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

QUARTERLY TECHNICAL REPORT (15/10/2021)

Table of Content

1. Quarterly Project Summary

1.1. Ongoing Research

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

With the goal of implementing and adding the OpenDSS-Based Distribution Network Analyzer into EDENORTE's (main stakeholder) software stack, a working group was created within the Distribution Management and Network Studies Department and the MG Research Team. The task at hand is 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. Several *Data Dictionaries* and *Workflows* are being created in order to standardize and summarize the efforts that have been conducted for future use.

The ongoing research is focused on solving the technical challenges that have arisen when translating the EDENORTE's information, contained in the Geographical Information System (GIS), to the OpenDSS terminal. A direct communication channel has been established with the lead researcher of the Power and Energy Research Laboratory (EPER-Lab) of the University of Costa Rica. Dr. Valverde has been collaborating in the implementation of the QGIS2OpenDSS plugin developed at the University of Costa Rica that extracts and processes GIS data to automatically generate the OpenDSS files required to run the model. To create a network model, OpenDSS follows a sequence of definitions, i.e., source, lines, transformers and loads. However, given the script-written nature of this software, the creation of large-scale networks must be done carefully. Using the QGIS2OpenDSS this process can be less troublesome, reducing the time dramatically.

In order to reduce complexity and to address the current challenges, while also testing the software capabilities and flexibility the selected distribution networks have been reduced significantly, but the simulations have been running flawlessly. A great deal of effort will be invested to fix the software bugs and to increase the simulation output which will allow for further automation. Automating the process allows for faster development on future stages of project development in the academic world and in terms of being able to transfer knowledge.

1.1.2. Indicative Plan for Critical Energy Infrastructure (Report for Vice Minister of Security and Energy Infrastructure)

The Vice Ministry of Energy Security and Infrastructure is a body of technical nature that is linked to the Ministry of Energy and Mines and is in charge of carrying out studies on energy security for the construction and protection of critical energy infrastructure related to the transportation, storage and refinement of fuels, as well as gas pipelines, oil pipelines, and electric networks.

Currently, the energy sector in the Dominican Republic faces great challenges due to the country's island status and the lack of conventional energy resources. The Vice Ministry of Energy Security and Infrastructure, in keeping with its mission of establishing policies to guarantee electric power service for the Dominican population, is working on a National Indicative Plan for the Development of Critical Energy Infrastructures.

PI Ramón Emilio De Jesús-Grullón is the main external assessor and editor for the Plan, whose executive summary draft (as of 21st of September) can be seen in the annexes. Check *Outreach and Collaborations 3.1.3* for more information.

2. Project Events

The MG Research Team organized two events, one workshop titled: *"Modeling and Simulation of Electrical Distribution Networks using OpenDSS and QGIS"* organized PI Ramón E. De Jesús and CI Abraham Espinal, where the team showed an introduction to one of the main tools being developed and utilized in the research: *a software add-on (plugin)* that creates the OpenDSS network model directly from an open-source GIS software environment (QGIS2OpenDSS - developed by a research laboratory in the University of Costa Rica) and that exponentially reduces modeling time to simulation time.

The other workshop titled *"Introduction to Matlab & Simulink for the Analysis of Electrical Power Systems" was* organized by CI Rafael Batista. The workshop reviewed the fundamental concepts for the application of the tools offered by the Matlab / Simulink® suite and focused on the study of electrical power systems.

Fig 1 - Project events | Modelling and Simulation of Distribution Networks using OpenDSS + QGIS (left) | Introduction to Matlab for Power System Analysis (right)

3. Outreach and Collaborations

3.1. Government Agencies

3.1.1. EDENORTE (Empresa Distribuidora de Electricidad del Norte)

The group is developing and using tools to automate the creation of network models directly from an open-source GIS software (QGIS) environment (QGIS2OpenDSS - developed by a research laboratory in the University of Costa Rica). Currently, final customer connections (*acometidas*) that go from low-voltage (LV) networks to homes, businesses, and industries are not created in EDENORTE's GIS database, so a great deal of effort has been invested in finding ways to automate its creation.

3.1.2. EDESUR (Empresa Distribuidora de Electricidad del SUR)

The team approached the "Grid Planning and Studies Department" of EDESUR in order to take advantage of the progress made with the EDENORTE. EDESUR's team is also working to map out its distribution networks in QGIS and they are at the same level of progress on its digitization journey. Professionals from EDESUR are attending the "QGIS2OPENDSS" workshop in order to start the adjustments necessary in their QGIS data to start running simulations with the software. The Planning Department in EDESUR has fewer resources than EDENORTE. Additionally, EDESUR has historically been criticized for the time delays on DG interconnection studies, which is driving their desire to receive the training. With the know-how gained in EDENORTE, the tests and implementation is expected to be faster in each follow on utility and due to the underlying conditions of the network, it will have a higher impact.

3.1.3. VSEI (Viceministerio de Seguridad Energética e Infraestructura)

The VSEI's new administration is now mapping the Critical Energy Infrastructure in the country, creating an Indicative Plan on how to enhance resiliency across the whole system. PI Ramón Emilio De Jesús-Grullón is the main external assessor and editor for the Plan, whose executive summary draft as of 21st of September can be seen in the annexes.

