Anguilla Renewable Energy Programme (AREP)
Ministry of Infrastructure, Communications, Utilities, Housing & Tourism
Coronation Avenue, The Valley, Anguilla
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Terms of Reference

Grid Studies for Solar Photovoltaic (PV)
and Battery Energy Storage Interconnection

1. Introduction

The **RESEMBID (Resilience, Sustainable Energy, and Marine Biodiversity Programme for Caribbean Overseas Countries and Territories)** is funded by European Union (EU) and implemented by Expertise France in collaboration with the Global Facility for Disaster Reduction and Recovery (GFDRR). The Grid Studies for Solar PV and Battery Energy Storage Interconnection will support the outputs of the project "***Streamlining Anguilla's Energy Sector Towards a More Sustainable Future***" under the ReSEMBID program.

Over the past ten years, the cost of technology for renewable energy (RE) such as solar energy, has declined considerably, providing a cost-effective and sustainable means of meeting electricity demand in small-island nations like Anguilla. Taking advantage of this energy source requires significant expansion and modernization of electrical grids. The implementation of RE-specific technologies, processes, and requirements will gradually transition power systems into "RE-friendly" grids that will significantly reduce integration costs in the long term. It is expected that the outcomes of this consultancy will support future renewable energy development and integration as part of the goal of *Streamlining Anguilla's Energy Sector Toward a More Sustainable Future.*

2. Objectives

The Consulting is expected to conduct a study that will analyze the electrical system impacts of distributed generation, primarily solar PV, and Battery Energy Storage systems (BESS) to the grid in Anguilla. The Consultancy Firm will also study the optimization of a BESS for the provision of spinning reserve, renewable energy firming, frequency support, and energy shifting for optimal levelized cost of energy (LCOE), and other potential ancillary services that will further benefit the island of Anguilla and ANGLEC.

This interconnection study will provide recommendations on the use of battery storage to allow for the further deployment of both utility and privately owned distributed generation assets to the grid while maintaining ANGLEC standards of power quality, resiliency, and reliability. This study will be used to inform an

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Integrated Resilient Resource Plan and updated Energy Policy and Tariff Studies which will be implemented concurrently under this project.

The Government of Anguilla will share with the awarded firm all relevant data from the existing power system in Anguilla.

3. Scope Of Work

The scope of work includes the following analyses which are needed to study the impact of increased solar PV installations on Anguilla's existing distribution network:

- Load flow calculations (Thermal ratings and Voltage levels to be verified)
- N-1 contingency calculation
- Short circuit calculations
- Transient stability
- Harmonic analysis
- The transformer(s)/cables energization and current in-rush study
- Battery optimization study
- Facility Cost Estimates (new transformers, conductors, regulators, protection relays, automation, SCADA, etc.)

The scope of work also encompasses the following scenarios (Table 1.). These scenarios reflect various operational conditions of the grid. Once the operation of the grid is understood within these conditions, informed design considerations can be included in the scope for grid upgrades.

Table 1. Scenarios for power flow assessments

Scenario Description	Scenario	Existing DERs	Utility Scale Solar PV (MW)	BESS (MW/MWh)
Normal operating conditions; all thermal generation, all feeders on Anguilla operating	1	All	2MW	0
	2	All	2MW	Largest Genset Set capacity with 1-hour duration
Optimal Levelized Cost of Energy (LCOE) Penetration of Solar PV and BESS	3	All existing plus optimal public buildings, parking lots, etc	Optimal capacity on crownland	Largest Genset Set capacity with 1-hour duration Plus optimal BESS to eliminate any feeder issues at least cost

The models developed under this scope of work which includes the outlined analyses and recommendations shall be provided to the Government.

3.1 Power System & PV Plant Representation

The main purpose of these analyses is to identify the impact of potential PV and BESS plants on the power system and to provide recommendations on equipment and systemwide upgrades necessary to accommodate future growth of renewable energy, solar PV, and electric vehicle charging. The system models generated and provided to the Government must be accurately developed and updated based on provided data. The analysis should include an accurate representation of all equipment typical to PV plants, including inverters, transformers, and protection relays.

The quality and the level of detail within the data provided to the Consultancy Firm will directly reflect on the study output, therefore special attention shall be given to model development, and data verification should be conducted with Government staff.

