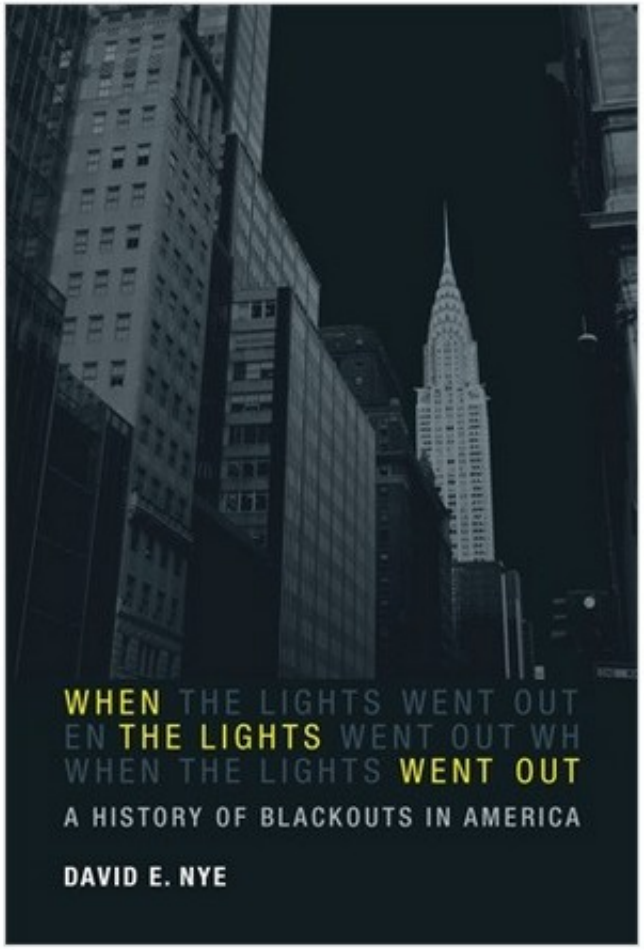
ETM521

Lecture 6 – Blackouts

Barış Sanlı

Resources



When the Lights Went Out

A History of Blackouts in America

By David E. Nye

Blackouts – whether they result from military planning, network failure, human error, or terrorism – offer snapshots of electricity's increasingly central role in American society.

https://mitpress.mit.edu/books/when-lights-went-out

Blackouts

- Blacked-out city becomes a new kind of social space
- Not only technical malfunctions
  - Also social events, economic problems, political emergencies...

At night

The Lindbergh Beacon at night, Los Angeles, February 15, 1929. General Electric Corporation.

ZİYA DALGALARI

Mevzuubahs olan adi tenvirat değil ziya dalgaları yani hakikî donanma tenviratı dır. Ziya dalgaları büyük satıhları aydınlatmak lüznmundan doğmuştur..

Meselâ 1925 de Paristeki tezyini san'atler sergisi 1931 de müstemlekât sergisi 1923 te Frankfurt 1929 da Berlindeki ziya şenliği 1933 da Cumhuriyetimizin 10 uncu senei devriyesi şenlikleri münasebetile abidelerin, resmî müesseselerin, parkların tenviratı ziya dalgaları vasıtasile elde edilebilecek harikulâde tesirleri göstermeği temin etmiştir.

Eski şehriayinlerin adi tenvirat gibi gözü çok yormak mahzuru vardı.

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New York 1920

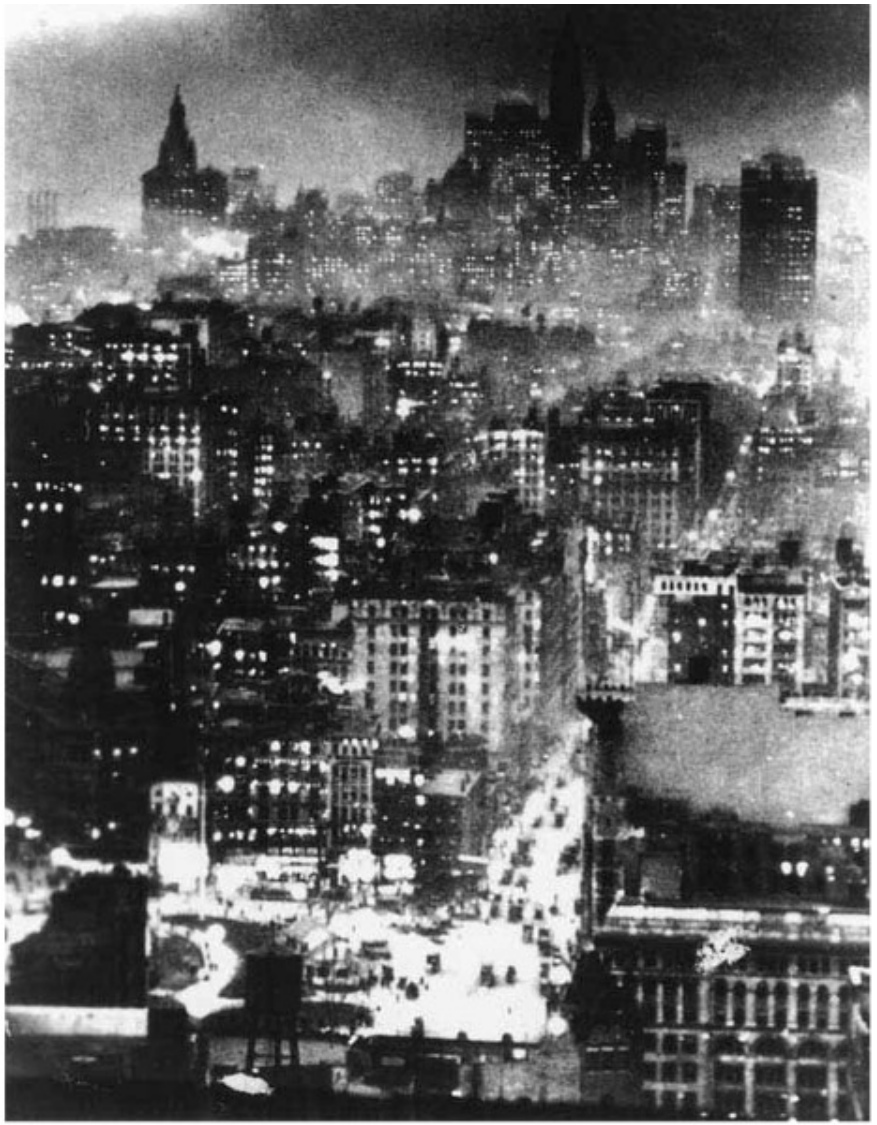


Figure 1.1
Night view of lower New York City from the Metropolitan Tower, c. 1920. Library of Congress.

