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# WEATHERING THE STORM: MANAGING A MAJOR WEATHER EVENT ON IRELAND'S TRANSMISSION SYSTEM

Insights from Ophelia

January 2018

## RESEARCH QUESTIONS

How did the transmission system operator in Ireland—a system with a high penetration of wind generation—plan for and manage a major storm that made landfall on the island? What lessons from the experience can be applied to other system operators for future major weather events?

## KEY INSIGHTS

- Early planning ahead of a major weather event is critical; staffing decisions and role assignments must be defined well before the event occurs.
- An external communications team should be established prior to the storm to keep stakeholders aware of progress, as well as to allow control center staff to focus on their tasks.
- Customer connections and/or business closures can make load forecasting difficult, which can result in the unintended consequence of high system voltage.
- Windfarm controllability is critical. To mitigate the risk of high-speed shutdown, wind generation constraints can be applied and released as the storm moves. Additional large thermal generation can provide inertia and reserve.

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## ABOUT THE IRISH TRANSMISSION SYSTEM

On the island of Ireland, EirGrid Group is responsible for the operation of the 400 kV, 275 kV, 220kV, and 110 kV networks. The all-island peak system demand is 6,878 MW. Approximately 4,000 MW of installed wind generation capacity is connected to the transmission and distribution systems in Ireland and Northern Ireland. The National Control Centers (NCC) are located in Dublin and Belfast.

## HURRICANE OPHELIA

Hurricane Ophelia originated in the North Atlantic near the Azore Islands around October 6, 2017. The storm was an unusually extreme weather event for Ireland; it was also the easternmost hurricane recorded since records began. Most hurricanes develop further south in the warmer waters of the Atlantic Ocean and, driven by the easterly trade winds, they typically gain strength before making landfall over the mainland United States, Mexico, and the Caribbean Islands. Due to a combination of unusual weather factors, Ophelia tracked North toward Europe with the hurricane cone of uncertainty on track to make landfall somewhere on the southern coast of Ireland. While western Atlantic cities have experience dealing with the impact of hurricanes on transmission and distribution systems, Europe and the eastern Atlantic do not. Ophelia peaked as a Category 3 hurricane on October 14. By the time it made landfall in Ireland on the morning of October 16, it had weakened enough to be categorized as a tropical storm.

## IRELAND'S WEATHER WARNING SYSTEM

Ireland has three weather warning categories:

1. Status Yellow–Weather Alert: Be Aware
2. Status Orange–Weather Warning: Be Prepared
3. Status Red–Severe Weather Warning: Take Action

Status YELLOW weather alerts are for weather conditions that do not pose an immediate threat to the general population, only threaten those exposed to risk by the nature of their location and/or activity.

Status ORANGE weather warnings imply that all recipients in the affected areas should prepare themselves in an appropriate way for the anticipated conditions.

The issue of a RED severe weather warning is a comparatively rare event; it implies that recipients take action to protect themselves and/or their properties. People in the affected areas may need to prepare by temporarily moving their families out of the danger zone, staying indoors, or by additional specific actions aimed at mitigating the effects of the weather conditions.

## THE PRE-PLANNING PHASE

### *Landfall Day -3: Friday, October 13, 2017*

A yellow weather warning was issued by the Irish Meteorological Service, Met Éireann, for Monday, October 16. At this stage, there was still uncertainty about the storm's landfall, intensity, and potential impact. Based on the weather alert and news reports of anticipated potential effects from the hurricane, EirGrid convened a preparedness meeting on the afternoon of Friday, October 13 comprising control center staff, operations, out-of-hours managers, and key members of staff to assess how to best secure the power system, as well as to review existing plans and policies for the impending weather event. At this meeting, the team determined preliminary roles and responsibilities for communications and additional staffing plans.

### *Landfall Day -2: Saturday, October 14, 2017*

As the forecasted path of the hurricane became more certain, a red weather alert was issued by Met Éireann, for October 16 for the west coast of Ireland. An orange weather alert was issued for the remaining counties. The UK Met Office issued an amber weather warning (comparable to status Orange weather warning) for Northern Ireland. A decision was taken by the relevant government departments to call a meeting of the National Emergency Co-ordination Group (NECG) to take place on the morning of Sunday, October 15.

### *Landfall Day -1 Sunday, October 15, 2017*

Met Éireann extended the red weather warning for October 16 to all counties in Ireland; warnings by officials through all media outlets meant that the population was on high alert. EirGrid's Operations Charge Engineer (OCE) attended Ireland's NECG meeting. The NECG coordinates and oversees the planning and response of state agencies to major emergencies in Ireland. At the NECG meeting, a decision was made to close all educational institutions in Ireland on October 16. In EirGrid, it was decided to keep most staff at home on October 16, though the most relevant operational staff were requested to arrive on Monday morning before the storm was due to reach the East coast.