3.2 Load Flow Studies

A load flow (power flow) study of the network is required to ensure that all elements in the system (principally generators, overhead lines, cables, switchgear, and transformers) remain within their steady-state thermal limits and that the voltage regulation across the network remains within acceptable limits for all network contingent scenarios considered.

Load flow studies shall be undertaken to assess the steady-state performance of the system for various combinations of demand, generation, and reactive power support conditions to check voltage conditions and thermal ratings. At least four load conditions shall be analyzed for each PV scenario.

Load flow studies shall be done for all scenarios for the following loading conditions and for the year 2024 when the proposed solar and batteries are operational.

- Evening peak loading conditions
- Daily peak loading conditions (16h)
- Daily solar maximum loading conditions (13h)
- Minimum loading conditions

Load flow results should be presented in single line diagrams and tabular form for all case studies. The minimum and maximum voltages at all network buses shall be tabulated in the summary report. Equipment ratings (if exceeded) shall be highlighted in tabulated report form. Any deviations from the agreed limits would be highlighted and appropriate remedial action recommended.

3.3 Contingency Analysis

An investigation of the power system security shall be performed through contingency analysis for all three scenarios. Dynamic stability analyses shall be performed for single-element outages in the distribution grid in Anguilla.

Types of outages that will be analyzed are:

— N-1 single outage of distribution/transmission lines and transformers. This will be performed for additional elements such as:
— Loss of thermal plant
— Loss of largest generator
— Loss of largest load feeder

The results of this analysis will be used to determine strategies to protect the network in disturbed state.

3.4 Short Circuit Calculation Studies

Fault level studies should be carried out using the system model for each PV scenario and compared with the grid without the proposed PV plants to determine the change in fault levels. Three-phase and single-phase fault levels will be calculated at the point of connection and in adjacent buses, and results will be included in the report.

The methodology which will be used for the calculation of short circuit currents should be in accordance with the latest IEC 60909 standard. Three-phase and singe-phase fault levels should be calculated with a voltage factor c = 1.1 to simulate maximum pre-fault voltage conditions. Initial symmetrical short circuit current will be calculated, and the obtained values should be presented in tabular form.

If it is found that three-phase or single-phase fault currents are exceeding relevant operational and security limits, conceptual design solutions should be proposed in terms of the selection of adequate additional equipment, grid sectionalizing, or insertion of earthing resistors.

3.5 Transient Stability Study

The Consultancy Firm should perform dynamic analyses with the aim of assessing ANGLEC power system stability for disturbances in the power system. It is important to study PV plant stability for external faults on the network to which it is connected. It is assumed that the faults to be studied will be of a worst-case three-phase zero impedance type and will be electrically close to the point of common coupling or within the main export path.

The dynamic model of the plants should be based on standard dynamic library models only, with additional augmentations if necessary. The duration of simulations will be minimum 20s and adjusted according to grid characteristics (system inertia).

Results of simulations will be presented in the form of time domain diagrams of critical quantities (bus voltages, system frequency, active/reactive power flows, generator rotor angle, etc.).

All dynamic studies will include, as per minimum following disturbances:

The Consultancy Firm shall do the following dynamic studies:

- Simulate 3ph faults at main substations and calculate critical clearance time for night peak, daily peak, and minimum loading conditions

- Outage of the largest generator for night peak, daily peak, and minimum loading conditions
- Cloud coverage for PV solar plant

For all these cases, the Consultancy Firm shall show responses of the largest generators.

3.6 Harmonic Analysis

The system should be carried out in general compliance with the standards of ANGLEC, and the best international practice applying IEC and IEEE standards (IEC 61000-4-7,61000-3-2, 50160, IEEE-519, etc.).

<u>The impact of PV plants on external electrical system will be carried out based on:</u>

— Current and voltage harmonic injected at the point of connection

— Current and voltage harmonic injected from the PV plant and background harmonic distortion (if provided) at the point of connection and neighboring system nodes.

