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AN ACT OF GOD

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William "Bill" Jurith, System Operator, reached for the ringing telephone on the console in Consolidated Edison's Power Control Center at the corner of West End Avenue and 65th Street in Manhattan. The caller was probably the System Operator at Orange and Rockland Utilities to the north. The displays on the control board in front of Bill were giving off the telltale signs of a problem with one of the main electric feeder lines coming into the city; the lights had begun flashing just moments before. Bill was acutely aware of his direct responsibility for delivering electricity to the occupants of New York City on that muggy evening in July. His job was to juggle the supply of electricity with power consumption, and any disruption in the flow from the north was of concern. After all, there were only a handful of high-capacity ties to the island. The loss of even one was important.

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Bill, 56 years of age, commuted into the city each work day from his pleasant, green ^{2 fl.}two-story house in Brooklyn where he and his wife raised their family. He took the job of System Operator about three years before when he accepted the promotion from his previous position as Power Dispatcher. Like many other senior operators in electric utility companies, Bill was chosen for his new job primarily because he had amassed considerable experience with the complex electric network during his years of service to the company. True, the new job was considerably more challenging and he had undergone treatment for a mild case of hypertension since starting, but the condition had not interfered with his performance during the normal work day.

But due to circumstances beyond his control, this was not going to be a normal shift in any sense of the word. Bill would soon find his skill, knowledge, and demeanor tested as never before. His actions at his console during the next hour would affect the lives of over eight million people in the City of New York.



Bill put the receiver to his ear. The operator from the utility got right to the point: "Severage."

Bill responded in the laconic vernacular used by utility technicians, technicians who work with each other day in and day out. He asked him if the feeder line, line Y88, had "opened" (stopped carrying power) as his control panel suggested: "Yeah, Y88 opened up?"¹

¹This dialogue, like all of the dialogue in this story, is taken from an actual tape recording of telephone conversations made the night of this event. Only selected conversations have been used in this story due to the length of the actual transcript.

"Well, this is what I am assuming," the operator replied. "I haven't heard a thing. I was just trying to get a hold of him before I called you to confirm the thing was off." The operator was talking about yet another operator in a distant facility who would know something about the status of the important power line.

Bill looked at his panel for the Y88 line and saw that the big circuit breakers up north had stopped transmitting power to New York City. "I see the breakers are opened up there." An "open" breaker meant that the circuit had been disconnected and electricity was not flowing.

The utility operator was obviously looking at his own control board as well: "Yeah, OK." They both hung up. It was a typically brief conversation.



One minute later at 8:38 p.m., less that two minutes after the "opening" of the Y88 line, Bill was into his third telephone conversation, this time with the Con Edison Westchester District Operator located in another control room next door. Bill learned that lightning was seen up north and that it might have hit the Y88 line.²

²What he did not know was that a severe lightning stroke hit two 345,000 volt (345-kV) lines called the W97 and W98. These two transmission lines ran together on the same tall towers, and the lightning bolt was sufficiently powerful to put both of them out of action. Four circuit breakers were triggered, as designed, but it resulted in the automatic shutdown of the Indian Point No. 3 nuclear plant located on the Hudson River some miles north. The nuclear plant, having no place to send its generated power, tripped off-line, thus reducing the electric flow toward New York City by 833 megawatts

Fortunately, redundancies and back-up systems made his job easier. For example, there were six major lines feeding New York City. Bill's primary responsibility was to maintain the supply of electricity to the city. If one of the six major feeder ties went out (by, say, a lightning stroke such as this), the remaining ties could take up the necessary load. Many of these recovery functions were provided by other technicians or automatic systems, but redistribution would require some quick action on Bill's part. The second action that had to be taken during a power loss was to increase in-city power generation, something for which Bill had direct responsibility.

But much of Bill's own time and energy during the next eight minutes was spent talking to other operators on the network about the distant power lines. His console was not up-to-date, and it did not present overall, supervisory information about the status of the sprawling system. He needed a global understanding of its condition in order to perform his job, and in this case he had to figure much of it out for himself. Even so, his conversations with other operators were very general and meandering, and he failed to learn anything of any real use for the task at hand.



(MW). The loss of the W97 and W98 lines also resulted in the isolation and loss of the Y88 Ladentown line, a 347-kV tie to the city. The combined loss to Con Edison was a whopping, but recoverable, 1,310 megawatts. The power flow over the five remaining ties to Manhattan increased to make up the loss of the power from the tripped lines and open tie. (The network power lines are referred to as "lines" and the six connections to the island of Manhattan are referred to as "ties" throughout this story.)

