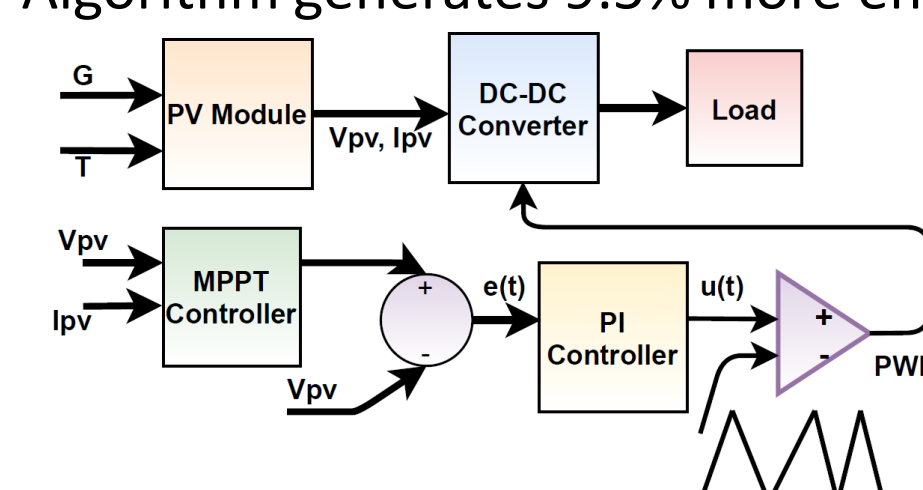


Figure: Block diagram of the system-design.

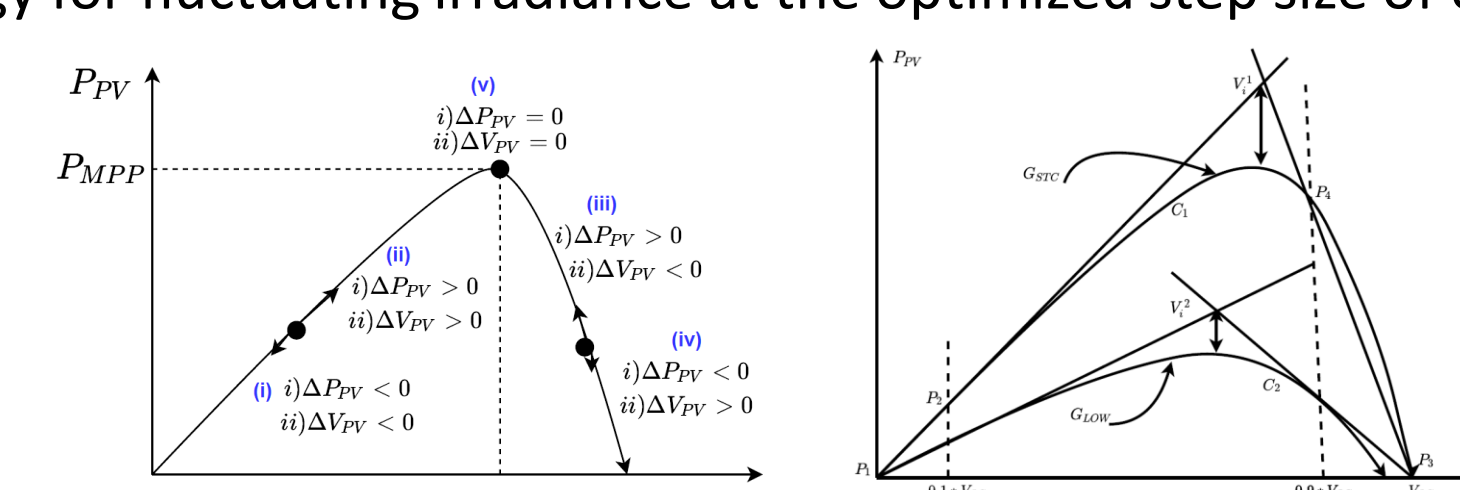


Figure: Concept behind P&O MPPT algorithm and the proposed algorithm.

