United Nations Industrial Development Organization

TERMS OF REFERENCE (TOR)

Title: The Bahamas power system stability study for the implementation of a higher renewable energy penetration level

CTCN request reference number: 2017000019
Country: The Bahamas

1 BACKGROUND INFORMATION

The Climate Technology Centre and Network (CTCN) is the operational arm of the United Nations Framework Convention on Climate Change (UNFCCC) Technology Mechanism and hosted by the United Nations Environment Programme (UN Environment) in collaboration with the United Nations Industrial Development Organization (UNIDO) and supported by 11 partner institutions with expertise in climate technologies. The mission of the CTCN is to promote accelerated deployment and transfer of climate technologies at the request of developing countries for energy-efficient, low-carbon and climate-resilient development.

These requests for Technical Assistance (TA) are being submitted to the CTCN by the National Designated Entity (NDE) of the respective country. The scope of services under these Terms of Reference shall be executed based on a restricted solicitation process. By mandate, only accepted Members of the CTC Network are eligible to execute the required services to implement the response. Should the bidder partner with another institution to deliver a minor part of the services described in these Terms of Reference, it is expected that the partner institution also joins the CTC Network.

In case you are not a CTCN network member yet, you may bid for implementation of the technical assistance, subject to the condition that you submit your completed application for CTC Network membership before the bid closure and the same is acknowledged by the CTCN. Furthermore, the contract award – should your bid be selected – is conditional to your network membership application having been successfully approved by the Director of CTCN.

The maximum budget for this contract is reflected in the GCF budget table enclosed to this RFX.

2 CONTEXT OF THE ASSIGNMENT

The Bahamas has a commitment to achieve at least 30% renewables in the energy mix by 2030, which will be met primarily by variable solar energy. The Government of The Bahamas is implementing different initiatives to achieve this goal, such as the Residential Energy Self-Generation Program or a reduced tax on energy efficient and solar system and solar system and battery imports. For continued reliability of the whole power supply of the country, it is critical that system operators understand the potential impacts of variable generation on their systems. To mitigate this challenge the Government of The Bahamas approached the Climate Technology Centre and Network (CTCN) for Technical Assistance.

To address these challenges the CTCN has developed these Terms of Reference that outline an intervention that will produce the outputs listed below and that will be implemented within a period of 18 months. The overarching goal is to develop a comprehensive methodology for assessing the stability of the power grid and provide a customized solution to enhance the country's ability to accommodate 30% renewables. The work is organized in the following main outputs:

- Data collection and analysis of power models and associated data
- Critical scenarios for stability study
- Dynamic model development
- Dynamic stability analysis

The full text of the request submitted to the CTCN can be found here: https://www.ctc-n.org/technical-assistance/requests/technical-assitance-conduct-country-wide-grid-stability-study

3 OBJECTIVE OF THE CONTRACT

The objective of this contract is to assist in the effective development of a plan for the roll-out of renewable energy that will protect the stability of the national grid and also ensure the reliability of power delivery to Bahamians. The key stability issues and challenges of integrating renewable generators in The Bahamas power grids will be addressed through stability analysis using realistic grid power flow based on generators' dynamic models. Base case power system models and associated data for both state and dynamic models will be adapted for the 2030 cases and then transferred to the utility together with training to ensure capacity and expertise are built to continue to utilize the models in planning and operations to accommodate a sustainable growth of reliable RE sources.

Scope and activities of the proposed contracted services

Once this contract is signed, the CTCN will organize a kick-off call among all relevant parties involved in the request to introduce the Contractor to the NDE and Proponent, to present the activities, their timeline and clarify roles and responsibilities. The Contractor is expected to undertake the following activities:

Output 1: Data collection and analysis of power models and associated data

Activity 1: Data collection on power models and associated data from the Utility, Bahamas Power and Light (BPL). An adequate system model obtained from BPL based on robust data will be essential for the success of this study. Throughout this activity, a strong collaboration with the utility staff is needed to obtain current power models and associated data. Base case models will be set up and validated with system operator. This activity will focus on critical data including:

- Power system steady state model:
  a) The existing power flow model of all fifteen of The Bahamas grids will provide the fundamental knowledge of system configuration and parameters.
  b) Any available production simulation model results of the Bahamas grids can be used to help define stressed system conditions.
- Power system dynamic model:
  a) The existing dynamic model of the Bahamas grid will provide key parameters for the dynamic study. For example, the parameters of the existing generators and their controllers, etc., will allow for setting a baseline of current grid health.
  b) Historical event data such as voltage and angle during and after an n-1 event can be used for simulation formulation.

Both inverter-based utility scale renewable power plants' and distributed renewable generators' models including the controllers will be used to study dynamic response and their stability impacts.

- Time-series load and renewables data, where available:
  a) Load profiles.
  b) Wind speed time-series profile for any future wind power plants.
  c) Solar irradiance/solar power time-series profile for both existing and hypothetical future solar power plants.

The statistical analysis of the load, wind and solar generation over multiple time frames will be used to quantify the grid variability before and after integration of the 2030 case with 30% renewables.

