Enable smarter, cleaner power through technology innovation

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Advanced electronic technologies allow the intelligent power grid to embrace renewable forms of energy generation, bringing greater efficiency and a greener world.

Grid parity will soon be upon us, bringing power from renewable sources that costs the same or less than power from fossil fuels and other traditional sources. We will achieve these low renewable energy costs through a continued investment in solar and wind turbine technology development and manufacturing, but also by investing in an intelligent power network, the so-called smart grid. As a leading supplier of analog and embedded processing technologies, Texas Instruments (TI) is closely involved in developing the smart grid, providing integrated circuit solutions that enable power equipment manufacturers to introduce greater measurement, control and communication in their products. The result will be an intelligent, efficient network that supports more extensive generation of energy from renewable sources, with a safer and more efficient energy grid for generations to come.

After years of work on solar- and wind-collecting technologies, we are now approaching the break-even point where using renewable energy systems will be competitive in cost with generating power from fossil fuels. We have long anticipated that alternate sources of energy will provide reliable power and avoid contributing to atmospheric changes through carbon release. Soon these renewable sources will also become economically advantageous, and it makes sound business sense to invest in power generation from sunlight and wind instead of coal, oil and natural gas.

Calculating the relative costs of different forms of power generation is complex. Costs vary among countries, regions within large countries, and even individual utility companies. As a result, we won't see an overnight changeover to what is being widely referred to as grid parity, when the cost of power delivered from renewable sources is equal to or lower than that from traditional sources. Rather, a gradual transition will occur during the next decade or more. Government subsidies will aid in the transition, but cost-reducing advances in technology and manufacturing are already overtaking subsidies as the primary growth driver.

Today, in fact, some wind farms that employ the latest multi-megawatt turbines have already achieved grid parity—that is, when the wind is blowing. Solar panels will take longer, though they promise to introduce an even more radical change in energy-gathering than windmills. While wind farms usually require large investments in infrastructure to operate efficiently, solar generation can be used effectively at almost any scale, from a handful of panels on the rooftop of an individual dwelling, to a field of panels covering acres. Both forms of energy gathering, but especially solar, will significantly change the topology of the power grid by introducing more widely distributed sources of power generation. As grid parity is achieved, it will accelerate this trend dramatically.

The smart grid enables decentralized power generation

Today, the momentum carrying us toward grid parity is strong, but issues remain before the promise can become a reality. One set of challenges we face today is around how to keep driving down the cost of sun- and wind-collected energy. This will require continued investments to develop new technologies and manufacturing techniques. Today's improvements focus on materials used in panels to increase sunlight conversion to electricity; increasing the scale and efficiency of wind turbines; and sophisticated algorithms to help solar and wind farms gather the maximum energy from continuously changing environmental conditions. Energy storage improvements are also crucial to help even out the supply of power when the wind dies down or the sun doesn't shine. Despite the issues remaining, numerous developments in these and other areas have already brought down costs significantly and will continue to do so in the years ahead.

Another set of challenges toward achieving grid parity lies in adding intelligence to the larger utility structure to make it operate more reliably and efficiently. Referred to as the smart grid, the intelligent power network aims to include measurement, communication and control at every stage, from the power generating station to the end appliance. Everything in the grid -- every generator, substation, relay, transformer, meter, machine, transmission line— and all that is attached to it can potentially be measured and observed to ensure that power is delivered effectively where it is needed and used without waste.

In addition to cost savings and reliable delivery, the smart grid will provide an essential infrastructure for the distributed generation of power from renewable sources. In the future, a utility grid must be capable

of managing the bidirectional flow of electricity to customers who sometimes consume power, and at other times generate their own. Therefore, the grid must be able to manage demand versus creation in real time, relying on the varied types of decentralized power generation and new capabilities of energy storage.

The increased electricity generation from renewable sources also means utilities will have to rely on power lines that transport energy over long distances and distribute across regions. This is because the sun shines brightest and the wind blows consistently in places that are often far from cities and industrial districts.

