Fortnightly

Take My Grid, Please! A Daring Proposal for Electric Transmission

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> Break the regions and interconnections into smaller zones, then connect them only with DC lines.

Facilis est descensis averni." ("The descent into hell is easy.") So the great Roman poet Virgil tells us in The Aeneid. By implication, it's the getting out that's difficult. And that's about where we are today with deregulation, transmission, and power system reliability.

In the real world - and even in the sometimes not-so-real-world of electric power deregulation - the laws of physics are immutable, and they cannot be changed by economic theory, legislative action, or regulatory mandate. While the laws of physics make it possible for us to enjoy the fruits of electric power, they also set the rules by which we may do so.

Nonetheless, deregulation is proceeding with a sometimes frightening lack of attention to the laws of physics. In fact, "deregulation" itself is a misnomer. While electric generation is moving toward eventual deregulation, bulk power transmission, system operations, and even the institutions of the electric power industry are being subjected to a level of federal regulation unprecedented in U.S. history. In fact, this new regulation (not "reregulation," but "new regulation") likely will give the federal government total effective control of the electric power system, its operation, and its organizations. And this is bad news for reliability.

Beyond the fact of increased, rather than decreased, regulation, the major threats to reliability in the "brave new world" are threefold:

1. Complication
   System operation is increasing exponentially in complexity as the industry moves into retail access. This effect can be seen both in the number of players, and in the number and complexity of procedures.
2. Culture Shift
   The industry is moving from a culture of "cooperation and coordination" to one of "competition and confidentiality."
3. Priorities
   They are shifting from reliability to price.

First, the electric power industry is experiencing a massive increase in the number of players. At the same time, industry organizations are struggling to cope by vastly increasing their operating procedures, and are making them far more complex. In any given region, countless generation owners, power marketers, electric service providers, and others are replacing a handful of traditional utilities. While this eventually may shake out, at present the sheer numbers constitute a major threat to reliability.

And it's only just begun. The U.S. barely has started down the road to full restructuring, unbundling, and retail access. Yet, we're already beginning to experience the consequences of complication in terms of blackouts, shortages, and price spikes. It will only get worse.

Second, the threat of complication is made worse by the fact that, in a competitive environment, the players no longer share common goals. There's nothing evil or underhanded about this. It's just the natural consequence of moving from a vertically integrated industry to an unbundled, competitive one. We cannot expect competitors to reveal their plans to each other, or cooperate very much. That's not how markets work. Did Macy's talk to Gimbel's? Yet this has unfortunate consequences for reliability. The "obligation to serve" isn't a viable concept in the marketplace. "Keeping the lights on" is now subject to the profit motive.

Third, priorities are shifting from reliability to price. This already has begun, and is probably behind several recent power failures and shortages. But the full impact will not be felt until the temptation to water down criteria is realized - as I think it will be, at least in some regions of the country.

Whenever someone raises the issue of reliability, someone else inevitably answers, "But deregulation is good for reliability, because all customers will now be able to purchase just as much reliability as they want or need." That sounds reasonable enough - unless you know something about electric power and how it's provided physically. To understand this, we must look at the two major elements of electric supply - generation and transmission - and see if "the marketplace" can actually function in each.

Generation Supply

For generation supply, the market can work. The customer has the choice of suppliers. Based on reputation, word of mouth, advertising, or whatever, each customer will select a supplier. Whether it's a utility, power marketer, electric service provider, or directly from a generator, consumers can calculate their own trade-offs between price and reliability.

The problems begin when there is an inadequate supply - like we've seen in California recently. And an inadequate supply is in the interest of generating companies, since inadequacy drives up the price, according to the law of supply and demand. So the first order of business is to make sure there is enough capacity available. But many industry organizations have eliminated adequacy from their criteria: For example, the North American Electric Reliability Council (NERC) dropped its requirement in 1997. Clearly, adequacy standards must be restored. Independent System Operators (ISOs) and Regional Transmission Organizations (RTOs) can do this by requiring that all Load Serving Entities (LSEs) contract for sufficient capacity (plus whatever reserve margin has been specified) in advance of each capability period.

We should institute installed reserve requirements for all LSEs. This would automatically result in greater generating capacity, because owners would have the opportunity to make money in the capacity as well as the energy markets. Likewise, it would reduce the investment risk for potential developers. Greater generating capacity means fewer shortages, and hence higher reliability. It also translates into lower prices (law of supply and demand). It's a far more effective and market friendly approach than a price cap, a la California. At least so far, this approach seems to be working in those ISOs who have chosen to use it - New York, for example.

Another thing that would improve reliability would be to have fewer control areas. Especially in the Eastern and Western Interconnections, the current large number of control areas unnecessarily complicates both the commercial generation market and the reliability of the overall system. Fewer control areas are a virtual requirement for both efficient markets and reliability. This could be accomplished as a byproduct of restructuring. For example, when an ISO or RTO is established, all participants should be merged into a single new control area. In addition, the system operators of these new control areas should be given real authority - essentially, military authority in the case of emergencies - if reliability is to be preserved.

There are things that could be done on the demand side, as well. LSEs could offer a variety of options to their customers, trading interruptions for lower price. At one extreme, customers would be offered very high availability, but at a premium price. Other plans would give the LSE power to interrupt, say, air conditioners and water heaters, a certain number of hours a year - but with commensurately lower overall rates. This is an intelligent way of dealing with the fact that electric demand typically exceeds 90 percent of peak only 1 to 2 percent of the time. It's expensive to provide capacity that will only be needed about 100 hours a year. LSEs could manage their peaks this way. In fact, they could also be permitted to bid their managed demands into the daily bidding system. Customers would have their choice of plans, balancing price and reliability. And, from the LSEs' point of view, direct control of demand would be a supply side balance in the supply and demand equation, thereby driving down costs for everyone.

As to energy, some sort of short-term bidding system is a requirement, the problems in California notwithstanding. But long term and bilateral transactions must be accommodated. Also, any supplier wishing to participate in the day-of market should also be required to participate in the day-ahead market. These requirements would go a long way toward moderating large price fluctuations.

Transmission System

When we look at bulk power transmission, we find a completely different situation. There is absolutely no way a system can be devised that would allow customers to pay for the amount of transmission reliability they want or need. No way, no how. That's because, when the bulk power transmission system goes down, everyone and everything connected to it goes down with it - there's no way any customers can exempt themselves by paying higher rates. The bulk power transmission system is very egalitarian!

The bulwark of reliability for bulk power transmission systems has long been the use of "worst single contingency" design and operation - often referred to as the "n-1" principle or criterion. It's kind of the "prime directive" of reliable power system operation. In short, it means that the system is planned and operated in such a way that it can sustain the worst single disturbance possible without adverse consequences - consequences like overloads on other facilities, instability, or loss of firm customer load. The contingency is usually the sudden outage of a key high voltage transmission line or major generating unit.

Sooner or later, people will argue that this isn't necessary - that it's far too conservative. I've already heard or read comments like, "The bulk power transmission system is a highly underutilized resource." Or, "If you're focusing on reliability, you haven't gotten the message." Or better yet, "First contingency design is just too expensive." Beyond them all is the unspoken conclusion that transmission systems in the U.S. are just too reliable. If the top priority is competition rather than keeping the lights on, these ideas are reasonable. After all, you get an immediate and seemingly free increase in transmission transfer capability just by lowering the criteria. Of course, you may have problems explaining this to the citizens of a city or state that has recently suffered a major blackout. Nevertheless, I'm convinced that, in some places, especially where there may be inadequacies in generation supply, people will give in to temptation, and it will be decided that the n-1 criterion should be dropped; just how likely is that worst single contingency, anyway?

Well, experience has demonstrated that, when you lower the criteria even a little bit beyond n-1, the probability of power failure goes up very rapidly. For a number of years, the Hydro-Quebec system was planned and operated with criteria just slightly less stringent than that used in the rest of North America. They didn't abandon n -1; they merely assumed a less severe fault condition. Yet they suffered, on average, one total system blackout per year during a 10-year period. Do away with the "prime directive," the n-1 principle, and you've essentially destroyed reliability.

My Personal Solution

A close friend and associate once told me, "We have to go back to the old, regulated form of the industry." I don't agree. For one thing, too many powerful people have invested too much of their reputations (and egos) in "deregulation." Call it hubris if you like. We need to look for ways to derive the promised benefits of the marketplace without sacrificing reliability.

A lot of folks say that what we need are more regulations and legislation. But that's what got us here in the first place! Others call for more and better rules and procedures. This is essentially the NERC approach. Well, that's engineers for you - they'll always try to make things work, somehow. Have you heard the joke about the condemned engineer and the guillotine that didn't work? Looking up, he says, "I think I see what the problem is." None of the recent blackouts or power failures were caused by someone ignoring or otherwise violating existing reliability criteria. Legislation and regulation will do absolutely nothing toward overcoming our current reliability problems. New rules and procedures just beget increased complication, and increased complication begets blackouts. It's a vicious circle.

If the problem is that the system is becoming too complicated, why not see if we can make it less so?

There are four synchronous interconnections in North America, with approximately the following peak loads:

Eastern Interconnection	500,000 MW
Western Interconnection	130,000 MW
Electric Reliability Council of Texas (ERCOT)	50,000 MW
Quebec	30,000 MW

They're pretty big. The first two are too big, I believe, to be manageable in the New World Order. The Eastern and Western Interconnections are just too large to be operable with the massive new increases in complication. And piling on more and more complex procedures only makes things worse.

So at least a partial solution would be to break up the present Eastern and Western Interconnections into smaller synchronous interconnections. Decide where you want to make the breaks, and open all the AC ties. Then tie them together again with high voltage direct current (HVDC) ties.

What's the advantage of this? Simply that DC ties are not synchronous like AC ties are. With the present interconnections, whatever happens in Maine is felt in Mississippi. An outage in Las Vegas has an effect in Vancouver. With DC, though, any disturbance in one synchronous interconnection has no effect outside that interconnection. With smaller interconnections and HVDC ties, there would be much simpler, more controllable systems, and fewer problems with differing criteria and procedures. There would be far fewer problems with loop flows, parallel path flows, congestion, and line loading relief. And any system disturbances, including major ones like blackouts, would be contained within a single synchronous system.

In other words, no more parallel path flow problems (there wouldn't be any parallel path flow), and no more contingency response problems (again, there wouldn't be any). Unlike AC, DC ties are asynchronous; what happens on one side doesn't affect the other. This would go a long way toward restoring the reliability balance.

Perhaps most important, marketers could actually schedule power transactions to a point, over a specific HVDC line (or lines) - an enormous advantage over the present system, since the power system would essentially emulate the way marketers like to think about the system. Markets could function over much wider geographical areas than are practical now. The power system would essentially emulate the way marketers like to think the system works. (If Mohammed can't go to the mountain. . . .) It's a sort of back door detour around Kirchhoff's Laws.

Existing AC lines could be used, essentially without modification, as HVDC lines. In fact, they would have higher capabilities. So there would be no significant cost for transmission and no need to build new lines. There would be significant costs associated with the AC/DC converter stations, however.

I've made a rough estimate of the approximate cost involved. I wouldn't even call it a back-of-the-envelope analysis; it's more a back-of-the-postage-stamp analysis! I'm an engineer, not an economist. I'm just trying to get in the ballpark.

I left the existing ERCOT and Quebec interconnections alone. For whatever reasons - bigger brains or dumb luck - the Texans and Quebecois are already doing it right!

I chose the NERC "1998 Summer Assessment, Figure 1: Normal Base Electricity Transfers and FCITCs" as a reference for the Eastern and Western Interconnections. I decided that, for a first cut, I'd break up the Eastern Interconnection by regional reliability councils, and size my HVDC ties to the same interregional transfer capabilities as in the NERC exhibit. For the Western Interconnection, I broke WSCC into four smaller interconnections, relying on the existing HVDC ties between the Pacific Northwest and Southwest, and installing 600-MW capability each between the Pacific Northwest and Rocky Mt. area, Rocky Mt. area and DesertStar, and DesertStar and Pacific Southwest. I used an average cost of $100,000 per MW for each converter station.

Here are the results of my four scenarios:

Scenario 1 - By NERC regions	$8 billion
Scenario 2 - NERC regions + SERC subregions	$10 billion
Scenario 3 - Loehr's protocol	$7 billion
Scenario 4 - By NERC regions with fixed 2,000 MW	$2 billion

"Loehr's protocol" represents my own idea of how the system should be split up. Hey, I'm a consultant! I don't do this for my health. The most likely cost, then, is in the range of $7 billion to $8 billion - about the cost of two large nuclear units.

That sounds like a lot, but consider the alternative: more and more devastating blackouts and power shortages. PG&E and Southern California Edison have claimed that their deregulation losses in the year 2000 exceeded $11 billion. It has been estimated that power failures in the U.S. cost more than $50 billion a year. That's more than the promised savings from deregulation! And it doesn't include the almost certain escalation in blackouts and power failures from all the reasons noted earlier.

It's also been estimated that the cost of a national blackout would be about $25 billion a day. The actual cost of the Aug. 10, 1996 West Coast Blackout was in the neighborhood of $1 billion. Suddenly a one-shot investment of $7 to 8 billion for the entire North American continent doesn't seem so exorbitant.

And let's put this cost in a more personal perspective. If we were to average the $7 billion to $8 billion among all North American consumers (excepting those in ERCOT and Quebec), we could recover all costs with a 1 mill per kWh over the space of two years. So for a residential consumer whose electric bill runs about 1000 kWh per month, the charge would amount to $1 per month for two years.

Further, several organizations (e.g., EPRI and TVA) are working on new designs for AC/DC converters that could cut the cost by as much as 50 percent.

So you say you're not satisfied? You say you want more for your money? OK. Here are some additional benefits:

Easier Management. Congestion solutions and Transmission Loading Relief (TLR) procedures would be far simpler.

Fewer Control Areas. There would be a less urgent need to combine control areas, or set up expensive new ones. ERCOT can (and does) work just fine with 10. The Eastern Interconnection, though, is another story - it has about 100. Each of the smaller synchronous interconnections I envision likely would have no more control areas than ERCOT.

Less Bureaucracy. We wouldn't need NERC's complicated, controversial and expensive systems like the TLR procedure or security coordinators.

Less Bureaucrats. In fact, both FERC and NERC would have a much lower profile.

Maybe Even No RTOs. There would be a less urgent need for ISOs, and regional transmission organizations (RTOs) in all their forms, because the smaller synchronous interconnections wouldn't necessarily need them.

Offsetting Cost Savings. Thus there would be some significant cost savings to partially offset the cost of the AC/DC converter stations.

More Intuitive. Perhaps most important, we would have a transmission system that operates the way economists think it operates!

It's a fair question: Why not leave the present interconnections intact and use Flexible AC Transmission System (FACTS) technology?

Well, for one thing, FACTS is a new and relatively unproven technology; at present, there are only about half-a-dozen test installations in the U.S. And there would have to be so many FACTS devices installed that the cost would probably be just as high as my HVDC proposal. The main problem, though, is that FACTS is still synchronous - what happens in Dayton would still be felt in Delray Beach. You'd still have to worry about long range effects, especially with transient stability. And you'd have a new concern - unintended mutual effects. Each of those FACTS devices would be shifting power flow from its own circuit to all other circuits, as per Kirchhoff's Laws. Multiply this by perhaps the hundreds of devices required in the Eastern Interconnection alone, and you begin to appreciate the scope of the problem. And, of course, failure of a FACTS device would become a first contingency design and operating criterion (loss of any element).

There is a role for FACTS technology in my proposal - a major one, in fact. But it's inside the new, smaller synchronous interconnections. FACTS technology should not be considered a substitute for the separation of the large interconnections, but a strategy to be used within the new ones. That way, the other problems associated with the use of FACTS devices could be properly managed, and they could assist in providing enhanced transmission transfer capability without adding to the overall problem.

This brings us to an important point: breaking the Eastern and Western Interconnections into smaller synchronous interconnections tied together with HVDC transmission would not eliminate all of the reliability problems brought about by deregulation. For example, congestion management would still have to be accomplished, and the attack on n-1 would still be a real threat. But smaller interconnections and HVDC would make those problems more localized, less complex, and hence more easily and more effectively addressed. Also, in the final analysis, if one interconnection had major problems and suffered blackouts, at least its neighbors would be protected.

How large should the new synchronous interconnections be? If you make them too large, you begin to lose the advantages of breaking up. On the other hand, if they're too small, you could experience technical problems. For example, the system might not be able to sustain the loss of the largest generating unit without excessive frequency deviations. And there also could be problems trading within the interconnection.

ERCOT is about 50,000 MW, and Quebec about 30,000 MW. Although there will surely be exceptions, these are probably good bookends - at least as a starting point for serious investigation. In my opinion, something in the neighborhood of 50,000 MW would be about right - about the size of ERCOT.

Another point: This doesn't have to be accomplished all at once. In fact, the changes would have to be phased in over a number of years. A high level of agreement and coordination would have to be realized; on doing it at all, how to do it, and how to schedule the changeover - not to mention how to pay for it!

Where to begin? Obviously, a national study would be required - conducted by totally independent parties. It should not be carried out, or perhaps even sponsored, by any entity with a vested interest in either the Old World Order or the emerging New World Order. Once a detailed feasibility study has been completed, then is the time to turn it over to the entire spectrum of players for discussion and debate.

We can have competition and a reliable system. Despite what your mother told you, sometimes you can have your cake and eat it too! Perhaps, as Scotty used to say on Star Trek, we "canna change the laws of physics," but we can design our institutions and procedures to accommodate them. In fact, we must.

Seven Ugly Sisters
The dark side of electric restructuring.

1. Increasing regulation, not deregulation.
2. Massive increases in complication - increases in both the number of players and the number and complexity of procedures.
3. A culture shift from "cooperation and coordination" to "competition and confidentiality."
4. Priorities shifting from reliability to price. We built the system to meet the "n-1 criterion," or the "worst single contingency," but that may soon fall under attack.
5. Threats of wide price swings, which call for quick fixes, as a cost of a market that functions only at the generation end and then only to some extent.
6. A nonfunctioning market at the transmission end, where the laws of physics still hold sway.
7. A rising probability of blackouts and other power failures. - G.C.L.

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