



Resiliency Analysis for the Development of Microgrid Architecture against Climate- Driven Events in the Dominican Republic's Electric Systems

QUARTERLY TECHNICAL
REPORT (15/07/22 -15/10/2022)



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1. Ongoing Research

1.1. OpenDSS-Based Distribution Network Analyzer in Open-Source GIS Environment Implementation in EDENORTE (VOLG101)

During this quarter the research group reached an important milestone with the presentation of results named Modeling of Distribution Networks with High Renewables Penetration in Open-Source Software (OpenDSS + QGIS), which we made available through a blog (see 9 Additional Information)

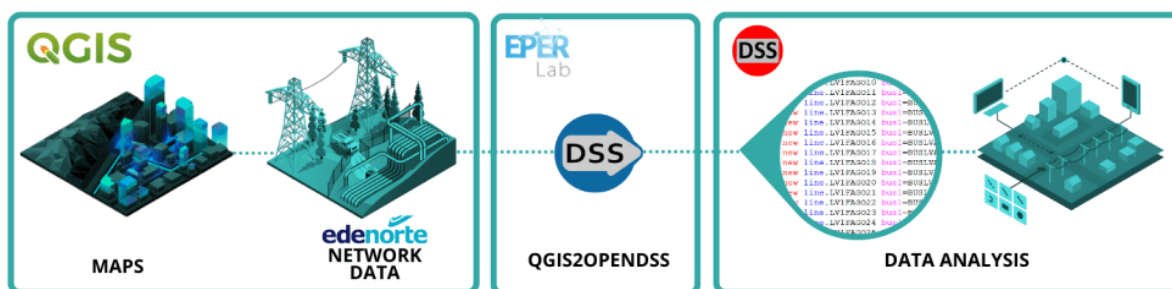


Fig 1 – Integration of QGIS and OpenDSS through QGIS2OPENDSS Plugin **Source:** Created by the author

There we report on the implementation of QGIS2OPENDSS, a plugin designed to automatically generate distribution network models for OpenDSS, which data comes directly from an open-source Geographic Information System (GIS) software environment, QGIS. This plugin was developed by researchers at the EPER Lab in the University of Costa Rica (UCR), and it's part of a series of tools under development to help researchers and power engineers to assess the evolution of distributed generation and power systems, reducing the time from model to simulation by orders of magnitude (months to weeks).

As previously reported, a working group has been created between PUCMM Researchers and EDENORTE's Distribution, Planning and Network Study Department. The main objective of the group is to develop the processes and models to **clean, fix, aggregate or remove incorrect, corrupted, incorrectly formatted, duplicated, or incomplete** data within the GIS network dataset, in order to enable the data to be processed by the **QGIS2OPENDSS** plugin in QGIS.

1.1.1. Integration of QGIS and OpenDSS

The QGIS2OpenDSS is one of those plugins developed at the University of Costa Rica to speed up the modeling of DN circuits. The plugin contains a Graphical User Interface (GUI) to guide the user in the data translation, and prompts the user to select the layer of DN elements to be modeled in OpenDSS (see Fig. 2). The process can be found in the plugins manual, where a detail description is given.

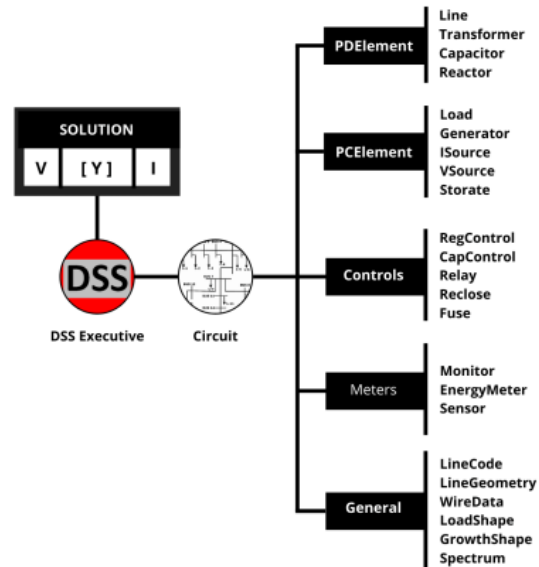
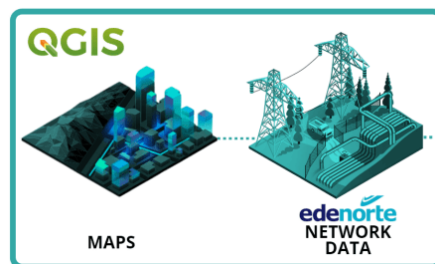


Fig 2 – Graphical User Interface for QGIS2OPENDSS **Source:** Create by the author based on [5]

To create the networks models QGIS2OpenDSS uses Kd-trees (quick nearest-neighbor lookup algorithm) to speed up the identification of connected elements. Load Allocation is done using the monthly kWh consumption for each customer type (residential, commercial, or industrial) and loading a set of available daily load profiles for each. Then it calculates, by integration, their quantized energy value (the plugin finds the largest kWh consumption to create an array of quantized energy values, starting from 25 kWh up to the largest monthly kWh value in fixed steps) When a customer has a quantized energy value without an associated curve, the program will create a new load profile curve by scaling up or down the closest available load profile.