Following the NECG meeting, further work was undertaken to secure the power system (including scheduling decisions) and to secure staffing of critical transmission stations (which are normally unstaffed) in line with the Power System Restoration Plan. The need for additional support staff was identified and clear roles and responsibilities for the NCC desks and support office staff were defined. The internal Emergency Communications Team (ECT) was appointed. The ECT was composed of operational and communications staff and management from across the organization, including executive directors and the CEO. It met hourly (the first meeting was scheduled for 07:30 on October 16), to discuss the latest information on weather, the status of the power system, and to receive updates from the NECG. Other key stakeholders, including large thermal generators, large customers, wind farms, energy regulators, and governmental departments were contacted and updated by the ECT.

In Northern Ireland, multi-agency meetings (equivalent to the NECG) were also held.

## THE DAY OF THE STORM: MONDAY, OCTOBER 16, 2017

### *Load Forecasting and Thermal Generation*

At 08:21 an Amber Alert 1 was issued by the NCC. An Amber Alert 1 is issued to generators, distribution system operators, and customers when multiple contingencies are probable because of thunderstorm or high wind activity. It was apparent that system demand was significantly lower than had been forecasted (see Figure 1 below), primarily due to the closure of businesses, industries, and schools that had heeded the red alert warning. Anticipating the system demand during the day was a significant challenge because of the amount of distribution-connected load that was disconnected through faults (in addition to the school and workplace closures); this made the planning of generator unit commitment and the schedule for the night shift much more difficult. During the day, the NCC faced the possibility that total minimum stable generation levels of the synchronized large thermal units would exceed night time valley load. However, that problem did not occur because the load recovered as the storm passed and the DSO worked to reconnect customers.

During the storm, one large CCGT power plant (located by the coast) tripped due to inundation of cooling water at the plant, but there was minimal system impact. The Amber Level 1 alert was cancelled at 20:20.

