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Managing Power Delivery in the Face of Extreme Weather Events

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Abstract: The number of extreme weather events that have affected the globe from hurricanes that devastated the Caribbean region and major coastal regions of the United States, to the lashing winds and rains that barreled down on the United Kingdom, have been record-breaking. The economic costs of these extreme weather events are staggering. For example, from the list of the top 20 hurricanes to affect the United States, experts estimated the combined economic costs into trillions of dollars. Hurricane Katrina was estimated at $300 billion, Harvey at $180 billion, Irma at $100 billion, Sandy at $71 billion, and Maria at $85 billion. These estimated figures are not just dollars lost in the damage done by the storm, but they also comprise other key components, including: disruption to business, unemployment periods lasting up to months, transportation and infrastructure damages, crop loss …, increased fuel prices, and property damages. This article explores the impact of several major hurricanes on the power supply systems during 2017. Besides the U.S. storms, Hurricane Ophelia also battered the United Kingdom. Of less frequency, but of great significance is the experience of a solar eclipse which resulted in the complete loss of the power to those relying on solar power, and a sudden and significant drop in atmospheric pressure? The importance of diversifying the power supply systems and boosting energy storage are highlighted as possible strategies for managing the effects of these increasingly extreme weather events on power supply systems.

Keywords: Power; weather; Ophelia

INTRODUCTION

Ophelia "caused damage estimated at £1 billion and claimed 18 lives" [1]. For perspective, the estimated costs for Hurricane Katrina ranged between $108 and $250 billion; other estimates put the combined cost of the 2005 hurricane season, which included Katrina, Rita, and Wilma, at nearly $200 billion in 2017dollars [2].

Undeniably, 2017 has been a record breaking year for the number of extreme weather events that have affected the globe from hurricanes that devastated the Caribbean region and major coastal regions of the United States, to lashing winds and rains that barreled down on the United Kingdom.

Hurricanes are considered by many to be the most devastating of all natural disasters [3]. The strength of the hurricane is classified based on the Saffir-Simpson Hurricane Wind Scale shown in Table 1 below.

Table-1: SAFFIR-SIMPSON HURRICANE WIND SCALE

Category	Wind Speed	Surge in Feet	Damage	Home Damage	Tree Damage	Power Outages
1	74-95 mph	4-5	Some	Some	Branches	Days
2	95-110 mph	6-8	Extensive	Major	Snapped	Weeks
3	111-129 mph	9-12	Devastating	Major	Snapped	Weeks
4	130-156 mph	13-18	Catastrophic	Severe	Toppled	Months
5	157+	19+	Catastrophic	Destroyed	Toppled	Months

ECONOMIC COSTS OF EXTREME WEATHER EVENTS

The economic costs of these extreme weather events are staggering. For example, experts estimated the economic costs of Katrina at $300 billion, Harvey at $180 billion, Irma at $100 billion, and Sandy at $71 billion, and Maria at $85 billion [3]. Table-2 below shows the estimated costs associated with the top 10 storms to hit the United States from 1992 to 2017. Note that four of the top five storms occurred within the last five years.

Table-2: TOP 10 HURRICANES

Rank	Name	States	Year	Category	ımage in Billions
1	Katrina	FL, LA, MS	2005	3	$108-$250
2	Harvey	TX, LA	2017	4	$180 (est.)
3	Irma	FL	2017	5	$100 (est.)
4	Maria	PR	2017	5	$85 (est.)
5	Sandy	NY, NJ, MA	2012	TS	$71.4
6	Ike	TX, LA	2008	2	$29.5
7	Andrew	FL, LA	1992	5	$26.5
8	Wilma	FL	2005	3	$20.6
9	Irene	NC	2011	1	$15.6
1*[0]*	Charley	FL	2004	4	$15.0

The costs associated with these storms are comprised of several key components, including: “disruption to business, unemployment periods lasting up to months, transportation and infrastructure damages, crop loss …, increased fuel prices, property damages” [4-8, 2]. The location of the hurricanes reinforces the position that the United States is very vulnerable to hurricanes as approximately one-third of its gross domestic product is generated from production along the Gulf and Atlantic Coastlines [3].

