Proposal Document

Design of the System Restoration Plan for Ireland

In accordance with the requirements of Articles 23 and 4.5 of the Commission Regulation (EU) 2017/2196 establishing a network code on electricity emergency and restoration

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EIRGRID

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1. Definitions

Relevant definitions as per Network Code on Emergency and Restoration

‘defence service provider’ means a legal entity with a legal or contractual obligation to provide a service contributing to one or several measures of the system defence plan;

‘restoration service provider’ means a legal entity with a legal or contractual obligation to provide a service contributing to one or several measures of the restoration plan;

‘high priority significant grid user’ means the significant grid user for which special conditions apply for disconnection and re-energisation;

‘restoration plan’ means all technical and organisational measures necessary for the restoration of the system back to normal state;

‘re-energisation’ means reconnecting generation and load to energise the parts of the system that have been disconnected;

‘top-down re-energisation strategy’ means a strategy that requires the assistance of other TSOs to re-energise parts of the system of a TSO;

‘bottom-up re-energisation strategy’ means a strategy where part of the system of a TSO can be re-energised without the assistance from other TSOs;

‘resynchronisation’ means synchronising and connecting again two synchronised regions at the resynchronisation point;

‘resynchronisation point’ means the device used to connect two synchronised regions, usually a circuit breaker.

2. Background

The System Restoration Plan provides a plan of action for TSO Control Engineers to restore the power system following a total or partial black out. EirGrid, and previously ESB National Grid, has had a Restoration Plan in place for many years. In the wake of the new Network Code requirements on Emergency and Restoration (NCER), the System Restoration Plan (SRP) is being revised as per the requirements of Commission Regulation (EU) 2017/2196 published on the 24th November 2017.

Following a consultation process on various aspects of the System Restoration plan as set out in Article 7 of the NCER, this document is being submitted to the regulatory authority in order to fulfil the requirements to submit a proposal on the design of the System Restoration Plan. The measures and actions outlined in this document will be enacted in the event of a partial or total black out of the Ireland power system. Note that for security and confidentiality reasons, the full details of the plan are not given here.

The relevant legislative and Grid Code articles relating to Power System Restoration are listed in the table below:

Requirement	Service	Currently Defined Within
Ancillary Service	TSO to ensure availability of ancillary services to operate the grid securely	SI 445/2000 Part 3 8(1)(a),(b)
Black Start Definitions and Requirements	Availability of certain units to start up without external power supply	Grid Code OC4.7.1.1
	Availability of interconnectors to start up without external power supply	Grid Code OC4.7.1.1 and Interconnector Operating Protocol (as agreed with TSO)
	Reference to Ancillary Service Agreement	Grid Code OC4.7.3.2
Re-energisation procedure	Power System Restoration and provision for TSO Restoration Plan	Grid Code OC 9.5.1
Black Start Testing	Powers for TSO to carry out tests on Black Start Generators once per year.	Grid Code OC10.5.7

The System Restoration Plan has been drafted with the following technical guidelines taken into account:

- The operational security limits set out in accordance with Article 25 of Regulation (EU) 2017/1485, and Article 23 of the NCER including:
    - The behaviour and capability of load and generation within the synchronous area.
    - The specific needs of the high priority grid users, such as generators and the DSO.
    - The characteristics of the transmission system and underlying distribution system.

3. System Restoration Plan Overview

3.1. Introduction

In accordance with the various provisions of Article 23 of the NCER, the SRP details a plan of action to restore the power system after a total power system blackout has occurred. A Blue Alert will be issued by the National Control Centre (NCC) when the Transmission System has entered the European Awareness System State 4 – Blackout, or when at least 50% of the transmission systems are blacked out.

The SRP is to be used by NCC operators who are trained in, and familiar with, power system restoration procedures. In parallel with this plan, the specific Blue Alert procedures for Generation and Transmission Stations are to be followed by the relevant Distribution System Operator personnel following the issue of the Blue Alert signal.