The transition

- "Before electricity conditions of life were more like those of Julius Caesar's day".

  George F. Will(Newseek)
- Early modern era -darkness was still notmal
- With electrification, abolition of darkness began to seem normal
- A blackout presupposes an electric grid that did not exist 1880-1940
- 1905 only 5% houses installed wiring. 1930 (90%)
- Momentum after 1895 with uniform standard
- Socio-technical system

1925 – wired house is

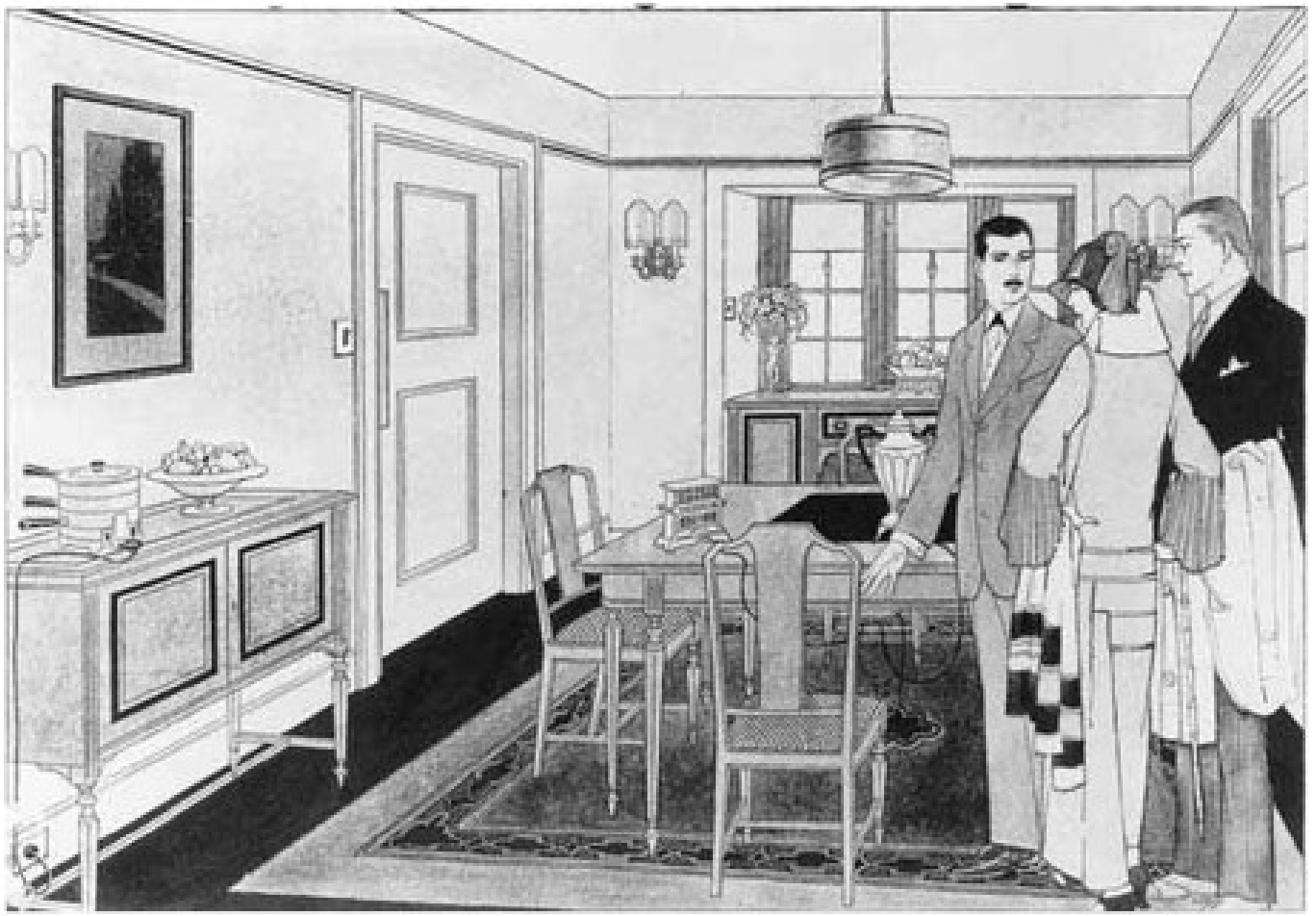


Figure 1.3

Illustration for booklet "Home of a Hundred Comforts" (March 1925). General Electric Corporation.

Two new social realities

- Interconnected world of the grid, encouraged linkages between technical system creating a network of networks
- As grid became the backbone of everyday life a latent social reality emerged: blackout
  - To invent the train is to invent train crash
  - To invent the plane is to invent plain crash

1898

- Chicago has 18 utility companies
- Insull persuaded Chicago factories and traction companies
- 37 MW, 7x London average
- Because of economies of scale, Chicago paid 2x less

Figure 1.4
"New American Homes," such as this one in Atlanta (July 1936), displayed the latest electrical appliances to an eager public. General Electric Corporation.

