And There Will Be Blackouts...

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THE PROBLEM

To Boldly Go Where No Electron Has Gone Before

You know the scene. The starship Enterprise circles dangerously closer to the surface of the planet in a rapidly decaying orbit. The only hope of pulling out of orbit and saving the Entereprise is a quick start of her engines. “Scotty, I need power *now*!” pleads a desperate Captain Kirk. Only to hear his Chief Engineer reply, “I canna change the Laws of Physics, Captain!” As Mr. Spock might have said, “Indeed.”

Of course, this being ‘60s television, some *deus ex machina* inevitably saves the ship. But not at the expense of a violation of the Laws of Physics -- at least within the artistic license of the show. As Emerson said, a “willing suspension of disbelief” may be required, but Lt. Commander Scott (a.k.a. actor James Doohan) always remains the defender of the inviolability of the Laws of Physics.

In the real world -- and even in the sometimes not-so-real-world of electric power deregulation -- the Laws of Physics are equally immutable. 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. Indeed.

No Economists Were Killed or Injured in the Writing of This Paper

"Deregulation" is a very seductive concept. It has its philosophical appeal -- most of us believe in free markets, and don't like government intervention. Other industries have deregulated, for the most part successfully. And, most attractive of all, there's the promise of lower rates. I believe in free markets, too -- but they must operate within the constraints of the Laws of Physics. Of all industries in our present society, electric power is perhaps the most dependent on the Laws of Physics. Electricity is different in essence from other commodities. It cannot be visualized like coal or oil or pork bellies. As former Federal Power Commission Chairman Joseph Swidler once said, "Electricity isn't a commodity; it's a phenomenon." Scotty would agree.

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") will likely give the federal government total effective control of the electric power system, its operation, and its organizations. Clearly, like the bear that wasn't, "deregulation" . . . isn't. Is this degree of federal control truly the way to free markets? Is this going to lead to lower electricity prices? Is this really a good idea?

This Article is Y2K Compliant

Some people think that, in the post-deregulation 21st Century, the power industry will go through a period of mergers and acquisitions, similar to that experienced by the railroads in the late 20th Century. With the recent break-up of Conrail, the United States, for better or worse, is down to only four trunk line railroads. Experts, or at least some of them, predict that, once the traditional utilities are "unbundled" into separate gencos, transcos, discos, power marketers and perhaps electric service providers, these organizations will begin merging into larger and larger entities. The "experts" I've read

estimate a final count anywhere from "five or less" to "about than two handfuls" (whatever that means). So, in effect, we may be moving from an industry which is vertically integrated to one which is horizontally integrated. Is this truly the way to free markets? Is this going to lead to lower prices? Is this really a good idea?

"Gallia Est Omnia Divisa in Partes Tres" (Julius Caesar)

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 have to look at the three elements of electric supply -- generation, transmission, and distribution -- and see if "the marketplace" can actually function in each.

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. Further, I think it's very likely that suppliers will offer a variety of plans. These will vary from plans with very high availability at a premium price (MW Deluxe), to those which will give the provider power to interrupt, say, air conditioners and water heaters a certain number of hours a year for a lower overall rate (Extra Value Meals). This is an intelligent way of dealing with the fact that electric demand typically exceeds 90% of peak only one to two percent of the time. So, in addition to choosing suppliers, customers will also likely have some choice of plans, balancing price and reliability.

While the reliability of the *distribution system* will likely be affected by deregulation to some extent, it is beyond the scope of this article. Economic pressures and the departure of that old warhorse, the "obligation to serve," may result in lower reliability. But traditional political and media pressures, coupled with wider use of performance-based rates, should provide an effective counterbalance.

When we look at *bulk power transmission*, though, we find a completely different situation. There is absolutely no way a system can be devised which 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. Anyone who tells you otherwise is trying to sell you a Whopper!