The power system failure that is addressed here is a total power system failure, based on the assumption that all transmission and generation plant is available and undamaged. The plan should be adapted to scenarios where there is a partial system failure and/or plant is unavailable.

The SRP sets out guidelines and procedures, and provides tested and proven restoration examples. The plan does not supersede standing operating instructions or safety rules regarding operation of the transmission system.

A high level illustration of the Restoration Plan Development Process is summarised in Figure 1. As mentioned previously, the sections that follow give a high-level summary of the restoration process. For security reasons, some specifics of the plan are not included here.

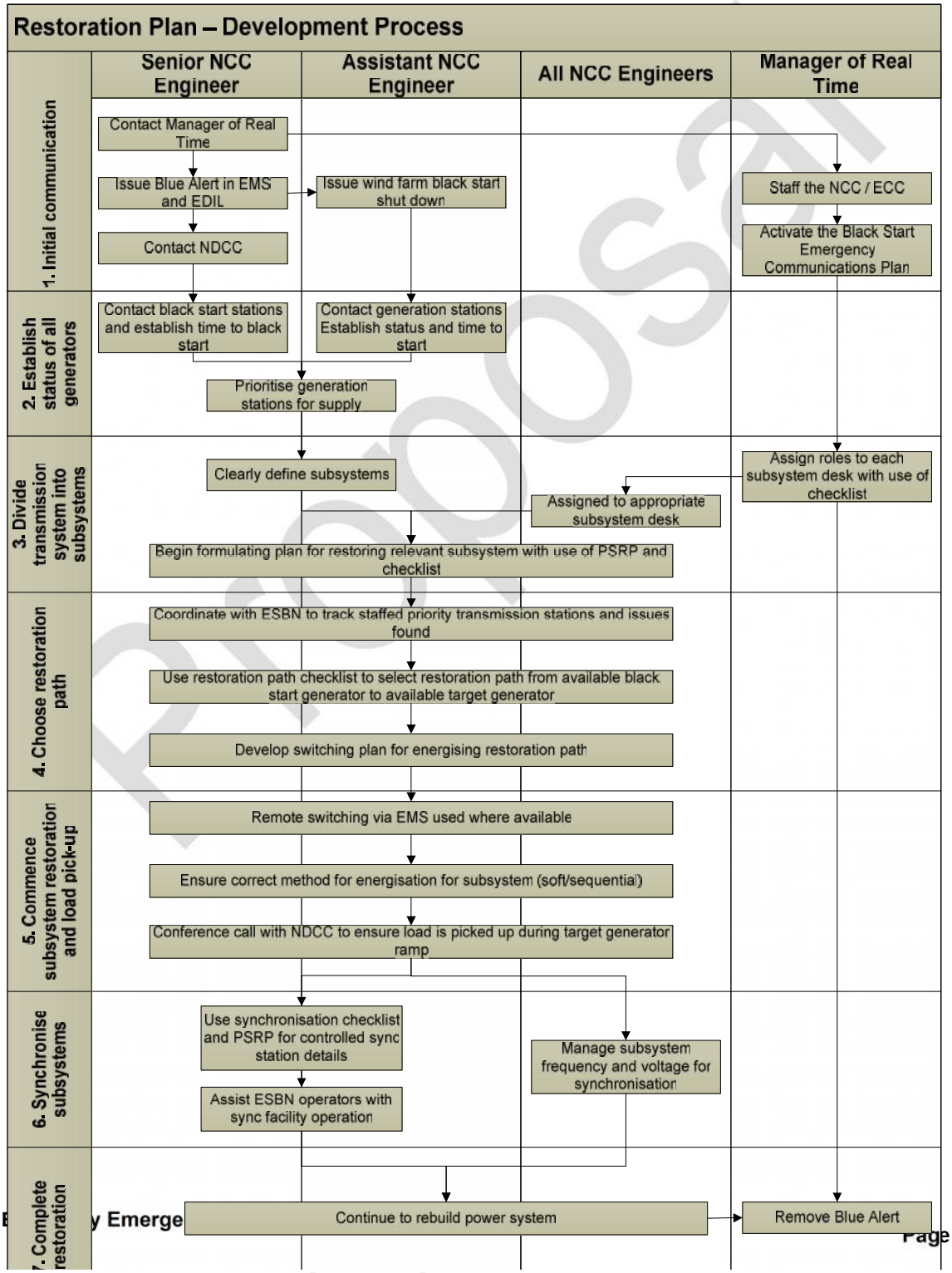

Figure 1 Restoration Plan-Development Process

3.2. Activation of the Restoration Plan

In Accordance with Article 25 of the NCER, the primary objective of the plan is to achieve restoration of continuous supply to all consumers as quickly and as safely as possible with minimum adverse consequences. After a Blue Alert has been issued, the following times are proposed as targets at which to aim to restore power to the 400 kV, 220 kV and 110 kV transmission network:

- A specific plan of action formulated by the National Control Centre (NCC) within 30 minutes of establishment of the nature and the extent of the blackout, appropriate to the nature of the blackout in accordance with Article 27 of the NCER
- Stable operation of the Black Start Stations within 1 hour of plan formulation
- External supply to primary target generation stations as specified in the plan within 2 hours of plan formulation
- Load restored to sub systems within 4 hours of plan formation
- Re-synchronisation of separate subsystems within 6 hours of plan formulation
- Restoration of continuous supply to all remaining 400 kV, 220 kV, and 110 kV transmission stations within 12 hours of plan formulation

Whilst the primary objective of the SRP is to restore supply to all customers, the following objectives also apply:

- Prevent any plant damage
- Maintain, as far as possible, normal shutdown conditions so that plant is ready to start up when system supply is restored
- Conserve station batteries and compressed air supplies whilst in islanded operation
- Restore supply as soon as possible to conventional generation stations
- Restore supply as soon as possible to customers or locations where loss of power involves significant concentrated risk. The NCC, in cooperation with the ESB Networks National Distribution Control Centre (NDCC), is to restore supply to priority consumers