Figure 1 shows the topology of the future smart grid. Along with the top-down flow of electricity from traditional large generating plants, there is now input from large solar and wind farms, and bidirectional flow from producer-customers of various sizes. Only an intelligent grid can integrate such widespread electricity generation from renewable sources, along with outputs from traditional large generating stations, and supply power effectively to all connected customers. The economies of scale required to achieve grid parity can only come about through the extensive application of solar

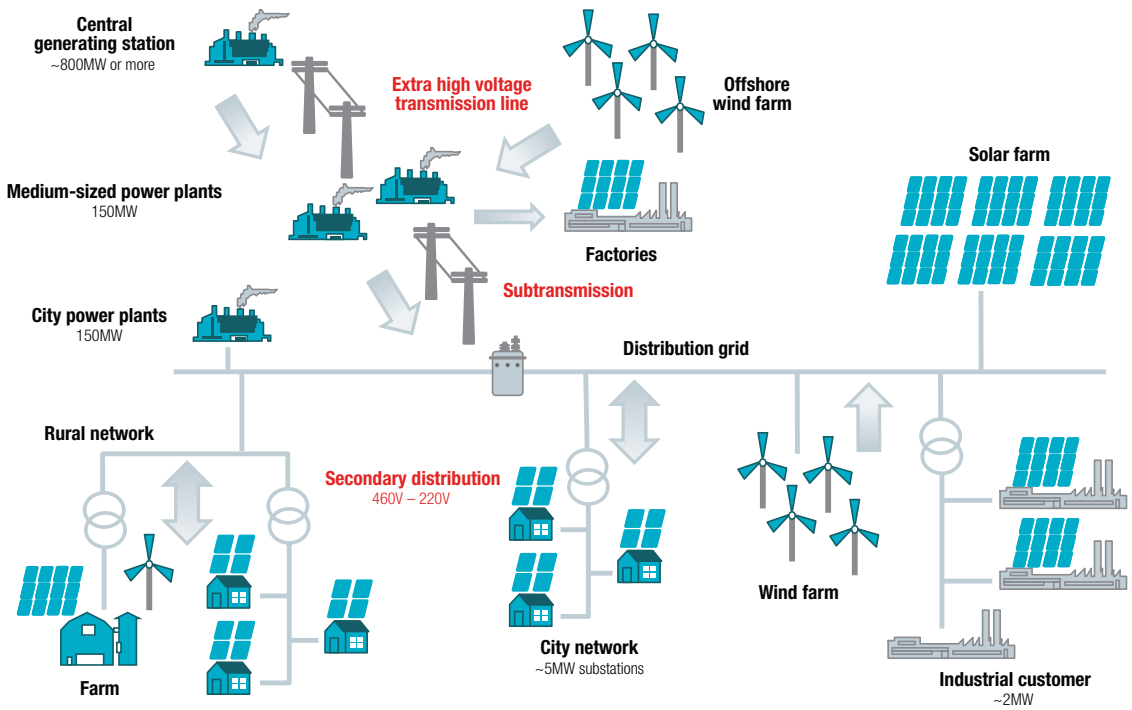

Figure 1. The future smart grid with decentralized generation of energy from renewable sources.

panels and wind turbines in decentralized energy generation, as represented in the figure, which can happen only through the smart grid.

It is difficult to not overstate the significance of smart grids in the years ahead. By some estimates, the world wastes as much as 40 percent of the power it generates. Intelligent, efficient grids can avoid much of that waste, saving us money and cutting deeply into the greenhouse gas emissions that threaten to destroy the earth's climate equilibrium. With a gradual changeover to renewable forms of energy production, made possible in large part by investing in smart grids and enabling grid parity, we can reduce waste and environmental damage even more.

Intelligent electronics for the decentralized smart grid

The intelligence that makes the power grid "smart" comes from advanced electronic technologies that sense, monitor, measure, and provide communication and control. These technologies serve as the foundation for a range of equipment used in the grid infrastructure, including protection relays, power quality monitors, circuit breakers and substation automation systems. Beyond the infrastructure are inverters for solar and wind power, smart meters at consumer sites, and a potentially limitless number of switches, sensors and other monitoring units that feed environmental information into the power grid.