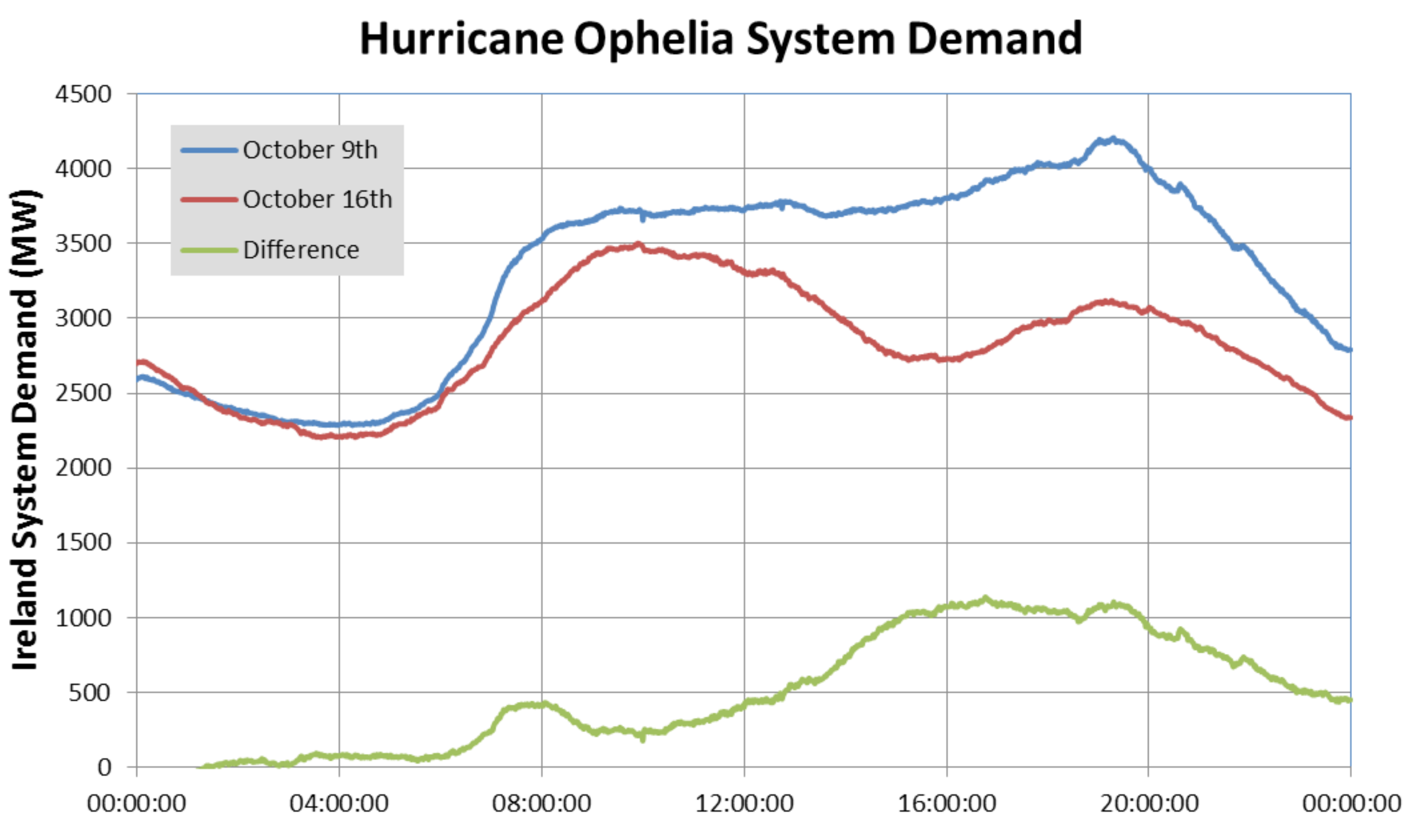


*Figure 1: System Demand in Ireland on October 16, 2017, during Storm Ophelia, compared with the previous week on October 9, 2017.*

## WIND GENERATION ON THE ISLAND DURING THE STORM

On the day of the storm, more than 2 GW of wind generation was anticipated at times. Some of this wind generation was pre-emptively dispatched down from 1200 MW to approximately 400 MW in the Southwest of the island at the start of the day. Other wind generators reduced availability independently of system operator instructions. These actions were taken to mitigate the risk of losing a large amount of wind generation due to high-wind-speed shutdown.

When wind speeds reach sufficiently high levels, wind turbine controls take action to protect the turbines by turning away from the wind and reducing production. This occurs at the high-speed cut out rating. Wind speeds and gusts recorded at meteorological stations on the west coast exceeded the high-speed cut out rating of turbines, justifying the preemptive management approach (See Figure 2).

Ophelia made landfall on the Southwest of the island. Dealing with the high levels of wind generation over the day and the potential for high-wind-speed shutdown was managed through effective remote control of the wind farms. Because the majority of windfarms on the island can be controlled directly from the NCC, it was possible to use the windfarm generation output to balance the system as demand fell.

### High Wind Speed Shutdown

When wind speeds at wind farms reach a sufficiently high speed, wind turbine controls act to protect the turbines by turning away from the wind and reducing production. This protective mode results in a reduction in power output from the plant at the high speed cut out rating (normally in the range of 25 m/s). When storm fronts move into areas with several wind farms at or close to their maximum output, there is a risk of a rapid significant loss of wind generation in the area due to high-wind-speed shutdown. System operators can act in advance of events to mitigate this risk, especially in situations such as hurricanes when system security faces hazards from multiple sources.

