Standard for Power Quality and Reliability in Electric Power Systems

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1. Regulatory Title

This regulation may be cited as “Standard for Power Quality and Reliability in Electric Power Systems”.

2. Definitions

APESL means Approved Public Electricity Supplier Licensee as defined in Section 46(1)(a)(ii) of the EA.

Abnormal Circumstances means acts of force majeure where the usual operation of the electricity supplier is disrupted by factors beyond the control of the supplier such as during an extreme weather event.

Consumer means any person who uses or may use or requests or may request, a supply of energy for business or residential purposes, As defined in Part I, Preliminary, of the Electricity Act 2015.

Customer means, in relation to a licensee, the person –

(a) to whom energy is supplied in the course of any business carried on as such by the licensee;
(b) to whom the licensee is seeking to secure that energy is provided;
(c) who wishes to be supplied with energy, or who is likely to seek to become a person to whom energy is supplied; and includes any of them whose use or potential use of energy is for the purposes of, or in connection with a business; as defined in Part I, Preliminary, of the Electricity Act 2015

EA means the Electricity Act of the Bahamas, enacted in 2015 as amended.

Electrical Grid or ***Electricity Grid*** means the electrical lines, conduits, or cables of any voltage level, providing electrical energy to a customer of the PESL or APESL and has the same meaning as “electricity supply system” as defined in *Part I, Preliminary*, of the Electricity Act 2015.

Frequency means the rate of oscillation of the electrical waveform every second. Frequency only applies to systems that use alternating current.

Grid means

(a) any BPL power system, inclusive of transmission and distribution, wherever located within The Bahamas;

(b) the power system, inclusive of transmission and distribution, of any public electricity supplier within The Bahamas other than BPL; as defined in Part I, Preliminary, of the Electricity Act 2015

GTDS means generation, transmission, distribution and supply *(of electrical energy);*

Harmonic Distortion means the interference in an AC power signal created by frequency multiples of the sine wave. Total Harmonic Distortion (THD) is used as a measure of the amount of harmonic distortion in the system.

Point of Common Coupling (PCC) means the point where the electrical conductors of the utility's distribution system are connected to the customer's conductors and where any transfer of electric power between the customer and the distribution system takes place. Typically, this is at the service meter.

PESL means Public Electricity Supplier Licensee as defined in Section 2 (Interpretation), of the EA.

Phase Imbalance means, in reference to a three-phase system, a mismatch in the line-to-line voltage of one or more conductors in that system. Three phase systems are intended to operate with phases balanced.

Power Quality means the condition of the electricity supply such that is in within the parameters specified in this consultation document and of such a condition so as to be safely and consistently used by customers without undue risk of damage to person or property.

Voltage means the amount of electrical pressure required or employed to effect the transfer of electrons (electrical current/energy) from one point in a conductor to another.

3. Measurement and Enforcement

The term *power quality* refers to a wide variety of electromagnetic phenomena that characterize the voltage and current at a given time and at a given location on the power system. In verifying limits of power quality that may be supplied by a PESL or APESL, it is necessary to ensure compliance with those limits through the establishment of an adequate monitoring program.

3.1 Measurement Regime

The characteristics of the electrical system shall be measured using the equipment such as that described herein for the purpose of establishing ongoing and continued compliance of the electrical grid with the requirements of these regulations. The power quality parameters listed in this standard shall apply to, and be measured at, the point of common coupling.

URCA envisions that equipment described herein will, where necessary, be permanently installed at various points on the electrical grid and monitored and read by the licensee at regular intervals to verify compliance but in any case, not less that once per month for reporting purposes, or on receipt of a specific instructions by URCA.

3.2 Equipment

For the purposes of monitoring and reporting, the licensee is required to utilize its own equipment to monitor compliance and act where necessary. It shall also provide the data to URCA in the manner and format specified. URCA may inspect the licensee's equipment to verify its accuracy and / or request the licensee to do the same and provide the results of such inspection to URCA.

As a check of the reported values, URCA may establish a contemporaneous monitoring program utilizing, inter alia, the following tools and equipment to monitor licensee electrical power quality:

Power Quality Analyzers

Power quality analyzers are devices that measure and record power quality parameters such as voltage, current, harmonics, and transients.

Power Quality Meters

Power quality meters are used for long-term monitoring of power quality parameters and will be installed at a specific location to monitor the electrical signals continuously.