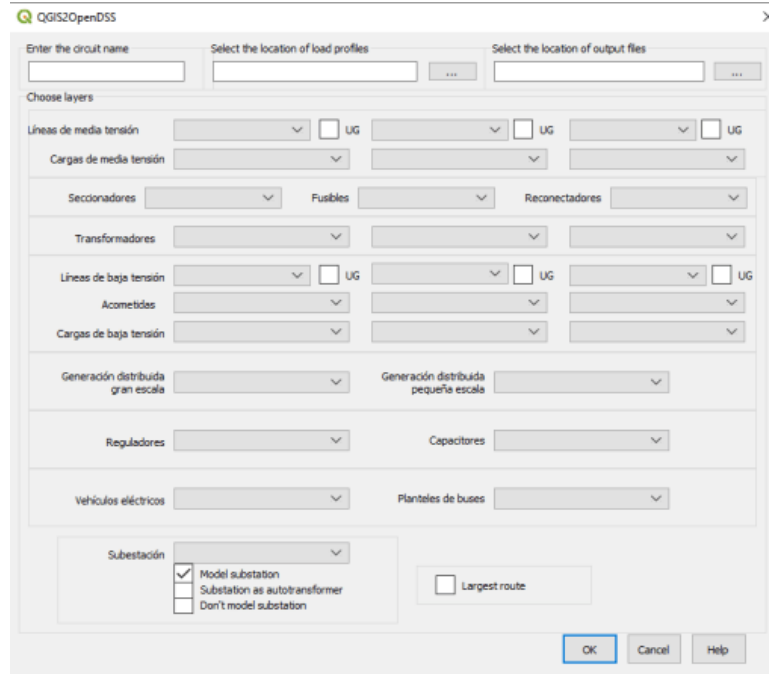


Fig 3 – Graphical User Interface for QGIS2OPENDSS

Once all elements are connected the plugin uses the list of attributes extracted for the GIS layers to create the OpenDSS files (see Fig 9). The output files are MVlines.dss, Transformers.dss, LVlines.dss, LVloads.dss and Loadshapes.dss. The pluggin also creates a *.csv file with the coordinates of the buses, which can later be used to plot the circuit in OpenDSS (see Fig. 13).

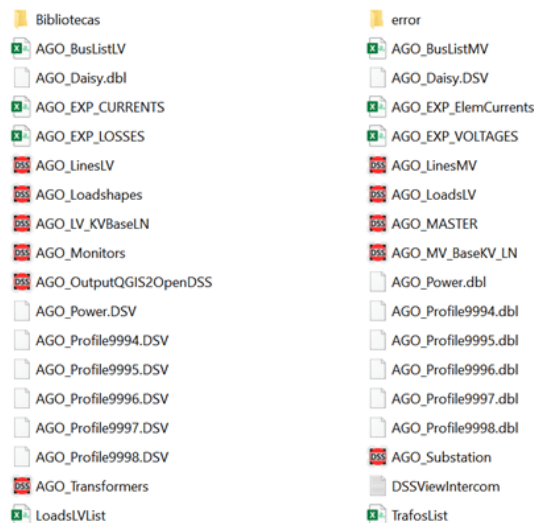


Fig 4 – Generated OpenDSS files – VOLG 101 (~ 7,500 Loads)