The Plan is derived from an extensive investigation on the effects of Hurricanes María and Irma (2017) on the Energy Infrastructure of Puerto Rico, and draws conclusions from the recommendations made by agencies of the United States Government (e.g. US Department of Energy) and Laboratories such as Rocky Mountain Institute (RMI) to the government of Puerto Rico: PREPA (Puerto Rico Electric Power Authority) and Puerto Rico Energy Commission (PREC), as well as the vision of the Critical Infrastructure Risk

Management Framework taken from the National Infrastructure Protection Plan (NIPP) of the United States Government, and of the literature in Energy Infrastructure Risk Management of U.S. Department of Energy Office of Energy Assurance.

The National Plan is organized as follows:

- **Section 2:** Introduction
- **Section 3: Overview of the Dominican Electricity Sector:** Current Status and Main Indicators
- **Section 4: SENI (National Interconnected Electric System) Vulnerabilities:** Describes the SENI structure and the cascading risks due to this structure.
- **Section 5**: **Critical Infrastructure Risk Management Framework:** Describes the objective and steps for designing a Risk Management Framework.
- **Section 6**: **Recommendations**: Specific and essential recommendations for the development and improvement of the Critical Energy Infrastructure.

3.1.4. National Energy Commission (CNE)

The research team contacted CNE's Alternative Sources and Rational Use of Energy Director, Ing. Yeulis Rivas, to present the research project and to discuss Critical Energy Infrastructure, as well as the evolution of the Energy Transition Project, led by *Deutsche Gesellschaft für Internationale Zusammenarbeit* (GIZ) GmbH together with 17 other partners from the energy sectors and climate in the country. The objective is to support the climate and energy sectors of the Dominican Republic to develop actions aimed at a low-carbon economy through the promotion of renewable energies.

3.2. Non-Governmental Organizations

3.2.1. INTEC (Instituto Tecnológico de Santo Domingo).

CI Rafael Batista is starting his doctoral formation as a result of networking activities promoted by this project. His doctoral program is focused on the management of Renewable Energy Resources (RES) and current trends related to smart grid infrastructure. His doctoral thesis work is going to be fundamental in one of the main research branches related to electrical grid resiliency, distributed control, and the dynamic formation of microgrids under fault conditions. Furthermore, this has open new interactions possibilities with the doctoral students of this program and the institutions involved, specially INTEC.

3.2.2. Puerto Rico and Caribbean Power and Energy Society (PES)

PI Ramón Emilio De Jesús was officially invited to be the Chapter Officer for Puerto Rico and Caribbean Power and Energy Society (PES), which consists of roughly 85 members including power engineering professionals, students, and associates in the Caribbean. The chapter provides high-quality technical meetings and technical courses to its members and non-members alike. Some of the topics that have been covered recently in our technical meetings include Grid Modernization, Energy Markets, Substation Automation, and Arc Flash Safety. PI De Jesús is in the process of developing a Chapter Plan for Q4 2021 and 2022 to advance the conversation with the committee and those involved in IEEE Dominicana, which will evaluate the plans.

3.2.3. Power and Energy Society (PES) Coordination in IEEE Dominicana (North Region)

PI Ramón Emilio De Jesús was also invited to coordinate and lead the efforts of IEEE across the norther region of the country, officially creating a subsection. This position will be open to the members of the research team if PI De Jesús is named Chapter Officer of PES Puerto Rico and Caribbean.

3.2.4. IEEE Dominicana (Institute of Electrician and Electronics Engineers – Subsección Dominicana)

Recurring workshops are being set up by IEEE Dominicana and the MG Research team. The workshops are going to reach greater audiences as an IEEE Student Young Professional section is in the ideation process to be founded in PUCMM's campus in Santiago de los Caballeros.

3.2.5. Universidad de Costa Rica (UCR)

A direct communication channel has been established with the lead researcher of the Power and Energy Research Laboratory (EPER-Lab) of the University of Costa Rica. Dr. Valverde has been collaborating in the implementation of the QGIS2OpenDSS plugin developed at the University of Costa Rica that extracts and processes GIS data to automatically generate the OpenDSS files required to run the model.

3.2.6. **Energía Journal –** *Portal to the most relevant information about the world of energy and sustainability in the Dominican Republic | PI De Jesús is a co-founder of Energia Journal.*

Energía Journal created a brief video (*Resiliencia Energética - Microredes frente a eventos climaticos | PUCMM*) that outlines the vision for the Research Project, going from the root of the problem: increasingly frequent climate-driven events and its aftermaths on the energy system, showing a brief history on interdependency and centralization of the energy systems, to the concept of energy resiliency and how microgrids enhance it.

URL: https://youtu.be/LhLgnICVCIU

Energía Journal Podcast

The research team MG, PI Ramón Emilio De. Jesús, CI Rafael Batista, and CI Abraham Espinal were invited to participate in the Energia Journal Podcast titled: *Episode 1.07: Microgrids against Climate Events in the Dominican Republic*, where the team detailed the vision of the project and where they talked about how Microgrids (MG) have emerged as a tool that increases resilience due to their potential to recover quickly and effectively, providing an alternative approach to the resilience dilemma.