When Edison died

- 1931he died
- As a tribute President Hoover suggested lights be turned out at 19:00
- Utilities warned
- Just dimmed

Different models

- Till 1930 – largely priate monopolies
- Roosevelt made Federal dams – TVA (Tennessee Valley Authority)
- 1935 - Federal Power Act
- As electrification increased, networks extended
  - Power failures became less and less tolerable
- Rule of thumb (loss of load 1 day in 10 years)
- EPRI: Blackouts cost 100 billion $/year
- 1000$ local blackouts a year by squirrels

Blackout

- A random event, a cultural disruption
- Not only electricity systm, but the social construction of reality breaks down too
- "What's called the dominant culture will fade away as soon as the electricity goes off"
- "Electric light eliminates the night, air conditioning eliminates climate, and electric devices replace physical labor such as pumping water or grinding wheat into fl our. The col lective result of such technologies is that people lose their direct experience of the world."
- It erases direct knowledge of and contact with the environment

War

- Artificial darkness desirable
- 1910-1920: blackout used exclusively in show biz
- 1930s, it described intentional act of hiding illumination
  - "news blackout"
- 1935 Istanbul acted out an air attack – planes dropping flamin fuses
- 1937 – Tokyo – 5 day b/o

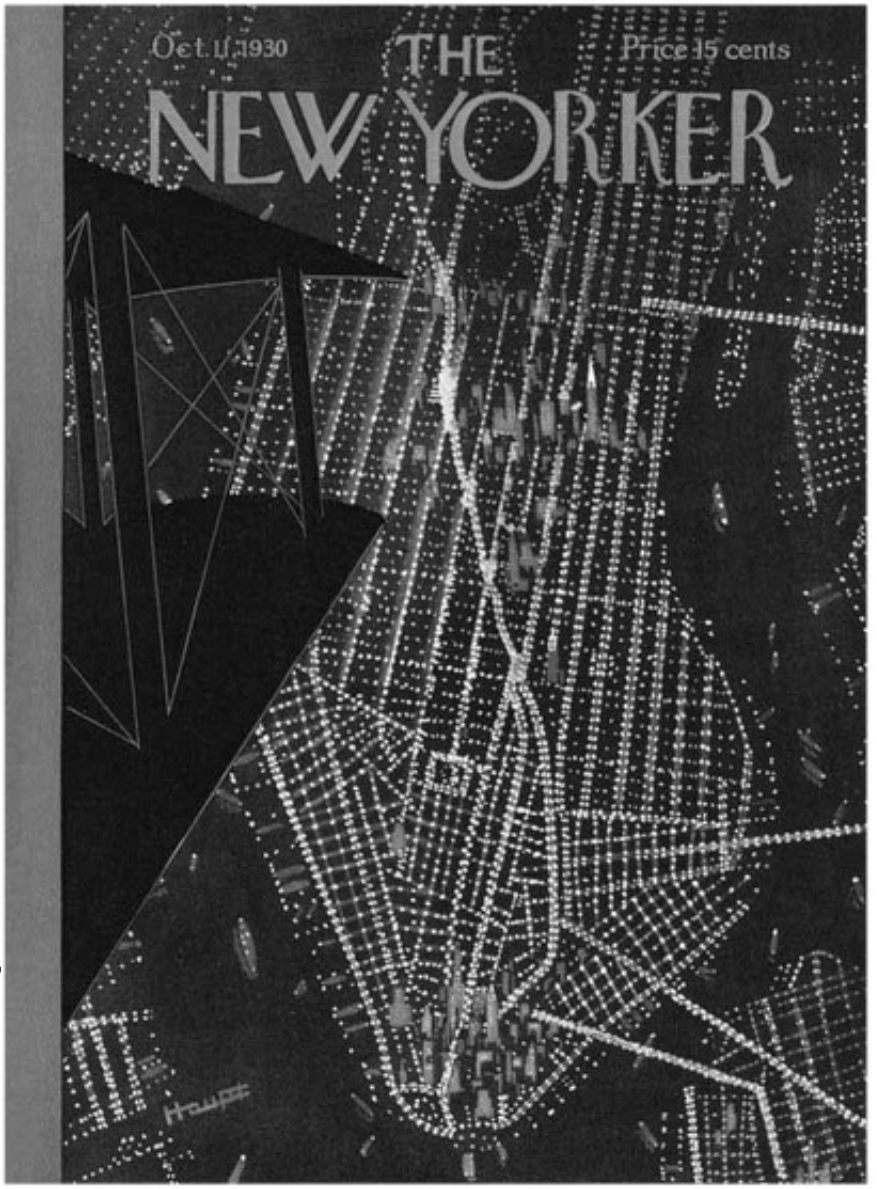


Figure 2.1
Cover of *The New Yorker*, October 11, 1930. Used by permission.

Blackout exercises

Figure 2.5

The New York skyline from across the Hudson River before and during a blackout trial in March of 1942. Library of Congress.

Brownout

- US enforced brownouts to save coal
- First used in Australia 1941, a form of rationing
  - Like War Production Board banned all daytime advertising
- April 1945 – as the end of war near lifting blackout restricitions did not immediately elicit lighting displays
- Before and after WWII labor conflicts
- Coal strike of 1946
  - During war a sort of comfort
  - During the brownout the city seemed melancholy

New metaphors

- After 1947, unexpected power outages-> blackouts
- No more power outage
- Electricity woven to metaphors
  - Human race horse (1820)
  - Human locomotive (1860)
  - Human dynamo (1920)
- Successfull people powerhouses
- Musicians gave "electrifying performances
- Bright idea -> bright bulb...
- A stupid person -> dim bulb
- Confused person -> wires crossed. Mental shortcut
- Tired person -> recharge his batteries

Nov 9, 1965

On November 9, 1965, Consolidated Edison was producing most of the 4,770 megawatts it required, importing only 220 MW from the north. Strictly speaking, it did not need any power from outside, as it had 1,350 MW in "spinning reserves." But the power from Niagara was an inexpensive way to meet the peak demand of late afternoon and early evening. When this power transmission was suddenly interrupted, it triggered a blackout that hit most of New York State at 5:27 p.m. The cause was a single improperly maintained circuit breaker on a Canadian high-tension line that was carrying power from Niagara Falls into Canada. The circuit breaker incorrectly responded to an increase in the load, acting as though the line was dangerously overloaded, although it was not. When it "tripped out," the energy on that line instantaneously shifted to four other lines, which then really were overloaded, and so they also tripped out.