Primary target generation stations are those generation stations identified in the plan of action developed by the National Control Centre to be targeted for earliest restoration of supply and synchronisation. Recommended primary target generation stations are provided for in each detailed sub-system restoration path.

3.3. Re-energisation Procedure – Initial Stage

In accordance with Article 26 of the NCER, at the initial stage of restoration, the NCC should establish the extent of the blackout, that is, whether it is total or partial. The NCC should also establish the status of the transmission system in Northern Ireland. This will determine if a top-down or bottom-up re-energisation strategy is to be employed. If there is a partial blackout the NCC should then establish the existence of islands. The key tasks required include:

- Informing the Manager of Real Time.
- Issuing the Blue Alert signal to all relevant stations.
- Issuing the European Awareness System State 4 – Blackout.
- Issuing the Electronic Dispatch Instructions (EDIL) messages to all relevant stations.
- Issuing the Black Start Shutdown command to all TSO windfarms in the blacked out area.
- Informing the National Distribution Control Centre (NDCC) of a Blue Alert event and requesting the NDCC to issue the Network Operator Initiated Shutdown to all DSO wind farms within the blacked out area.
- Assigning roles and responsibilities to individuals (roles checklist).
- Informing all relevant parties as directed in the NCC Communications Checklist and the Black Start Emergency Communications Plan.

3.4. Re-Energisation Procedures – Black Start Generation

EirGrid has contracts with several generators around the country (mainly hydro generators) that can start without an external supply. These are called black start generators. If EirGrid deems that it needs more black start generation in an area, then it can contract for that generation. EirGrid does not propose to change this approach at present.

The NCC Engineers will establish the status of the generators in each of the subsystem checklists. Each black start station should run up according to its own Black Start procedures. The primary purpose of black starting these stations is to extend supply to target generation stations that cannot start without an external supply.

The NCC will communicate with each of the Black Start Stations and establish the time before these stations will be able to run up to full speed no load and energise the transmission system. Following this, the NCC needs to establish which power stations are available and where the restoration paths should be extended to.