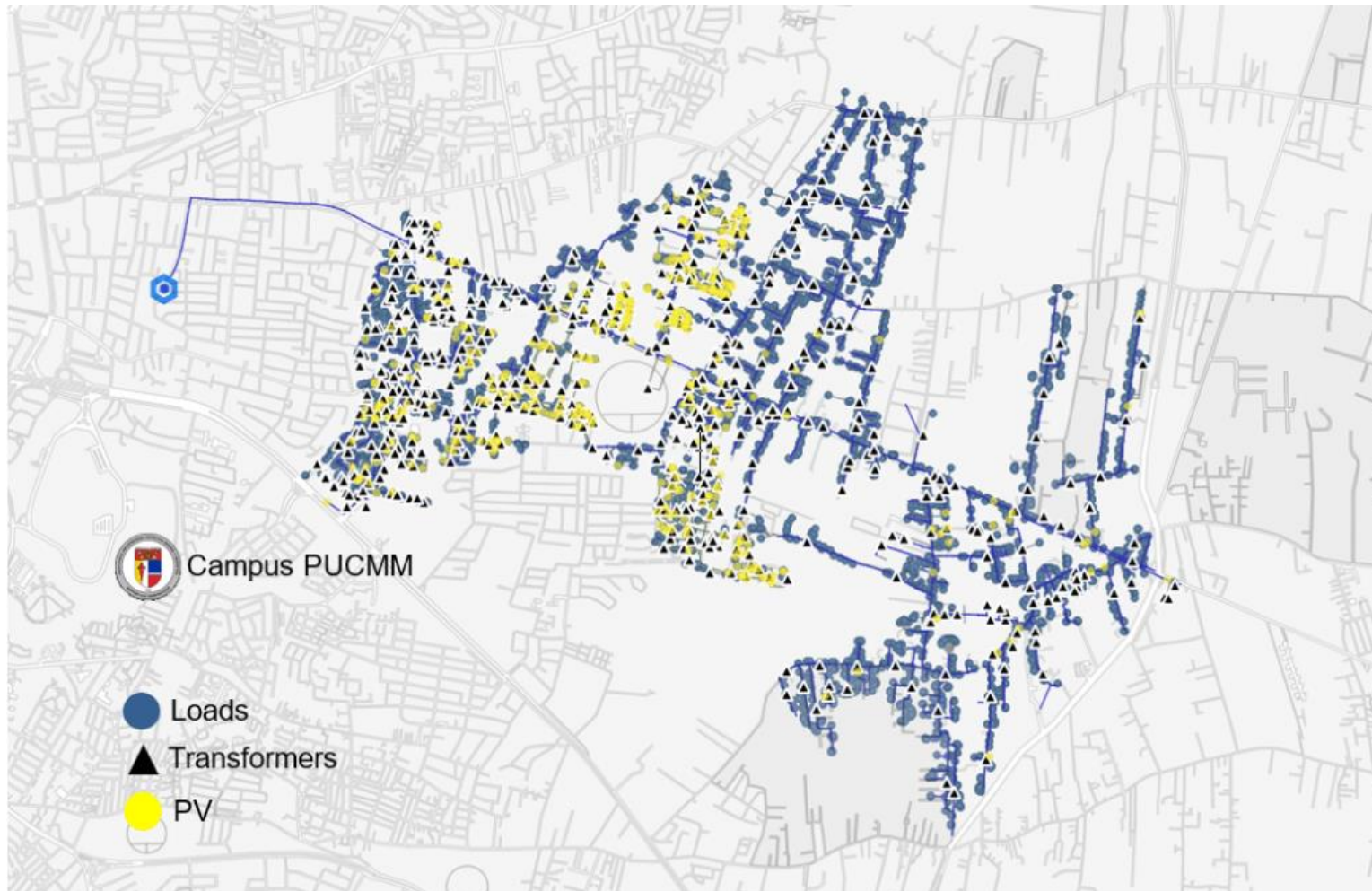


Fig 5– Villa Olga 101 Feeder, Santiago. Source: Created by the author in QG

1.2.UPDATE- EDENORTE's Distribution Network Data Extraction Process

With the goal of implementing and adding the OpenDSS-Based Distribution Network Analyzer into EDENORTE's software stack, a working group was created within the Distribution Management and Network Studies Department (Joan Nuñez and Saúl Azcona) and the MG Research Team. The task at hand was to create a blueprint of the processes that are necessary to obtain, clean and transform the utilities' existing GIS Data to be fed into the QGIS2OPENDSS Plugin.

QGIS2OPENDSS attributes are classified as mandatory (indispensable) and optional (these attributes can be extracted indirectly from the files generated by the GIS departments of the electricity distribution companies). EDENORTE's GIS Database contains most of the attributes required by the plugin, however an extensive work of data cleaning was necessary before testing the plugin capabilities. Engineers from EDENORTE created several Data Dictionaries, Workflows and Models that are now being used to standardize and summarize the efforts that have been conducted for future use (See Fig 10).

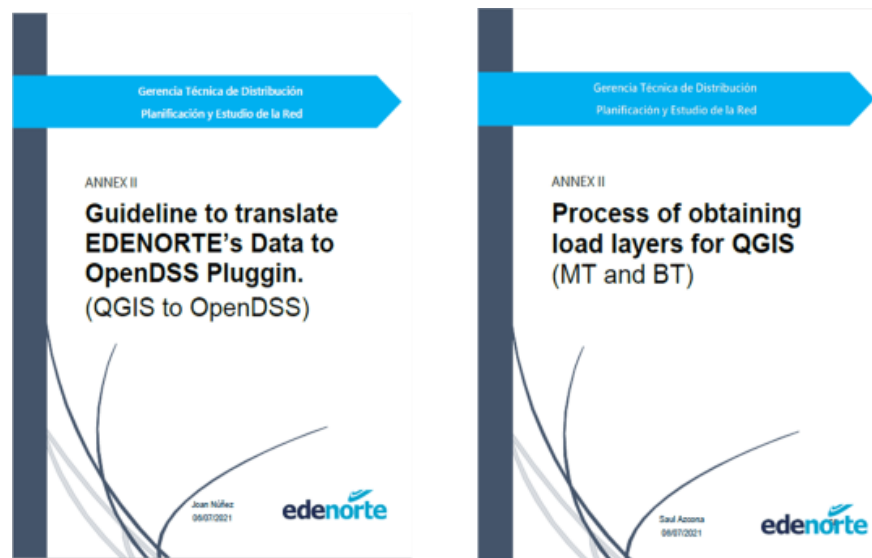


Fig 6 – Guidelines and Process created by EDENORTE **Source:** Created by the author

1.3. Work in progress - From modelling to Simulation in OpenDSS

Using the output files and other databases that contain the characteristics and configuration of conductors (see list below), initial simulations were run using the Snapshot Mode (see **OpenDSS script in Fig 9**), which performs a single power flow solution under static condition.

1. **WireData:** Database that defines the raw conductor data that is used to compute the impedance for a line geometry (i.e., name, resistance, diameter and GMR) of each wire.
2. **Config Lines:** Database that defines the conductors and positions of the conductors in a type of line construction. (i.e., number of conductors, phases and spacing) of each line.

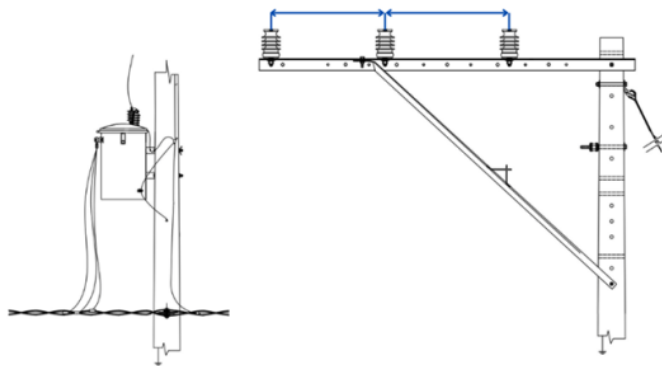


Fig 7– Line Spacing: (a) single phase MV line and single-phase LV line (b) Horizontal MV line

3. **LoadShapes:** Database that provides the electrical behavior of a load, consists of a series of multipliers that are applied to the base kW values of the load to represent variation of the load over some time period.