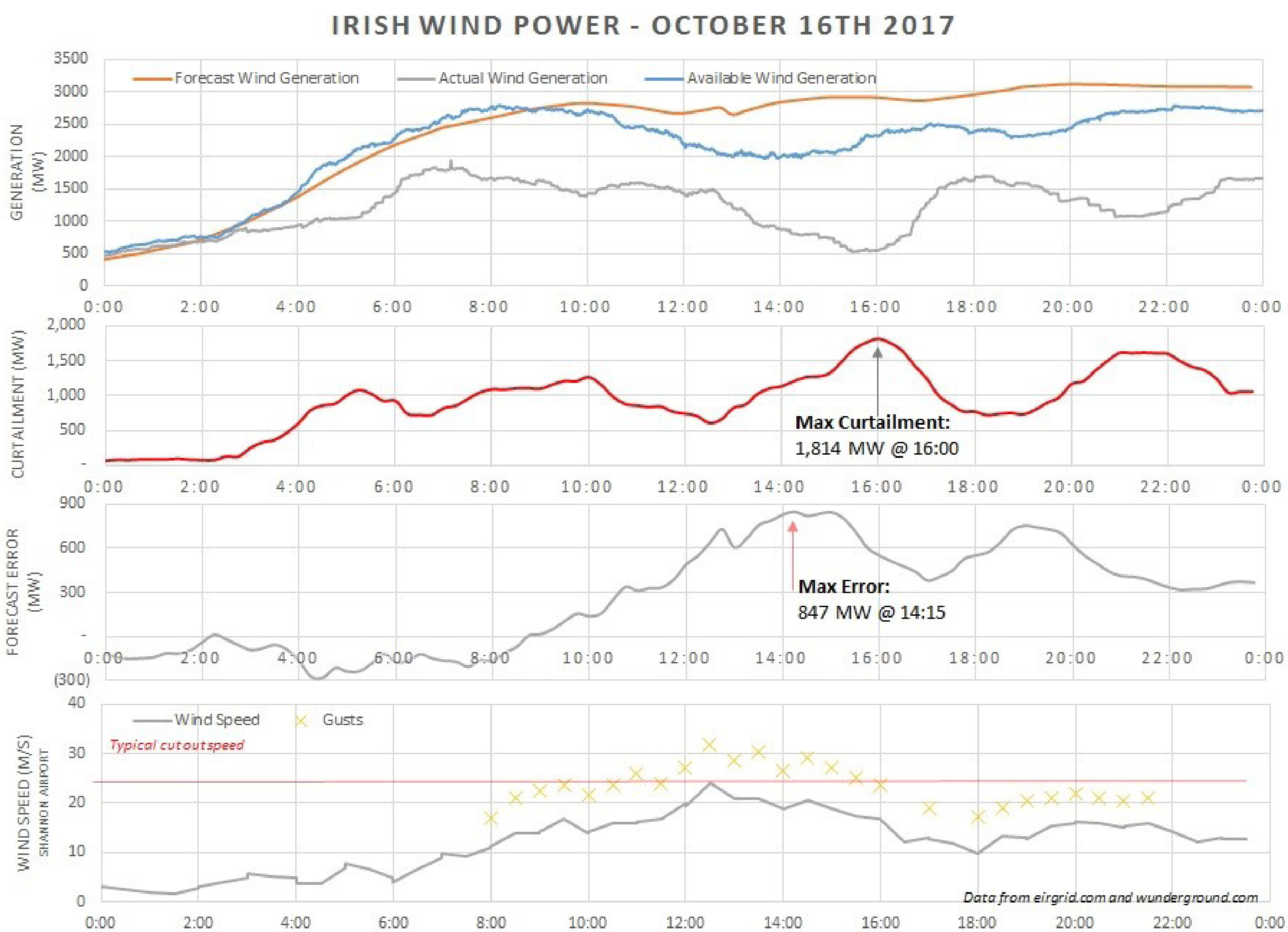


*Figure 2: Wind power on the island of Ireland: actual generation, availability, day ahead forecast, and wind speed, October 16, 2017.*

To increase the inertia and stability of the power system, additional conventional power plants were synchronized, albeit at minimum load to provide reserve. As the storm moved across the island, the constraint of wind generation was lifted in southern regions and applied in more northern regions to offset potential high-wind-speed shut down in those areas. When commenting on the experience of operating the system through Hurricane Ophelia, EirGrid Operations Charge Engineer Marie Hayden noted:

> *"Overall, I feel the system was easier to manage because we had high levels of wind generation. High speed-shutdown, where it occurred, happened gradually so we did not experience sudden imbalances–this was partly because we constrained down some of the windfarm output in the stormiest parts of the country to avoid experiencing sudden imbalances."*
>
> *"The power system was much more robust than I expected. The wind speeds anticipated and experienced were higher than any storm experienced in Ireland in the previous 50 years. Based on the damage to the system in two previous major storms, Storm Darwin (2014) and Hurricane Charlie (1986), I expected a lot more damage to power lines and a significant loss of transmission and generation facilities to occur. In the end, this did not materialize."*

## HIGH VOLTAGE ISSUES

Due to the substantial loss of distribution-connected load, high voltages were seen in certain parts of the system. For example, voltages of 239 kV (1.09pu) were observed on the 220 kV network in the Southwest of Ireland. These high voltage levels necessitated studies to be performed throughout the day by NCC operators and the support staff. The aim of the studies was to determine the best network configurations and transmission switching options, as well as to look ahead to the night valley in the case of continued low load. The voltage control capability of the more modern windfarms was used and it proved to be effective in dealing with the high transmission system voltages.

## EXTERNAL COMMUNICATIONS AND CONTROL CENTER STAFFING

The Emergency Communications Team (ECT) held twelve meetings between 07:30 and 22:00 on the day of the storm. These meetings reviewed the latest storm updates, updates on the status of the power system, and the decisions regarding staffing arrangements. Additionally, the OCE and a communications manager attended three meetings of the NECG throughout the day to provide updates on the power system as requested. The OCE also reported back to the ECT on any developments at a national level. Additionally, three Northern Ireland multi-agency meetings were held and attended by a member of EirGrid staff. Proactive engagement on social media and with key stakeholders reduced the number of expected queries and minimized nuisance calls made to EirGrid.

