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PV System Integration and Monitoring in Buildings

Manef BOUROGAOUI

Fulbright Visiting Scholar

جامعة قرطاج Université de Carthage

VIRGINIA TECH

Bluefield State COLLEGE

Arlington, VA, USA, November 16 - 2020

About Me

Country geographic position

Tunisia

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Education and Appointments

Teaching

ISTIC

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Université de Carthage

Education and Appointments

Research

École Nationale d'Ingénieurs de Tunis

U T M
جامعة تونس المنار
UNIVERSITÉ DE TUNIS EL MANAR

My research team in Tunisia

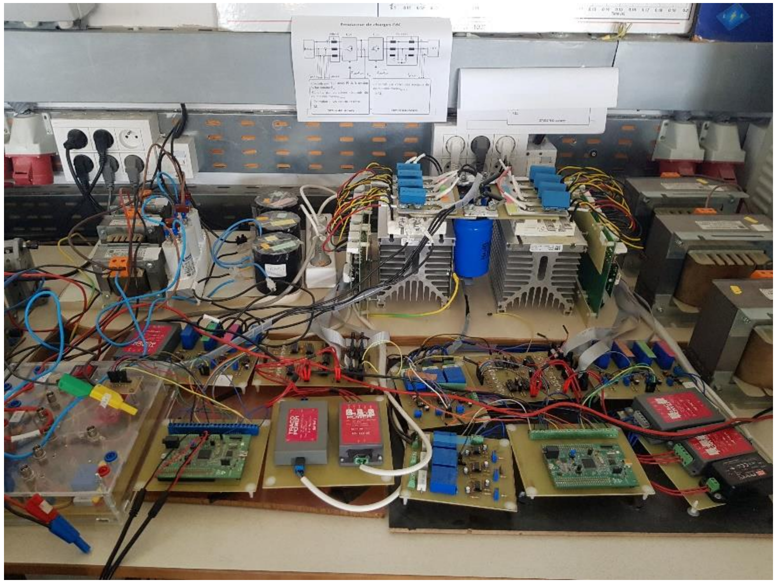
Research

http://www.lse-qehna.tn/en/home/

Current Projects

- Impact of rooftop PV system integration on Tunisian electrical distribution network
- Development of smart e-monitoring system of PV energy generators with high marketability
- A Platform for investigation and integration of new energy technologies into an electrical distribution network

QehnA
Power quality research with power electronics and advanced control



My fellowship program

Summary

Project title:

PV system integration and monitoring in buildings

Project started in January 01- 2020 for one year.

Host Institution:

Advanced Research Institute

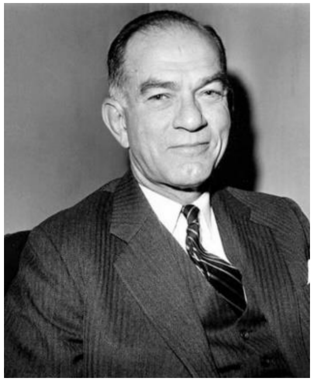
VIRGINIA TECH

Advisor:

Professor Saifur Rahman

About Fulbright

About…



Senator James William Fulbright
ARKANSAS

- 1946: Created by U.S. Congress
- Over 8,000 grantees from 155 countries annually
- Administered overseas by bi-national Fulbright Commissions and U.S. Embassies

Goal

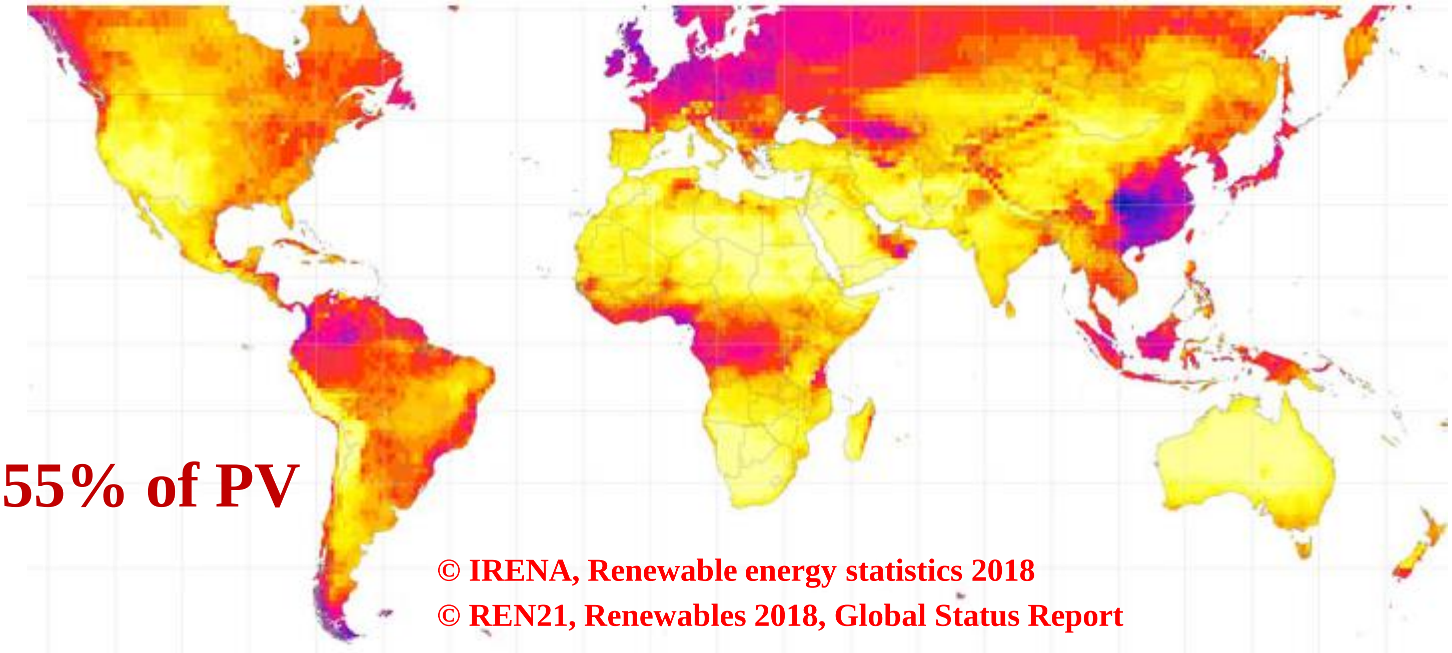
*To increase **mutual understanding** between people of the U.S. and people of other countries through exchange*

For more information, visit:

http://eca.state.gov/fulbright

Research Field Background

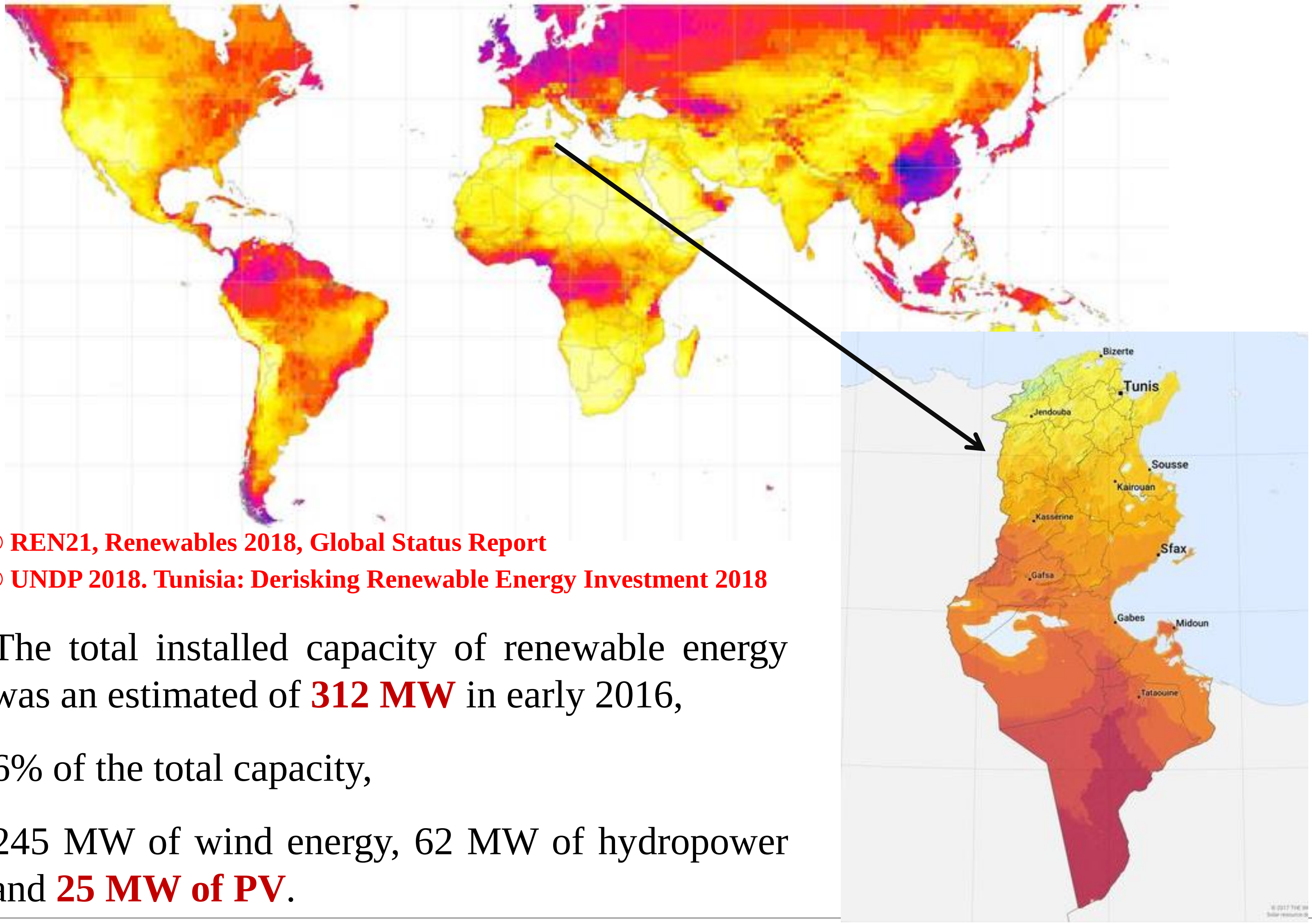
Photovoltaic energy consumption in the world



- The photovoltaic solar market grew by **25%** between 2014 and 2015, reaching a power record level of 50GW.
- In 2015, the annual market was ten times higher than the total produced energy through the last ten years.
- Solar PV accounted for nearly **55%** of newly installed renewable power capacity in 2017.

