(Harry Goldstein)

HOW TO BLACKOUT-PROOF A CITY

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The squeals of children at play slice through the thrum of cars and powered rickshaws motoring by a high rise apartment complex in Khar, a neighborhood of narrow, tree-lined lanes in west central Mumbai, the city formerly known as Bombay. This pulsating island of 18.2 million, the most populous city in India, is the economic engine that is propelling the country into the ranks of the developed world.

The cacophony of traffic noises, construction clatter, and cawing crows filters into the spacious one-bedroom apartment I'm staying in, where the clamor from the street melds with the sounds of modern electrical conveniences: the humming refrigerator, the shushing ceiling fan, the burbling water heater, the droning air conditioner, and the howling espresso machine.

A THICKET of tangled wires brings electricity to shops at Crawford Market in Mumbai.

I crank up the volume on the cable-connected TV to hear the BBC anchor report the day's headlines. Three new luxury condominium complexes are going up where a slum used to be. Many such developments are ringed by tarp-covered shacks and ramshackle low-rise concrete boxes of the sort that house half the city's citizens, making Mumbai home to one of the world's largest slum populations. In mid-2006, former slum dwellers in this particular neighborhood—many of whom provide the surrounding middle-class households with essential services such as garbage removal and delivery of newspapers, as well as bread, fruits, and vegetables—were moved into an unfinished apartment building, positioned cheek by jowl with the flashy new condos.

The recently relocated slum dwellers might not have glass in their window frames, but they have lights and televisions. They are by no means uniquely privileged among Mumbai's poor, nor is the cost of power generally out of reach even for the less-well-off inhabitants of the city. At as little as 2 rupees (less than 5 U.S. cents) per kilowatt-hour, Mumbaikars are not shy about using electricity. At dusk, a few kilometers farther east and south in Dharavi, the largest slum in Asia, with about 1 million residents, cramped one-room apartments glow with electric light, and TVs flicker blue through open windows.

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Readily available, affordable, and reliable power is the basis for any modern city. With it, you have the signature bright lights of Times Square in New York City and the psychedelic neon orgy of the Shibuya district in Tokyo. Without it, you get Lagos and a choking haze of diesel fumes spewed by thousands of generators, dirty and expensive substitutes for grid- connected electricity. Visitors often compare Mumbai not with Lagos but with New York City. One big reason is that Mumbai enjoys dependable electricity and always has, ever since Mumbai-based Tata Power Co.'s first hydroelectric stations started pumping electricity to the city's textile mills in 1914.

It seems like a cruel joke, then, that just as India is poised to become an economic superpower, the utilities in the country's showcase city have launched their own public-service campaign urging Mumbaikars to conserve energy or face extensive planned outages this summer for the first time ever. A blackout that knocked out power in the northern half of the city this past February further illustrates Mumbai's precarious situation.

"The load is rising a lot faster than anybody realizes," says Gerry F. Grove-White, Tata's executive director and chief operating officer. "I look out my flat and every tower crane I see, I see increased load," he says over the loud rasp of his office air conditioner. "And the investment in generation has not kept pace. Last year we scraped by. This year the jury is out when summer comes."

Everyone who has access to electricity in Mumbai—up to 95 percent of the population according to the utilities—has it 24 hours a day, every day of the year. "The reliability of power is so good in Mumbai that it is not an exaggeration to say that most of the people don't keep any torches or even candles for emergencies," says Dilip A. Sathe, general manager of Tata.

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No one else in India is so fortunate. Last January, total peak demand for power in the country exceeded supply by 15 540 megawatts. Planned load shedding is common, especially in rural areas, although cities, including the megacities of Delhi and Kolkata, are not immune: utilities cut power to customers for hours at a time to balance load and generation capacities and in so doing keep the generators turning between 48.5 and 50 hertz, the frequency specification of the Indian electric system.

Five major grids—located in the north, east, northeast, west, and south—serve India. Except for the southern grid, all the others, totaling more than 100 000 MW in generation capacity, are on a synchronous tie, meaning that they are interconnected and share a common system frequency. Maharashtra state, of which Mumbai is the capital, is part of the western grid, which also includes the states of Gujarat, Madhya Pradesh, Chattisgarh, and Goa, an area of 11 million square kilometers with an installed capacity of around 47 000 MW.