Information on island modes, start-up times and loading of generation stations is contained in the NCC version of the SRP. Having gathered this information, the NCC should then prioritise non-Black Start Stations in terms of the order in which stations will be targeted for receiving supply from a Black Start station.

3.5. Re-Energisation Procedures – Subsystems

The SRP divides the transmission system into four restoration subsystems. Each subsystem contains at least one Black Start station and non-Black Start Stations which have been identified as primary target generation stations. The NCC should clearly delineate between the subsystems to avoid the possibility of an accidental crash synchronisation during the restoration phase. The chosen boundaries of each subsystem should be highlighted on a large network overview diagram that all the NCC Operators can see. The NCC should ensure that each subsystem contains at least one location where the field frequency measurements are telemetered back to

the NCC. The NCC should choose an appropriate path based on the following criteria:

1. The target generation stations, based on their availability and how long it will take them to synchronise once they have had supply restored.
2. The known status of the transmission path – including the status of transmission circuit breakers and generator transformer circuit breakers.
3. The recommendations contained in the SRP (this is particularly important in Dublin where there is a large cable network).

The relevant path checklist for each subsystem should be used to assist with choosing the appropriate energisation path from the Black Start station to the target generator

Transmission stations on the preferred routes from Black Start Stations to primary target generation stations that require ESBN operators on site during a Blue Alert are designated as priority stations, and will be staffed on receipt of a Blue Alert signal without further instruction from the NCC. Priority 1 transmission stations have a target time to be staffed by ESB Networks within 30 minutes of a Blue Alert being issued, and Priority 2 transmission stations have a target time of 60 minutes. ESBN Operators are trained in the procedures to be followed on receipt of a Blue Alert, and should regularly update and customise the station Blue Alert procedure to meet their own specific requirements.

A number of assumptions have been made in the subsystem restoration sections of the SRP, so whilst choosing the appropriate path the following should be considered:

1. Total blackout of the power system
2. No damage to generation plant has occurred.
3. Black Start generation stations remain fully operational.
4. Sufficient water is available in all hydro and pumped storage stations in order to energise a restoration path.
5. All generation stations are adequately staffed
6. No major loss of telecommunications facilities (voice/data) has occurred.
7. No major loss of NCC computing facilities (hardware/software) has occurred.

3.6. Re-Energisation Procedures – Restoration Paths

When building the restoration path from the black start generator to the target generator, either soft or sequential energisation is employed. Soft energisation is preferable, as the de-energised transmission path can be built in parallel to the black start generator starting up. The generator can then energise the path at a reduced voltage. However, soft energisation is only possible where the black start generator has the facility to start at a reduced excitation. For paths where the black start generator does not have this facility, sequential energisation is recommended. This method requires the black start generator to start up before the transmission path is built, and then the path is sequentially built energising one transmission station at a time.

3.7. Frequency Management

The following principles are applied, in accordance with Articles 28-31 of the NCER. Note that in Ireland, EirGrid is the sole TSO, and as such, the concept of 'frequency leader' does not apply. However the principles of Article 29 of the NCER are adhered to inasmuch as they apply to the restoration sub-systems prior to re-synchronisation. The NCC also work closely with their counterparts in Northern Ireland, as the system is usually operated as a single synchronous area for Ireland and Northern Ireland.

Load restoration increments should be of magnitude and at the locations specified by the NCC. Initial load restoration should be carried out in the smallest steps possible to minimise system frequency and voltage deviations. Once a number of generators have synchronised, load restoration should be in steps appropriate to the size of the sub-system. Load should be restored initially in those parts of the system that are adjacent to generation sources.