Research Field Background

Tunisia case: Actual installed renewable energy



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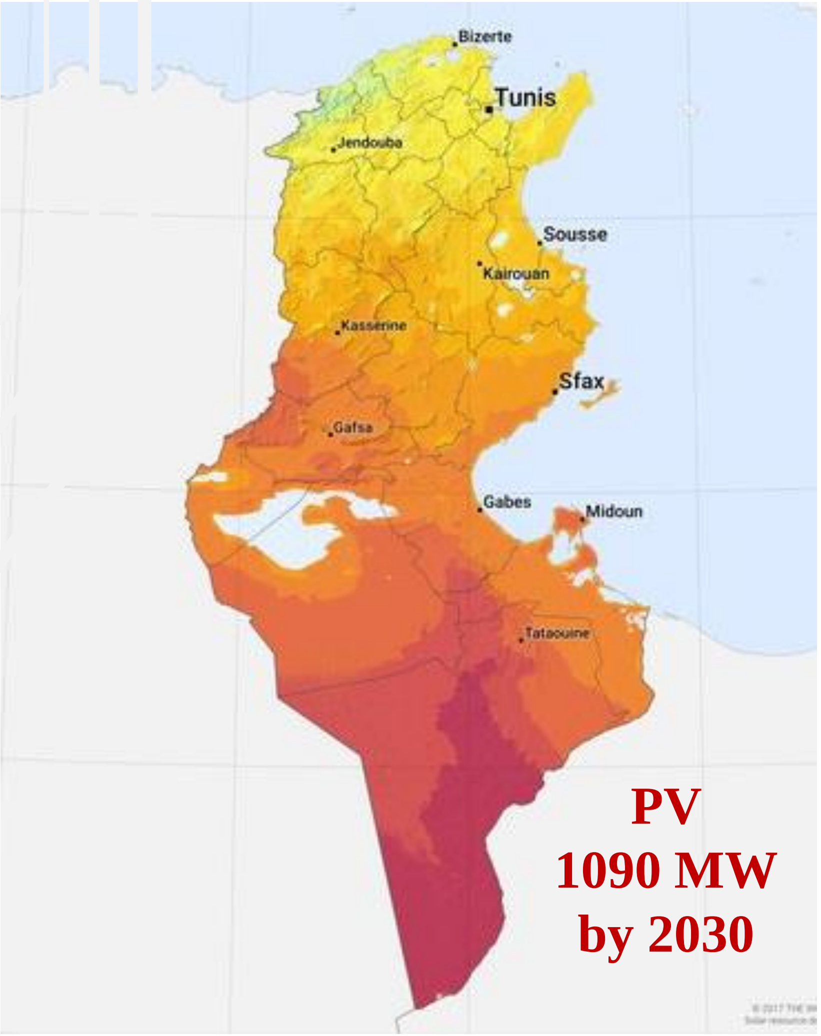
© UNDP 2018. Tunisia: Derisking Renewable Energy Investment 2018

- The total installed capacity of renewable energy was an estimated of **312 MW** in early 2016,
- 6% of the total capacity,
- 245 MW of wind energy, 62 MW of hydropower and **25 MW of PV**.

Research Field Background

Tunisia case : Targets



Total utility-scale electricity generating capacity by 2030

10.9 GW

Renewables Capacity by 2030

3725 MW - 30%

Solar Photovoltaic Capacity by 2030

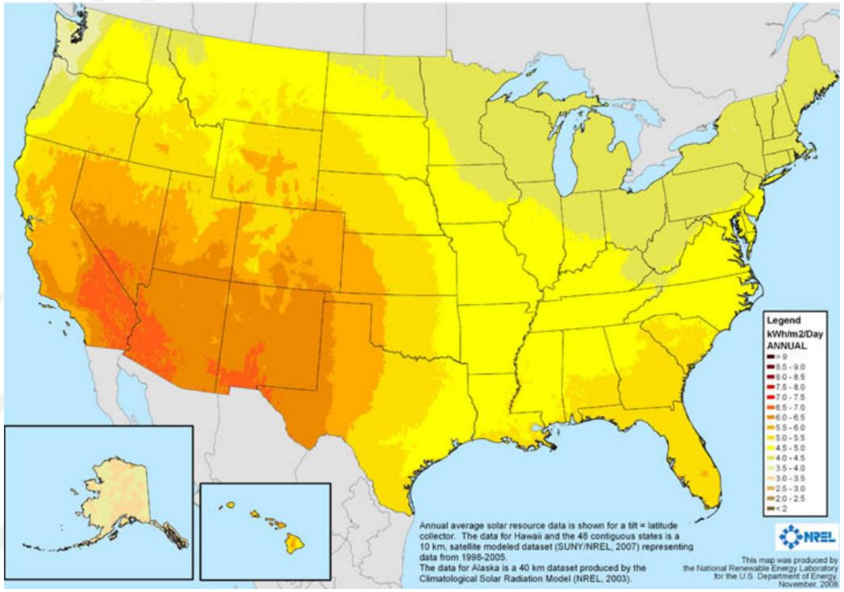
1090 MW - 10%

25 MW in 2016 → 1090 MW by 2030

Tunisian Solar Plan (TSP)

Research Field Background

USA case



Total utility-scale electricity generating capacity by 2030

1476 GW

Renewables Capacity by 2030

442.8 GW - 30%

Solar Photovoltaic Capacity by 2030

220 GW - 10%

75.3 GW in 2018 → 220 GW by 2030

US SunShot Initiative

https://www.globaldata.com/renewables-to-represent-30-of-us-total-installed-capacity-by-2030/

Research Field Background

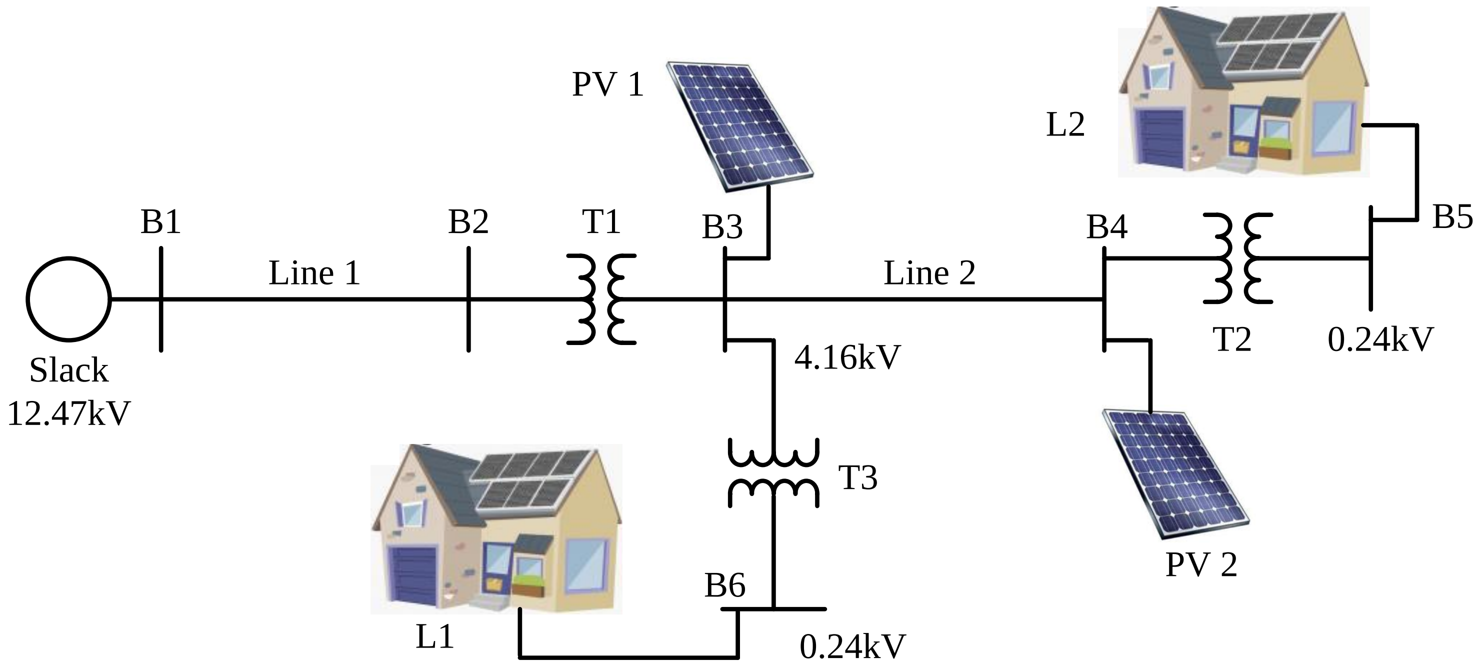
Challenges

- Emerging Issues and Challenges in Integrating High Levels of Solar into the Electrical Generation and Transmission System
- The characteristics of PV-generated electricity, including:
  - Variability: PV output can vary as underlying resource fluctuates
  - Uncertainty: PV output cannot be predicted with perfect accuracy
  - Nonsynchronous generation: PV does not currently help maintain system frequency

Technical solutions for an holistic energy integration into the grid ??