Eight minutes and eight telephone calls after the line failure up north, Bill's phone rang again. It was Bill Kennedy, the Senior Pool Dispatcher at the New York Power Pool in Guilderland, New York. Kennedy was calling to check up on Bill and to make sure he was increasing in-city generation.

Bill answered the phone and identified himself. "Yeah, Bill."

Kennedy was polite but direct. "You getting your turbines on -- eh, Willie?"

"Yes."

"Yeah, OK, fine..." Kennedy eased out of the conversation and left Bill alone to carry out his important work.

Within a minute, Bill sent out a request for reserve in-city generation to help replace the loss caused by the lightning stroke. This required the stations within the city to increase their output immediately and to provide some level of reserve in the unlikely event of another transmission failure. It was something Bill should have done eight minutes before, but he was busy on the telephone. He also was not fully aware of the magnitude of the power line outages up north.

At 8:50 p.m. Bill believed he had taken the appropriate steps to address the problem, albeit somewhat slowly. The load on the major ties leading into New York City had been increased. Also, the in-city generating capacity was on the rise. The situation was disconcerting, but certainly still manageable as the top of the hour approached.³

³Bill was not aware of the precarious state of the entire system. First, the power output from four of the five in-city steam plants was coming on much more slowly than planned. Like Bill's request to increase power, the response of the in-city generating stations was very slow, and only one, the Arthur Kill Steam Station, was actually generating as much power as required. Second, the energy combustion turbines stationed throughout Manhattan were not being started as quickly as needed. One group of turbines was even out of service due to



Fate struck again at 8:56. A powerful bolt of lightning hit a tower supporting a major connecting line upstate, putting two 345-kV lines out of service. This loss, in turn, resulted in the isolation of another northwestern tie to Con Edison, the 1,044 MW Y94 Ramapo tie. When it failed, a resulting power surge caused the W81 line leading down from the north to trip out as well. All of these line losses meant that two of the six ties feeding power to New York City were now out of commission. The four remaining ties were overloading as they took up the slack to meet the power demands of the city. There was still hope of recovery, however, but it required that Bill increase in-city generation, balance the load of imported power over the four remaining ties, and institute a reduction in power supplied to the city.

But due to the sketchy information presented on his control panel and, perhaps, to his predisposition and hesitancy, Bill failed to understand that two of his major ties to the city were out of action. Specific transmission-circuit in-service status was not displayed explicitly on his panel, and it was up to him to decipher the power flow data and determine which, if any, lines were down. Unfortunately, his conclusion that it was sufficient to spend his time continuing to talk with other operators about the status of various lines was entirely incorrect. He had to act on maintenance work, something that should have been reported to Bill long before. In all, the in-city generating stations were providing 341 MW less than they, in combination, told the control center they could produce. Third, and perhaps most importantly, Bill did not understand the status of the entire network and its current vulnerability. His control panel consisted mostly of hundreds of independent displays, each associated with an important network component.



in order to avoid a possible series of line losses, line losses that could rapidly escalate into a system-wide failure.⁴

His 13th call in 18 minutes was from Kennedy, the Senior Pool Dispatcher at the New York Power Pool. It was the third time Bill talked to Kennedy that evening.

Bill responded "Yeah" when he picked up the receiver.

Kennedy warned him that he was in danger of losing even another tie if he failed to increase the city's own generation, lighten the load, and get power from somewhere else. "Bill, you'd better get that Linden back or you'll lose that baby too." Linden was one of the important ties into the city. Kennedy was telling him that he had better lower the load on the Linden/Goethals line or it would blow. The Linden tie brought power in from the west, down below Manhattan, across Staten Island, over to Long Island, and then back westward to New York City.

"Yeah, I just lost 81." Bill was referring to one of the lines up north that he lost moments before.

"Yeah."

"Yeah," responded Bill.

"You lost the Jamaica tie, too," continued Kennedy.

"Which Jamaica tie?"

"Ah, Jamaica Valley Stream," said Kennedy. Another tie into Manhattan had ceased transmitting, but only temporarily. This was the first Bill had heard of it.

⁴The control board for the Westchester District Operator, located in the room next to his, had a more modern graphic display of the network. Lights flashed and a siren sounded, telling the operator that the ties to New York City had failed. But this was of no use to Bill, as he could not see the lights or hear the alarm from his control room.