Because Mumbai is connected to the western grid and receives some electricity to meet peak demand from the Maharashtra State Electricity Transmission Co., the city's load directly affects conditions elsewhere in the state. Mumbai's peak load of about 2600 MW now substantially exceeds local generation capacity, which is only 2277 MW. Tata provides 1777 MW to its direct customers, which include the commuter railway and heavy industry and whose peak load is about 500 MW. Tata also supplies the Brihanmumbai Electric Supply & Transport Undertaking (BEST), a public company that runs the city's bus system and that distributes power to the southern portion of Mumbai. BEST's customers' peak load is about 800 MW. Reliance Energy, Mumbai's other major utility, which supplies the northern half of the city, also buys electricity from Tata to supplement its own 500 MW of generation and meet its customers' peak load of 1300 MW. To make up the shortfall, Tata often purchases power from the state of Maharashtra, for which the company pays an annual standby fee of $94 million on top of the actual cost of the electricity it imports.

Peak demand in Maharashtra, about 17 000 MW, exceeds generation capacity by about 5000 MW. That means planned load shedding goes on every day in parts of Maharashtra, where many rural areas have power for only 10 hours. Such privations are a fact of daily life that most Indians outside Mumbai have learned to live with and plan for, like the monsoons.

Increasing the availability, reliability, and quality of electricity is a long-term goal that will be met only with tens of

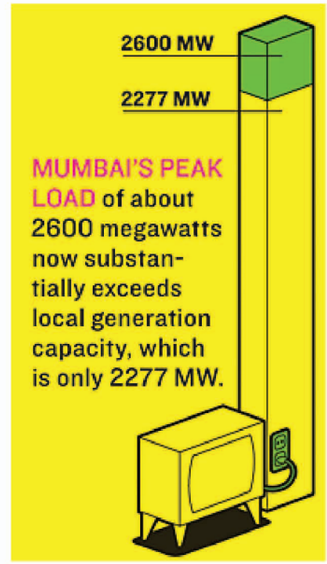

ILLUSTRATION: BRYAN CHRISTIE DESIGN
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thousands more megawatts of generation capacity. In the near term, administrators and engineers from both Mumbai power companies, Tata and Reliance, along with officials from the Maharashtra Electricity Regulatory Commission, are doing their best to stave off planned load shedding and avoid a catastrophic blackout that could cost the local economy billions of rupees.

Blackouts occur when load so far outstrips generation, either because of the loss of a generator or a major transmission line, that the frequency dips to 47.5 Hz. At that point, the generators automatically trip off and a blackout ensues. For example, on 25 February India's western grid went down, and the citizens of Maharashtra were without power for several hours.

But as always, Mumbai was mostly spared. Both Tata and Reliance invoked "islanding" schemes, whereby they take the city off the national grid and supply customers with power from their own local plants until the larger network comes back up. First deployed by Tata in the late 1960s, the separation happens only when the integrity of the system cannot be maintained despite automatic emergency load shedding. The islanding does not require centralized computer control. Instead, reverse-power and underfrequency relays sense that the system frequency has dipped to 47.6 Hz and independently trip -breakers on the six power lines that connect Tata and Reliance with the regional grid.

Most times the Tata and Reliance systems survive together as one island, but occasionally Reliance separates into an independent grid, as happened this past February. On that day, Tata generation was low due to the outage of a 500-MW coal-fired generator and a 150-MW gas turbine. According to K. Rajamani, chief consultant for Reliance, the utility had been importing electricity from Tata over tie lines with a capacity of 30 MW. That same day, a problem with a 400-kilovolt transmission line located near Mumbai destabilized the grid.

When system frequency dipped to 47.6 Hz, Tata and Reliance separated from the sinking western grid. Under normal conditions, power flows from Tata to Reliance over the interconnecting tie lines. But on 25 February, the problem with the western grid, coupled with generation deficiency in the Tata system, created a huge power swing that reversed the normal flow of electricity from Tata to Reliance.

The reverse-power condition fooled the load-shedding logic in Reliance's Supervisory Control And Data Acquisition (SCADA) system, which is based on importing power from Tata. As a result, the SCADA system did not initiate automatic load shedding, and the Reliance generators fed Tata loads. This led to a steep decline in frequency, which tripped the generators at Reliance's 500-MW plant at Dahanu and shut off power to about 1.7 million customers for 1 to 4 hours. Once Reliance's system began to fail, Tata became its own island within an island. Despite its lower-than-normal generating capacity, Tata managed to keep the lights on in the southern part of the city served by its customer BEST, the 14th time it has islanded successfully since the last citywide blackout in 1997.