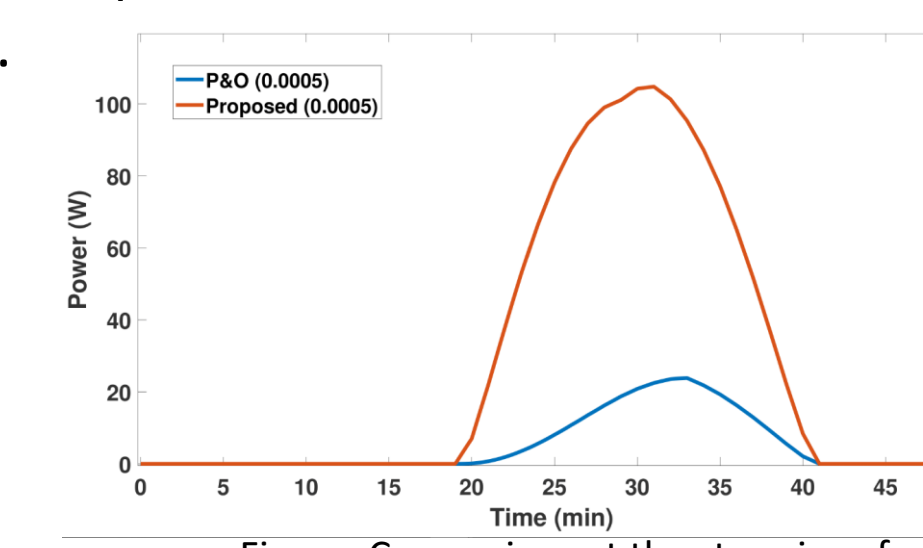


Figure: Comparison at the step size of 0.0005 for a sunny day.

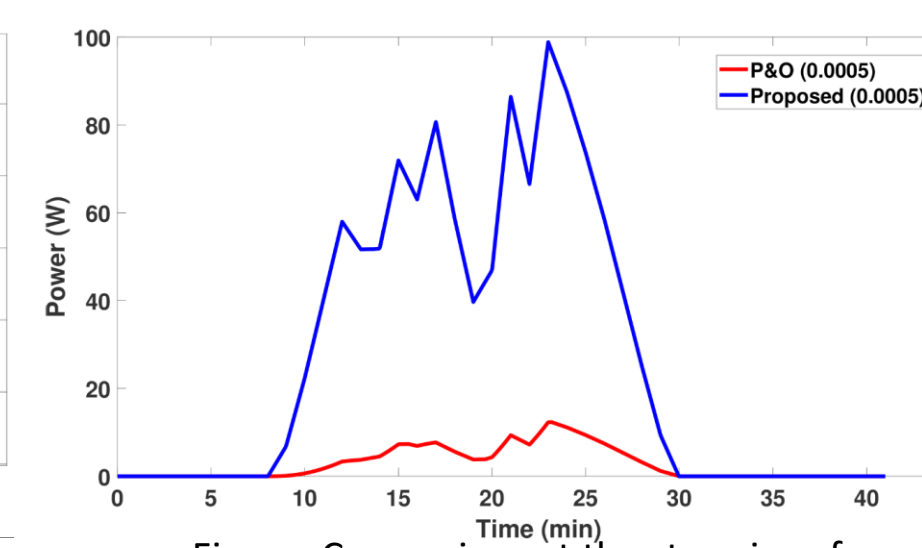


Figure: Comparison at the step size of 0.0005 for a cloudy day.