Current Research Work

Analysis of a microgrid operation based on IEEE 4 and 13 –node feeders



IEEE 4-node test feeder

First configuration: Original feeder

Second configuration: IEEE 4 node with PV

Current Research Work

Analysis of a microgrid operation based on IEEE 4 and 13 –node feeders

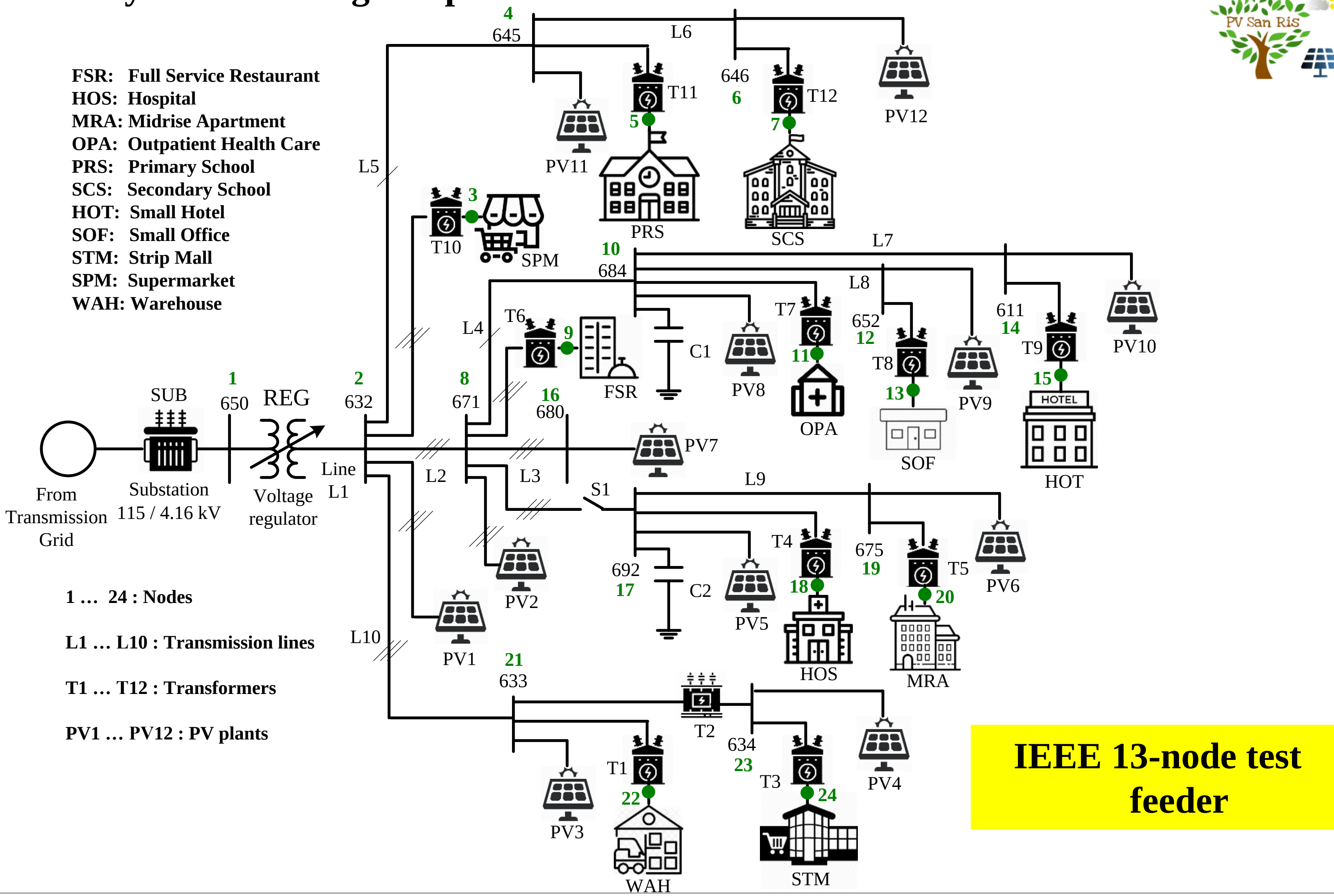
FSR: Full Service Restaurant
HOS: Hospital
MRA: Midrise Apartment
OPA: Outpatient Health Care
PRS: Primary School
SCS: Secondary School
HOT: Small Hotel
SOF: Small Office
STM: Strip Mall
SPM: Supermarket
WAH: Warehouse