Suddenly, a huge flow of power from Niagara Falls—1,800 MW—could not go north. Shifting south, it overwhelmed the transmission lines that served a string of cities across upstate New York—Buffalo, Rochester, Syracuse, Utica, Schenectady, Albany—then rushed down the Hudson River to New York City. The surge of power caused an automatic cascade that raced through these cities almost at the speed of light, shutting down all parts of the system in less than 4 seconds.[31] The disruption

Figure 3.2
Commuters stranded by the power failure settle down for a long wait on the steps of New York's Commodore Hotel, November 9, 1965. Associated Press.

Birth rate

couples became intimate in the gloom. They might not have been able to find contraceptives in the dark. Perhaps some people trapped with attractive strangers enjoyed one-night stands. On August 10, 1966, the *New York Times* ran a page-one story headlined "Births up 9 months after the blackout," but subsequent demographic analysis covering the years 1961–1966 found a normal birth rate for the day and the week in question.[53] The persistence of this story in popular memory testifies not to an increase in copulation, but to the sudden intimacy with strangers and the liminality of an event that in many ways felt like a gigantic party.

Experience

- Social divisions broke down
- In a blackout, the electrified city is juxtaposed with a darkened twin of itself. The city stripped of its power system has the same contours and occupies the same physical location as the electric city, but it is a different place, and it both looks and sounds different.
- Blackout: a violation of the expected order

Progress

- Each major city a noticable heat island (+5C)
- %2 more power for 1.8 C increase
- Smog increased 3% for every 1.8C above 20C
- Coal burned decreased %70 between 1920-1959
- Consumers paid 2x in 1975 than 1970 and 2x in 1980

1977

However, the 1977 blackout was not caused by energy shortages, even if they did provide a contextual frame for the event. Lightning initiated the outage, which could have been avoided if Consolidated Edison's circuit breakers and grounding system had been properly maintained.[36] When lightning struck two 345-kilovolt power lines, each should have been out of commission for only a few seconds. Instead, both went completely out of service, triggering a cascade of other malfunctions. Most seriously, the Indian Point nuclear power plant automatically shut down because there was no outlet for its generators. Even so, at first the system coped with the emergency by bringing in additional power from elsewhere on the grid. However, less than 20 minutes later lightning struck again and short-circuited two additional 345-kilovolt lines. Again circuit breakers failed to function properly, and Consolidated Edison's largest steam turbine ("Big Allis") automatically went off line. Investigators later conceded that being struck by lightning twice in rapid succession was bad luck, but the blackout occurred because equipment malfunctions put four major transmission lines and two major generating plants out of service. A huge overload stressed the system that remained. Almost exactly an hour after the first lightning strike, the entire city plunged into darkness.

Looting

New York was not dark during much of the 1977 "blackout," and the pillaging continued into the daylight hours. The word "blackout" had ceased to be closely related to light and darkness

Figure 4.2
An Associated Press photograph taken on Utica Avenue in Brooklyn after the 1977 looting.

But Berkowitz, the serial killer better known as Son of Sam, remained In his apartment

1980s

- Demand outstripped supply
- Public resisted building new Transmission lines & power plants
- New England 10 brownouts in 1988
- PURPA 1978
- A decade after -> 1/4 of inv by other entitites
- Energy Policy Act of 1992 -> companies exempt from utility reg

California and 2000s

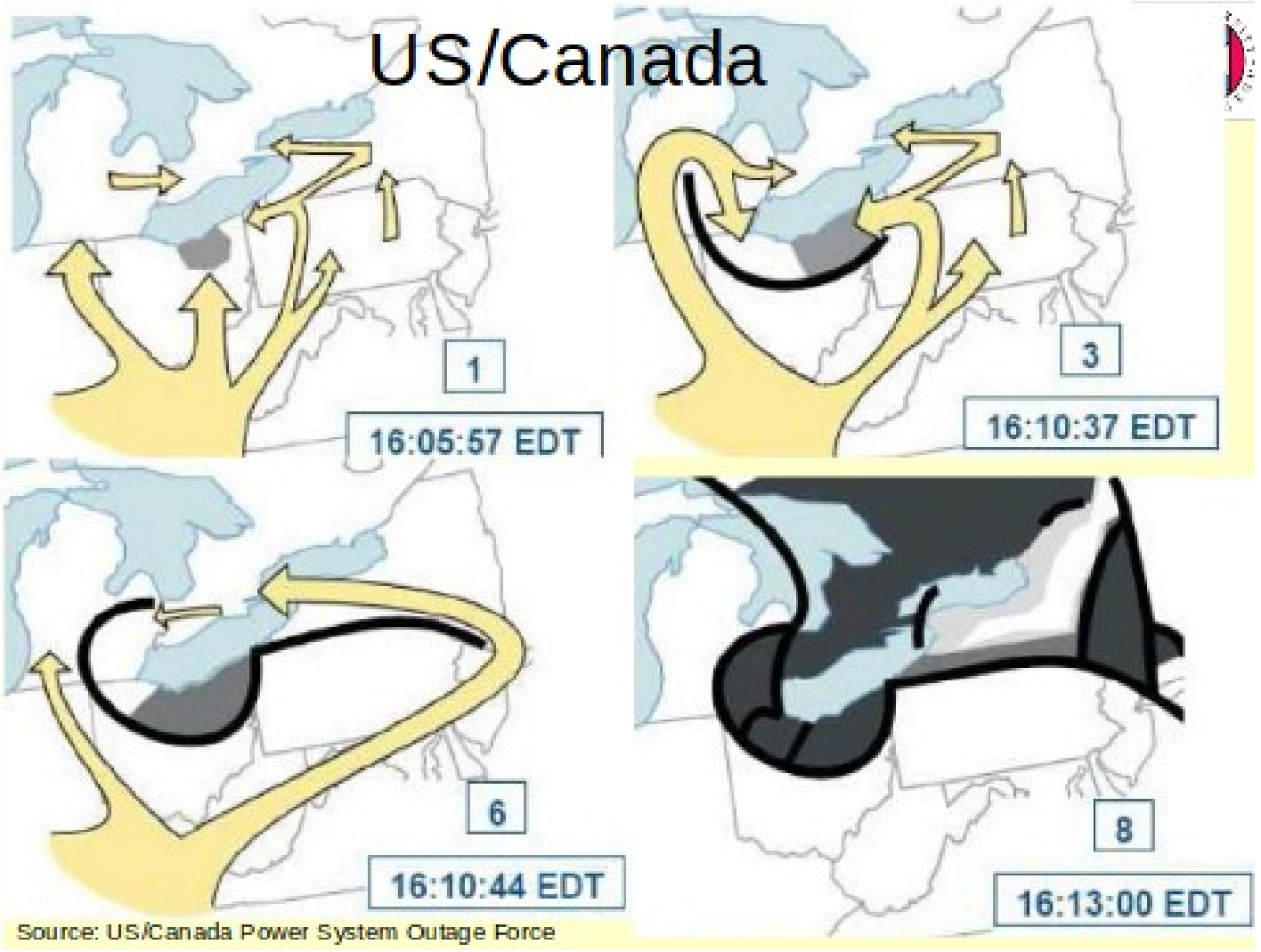
- Enron
- 150 days of 2001, 38 rolling blackouts
- US DOE : 1999-2004 : 125 "significant" blackouts
- Deregulation -> reduced costs (&maintanence)
- Insufficient transmission protected local markets
- 1975-2005 utilities reduced inv by 25%
- 2001 - > failed transmission & congestion: +800m$
- 2002 -> PJM 430 m$, NY ISO 525m$