One of the strangest extreme weather events of 2017 was Hurricane Ophelia that battered the United Kingdom on October 16, 2017 [4]. Although only a category 2 system based on the Saffir-Simpson Hurricane Wind Scale as it approached the United Kingdom, the impact was devastating. Even though weakened after making landfall, Britain, Ireland, Scotland, and Wales, felt the punishing winds and waves from Hurricane Ophelia. Exactly 30 years after the Great Storm hit the UK in 1987, another extreme weather event occurred, plunging 360,000 homes in Ireland into darkness. This caused the Government in Ireland to declare a state of emergency.

Rail service was disrupted and schools, hospitals and public transport were closed in the face of this threat to life [9-11, 1]. Hundreds of flights were also disrupted, severely impacting the operations at several regional airports. The list of affected airports includes: Cork, Kerry, Shannon and Dublin. Three people died in storm-related incidents across the Republic [4]. Reporters concluded that dust from southern Europe and the African continent was pulled up by Ophelia’s winds which accounted for the bizarre red and orange colour of the sky.

Wales and Western England were also affected. In Scotland and Northern England, winds gusting around 70 mph along with the rainfall affected travel and resulted in delays in rail service. The areas most affected were Glasgow to Edinburgh, Aberdeen to Dundee and Perth. There was significant damage from fallen trees and downed power lines. Some flooding was also anticipated for the region [1, 9, 11]. What was the price tag for Ophelia’s punishing winds and rain? The people are undoubtedly still adapting to the effects of Ophelia, but the economic cost was estimated at £1 billion, with a total of 18 lives lost across the region [11, 10, 1]. Extreme weather events do not necessarily occur often.

However, when they do occur they cause tremendous disruption in the region and impact the lives of the people who live in the surrounding areas. Another such infrequent extreme weather event occurred in the United States during August 2017. The people of North Carolina experienced a solar eclipse which resulted in the complete loss of the sun and a sudden and significant drop in atmospheric pressure that momentarily challenged the power supply of millions of consumers who rely on solar power and whose energy supply was not mixed to compensate for the loss of solar power [12]. Boosting energy storage may be one of the most suitable strategies for mitigating the effects of these increasingly severe weather effects on power supply system’s [10, 13].

STRATEGIES FOR MANAGING POWER SUPPLY SYSTEMS FOR EXTREME WEATHER EVENTS

To understand the need to manage power systems in the face of increasing numbers of extreme weather events, it is necessary to understand the process of human civilizations and urban development. Historically, human beings have followed a similar process of development across the world.

Civilizations search for water sources and select places on the surrounding landscape to settle their families and their livestock. The water source provides resources for maintaining life and hygiene. People use the freshwater resources in many ways. First for hygiene. In bathing and washing their personal items in running freshwater sources, populations have been able to reduce the transition of disease and support recovery in the event of ill-health. Additionally, every member of the community is enabled to maintain a minimum level of personal hygiene necessary for good health. As is true for the rest of the world, this holds true in Jamaica and the wider Caribbean region where I reside [14-16].

In addition to consuming the water for personal hygiene, families use the water for household purposes such as cooking, cleaning, maintaining backyard gardens, and more. As humans are approximately 70% water, adequate hydration from unpolluted freshwater resources ensures the maintenance of the physiological balance necessary for human life. Water is involved in all bodily functions ranging from the completion of cellular processes to more complex functions of brain activity and cognitive functioning. So, freshwater resources have always been and continue to be critical in the support of all life forms.

As more people migrated from their remote locations closer to water sources, networks of social systems began to develop requiring coordinated and integrated processes of managing the social life around the public infrastructure. As towns grew into cities that process became more complex, ultimately requiring that city planning authorities design their buildings to accommodate residential and commercial needs. The need for ventilation became an issue in design, particularly for interior rooms. As towns became more populated and land less available, the number of floors above the ground level increased to accommodate these new commercial and residential needs. This form of lifestyle, along with the advances in technology demanded innovation in the way that these populations would provide energy to provide light for extended hours beyond the normal pattern of the sun and the moon. As the technology advanced, industry developed around coal and gas that allowed for innovative ways of supplying safe energy to large populations of people in major cities around the world.