1 … 24 : Nodes

L1 … L10 : Transmission lines

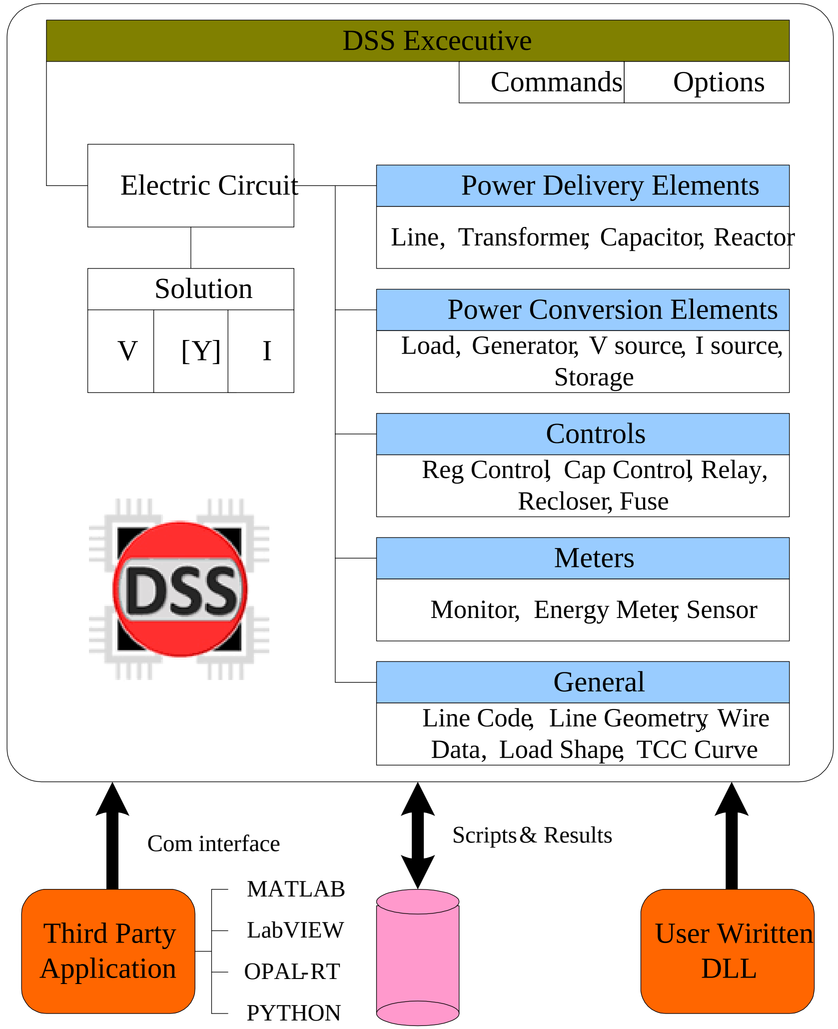
T1 … T12 : Transformers

PV1 … PV12 : PV plants

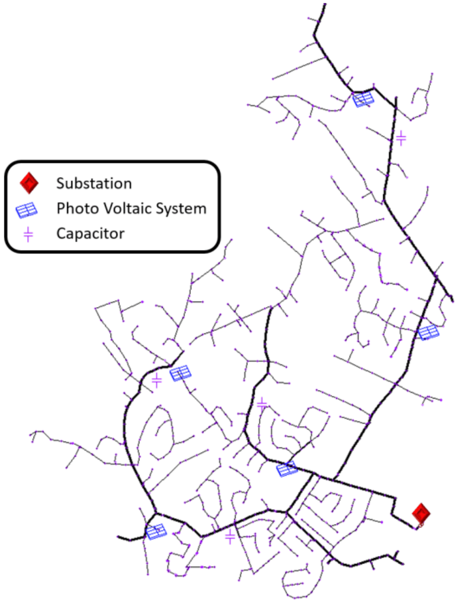


Current Research Work

OpenDSS Software



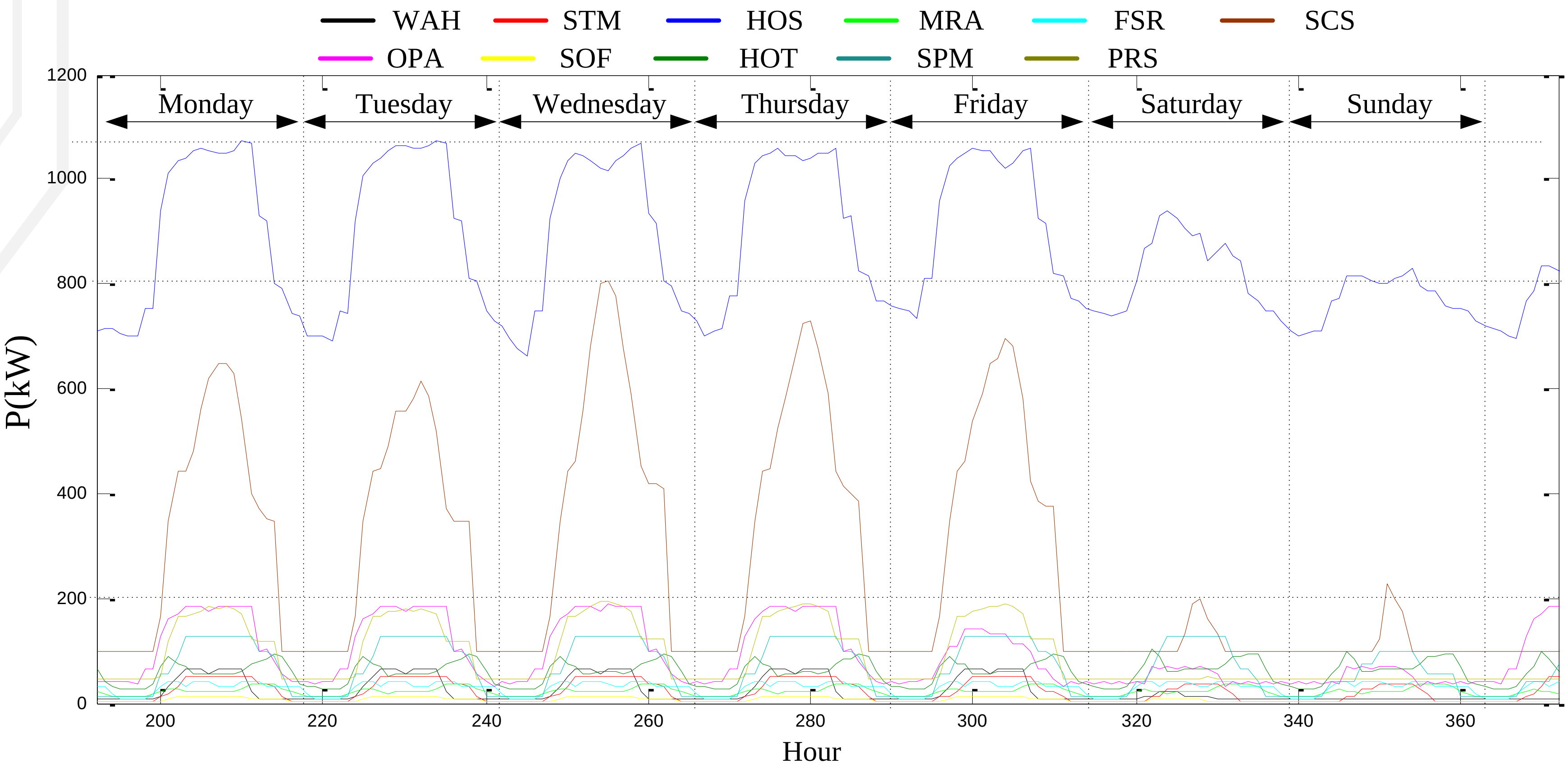
Example of an electric Network



Current Research Work

Forecasting of loads and presenting statistics about loads consumption for the proposed feeder

Real power hourly consumption during a week in January for each building



IEEE 13-node test feeder

Current Research Work

Forecasting of loads and presenting statistics about loads consumption for the proposed feeders

Annual MW consumption order of the different loads in each building

Building	1	2	3	4
FSR	Interior equipments	Interior lights	Fans	Cooling
HOS	Cooling	Interior equipments	Interior lights	Fans
MRA	Interior equipments	Interior lights	Cooling	Fans
OPA	Interior equipments	Cooling	Fans	Interior lights
PRS	Interior lights	Interior equipments	Cooling	Fans
SCS	Cooling	Interior lights	Interior equipments	Fans
HOT	Interior equipments	Interior lights	Cooling	Fans
SOF	Interior equipments	Interior lights	Fans	Cooling
STM	Interior lights	Interior equipments	Fans	Cooling
SPM	Interior lights	Interior equipments	Fans	Cooling
WAH	Interior equipments	Interior lights	Fans	Cooling

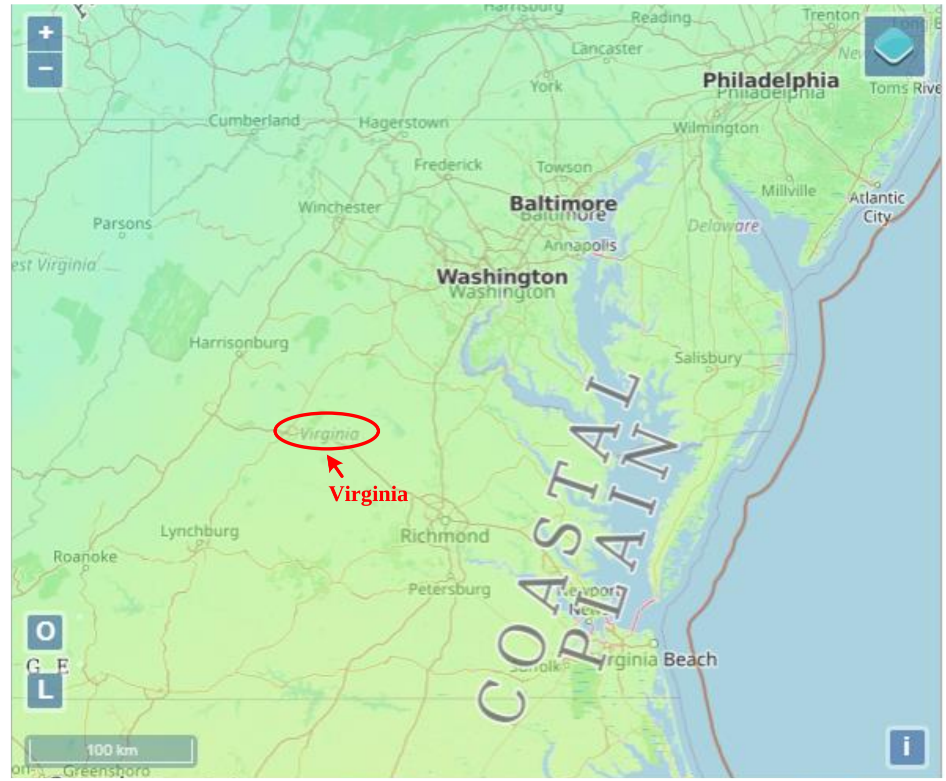
IEEE 13-node test feeder

Current Research Work

Implementation of a model of PV cell temperature to estimate the practical operating of the cell taking into account real weather conditions

PV San RiS

First location, Tozeur–Tunisia (source – PVGIS)



Second location, Virginia – USA (source – PVGIS)

Source: Photovoltaic Geographical Information System (PVGIS)

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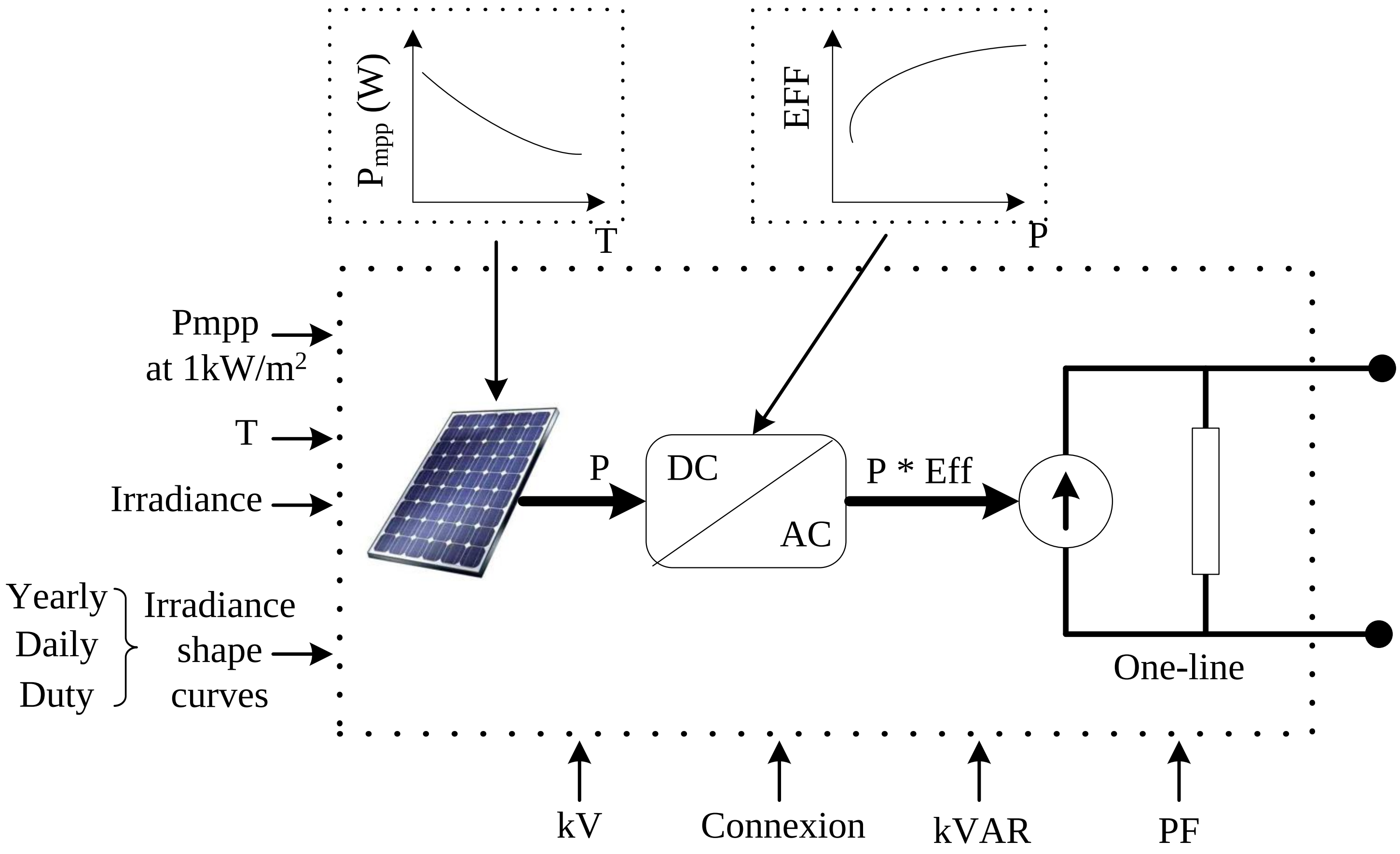
Current Research Work