URL:https://anchor.fm/energiajournal/episodes/Episodio-1-07-Microredes-contra-Eventos-Climticos-en-Repblica-Dominicana-estk9m/a-a40htcj

Fig 2. Microgrids against Climate-Driven Events in the Dominican Republic **-** Energia Journal Podcast Banner

3.2.7. Island Innovation's Virtual Island Summit

Ramón Emilio De Jesus, PI, Joined a network of 10,000 islanders from around the world as a speaker and ambassador at the #VirtualIslandSummit from Island Innovation. Under Unite Behind The SC1.5NCE - an Intergenerational Dialogue on the Future of Islands, PI De Jesús shared his experience as a researcher as well as in the Island Innovation network and Ambassador program. and how he thinks it shaped and helped create change on the island, as well as how it influenced Ramon and his colleague Miguel H. Estévez S. to create Embajadores de Energia at Energía Journal RD.

URL: https://www.youtube.com/watch?v=FBLA_JmOAWQ&t=4255s

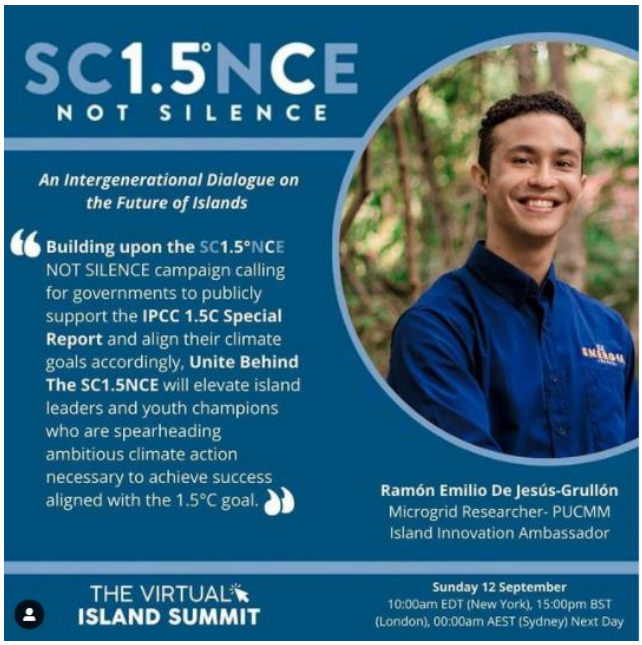


Fig 2. Virtual Island Summit – United Behind Science International Dialogue. Pi Ramón Emilio De Jesús Banner

3.2.8. Collaboration with Madre y Maestra Foundation

C.I Abraham Espinal, through his company (ENESTAR), has made agreements to donate scholarships and equipment to the School of Electrical and Mechanical Engineering and the Microgrid and Renewable Energy Laboratory of the University for an estimated value of USD$20,000.00.

URL: https://www.elcaribe.com.do/panorama/region-norte/enestar-y-fundacion-madre-y-maestra-firman-acuerdo/

Fig 3. ENESTAR signed an agreement for a scholarship and donation program with the Fundación Madre y Maestra

4. Technical Research Presentations

Outreach activities for the coordination of new technical presentations have been arranged with the Universidad Católica de Oriente Rionegro de Colombia. As a result, CI Rafael Batista has been invited to participate in a series of seminars that will focus on the use of Matlab as a real-time simulation tool, as well as an overview of the infrastructure that has been selected for the design and development of PUCMM's microgrid testbed.

5. Potential Development Impacts

5.1. Use of developed tools by EDENORTE

The research tools being developed alongside the utility personnel will be applied immediately by the Technical Management of Distribution Network Planning and Study in their daily operations. The knowledge derived from this experience will help us to create the conceptual and information maps necessary to interact with the other distribution utilities in the country, thus reducing the learning curve and barriers to entry.

Joint training activities are being planned between EDENORTE's technical team and MG Research Team in order to teach students the tools that the regional utility uses to carry out network studies.

5.2. Capacity building in the DR Government (Vice Minister of Security and Energy Infrastructure)

With the invitation to participate in the creation of the Indicative Plan of the Vice Ministry of Security and Energy Infrastructure, the researchers are already influencing state policy on energy resilience. In the report conclusion and recommendations (*see executive summary in annexes)*, two sections have been dedicated to Selective Segmentation in Transmission and Distribution and to Microgrids, both important theses of the research. The recommendations are described as essential to the energy resiliency of the island and vital information to start its study and implementation is provided.

5.3. Implementation of OpenDSS in EDESUR

The Energy Utility company in charge of Distribution and Commercialization in the south region (EDESUR) lacks expertise in novel distribution network simulation and modeling software, and as its counterpart of the north, the technical team uses outdated software that needs to be updated manually every time a new study is required. Even though they have been in the process of acquiring distribution-oriented software for a couple of years, the advantage of free, scalable open-source software is evident. The conversations about the scope of the collaboration with EDESUR for this purpose are in the initial state and will be retaken after the workshop finishes since they will have a better sense of the capabilities of the OpenDSS.