The backup Emergency Control Center (ECC) was staffed with operators throughout the day to aid NCC staff and to provide support in case of an evacuation of the NCC. Three sub-teams from the operations support office were tasked with investigating various aspects of system operation during the day, including communications and restoration plans. Support staff in Belfast were also available to support the NCC and to attend the meetings via conference call. On-call arrangements were put in place after 19:00.

SCADA remained operational at all times, ensuring visibility across the system. However, main and back-up voice and internet communication links with one large CCGT plant was lost, but mobile and 3G networks were operational and facilitated communication with the station.

## SYSTEM FAULTS AND DISTURBANCES CAUSED BY THE STORM

Multiple transmission system overhead-line faults occurred during the storm. A combination of automatic and manual reclosing of plant connections ensured that no transmission station lost supply during the event. Many voltage sags arising from distribution system faults were observed, particularly in the southern part of the country. Sixteen 110 kV transmission trip/recloses occurred between 11:07 and 14:22. There was one 110 kV circuit that appeared to have a permanent fault and could not return to service until inspected. There were also system faults and disturbance events in Northern Ireland.

### *Post-Storm Analysis and Outcomes*

Overall, there was little impact on the extra-high-voltage and high-voltage transmission systems or on generators connected to the transmission system. There were multiple transmission-level short circuit faults; however, most faults were temporary, and automatic reclosing helped to minimize system impact. A number of pole sets on one 110kV line were leaning over after the storm. This line required a five-day outage for repairs after the storm, but did not experience a fault during the storm. No large industrial customers directly connected to the transmission system were disconnected during the storm. ESB Networks, the distribution system operator in Ireland, estimated that 375,000 homes lost supply. Power was restored to all homes in Ireland by October 24.

## KEY INSIGHTS WHEN PLANNING FOR AND MANAGING A TRANSMISSION SYSTEM DURING A STORM

- Despite excessive wind speeds, a considerable amount of wind generation can be still be accommodated (see Figures 1 and 2), provided that remote control of windfarms is available to control centers.

- It is important to allocate clear roles and responsibilities to staff within the control center. Since there may be more than normal number of operators in the control center, it is vital to ensure that each individual has clarity about their role, authority level, and decision-making responsibilities during abnormal events.

- It is equally important to allocate roles and responsibilities for external stakeholder and customer communications. Due to pre-emptive action by the transmission system operator (TSO), the number of calls to the TSO requesting information and updates was minimal, indicating clear and effective external communication; this, in turn, allows operations staff to stay focused on their roles.

- Having facilities, corporate services, key staff, and executives involved in the hourly communications briefings means that all aspects of business continuity were aware of needs and were able to address issues as they occurred.

## PUTTING THE EVENT INTO CONTEXT

As resiliency continues to be a major factor influencing the design and operation of power systems, lessons learned from this experience provide insight into the roles that wind generation and defined operational procedures can play in securing the transmission system during extreme events. The experience demonstrated how pre-curtailment of renewables prevented widespread, high-speed cut out of wind generation while leveraging the curtailed energy for balancing during a period with considerable demand forecast uncertainty. The experience also demonstrated how renewables could be used to control system voltages when disturbances occurred and, as demand was lost from the distribution network, further contributed to system resiliency.

The experience highlighted the benefit of clear and structured organization in control centers, ensuring that they were well equipped to manage the system during an extreme weather event. It also highlighted the role that active communication with the wider community can play; clear, accurate, and timely information helped to ensure that operators could focus on the task at hand with minimal distraction.

The Electric Power Research Institute (EPRI) has a number of research projects which relate to the experience operating in these extreme conditions including topics focused on: distilling important insights about the state of the system during events from the stream of alarm information coming to the control center; providing guidance to operators as to the operational limits of the system; providing support tools for voltage and frequency management generation scheduling; and planning tools to support systems in preparing for high-impact, low-frequency events.

## ONGOING EPRI RESEARCH

- Program 39 Grid Operations
  - P39.11A Identifying and Visualizing Operating Limits
  - P39.11B Alarm Management and Integration of Non Traditional Data sources
  - P39.12A Voltage Control Reference Guide
- Program 40 Grid Planning
  - P40.022: Incorporation of Risk Analysis into Planning Processes
- Program 173 Bulk System Integration of Renewables and Distributed Resources
  - P173.5 Operational Support Tools to Manage Renewables
  - P173.11 Voltage and Frequency Performance with Renewables

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