The specific requirements for these applications vary widely, according to equipment usage, industry and proprietary standards, and regulations of different countries. As a result, designing circuits that bring intelligence to these functions can be demanding, forcing designers to look for integrated circuit (IC) solutions that provide flexibility while keeping costs down.

Despite the variation found among smart grid applications, the underlying electronic technology, especially in grid infrastructure equipment, can be generalized as shown in Figure 2.

In the measurement block on the left of the figure, inputs come from external sensors in the form of analog signals such as voltage or current levels. Analog components condition the inputs and convert them into digital signals that are fed into the analytics and control block. Here a microcontroller (MCU), microprocessor (MPU) or digital signal processor (DSP) analyzes the digital signal data to determine, say, usage of electricity, quality of service or a potentially dangerous condition. The processor then orders an action by, for example, a circuit breaker or relay, if such an action is necessary. Then the processor notifies control nodes in other equipments and possibly a central control computer via specialized modules in the communication block, through which it also receives messages from the other units. These blocks all require low-voltage power to operate, which is supplied through separate power management and isolation circuitry.

Since these functions will appear in many applications following different standards, integrated circuit solutions must include options to allow equipment designers to select the capabilities they need. A high level of analog and digital system-on-chip (SoC) integration can help keep costs low and support multiple channels, though in some cases design requirements may dictate the use of separate ICs for functions such as op amps and analog-to-digital converters (ADCs).

On-chip communication solutions such as Industrial Ethernet and Industrial Fieldbus can also provide both economy and flexibility. The processor complex at the heart of a solution should be completely programmable and scalable, supporting multiple