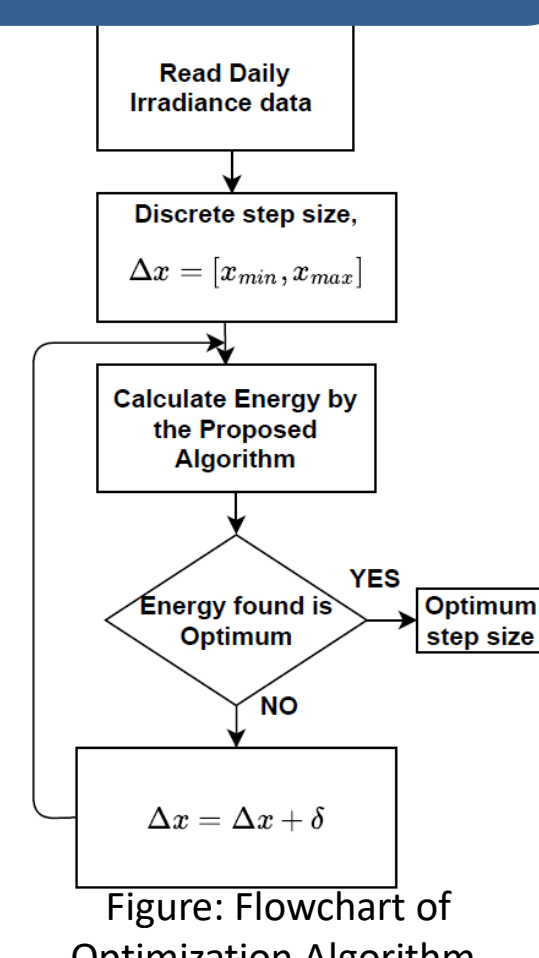


Figure: Flowchart of Optimization Algorithm.

Multiphysics and Multiobjective Design Optimization of High-Frequency Transformers for Solid-State Transformer Applications

- Multiphysics-based and multiobjective design optimization of high-frequency transformers (HFT) for solid-state transformer (SST) applications is proposed.
- The proposed algorithm (based on time-harmonic, electromagnetic, thermal, and fluid physics model coupling) minimizes the volume of the HFT, total cost as well maximizes its efficiency.
- A case study of 20 kW, 10 kHz is investigated and its Pareto optimal solutions (POS) are observed.
- An experimental implementation of the optimized HFTs (HFT1 and HFT2) is integrated with a self tuned dual active bridge converter to validate their performance.

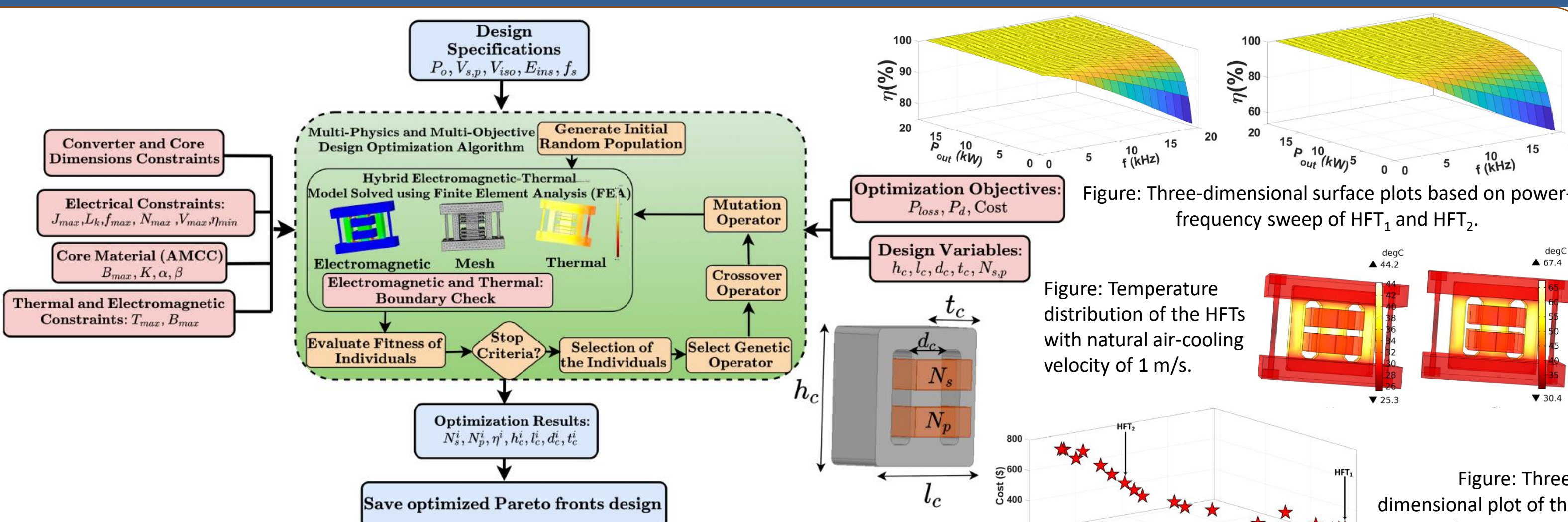


Figure: Proposed multiphysics-based, multiobjective optimization algorithm.