Mumbai's dramatic increases in load over the past five years—averaging 5 percent annually—have strained the existing to the breaking point. Only a small part of that growth can be attributed to the influx of perhaps 1000 immigrants a day, most of whom are destined to sleep on the footpaths or seek

shelter in the slums. Some of the recent demand comes from new air conditioners and washing machines, purchases enabled by a robust national economy, which expanded at a rate of 8.5 percent last year. And then there is the building boom. Much like Manhattan, Mumbai can only accommodate a swelling and increasingly affluent population by going vertical. Everywhere you look you see tower cranes helping buildings shoulder their way into the skyline. In addition, the mass conversion of 243 hectares of old textile mills in the heart of the city into commercial and residential space is creating glitzy, fully air-conditioned malls that rival the suburban temples of consumption found all over the United States. Add it up and it's no wonder that the power companies, which have not built a new plant in a decade, are scrambling to keep the lights on. How did it get to this point? Simply put, the electricity business in India has proven to be a financial minefield. Take the 2184 MW Dabhol power plant near Mumbai. Had it become fully operational, this one facility might have wiped out almost half of Maharashtra state's shortfall in generation capacity. As it stands, just the 740-MW first phase was completed, and it operated for only a short time before the plant was shuttered in 2000. Last May, Ratnagiri Gas and Power, a company jointly owned by seven companies including the National Thermal Power Corp., headquartered in New Delhi, and the Maharashtra State Electricity Board, took over the plant, which runs on naphtha, a product of the crude-oil refining process. But with oil prices at record highs, Ratnagiri has so far not resumed daily operations, because electricity from a naphtha plant would be prohibitively expensive.

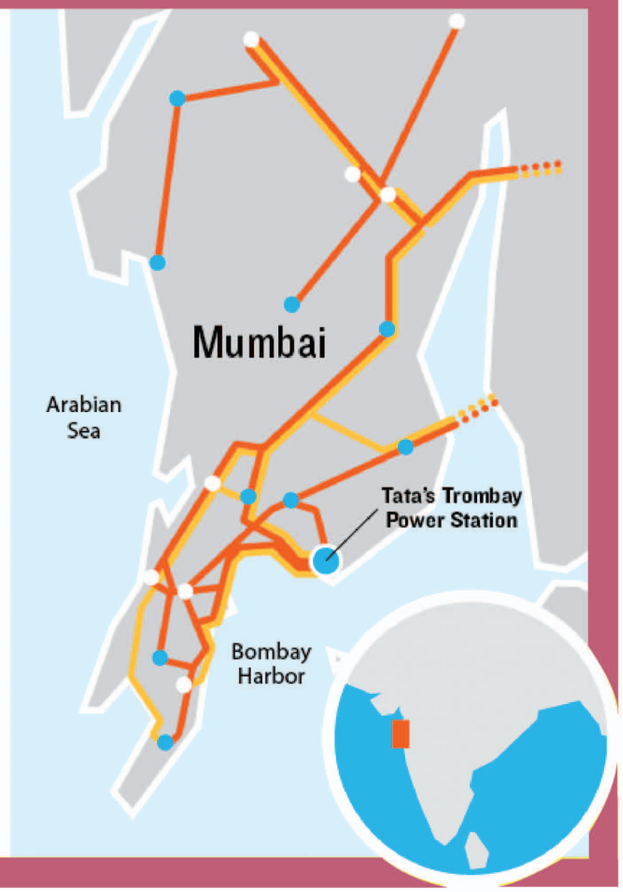
Power Puzzle

PROBLEM: Demand for power outstrips generation capacity.

SOLUTION: Build more power plants and control demand through pricing mechanisms and load shedding.

WHAT IT TAKES: Hundreds of millions of dollars in investment.

PITFALLS: More generation capacity without accompanying investments in transmission and distribution will strain an already overtaxed grid.



BIRDS ON WIRES, attracted to the garbage, in slums like Dharavi often cause shorts that knock out power to entire neighborhoods.

Mumbai's power companies have also been burned in the past when building new generating plants. Because India did not have a unified national grid or regulatory mechanisms that could facilitate power trading until just recently, there was no way to sell excess electricity. That inability spelled economic disaster for the 500 MW coal-fired plant at Dahanu, which was commissioned by Mumbai-based Brihanmumbai Suburban Electric Supply (BSES) during a short-lived economic boomlet in the mid-1990s. The plant was erected in anticipation of

increased demand, which did not materialize until just recently. In the meantime the expenses associated with Dahanu crippled BSES, and in 2003 Reliance took over the plant along with the rest of BSES's Mumbai operation.

A decade on from the Dahanu debacle India is a different place. People here are bullish on their economic future, a feeling underscored by the thousands of Indians returning home from abroad to seek their fortune. "There is a collective belief that the economic surge that we're seeing this time is here to stay," says Grove-White. And thanks to maturing power- trading mechanisms and a new regulatory environment facilitated by the Electricity Act of 2003, Tata officials are confident that they can get a decent return on investment in new plants. "We're going to have to take a big deep breath and say, we're going to invest," Grove-White adds. "We know what we need to do, and we will sell this output ultimately."

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In fact, with an infusion of cash from the private sector several new plants are now under construction or soon will be. A 250 MW coal-fired unit is scheduled to come on line at Tata's Trombay complex in March 2008, with another 250 MW unit slated to follow in 2009. India's central government is also stepping up, awarding contracts for four so called ultramega coal-fired power plants of 4000 MW each. They will be constructed by various Indian companies, including Tata.

The move to create more generating capacity in response to surging demand underscores an essential dynamic governing energy planning the world over, according to Clinton J. Andrews of Rutgers University, in New Brunswick, N.J. "Economists prefer you to build infrastructure in response to demand because then you won't waste any of it, and engineers prefer to build it ahead of demand because then you always have enough capacity," he says. "In the electric-power industry, engineers' influence is decreasing, and the economics and business perspective is gaining strength. That means that everywhere we see power systems operated closer to the margin, including the U.S. And certainly in Mumbai, they have the added complication of being undercapitalized, so that they can't build as many power plants as they need."

In Mumbai, a delicate dance goes on between the companies that generate and distribute the city's electricity and the state regulator, which acts primarily as a consumer advocate, always looking to keep the price of electricity as low as possible. But the current situation forced the regulator's hand in April, when the Maharashtra Electricity Regulatory Commission approved rate hikes for Mumbai customers of up to 27 percent for residential consumers and up to 75 percent for commercial and industrial users. Andrews, director of the program in urban planning and policy development at Rutgers's E.J. Bloustein School of Planning and Public Policy, agrees that raising prices might help Mumbai's situation in both the long and short terms.

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"Usually part of the solution for a city like Mumbai is to start charging enough for electricity," Andrew points out. "That does two things. First, it creates a stream of revenue that you can use to borrow money against for building power plants. Second, it dampens demand, especially if you can do time of day metering, which encourages people to do peak shifting and peak reduction."

Indeed, Maharashtra state has recently introduced what are known in India as time-of-day tariffs for industrial customers, according to Rangan Banerjee, professor of energy systems engineering at the Indian Institute of Technology, Bombay. There are four time slots under the new tariff schedule: morning peak from 6 a.m. to 11 a.m.; evening peak between 6 p.m. and 11 p.m.; and two off-peak troughs, where demand dips, from 11 a.m. to 6 p.m. and from 11 p.m. to 6 a.m. The idea is for users in heavy industry to shift load-intensive operations to off-peak hours when the costs are lower.

It's a good idea, says Banerjee. But so far the plan has been a bust. "When the tariff was introduced, there was also a price rationalization," he explains. "Before, industry was subsidizing commercial customers and agriculture by paying the highest tariffs. When we shifted from the flat tariff to the time-of-use tariff, industry's bill was reduced. So they haven't yet perceived an incentive to off-shift."

Despite the slow pace of adoption, Banerjee is convinced that such demand-side management will eventually win the day. "Load management and energy efficiency are more convenient options than shedding the load and much cheaper than building new plants. But demand-side management [DSM] is not going to offset any power plants completely. We're going to have new power plants and DSM, because whatever we build we're still going to have shortages."

Mumbai's power companies know that electricity shortages will become acute in just a few months. Throughout the spring, Tata, Reliance, and BEST have waged a public-¬awareness campaign on TV, radio, billboards, and flyers. The goal is for citizens to conserve 20 percent of energy usage by turning off electrical equipment when it is not required, running large appliances such as washing machines at off-peak hours, minimizing the use of air conditioners during peak time, using compact fluorescent lamps in place of incandescent bulbs, and switching off the power to the advertising billboards during the evening peak. (One wonders whether those billboards promoting energy conservation will also be darkened.)

The message from the power companies is clear: to get through the tropical summer without significant load shedding or blackouts, Mumbaikars will have to sacrifice a few of the conveniences they've come to enjoy over the past few years. If they don't, the noise of TVs, washing machines, and espresso makers might be replaced by the sound of matches being struck in the dark.

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