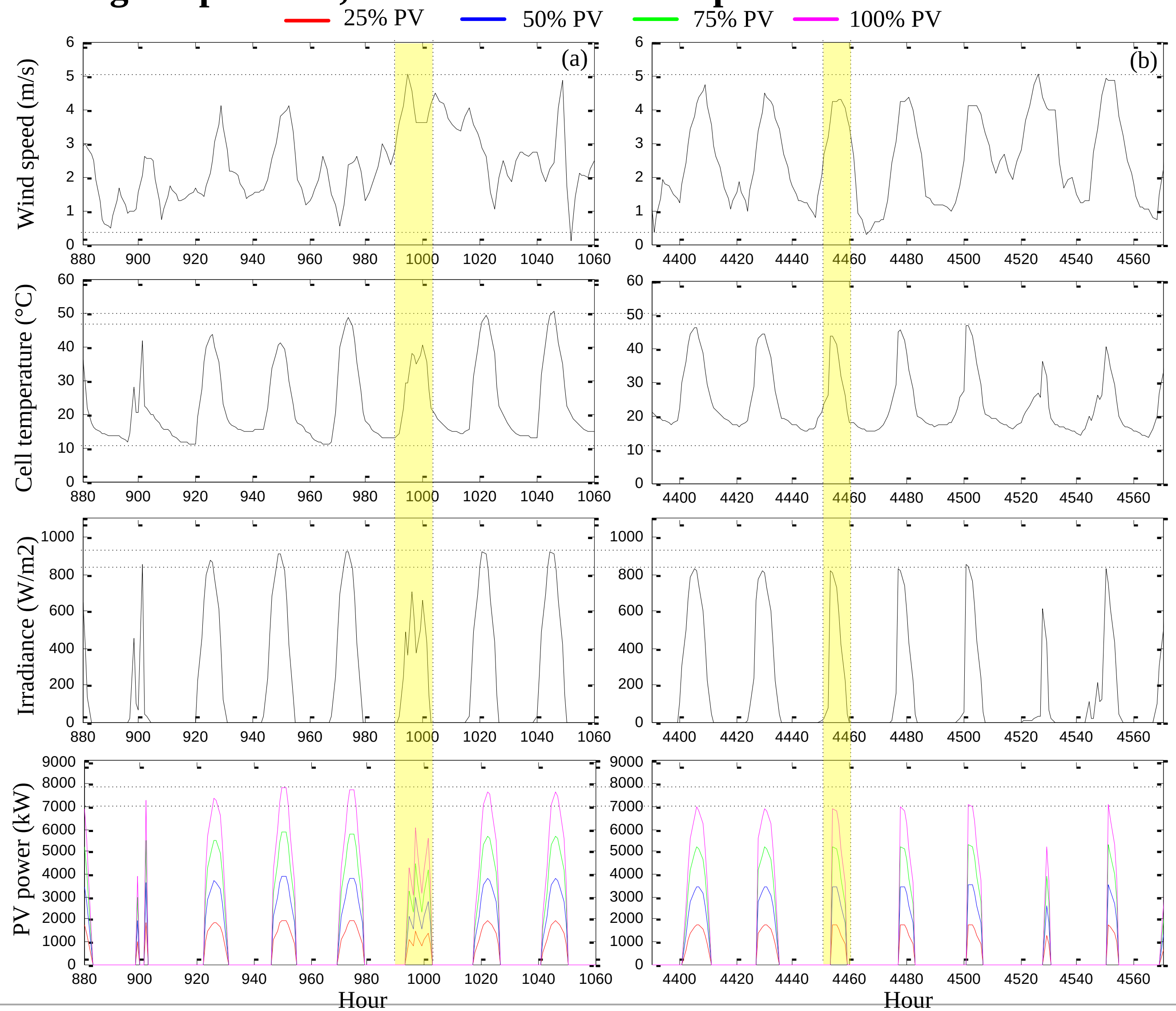
Implementation of a model of PV cell temperature to estimate the practical operating of the cell taking into account real weather conditions.

Block Diagram of the PV system element model in OpenDSS



Current Research Work

Assessment of PV energy penetration using real data of weather conditions including temperature, irradiance and wind speed



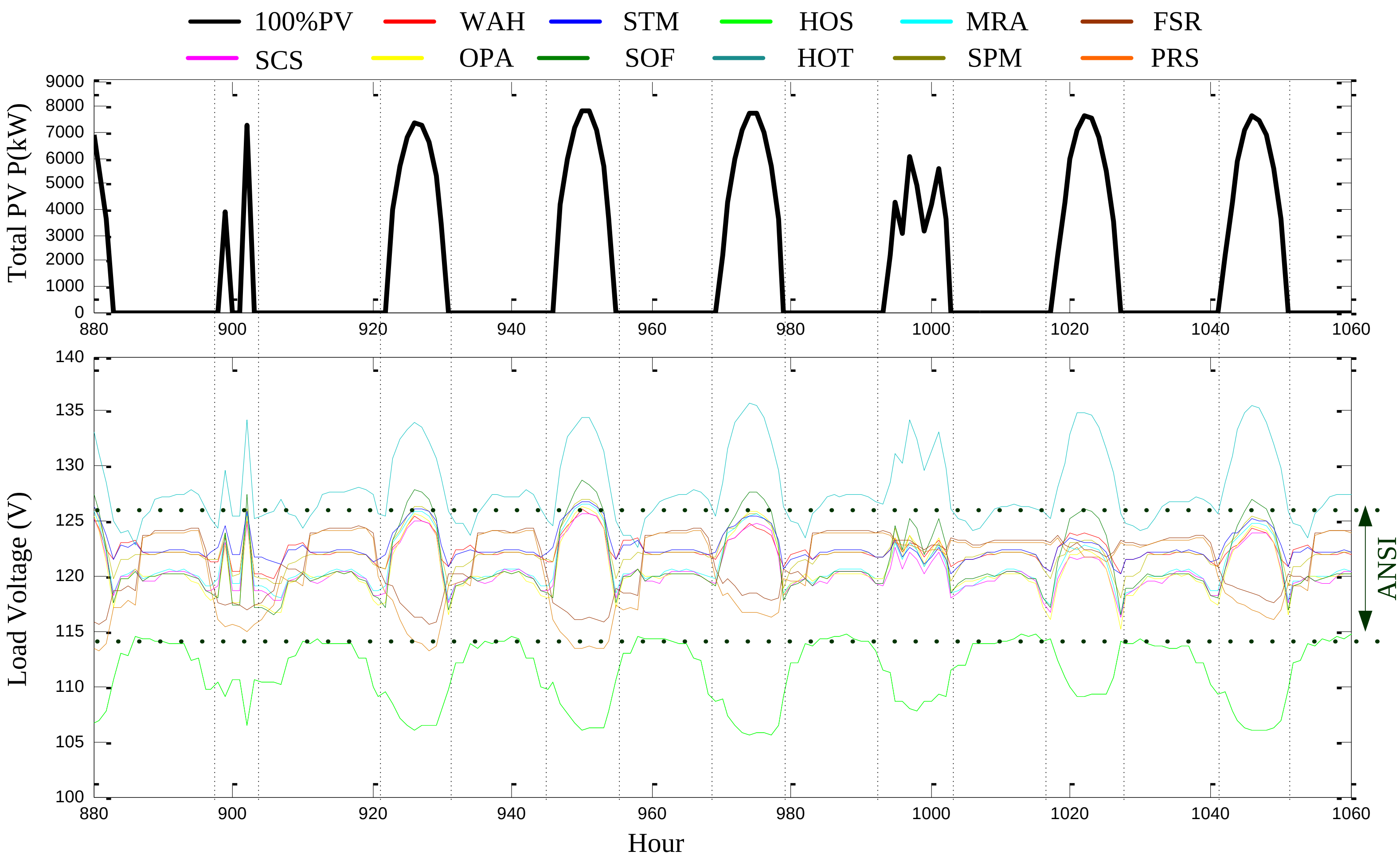
Influence of the weather conditions on the PV power generation, (a) a week in February, (b) a week in June