"Oh, that could be. Alright, but, ah, help me out with the 81/80 feeder, huh?"

The situation had been mildly stressful since it began 25 minutes before, and he knew he had been a little slow getting in-city generation up. But this was the first time Bill let anyone else know that he might be in over his head. The demands on him had increased considerably during the past minute, and his request for assistance from someone who was not necessarily in a position to help him was the first outward sign of the difficulties he faced.

"Yeah," said Kennedy.

"Right," responded Bill, prior to hanging up the receiver.



Bill's phone rang again less than a minute later. It was Kennedy again.

"Bill, you better shed some load until you get down below this thing because I can't pick anything up except from the north, see?"

"Yeah."

Kennedy continued. "So you'd better get -- do something to get rid of that until you get yourself straightened out."

"I'm trying, I'm trying," he snapped back.

Bill fielded two additional telephone calls during the next 60 seconds -- one from a system operator at the Long Island Light Company and another from the Con Edison District Operator at Brooklyn and Queens. Meanwhile, the lines serving the ties to New York City began to shut down from overloads, like a long line of teetering dominos. The load on the remaining lines increased with each successive failure. All the while, Bill presumed that his major tie to the north, the one lost during the second lightning strike, was still available. He continued

spending much of his time talking to other operators on the telephone.⁵



The phone rang at 8:58. It was Kennedy.

"Bill, I hate to bother you but you better shed about 400 MW of load or you're gonna lose everything down there." Kennedy's tone of voice had changed from their last exchange. He was slightly sarcastic and much more direct.

Bill said the first thing that came to mind. "Yeah, I'm trying to."

"You're trying!" Kennedy popped back. "All you got to do is hit the button there and shed it and then you worry about it afterwards, but you got to do something or they're going to open up that Linden tie on you." The big Linden tie was one of Bill's hopes for getting out of this mess. It too was becoming severely overloaded, and it was usually preferable to have a controlled shutdown of a line rather than let it blow by itself.

"Yeah, right, right," said Bill.



Two minutes later they were on the phone again. This time Bill called Kennedy, signaling a change in circumstances and Bill's renewed awareness of the growing severity of the

⁵During none of the 16 telephone conversations since the first lightning stroke had anyone explicitly told Bill that his main northern tie, the second one to go, was out of service. If he had known this, he could have flipped a switch on his panel to reset a breaker. This would have restored power over this major tie to the city.

situation. It was a call for help.⁶

There was a strange urgency to Bill's plea. "Does it look any better?"

Kennedy's response was immediate and direct. "No, you still got to get rid of about 400, Bill, because you've got - - you're 400 over the short-time emergency on that 80 line."

"Yeah, that's what I'm saying. Can you help me out with that?" Bill was asking for some help with that northern line that he mistakenly believed was in service.

Kennedy's response was harsh. "I can't do nothing because it's got to come from the lower part of the state and there's nothing there to help you with. You got to do it...."

Kennedy's words were downright unfathomable. Perhaps he didn't have all of the facts. Bill shot back: "I got no GT (Gas Turbines) to put on 'cause they went home." Bill was referring to the slow start-up of the in-city gas turbine generators due to the slowness of his own actions, the unannounced maintenance work, and the generally slow response time.

Kennedy laid it all on the line for Bill. "OK, then you're gonna have to shed load, because that's the only way that thing's

⁶Bill was still under the impression that the big feeder line up north, the Ramapo tie, was available to route power down to him. It alone had more than enough capacity to carry the load from the New York Power Pool down to Con Edison's system. All he had to do (in his own mind) was get the Pool Dispatcher to reroute the load down to the available tie. But without explicit information, together with the continued diversions on the telephone, it never occurred to Bill that the line was out of commission. Furthermore, Bill was never explicit in his request. At the same time, it had not occurred to the Senior Pool Dispatcher that Bill didn't know that this line was unavailable. It was such a fundamental part of the whole problem. Bill and the dispatchers just talked around the problem, and Kennedy never really answered Bill's question. Instead, he continued telling him what to do.

gonna save you."

"Yeah," acquiesced Bill.

"So you get those.... things on," he said, referring to the Gas Turbines.

Yeah, right," responded Bill.

"I told Long Island to pick up everything that he has. That's the only place I can get into you."

"Anything you can do to help?" pleaded Bill again. It was as if he had not heard a thing Kennedy had just said.

"There's no way I can help you, see. OK, Will?" shouted Kennedy as they cut off.