5.4. Capacity building in Energy Education

The project is strengthening in-country research capacity by involving a broader group of students and local researchers. By using the existing IEEE Student Network, the researchers are now connecting with students from across the country intending to offer consultancy and insights about the project, making tools, manuals, and information open to them using our blog.

PI De Jesús is also working to create an outreach channel using the Energía Journal's Energy Ambassador program to externalize the results of the research to the Spanish language.

6. Challenges

The main challenge so far has been the process of finding and fixing software bugs in the OpenDSS and QGIS plugins. This is mainly due to the high learning curve and the

arduous process of cleaning the existing data from EDENORTE. Another important challenge in the medium term will be the creation of shared simulation environments between OpenDSS and MATLAB that remains crucial to the objectives of the research.

Regarding the purchase process of the lab equipment, the main challenges continues to be the current crisis affecting the supply chain and the intercontinental shipping. Nevertheless, the manufacturing process of our two main critical components (OpalRT and Taraz Inverter) is completed and the shipping process is on the way. Right now, the main impact has been related to the Digital resistive load.

7. Future plans

Ongoing research (3-6 months)

1. **Co-simulation studies between OpenDSS and Matlab/Simulink/Python**

   The researchers will explore how RT-HIL systems improve the OpenDSS capabilities, interfacing the data delivered for this platform using analog and digital signals in Real Time (RT). The team will also explore DSS Python: The Unofficial bindings for EPRI's OpenDSS developed by researcher at University of Campinas (Unicamp), as well as s Multi-Agent OpenDSS open source and scalable distribution grid platform developed by researchers at University of Central Florida.

2. **Renewable Hosting Capacity Analysis in Real Distribution Networks**

   Based on the results already obtained with the QGIS to OPENDSS traslation the Renewable hosting capacity analysis will become an easier process and will help utilities, policymakers, and solar developers to be more agile when analyzing the impact of adding new distributed photovoltaic (DPV) systems to the electrical distribution system. The creation of a map with the different circuits of the utilities and their actual level of penetration would help improve the access to information for the end clients and will help the general public understand the state of the actual grid and how it could host more renewable. Continuous conversations are held with the UCR researchers to conduct similar studies in DR networks.

3. **Testbed Integration**

The integration of the hardware purchased for the project will begin as soon as all the equipment is available at PUCMM facilities. This will imply using the load center for the connection of the three-phase inverters system and the interaction with the OpalRT central controller, creating the Power-Hardware-in-the-Loop (PHIL) architecture. Initial simulations will be done to ensure the correct functioning of all purchased equipment.

4. Component level modelling of actual scenario

The system modelling activities will continue, enhancing the complexity of our first simulations to better represent the actual behavior expected from our electrical feeder under test. The creation of a simulation model for electrical protections devices in the Matlab/Simulink environment is of importance for enabling the application of the proposed resiliency indexes after a fault condition occurs. Furthermore, probabilities models for the fault occurrence simulation will be studied, and the inclusion of renewable energy resources modelling to be added to our simulation environment.

5. Training Activities

5.1. Development more training courses on OpenDSS and Matlab/Simulink

The main platforms/software to simulate the electrical grid components and interactions have been already identified by the team, and training courses on how to utilize them were already developed to build capacity among the students and professionals that 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.

5.2. Development more training courses on QGIS and OpenDSS integration

The integration of OpenDSS and QGIS has been crucial in order to have the capability to represent the existing large distribution networks and its components in the scripting language of the OpenDSS software. There are several plugins available under the QGIS stack that help correct and filter the information prior to its translation into the scripting language, therefore a course on these special plugins will be very convenient to be linked to the previous OpenDSS course, giving it a broader applicability.

8. Additional information

8.1. Professional Development

8.1.1. IEEE Professional Membership

The team joined IEEE with a professional membership. IEEE is the leading professional association for the advancement of technology. With more than 400,000 members in more than 160 countries, IEEE is the world's largest technical professional society. Through its global membership, IEEE is a leading authority in areas ranging from aerospace systems, computers, and telecommunications to biomedical engineering, electric power, consumer electronics, and many other technical areas.

8.1.2. Puerto Rico and Caribbean Power and Energy Society (PES)

PI Ramón Emilio De Jesús was officially invited to be the Chapter Officer for Puerto Rico and Caribbean Power and Energy Society (PES), PI De Jesús is in the process of developing a Chapter Plan for Q4 2021 and 2022 to advance the conversation with the committee and those involved in IEEE Dominicana.

8.1.3. ASOFER (Asociación Fomento a las Energías Renovables)

ASOFER’s mission is to promote, defend and represent renewable energies in the country to promote responsible growth and protect the right to sustainable development in the Dominican Republic. C.I Abraham Espinal is already a member through its company “Enestar”, and the rest of the team is planning to join the association with the idea of not only promoting the research but finding possible collaboration opportunities.

8.2. Microgrid Research Blog

URL: https://microgridresearchpucmm.blog/

A Website/Blog was created to share the project vision and to externalize results

The blog will serve as a channel of thought and as a support to publicize the project and to attract students and collaborators, in addition to work as an excellent presentation letter and summary of the status of the investigation. It will be linked to PUCMM's *Vicerrectoría de Investigación* (VRI) website and will have a blog section that will be updated regularly and will be linked to social networks profiles to increase the visibility of the site and the results.