Output 2: Critical scenarios for stability study

<u>Activity 2:</u> Determine critical scenarios for all of The Bahamas' power grids through a continuous interaction with BPL. A qualitative report to describe the system and its associated operational challenges will be developed. Further, the data itself, with the critical scenarios defined, will be delivered and owned by the utility.

A participative approach with all relevant stakeholders will be applied: with government agencies, private developers, distributed generation candidates, and utility staff will be convened as needed (depending on information availability) to provide feedback on likely geographical locations of future renewable energy plants for all systems. In parallel to this consultations, an expert will also conduct gender focused baseline studies for the RE sector.

Stressed system dispatch scenarios will be defined which are critical for stability studies. A meeting will be held to present the defined critical scenarios with the utility and pertinent stakeholders and allow for interaction with utility staff to enable capacity building for addressing operational challenges associated with a higher variable generation level. The utility staff will have the opportunity to engage with the critical scenarios in a "hands-on" fashion themselves to track the work being performed to evaluate the Bahamas systems. This will apply to all electrical system operators in the Bahamas – Bahamas Power and Light as well as any other system operators.

Deliverable 2.1: Qualitative study (including data) of the system and its operational challenges. In addition, one section will cover the gender baseline study.
Deliverable 2.2: Meetings minutes. An initial meeting report will be submitted. Then a report will be delivered every time a new meeting with BPL/Ministry of Environment is held during the whole duration of the project.

Output 3: Dynamic model development

Activity 3: Develop the dynamic models of the fifteen Bahamas grids which can properly represent 30% renewable energy penetration in 2030 using a commercially available power flow model in collaboration with BPL as primary local energy producer. This task will adopt dynamic modelling of hypothetical utility-scale and residential PV as well as any projected wind power plants. The software model selection will be undertaken by the selected implementer depending on his in-house capabilities and practices; however it will need to be compatible with BPL model in-use. Interaction with BPL during activity 1 will be instrumental for the software choice.
Subtask 3.1:
Develop a high renewable penetration model based on the investigation and work from Activity 1 and 2, which includes:

a) Modelling any existing renewable generators,
b) Modelling the hypothetical future renewable projects (wind, PV or energy storage) with or without advanced controllers for grid support, and
c) Modelling any planned transmission upgrades based on input from BPL.
d) Validation of the model simulation/results

The dynamic model (along with the dynamic stability analysis subject of the next activity) will represent key enabling environment products to understand the gaps/barriers to private sector investment in light of the expansion of the electric grid and the relating RE increase. The model will be in fact a tool that can be shared with and presented to potential private sector players willing to invest into the local power infrastructure. The participative approach already described will make sure that BPL and local stakeholders will be continuously involved in the model development by the implementer. This process will culminate in the final training module (month 18), during which the main findings and procedures will be collected and organized into training materials to be presented in a workshop.

Deliverable 3.1: Dynamic Models of The Bahamas grids for the year 2030 (PSS/E or other software).
Deliverable 3.2: An operations manual for the models including detailed descriptions.

Deliverable 3.3: Demonstration and training on the power flow models for the utility's future use, including M&E system. Deliverables include training materials, list of participants, and outcomes report.

Output 4: Dynamic stability analysis

Activity 4: Understand and evaluate the island grids' dynamic performance with high renewable penetration. This task will conduct a comprehensive study of the multi-faceted dynamic and stability issues and will result in a risk evaluation of dynamic stability for the 2030 case. Further, this task will provide corresponding practical suggestions, and will provide BPL with the information and tools to enhance grid security and decrease the likelihood of island-wide grid blackouts, including indications on the most suitable energy storage solutions.

Dynamic stability analysis includes:

- Frequency response study

  It is particularly important that frequency is properly regulated in response to critical emergency events. In an island system, a relatively small disturbance from either generation or load can lead to large, and potentially unstable, deviations in grid frequency, due to the low inertial constant of the grid and limited number of synchronous generators providing primary frequency support.

  To address the potential issues, this subtask will develop and adopt different critical scenarios and model cases based on Activity 3. To study the systems' frequency response, the frequency metrics from the North American Electric Reliability Corporation (NERC) standard BAL-003 will be used as the evaluation index and the following typical tests will be simulated under this subtask:

  a) The largest loss of generation event (N-1 generator contingency) for light load case.
  b) The largest loss of generation event (N-1 generator contingency) for heavy load case.
  c) The largest loss of load event (N-1 load contingency).
  d) The renewable generation tripping event due to the extreme weather.
  e) Frequency support from a large PV plant inverter.

- Transient stability

  In addition to maintaining the balance between generation and demand, power system operators must ensure that the grid can successfully transition from normal operation through a disturbance and into a new stable operating condition in the 10–20 seconds immediately following the disturbance.

  In this subtask, the power angle-based stability margin index and fault critical clearance time (CCT) will be used as the evaluation index and the following studies will be conducted for all fifteen grids under this subtask:

  a) Sensitivity study of different composite load models, considering increased distributed resources and their integration.
  b) Study of different fault conditions including generation loss, load loss, transmission line fault, low voltage ride through, etc.