It was now 9:04 and the situation was deteriorating rapidly. Yet Bill, overwhelmed with his predicament, took no action to shed load within the city, and continued to talk about the tie losses with various operators in the network. In the span of just under 30 minutes, the power grid supplying New York City had gone from a functioning state to the brink of total collapse. One of Bill's last remaining ties to the outside world, known as Feeder 80, was drastically overloaded, and he called the Westchester Emergency Supervisor to talk about cutting out the 80 line. The facility was not fully staffed at that late hour, so Bill and the Emergency Supervisor decided that Bill could cut out Feeder 80 himself from his control room if that is what he wanted to do.

But before he made the final decision, Bill called Kennedy once again. He got right to the point. It was now 9:05.

"I'm going to cut Feeder 80. I have no way of deloading it right now. I'm gonna cut it out."

Kennedy was equally direct. "Can't you shed load and

relieve it? If you cut Feeder 80, then you'll really be in trouble!"

Bill reconsidered. "Ah, I'll see what I can do."

Bill's options were diminishing each minute he failed to act. He had four principal problems. First, it was still not entirely clear to him that two of the six lines to the city - - both of the lines from the northwest - - were out of commission. Second, he wasn't getting any help from the north or northwest (for reasons he did not fully understand), and, based on what Kennedy had to say, he couldn't expect any. Third, his Feeder 80 tie was seriously overloaded. If he cut that link, the loads on the other ties would increase even more. Fourth, his in-city generators were still painfully slow making up for the loss of imported power.

At 9:08 he could think of just one thing to do: call his boss at home. He was Charlie Durkin, Con Ed's Chief System Operator.



Bill introduced himself as Charlie picked up the receiver at home. "Hello, Bill."

"Hi ya, Bill," responded Charlie. Charlie was sitting at home under the light of a kerosene lamp. He had lost power to his neighborhood some minutes before, so he had some forewarning of Bill's problems, but certainly no awareness of their magnitude. "You got some problems, huh?"

Bill gave Charlie a hurried but rambling run down of his "problems." It was a frantic summation. "Yeah, Charlie. Just one moment, huh. I got - - I lost Y88 and W98, and it looks like W97 is alive back on one breaker from Millwood. Indian Point - - then I got overload, and I got 81 taken down, but it must have been struck by lightning - - because 81 went out. I'm overloaded on 80 by 1,430 megawatts. I'm trying to get everybody back up but I have no GT's. I had....."

"One thousand four hundred thirty MWs on 80?" exclaimed Charlie.

Bill could depend on old Charlie. He was a young, bright engineer and had an expansive understanding of the system. Not surprising, within a minute Charlie had deduced that the big Ramapo Y94 tie from the northwest was out of commission. This was the first time anyone had communicated this directly to Bill. He had not determined it himself before due to the sketchy information on his control board, his knowledge of the system, and his own powers of deduction under the severe stress.

The hour was getting late, but Bill spent all of the next ten minutes bringing Charlie further up to date on the worsening situation. It was difficult to think clearly under all of the pressures. Bill's comments were confused and segmented. At first he told Charlie that he wanted to sever the 80 line because it was overloaded, but, as Kennedy had said earlier, this would only compound the problem by increasing the demand on the remaining ties and in-city generation stations. Bill listened as Charlie told him that cutting the 80 tie would only make matters worse. Charlie made it clear that Bill had to reduce the electric load within the city. At 9:09 Charlie started to tell Bill to go into voltage reduction, but then Bill interrupted him.

"You either go into voltage..."

Bill broke in in a panicky voice. "And the Linden tie is way up there. I had to back off, because he was up to 900 MW; the guys down there are about 500."

Things were spiraling out of control.



They continued to discuss line loading until 9:13, at which time Bill finally admitted for the first time that they had no alternative but to reduce power output. "We've got to get more

off; we're going to have to go into voltage reduction."

Charlie agreed wholeheartedly, and Bill began to operate the panel in order to reduce voltage five percent. It took him five long minutes.⁷

At 9:17 Charlie told Bill that the five percent voltage reduction was obviously not enough. He would have to go to eight percent reduction. Bill began to initiate these changes on his panel, but it was a slow and tedious process.

At 9:19 there was another line failure up north. This time a 345-kV line, extremely overloaded for the past 23 minutes and stretching low toward the ground, tripped out when it contacted a tree. It had been supplying 1,202 MW to the ties leading to New York City. The four remaining ties to Manhattan were importing 1,900 MW of the load that was not being supplied by in-city generating plants. One of the lines, the Linden/Goethals tie, was now carrying a load of 980 MW, well above its rated load of 505 MW.