Data Loggers

Data loggers are used for monitoring voltage variations, current fluctuations, and other power quality parameters at high speed and with high accuracy.

Power Quality Monitoring Systems

These tools provide a comprehensive approach to power quality monitoring and will include sensors and analyzers to monitor and track the quality of the power supply.

Other Special tools

URCA may use any other tool or equipment device, or process not specifically referred to in this document to ensure compliance with the power quality levels described herein.

3.3 Enforcement

Enforcement is an on-going regulatory obligation and a necessary outflow of the establishment of technical standards. When implementing enforcement measures, URCA will do so for the benefit of all stakeholders to enforce regulated sector laws, encourage competition, and to ensure that licensees are compliant with the license conditions and other technical rules and regulations published by URCA.

Enforcement is a necessary component of regulation to ensure the integrity of the electrical supply system. The enforcement framework therefore includes both ex-ante and ex-post regulatory measures intended to allow URCA to prevent, detect and investigate electrical supply

issues. As part of enforcement a licensee may, among other remedies, be subject to a fine for a breach.

3.4 Inspections

URCA, acting in accordance with section 40(6) of the Electricity Act, has the right to monitor and enforce the consumer protection conditions in licenses and, in this regard, URCA may from time to time appoint in writing one or more suitably qualified electrical inspectors to inspect;

(a) any electrical installation or apparatus of BPL or of any other public electricity supplier; or,

(b) the wirings, fittings or apparatus used by any consumer.

This statutory provision provides URCA with the legislative underpinning to ensure that electrical systems are established, operated, and maintained in a manner that is consistent with regulatory standards.

4. Nominal Supply Levels

Public Electricity Supplier Licensees (PESL) and Approved Public Electricity Supplier Licensees (APESL) shall supply their service at the following voltages and frequencies, unless alternative levels are agreed between the licensee and customer.

Table 1 Allowable Supply Voltages and Frequencies

Distribution	Voltage (Volts)	Phases	Frequency (Hz)
Level A	120	1	60
Level B	120/240	1	60
Level C	120/208	3	60
Level D	277/480	3	60

5. Allowable Deviation to Nominal Supply Levels

5.1 Voltage Deviation

The steady state supply voltage shall be maintained within plus or minus six percent (+/- 6%) of the nominal supply level.

5.2 Allowable Voltage Phase Imbalance

The maximum phase imbalance, measured under no load conditions, shall be limited to plus or minus three percent (+/- 3%).

$$Percent\ volage\ unbalance = \frac{\mathrm{V\,max}\,dif\ - Vav\ 3\ ph}{\mathrm{Vav\ 3\ ph}} * \ 100\%$$

Where:

Vmax dif = the phase voltage with the largest difference from the average of the three phases.

Vav 3 ph = the average voltage of the three phases

5.3 Frequency Deviation

The steady state supply frequency shall be maintained within plus or minus two percent (+/- 2%) of the nominal supply level.

5.4 Harmonic Deviation

Harmonics are produced both by the system operator and the end user. The harmonic currents produced by the end user flow through the owner's or operator's system which leads to voltage harmonics in the voltages supplied to other users. Both the licensee and the customer have a responsibility to limit harmonic currents.

URCA recognizes the impact that the addition of harmonic adding equipment can have on the system and encourages system operators to advise consumers of these effects and to not add equipment that affects the impedance characteristics in a way such that the voltage distortions are increased. Also, system operators shall make every effort to minimize the harmonics produced and supplied to end users and transmitted to the grid from end users.

At the PCC, system owners or operators shall limit line-to-neutral voltage harmonics as follows:

- Daily 99th percentile very short time (3 s) values shall be less than 1.5 times the values given in Table 2.
- Weekly 95th percentile short time (10 min) values shall be less than the values given in Table 2.

All values shall be in percent of the rated power frequency voltage at the PCC. Table 2 applies to voltage harmonics whose frequencies are integer multiples of the power frequency up to and including the 50th harmonic.

The limits in this clause are based on the fact that some level of voltage distortion is generally acceptable [1]and the underlying assumption of these limits is that by limiting harmonic current injections by users, voltage distortion can be kept below objectionable levels. In the event that limiting harmonic currents alone does not result in acceptable levels of voltage distortion, system owners or operators should take action to modify system characteristics so that voltage distortion levels are acceptable. The acceptable voltage distortion levels form the basis of the harmonic voltage limits in table 2.