Impact Analysis of Cyber-Attacks on Smart Grid: A Review and Case Study

- This effort comprehensively reviews the impacts of cyberattacks on the smart distribution grid and discusses the potential methods to mitigate them.
- The review covers different real-world case studies of successful cyberattacks on multiple grid assets, in the networks with high-penetration of distributed energy resources (DERs).
- A false data injection (FDI) attack on a PV production meter data used for 15-minute ahead forecasting is considered as a specific use-case for further analysis.
- Various impacts of this incorrect operational settings on the dynamics on the grid is theoretically and analytically analyzed on an IEEE 34 bus system with three PVs, one synchronous generator and one energy storage.

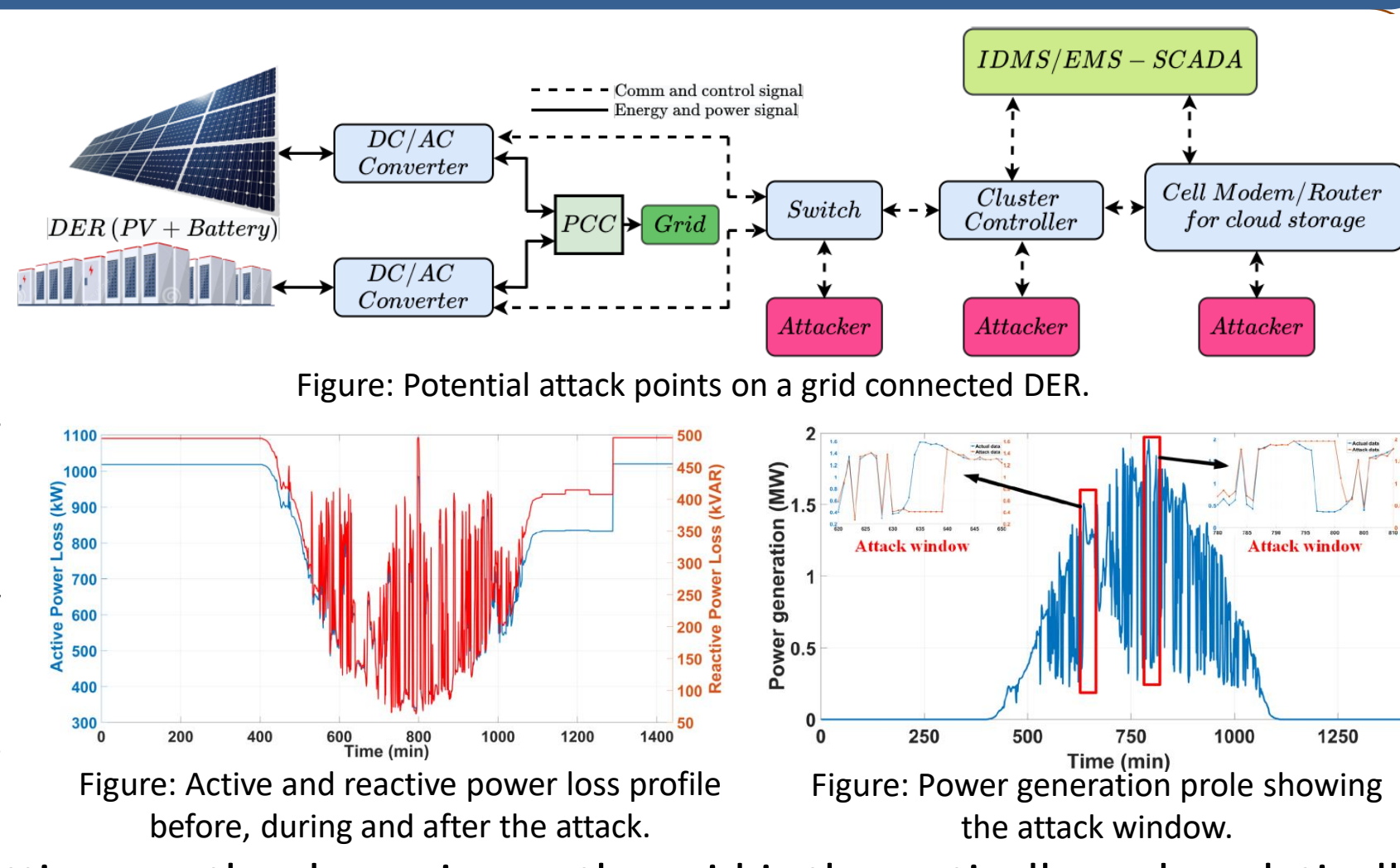


Figure: Active and reactive power loss profile before, during and after the attack.

Figure: Power generation profile showing the attack window.

A Binary Search Algorithm based Optimal Sizing of Photovoltaic and Energy Storage Systems

- In this effort, a binary-search based optimization algorithm determines the size of photovoltaic (PV) plus battery standalone system in order to meet a defined load profile.
- The algorithm is fed with a year-long actual irradiance and load profile data for facility located in Miami FL.
- The simulation results verifies that SOC_{max} and SOC_{min} remains within the predefined value -95% and 15% respectively and the load deficit by the optimum parameters is zero throughout the year.

