Q. What criteria is used by Newfoundland Power to determine where and when there will be a rotating power outage? Include in the answer whether any priority is given to any particular class of customer, such as hospitals, personal care homes and retail malls.

A. **1. Introduction**

A reasonable amount of context is necessary for Newfoundland Power to explain decisions made in respect of rotating power outages through the January 2-8, 2014 timeframe. This includes decisions made to determine where and when rotating power outages were to occur and the priority given, if any, to particular classes of customers such as hospitals, personal care homes and retail malls.

In addition to providing an explanation of the decisions taken by Newfoundland Power, as requested, this response also provides the context for those decisions.

2. Background

Basic Electrical System Dynamics

It is an essential requirement of electrical system operation that the generation available in all points in time is sufficient to serve the total customer demand. When the amount of generation available is less than total customer demand, the quality of the electricity provided starts to degrade.[1] Without appropriate actions to restore the balance between electricity supply and demand, the physical integrity of the electrical system is jeopardized.[2]

Modern electrical systems are engineered to respond automatically to temporary or transient imbalances in electricity supply and demand. One example of an automatic response to imbalance is Newfoundland Power's underfrequency load shedding system. This computer-based system automatically turns off pre-selected distribution feeders once it detects an imbalance in electricity supply and demand.[3] These systems are designed to protect the electrical system while the balance of electricity supply and demand is restored.[4]

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1 A prominent aspect of the degradation in the quality of electricity in this situation is an inability to maintain system voltage within permissible CSA standards. This, in turn, can damage customer equipment.

2 If left unaddressed, this can lead to catastrophic electrical system damage.

3 Electrical systems operate at a pre-determined number of cycles per second, or frequency. The North American standard for electrical system frequency is 60 cycles per second, or 60 Hz. When a situation of insufficient generation occurs on an electrical system, the frequency of the system will fall and create an underfrequency condition which requires immediate action. The underfrequency load shedding system consists of a series of digital protective equipment which continually monitors system frequency. The system automatically operates electrical equipment to turn off distribution feeders serving customers when an underfrequency condition occurs to restore the balance of supply and demand on the electrical system.

4 A typical scenario in which the underfrequency load shedding system would operate would be the unplanned outage of a generator at Newfoundland and Labrador Hydro's ("Hydro") Holyrood Themal Generating Station. When such a "trip" occurs, customers are disconnected from the distribution system while other generators pick up the necessary load to restore service to the disconnected customers.

Such engineered solutions do not exist for situations where there is a sustained imbalance in electricity supply and demand which results from insufficient available generation on the Island Interconnected System. These situations require manual engineering intervention. A primary tool for Newfoundland Power to respond to these situations is to undertake rotating outages of distribution service to its customers until sufficient generation is made available to meet total customer demand.

Rotating Power Outages

Newfoundland Power serves approximately 255,000 customers via 306 distribution feeders. A distribution feeder is an electrical circuit which originates in a substation, and along its route connects customer premises to the electrical system. Distribution feeders vary in length, voltage and number of customers served. Some distribution feeders are only a few hundred metres in length while others are over 100 kms in length. Feeder voltages vary from 4,160 volts to 25,000 volts. Some feeders serve only a handful of customers while others serve thousands.

By operation of substation switching equipment, distribution feeders can be disconnected from and reconnected to the electrical system.[5] Rotating outages involve the systematic disconnection and reconnection of distribution feeders to maintain the overall balance of electricity supply and demand in circumstances where there is insufficient available generation on the Island Interconnected System for a sustained period of time.

When there is insufficient available generation on an electrical system to supply the customers served by that system for an extended period of time, a condition of distress exists from both an electrical operations perspective and a customer service perspective. This condition is extraordinary.[6]

3. Preparing for Rotating Power Outages

Balancing Supply and Demand

When Hydro foresees a possible generation shortfall on the Island Interconnected System, Hydro will advise Newfoundland Power of the amount of the forecast shortfall and indicate the requirement for a specific quantity of load to be shed in a

[5] For Newfoundland Power, approximately 60% of its distribution feeders can be remotely operated from the Company's System Control Centre located at Mount Pearl. The remaining distribution feeders can only be disconnected from or reconnected to the electrical system by manual intervention at the substation.