Benefits of Diversifying the Energy Mix

Accompanying advances in technology were increasing costs in producing reliable sources of energy. Subsequently, the systems for delivering reliable energy supply to cities and small towns can be quite expensive. In the search for more affordable forms of energy, innovations in technology have allowed the harnessing of the natural elements to provide energy. This includes solar power, wind power, hydro power, and nuclear power which constitute the power mix in the United States. With all the innovations however, energy delivery systems can be very costly to implement as well as to maintain. For example, when engineers in Houston, Texas drill for oil, they have significant costs in equipment and in labour to get the oil from deep in the earth's core up to the storage tanks where it can be processed and exported to cities across the North American continent or exported to other countries, like the Bahamas, Jamaica, Barbados, and the Cayman Islands in the Caribbean region. Oil refineries, and by extension shipping companies, like the ones located in Houston, Texas are increasingly vulnerable to the impact of severe weather effects, like Hurricane Harvey [22]. Any disruption in production at any stage – drilling, storing, refining and shipping can result in increased prices at the pump as was seen during summer 2017 when gas prices went up by approximately 25c, and in some instances as high as 50c. This has sometimes resulted in gas prices being raised to as much as $5 per gallon in some areas [3].

Diversifying the energy mix has been beneficial to the UK as they have reported positive feedback in their consumption of low carbon electricity. According to the Department for Business, Energy & Industrial Strategy 2017, "Low carbon electricity's share of electricity generation reached a record high of 53.4 per cent in the second quarter of 2017, compared to 46.7 per cent in the second quarter of 2016, with renewables' share of electricity generation also at a record high of 29.8 per cent ..." (p. 1). Figure 1 shows the UK's energy mix as at January 2017.

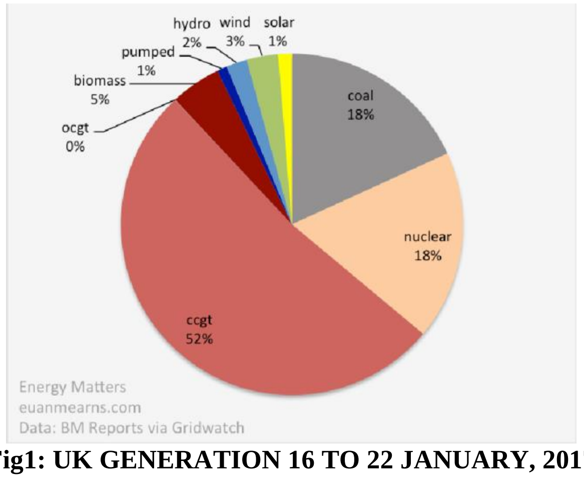

Fig1: UK GENERATION 16 TO 22 JANUARY, 2017

A more detailed summary of the contribution of each type of energy is presented below.

- Of electricity generated in the second quarter of 2017, gas accounted for 41.3 per cent, whilst coal accounted for a record low of only 2.1 per cent. Nuclear generation accounted for 23.6 per cent of total electricity generated in the second quarter of 2017.
- Renewables' share of electricity generation was a record
- 29.8 per cent in 2017 Q2, up 4.4 percentage points on the share in 2016 Q2, reflecting both increased wind capacity and wind speeds, as well as lower overall electricity generation.
- Renewable electricity generation was 22.5 TWh in 2017 Q2, an increase of 13.6 per cent on the 19.8 TWh in 2016 Q2. Renewable electricity capacity was 38.0 GW at the end of 2017 Q2, a 13.2 per cent increase (4.4 GW) on a year earlier, with over half of the annual increase coming from onshore wind.
- Switching rates increased in Q2 2017, up by 16 per cent compared to the levels of a year earlier for electricity and up by 20 per cent for gas, based on data provided by Ofgem. An average of 410,000 households per month switched electricity supplier, with 320,000 households per month switching their gas supplier in the quarter [17].