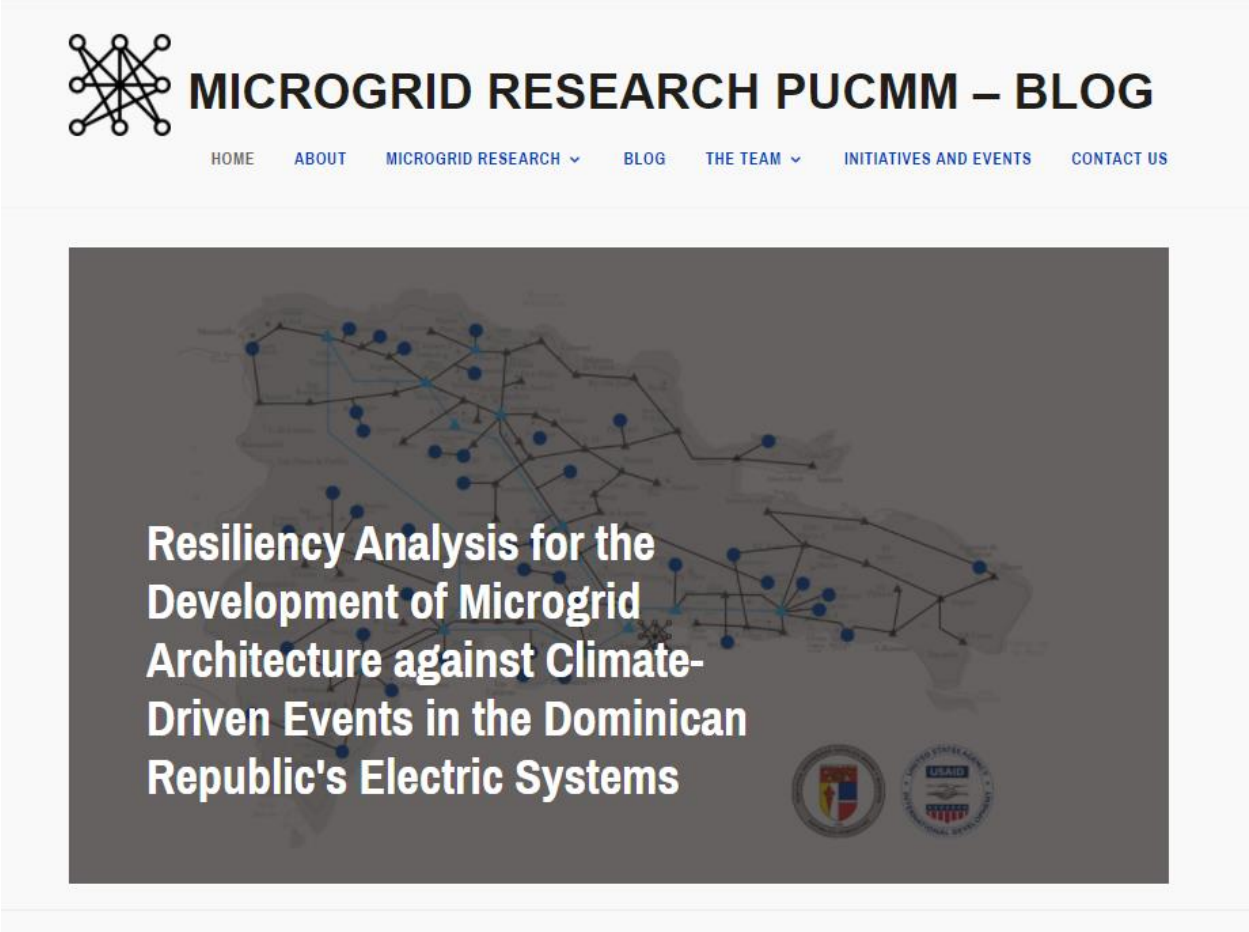


Fig 4. Microgrid Research PUCMM Landing Page

8.3. Research Assistant

Juan Pichardo, an engineering student of 3rd year, from the Mechanic and Electric Engineering School was selected as the Research Assistant. Juan is responsible for assisting the research team in a variety of non-administrative tasks, which may include preparing resources, equipment, materials for the research, and/or documenting the results of research activities. The research assistant is focusing his undergraduate thesis on a topic related to the objectives of this project.

9. Major Equipment Purchased

Status:

- **Opal RT:** Acquisition and manufacturing process has been completed and ITEM has been dispatched. We are waiting for its arrival in the Dominican Republic in the middle of October. It is important to note, that the customs clearance process may take up to three weeks, due to the exonerations that need to be applied to equipment that is going to be used in academic related activities.

- **Taraz Inverter:** Acquisition and manufacturing process has been completed and ITEM has been dispatched. We are waiting for the arrival of the shipment to Karachi port in Pakistán. After this, a logistic company hired by PUCMM will be in charge of bringing the equipment to the Dominican Republic. We estimated that this process may be completed by mid-November.

- **DC power supply**: Purchase and manufacturing process completed. Waiting for custom clearance in the Dominican Republic.