Smart grid control system functional blocks

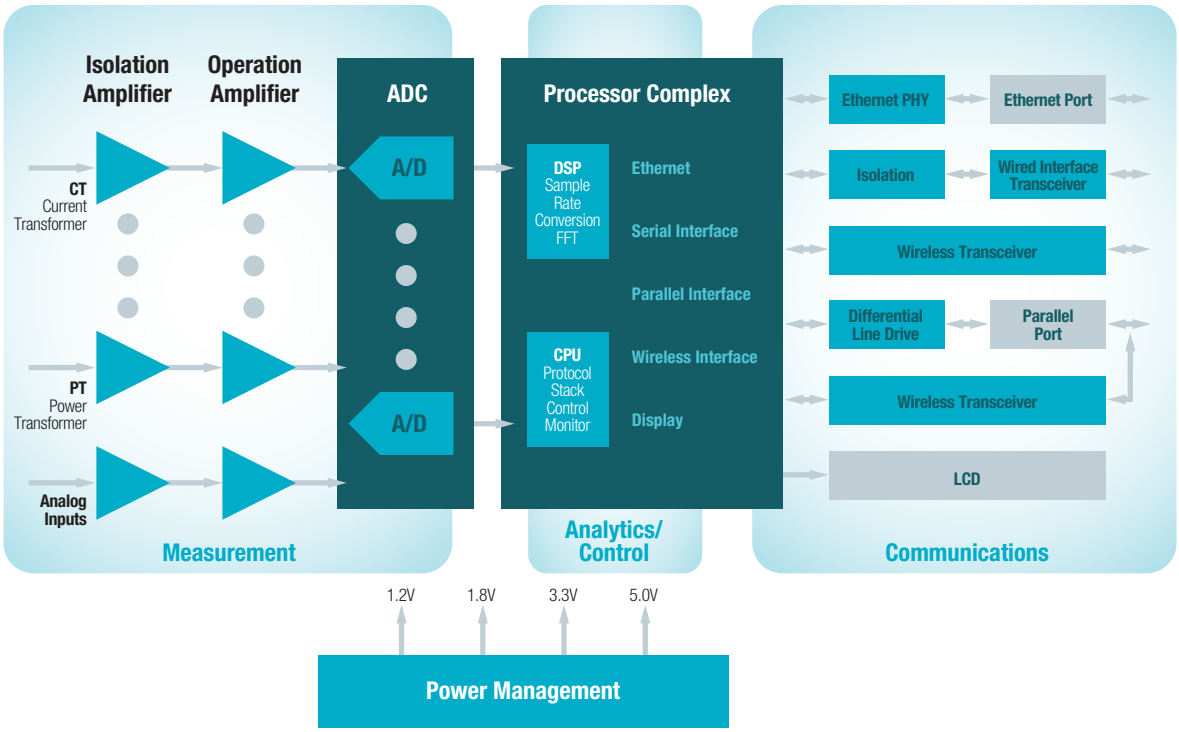

Figure 2. TI's product portfolio provides solutions for all IED blocks

protocols with the same hardware to help reduce system cost and complexity and eliminate the need for custom-designed logic. Software frameworks can speed and simplify development along with tools, reference designs and other support.

Providing solutions for smart grid design

Recognizing the importance of the smart grid and decentralized power generation, TI is working to solve energy problems through innovative technologies, and ongoing research and development. As a leading semiconductor provider for intelligence in the power network, TI has a dedicated smart grid team that develops solutions and participates in international industry standards committees and alliances to understand and drive collaboration to solve future challenges.

TI is driving development in a number of areas, including smart meters, automated substations and solar inverters. These types of systems illustrate the use of electronic intelligence to produce power, to measure power consumption instantaneously for more efficient usage, and to automatically regulate the production of power from different sources and supply it safely to customers.

TI technology is making grid parity a reality by enabling the conversion from traditional one-directional grids into bidirectional smart grids. Using its long-term experience in power inverters, the company enables fast development of renewable generating systems to help achieve grid parity. Its solar inverter and micro-inverter solutions are cost-effective and provide high efficiency by enabling more power output, reducing detrimental heat dissipation and increasing system longevity. The company's solutions allow systems to extract greater power through advanced conversion and maximum power point tracking (MPPT).

TI technology is also at work in smart energy meters, or e-meters, which are rapidly changing the knowledge of electrical consumption patterns. Smart meters use low-power RF or power line communication (PLC) technologies to report customer energy consumption data to utilities. The meters can deliver useful energy consumption information into the home or office through an on-site display or a gateway, allowing consumers to adapt their energy behavior and lower utility bills.

To aid system developers, TI's three-phase and one-phase metering SoCs and a fully integrated Smart Meter Board combines all of the technology required for measurement, communication and control. A smart grid data concentrator aggregates data supplied by local meters and other grid devices before sending it to utilities. It also supports multiple communication standards and various communication interfaces on a single board.

In the power network infrastructure, TI is driving substation automation with new protection relays, circuit breakers, and monitoring systems to control and manage the grid, along with backhaul communication to utility control centers. A broad, scalable portfolio of complementary analog and embedded processing components, covering the full range of functions shown in Figure 2, provides flexibility and ease of development for designers of substation equipments. The company's readily available hardware, software, tools, expertise and reference designs enable customers to easily solve complex measurement, control and communication problems. TI can support multiple worldwide grid deployments, while simultaneously leading field tests with local utilities and manufacturers to ensure the reliability of the grid and interoperability with various standards.

A vision for clean, reliable energy

As the world looks ahead to a growing population with greater energy needs, we must do all we can to conserve and efficiently use power. We must strive to add renewable resources that can generate energy without releasing greenhouse gases or impacting the environment. Smart grids with decentralized energy production from solar panels and wind farms, enabled by advanced electronic technology, can help us reach these ends.

As a leading supplier of analog and processing IC solutions to the power industry, TI plays an important role in developing technology in the changeover to more intelligent, efficient power networks. The company's flexible, high-performance solutions for applications such as solar inverters, smart meters and automated substation equipment are crucial to developing the smart grid with distributed power generation. TI technology advancements help introduce the intelligent measurement, communication and control that is rapidly transforming worldwide energy grids to provide cleaner, more reliable energy in the future.

For more information, visit www.ti.com/corp-ino-ind-mc-lp