August 14, 2003

Figure 6.1
People walk home across the Brooklyn Bridge, August 14, 2003. *Newsday Magazine*.

Figure 6.2
The Manhattan skyline at dusk during the blackout of August 14, 2003. *Newsday Magazine*.

Flow



https://www.eprg.group.cam.ac.uk/wp-content/uploads/2008/12/original-bialek-web.pdf

August 14, 2003

- Blackout-> Michigan and Ohio – Toronto – NYC
- First Energy neglected tree trimming in transmission corridors
- No effective accident contingency plans
- Coordination could not left to "the invisible hand"
  - US experiences blackout every 13 days
  - Same frequency of events for the last 30 years

Observations

- No compression of time and space anymore
- You'r left with the disvirtual reality of space
- "Without neon lights and electronics, space becomes what it has always been"
- Refineries, factories stopped
- A Steel factory suffered a fire : "unable to cool down molten iron before it burned through a furnace wall"
- Power loss 60000$/hour
- Without electricity no IT industry

1962 and the Soft bomb

- 1962 – Open air nuclear test Johnston Island (Pacific)
  - Thousand miles away at Hawai grid & radio stations broke down
  - Gamma rays of Electromagnetic Pulse (EMP)
- BLU-114/B
- A bomb to incapacitate electrical networks
- Used in Serbia, May 1999, blacked out %70 of country
- A small cloud of carbon graphite filaments

2003

- US-Canada blackout
- 2 weeks after London
- 4 weeks after Sweden-Denmark
- 1 week after Italy lost power
- 2005 Russia

Dilemma

- In making technologies more robust and interconnected
  - You increase grid's complexity, more vulnerable
- Large blackouts difficult to anticipate -> complexity
  - Makes grid fragile
- Small outages reduced
  - Blackouts as feedback loops (countering managerial)
- Critical loading point -> less resilience, any component failure
- Blackouts resemble earthquakes along and active fault line (like forest fires)

Terminology

- Outage used 1931, only in theaters "blackout" used
- 1945 darkness no longer seemed natural - > blackout
- 1950s artifical darkness an unintended, ephemeral return to pre electric era
- 1960s power outage->temporary loss of technical control
- 1977 NY blackout-> inseperable from a larger loss of political and social control
- Blackout a social and cultural disruption
- Earth hour – green outs

4 November 2006

Timeline

- 18 Sept: a shipyard request EON for a routine disconnection of double circuit 380 kV line Diele-Conneferde on 5 Nov
- EON, RWE TSO and TenneT approve provisionally
- (N-1) criterion security rule: a single incident (unexpected tripping of a line, transformer or a plant) should not jeopardise security
- 3 Nov: the shipyard request to bring forward the disconnection by 3 hours. Late announcement could not change exchange programs
- EON agrees provisionally but does not modify Day Ahead Congestion Forecast (DACF) distributed to all TSOs

https://www.eprg.group.cam.ac.uk/wp-content/uploads/2008/12/original-bialek-web.pdf

4 November 2006

- 7 pm: EON informs RWE and TenneT about new time for the line outage
- 9.30 pm: EON concludes empirically, without doing (N-1) analysis, that the outage would be secure. Post-mortem analysis showed that the system would not be (N-1) secure
- RWE does (N-1) analysis of its area which indicates high but secure loading
- 9.38: EON switches off of the line
- 9.39-41: warnings of high flows
- Protection settings on EON-RWE line were different but EON dispatchers did not know about it