- Voltage stability

In conventional power grids, synchronous machines can support grid voltage during a sudden voltage drop. Conversely, in a "weak grid," a large voltage fluctuation may happen as a result of a sudden disturbance. Voltage instability may increase in scenarios of high solar penetration because, at least current or 'legacy,' residential PV is incapable of providing reactive power support.

Short-circuit ratios (SCR's) will be calculated at different locations in the grids using the 2030 high renewables case to determine areas of power system weakness. The following analysis will be conducted under this subtask:

a) Quantify the relative grid strengths based on different scenarios.
b) Identify impacts of line outages, the loss of reactive power devices, etc.
c) Consider cloud coverage impacts on voltage stability.
d) Analyze potential mitigation to low grid strength.

Deliverable 4.1: Technical report approved by the NDE and NDA on the comprehensive methodology for grid stability assessment of The Bahamas' including sections on Frequency Response, Transient Stability, and Voltage Stability detailing the various studies undertaken. The report will include clear calculations and recommendations regarding:

- Necessary investments in the 15 grids required (and estimate of $) to guarantee stability at certain RE integration levels (e.g. 20% RE, 30% RE, etc.)
- Necessary changes required in terms of technical standards and regulatory framework to facilitate the grid integration of RE and remove market barriers.
- Summary for policy makers

Deliverable 4.2: Recommendations of technological options for grid stability and RE integration. The deliverable will include an analysis of the most suitable energy storage solutions applicable to the specific case of the islands as well as a particular section with gender mainstreaming recommendations for the RE integration technological options; as well as for environmental, social and gender issues (ESS). CTCN gender mainstreaming tool will be used as baseline reference to assure that gender issues will be included since the early stage of the technology analysis of this proposal and throughout all the subsequent Outputs. A description of the gender tool can be found at this link: https://www.ctc-n.org/technologies/ctcn-gender-mainstreaming-tool-response-plan-development

Output 5: Monitoring of the Readiness proposal

Activity 5: Monitor the implementation of the Readiness proposal.

Deliverable 5.1: Outcome and impact description - produce a one page description of intended outcomes and impacts

Deliverable 5.2: Prepare a monitoring and evaluation plan

<u>Deliverable 5.3:</u> Closure and Data Collection Report – produce a Readiness "Closure and Data Collection Report"

4 GENERAL TIME SCHEDULE

The activities under this contract have an expected duration of eighteen (18) months from the contract signature. The proposed plan for the implementation of activities and deliveries:

Activity	Month																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1. Data collection and analysis																		
2. Determine critical scenarios for stability study																		
D2.1 Qualitative report and model data delivery							*											
D2.2 Minutes of the meeting presenting critical scenarios								*										
3. Dynamic model development																		
D3.1 Dynamic Models of The Bahamas grids for the year 2030 (PSS/E or other software)										*								
D3.2 An operations manual for the models including detailed descriptions											*							
D3.3 Report on the training (incl. list of participants, training materials, outcome report)																		*
4. Dynamic stability analysis																		
D4.1 Technical report on the comprehensive stability study																	*	
D4.2 Plan of recommended practices & technologies																		*
5. Monitoring of the Readiness Proposal																		
D5.1 Outcome and impact description	*																	
D5.2 Monitoring and Evaluation Plan	*																	
D5.3 Closure and Data Collection Report																		*

All drafts and final deliverables are subject to approval by the CTCN Climate Technology Manager, before these can be considered as completed.

5 PERSONNEL IN THE FIELD (PROFESSIONAL EXPERIENCE AND QUALIFICATIONS)

The Contractor is expected to provide the services of a team that should ideally comprise the following competencies:

- Master degree in electrical, industrial engineering, or similar
- A minimum of 15 years relevant work experience in power grid analysis and modelling

- Demonstrated experience in power system simulators, such as PSS/E or similar
- Demonstrated experience in the integration of renewable generation in the grid
- Demonstrated experience in carrying out grid analyses for high penetration of renewable generation
- Demonstrated experience in grid analyses in island states
- Demonstrated experience in developing and delivering trainings
- Demonstrated experience in the development, implementation and management of projects in a climate change mitigation technology context.
- Excellent abilities to interact with stakeholders, collect and evaluate data and transform the information into high quality documentation tangible to the target audience
- Excellent written and communication skills in English.

The CVs of the respective experts assigned to this assignment by the Contractor must be provided.

6 LANGUAGE REQUIREMENTS

The working language for the purposes of this assessment is English, thus an excellent command of English is required for the proposed personnel. Proficiency in relevant local languages is considered an asset.

All delivered documents must be of sufficient enough quality so that no further editing shall be required.

7 PREPARATION OF YOUR BUDGET TABLE

- Bidders are to ensure that they complete their financial proposal using the GCF Budget Allocation Template reflecting the Total cost per activity split up between the Cost Categories (consultants, travel, workshops/training and others as well as the expenditure and implementation schedule
- Bidders are to ensure that they complete their financial proposal in line with the General principles and indicative list of eligible costs covered under GCF fees and project management costs (document attached to the Rfx Event).
- Bidders should confirm that they will provide project audited statements including supporting documents for the activities carried out under the Contract.