[6] While Newfoundland Power has significant experience in restoration of service following severe weather events which typically involve extensive transmission and distribution failure, Newfoundland Power personnel have never experienced a period of sustained insufficient available generation prior to January 2nd, 2014. In Canada, such conditions tend to be matters of national attention. For example, the supply shortages experienced in Ontario in July 2013 and August 2005 resulting from transmission station flooding damage because of record rainfall, and a summer heatwave, respectively, were reported upon nationally. Similarly, the events of January 2-8, 2014 on the Island Interconnected System were reported upon nationally.

specific area of the province.[7] The planned response to a possible generation shortfall typically involves multiple distribution feeders. The number of feeders involved and customers affected will depend on the size of the forecast generation shortfall.[8]

Once a generation shortfall materializes, the first priority is to re-establish the balance between electricity supply and demand. This is because rotating power outages can commence only when this balance is achieved.[9]

Rotating Distribution Feeders

Newfoundland Power compiled a list of distribution feeders to be considered for feeder rotation based on experience in the January 2013 loss of supply event.[10] This list includes information for each distribution feeder such as peak load, critical customers served, and whether the feeder has remote control capability.[11]

To prepare for rotating power outages, the Company's customer service, communications, engineering, operations and System Control Centre staff were mobilized.[12] The aim of the mobilization exercise was to ensure appropriate customer communication and maximize the use of available generation so as to minimize the number of customers impacted at any given time. The rotating power outage process itself is a dynamic engineering driven activity outlined in detail in *4. Features of Rotating Power Outages* below.[13]

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7 On the Island Interconnected System, generation is primarily located off the Avalon Peninsula and demand is primarily on the Avalon Peninsula. This practically requires that in certain circumstances (i.e. when some generators located on the Avalon Peninsula are unavailable) that demand be reduced on the Avalon Peninsula to restore the balance of supply and demand on the Island Interconnected System. During the rotating power activities of January 2014 the majority of the load shedding and distribution feeder rotations were required to be located on the Avalon Peninsula.

8 For example, on January 2nd, 2014, Hydro requested Newfoundland Power to start customer load shedding at 16:13. Between 16:13 and 16:31, a total of 10 distribution feeders or 54 MW of customer load were shed. This level of load shedding was required in order to re-establish system stability.

9 This is an essential criteria. As the system events referred to in footnote 17 occurred in the period January 2-8, 2014, the requirement to re-establish system stability effectively required discontinuing rotating power outages.

10 On January 11-12, 2013, Hydro's Holyrood Thermal Generating Station was unavailable for 21 hours. During the outage of the generating station, Newfoundland Power implemented limited rotating power outages to its customers. The scope of this effort is not comparable to that required to respond to the events of January 2-8, 2014 where multiple generating stations were unavailable for a much more extended period of time.

11 Distribution feeders with remote control capability can be turned on and off from the Company's System Control Centre without needing to have personnel on site at the substation. Remote control of feeders also includes the ability to remotely adjust safety protection settings, as may be required when cold load pick-up or other abnormal conditions are anticipated.

12 See the responses to Requests for Information PUB-NP-025 and PUB-NP-028.

13 This includes recording the load (MW) on each distribution feeder immediately prior to initiating a rotating outage, and then using this information in estimating the load impact which may occur upon restoration of power to that feeder (including cold load pick-up effects). Distribution feeders to be included in subsequent rotating outages can then be selected based on matching available generation and the estimated load that will be picked up from feeders which had previously been rotated off. The matching of customer load to available generation is maximized by monitoring the system frequency and voltage levels at Newfoundland Power's supply points.

Critical Customers
Prior to implementing rotating power outages, the distribution feeder list was reviewed for accuracy and was further prioritized to minimize impact of feeder rotation to critical customers. Critical customers included, but were not limited to, hospitals, fire and police stations, seniors' homes, and water pumping stations.

In total, 247 of Newfoundland Power's 306 distribution feeders were considered eligible for rotating power outages. Not all of the eligible feeders were necessarily included in the rotation of power outages for technical or operational reasons.[14]

The list of distribution feeders considered for rotation is adjusted based on operating experience and consultation with customers and other stakeholders. For example, following the system disruption associated with the Sunnyside transformer fire on January 4th, 2014 and after communication with municipalities, the Company modified the feeder rotation list to exclude feeders serving community warming centres and fuel supply depots.[15]

4. Features of Rotating Power Outages

General Approach and System Limitations
The general approach used for rotating power outages by Newfoundland Power attempted to best match the customer load to the available generation. This was done on a minute by minute basis with the overriding goal of keeping as many customers connected to the electrical system as possible at all points in time. In addition, the Company attempted to provide as much meaningful customer communication as the circumstances would permit.