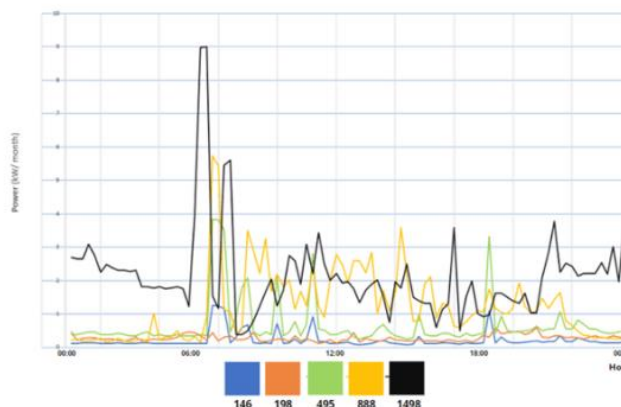


Fig 8 – Load Profiles (Daily)

4. **MVLines:** Database that details the connectivity of each MV line/cable segment, geometry of line/cable and its length.
5. **Transformers:** Database that provides the information of all transformers (e.g., losses, impedance, voltages, etc.).
6. **LVLines:** File that details the connectivity of each LV line/cable segment, geometry of line/cable and its length.
7. **Loads:** File that indicates load location, type, nominal voltage, and power factor and the associated load shape

```

Clear
New Circuit.AGO baseKV=69 pu=1.05 R1=0.63 X1=6.72 R0=4.07 X0=15.55
!R1=0.63 X1=6.72 R0=4.07 X0=15.55

redirect Bibliotecas/bibliotecas.dss
redirect AGO_LinesMV.dss
redirect AGO_Substation.dss
redirect AGO_Transformers.dss
redirect AGO_LinesLV.dss
redirect AGO_Loadshapes.dss
redirect AGO_LoadsLV.dss
redirect AGO_Monitors.dss
!Layer Substation: SUB

Set voltagebases=[345, 115, 69, 13.8, 12.5, 7.22, 4.16, 0.48, 0.415, 0.208]
Calc voltagebases

redirect AGO_LV_KVBaseLN.dss
redirect AGO_MV_BaseKV_LN.dss

! Define an energy meter -- needed for plot profile and yearly simulations
New Energymeter.test element=line.MV3PAGO314 terminal=1

Set emergvminpu = 0.7
!Set emergvmaxpu =

Set normvminpu=0.80
Set normvmaxpu=1.10

Solve

! Define bus coordinates
Buscoords AGO_BusListLV.csv
Buscoords AGO_BusListMV.csv

Plot Profile Phases=ALL

```

Fig 9 – Load Profiles (Daily)

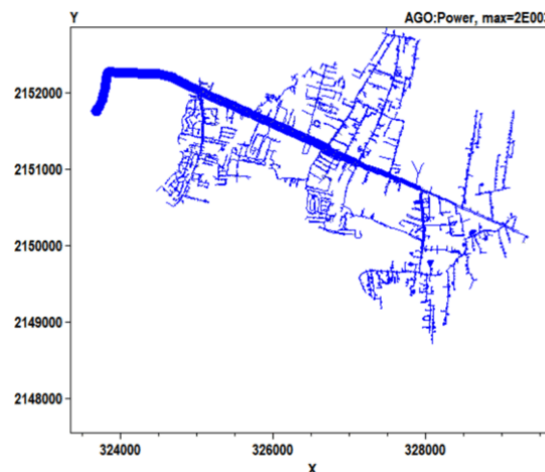


Fig 10– Circuit Plot of PowerFlow Snap Simulation in OpenDS

Upon inspection of the simulation results, an unusually high level of distribution losses were found around specific spots in the circuit (see Fig. 14).

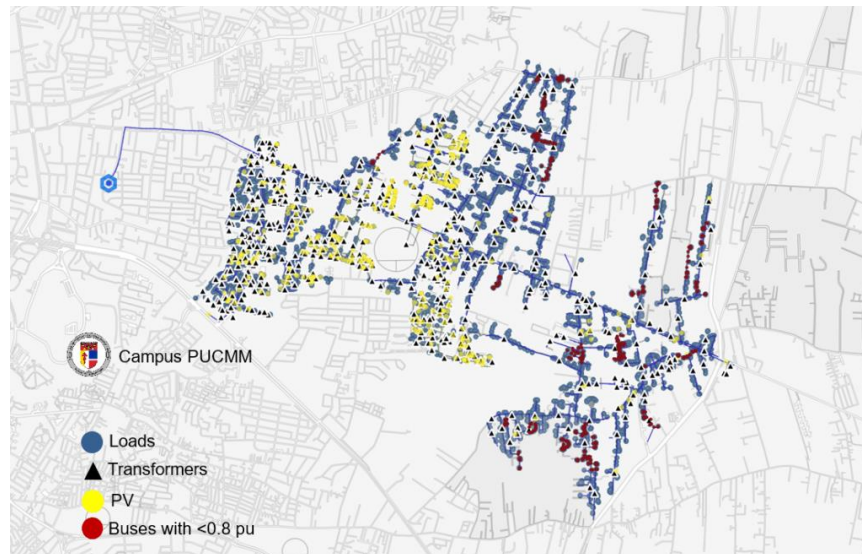


Fig 11– Low Voltage Level (<0.8pu) Villa Olga 101 Feeder, Santiago. Source: Created by the author in QGIS

A voltage profile of the circuit (per unit) can be seen in Fig X, where it is evident that some LV buses (around 600 out of 12K or 5%) show a low voltage level (<0.8 p.u). Studying and solving this issue is the ongoing work the team is conducting. A hypothesis is that transformers in these segments have associated more loads than they should, this might lead us to more data cleaning or to some insights for EDENORTE.

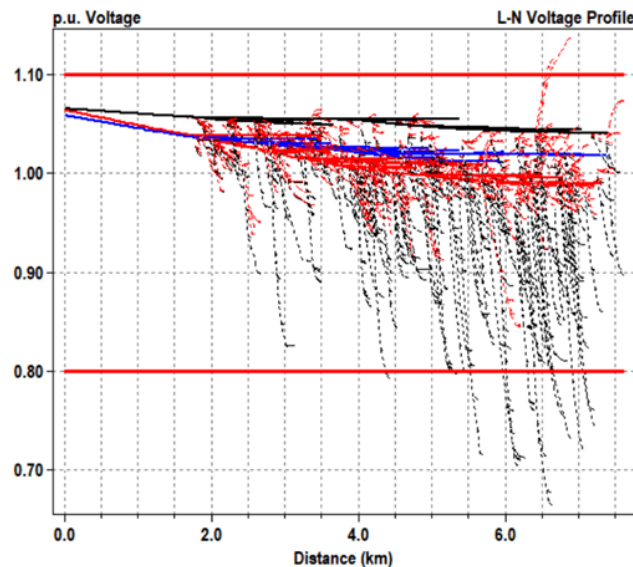


Fig 12 – Voltage profile Villa Olga 101 Feeder, Santiago. Source: Created by the author in OpenDSS

1.4. Ongoing Equipment Installation



Fig 13 – Technicians installing the remaining electrical wiring and conduits

1.5. Lab Labels and Placard

With the intention of getting everything ready for the forthcoming inauguration of the laboratory, the final details such as information signs and equipment labels have been put in place.