3.7 The Transformers/Cables Energization and Current In-Rush Study

For the transformer energizations studies, the firm should use a high-frequency computer model of the power station equipment and adjacent feeders using the Alternative Transients Program (ATP) version of the universally accepted Electromagnetic Transients Program (EMTP) or PSCAD. Using this model switching/energization/inrush current and lightning phenomena can be examined with a view to ascertaining the maximum over-voltages likely to occur in the operation of the plant. Peak over-voltages will be compared with relevant equipment ratings as specified in the IEC insulation coordination standards, IEC 60071-1 & 60071-2.

<u>Specifically, the studies consider the following:</u>

— Voltage depression due to the energization of transformers.

— Voltage increase due to the energization of any reactive power compensation equipment.

The above analysis should be performed under maximum and minimum fault level conditions to fully assess the dynamic stability. Should any part of the PV plant or the power system experience voltage in excess of its BIL, then the addition of surge arresters or other measures will be investigated in order to achieve compliance with insulation requirements. Specifically, if surge protection measures are necessary to protect substation equipment, then relevant studies will be repeated for the worst scenarios to prove that adequate protective margin exists with respect to the BIL of equipment.

3.8 Battery Optimization Study

The BESS optimization study should start with a review of the current generation plan and demand forecast for Anguilla's power system. The Consultancy Firm will review spinning and non-spinning reserve policy in terms of the integration of solar PV. The firm shall develop a grid dispatch model for the ANGLEC generation fleet for the next 5 years in PLEXOS. This shall serve as a basis for justification of PV penetration, the feasibility of BESS and its sizing as well as provide battery optimization (usage, charging/discharging cycle, etc.).

To reach that objective, it is expected that the firm shall assess two energy storage alternatives:

1. The first consists of the battery storage equipment integrated with the synchronous reserve strategy and capable of covering all spinning reserve and compensating all intermittent renewable energy systems currently installed or planned to be installed up to and including the year 2027.

2. The second scenario is all the components of scenario 1 plus a secondary battery storage system connected to feeders or a dedicated substation (or gen bus at the power plant) serving to support the firming of the solar PV required to reach the most optimal levelized cost of energy (LCOE) in the year 2027.

The Firm shall study the following:

- Analyze the history of the demand, for solar generation, as well as meteorological data, including the temperature, to determine the level of solar variations to be compensated by battery systems.
- Feasibility for ANGLEC to store excess solar energy and sell that energy at another moment in time (energy time shift)
- Present the advantages/disadvantages of ANGLEC using solar and energy storage for generation purposes.
- Perform a technical-economic analysis of various battery BESS capacities to be considered by ANGLEC including performance and cost estimates in USD $ MW/MWh.

- Perform a techno-economic analysis comparing the use of battery storage to thermal generation for synchronous reserve purposes
- Optimize the sizing of the battery in terms of kWh, the required MW of power, and its charge/discharge category.

More specifically, in the context of contribution to the synchronous reserve following a unit loss event, it is also important to:

- Size the battery by taking into account the global synchronous reserve strategy in the short and medium term and by checking the duration of the battery discharge cycle required according to the other generation sources available. Check the amount, the duration, and the availability of the other generation sources that must intervene before the batteries are fully discharged to maintain the network stability criteria. The time of discharge of the battery shall be specified and the response time as well.
- Determine the discharge time of the BESS (Battery Energy Storage System) so that its contribution is optimized with the load. Then, determine the costs for different BESS discharge times to support the decision process.

Regarding the contribution of batteries during the peak period, it is important to determine the energy mix present at the peak of usage and their power levels.

Study the contributions of the various sources and analyze the possibility of adding the energy of batteries during the peak period, but also identify other strategic moments where they would represent an advantage.

<u>More generally:</u>

- Recommend the minimum characteristics of a battery power dispatch management system suitable in the context of renewable energy integration and estimate the cost benefits of such a management system.
- Estimate the full costs of the storage system, the connection to the substation, and all related works necessary for the implementation of this system in relation to the location of the identified battery solution.

The estimation should consider recent and prospective cost data and electrical demand forecast data.

<u>This study should consider the:</u>

a. Maximization of PV penetration
b. Optimization of battery life and of the charge/discharge cycles
c. Cost of the investment (CAPEX)
d. Cost of the operation (OPEX)

<u>Recommendations and Justification</u>

For the proposed ground mount solar PV site, provide any required network reinforcements (above and beyond a direct express circuit), and the optimum level of solar PV on Anguilla in relation to the BESS. For the proposed BESS, provide recommended sizing in power (MW) and energy (MWh) and use cases for the applications considered. Relevant justification shall be provided for the proposed conclusions on the location, and sizing of the BESS, including findings from the power systems analysis, cost-benefit analyses, business cases, etc. that demonstrate various value streams for the power system.