The achievement of these objectives was subject to the dynamic conditions which exist in circumstances where there is insufficient electricity supply to meet demand.[16] These circumstances were aggravated by a series of significant system events not directly related to the shortage of supply. For virtually all of the period from January 2-8, 2014 the status of supply on the Island Interconnected System, particularly on the

[14] Technical reasons for excluding distribution feeders from rotating outages would include the location of available generation and customer demand (see footnote 7). For these reasons, more rotating outages were required on the Avalon Peninsula than were required in, say, Western Newfoundland. Operational reasons would include resource limitations. For example, Newfoundland Power might choose not to rotate an outage to a small rural distribution feeder without remote control capability where the rotation would require a dispatch of technical or line resources for a relatively small system impact.

[15] A total of 59 of Newfoundland Power's 306 distribution feeders were designated critical feeders for the purposes of the events from January 2-8, 2014.

[16] In a situation of insufficient supply where some customers are connected to the grid and others are disconnected from the grid, routine events can have extraordinary impacts from a customer perspective. For example, routine changes in demand by some customers receiving service can delay the reinstatement of service to customers who have no service. The longer a distribution feeder is disconnected the greater the impact of cold load pickup which can delay reinstatement of the feeder.

Avalon Peninsula, was highly uncertain from Newfoundland Power's perspective.[17] These factors limited Newfoundland Power's flexibility considerably.

Cold Load Pickup

Reconnecting a distribution feeder that has been disconnected from the electrical system requires due regard for an engineering phenomenon known as cold load pickup. Cold load pickup is simply the additional electrical demand which presents itself when a disconnected feeder is reconnected. The electrical demand which can be expected upon reconnection will be higher than that which existed at disconnection.[18]

One of the implications of cold load pickup is that when matching supply and demand during the power rotation process, larger amounts of load must be disconnected prior to the reconnection of previously disconnected distribution feeders. For Newfoundland Power, demand at reconnection could be as high as twice that at disconnection.[19] So, in a situation like that which presented itself from January 2-8, 2014, to enable the reconnection of a distribution feeder which was disconnected with 10 MW of customer load could require the disconnection of a distribution feeder(s) with as much as 20 MW of customer load.

Another implication of cold load pickup during the power rotation process is an increased risk of overloading distribution feeders or sections of feeders. The increased demand associated with cold load pickup increases the risk that fuses protecting distribution equipment will operate to protect the equipment. Once this occurs, Newfoundland Power is typically required to dispatch a line crew to re-fuse the equipment. This serves to extend the duration of customer outages.[20]

Customer Notice

During the period January 2-8, 2014, Newfoundland Power endeavored to limit rotating power outages to one hour. The Company did not attempt to provide its

[17] Shortly after commencement of rotating power outages at approximately 4:15 pm on January 2nd, 2014 Hydro's Granite Canal Hydroelectric Plant went out of service; at approximately 9:00 am on January 4th, 2014 a transformer failure at Hydro's Sunnyside Terminal Station triggered a near complete collapse of the Island Interconnected System; at approximately 3:30 pm on January 4th, 2014 a bus protection failure at Sunnyside Terminal Station triggered a subsequent system failure; at approximately 9:30 pm on January 5th, 2014 a switchyard fault at Hydro's Holyrood Thermal Generating Station resulted in loss of supply to over 100,000 customers; and at approximately 5:45 pm on January 8th, 2014 an issue with transformer capacity at Hydro's Western Avalon Terminal Station resulted in loss of supply to the Trinity-Conception area.

[18] This is the result of a lack of diversity of demand at the time of reconnection. Prior to disconnection, a distribution feeder normally has a degree of diversity (randomness of electrical devices on at any given time). When that distribution feeder is disconnected and later reconnected, or "picked up", this diversity is lost (all electrical devices are on at the moment of reconnection). This serves to increase the demand on the feeder at the moment of reconnection from what it was at the moment of disconnection.