System or local frequency should be at least 50.0 Hz (preferably higher) before restoring any load. One generator on the subsystem should control the frequency (the swing generator, operating in isochronous speed control mode). The other generators on the subsystem should operate with a load set point as dispatched by NCC and in normal

droop governor control mode, unless otherwise instructed by the NCC. No more than one generator should operate in isochronous speed control mode in any system.
Prior to each increment of load restoration, ensure that the swing generator is operating near mid operating range and that the proposed increment of load does not exceed the remaining available capacity on that unit. As an increment of load is restored, the swing generator will increase output to meet the additional load and return the system frequency to 50 Hz. Following this, the load set point(s) of the other generator(s) on the subsystem should be increased (dispatched up) to take up the load increment, returning the swing generator to mid operating range.

All load restoration must be closely coordinated between the NCC, the NDCC, and the swing generator on the subsystem. No generator should be exporting in excess of 50% of availability during subsystem load restoration if possible.

The total load restored should not exceed the sum of available synchronised generation less the availability of the largest synchronised generator on the subsystem.
If any generators have tripped to house load, consideration should be given to prioritising restoration of supply to these units ahead of the suggested order for restoration.
Ensure that automatic frequency restoration (AFR) facilities are switched off on all load feeders included in the under-frequency load shedding scheme. AFR may only be restored by agreement with the NCC.

- Ensure that under voltage schemes are switched off on all load feeders.
- Ensure that special protection schemes are switched off (if appropriate) on all load feeders.

3.8. Voltage Management

As feeders are energised and load is picked up, the NCC should pay attention to the following:

- The system should be re-energised at as low a voltage as possible, in order to reduce the MVAr generation of unloaded transmission feeders.

- The target voltages on the 220 kV and 110 kV systems are 205 kV (or lower) and 100 kV (or lower) respectively.
- The switching in of a large transformer on a small isolated system can cause large magnetising inrush currents, and an associated voltage dip. In theory a transformer can take up to 10 times its rated current on energisation. To minimise inrush currents in a transformer, the tap changer on the transformer should be positioned so that the maximum amount of turns will be excited in the transformer.
- When energising tie transformers on a Black Start path:
    - The tap position will only have an effect on transformer inrush current where the tie transformer is being energised from the HV side. Where a tie transformer is being energised from the LV side, the tap position should be chosen to give the desired steady state voltage on the Black Start path once the transformer is energised.
- Remote end awareness: prior to energising a transmission station the NCC should check to ensure that no loads or wind farms are connected at that station.
- Once all generation stations have received supply, the transmission system should be restored feeder by feeder to limit the increments of MVArs generated by the developing system. Load restoration should be suitably interspersed with feeder restoration to limit the MVAr absorption of the generators to an appropriate value.
- Only one circuit of a double circuit feeder should be used during the early stages of restoration. This minimises the MVAr generation of the developing system. It also maximises the short circuit current in that one circuit while system short circuit levels are still low and thus enhances system protection performance.
- Care should be taken to avoid energising a long 400 kV, 220 kV or 110 kV transmission line with an unloaded transformer connected to the remote end. This is a possible resonant condition with resultant high overvoltages.

3.9. Synchronising Generators

A sufficient number of generators should be started to ensure that no one unit is operating at full output. Generators should be partly loaded. A range of partly loaded rather than a few heavily loaded generators provide the following advantages:

- Increased flexibility;
- Increased load response;
- Increased MVAr absorption capability and consequently better control over the voltage of the developing system;
- Increased MW and MVAr spinning reserve;
- Increased short circuit levels.

System stability must take precedence over speed of restoration. Idle generators in large thermal non-Black Start Stations should not be run up automatically on isolated island subsystems supplied by hydro generation. Instead, they must wait for instruction from the NCC. This is necessary to avoid the possibility of de-stabilising that system.

3.10. Resynchronisation

The idea of restoring subsystems independently is to allow progress to develop simultaneously in different parts of the network in a controlled manner. The Manager of Real Time shall monitor progress in each subsystem and shall decide when it is appropriate to synchronise the subsystems.

Synchronising should take place only where a controlled synchronising facility exists. The use of controlled synchronising facilities on all circuit breakers should be carried out by appropriately qualified staff.
Once all the subsystems have been synchronised restoration can continue to be extended to all remaining locations until all system demand has been restored (subject to generation availability).

