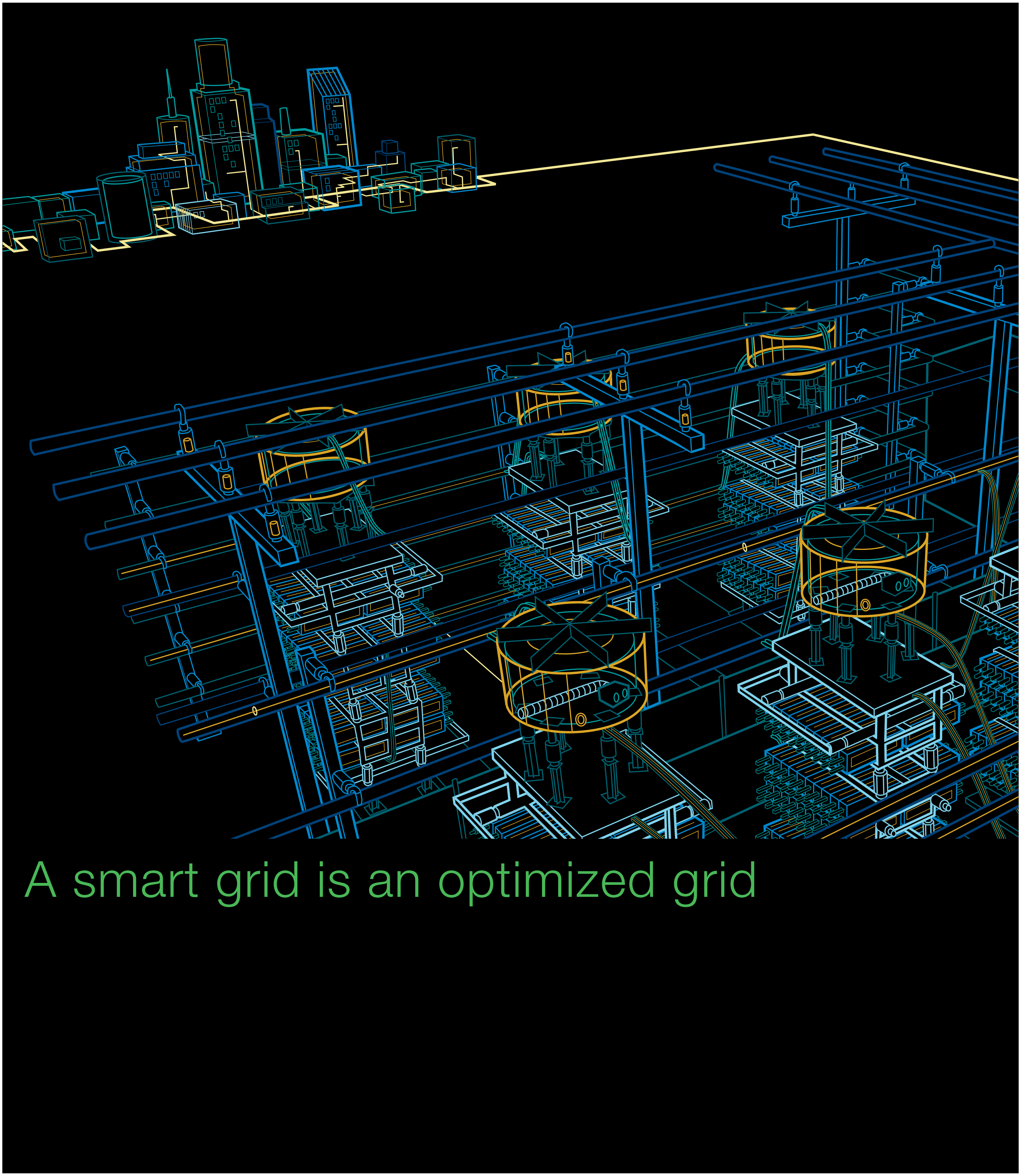

A smart grid is an optimized grid

Power and productivity
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The term "smart grid" has been used to describe a broad range of technologies, design concepts and operating practices that collectively paint an exciting picture of what our electric power infrastructure might look like in ten or twenty years. But what about the grid we have today? Certainly one of the most important attributes of a smart grid is the ability to wring more out of the assets currently deployed throughout our electricity delivery system. That is the essence of optimization.

The benefits of grid optimization are fairly straightforward:

- To get more out of the existing infrastructure and thus defer investments in new generation, transmission and distribution facilities
- To reduce the overall cost of delivering power to end users
- To improve reliable delivery of power to end users
- To reduce resource usage and by extension, emissions of CO_2 and other pollutants

Running through all of these is the concept of efficiency, whether in an economic or physical sense. So, how do we go about improving the efficiency of our power grid, short of wholesale replacements of aging equipment and massive investments in the latest technologies? In short, what can be done now to make the grid operate better?