3.9 The Facility Cost Estimates

Whether new equipment is required would be informed by the results of the studies and how this relates to the relevant grid code. The results from the studies performed would be used to inform a series of recommendations and conceptual design that outlines what upgrades to the solar farm substation and distribution system are required.

The Consultancy Firm will develop a conceptual design of the new interconnection facilities and obtain vendor price quotes for required major equipment items including new circuit(s), transformers, capacitor banks, SVCs, and STATCOMS. Balance of system equipment and installation costs will also be estimated using regional industry standard assumptions and local fully burdened labor costs and information provided by the Government.

Should network and other facility upgrades be required for interconnection, the above-referenced power system studies will be re-modeled to include such upgrades and to demonstrate that the proposed upgrades remediate any of the identified issues.

Supporting details for the studies contained in this scope:

Impact Studies – Conduct studies and/or adhere to Codes and Standards as noted:

1. Analyzing power flow, short-circuit analyses, protection device coordination, power stability, steady-state and dynamic stability, electro-magnetic transients, and spinning reserve to properly evaluate grid stability impacts of the proposed ground mount solar PV system on the grid.
2. The following standards will be applied to studies related to this project, including the ongoing ANGLEC studies:
    a. IEEE Std 1547-2018, IEEE 1547a-2020, IEEE C37, UL489, IEC 60909, and IEEE 1547.7-2013 Guide for Conducting Distribution impact studies for Distributed Energy Resource (DR) Interconnection.
3. Islanding Studies:
    a. Evaluate bi-directional power flow and ensure voltage regulation is maintained; bidirectional sensing may be needed for all anticipated fault conditions.
    b. Evaluate that feeder conductor sizing is acceptable to reverse power flow condition (as applicable/express circuit conclusion).
    a. Determine what is needed for parallel operation for connection or restoration to the normal distribution grid (e.g., synch-check, reverse power flow, automatic islanding control, etc.)
4. Fault studies:
    1. Check for relay desensitization, and report findings.
    2. Check/change relay settings as needed, and report findings.
    3. Check for additional relay protection required, and report findings.
5. Stability studies:
    1. Check generator-generator-load to assure islanding will be stable, and report findings.
    2. Demonstrate that islanded systems can deliver power to within parameters established in IEEE Std 1547 (and related IEEE Standards and ANSI C84.1).
    3. Demonstrate voltage regulation capabilities of the distributed energy resources (DR).
    4. Demonstrate frequency regulation capabilities of the DR.
    5. Upon blending of generation sources, demonstrate the voltage and frequencies remain within acceptable limits.
    6. Demonstrate switching and other transients are within acceptable limits.

4. Timeline

The firm should be prepared to deliver all reports, models, and results within 110 working days from the time of the award.

5. Key Deliverables

During the execution of the study, the firm will prepare the following documents and reports:

- Inception Report / Data and Assumption Verification – 2 weeks from the award. The inception will report will include a detailed work plan and schedule.
- Draft Report – 8 weeks from Inception Report
- Final Report – 3 weeks from Draft Report

The Study reports will be submitted in electronic form (.pdf) and computer model files handed over to the Government of Anguilla.

The final Report will be produced in English and will include:

- Documentation of all input data
- Calculation results (plots, tables)
- Analysis of the results
- Final recommendations

6. Timeframe And Milestones

6.1 Location

The Consultancy Firm will be located at the usual place where they conduct business. The team of consultants will be required to make themselves present in Anguilla for key stakeholder consultations as necessary during the execution of this consultancy.

6.2 Performance Period

The services of the Consultancy Firm will be retained for a period of six (6) months from the date of the signing of the contract, that is, the team is expected to complete and deliver their work within a six-month period. This is not an indication of the number of man-days to be worked.

6.3 Milestones and Payment Schedule

The implementation of this work is expected to take place over a period of five (5) months. The below is an indicative schedule, with a full project schedule to be provided upon commencement of the contract.