This is made worse by the fact that failures of the transmission system account for more than 90% of all bulk power system reliability problems. Generation deficiencies account for less than 10%. Shortages in generation can usually be foreseen, too -- and worked around; while brownouts and rotating blackouts aren't pleasant, they're far preferable to the sudden, unexpected, uncontrolled outages triggered by problems on the transmission system. All the great blackouts, from November 1965 in the Northeast and Eastern Canada, to December 1998 in San Francisco, were caused by transmission problems. In short, if the bulk power transmission system goes down, everything goes down -- and there's no way any customers can exempt themselves by paying higher rates.

"Things are Getting Curiouser and Curiouser" (Alice in Wonderland)

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

COMPLICATION

The complication of operating the transmission grid will increase exponentially as the industry moves into retail access. This will be seen both in the number of players, and in the number and complexity of procedures.

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, a handful of traditional utilities are being replaced by countless generation owners, power marketers, electric

service providers, and others. While this may eventually shake out, at present the sheer numbers constitute a major threat to reliability.

And it's only just begun. We've barely 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.

CULTURE SHIFT

The industry is moving from a culture characterized by Cooperation and Coordination to one characterized by Competition and Confidentiality.

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 with one another very much. That's not how markets work! Does Macy's talk to Gimbel's? Yet this has unfortunate consequences for reliability. The "obligation to serve" just isn't a viable concept in the marketplace. "Keeping the lights on" is now subject to the profit motive.

PRIORITIES

Coming soon to this theater: not "The Phantom Menace," *but* "The Attack on n -1."

Priorities are shifting from reliability to price. This has already begun, and is probably behind several recent power failures. 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.

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 such that it can sustain the worst single disturbance possible without adverse 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.

"The Devil Made Me Do It" (Flip Wilson)

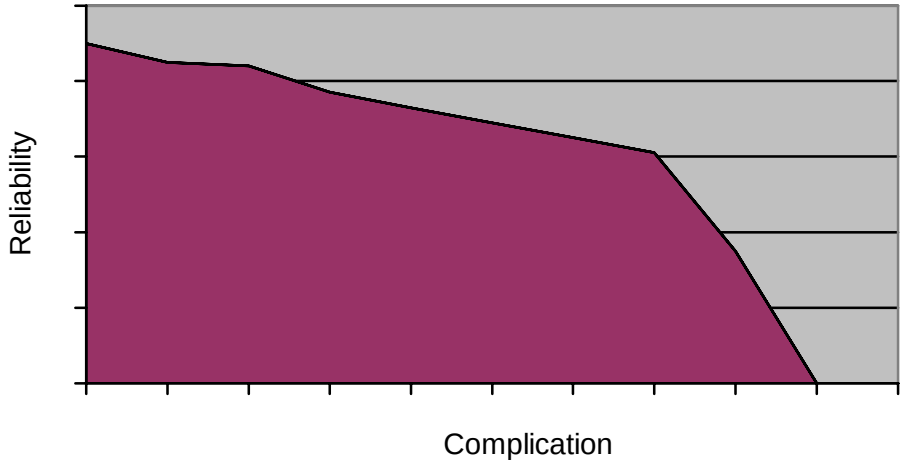
Sooner or later, people will argue that this isn't necessary -- that it's far too conservative. I've already heard or read comments like, "the bulk power transmission system is a highly underutilized resource," "if you're focusing on reliability, you haven't gotten the message," and "first contingency design is just too expensive." Beyond them all is the unspoken conclusion that the power 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 that has recently suffered a major blackout. Nevertheless, I'm convinced that, in some places, 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 about ten 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 even abandon n -1; they merely assumed a less severe fault condition. Yet they suffered, on the average, one total system blackout per year during that decade. Take my word for it -- do away with the "Prime Directive," the n -1 principle, and you've essentially destroyed reliability.

"Employees must wash hands before leaving." Department of Business and Professional Regulation, Division of Hotels and Restaurants.