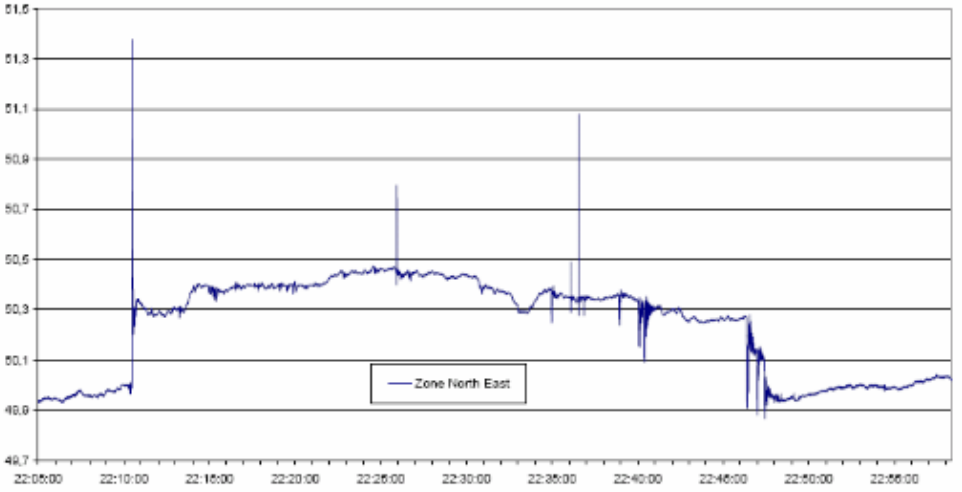
	E.ON Netz (Landesbergen)	RWE TSO (Wehrendorf)
Steady state value (thermal capacity of the line)	2 000 A	2000 A
Warning value (alarm)	1000 A and 2 000 A	1 795 A (90 % of the max. limit value)
Maximal accepted value	2 550 A (85% of Tripping current) for a max. time 1 hour.	1995 A (95 % of the tripping current
Tripping current	3 000 A	2 100 A

Table 1: Current limit values on the line Landesbergen-Wehrendorf

Source: UCTE

4 November 2006

- 10.07: increased load on the line triggers alarm in RWE who ring EON requesting action
- EON assess the situation empirically, without simulations, and decides to couple a busbar to reduce the current by 80 A
- Result: the current increases by 67 A and the line trips
- Cascading line tripping all over UCTE and separation into 3 regions with different frequencies



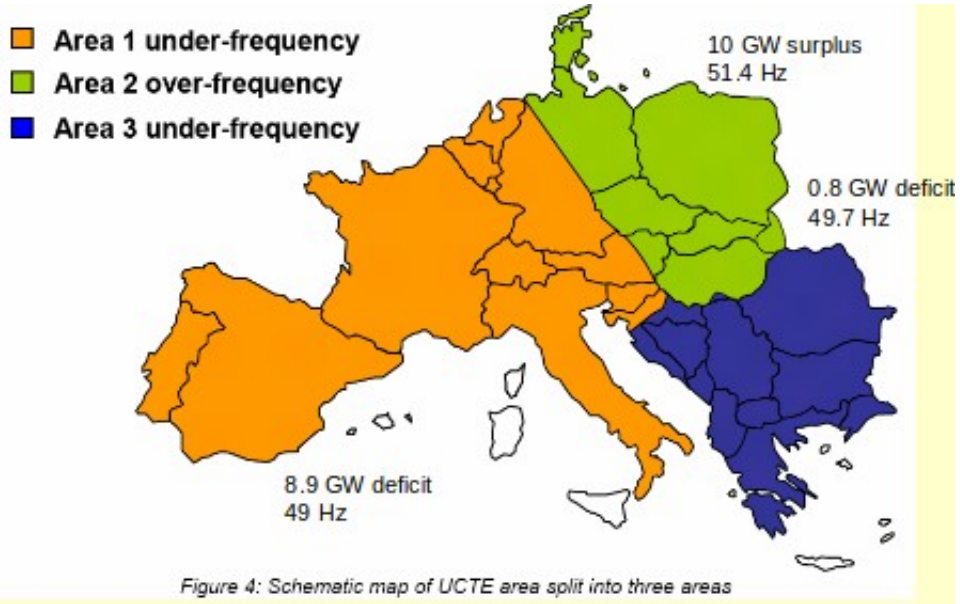
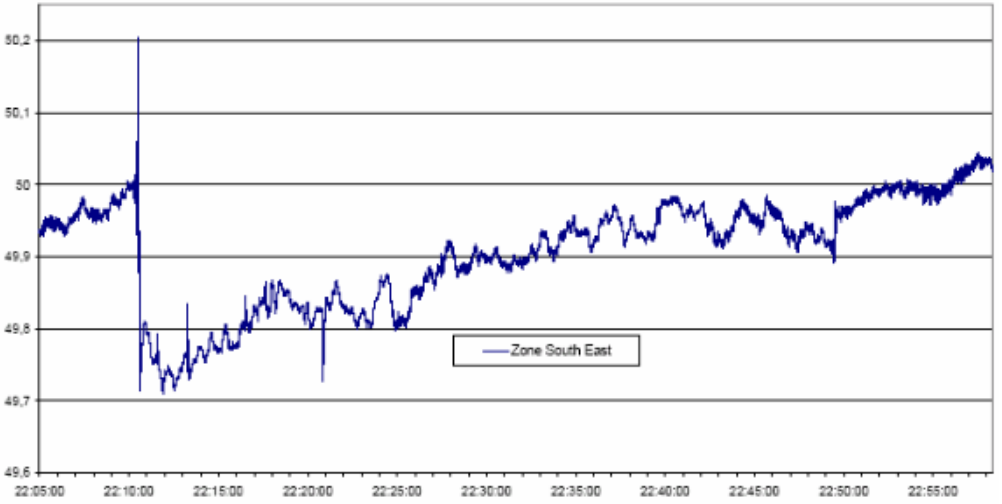