IEEE 13-node test feeder

Current Research Work

Assessment of PV energy penetration using real data of weather conditions including temperature, irradiance and wind speed

Voltage hourly profile for each building in February

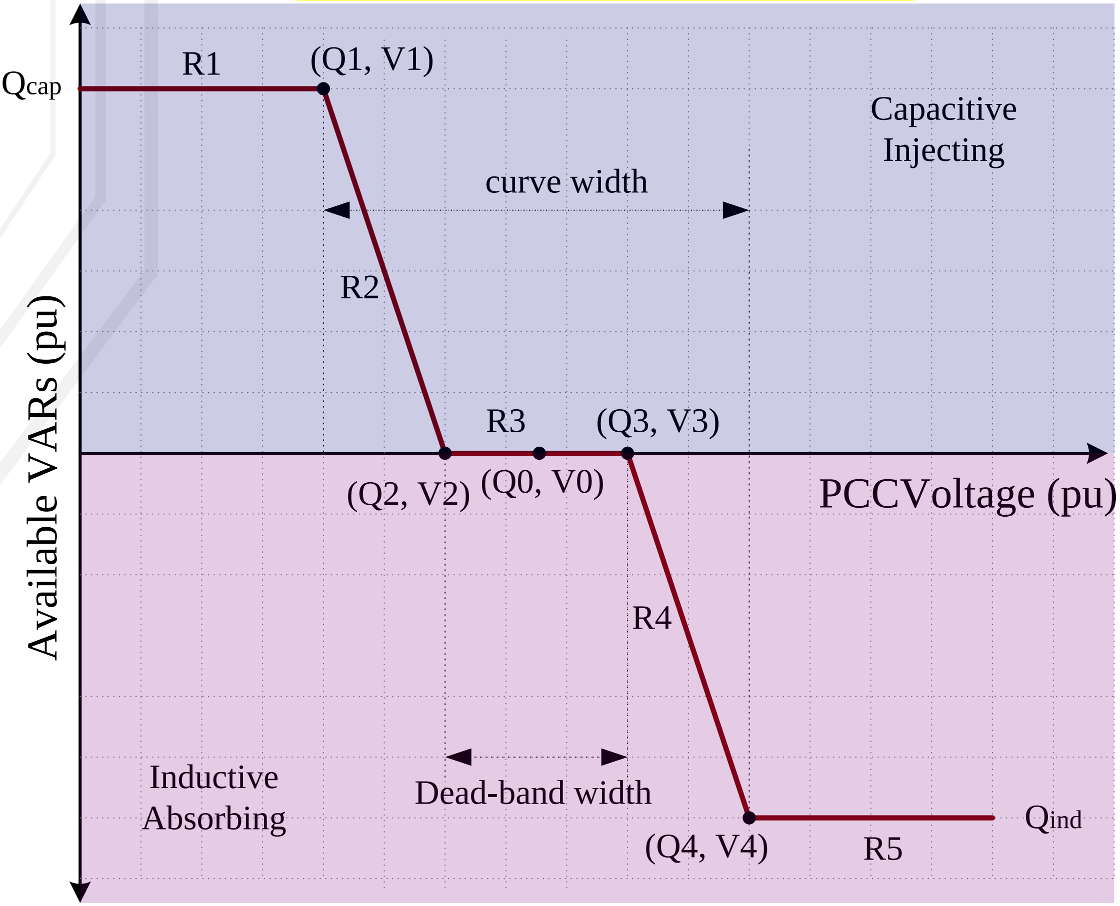


IEEE 13-node test feeder

Current Research Work

Microgrid control using VOLT-VAR technique to mitigate the impact of PV energy penetration

Example of VOLT-VAR curve



The VOLT-VAR curve main objective is to maintain the voltage at the PCC within **ANSI limits (0.95-1.05pu)** despite the different existing circumstances during the grid operation.

When the voltage value exceeds an upper value limit as defined in the curve, reactive power (inductive vars) absorption is performed.

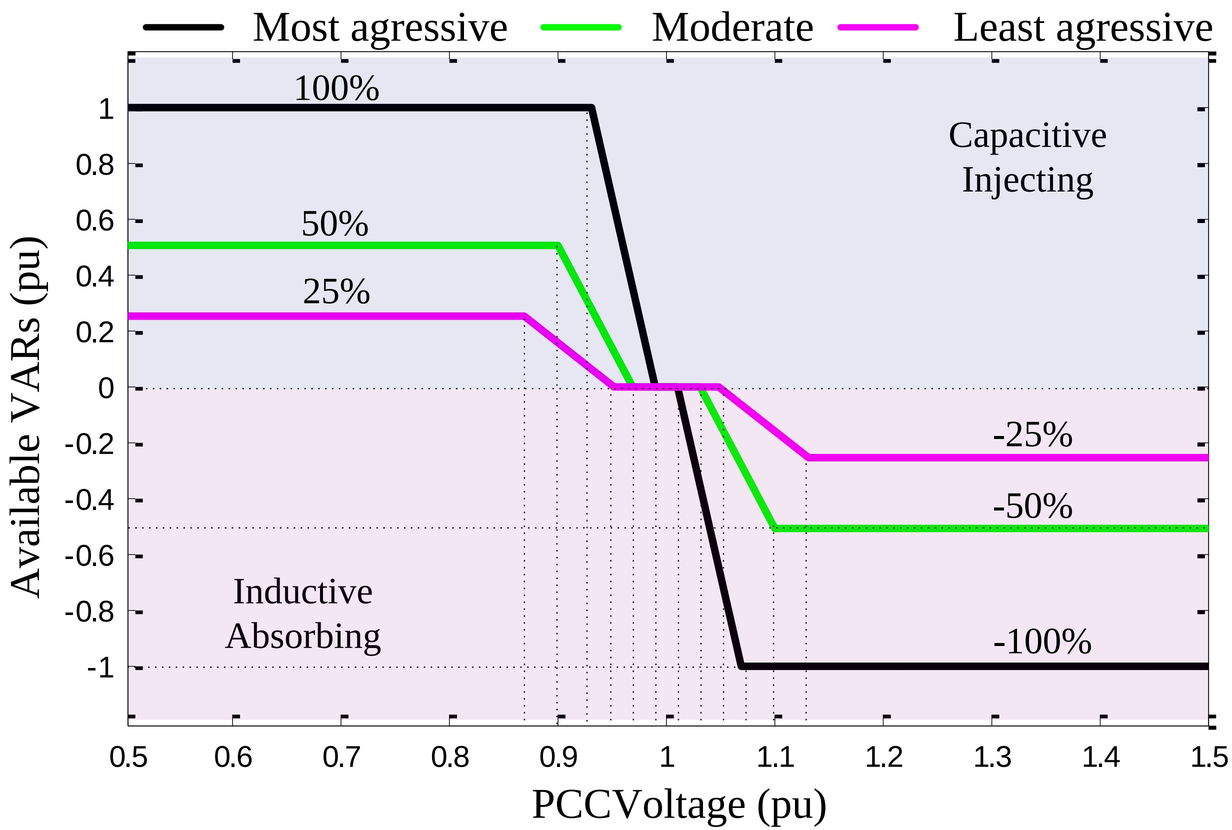
Otherwise, if the voltage drops to a value less than a lower limit, capacitive vars can be delivered to the grid to push up again the voltage to its acceptable levels.

IEEE 13-node test feeder

Current Research Work

Microgrid control using VOLT-VAR technique to mitigate the impact of PV energy penetration

Proposed VOLT-VAR curves based on real solar inverters data of different companies like SMA, ABB and Schneider