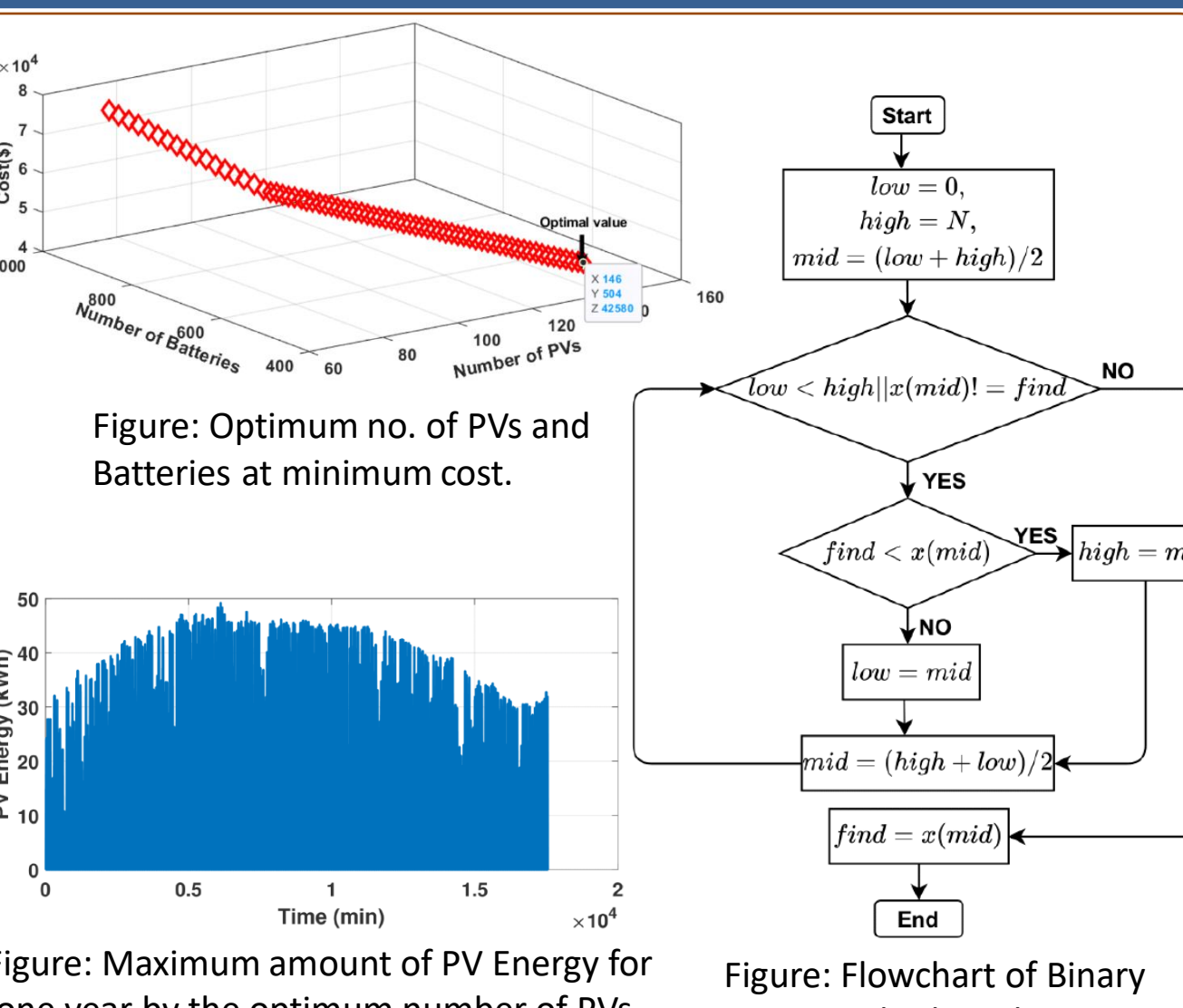


Figure: Optimum no. of PVs and Batteries at minimum cost.

Figure: Maximum amount of PV Energy for one year by the optimum number of PVs.

Figure: Flowchart of Binary Search Algorithm.

A Low-complexity FS-MPDPC with Extended Voltage Set for Grid-connected Converters

- The computational load involved in finite set model predictive direct power control (FS-MPDPC) has been reduced.
- The controller is designed for bidirectional active-reactive power flow control of a converter that interlinks a BESS with the grid.
- This constriction algorithm reduced the size of the candidate voltage vector set for optimization from 37 to 8.