A few tenths of a second later, one of the remaining ties from the northeast tripped out from the overload (the Pleasant Valley 345-kV 80/81), leaving three main ties to carry the power into the city. As before, each remaining tie was loaded with the current that was previously carried by the lost tie. The Linden/Goethals tie was now transmitting 1,090 MW, more than double its normal rating; the Jamaica/Valley Stream tie from Long Island was up to 310 MW, above its normal rating but below its emergency rating; and the last tie from New England was carrying 340 MW, well above its emergency rating of 250

⁷While Bill was on the telephone with his boss, Bill Kennedy, the NYPP Senior Pool Dispatcher, was trying frantically to contact him to coordinate corrective actions. The situation was still salvageable, but it required close coordination and load shedding within the city. But he could not get through because Bill was still on the telephone.

MW.

At 9:22 the operator at the Long Island Lighting Company, unable to contact Bill, manually cut out the Jamaica/Valley Stream tie to Manhattan after it reached a dangerous load of 520 MW. It was a prudent move, for the Long Island power system was in danger of being pulled down with the Con Edison system. But this left only two of the original six ties to New York City.

The whole thing had avalanched beyond belief. Each failure led to two others, and each of these led to two others in turn. The entire system was crashing down. They had no choice but to start cutting off sections of the city that still had power. Charlie instructed Bill to begin the procedure, but Bill hesitated, as if he did not know what to do. He had rehearsed the operation years before and knew the procedure in the manual, yet under the stress of the moment it all seemed so confusing. Accordingly, Charlie tried to step Bill through the task over the telephone. It wasn't all that difficult.

All Bill had to do was activate the system and press the "Area Trip" pushbutton for a given station. But when he reached for the selector dial to start the process, Bill turned it the wrong direction - - toward the "Frequency Control" position rather than to the "Trip/Reclose" position! The "Frequency Control" position was a relatively unrelated function, yet it was controlled by the same dial.⁸

Bill then proceeded to press the "area trip" buttons for the various stations, but nothing happened.

"It won't trip the son of a gun..." he pleaded to Charlie through the telephone.

⁸This analysis is based on information provided on page 33 of The Con Edison power failure of July 13 and 14, 1977, final staff report (June 1978). U.S. Department of Energy, Federal Energy Regulatory Commission.

Charlie kept encouraging him. "Just keep going. Give it a shot -- if it won't go, go on to the next one."

"What the..."



With the power demands vastly exceeding supply and Bill unable to black out sections of the city to relieve the electric demand, the loads on the two remaining ties to Manhattan continued to mount. At 9:29 the Linden/Goethals tie, now carrying 1,150 MW of power to Con Edison, failed. At that point the total generating deficiency of 1,680 MW was placed on the remaining ties from Pleasant Valley. They tripped out immediately. Manhattan was now isolated from the outside power grid.

Bill was unable to shed load from his panel because the selector switch was in the wrong position ("Frequency Control" instead of "Trip/Reclose"), and the regional in-city generating stations were unable to meet the power demands of Manhattan. At 9:36 p.m. the Con Edison electric system collapsed and Manhattan plunged into total darkness. Power would not be restored for 25 hours. The unequalled failure was, in the words of one Con Edison official who spoke to the press the next day, due to "an act of God."

EPILOGUE

The U.S. Department of Energy's Federal Energy Regulation Commission's investigation into the calamity concluded that "The single most important cause of the July 13, 1977 power failure was the failure of the system operator to take necessary action. The Con Edison system could have survived the lightning-induced line outages, the loss of the Indian Point No. 3

generator, and the equipment malfunctions that extended the impact of these events. It could not have survived these events, however, without either some load shedding or prompt increase in in-city generation. The system operator, the only person authorized and able to take these actions, did not call for increased in-city generation at the proper time and did not initiate manual load shedding until too late, although repeatedly advised or directed to do so and even when that action became the last hope of averting a major interruption." In addition to making extensive recommendations regarding lightning protection and transmission system design, the Commission made numerous recommendations pertaining to the design of the control room, automated decision-aiding systems, communication, training, and selection of operators. Con Edison implemented most of these recommendations, as well as the recommendations made by internal investigators, the City of New York, and the State of New York.

REFERENCES AND NOTES

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- Boffey, P. M. (1978). Investigators agree N.Y. blackout of 1977 could have been avoided. *Science*, 201, September 15, 994-998.