Fig 14 – Lab Labels and Placards

2. Project Events

2.1. Presentation of progress of the Microgrid Research Lab to the Innovation Cabinet of the Dominican Republic

The research group presented the work in progress of the research project on energy resilience and microgrids to the Innovation Cabinet of the DR Government. During the visit the advances and the objectives of the investigation were present with the objective of gathering interest in the evolution and possible additional funding for the laboratory.

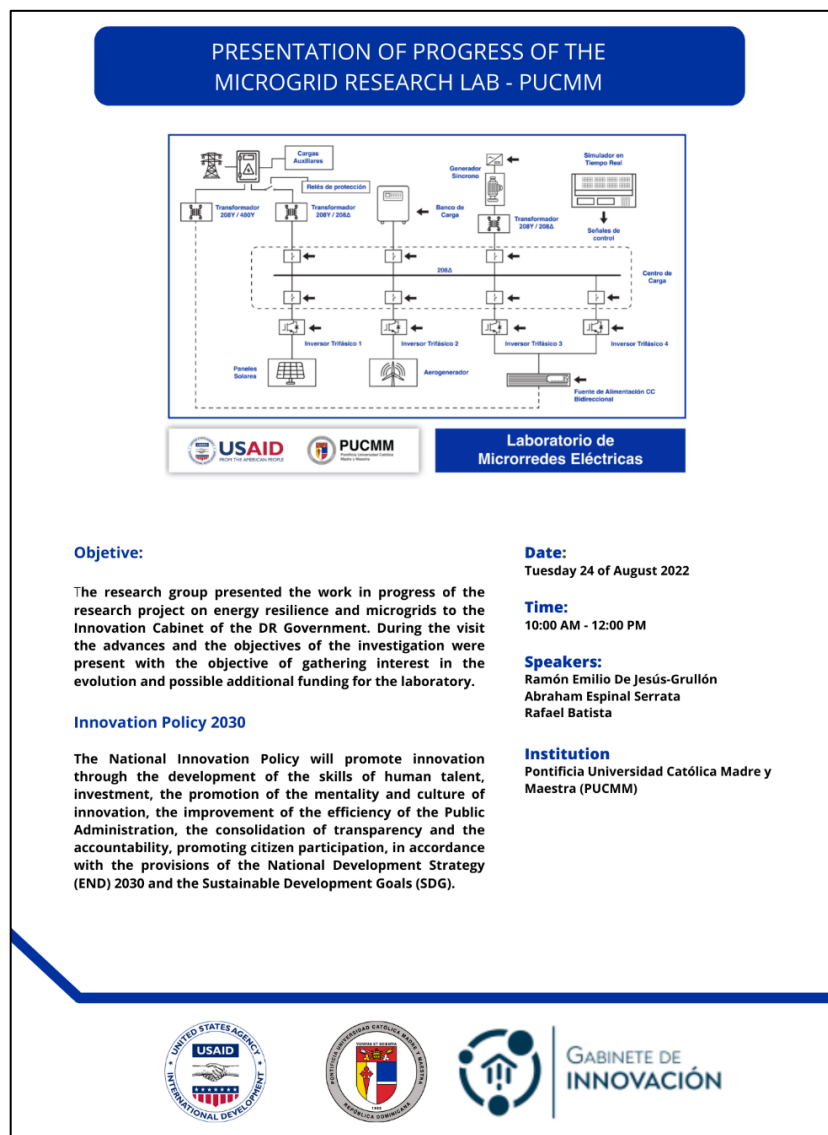


Fig 15 –Presentation of progress of the Microgrid Research Lab to the Innovation Cabinet of the Dominican Republic

2.2. Presentation of Research Lines to the Association of Merchants and Industrialists (ACIS)

The research group presented the active lines of research to the directors of the Association of Merchants and Industrialists of Santiago. The event organized by the *Vicerrectoría de Investigación* sought to connect the business community of the city of Santiago with possible opportunities for collaboration and financing.