- **Digital AC resistive load:** Purchase process completed, awaiting for manufacturing. Due to the current situation with supplies and shipping, manufacturer updated their delivery day to the third week of November.

- **LOAD CENTER**: Design process has been completed, currently working with PUCMM administrative staff to create the PO. This supplier has been selected based on previous work interaction. As this LOAD CENTER is of custom nature, we wanted to ensure that the selected supplier could comply with our requirements.

ANNEX

GOBIERNO DE LA
REPÚBLICA DOMINICANA

ENERGÍA Y MINAS

VICEMINISTERIO DE SEGURIDAD ENERGÉTICA E INFRAESTRUCTURA

National Indicative Plan for the Development of Critical Energy Infrastructures

Draft_v1.7 (27/09/2021)

Dirigido por:
Ing. Fausto Pérez Santos
Viceministro de Seguridad e Infraestructura Energética

Preparado por:
Ing. Kemuel Ávila
Coordinador

Revisado por:
Ing. Wilson Núñez
Director de Infraestructuras Energéticas

Carolina Rodriguez
Asistente Viceministro

Asesor externo:
Ing. Ramón Emilio De Jesús-Grullón
Investigador en Microrredes - PUCMM

1 EXECUTIVE SUMMARY

Preamble

The Vice Ministry of Energy Security and Infrastructure is a substantive body of a technical nature that is linked to the Ministry of Energy and Mines, and is in charge of carrying out studies of the security schemes for the construction of new infrastructures. strategic energy, related to the transportation, storage and refinement of fuels, as well as gas pipelines, oil pipelines and distribution networks.

Currently the energy sector in the Dominican Republic faces great challenges due to the country's geography as an island and the lack of conventional energy resources. The Vice Ministry of Energy Security and Infrastructure, in keeping with its mission of establishing policies to guarantee electric power service for the Dominican population, is presenting the Proposal for the National Indicative Plan for the Development of Critical Energy Infrastructures.

Objective

The objective of this plan is to increase the level of reliability and supply of the energy supply through the strategic planning of the development of new Critical Energy Infrastructures.

Methodology

The ultimate goal of the plan is to guide the national effort to manage the nation's critical infrastructure risks. To achieve this end in the medium term, national priorities must be collectively identified; articulate clear goals; mitigate risk; measure progress; and adapt based on feedback and the changing environment. Success in this complex endeavor leverages the full spectrum of skills, knowledge and experience from a strong partnership between the institutions involved.

In order to establish the best strategies for the National Indicative Plan for the Development of Critical Energy Infrastructures, the Vice Ministry of Energy Security and Infrastructure carried out preliminary studies in order to establish the criteria for the *Identification and Classification of Energy Infrastructures* to be considered critical for the national energy sector, including infrastructure dedicated to the storage and supply of fuels for electricity generation in the Dominican Republic, including transmission, substations, distribution and demand. A study was also carried out to determine and evaluate the risks that impact the energy sector and the most intangible impacts on the economy and national security due to their operation. In the same way, studies and reports carried out by the National Energy Commission (CNE), the Dominican Electricity Transmission Company (ETED) and the Coordinating Agency (OC), as well as the international cooperation project with the International Energy Agency were used. These reports were key to determine the projection of the national energy demand in order to identify the development needs of the national electricity system and prioritize the strategies suggested in this plan.

To achieve this objective and make recommendations and proposals, the following were analyzed:

- The Current Status of the National Interconnected Electric System (SENI)
- The current vulnerabilities of the SENI and the Catastrophic Risks for Network Security.
- A Risk Management Framework for Critical Energy Infrastructur

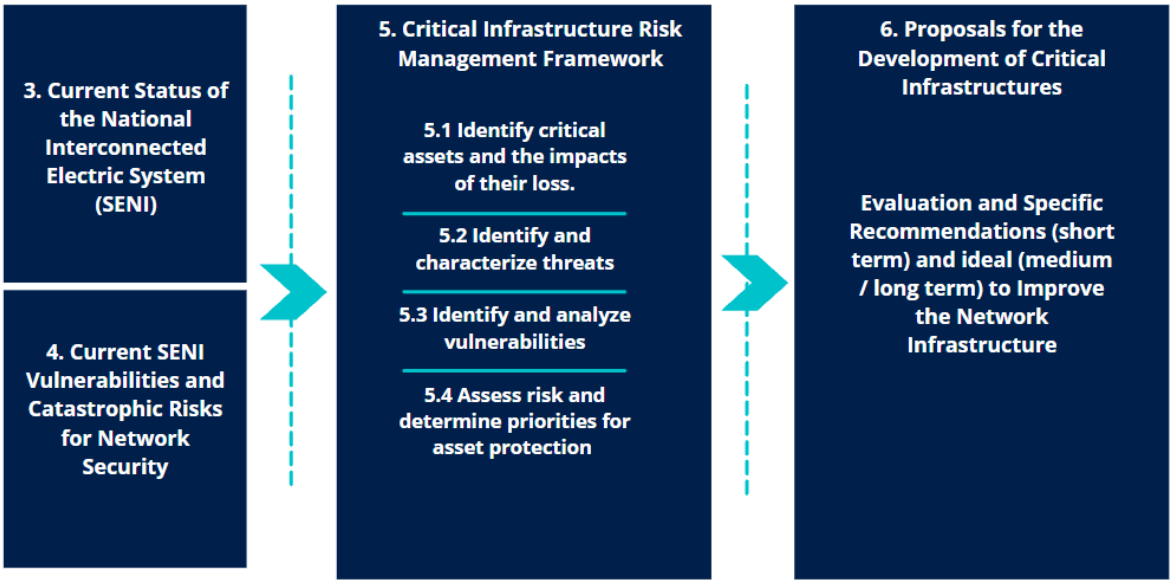


***Fig1**- Summary and Framework of the Plan*

The recommendations have been divided as:

- **Priority:** specifying priority initiatives with a short-term time horizon.
- **Essential:** those initiatives that are considered important with a medium-long term time horizon.

Generation

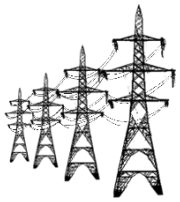
Short Term Recommendations:

• *The most attractive projects for the Dominican electricity system are natural gas combined cycles, both turbines and engines, with combined cycle engines being the best investment, in case the conditions exist demanding to install a large amount of variable renewable energy beyond 2021.*

• *All engines installed in the system must be flex fuel, due to the fast that they can handle more than one fuel type in order to decrease the risk any specific situation of fuel shortage.*

• *The new generation plants must be built in the northern region of the country with the perspective of increasing the resilience of the sector, since the northern region has around 33% of the demand and is currently a net importer of energy.*

Transmission



Short Term Recommendations:

• *It is necessary to expand the 345kV transmission system to areas with a high renewable energy profile, this will allow the expansion of the generation parks, based on the renewable resources available in those specific regions, without network restrictions.*

• *Install a 345kV El Naranjo - Guayubín transmission line that will increase the availability of wind and solar power plants in the northwest zone, in addition to transporting energy from the Manzanillo Power Plant.*

• *Install a 345kV Azua - Los Alcarrizos transmission line, which will increase the transmission capacity of energy projects in the southern region.*

• *New distribution lines from the main substations to Santo Domingo and Santiago.*

Essential Recommendations:

Better forecast of Renewable Generation.

As a result of the findings of the "Diagnostic Study of VRE Forecasts in the Dominican Republic", the Energy Transition Project has been developed by the Organismo Coordinador(OC) and it is proposed to have:

- *Centralized approach to receiving generation forecasts*
- *Higher forecast update frequency*
- *Greater temporal resolution of forecasts.*

Fragility Studies and Resilience Assessment of the Transmission Network

- *A variety of fragility curves and statistical methods have to be developed to analyze the data in order to understand the vulnerability of the existing electrical network, especially those that play an essential role in the safety of the network (i.e Autopista Eléctrica 345kV)*
- *Carry out undergrounding of the new networks of Greater Santo Domingo and the reconfiguration of existing networks.*

Distribution

Short Term Recommendations:

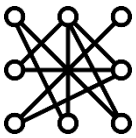
Mesh Studies for Distribution Circuits

• With expectation of increasing the resilience of critical loads (hospitals, military bases, water infrastructure, etc.), alternative and simultaneous circuit routes in urban and rural areas should be studied.

Substations Fire Fighting Systems Review

• In the routine inspection reports of substations carried out by the VSEI in 2021, the deteriorated state and the lack of revision of the fire systems have been identified. The procedures and processes for reviewing these systems must be identified.

Segmentation and Micro-Grids



To better allow for system recovery in an extreme weather event and / or black start restoration, there may be operational benefits to segmenting the transmission and distribution system into smaller chunks (Mini-grids).

Selective Segmentation in Transmission and Distribution

- *Follow up and use the SENI Operation Island report, issued by the Coordinating Body (OC) for the Superintendency of Electricity and the MEM Agents, as a basis for the purpose of analyzing the isolated operation of each of the SENI areas, based on of the potential occurrence of an atmospheric phenomenon.*

Essential Recommendations:

Studies and Verification of Structural Load in Distribution Poles

- *It is necessary for the communications industry and distribution companies to carry out structural load evaluations on distribution poles.*

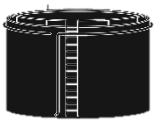
Hydrological Studies and Base Flood Assessment (BFE)

- *Hydrological Flood Mapping studies should be done to locate substation assets avoiding the base flood elevation (BFE) + 3.0 feet or 0.2% flood elevation, whichever is greater.*

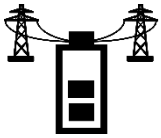
Microgrids Implementation Studies for Critical Infrastructure

• The modeling, study and analysis will contribute to the identification of the potential microgrid locations most advantageous for the government and civil society, ideally in places where there are critical loads (hospitals, military bases, food distribution centers, cold chain , pharmaceutical sector, etc.).
• Microgrid designs should build on an existing set of tools (eg DER-CAM ™ and OpenDSS ™) to help design and assess microgrids, once their location has been identified.

