Q. Reference: NLH-NP-017.
Newfoundland Power states that its voltage regulation methods ensure that customers experience voltages within normal planning limits. In this context, please explain the consequence of low incoming transmission voltages.

A. Both Newfoundland Power and Newfoundland and Labrador Hydro ("Hydro") define normal transmission voltages to be between 0.95-1.05 per-unit ("pu") and the lower bound of emergency or post-contingency transmission voltages to be between 0.90-0.95 pu.[1] Such voltage limits are based on the American National Standards Institute ("ANSI") Standard C84.1 and are considered to be standard limits for utilities.[2]

To maintain normal distribution voltages despite low incoming transmission voltages, many of Newfoundland Power's distribution transformers are equipped with on-load tap changers ("OLTC's"). For example, the OLTC on Twillingate ("TWG") substation distribution transformer TWG-T1 permits increasing its secondary voltage to compensate for low incoming transmission voltages from the bulk system.

The consequences of low incoming transmission voltages are associated with equipment damage at the point of regulation as well as further upstream of the low voltage condition. Specifically, the following types of equipment damage are associated with deviations from normal voltages: harmonic resonance, ferroresonance, high neutral currents, and conditions causing overheating.[3] For example, low transmission voltages result in additional reactive power to be supplied from Hydro's and Newfoundland Power's generators, resulting in increased thermal loading and heat-related stress on these units. In addition to increased generator stress, the increased load levels also negatively impact Hydro's and Newfoundland Power's system power transformers, which could also operate above normal limits and could therefore be subject to unnecessary wear and tear which may negatively impact their expected lifespan.

Furthermore, increased current flowing through Hydro's and Newfoundland Power's equipment resulting from low transmission voltages results in additional line losses and reduces system efficiency. Moreover, due to higher levels of reactive load on the transmission network, both Hydro's and Newfoundland Power's transmission protection and control systems may activate more often to prevent equipment damage and to ensure stability, thereby negatively impacting reliability.

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1 See Hydro's *Transmission Facilities Rating Guide*, document #TP-S-001, page 16.

2 Both the Institute of Electrical and Electronics Engineers ("IEEE") and the North American Electric Reliability Corporation ("NERC") have adopted ANSI C84.1 voltage limits for power systems. For example, see IEEE Standard 1250-2018, *Guide for Identifying and Improving Voltage Quality in Power Systems*, and NERC Standard TPL-001-04, *Transmission System Planning Performance Requirements*. ANSI C84.1 states that voltages between 0.90-0.95pu "shall be limited in extent, frequency and duration" and "corrective actions be undertaken within a reasonable time". For voltages less than this limit, ANSI C84.1 states that "prompt, corrective action should be taken".

3 See IEEE Standard 1250-2018, page 14.