What does "efficiency" mean for a power grid?

Efficiency at the utility level is often overlooked outside of industry circles, in particular the substantial gains that could be made in the efficiency of power transmission and distribution systems. Grid efficiency comes down largely to "line losses," the amount of power leaving a generation plant that is lost on the way to our homes and businesses. Losses in the transmission and distribution system of 6 to 8 percent are typical even in the world's most advanced countries, and they can run even higher.

In 2006, a total of 1,638 billion kWh of energy was lost on the US power grid, with 655 billion kWh lost in the distribution system alone. To put this in perspective, consider that a 10 percent improvement in grid efficiency at the distribution level alone would have produced $5.7 billion in savings based on the 2006 national average price of electricity. It would also have saved over 42 million tons of CO_2 emissions.

But achieving that ten percent is not as difficult as one might think. As we'll see in a moment, there are technologies available today that can have a tremendous impact without bank-breaking investments. What's also important to note, though, is that far from convincing millions of consumers to try something new, applying these technologies involve only utilities. Of those, the 210 investor-owned utilities operating in the US today serve over 70 percent of all end users, so the universe of "customers" for improved grid efficiency is remarkably small. Compare that to the millions of consumers who would have to change their energy usage under demand response programs, for example, in order for those initiatives to realize their full potential.

Reducing losses

Improving the efficiency of power transmission and distribution comes down to two choices: you can reduce the resistance of the wires by making them larger or using better materials (not a practical solution), or you can improve the effectiveness of the flow of electricity. To address the latter, it's important to understand one technical concept and that is the difference between active and reactive power.

Real power is what we use to run our lights, computers and production lines. It's the power the "does the work." Reactive power does not contribute anything to doing work, but it does cause conductors to heat up and it takes up a certain amount of "space" in the wires. The more reactive power flowing on a line, the less "room" there is for real power, and the less efficient the transmission and/or distribution system will be.

So, to optimize the movement of electric energy, we would ideally like to eliminate reactive power flows, or at least minimize them. Utilities do this today on their local distribution systems using devices such as capacitor banks or special transformers, typically located at substations or on feeder. These devices work to keep reactive power flows down, making the full capacity of the conductor available for the real power that will be used by our lights, TVs and refrigerators. This process is known as volt/VAr control.

Historically, volt/VAr control devices have operated autonomously, independent of one another and without centralized coordination. This approach worked, but it left a good deal of efficiency on the table since actions taken by one device might have less-than-optimal results for another location on the grid or for the system as a whole.

Enter VVO: volt/VAr optimization

Advances in automation and communications have laid the foundation to make centralized, coordinated voltage control possible and in fact applications to take advantage of it have been in the works for years. The problem lies in the fact that the computing requirements for such applications to generate useful solutions in near real time are staggering. However, new methodologies and today's faster computers have converged to make volt/VAr optimization viable.

VVO, as it is known, is an advanced application that runs periodically or in response to operator demand at the utility control center or in substation automation systems. Combined with two-way communication infrastructure and remote control capability for capacitor banks and voltage regulating transformers, VVO makes it possible to optimize the energy delivery efficiency on distribution systems using real-time information.

The real breakthrough here is in the speed and quality of the computation. VVO uses advanced algorithms to identify the optimal operation strategy from millions, or even billions of possibilities. Arriving at that result fast enough to apply it in practice, in a day-to-day utility working environment, is a tall order.

The result is improved efficiency that reduces the amount of power that must be generated and with it the emissions of CO_2 and other pollutants associated with power generation. VVO also allows utilities to control costs better by getting the most out of their networks.

What's next

More applications are being developed now that address not only the efficiency of grid operations but also reliability. For example, fault detection, isolation and restoration (FDIR) will require more components (devices on the grid and software applications) than VVO, and different utilities are likely to take different approaches to implementing this type of functionality. Similarly, managing large volumes of distributed generation resources like rooftop solar panels will take even more sensors, faster computers and more robust algorithms to manage the interrelated effects of so many devices on the utility's system.

For all of these applications, however, one component is vital: communications. The ability to move large amounts of data from disparate points on the grid is the key to enabling the applications that will in turn facilitate the widespread adoption of distributed generation and maintain (or even improve) the level of service customers expect. Of course, challenges remain. There are issues surrounding standards and interoperability, security, and of course cost to name a few. The long-term benefits, though, are compelling. VVO is only the beginning of a new stage in the evolution of our power systems that will make them simultaneously more reliable, more efficient and more economical.

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