Deliverable	Deadline	Payment %
Inception Report	T+2wks	20%
Draft Report	Inception +8wks	35%
Final Report	Draft +3wks	45%
Total		100%

7. Qualifications And Experience

Team must possess *at least*:

- One Lead expert with Professional experience and track record working in the utility, generation, and/or transmission/distribution sector of at least 10 years. The expert should have at least an advanced degree in electrical, mechanical, or another related engineering field.
- One expert with at least Eight (8) years of experience with energy flow modeling, specifically renewable energy integration and impact studies. The expert should have at least a bachelor's degree in electrical, energy engineering, renewable energy technology, or another related field.
- One expert with at least 5 years of experience in the field of energy storage and possess at least a bachelor's degree in engineering or any related field.

Other skills:

- Fluency in the English language with excelling verbal and written reporting and communication skills
- Extensive knowledge of renewable energy, particularly PV solar and battery energy storage systems.
- Knowledge of relevant legislation and regulation relevant to Anguilla's electricity sector is an asset.
- Experienced working with donor-funded projects and government agencies in the Caribbean would be an asset.
- Previous experience working with medium-sized utilities.
- Possess a strong ability to collect and manage data and development transparent evidence-based supported tracking models
- The ability to control the consultation process and create a synergy of the group/ subgroups to complete the consultation effectively and efficiently.

Other experts

CVs for experts other than the key experts should not be submitted in the tender. The Consultancy Firm shall select and hire other experts as required according to their needs. The selection procedures used by the firm to select these other experts shall be transparent and shall be based on pre-defined criteria, including professional qualifications, language skills, and work experience.

8. Equipment

No equipment is to be purchased on behalf of the Contracting Authority/beneficiary country as part of this service contract or transferred to the Contracting Authority/beneficiary country at the end of this contract.

9. Reports

The Consultancy Firm shall submit to the Project Manager and Project Coordinator reports in the format prescribed by the Project Coordinators at each milestone deliverable stage.

The Project Manager is responsible for approving the periodic reports at each milestone deliverable stage, in consultation with Project Coordinators in Anguilla.

All final plans and reports delivered under the contract must receive approval in writing from the Project Coordinators.

Upon conclusion of this consultancy, the Firm shall submit to the Project Coordinator one original report of all reports/modules generated from this consultancy, including but not limited to, the Inception Report, Draft Report, and Final Report.

10. Monitoring and Evaluation

The indicators against which The Firm will be evaluated with respect to its performance include:

- Compliance with the schedule for the submission of deliverables.
- Quality and comprehensiveness of the final study
- Adherence to established professional standards in clarity of thought, knowledge of the subject, vision, etc.

11. Proposal Format, Delivery and Deadline

Any suitable format may be used but must include the following items:

1. CV for each team member with Relevant qualifications and experience
2. Technical Proposal (including proposed methodology and workplan)

Questions regarding this procurement should be sent by 9 June 2023 to the following:

Ministry of Infrastructure, Communications, Utilities, Housing & Tourism (MICUHT)
Attn: Melissa Harrigan
melissa.harrigan@gov.ai

Proposals are to be submitted electronically to the following and shall include the subject line "Grid Studies for PV Solar and Battery Energy Storage Interconnection":
melissa.harrigan@gov.ai
karim.hodge@gov.ai

DEADLINE FOR SUBMISSION OF PROPOSALS:
23 June 2023 at 5pm

EVALUATION CRITERIA

The evaluation criteria and weightings that will be applied to this TOR are as follows:

Category	Description	Weighting
1	Qualifications i. Advanced university degree in electrical engineering, or another related field ii. Certified in the use of power/energy modeling software for utilities iii. Other relevant certifications	20
2	Overall experience i. Professional experience and track record working in the utility, generation, and/or transmission/distribution sector for at least 10 years. ii. At least Eight (8) years of experience with energy flow modeling, specifically renewable energy integration and impact studies. iii. At least 5 years of experience in the field of energy storage	40
3	Demonstrable, competency-based track record of success working in areas outlined in Scope of Works. Examples of working experiences shall be supported by references within your application package including contact information.	30
4	Technical Proposal i. Work plan based on the deliverables	20
5	Overall presentation	10
6	Financial proposal	40
	Total	160