While every effort must be made to return the system to normal as soon as possible following the disturbance, stability and correct operating practices must be observed at all times.

In principle, the NCC should establish N-1 security for the transmission system as early as possible. It is particularly important to ensure that plant is operated within normal tolerances. As the system is rebuilt the system voltage can be returned to the normal

operating range. All standard sectionalising arrangements should be re-established and normal protection settings re-applied (such as reclosing, AFR etc.)

Once the restoration is deemed to be complete the NCC should issue a Blue Alert Off signal. The NCC should ensure that each of the operations identified in the “NCC Black Start Check List – Returning System to Normal” has been carried out.

Non-centrally dispatched units (such as wind farms) should only be restored when the NCC considers frequency and voltage implications can be dealt with or otherwise as considered beneficial to the restoration requirements.

4. Article by Article Summary

The following table summarizes the SRP with respect to the relevant articles of the NCER.

Article	Details	EirGrid Comments
1-3	General Provisions and Definitions	
4	Regulatory Aspects including general principles / transparency; Terms and Conditions Consultation; December 18th Notification to RAs	This document and related documents comprise the public consultation documents that are being carried out to satisfy the provisions in Article 4 (and 7).
5	Consultation and Coordination	No issues
6	Regional Coordination	Ireland SRP will be compared with Northern Ireland SRP to ensure consistency. As not AC connected to GB, Article 6 does not extend to consideration of GB SRP in any detail.
7	Public Consultation	This document and related documents comprise the public consultation documents that are being carried out to satisfy the provisions in Article 7 (and 4).
8	Recovery of Costs	EirGrid does not anticipate any additional costs stemming from this Regulation.
9	Confidentiality Obligations	Note that only a high level version of the plan has been described in this document, and does not contain any confidential material.
11-22	System Defence Plan	Covered in SDP Document
23	Design of the SRP	Although the SRP has been in

Article	Details	EirGrid Comments
		existence for many years, the principles set out in this Article strongly align with the design of the current plan. The current plan is being reviewed to further align with the provisions of the NC ER, including for example the concept of bottom-up vs top-down restoration.
24	Implementation of the SRP	No changes expected here, as there is already a plan in operation.
25	Activation of the SRP	Self-explanatory – the SRP is enacted once the system is in a blackout or partial blackout state.
26	Re-energisation Procedure	Bottom-up and top-down approaches – will be spelled out more clearly in next version of SRP.
27	Activation of Re-energisation Procedure	Concerns an assessment of the system state following the blackout event and determining the best course of action. Control engineers are trained to anticipate many different scenarios.
28-31	Frequency Management after Frequency Deviation; Frequency Management after Synchronous Area Split	These Articles are really concerned with continental restoration where the actions of TSO can impact on restoration. They do not apply in general to the Ireland / Northern Ireland context where there is a single TSO with two control rooms co-ordinating system restoration.
32-34	Resynchronisation Procedure; Appointment of Resynchronisation	Although the general principles in these Articles are adhered to, they

Article	Details	EirGrid Comments
	Leader; Resynchronisation Strategy	again relate to continental Europe where several TSO may be attempting to resynchronise areas, and where one TSO needs to be in charge.
35-39	Market Activities	Covered in separate documents
40-42	Information Exchange, Communication Systems, Tools and Facilities	Where applicable, the TSO already has enough information to carry out its function to restore the power system. There are OPTEL and TETRA systems in place in case of problems with communications during a blackout. There is also a backup control room available and regularly tested.
43-52	Compliance Testing and Monitoring	EirGrid regularly carries out testing of blackstart generation, blackstart procedures, and simulations for Control Centre staff, as well as communications exercises with key stakeholders.

5. Next Steps

EirGrid is currently revising the Power System Restoration Plan, and aims to release a new version mid-2019. This new version will take into account any extra requirements set out in the Network Code on Emergency and Restoration, including new definitions and approaches to restoration. A copy of the new plan will be sent to the Commission for Regulation of Utilities.