These statistics from the UK and the rate at which customers are switching energy providers show that there is resilience in the energy market which gives customers opportunities to select cleaner and more affordable power supply. The increasing production of renewable energy at a record high for the UK suggests that stakeholders in the energy sector see more opportunity for a better return on their investment than reinvesting in ancient technologies of coal and gas. The increasing production of renewable energy also signals the UK's desire to reduce their vulnerability to the shifts in the oil market. This energy mix has without question contributed to the swift return of power to the UK consumers after the passage of Hurricane Ophelia in October.

Benefits of Energy Storage

An analysis of global trends in the management of power supply systems, suggests that the solution to the challenges facing the expansion of the sector and to also protect it from vulnerabilities to extreme weather events is to invest in energy storage [18]. A survey of the energy storage landscape suggests that the industry has been grappling to find an answer to the excess energy that is generated from the varied sources of energy production. Rather than allowing the excess production to be wasted, companies and universities are investing billions of dollars in storage facilities, in particular in the event of extreme weather events. For example, California's policy has been adapted to facilitate the development of virtual energy storage for customers. Ted Ko, Director of Policy in California, summarized the history of California's progress in this area and the benefit that it had in the face of unprecedented heatwaves for the state.

In late 2015, the three largest California utilities held auctions for contracts for the upcoming first year of the DRAM program, offering contracts that enabled customer- sited energy storage to provide Resource Adequacy to the wholesale market. These DRAM contracts allow Stem and other energy storage developers to facilitate residential and commercial customer participation in the wholesale markets via each storage developer's network when there is a "call" from the CAISO. What is remarkable about the Commission's efforts is that DRAM has proven the technical viability of the first customer-based Virtual Power Plants (VPPs) in the country and achieved a record frequency of customer participation in a wholesale market, on the order of hundreds of dispatches in 2017 as compared to the low tens of dispatches for traditional DR.

Weather-related grid stress certainly contributed to the high engagement. Heading into the summer of 2017, California's energy markets witnessed unprecedented heat waves, resulting in a very high number of calls, which signaled a need for resources that could act quickly to increase energy supply or reduce demand in order to prevent widespread blackouts [20].

In the UK, a new energy company has recently commissioned the first energy storage facility [21]. According to the CEO of Eelpower, Mark Simon, "Leverton is the first of a pipeline of battery storage projects that Eelpower plans to build and operate over the next three years. They will support the grid, underpin security of supply and help reduce energy costs for customers, in particular for businesses that are major energy users" [21]. The technology utilizes the familiar lithium-ion batteries used in most laptops and other electronic devices. To meet their target storage capacity of 12MW, the engineering design will pair the 10MW/10MWh BYD lithium- ion battery with two 1.2MW hydroelectric battery units.

The global trends suggest that energy storage will be a significant contributory factor to making cities, states and regions more resilient in the face of extreme weather events [19]. From the USA to the UK, from Asia to Australia, and many regions across the world, energy storage at the very least provides access to information for those in the midst of hurricanes like Ophelia [9] and would have proven useful to those who experienced the solar eclipse in North Carolina this past summer.

LIMITATIONS AND FUTURE RESEARCH

As with all studies, this article had a disadvantage in the time and financial resources available to the author to conduct first hand investigation of some of the sites that have been affected by some of the extreme weather events of 2017.

However, the breadth of data available from video images, press releases, media footage, and other government and private sector documents provided enough material to develop this discussion around the management of power supply systems in the event of extreme weather events such as the ones which occurred during the past summer of 2017.

As with all technological systems, power systems have inherent weaknesses. However, the research has shown that there are ways of managing the power supply system so that it is resilient during and after an extreme weather event. Innovations in technology to increase the energy mix available to the country and the consumers, as well as investing in the development of energy storage devices to have excess power available after loss of power from the grid, can have a huge impact [12].

Future research must continue to find ways of accessing power during and immediately following extreme weather events. The research and subsequent innovations will have implications for the major sectors that affect public and private life, namely housing, health, transportation, work, water consumption and more.

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