Storage of Fuels



Energy Storage



Short Term Recommendations:

Increase storage capacity and state oversight

• *There is a need to increase storage capacity on the north coast of the island with an expectation of not only increasing capacity, but improving the resilience of the sector while attracting additional investment in generation in the Northern region.*

• *Increase state intervention and oversight in fuel storage and inventory.*

Essential Recommendations

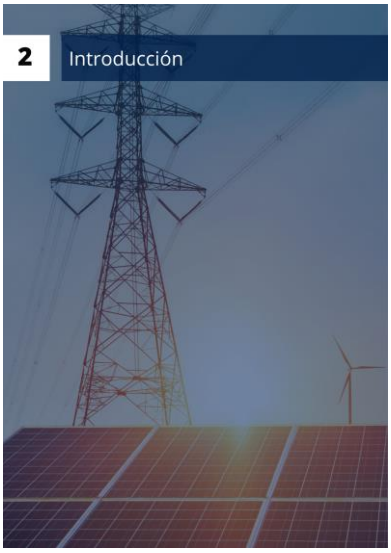
Regulation for Energy Storage in batteries and essential services to the grid.

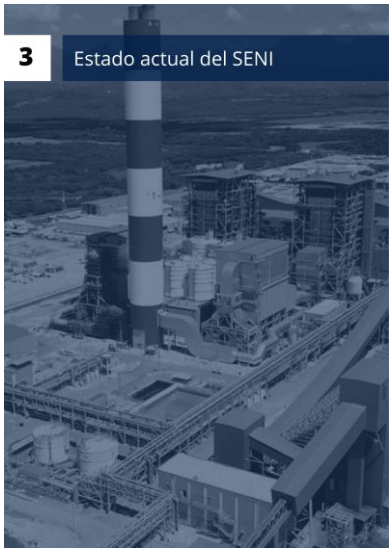
Large-scale energy storage is critical to increasing grid resilience and integrating variable energy resources such as wind, solar, and hydro, to fossil fuels, demand-side resources, and system efficiency assets. It can act as a generation, transmission or distribution asset, sometimes in a single asset. It is recommended to study and create a work table for the promotion of energy storage projects that fulfill the following functions:

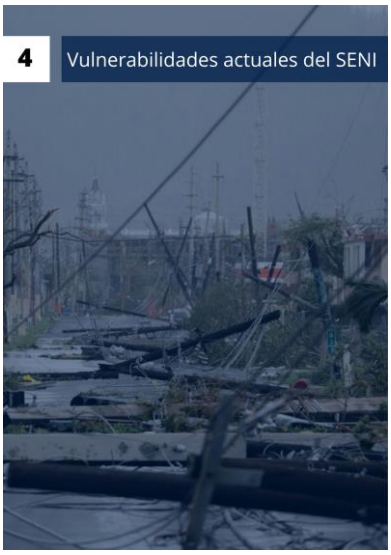
- *Postponement of needed upgrades to the distribution system.*
- *Relief of congestion in transmission*
- *Revolving, non-revolving and supplementary reserves.*

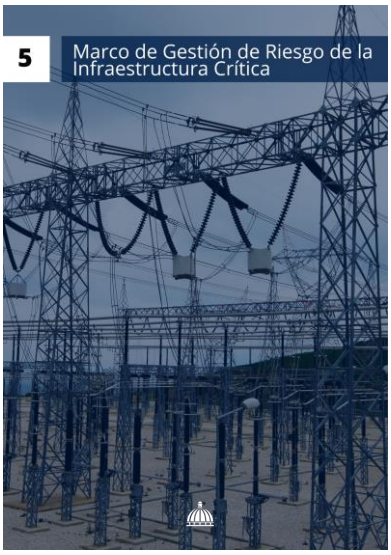
The National Plan is organized as follows:

- **Section 2**: **Introduction**
- **Section 3: Overview of Electric System in the Dominican Republic:** Actual State and Principle Indicators
- **Section 4: Vulnerabilities of the SENI:** Define the structure of the SENI and how the cascading risks should be structured.
- **Section 5: Critical Infrastructure Risk Management Framework:** Define the objectives and the phases to design the Risk Management Framework.
- **Section 6: Recommendations and Calls to Action**: Short term Recommendations and the essencial changes to develop and increase resiliency for the Critical Energy Infrastructure.

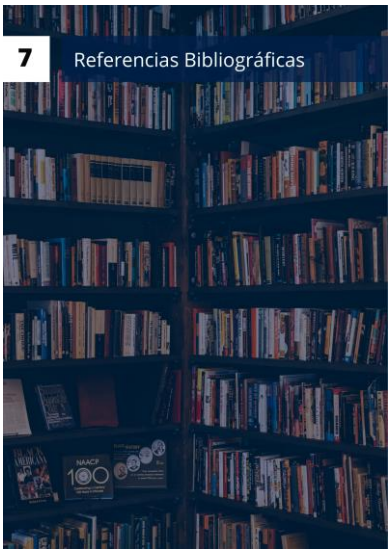

2
Introducción


3
Estado actual del SENI


4
Vulnerabilidades actuales del SENI


5
Marco de Gestión de Riesgo de la Infraestructura Crítica


6
Propuestas para el Desarrollo de Infraestructura Crítica


7
Referencias Bibliográficas