Figure 4: Schematic map of UCTE area split into three areas



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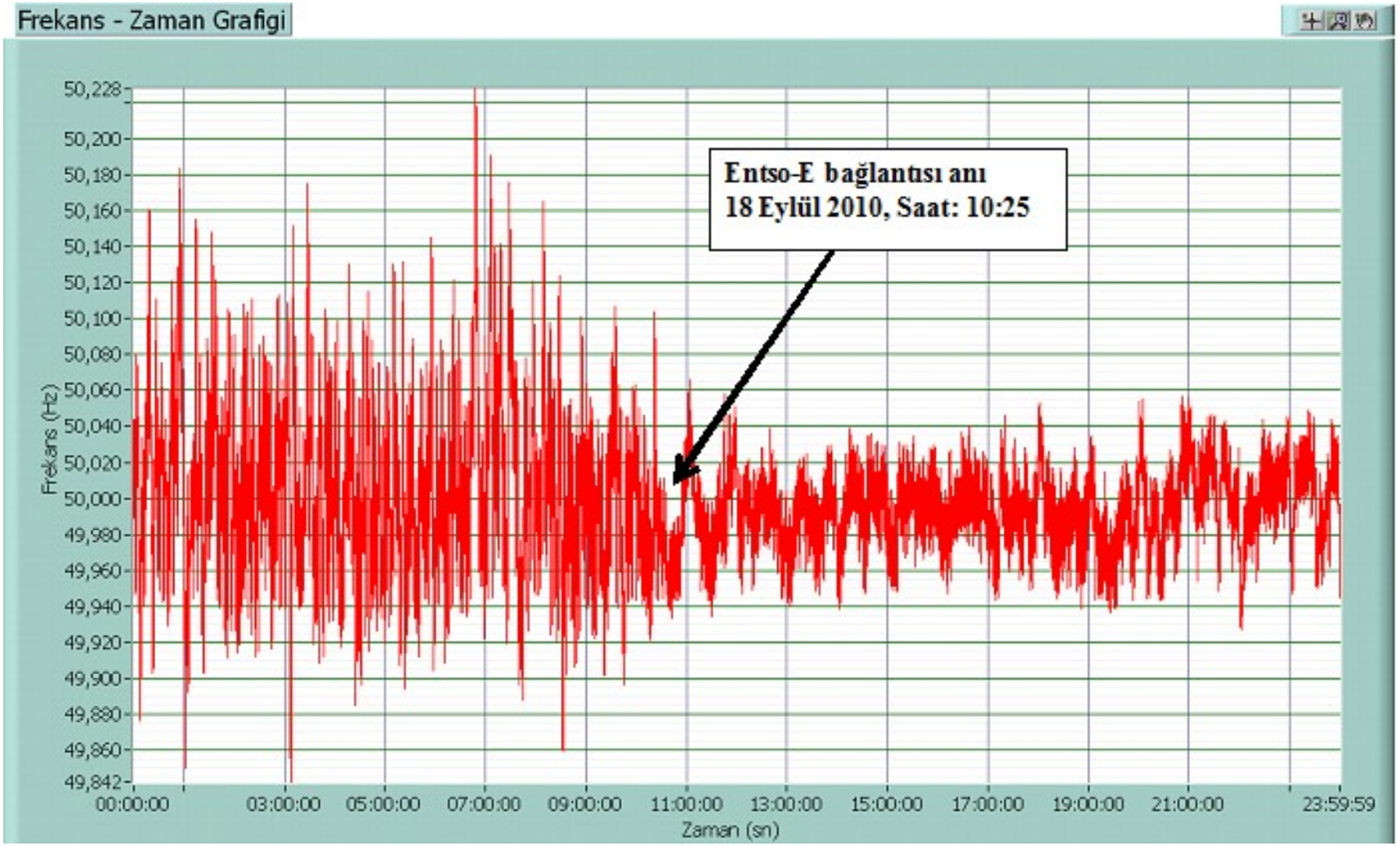
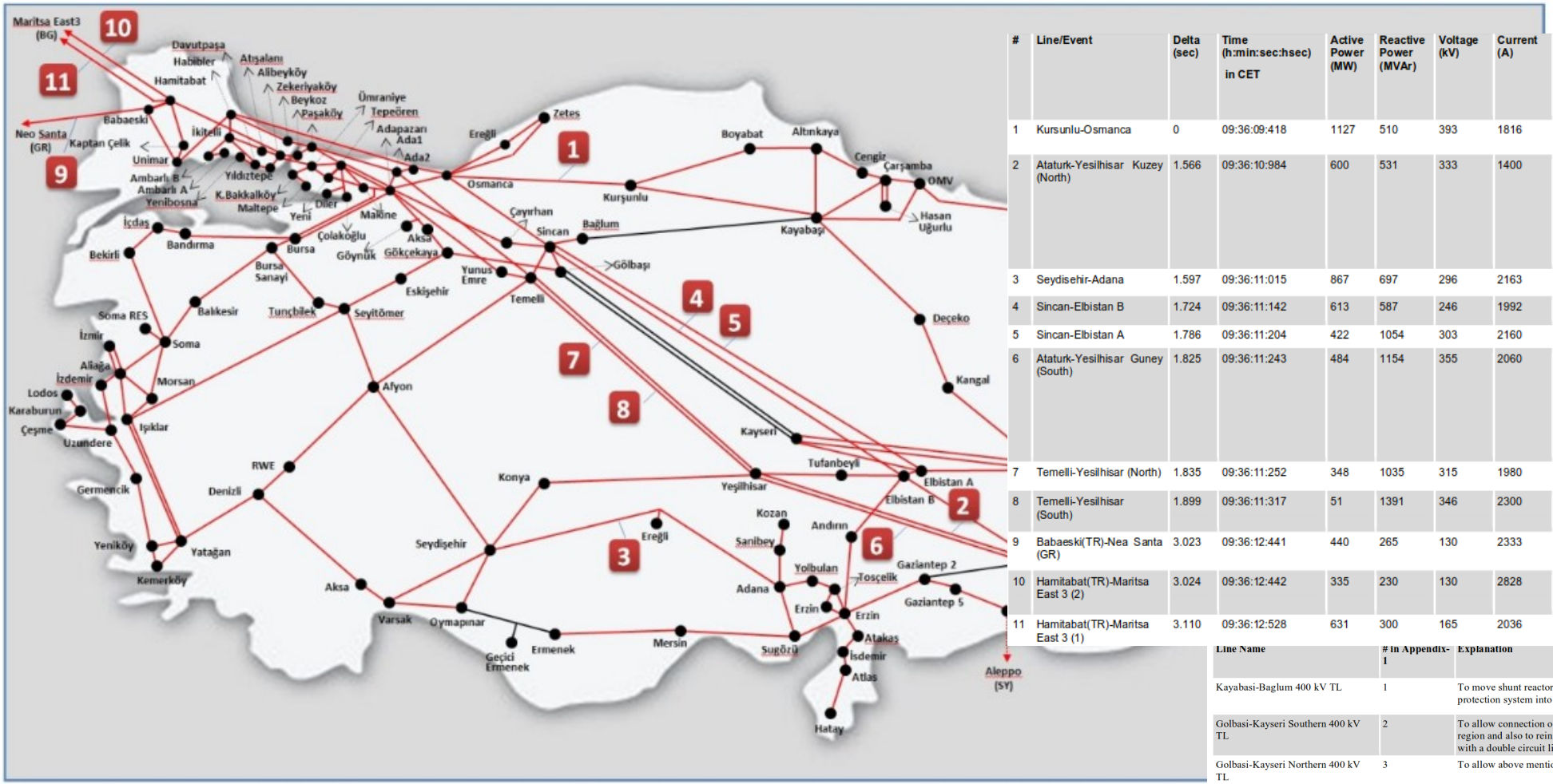
Entsoe Connection Moment