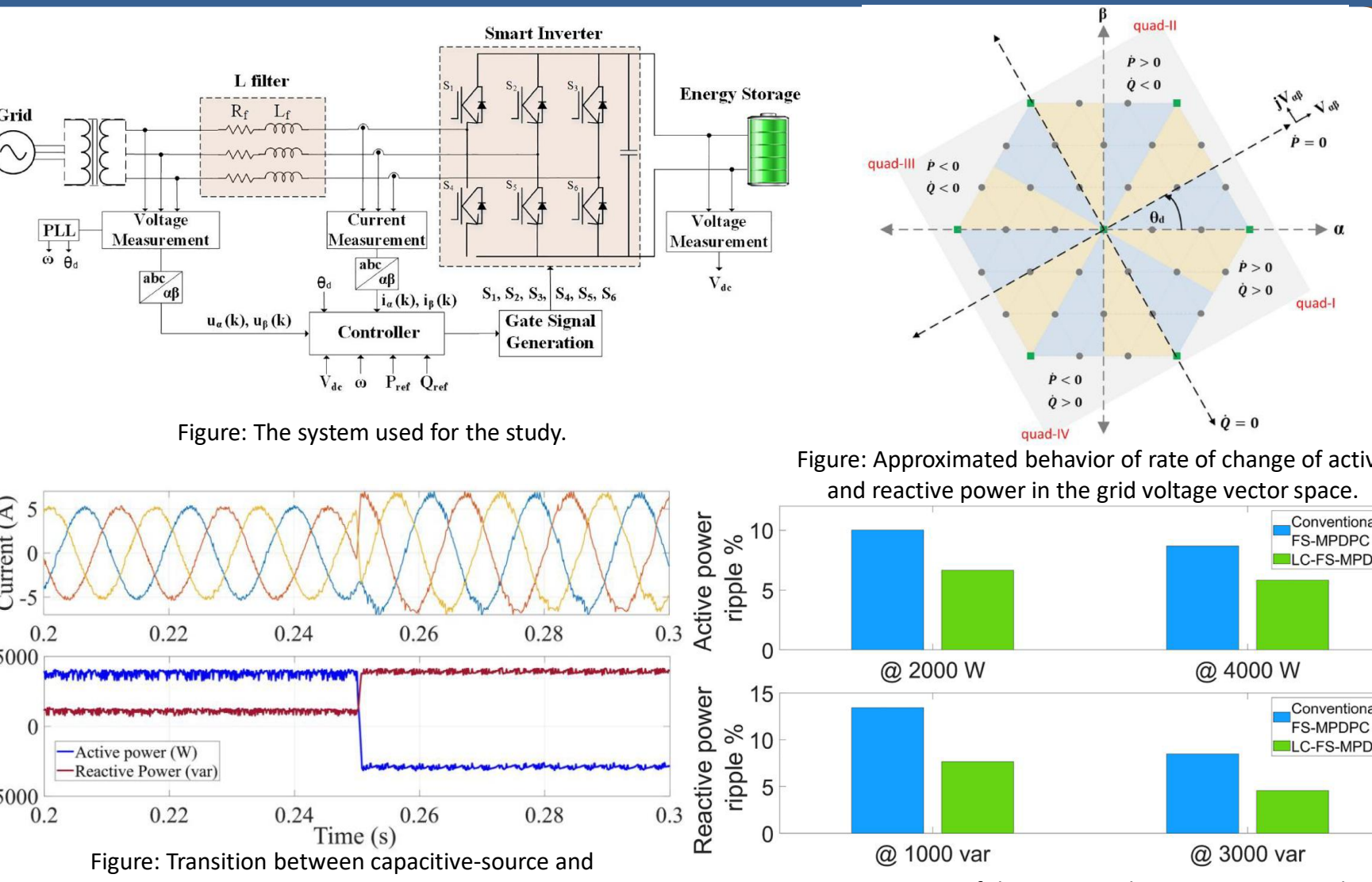


Figure: The system used for the study.

Figure: Transition between capacitive-source and capacitive-load modes.

Figure: Comparisons of the active and reactive power ripples.

Broader Impacts

1. Developed Center for Proactive Analytics and Data-Oriented Research on Availability & Security (PANDORAS) at Florida International University (FIU).
 2. Launched the Master of Science in Energy Cybersecurity program at FIU.
 3. 7 Ph.D. students graduated.
- Recent Publication List:**
- Journal Paper:**
1. A. Debnath, T. O. Olowu, I. Parvez, A. Sarwat, "Step-size Optimization of New Straight Line approximation-based MPPT Algorithm for Photovoltaic Systems," Power Electronics for Distributed Generation Systems, 2021.
 2. S. Dharmasena, T. O. Olowu, A. I. Sarwat, "A low-complexity FS-MPDPC with extended voltage set for grid-connected converters," IET Energy Systems Integration, 2021.
 3. T. O. Olowu, Hassan Jafari, Masood Moghaddami, and Arif I. Sarwat, "Multiphysics and Multiobjective Design Optimization of High-Frequency Transformers for Solid-State Transformer Applications," IEEE Transactions on Industry Applications, 2020.
- Conference Paper:**
1. T. O. Olowu, M. Moghaddami, and A. I. Sarwat, "Soft-switched, Self-tuned and Optimization Technique for Solid State Transformers Based on Direct AC-AC Matrix Converter Topology," in 2020 IEEE Industry Applications Society Annual Meeting, IEEE, 2020.
 2. S. Dharmasena and A. I. Sarwat, "Fuzzy Decision Making Assisted Model Predictive Direct Power Controller for a Grid-Interlinking Converter of a Battery Energy Storage System," IEEE North American Power Symposium, 2020.
 3. A. Debnath, T. O. Olowu, I. Parvez, A. Sarwat, "A Binary Search Algorithm based Optimal Sizing of Photovoltaic and Energy Storage System," IEEE GreenTech, 2021.
- Book Chapter:**
1. T. Olowu, S. Dharmasena, A. Hernandez, A. Sarwat, "Impact Analysis of Cyber-Attacks on Smart Grid: A Review and Case Study" New Research Directions in Solar Energy Technologies (Energy, Environment, and Sustainability), Springer, 2020.
- Please check <https://eps.fiu.edu/> for the whole publication list.