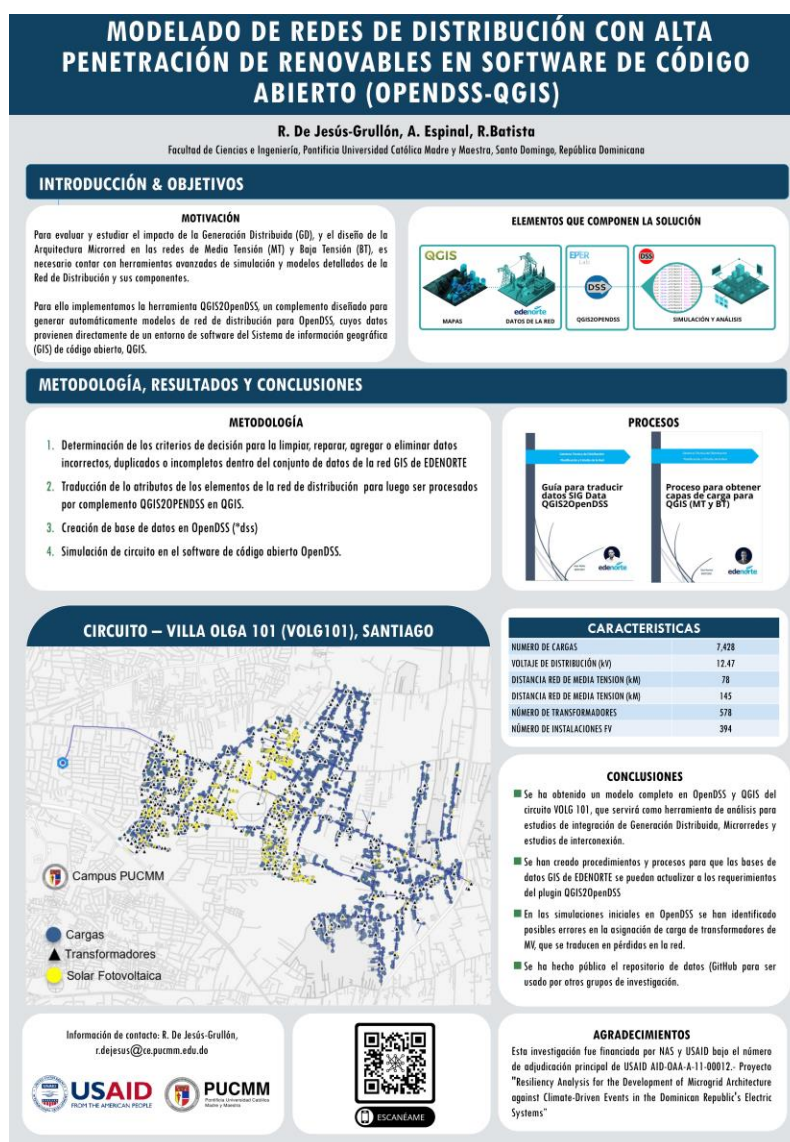


Fig 16 - Presentation of Research Lines to the Association of Merchants and Industrialists (ACIS)

OPTIMIZACIÓN DE MICRORREDES ELECTRICAS INTERCONECTADAS MEDIANTE EL USO DE ALGORITMOS DE INTELIGENCIA DE ENJAMBRE

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INTRODUCCIÓN & OBJETIVOS

MOTIVACIÓN

La operación de los sistemas eléctricos de potencia bajo los nuevos esquemas de la red eléctrica inteligente plantea importantes retos en la coordinación de la operación multiagente de los distintos elementos generadores/consumidores de potencia que pueden encontrarse dentro de la utilidad eléctrica. Esto marca la transición de un paradigma de generación/consumo centralizado hacia uno altamente descentralizado. Es necesario definir técnicas que permitan coordinar este nuevo esquema de operación bajo condiciones de aumento de la resiliencia y disminución de pérdidas técnicas.

OBJETIVOS

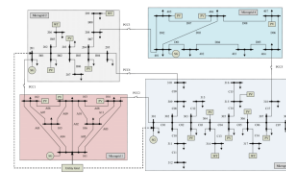
- Implementar técnicas de optimización para sistemas de alta complejidad mediante el uso de algoritmos de inteligencia de enjambre.
- Aplicar el algoritmo de optimización por enjambre de partículas en un sistema de microrredes interconectadas.
- Obtener una solución casi óptima en un bajo tiempo de convergencia y con buena estabilidad en el algoritmo.
- Validar la aplicación de este tipo de estrategia en la gestión de sistemas eléctricos de potencia

METODOLOGÍA, RESULTADOS Y CONCLUSIONES

METODOLOGÍA

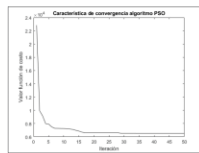
1. Se utiliza un sistema de potencia de referencia propuesto en la IEEE para la validación de la estrategia planteada, con un total de 48 buses de potencia.
2. La estructura se encuentra creada como una microrred interconectada en tipo malla, topología característica de las redes eléctricas inteligentes.
3. Se inicializa un algoritmo de optimización basado en restricciones de cargas críticas, minimizar pérdidas técnicas, servir la mayor cantidad de clientes y minimizar costos operativos.
4. Este algoritmo fue inicializado con una población de 200 partículas y un máximo de 50 iteraciones.

ALIMENTADOR DE PRUEBA



EJECUCIÓN ALGORITMO PSO

TABLA I						TABLA I					
Evaluación de la función de costo de la red eléctrica						Evaluación de la función de costo de la red eléctrica					
Iteración	Costo	Pérdidas	Reserva	Reserva	Observaciones	Iteración	Costo	Pérdidas	Reserva	Reserva	Observaciones
1	1.0	0.0	0.0	0.0	Observaciones	27	0.0	0.0	0.0	0.0	Microrredes Generadas
2	1.0	0.0	0.0	0.0	Observaciones	28	0.0	0.0	0.0	0.0	Observaciones
3	1.0	0.0	0.0	0.0	Observaciones	29	0.0	0.0	0.0	0.0	Observaciones
4	1.0	0.0	0.0	0.0	Observaciones	30	0.0	0.0	0.0	0.0	Observaciones
5	1.0	0.0	0.0	0.0	Observaciones	31	0.0	0.0	0.0	0.0	Observaciones
6	1.0	0.0	0.0	0.0	Observaciones	32	0.0	0.0	0.0	0.0	Observaciones
7	1.0	0.0	0.0	0.0	Observaciones	33	0.0	0.0	0.0	0.0	Observaciones
8	1.0	0.0	0.0	0.0	Observaciones	34	0.0	0.0	0.0	0.0	Observaciones
9	1.0	0.0	0.0	0.0	Observaciones	35	0.0	0.0	0.0	0.0	Observaciones
10	1.0	0.0	0.0	0.0	Observaciones	36	0.0	0.0	0.0	0.0	Observaciones
11	1.0	0.0	0.0	0.0	Observaciones	37	0.0	0.0	0.0	0.0	Observaciones
12	1.0	0.0	0.0	0.0	Observaciones	38	0.0	0.0	0.0	0.0	Observaciones
13	1.0	0.0	0.0	0.0	Observaciones	39	0.0	0.0	0.0	0.0	Observaciones
14	1.0	0.0	0.0	0.0	Observaciones	40	0.0	0.0	0.0	0.0	Observaciones
15	1.0	0.0	0.0	0.0	Observaciones	41	0.0	0.0	0.0	0.0	Observaciones
16	1.0	0.0	0.0	0.0	Observaciones	42	0.0	0.0	0.0	0.0	Observaciones
17	1.0	0.0	0.0	0.0	Observaciones	43	0.0	0.0	0.0	0.0	Observaciones
18	1.0	0.0	0.0	0.0	Observaciones	44	0.0	0.0	0.0	0.0	Observaciones
19	1.0	0.0	0.0	0.0	Observaciones	45	0.0	0.0	0.0	0.0	Observaciones
20	1.0	0.0	0.0	0.0	Observaciones	46	0.0	0.0	0.0	0.0	Observaciones
21	1.0	0.0	0.0	0.0	Observaciones	47	0.0	0.0	0.0	0.0	Observaciones
22	1.0	0.0	0.0	0.0	Observaciones	48	0.0	0.0	0.0	0.0	Observaciones