[19] This is consistent with broader electrical engineering observations (see, for example, *Stepwise Restoration of Power Distribution Network under Cold Load Pickup*, Kumar, Gupta and Gupta, IEEE, where it is estimated that post-outage demand is up to 2 to 5 times diversified load.)

[20] In some circumstances the impact of cold load pickup may require adjustments to be made to substation equipment by engineers and technologists in addition to linecrews. This would tend to extend the duration of customer outages even further.

customers with specific advance notice of the precise timing and location of rotating power outages.[21] One reason Newfoundland Power did not do this was the dynamic and uncertain state of affairs on the Island Interconnected System throughout the period. Another reason was that to provide such advance notice would practically require more customers to be without power than otherwise would be the case.

In the rotating power outage protocol adopted by Newfoundland Power in the period from January 2-8, 2014, as customer demand approached the limit of available generation, small blocks of customer load were rotated off the system so that the actual load matched the available generation. Through the monitoring of system frequency and voltage levels additional small blocks of load were rotated on and off as required to limit the duration of outages and maximize the use of available generation. This dynamic process was responsive to both the available generation and the load dynamics of the customers who remained on the system.

As an alternative approach to rotating power outages Newfoundland Power could have attempted to provide all customers affected with advance notice of the timing and location of rotating power outages. Providing customers with advance notice would necessarily have involved planning to remove blocks of customer load based upon the *forecast* peak load and generation for the planned rotation period. Under this approach, the timing and magnitude of the supply shortfall would need to be forecast hours in advance. Using this forecast, a schedule would be developed to address the anticipated shortfall. The schedule would identify groups of distribution feeders with sufficient load to rotate such that demand would not exceed supply, with an appropriate allowance for forecast error.[22] Due to the practical restrictions created by notice requirements, more customers would have been off the system under this approach than under the more dynamic approach used by Newfoundland Power in January 2014.

The approach to rotating power outages adopted by Newfoundland Power from January 2-8, 2014 was intended to maximize the use of available supply and minimize the duration of aggregate customer outages. Providing customers with advance notice of rotating power outages was impractical in the circumstances which existed at the time. Had such an approach been adopted it would likely have contributed to more customers being without power through the period.

[21] Newfoundland Power did provide general advice to customers that (i) rotating outages were imminent and (ii) Newfoundland Power was targeting individual customer outages to be no more than one hour.

[22] The identified groups of distribution feeders would have to include sufficient load to accommodate forecast error in the system peak as well as the individual distribution feeder loads identified for rotation, as well as to accommodate the dynamic and uncertain system circumstances which exist in an environment where there is insufficient supply.

5. Duration of Rotating Power Outages

Table 1 shows the date, time, and number of distribution feeder rotations completed together with the average duration of customer outage from January 2-8, 2014.[23]

Table 1
Rotating Outages
January 2-8, 2014

Date	Time	Feeder Rotations	Average Duration (minutes)
January 2, 2014	4:13pm to 10:46pm	77	88
January 3, 2014	6:57am to 7:36pm	141	44
January 5, 2014	7:23am to 8:29pm	158	54
January 6, 2014	5:17am to 10:48am	39	47
January 8, 2014	3:23pm to 5:42pm	32	25

Newfoundland Power endeavored to limit rotating power outages to one hour during the period January 2-8, 2014. A one-hour target was thought to be a reasonable compromise of customer inconvenience and the technical complications associated with rotating power outages, including cold load pickup.

On January 2nd, 2014, the average duration of rotating power outages was 88 minutes, which was materially in excess of this target. From January 3rd, 2014, Newfoundland Power was able to achieve an average duration of rotating power outages of less than one hour.[24] The improvement in effectiveness of Newfoundland Power's efforts was attributable to a combination of better management of the process and experience.[25]

[23] Table 1 does not include the outages which occurred as a result of the various system events described in footnote 17.

[24] On January 2nd, 2014, 14 of 77 rotating power outages lasted for 2 hours or more. From January 3-8, 2014, 6 of 370 rotating power outages lasted for 2 hours or more.

[25] A primary component of improved management of the process was the result of a review of the coordination process between Newfoundland Power and Hydro on January 3rd, 2014 which is described in more detail in the response to Request for Information PUB-NP-020.