Reliability isn't an absolute. There's no sharp, black-and-white division between what's reliability ant what isn't. Any statement about reliability could reasonably be followed by the question, "Compared to what?" Actually, power system reliability is a continuum; or a curve (see below).

Reliable? How far down the slope?



Many of the influences tending to degrade reliability can be offset in part by things like better communications or the application of new technologies. The real problem comes as we approach the "knee" of the curve. Where are we right now? I would say we're just a little above the knee. What could push us over? Possibly the increased complication that follows full retail access; is it just a coincidence that California, the first state to embrace retail access, experienced three large blackouts in less than three years? But if not retail access, certainly any significant watering down of reliability criteria, such as abandonment of the n -1 principle, will push us over the edge.

A Whole Lot of Begattin' Goin' On

Remember that part in the Book of Genesis with all the begattin'?
"Adam begat Seth . . . Seth begat Enos . . . Enos begat Cainan . . . Cainan begat Mahalaleel . . . " And so on.

Well, you could do something similar for "deregulation" in the power industry:

Profit Potential begat Competition . . .
Competition begat Deregulation . . .
Deregulation begat Restructuring . . .
Restructuring begat New Regulations . . .
Restructuring & New Regulations begat *Complication* . . .
Restructuring, New Regulations & Complication begat the concept of "underutilized resource" and the *attack on n -1* . . .

Restructuring also begat Mandatory Conformance . . .
Mandatory Conformance begat Federal Legislation . . .
Federal Legislation begat *FERC Authority* . . .
Federal Authority begat NERC/NAERO transmutation . . .

All of the Above begat *Who's in charge of Criteria* (and thus Reliability)

All of the Above begat ***Blackouts***

CONCLUSIONS

"Facilis est Descensis Averni" (Virgil, The Aeneid)
The descent into hell is easy -- it's the getting out that's hard!

So where does this all leave us?

- We have increasing regulation rather than de-regulation.
- We have massive increases in complication -- through both the number of players and the number and complexity of procedures.
- We have a culture shift from Cooperation and Coordination to Competition and Confidentiality.

- Priorities are shifting from reliability to price, with a likely attack on the n -1 criterion in the future.
- As a result, the probability of blackouts and other power failures is increasing and will continue to do so.

Is there anything we can do about it?

THE SOLUTION

"Doctor, it hurts when I do* this.*"
"Well, don't do* this*!"

A close friend and associate 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. As Thomas Wolfe said, "You can't go home again." Further, maybe there's some way we *can* provide the benefits of the marketplace without sacrificing reliability.

A lot of folks say that what we need is more regulations and legislation. But, *Duh!* That's what got us here in the first place!

Others call for more and better rules and procedures. This is essentially the NERC (North American Electric Reliability Council) 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." The problem is, new rules and procedures just beget increased complication, and increased complication begets blackouts. It's a vicious circle. Or, if you prefer, a "Catch 22."

I have a better idea.

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:

Interconnection	*Peak Loads*
Eastern Interconnection	**500,000 MW**
Western Interconnection	**130,000 MW**
ERCOT	**50,000 MW**
Electric Reliability Council of Texas	
Quebec	**20,000 MW**

They're pretty big. The first two are too big, I believe, to be manageable in the New World Order. They were never intended to function in the kind of market-driven environment we're now creating. 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 is 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. Within the present interconnections, whatever happens in Maine is felt in Mississippi. An outage is 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 controlable 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.

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

essentually emulate the way marketers like to think about the system! (If Mohammed can't go to the mountain . . . .)

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 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.

Nolo Texas Tangere! Don't Touch Texas!

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 600MW capability each between the Pacific Northwest and Rocky Mt. area, Rocky Mt. area and DesertStar, and DesertStar and Pacific Southwest.