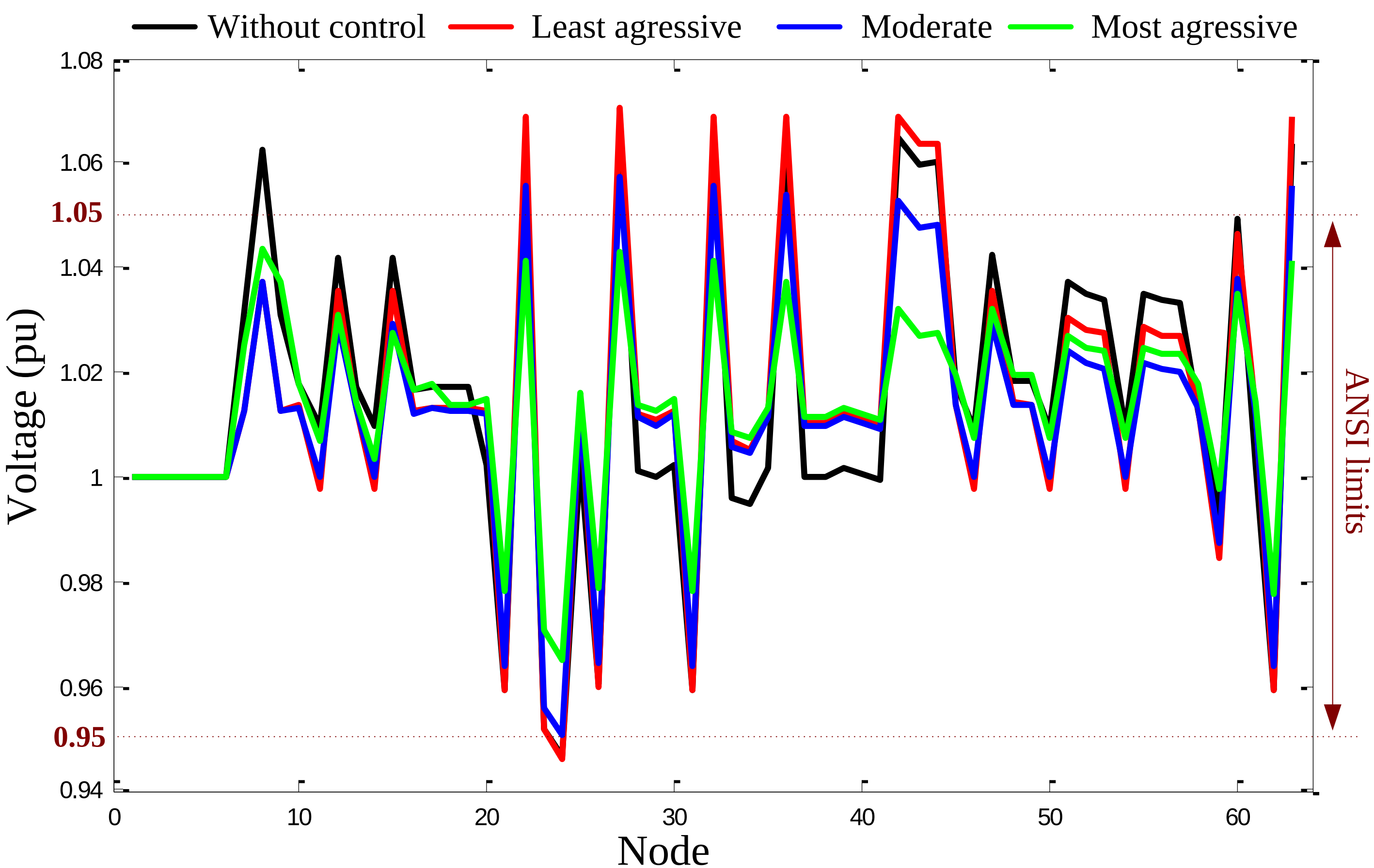


IEEE 13-node test feeder

Current Research Work

Microgrid control using VOLT-VAR technique to mitigate the impact of PV energy penetration

Nodes pu voltages without and with reactive power control

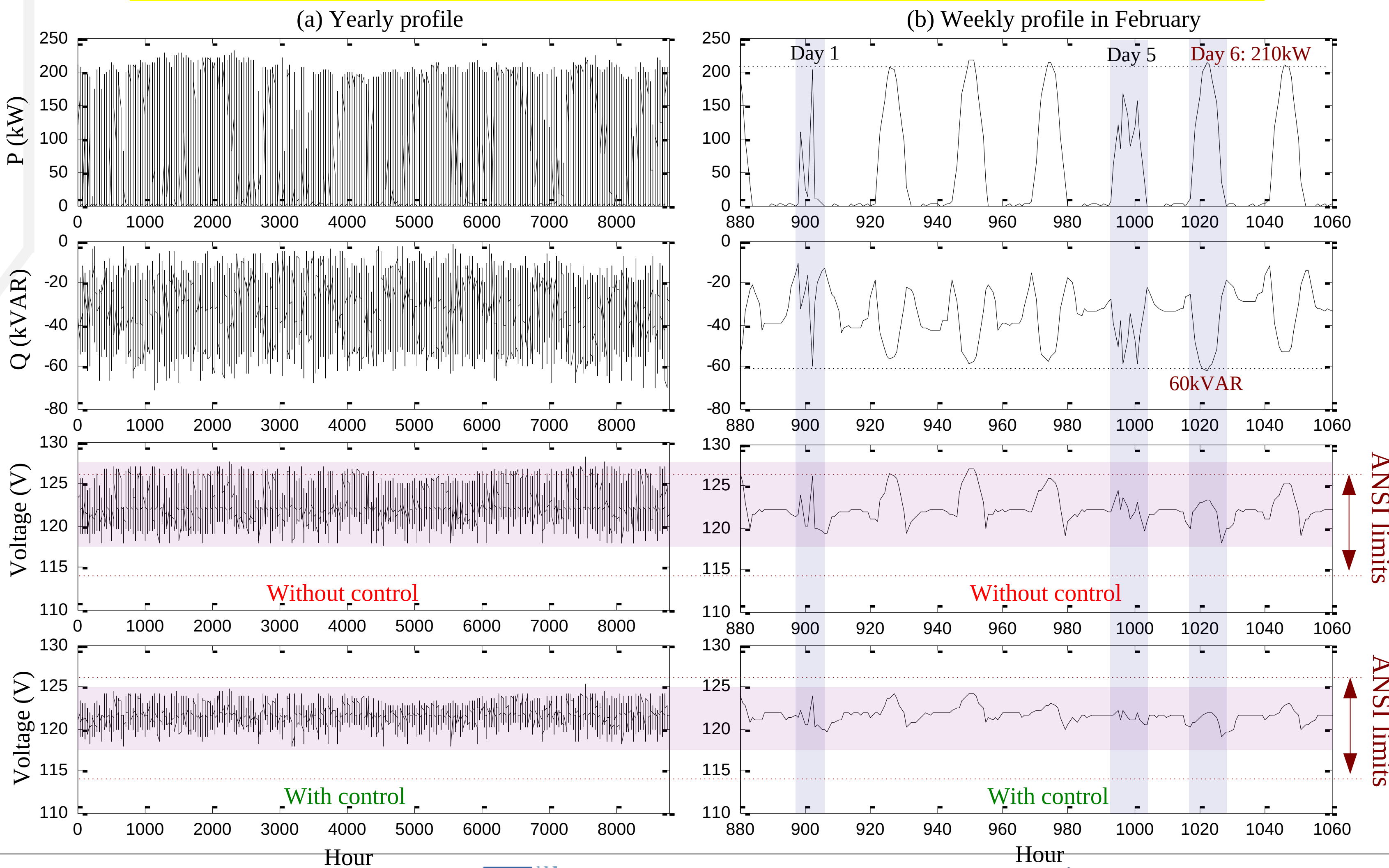


IEEE 13-node test feeder

Current Research Work

Microgrid control using VOLT-VAR technique to mitigate the impact of PV energy penetration

One-phase PCC voltage, real and reactive power output for PV Number 4



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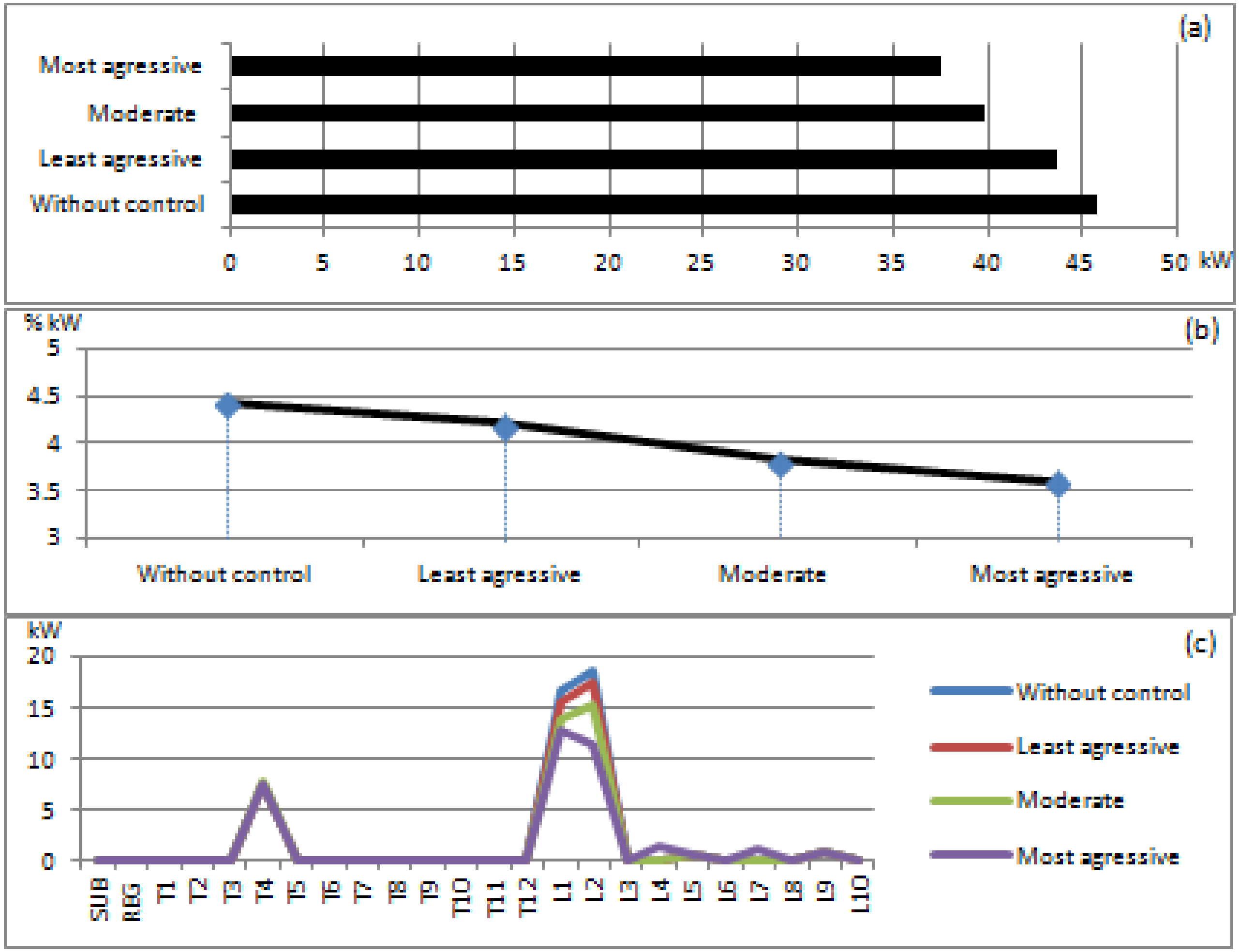
Current Research Work