Table 2: Allowable Harmonics[2]

Level	Bus Voltage at PCC	Individual Harmonic (%) h ≤ 50	Total Harmonic Distortion THD (%)
A	V ≤1.0 kV	5.0	8.0

[1] IEEE Std 519 – 2022 Clause 5 para 1
[2] IEEE Std 519 – 2022 table 1 – voltage distortion limits (V≤1.0kV)

6. Reliability

6.1 Definitions, acronyms, and abbreviations

6.1.1 Definitions

For the purposes of this standard reliability indices shall mean those parameters when measured, recorded, and reported track the *consistency* of supply of the electrical grid. And the following event definitions shall apply.

Interruption: An interruption is the total loss of electric power on one or more normally energized conductors to one or more customers connected to the distribution portion of the system.

Interruption duration: The time period from the initiation of an interruption until service has been restored to the affected customers.

6.1.2 Acronyms and Abbreviations

The following parameters are used in the calculation of performance indices:

CI	Customers Interrupted
CMI	Customer Minutes of Interruption
K	Number of interruptions experienced by an individual customer in the reporting period.
$\mathbf{L_i}$	Connected kVA load interrupted for each interruption event
$\mathbf{L_T}$	Total connected kVA load served
$\mathbf{N_i}$	Number of interrupted customers for each sustained interruption event during the reporting period
$\mathbf{N_{mi}}$	Number of interrupted customers for each momentary interruption event during the reporting period
$\mathbf{N_T}$	Total number of customers served for the area
$\mathbf{r_i}$	Restoration time for each interruption event
$\mathbf{T_{MED}}$	Major Event Day threshold

6.2 Recording and Reporting of Indices

A recordable event is any interruption that lasts more than 5 minutes

The indices shall be measured, recorded and reported to URCA by PESL and APESL as referenced in the licensees' reporting requirements e.g. outage reporting and biannual reports.

6.3 Reliability Indices

6.3.1 System Average Interruption Duration Index (SAIDI)

SAIDI indicates the total duration of interruption for the average customer during a pre-defined period of time. It is commonly measured in hours of interruption. A sample calculation of SAIDI is shown below:

$$SAIDI = \frac{\Sigma \text{ Customer Minutes of Interruption}}{Total\ Number\ of\ Customers\ Served}$$

To calculate SAIDI, the following formula is used:

$$SAIDI = \frac{\Sigma r_i N_i}{N_T} = \frac{CMI}{N_T}$$

6.3.2 System Average Interruption Frequency Index (SAIFI)

The System Average Interruption Frequency Index (SAIFI) indicates how often the average customer experiences a sustained interruption over a predefined period of time as represented in the equation below.

$$SAIFI = \frac{\Sigma \text{ Total Number of Customers Interrupted}}{Total\ Number\ of\ Customers\ Served}$$

To Calculate SAIFI, the following formula is used:

$$SAIFI = \frac{\Sigma \mathrm{N}_i}{N_T} = \frac{\mathrm{CI}}{N_T}$$

6.3.3 Customer Average Interruption Duration Index (CAIDI):

The Customer Average Interruption Duration Index (CAIDI) represents the average time required to restore service. It is represented by the equation below:

$$CAIDI = \frac{\Sigma \text{ Customer Minutes of Interruption}}{Total\ Number\ of\ Customers\ Interrupted} = \frac{\mathrm{CMI}}{CI}$$

To Calculate CAIDI, the following formula is used:

$$CAIDI = \frac{\Sigma r_i \mathrm{N}_i}{\sum N_i} = \frac{\mathrm{SAIDI}}{\mathrm{SAIFI}}$$

6.3.4 Average System Availability Index (ASAI):

The Average System Availability Index Average System Availability Index (ASAI) measures the percentage of time a customer receives an electricity service over a defined period (e.g. monthly/yearly). It is calculated as follows:

$$ASAI = \frac{Customer\ Hours\ of\ Service\ Demanded}{Customer\ Hours\ of\ Service\ Provided}$$

ASAI can also be calculated numerically from either of the following equations:

$$ASAI = 1 - \left(\frac{\Sigma(r_i * N_i)}{(N_T - T)}\right) * 100 = \left(\frac{8760 - SAIDI}{8760}\right) * 100$$

Where

T = Time Period being monitored (hours)
R_i =restoration time (hours)
N_i = total number of customers interrupted

N_t = Total number of customers served.