Dispatch Center

31 March 2015



#	Line/Event	Delta (sec)	Time (h:min:sec:hsec) in CET	Active Power (MW)	Reactive Power (MVAr)	Voltage (kV)	Current (A)	Comments
1	Kursunlu-Osmanca	0	09:36:09:418	1127	510	393	1816	Tripped
2	Ataturk-Yesilhisar Kuzey (North)	1.566	09:36:10:984	600	531	333	1400	Both Ataturk - Goksun SKM section and Goksun SKM - Yesilhisar sections of the Ataturk - Yesilhisar (North) TL open.
3	Seydisehir-Adana	1.597	09:36:11:015	867	697	296	2163	Tripped
4	Sincan-Elbistan B	1.724	09:36:11:142	613	587	246	1992	Tripped
5	Sincan-Elbistan A	1.786	09:36:11:204	422	1054	303	2160	Tripped
6	Ataturk-Yesilhisar Guney (South)	1.825	09:36:11:243	484	1154	355	2060	Both Ataturk - Goksun SKM section and Goksun SKM - Yesilhisar sections of the Ataturk - Yesilhisar (South) TL open.
7	Temelli-Yesilhisar (North)	1.835	09:36:11:252	348	1035	315	1980	Tripped
8	Temelli-Yesilhisar (South)	1.899	09:36:11:317	51	1391	346	2300	Tripped
9	Babaeski(TR)-Nea Santa (GR)	3.023	09:36:12:441	440	265	130	2333	Tripped
10	Hamitabat(TR)-Maritsa East 3 (2)	3.024	09:36:12:442	335	230	130	2828	Phase A opens at 9:36:12:267
11	Hamitabat(TR)-Maritsa East 3 (1)	3.110	09:36:12:528	631	300	165	2036	Tripped

Line Name	# in Appendix-1	Explanation
Kayabasi-Baglum 400 kV TL	1	To move shunt reactors and series capacitors protection system into a new building
Golbasi-Kayseri Southern 400 kV TL	2	To allow connection of new PPs in Anatolia region and also to reinforce the existing corridor with a double circuit line
Golbasi-Kayseri Northern 400 kV TL	3	To allow above mentioned work for safety reasons
Oymapinar-Ermenek 400 kV TL	4	Due to fault

https://docstore.entsoe.eu/Documents/SOC%20documents/Regional_Groups_Continental_Europe/20150921_Black_Out_Report_v10_w.pdf

Entsoe Report

Main Causes

1. The four 400 kV lines out of service in the critical central section of the East to West corridor line system (three for construction works of new assets; one for maintenance), the long transmission distance (1300 km from the remote Coruh river hydroelectric power plants (HPPs) of the North – East to the major load area of Istanbul), and the out of service of all the series capacitors resulted in a high East to West transfer impedance. In this grid situation, with high hydroelectric generation in the East and relatively high power transmission to the West, the system was not compliant with the (N-1) dynamic security criterion. The tripping on overload of the line with the highest load initiated angular instability and consequently system separation.
2. Prior to the blackout there was no adequate awareness about the importance of the series capacitors for angular stability of the system operation condition.
3. Although the Turkish 400 kV grid is equipped with a protection system that is in line with international standards, the effect of the distance relay settings on the line that tripped first was not correctly evaluated.
4. During the frequency decay transient after the separation of the Western subsystem from CE power system several large thermoelectric generators were disconnected at frequencies higher than the 47.5 Hz, which is in contradiction to the specification by the Turkish Grid Code.
5. Owing to the less than satisfactory recorded stability of several power plants during the severe electromechanical transient, a larger amount of load shedding by the underfrequency relays would have been needed to compensate the irregular early disconnection of generators.
6. Regardless from the system configuration and specific load flow prior to the March 31st events in the Turkish power system, the quite huge imbalance of respectively 21% and 41% between load and generation in the Western and Eastern Turkish power subsystems, remains a challenge which is hard to manage. Current protection schemes in use in these power systems are possibly not suitable for saving the system during such extreme imbalances.
7. The exceptional exceedingly large weakening of the East to West corridor line system, in particular in the Central – Northern section, and the effect of all the Series Capacitors (SC) banks out of service, have not been correctly evaluated for the 4700 MW to be transmitted from East to West on March 31st. TEIAS' latest load flow and angular stability calculation analyses have shown that the East to West transmissible power with all the 400 kV lines and SCs banks in service is up to about 8000 MW, in compliance with the (N-1) steady state and dynamic security criteria specified by ENTSO-E for the CE system.

Questions