RESTRICCIONES

$$Cost_{total} = Cost_{operativo} + Cost_{tecnico}$$

$$Cost_{tecnico} = P_{util} + Q_{util} + P_{line_loss} + Q_{line_loss} \dots$$

$$\dots + (P_{load_total} - \sum_{i=1}^M P_{d_i}) + (Q_{load_total} - \sum_{i=1}^M Q_{d_i})$$

$$Cost_{operativo} = C_{kwh_DIESEL} \cdot \sum_{i=1}^M P_{d_i} + \dots$$

$$\dots + C_{kwh_UTIL} \cdot P_{util}$$

CONCLUSIONES

- Se ha validado el uso de sistemas de inteligencia de enjambre para la determinación de una configuración óptima en sistemas eléctricos de potencia con característica descentralizada.
- Es posible combinar restricciones de operación a nivel de cargas críticas, disminución de pérdidas técnicas e integración de costos de operación.
- El algoritmo ofrece un buen nivel de convergencia y tiempos de ejecución compatibles con un nivel de control terciario.
- Este tipo de trabajos muestran la importancia de la transición hacia un modelo energético descentralizado y fundamento en la red eléctrica inteligente.

AGRADECIMIENTOS

Esta investigación fue financiada por NAS y USAID bajo el número de adjudicación principal de USAID AID-OAA-A-11-00012.- Proyecto "Resiliency Analysis for the Development of Microgrid Architecture against Climate-Driven Events in the Dominican Republic's Electric Systems"

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Fig 18 –(3) Presentation of Research Lines to the Association of Merchants and Industrialists (ACIS)

3. Major Equipment Purchased

Since previous report all equipment have arrived at PUCMM and either installed or pending installation and testing. See 1.4

4. Outreach and Collaboration

4.1. Governmental Agencies

4.1.1. Innovation Cabinet – DR Government

Representatives from the Innovation Cabinet of the DR government. The objective of the visit was for them to get a first-person view of the installation, and to communicate their interest in promoting the emergence of new companies and public support for investment in R&D&i and risk capital.

One of the listed challenges of the Innovation Policy is sustainability:

“It is a challenge to prepare the nation with greater resilience to face the environmental challenges caused by climate change, directing the capacities and knowledge in a more sustainable management of natural resources, in addition to promoting the transition to clean and efficient energies”

URL: <https://www.innovacionrd.gob.do/>



Fig 19 – Presentation at the MG Laboratory - Innovation Cabinet – DR Government

4.2. Non-Governmental Agencies

4.2.1. ASOFER – National Energy Plan

As members of ASOFER (Association for the Promotion of Renewable Energies) we received an invitation to attend the presentation of the National Energy Plan (2022 – 2036), where we questioned and received feedback on the process to amend/update the plan, and how to get involved in the consultation processes.



Fig 20 – Socialization of the National Energy Plan

4.2.2. USAID – SEED (Sustainable Environment and Economic Development Office)

The MG Research team met with the USAID’s Sustainable Environment and Economic Development Office (SEED) to present the PEER project updates, discuss the upcoming USAID/DC site visit and receive information on the USAID Energy Sector Reform (ESR) and other potential collaboration opportunities.

During the meeting the USAID team shared with us several opportunities, like the Fulbright Scholar program, the GRID (Green Recovery Investment Platform) and the Annual Program Statement (APS), that we will explore in the next coming months.

4.2.3. ACIS - Asociación de Comerciantes e Industriales

The event organized by the *Vicerrectoría de Investigación* sought to connect the business community of the city of Santiago with possible opportunities for collaboration and financing for the projects.



Fig 21 – Presentation for the Asociación de Comerciantes e Industriales

4.2.4. EATON – Electrical and Industrial Power Management Solutions

EATON, a manufacturer of electrical equipment with local production, was contacted to strengthen relations and offer the laboratory and research resources for the creation of interinstitutional agreements. EATON was interested both in equipment donation and in collaboration for its research and development department, and the conversation is kept open waiting on them to finish a new Engineering location in Santo Domingo that is under construction.

5. Technical Research Presentations

5.1. Presentation to EDENORTE



URL: [Technical Presentation to EDENORTE](#)

A technical presentation of results was given to our main stakeholder (EDENORTE). The main goal of the presentation was to showcase the tools we have been building and using, providing insights on how EDENORTE can use them in their internal processes, and the possibilities to use them for more in depth analysis. Professionals from various directions were present (losses, projects, information technology, communications).



Fig 22 – Delivery of the documentation to the EDENORTE's technical management of distribution and network studies.