ASAI directly measures the generation and system adequacy and complements the other reliability indices. Additionally, the ASAI measure requires no additional information for computation. Together, these indices provide comprehensive indicators of the reliability performance of the electricity network.

6.3.5 Major Event Day (MED) Definition

It is important to define a further term which is useful in tracking of reliability indices in the supply of electrical power. That term is a Major Event Day. A Major Event Day is a day in which the daily system SAIDI exceeds the threshold value, TMED. The SAIDI index is used as the basis of this definition since it leads to consistent results regardless of utility size, and because SAIDI is a good indicator of operational and design stress. Even though SAIDI is used to determine the MEDs, all indices should be calculated based on removal of the identified day.[3]

URCA does not propose that Major Event Days be tracked by PESL and APESL, at this time, but intends, by introducing the terminology, to make licensees aware of the term, and its utility in conjunction with SAIDI as an indicator of operational and design stress.

A major event day can also be used as a classification of major outages. URCA notes that such a definition was recently determined by URCA (ES 01 /2023) but signals its intent to introduce the new definition once licensees have attained necessary familiarity of and facility with the terms introduced in this standard.

6.4 Sample Calculations of SAIFI, SAIDI and CAIDI

To table below is used to calculate the referenced indices. In the example the utility serves 2000 customers in the geographical area.

[3] IEEE Std 1366-2022 IEEE Guide for Electric Power Distribution Reliability Indices

Table 3 Interruption Data for Electric Utility 2022

Event Number	Date	Time Off	Time On	Duration (min)	Number of Customers Affected	Interruption Type
1	Jan 7	12:12:20	12:20:30	8.17	200	S
2	Feb 2	18:23:56	18:24:26	0.5	400	M
3	Mar 15	00:23:10	01:34:29	71.32	600	S
4	May 12	23:17:00	23:47:14	30.23	25	S
5	Jun 6	09:30:10	09:31:10	1	2,000	M
6	Aug 15	15:45:39	20:12:50	267.18	90	S
7	Sep 31	08:20:00	10:20:00	120	700	S
8	Oct 18	17:10:00	17:20:00	10	1,500	S
9	Nov 21	10:15:00	10:55:00	100	100	S
	Note 1: Interruption type S = Sustained; M = Momentary Note 2: Total Customers Served = 2000					

From Table 3: the number of customers who have experienced a sustained interruption is 3, 215. The total number of customers who have sustained a momentary interruption is 2,400.

These technical standards do not require the reporting of momentary interruptions, but they are included here for the guidance of licensees in the calculation of the indices.

Calculation of SAIFI

$$SAIFI = \frac{200 + 600 + 25 + 90 + 1500 + 100}{2000} = 1.61$$

Calculation of SAIDI

$$SAIDI = \frac{(8.17\times200)+(71.3\times600)+(30.3\times25)+(267.2\times90)+(120\times700)+(10\times1500)+(40\times100)}{2000} = 86.11 \text{ minutes}$$

or 1.43 hours

Calculation of CAIDI

$$CAIDI = \frac{SAIDI}{SAIFI} = \frac{86.110}{1.6075} = 53.57\ minutes$$

Calculation of ASAI

$$ASAI = \left(\frac{8760-SAIDI}{8760}\right) * 100 = (-\frac{8760-1.435}{8760})*100 = 99.98\%$$

6.5 Quality of Service Standards for Reliability

Licensees shall incorporate the following quality of service standards into their Consumer Protection Plans:

Table 4 Proposed Reliability Indicator Targets for New Providence

Parameter	Units (Per Year Per Customer)	Reliability Indicator Targets		
		2024	2025	2026
SAIDI (1)	Hours	4.25	4.16	4.07
SAIFI (1)	Outages	6.24	6.12	5.99
CAIDI (1)	Hours	0.68	0.68	0.68
ASAI (2)	Percentage	99.951	99.952	99.953

Notes:

1) Values for SAIDI, SAIFI and CAIDA are maximum values

2) Values for ASAI are minimum values.

Table 5 Proposed Reliability Indicator Targets for The Family Islands

Parameter	Units (Per Year Per customer)	Targets		
		2024	2025	2026
SAIDI (1)	Hours	6.25	6.12	5.99
SAIFI (1)	Outages	8.24	8.07	7.91
CAIDI (1)	Hours	0.76	0.76	0.76
ASAI (2)	Percent	99.928	99.930	99.932

Notes:

1) Values for SAIDI, SAIFI and CAIDA are maximum values

2) Values for ASAI are minimum values.