Microgrid control using VOLT-VAR technique to mitigate the impact of PV energy penetration

kW losses without and with control, (a) MG total losses, (b) percentage of total losses, (c) losses per power delivery element

The total kW losses dropped from 45.7kW to 37.5kW which represents 3.61% of the total consumed real power



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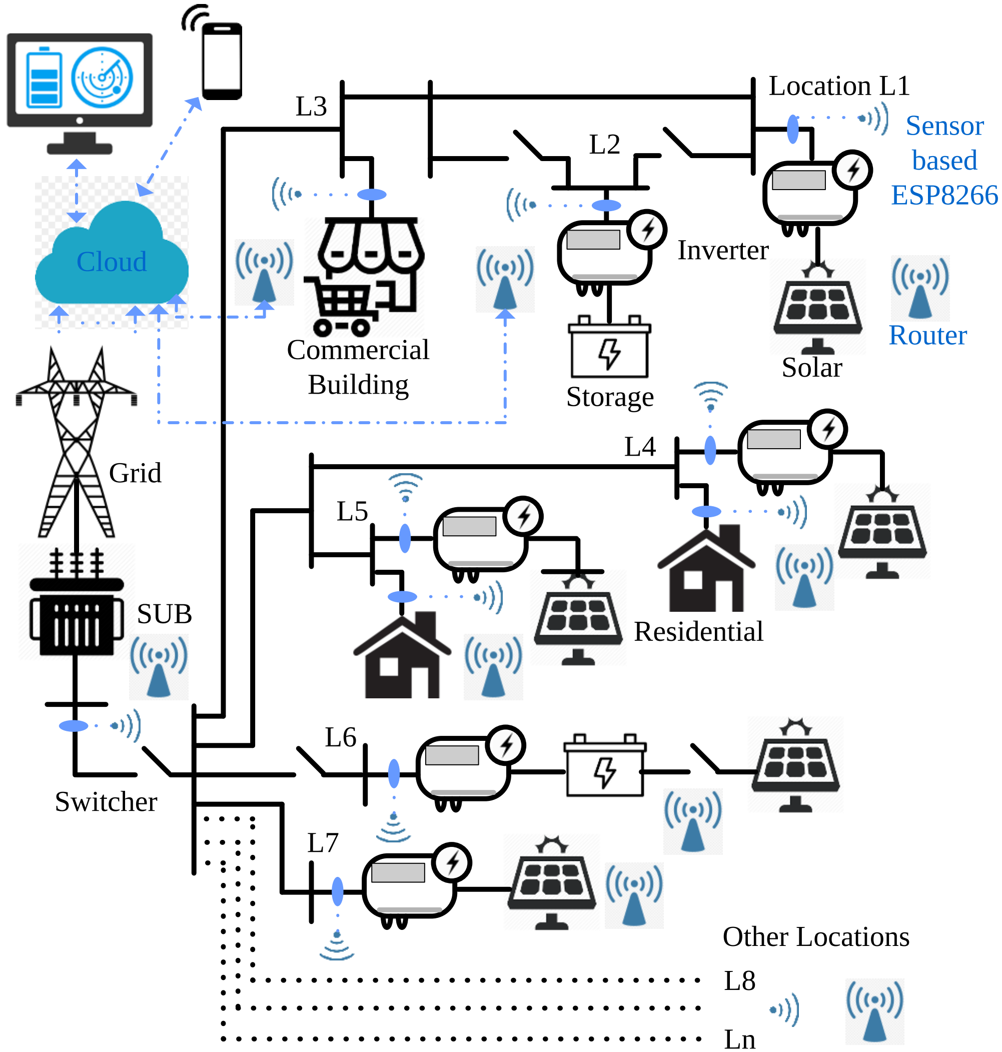
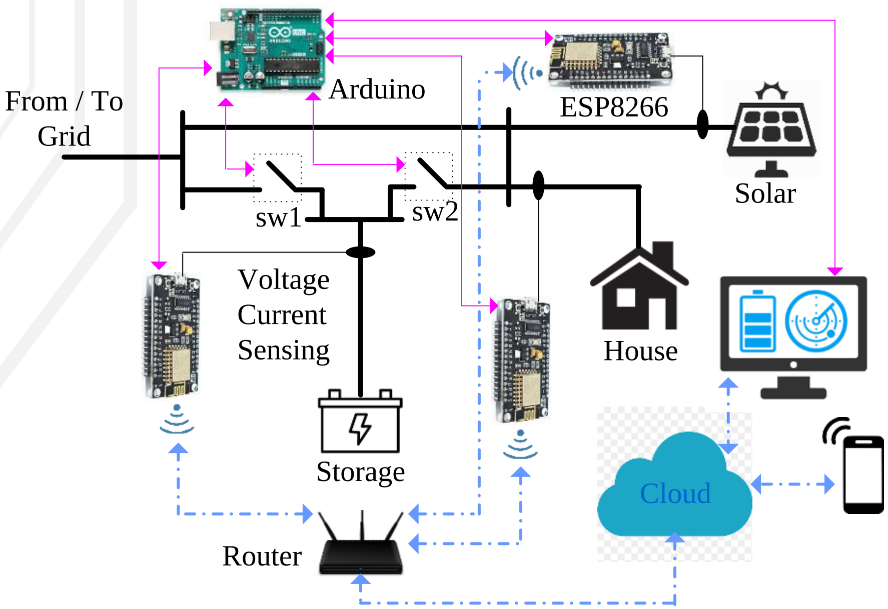
Current Research Work

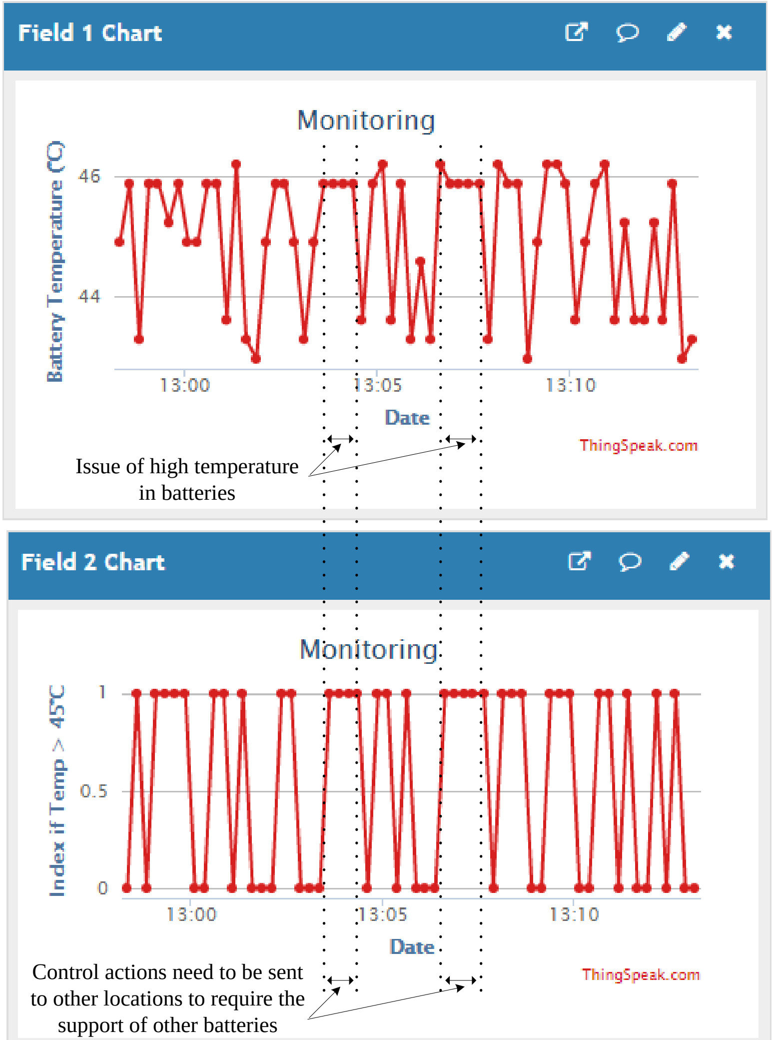
An Internet of Things application for Monitoring and Control in Electrical Systems



Current Research Work

An Internet of Things application for Monitoring and Control in Electrical Systems





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Arlington, VA, USA, November 16 - 2020