6. Potential Development Impacts

As part of his PhD Research, CI Rafael Batista is conducting research on the use of biological inspired optimization techniques for the consensus making on the formation of networked microgrids in order to enhance resiliency and operational characteristics of the electrical grid. Swarm Intelligence (SI) is being explored with the particle swarm optimization algorithm (PSO) and validated using a simulation of an IEEE benchmark system for the testing of networked microgrids, presented in (Alam et al., 2020).

Currently work is being done in the solution of the power flow equations for this benchmark system, which allows multiple reconfigurations by the activation of redundant 18 points of power coupling (PCC) for each microgrid presented. The decision of activating/deactivating PCC, increasing or reducing generation, and demand management will be done by the optimization algorithm. Various constraints are being included in the optimization process related to: serving critical loads, reducing transmission losses, improving operational cost, and minimizing power requirement from the central utility. This work will be the fundamental part for the reconfiguration ability for improved resiliency proposed by this project.

7. Challenges

7.1. Budget constrains in the re-building of MG Research Lab.

Unexpected delays have arisen regarding the adequation of the selected space for the Microgrid Laboratory. Securing the required budget for covering these activities was a process that took longer than expected. Furthermore, the purchasing process of the needed materials for the reconstruction and some adjustment to the building electrical installation that needed to be done, contributed to these unexpected delays.

All these adequation activities were challenging for the project because there were limitations of the available funds. Also, security requirements (access control, camera surveillance, and fire detection) and the air conditioning of the selected space were completed but these also contributed in the presented delays.

8. Future Plans

8.1. Fulbright Scholar Program – USAID

Our society's high dependency on electrical energy indicates the importance of correctly handling the distribution, generation, and consumption of this resource. Nevertheless, there is an important need in Dominican Republic's electrical energy sector for the adoption of the latest trends in **management, coordination, and control of the operation of electrical distribution networks**. To that end, this project aims to procure funding to organize a series of ***academic and professional lectures*** in collaboration with the University of Puerto Rico at Mayagüez (UPRM) directed towards final year electrical engineering students and professionals currently working in Dominican Republic's electrical sector. The Pontificia Universidad Católica Madre y Maestra (PUCMM)'s Microgrid Laboratory (sponsored by USAID and NAS PEER program grant number 9-140) offers the perfect setup for the development of a series of training sessions related to electrical power system simulations and implementation of electrical smart grid technologies. Professor Fabio Andrade is the Director of the Sustainable Energy Center (SEC) at UPRM, this center has had vastly experiences regarding the simulation and creation of control strategies of power systems, promoting these exchanges will greatly improve the proficiency of electrical engineering students and professionals that will take part in this series of training. Furthermore, a better understanding of these future trends in the electrical sector will clearly help in the integration of technologies which could improve the resiliency of Dominican Republic's electrical sector. This improved resiliency could have great impacts in the security and stability of Dominican Republic's entire society. Finally, this project will be a key enabler for the creation of new study programs which will relay on the Microgrid Laboratory and promote higher level education in the form of master or doctoral programs.

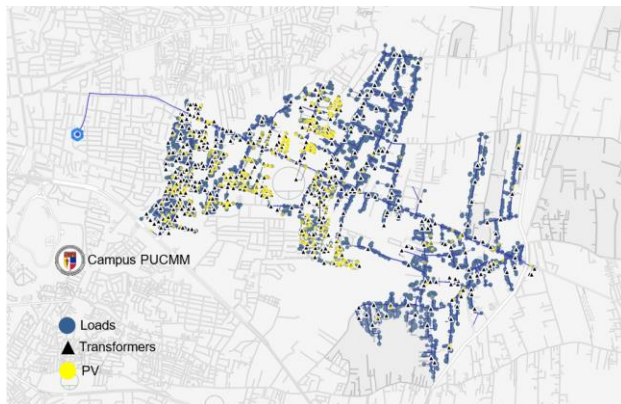
8.2. Development of additional training courses on OpenDSS and Matlab/Simulink

The main platforms/software to simulate the electrical grid components and interactions have already been identified by the team, as well as training courses on how to utilize them were already developed to build capacity among the students and professionals that will interact with the project. This will serve as a platform for developing future work and investigations. The team will organize workshops on the use and capabilities of these two tools for developing Power Systems simulations and to address studies on specific electrical grid issues. The training courses and workshops will be held at PUCMM with the support of the Engineering faculty and student's committee. Furthermore, these training courses will help the integration of future students into the project as well as serving as a base for the development of the engineering curriculum of the local universities.

8.3. Testbed Integration

Currently the team is working on the preparation of the laboratory area for the placement and initial testing of the OPALRT real time control system. Network and protected electrical connections are currently being built. The initial validation will be done without the use of the inverters. The inverters are scheduled to arrive in the Dominican Republic in mid-January. The custom clearance process and tax exemption is expected to take about one month. Additionally, we are planning to test the DC power supply in January. We expect that the resistive digital load will be in the Dominican Republic by the end of January but will also have to go through the customs clearance process expected to take a month as well.

9. Additional information



Blog Entry 8 (September 2, 2022) |
Modeling of Distribution Networks with High
Renewables Penetration in Open-Source
Software (OpenDSS + QGIS)

This blog presents the implementation of QGIS2OPENDSS, a plugin designed to automatically generate distribution network models for OpenDSS, which data comes directly from an open-source Geographic Information System (GIS) software

environment, QGIS. This plugin was developed by researchers at the EPER Lab in the University of Costa Rica (UCR), and it's part of a series of tools under development to help researchers and power engineers to assess the evolution of distributed generation and power systems, reducing the time from model to simulation by orders of magnitude (months to weeks)

URL: <https://microgrid.pucmm.edu.do/modeling-of-distribution-networks-with-high-renewables-penetration-in-open-source-software-openss-qgis/>

The data has been made public in a GitHub repository: