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Powering the Telecosm
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Gates in the Grid

At the most fundamental level, American Superconductor and ABB are in the business of caching power and switching it intelligently. And they do it better than anyone else.

It's a clear day in Silicon Valley. We're on Sun Microsystems' (SUNW) sprawling corporate campus. Why is the air around us literally humming? That's the sound of electrons, as they pulse through the five main megawatt-level transformers — truck-sized gray boxes of copper wire. The transformers are arrayed in Sun's tennis-court sized personal substation. This is where two feeds from PG&E's 12.47 kV grid interface with Sun's in-building power system, which lights tens of thousands of SPARC CPUs inside the row upon row of Sun Enterprise 10,000-class servers and StorEdge RAIDs beyond.

The substation is where logic is added to the grid. And where electrical noise (or worse) is added also, in a bad substation – or subtracted, in a good one. Essential though they are, the wires embody the grid's stupidity. Its intelligence, such as it is, resides in its nodes, in its substations and switches. Like gates on a microprocessor, those are the decision points, the places where intelligent choice occurs, if it is going to occur at all.

Much of the break-down of order and the collapse of power happens here too. At 1:00 p.m. on August 12, 1999, cooling equipment failed in a substation serving the Loop in Chicago, and a transformer overheated. Then a 1950s-vintage plastic sleeve used to splice cables at the substation fried. That was it for power in the Loop. The Mercantile Exchange and Chicago Board of Trade (CBOT) crashed. Every last soul in the pit had to stop trading. Bulls, Bears, and Hogs, pork bellies, soy beans, and even bulk electricity. It took Commonwealth Edison 90 minutes to restore power to the financial district, and another ten hours for most other customers. Some 100,000 others were powerless for three days, while summer temperatures hovered in the 100s.

U.S. spending on "transmission and distribution" fell between 1990 and 1995; it has been on the rise since. It will hit $12 billion this year, and rise sharply from there on out. The political and regulatory stars are now aligned with the market and technology imperatives – something that doesn't happen often in any business related to utilities. A big share of the new spending will go into faster, smaller, smarter switches and substations. By shrinking the existing components, the architects of the new substations will make room for thousands of new ultra-low-emission 15 to 60 MW gas-fired turbines, distributed and deployed closer to the loads to sharply improve grid reliability. The October companion issue (Heavy-Iron Lite) addresses that half of the story. This issue is about switches and substations – the logic gates in the grid.

American Superconductor (AMSC), which we placed on our Power Panel a year ago, is one of the leading manufacturers of local-area grid and sub-station level superconducting wires and components. It is now joined by the Swiss ABB (Asea Brown Boveri, global headquarters in Zurich, Switzerland; U.S. headquarters in Norwalk, Connecticut). ABB is a global leader in the manufacture of substation components, grid operations, and the contract design and engineering of entire substations. ABB is planning a U.S. listing on the NYSE later this year.

The K-9 Grid

So America has "the grid of a third-world nation"? The Secretary of Energy said so recently. That's nonsense, of course, as anyone who has actually been to the third world knows. America has a first-world grid, a twentieth-century grid. What we need, however, is a twenty-first-century grid. The grid has kept pace with motors and light bulbs. It hasn't kept pace with microprocessors and lasers.

In "The Powerchip Paradigm", our inaugural issue of a year ago, we described the widening gap between the quality of power supplied by the grid, and the quality required by the digital infrastructure. The digital economy requires power that's up 99.9999 percent (and better) of the time, power that's rock steady, from milliseconds to days to years. The old grid typically manages about three 9s – 99.9% up time, with interruptions ranging from fractions of a second to fractions of a day. Call it the "K-9" grid. By digital-economy standards, it's a dog.

No matter what utilities spend, the grid alone will never be good enough for the AOLs (AOL), Ciscos (CSCO), Suns, and Oracles (ORCL), the Powercosm hotels and the server farms. Long, shared wires just can't be made that reliable. But to say so is to miss the point. Every last factory, store and home is going digital. Every one will demand power more reliable than it's getting today. But most won't need power as good as Oracle's. Millions of smaller customers aren't going to install their own turbine or ride-through flywheel any time soon. But neither will they tolerate the canine grid any longer.

The opportunity now is for those who have the technology to build its new, high-9s successor. In last month's mailing we included "Goodbye To The Grid", the September issue of our sister Gilder publication, *New Economy Watch*. Make that "Goodbye to the 20th-century Grid". In the months after its CBOT-crashing outage, ComEd spent $1.5 billion upgrading its local transmission and distribution facilities in Chicago – over $100 million of which was used by ABB to build one new 200 MW substation and upgrade four others with new transformers and switchgear. For the next decade, utilities and large private users across the country will be investing massively in similar rebuilds.

The grid, to most people, suggests wires. And it certainly does have wires. Some 680,000 miles of long-haul copper and aluminum backbone supply high-voltage (230 to 765 kV) transmission; another 2.5 million miles of local wires (generally under 170 kV) supply distribution. Measured by route miles and physical footprint, it's (by far) the largest network on the planet. Distribution plant alone accounts for about half of a typical utility's investment.

In the dumbest possible configuration, it's just wires, nothing more. Power is generated at the top, consumed at the bottom, and transported in between by a passive, unswitched, trunk-and-branch network. This was the structure of the very first grid, from Edison's Pearl Street, NY station in 1882. In that architecture, there is no possibility of making dynamic choices among alternative transmission lines, feeders, or generators; the most the nodes can do is shut off power to one or more of the branches down the line. The higher up things fail, the more widely the failure is felt.

Overall, the local distribution network is responsible for over 80 percent of the power quality problems experienced by the typical customer. Lightning, weather, "car-pole interactions," and "suicidal squirrels" all cause their share of trouble. So do customers themselves, when they abruptly add or subtract loads, whether from an arc welder firing up, or a server farm lighting-up. But the sheer physical bulk of the wires is really the biggest problem.

The grid's wires store power in the electric and magnetic fields that surround them — huge amounts of power, because the wires are so long, and carry so much current. Whenever loads or supplies change quickly at the ends, the electrical inertia of the wires (their capacitance and inductance) knocks the grid's voltage and current out of phase. Grid engineers call this reactive power: from where they stand, the wires appear to contain malignant generators of their own, that send huge amounts of rogue power sloshing up and down the system, like waves in a bathtub moving water independently of the faucet and drain.

The substation — "sub" to the power plant, the prime mover of the electrons — is where the grid engineer tries to re-impose law and order, and other things besides. It is typically a high-fenced plot of land, about the size of a tennis court or football field, filled with arrays of car- and or even house-sized transformers, ten-foot-high ceramic insulators (they look like wavy pillars of soft ice cream), and massive spring actuated circuit breakers. The 100 largest utilities have some 7,000 bulk power substations; there are well over 100,000 lower-tier substations.

Here, power flows are switched, combined, or rerouted. Here, voltage is stepped up or down. And here, logic is added, and electrical noise is – or at least in theory, can be, and should be — subtracted. At the very least, a substation will cut off power (temporarily or permanently) when a line gets short-circuited downstream, or when the substation is directed to implement a rolling blackout. If the substation has a second source of power — from a second, independent high-tension trunk, for example, or from a back-up generator situated at the substation itself – then the substation can contain still more logic, and be called upon to make more complex logical choices.

The grid already has multiple points of interconnection at the top, at key crossroads on the transmission grid, and lower down, among trunks, feeder lines, and distribution wires. It all appears, at first blush, to be quite a web of complementary pathways and smartly designed redundancy. And so it is, by the standards established to serve refrigerators, motors, and light bulbs. For traditional requirements, the substations perform quite adequately. They represent

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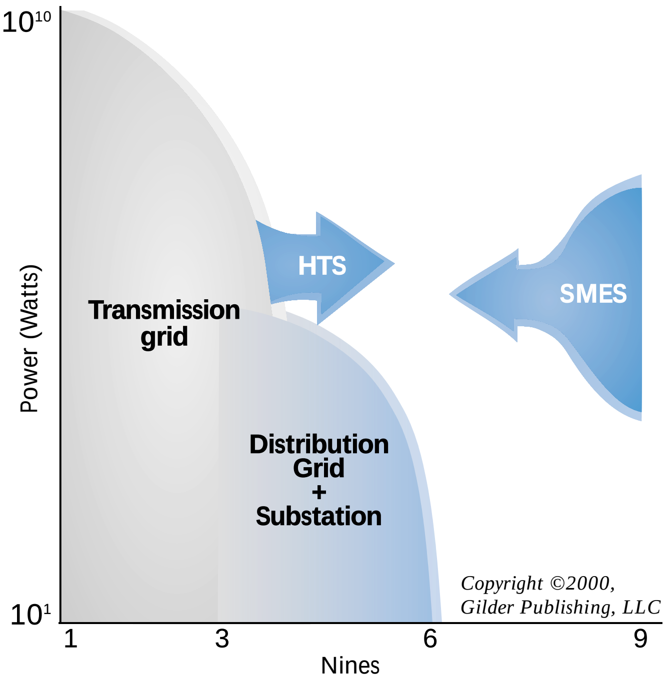
relatively cheap, robust, tried-and-true technology.

But as often as not they degrade power to chip-crashing levels, even as they scramble to do the right thing for refrigerators and light bulbs. Existing substations switch power almost entirely with crude (by digital standards) electromechanical switches and even cruder circuit breakers. They deal with reactive power and other electrical transients by means of huge, baffle-like analog capacitors or inductors, and by dissipating the reactive power as heat in the lines themselves. They add high-frequency electrical noise even as they strain to suppress lower frequency outages. And – far too often – they just can't handle the reactive-power transients at all – so when things get bad enough, they blow up instead. Substation transformers are the most common casualties; switches rank second. In the best of circumstances, the substation's thrashing doesn't quite fry your GE refrigerator or Dell PC. In the worst, it halts trading at the CBOT.

The traditional utility solution: fill the tub only half full, hope for the best, assume the refrigerator can handle the noise, and let the digital economy take care of itself. Traditional – but no longer acceptable.

Grid Networks and 9s



The first step in pushing the grid to higher 9s is to install a best available technology substation. High temperature superconductors (HTS) add substation-to-load capacity and 9s in urban centers, while superconducting magnetic energy storage (SMES) adds unprecedented 9s capabilities at the grid level.

The Personal Substation

How do you make a smarter grid? Much the same way as you make a smarter Web, or a smarter microprocessor. Build more gates, and make them faster. Cache power near the loads. Create more links between the nodes themselves.

The first step in pushing the K-9 grid to higher 9s is to install your own, best-available-technology substation – your "personal substation," so to speak. Which is perfectly practical, if you're big enough. AOL is. Its newest campus in Prince William County, Virginia, is home to 60,000 servers. AOL's dedicated substation takes two separate 115 kV high-voltage feeds from the grid, steps the voltage down to 24 kV through redundant transformers, and feeds the power to two 25 kV sets of switchgear. If either of the two primary grid feeds fail, the substation turns to power from a thirteen-unit string of 2 MW Cat diesels, sitting on five days of fuel oil. Company-wide, AOL has 55 MW of its own back-up capacity at its current facilities, with 29 MW destined for facilities under construction – each one with its personal substation.

Multi-megawatt private substations sprout up at fab plants for smart chips [Intel (INTC)] and powerchips [International Rectifier (IRF)], server manufacturers [Sun Microsystems, and Hewlett Packard (HP)], software factories [Oracle and Microsoft (MFST)], and information servers (AOL and NASDAQ). Oracle operates its own $6.6, million, 13 MW substation in Redwood Shores, CA. It's connected to a 60 kV feed, and distributes power to buildings on a 21 kV campus bus. Additional transformers (lower-tier substations) in each building take it from there. Substations appear wherever servers, RAIDs, and routers accumulate. Some 30 million square feet of Exodus and AOL-level data hotels are now scheduled for completion in the next eighteen months. The increasingly common 200,000 sq ft facility is a 20 MW load. Every such node added to the Web will add a matching substation to the grid.

Utilities themselves often locate their own substations on the doorstep of large loads, from airports to refineries, and hospitals to hotels, because a direct link between high-voltage lines and the large customer at the feeder is the best way to provide the power required. A substation linked to two separate points on the grid, as AOL's does, increases reliability too. But important though they are, large private customers represent only the leading edge of the substation boom. Utilities need more substations to improve overall grid reliability for everyone else. By building more substations, utilities shrink the footprint – i.e. reduce the number of customers affected – by the common sources of spikes, dips, short-circuits, and meltdowns. More substations create more points at which to interconnect independent parts of the grid, so that distant transmission lines and power plants effectively back each other up.

Finally, substations must proliferate to accommodate the many competing suppliers of wholesale electrons that want grid access. Utilities have been ordered to interconnect with independent power producers, and sister utilities. Well over one half of all electricity produced is now sold several times through broker contracts (the new wholesale, competitive kWh commodity market). The MCI's (WCOM) and Sprints (PCS) of new power – the likes of Enron (ENE) and Calpine (CPN) — are now congregating around the old Bell System of the power grid, and clamoring for open access and non-discriminatory interconnection.

AMSC's technology is real–real enough for GE to put its carefully guarded nameplate on the side of the AMSC trailer

So there will be more substations, as certainly and inevitably as there will be more corporate suppliers of power, more generators pumping electrons into the grid, and more large loads drawing them out. Better substations, too. If they are slow, stupid, and fragile – as they still are, for the most part — substations add high-frequency noise in the process of subtracting low-frequency noise. But technology now at hand allows them to be smart, fast, and robust enough to subtract noise (and thus raise 9s) across the board.

American Superconductor

In the bit networks, copper gave way to ultra-pure erbium-doped glass. In the electron networks, copper will give way to ultra-pure bismuth-strontium-calcium-copper oxide ("bisco"). Two quantum-physical ceramics, one for the Telecosm, a second for the Powercosm.

American Superconductor (AMSC) manufactures bisco and builds things with it. "Superconductor" brings to mind long wires, but the main use for AMSC's wires is in substation components. Among other things, AMSC builds wave-suppressing devices. Big devices, for grid-scale waves. AMSC's principal customers are utilities, along with large Powercosm customers that have megawatt-scale loads. Both are now using AMSC's technology to push their power control nodes into the twenty-first century.

Where the electrical inertia of the grid is the problem, a countervailing electrical inertia in the substation is the solution. AMSC makes the SMES (or D-SMES), the (Distributed) Superconducting Magnetic Energy Storage unit. A semi-tractor trailer houses the superconducting coil, the liquid nitrogen cooling system, and power electronics.

What is it? It's a huge inductor, the electrical equivalent of a flywheel, a "virtual generator" that is pumped full of power when the grid is up, and that almost instantaneously pumps back huge amounts of power, for very short intervals, whenever grid power abruptly dips. Suitably controlled, a D-SMES cancels out junk on the wires in much the same way as an active noise cancellation system cancels out noise in a helicopter pilot's headphones – by supplying anti-noise. The only difference is that AMSC works with megawatts, not watts. Last July, AMSC deployed six D-SMES units at substations along Wisconsin Public Service's 200-mile Northern Transmission Loop, their first utility SMES deployment. The company has already supplied similar fixes to a number of industrial customers, as well, including the Tinker Air Force Base in Oklahoma and a plastics factory in North Carolina.

A few months after AMSC's arrival on our Power Panel, General Electric (GE) signed up as the exclusive U.S. distributor for the D-SMES. Last month GE announced the first commercial order for a D-SMES – a sale to Entergy, a $9 billion utility based in New Orleans, that owns 15,500 miles of high voltage transmission lines and 1,450 substations. Other utilities will follow. One by one, at first. And then, as they grow weary of losing digital customers and being denounced for their "third-world" engineering, the herd will thunder.

A massive, super-fast, energy-storage device requires power electronics to synchronize its anti-noise to the grid's noise. That takes some doing. From the get-go, the SMES is a DC storage device; the grid requires precisely timed AC.

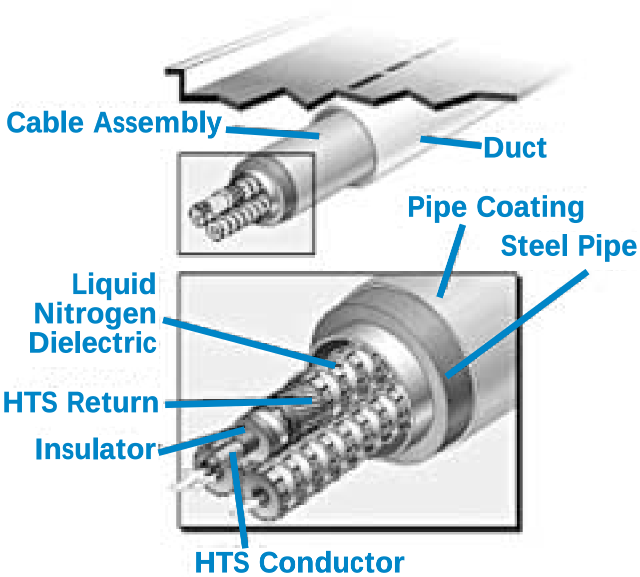
Through a longstanding collaboration with Integrated Electronics, AMSC has developed solid-state power converters that can bridge that divide — converters capable of switching megawatts of power in microseconds. These extremely fast, high-power units are built around insulated gate bi-polar transistors (IGBTs) and the integrated gate commutated thyristor (IGCTs) (see April DPR). Last June, AMSC acquired Integrated Electronics outright.

Founded in 1996, Integrated Electronics specializes in industrial-level power converters, cramming them on to printed circuit boards, rather than in hand-built boxes. The most powerful circuit-board inverters in 1996 handled 15 kW. Within a year, IE released a 100 kW unit using a proprietary printed-circuit board; today its modules handle up to 1,000 kW. The converter modules can be stacked in Lego block-like arrays to handle 10 MW and beyond. Employing a Motorola PowerPC for logic, and fiber-optic serial communications for synchronization, IE software can reprogram and reconfigure a module array for a wide variety of different applications.

An enormous market for these units is now just beginning to unfold. AMSC plans to start shipping powerchip-only trailers to add control, conditioning and intelligence to grid nodes. For every node that needs switches and a bucket of electrons, many, many more need switches alone. The dominant solution to grid transients today is to over-engineer everything – just keep the bathtub a good bit less than full, in other words. But with the right storage and switching technologies in substations, utilities can run the wires a lot closer to full capacity. For that reason alone, we consider it inevitable that high-power, solid-state silicon will progressively take over all grid switching functions. Not overnight – nothing in this gargantuan business happens overnight. Just step by inexorable step, as the market gradually discovers what this new generation of silicon technology can do.

AMSC's high-end powerchip control systems will also find applications in high-power private "grids" of every description: in big industrial motor drives, UPSs, flywheels, big fuel cell arrays (FuelCell Energy's 3 MW systems, for example), or RAID-like arrays of Capstone microturbines, as well as electric cars, trains and trucks. (Caterpillar's building-sized mining trucks are silicon-controlled, electric-power plants on wheels – an on-board diesel generator produces the electricity; electric motors turn the wheels.)

Finally, AMSC is the leading supplier of superconducting wires for power cables themselves. Many cities already lack sufficient space in their underground ducts to place enough conventional wires to handle the ascending loads of the digital economy. Combine a bad transient with a peak load, and cables overheat, transformers blow, and iron manhole covers pop into the air like tiddlywinks. Working with its Italian partner, Pirelli Cables and Systems (the world's largest manufacturer of power cables) AMSC is now offering the most straightforward and economical solution: much more power in much less space.



Detroit, for example, experienced a blackout this past June because of a failed substation tie-line. AMSC is currently deploying the first-ever commercial superconducting cable — a 400 foot run with a 100 MW capacity — at Detroit Edison's Frisbie substation. Some 18,000 pounds of copper in nine cables will give way to three cables, with just 900 pounds of AMSC's superconducting wire contained in cables manufactured by Pirelli. This will free up six ducts for still more electric power, or perhaps, more digital power in glass fibers.

The AMSC/Pirelli cable is already cost competitive, and costs have nowhere to go but down. AMSC's CEO, Greg Yurek (a long-ago MIT professor), is now happy to report that demand for bisco wire exceeds supply. AMSC can produce 500 km/year today, and it has broken ground for the world's first commercial superconducting-wire fab plant designed to churn out 10,000 km of wire per year by 2002. Pilot production should begin in a year and commercialization a few years after. AMSC has over 250 U.S. patents, and an equal number internationally — a deep, Corning-like moat of intellectual property around its technology fortress.

When he dares to draw the inevitable analogy between bit and electron ceramics, Yurek does so only with professorial reticence and understatement. So he should – the whole superconductivity field has suffered from a decade of excessive media hype, failed forecasts, and commercial vaporware. There will undoubtedly be more of the same. But AMSC's technology is real – real enough for GE to put its carefully guarded nameplate on the side of the AMSC trailer. Ceramics will rule the Powercosm as certainly and inevitably as glass came to rule the Telecosm.

Soft Switching Technologies and Intermagnetics General

Two other, closely related technologies to watch are the superconducting transformer and the solid-state soft switch.

A superconducting transformer? AMSC and ABB have collaborated for a number of years building a prototype. So have Siemens and Hydro-Quebec, Toshiba (TOSBF) and TEPCO, Waukesha Electric and Intermagnetics (IMG). They work. They're more efficient (which can lead to serious savings in 100 MW boxes) and they're a lot smaller – the two-story house shrinks down to a mere U-Haul trailer. But at high-power AC, even superconductors develop inductive resistance (small magnetic vortices that dissipate power). The problem can be solved, and has been, with clever geometries and changes in materials. But no very attractive configuration has yet emerged.

If one does, Intermagnetics General Corporation (IMG) could well have a hand in it. Founded in 1971 as GE spin-off, IMG went public in 1981. It now ranks as a venerable pioneer in commercial low-temperature superconductors for magnetic imaging in medical applications. Last February IMG launched a new subsidiary, SuperPower, to take charge of IMG's high-temperature superconductor technology. (AMSC is entirely anchored by high-temperature superconductors.) Intermagnetics has already collaborated with (privately held) Southwire and the Department of Energy to build a prototype 100-foot superconducting power connection at a Southwire plant. The company's most intriguing project is a superconducting fault current limiter – a very fast, smart, powerful, circuit breaker for big substations, which IMG is developing in partnership with Waukesha Electric, General Atomics, Lockheed Martin (LMT), Southern California Edison and Los Alamos Labs. The 17 kV prototype can absorb enormous quantities of current — the "fault" — almost instantly. It's more efficient, robust, reliable — and smaller – than the units it might replace.

Then there's Soft Switching Technologies [(SST) still private]. For the most common, relatively modest power sags that plague the grid, super-fast powerchips alone can often take care of things, without any additional energy storage device at all. The most important practical application here is one step below the substation, on the internal, local-area power grid of a power-hungry corporate campus. A single General Motors (GM) factory, for example, requires nearly two-dozen 2 MW transformers on its premises to handle its power. Ford (F), Novell (NOVL), Lucent (LU), and International Rectifier (IRF), have comparable scale private grids on their property. All are already customers of Soft Switching Technologies (Middleton, WI).

Some 90 percent of the "faults" in grid power are created by "first reclosure events." Think of it as rebooting the substation. A sudden current surge downstream suggests the possible need to shut off power flows through the substation completely. But is such drastic action really needed? Perhaps the suicidal squirrel won't linger. The substation's hardware doesn't know, so it opens and immediately re-closes a huge switch, once, and then again, and then (if it must) a third time, each time hoping that the problem will somehow have gone away in the meantime. Which indeed it will have, if the current-surging squirrel has been vaporized. A single reclosure event typically lasts about 12 cycles, or 1/5th of a second. Which merely blinks the lights, but crashes everything digital in the line of fire.

The standard defense today: pile on capacitors and inductors down closer to the load. Or, if the power levels warrant it, an AMSC D-SMES and powerchips. But when the interruptions are short enough, and the loads small enough, smart switching alone can solve the problem. The trick is to build a box that's smart and fast enough to draw more current at the intake when voltage drops, and instantaneously recreate the proper output voltage and current at the outlet.

In the complex and expensive challenge of adding intelligence to the power grid, ABB ranks as the technology leader worldwide

Soft Switching builds it. Their president, Deepak Divan, left academe in 1995 to found a company based entirely on this simple but hugely powerful idea. The company's leading product today is its Dynamic Sage Corrector (DySC). It's built around powerchips supplied by Semicron, Toshiba, and Eupec; it can handle from 1.5 to 2,000 kW, and in size, it runs from about shoe box to commercial refrigerator (tiny in the world of big power). On the strength of superfast, supersmart switching alone, the DySC can smooth out the most common voltage sags — sags of up to 50 percent voltage deficit, lasting up to 15 cycles (1/4 second). Add a modest bank of capacitors, and the DySC can ride out 3 cycles of 100 percent voltage sags. Functionally, the DySC power electronics replace or at least greatly extend the lives of less exotic ride-through technologies like batteries and flywheels. At the margin, it can compete directly against them.

In addition to its direct sales to companies like General Motors, Ford, Lucent and International Rectifier, SST manufactures the DySC as an OEM product sold through Square D, a large supplier of conventional high-power switches. SST also has an operating relationship with Asian Electronics Limited (India), where SST is establishing a wholly-owned subsidiary to manufacture products for shipment to U.S. markets. SST is also in discussions with Invensys (INVSY), a major UPS supplier. The DySC is already priced below the old analog solutions (which center on huge, slothlike, analog inductors). And the old-guard technologies have already bottomed-out on their cost curves. The costs of SST's powerchips, by contrast, have only just begun to fall – and they're going to fall as far as silicon generally falls, which is pretty close to forever.

ABB

What do sub-sea oil production platforms, pharmaceutical companies, food processors, pulp & paper mills, chemicals, airports, and dot-coms all have in common? A 10 MW substation, engineered by ABB. When the CBOT went down in Chicago, Commonwealth Edison called on the best in the business, ABB again, to reengineer and rebuild — and on a panic, seven-month deadline. ABB delivered. It built one new 200 MVA 138/12.47 kV substation from scratch, and refurbished four others, largely by modifying switchgear/breaker configurations.

The $25 billion-a-year ABB is both the world's leading manufacturer of many substation components and the leading integrator of complete substation solutions. ABB also owns the power industry's only counterpart to Bell Labs – a $2 billion/year (8 percent of ABB's revenues!) research operation headquartered in Baden-Dättwil, Switzerland, with additional facilities in seven other countries, including the United States. ABB now ranks as the world's leading developer of grid hardware, and the owner of the most sophisticated software assets required to add logic intelligently to high-power grids. Headed up by Randy Schrieber, VP in Raleigh, NC, the company's U.S. Power Distribution group handles city-level grid operations. Over the next decade, this group will emerge as the leading provider of logic gates to the U.S. grid.

ABB's component technology begins with the most basic – the high-power powerchip. ABB's proprietary 1 MW monster IGCT single-wafer powerchips are aimed squarely at the power levels typically encountered in the distribution layers of the grid. And with the opening of a new fab plant in Lenzburg, Switzerland last spring, ABB has significantly expanded its powerchip manufacturing capabilities. ABB also has retained a stake in lower power powerchips through its large institutional holding in IXYS (SYXI) (April DPR).

One step above powerchips, ABB manufactures powerchip modules. The company is a major player in the Navy Power Electronics Building Block, PEBB, program (April DPR); ABB expects to release a commercial PEBB within the next year or so. The unit will be capable of serving as a building-level super-UPS at the front end of Powercosm hotels. ABB already has pilot customers in a Mid-West plastics manufacturer, and in a university that found itself being "UPSed to death," in Schrieber's words.

ABB also manufactures a wide range of more conventional substation components. It is the largest transformer manufacturer in the world ($2 billion in sales). It manufactures sealed, gas-insulated switchgear that has a dramatically smaller footprint (it cuts a high-voltage 10-foot connection down to 10 inches) and is a lot more reliable than the conventional air-insulated alternatives. ABB also makes surge arresters, generator circuit breakers, advanced converters, and control technologies.

Finally, ABB is the world's leading provider of turnkey substation analysis and rebuilding. ABB now offers customers Dell-like capabilities to build-your-own personal substation on an ABB website. This takes some doing. The dynamics of massive current flows through long wires and nodal equipment are very complex indeed – as complex as the dynamics of a jumbo jet – which, as it happens, processes about as much thrust power under its wings as a typical substation conveys through its transformers and wires. About half the cost of building a traditional substation lies in the components themselves; the other half in the engineering and construction. ABB does both.

Extremely sophisticated modeling allows ABB to optimize the delivery of 9s to any customer at any node. The software dynamically analyzes the surrounding grid, its wires, switches, and transformers, assigning to each a probability of failure, duration of outage, and a time-to-repair horizon. And on that basis, it searches out optimal equipment configurations within the constraints imposed by the surrounding grid, the customer's needs, the utility's budget, and a host of other factors. Footprint is one of them. As it did in Chicago, ABB can configure systems small enough to go inside commercial buildings. Much of the footprint reduction in Chicago came from applying logic, software and controls to existing components.

Until quite recently, ABB was vertically integrated from big turbines down to low-power switches. But it has recently shed about one-third of its operations (accounting for $10 billion-a-year in annual revenues). Today half of its six business segments, and some 60 percent of its revenues, are anchored in core technologies of the Powercosm. Another 25 precent come from electric technologies for commercial buildings (circuit breakers, control panels, fuse gear, switches and so on) that will increasingly come to be centered in powerchips and the Powercosm. The remainder of ABB's business lies in the enabling technologies for the oil and gas industries, a tiny share in renewable energy (politically very important in Europe), and a modest (by GE standards) $1 billion financial services account. Among the businesses recently shed are: refrigeration, rod and wire operations, rail operations, and heavy turbines. ABB did, however, recently launch a microturbine — the TURBEC single shaft, oil bearing, 100 kW unit, a joint venture with Volvo Aerospace.

ABB's traditional focus has been outside the United States. But ABB is a global company, and it clearly recognizes the ascendancy of the U.S. Powercosm market. Its Raleigh-based operations, and pending NYSE listing testify to that. We suspect it has a significant U.S. acquisition or joint-venture in the works. In the enormously complex and expensive challenge of adding intelligence to the power grid, ABB now ranks as the clear technology leader worldwide. This is the company that brings together and knows how to integrate powerchips, power switches, smartchips and software. Judge it, too, by its technology alumni: Ake Almgrem of Capstone (July DPR) and Jerry Lietman of FuelCell Energy (September DPR). Look to ABB to announce several breakthrough power products at the time of its NYSE listing a month or two from now.

Gates in the Grid

The grid will get more gates. It will get smarter. Utilities know what must be done, and have the resources to do it; given some reasonable certainty of cost recovery, they are perfectly willing to invest them. The best among them are eager to – eager to push 9s down the grid, toward the multiplying number of grid-dependent digital users, who need more 9s, but can't realistically embark on supplying them to themselves.

Regulators won't stand in the way: to the contrary, they are already clamoring for the upgrades. Environmental activists won't block things either. Some will merely stand aside; other will even applaud increasing the intelligence of the grid at substation nodes, because electrical efficiency of the grid can be improved, with much of the work occurring on brownfield urban sites.

At the most fundamental level, AMSC and ABB are in the business of caching power and switching it intelligently. And they know how to cache and switch it better than anyone else. Intel works with nanometers and microwatts. AMSC and ABB, with kilometers and megawatts. Ceramics for bits and ceramics for electrons. Gates on a chip and gates on the grid. Same business, really. Just twelve orders of magnitude apart on the power curve.

Peter Huber & Mark Mills
October 10, 2000

The Power Panel

Ascendant Technology	Company (Symbol)	Reference Date	Reference Price	9/29/00 Price	52wk Range	Market Cap	Customers
Network Transmission and UPS: High-temperature superconductor	ABB***	9/29/00	96 61/64***	96 61/64***	N/A	N/A	National Grid (UK), Microsoft, Commonwealth Edison, American Electric Power
	American Superconductor (AMSC)	9/30/99	15 3/8	49 5/32	15 9/16 - 75 1/8	$987m	ABB, Edison (Italy), ST Microelectronics, Pirelli Cables, Detroit Edison, Electricite de France
Power: Heavy-Iron-Lite	General Electric (GE)	9/29/00	$57 13/16	$57 13/16	38 21/100 - 60 3/4	$572b	Reliant Energy, Enron, Calpine, Trans Alta, Abener Energia, S.A.
	Catalytica (CTAL ➪ CATX)*	9/29/00	$12 3/8	$12 3/8	7 1/2 - 16 1/4	$0.7B	GE, Kawasaki Turbines, Enron, Rolls Royce, Solar Turbines
Electron Storage & Ride-Through Flywheels	Active Power (ACPW)	8/8/00	$17**	62	17 - 79 3/4	$2.3b	Enron, Broadwing, Micron Technologies, PSI Net, Corncast Cable, ABC
	Beacon Power (BCON)	IPO date pending	$11-$13**	N/A	N/A	N/A	Century Communications, Verizon, SDG&E, TLER Associates, Cox Cable
Hydrogen Generation	Proton Energy Systems (PRTN)	9/29/00	$17**	28 5/8	N/A ††	$916m	Matheson Gas, NASA
Distributed Power Generation Microturbines	Capstone Turbine Corp. (CPST)	6/29/00	$16**	69 1/4	16 - 98 1/2	$5.2b	Chevron, Williams ECU, Tokyo Gas, Reliant Energy
Fuel Cells	FuelCell Energy (FCEL)	8/25/00	49 7/8 †	96 7/32	8 - 107 3/8	$1.5b	Santa Clara, RWE and Ruhrgas (Germany), General Dynamics, LADWP
Micropower Nano-fuel cells	Manhattan Scientifics (MHTX)	8/25/00	2 3/4	3 9/32	15/16 - 8 5/8	N/A	Incubator (no customers)
Silicon Power Plants In-the-room DC and AC Power Plants	Emerson (EMR)	5/31/00	59	67	40 1/2 - 70 3/8	$28.6b	Citicorp, Verizon, Nokia, Motorola, Cisco, Exodus, Qwest, Level 3, Lucent
	Power-One	*(see below)*					
Motherboard Power Bricks, High-end DC/DC converters	Power-One (PWER)	4/28/00	34 1/8 †	60 1/2	4 7/8 - 89 13/16	$4.5b	Cisco, Nortel, Teradyne, Lucent, Ericsson
Powerchips: Insulated gate bipolar transistors (IGBTs)	IXYS (SYXI)	3/31/00	6 25/32	26 1/8	1 17/32 - 45 3/8	$639m	Rockwell, ABB, Emerson, Still GmbH Eurotherm Ltd. (UK), Alpha Technology
IGBTs	International Rectifier (IRF)	3/31/00	38 1/8	50 1/2	15 1/4 - 67 7/16	$3.1b	Nokia, Lucent, Ericcson, APC, Emerson, Intel, AMD, Ford, Siemens
	Advanced Power (APTI)	8/7/00	15	33 1/8	15 - 49 5/8	$260m	Alcatel, Ericsson, ITI, Power-One, Advanced Energy Industries, Emerson

Note: This table lists technologies in the Powercosm Paradigm, and representative companies that possess the ascendant technologies. But by no means are the technologies exclusive to these companies. In keeping with our objective of providing a technology strategy report, companies appear on this list only for the core competencies, without any judgment of market price or timing. Reference Price is a company's closing stock price on the Reference Date, the date on which the Power Panel was generated for the Digital Power Report in which the company was added to the Table. All "current" stock prices and new Reference Prices/Dates are based on the closing price for the last trading day of the month prior to Digital Power Report publication. IPO reference dates, however, are the day of the IPO. Though the Reference Price/Date is of necessity prior to final editorial, printing and distribution of the Digital Power Report, no notice of company changes is given prior to publication. Huber and Mills may hold positions in companies discussed in this newsletter or listed on the panel, and may provide technology assessment services for firms that have interests in the companies.

** On August 2, Catalytica (CTAL to become CATX) announced plans to merge with DSM, (Heerlan, Netherlands). The Combustion Systems unit and Catalytica Advanced Technologies, will be spun off together, to shareholders, as "Catalytica Combustion Systems" (CATX) in December 2000. This will leave Catalytica's third subsidiary, Catalytica Pharmaceuticals (largest current source of corporate revenue) with DSM.*

*** Offering price at the time of IPO.*

**** ABB presently trades on the Zurich Exchange but plans on a U.S. listing on the NYSE later this year.*

† *Split adjusted this issue.*

†† *The IPO for Proton Energy was 9/29/00, the same day as the reference date of this issue, trading range not yet established .*