I did a non-scientific survey of cost from about half-a-dozen sources, and came up with both a median and average of $100,000 per MW, per 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 2,000 MW standard	$2 billion

"Loehr's protocol" is my own idea of how it should be split up -- and I'm not revealing what I recommend in this article. I'm a consultant -- I don't do this for my health, you know!

The most likely cost, then, is in the range of $7 to 8 billion. About the cost of two large nuclear units.

"A billion here, a billion there -- pretty soon you're talking real money." (Former Senator Everett M. Dirksen of Illinois)

That sounds like a lot! But consider the alternative; more and more devastating blackouts and power shortages. 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 August 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 you averaged the $7 to 8 billion among all North American consumers (excepting those in ERCOT and Quebec), you could recover all costs with a 2 mill per KWH charge for one year, or 1 mill per KWH for two years. (Ref. NERC ES&D Report.) My home electric bill runs about 600 KWH per month; so the charge for me would amount to $1.20 per month for one year, or $0.60 per month for two years.

You say you're not satisfied? You say you want more for your money?

OK -- here are some additional benefits:

- Congestion solutions and transmission loading relief procedures would be far simpler.

- There would be no urgent need to combine control areas, or set up expensive new ones. ERCOT can (and does) work just fine under deregulation with ten; the Eastern Interconnection is another story -- it has over one hundred. Each of the smaller synchronous interconnections I envision would likely have no more than ERCOT.

- We wouldn't need NERC's complicated, controversial and expensive systems like the Transmission Loading Relief (TLR) procedure or Reliability Coordinators.

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

- There would be a less urgent need for ISOs, transcos, and RTOs in general, because the smaller synchronous interconnections wouldn't necessarily need them.

- Thus there would be some significant cost *savings* to partially offset the cost of the AC/DC converter stations.

"We just want the facts, ma'am" (Sgt. Joe Friday)

It's a fair question: why not leave the present interconnections intact and use FACTS (Flexible AC Transmission System) 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. 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; muliply this by perhaps several hundred 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 its *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 their use can be properly managed, and they can assist in providing enhanced transmission transfer capability without adding to the overall problem.

This brings us to an important point: the break-up of the Eastern and Western Interconnections into smaller synchronous interconnections tied together with HVDC transmission will not eliminate all of the reliability problems brought about by deregulation. Problems of congestion management, for example, will still have to be solved, and the attack on n -1 will still be with us. But it will make those problems more localized, less complex, and hence more easily and more effectively addressed. Also, in the final analysis, if one interconnection really fouls up and suffers blackouts, at least its neighbors will be protected.

How . . . Large . . . Are They?

Or, 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 can 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 50,000MW, and Quebec about 20,000MW. 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 50,000W would be about right -- about the size of ERCOT. It wouldn't be the first time Texas has led the way!

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.

SUMMARY

Because of deregulation, the reliability of the bulk power system is declining -- and, unless radical measures are imposed, it will get worse. Legislation, and more rules and regulations, will only accelerate the decline. Since the underlining problem is increasing complication, the most effective solution is to make the systems simpler. This can best be accomplished by breaking up the Eastern and Western Interconnections into smaller synchronous interconnections, and tying them together with high voltage direct current (HVDC) lines.

In brief, the most appropriate solution is:

- **Think smaller interconnections** *(problems contained, transactions simplified)*
- **Think HVDC ties** *(they're milder, much milder)*

The resultant benefits will be:

- **Higher reliability** *(engineers and all "reliability guys" will be happy)*
- **Simpler trading arrangements** *(a boon to marketers, economists, and all supporters of market solutions)*

We can have competition *and* a reliability system. Despite what your mother told you, sometimes you *can* have your cake and eat it too! Perhaps, as Scotty said, we "canna change the Laws of Physics," but we can design our institutions and procedures to accomodate them. In fact, we must.

This article was written by a professional power systems engineer on a closed course. Do not attempt this at home!

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Mr. Loehr's views are his own, and do not necessarily reflect those of the organizations with which he is or has been affiliated.