Smart grid leverages Arm®-based solutions to enable intelligent power consumption with a more robust end-to-end communication network

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The supply of electrical energy has never been so tight. According to the 2018 Annual Energy Outlook[1], total US energy production will increase by 31% from 2017 to 2050. Countries in various stages of development have faced blackouts for different reasons, even in the most developed countries like the United States.

In October 2012, Superstorm Sandy left an estimated 8 million customers without power in the Northeast region of the U.S.[2], and in July 2012, hundreds of millions of people were left without power in India because utilities failed to build up enough power capacity to meet the demand[3].

Furthermore, a four-hour blackout left an estimated 53 million people in Brazil without power in 2012[4] because of a flaw in a piece of equipment located between two energy substations where the equipment's safety mechanism was not properly programmed[5]. The fact of the matter is global demand for electrical power has outstripped supply and there's no end to the situation in sight. Demand will certainly not abate. In developed countries, consumers will only add to the number of power hungry devices and appliances they already possess and developing nations will continue to expand their power generation plants and distribution grids throughout their countries.

Unfortunately, generating more power is not a viable solution. Those rolling blackouts have pointed out the limitations and in some cases, the weaknesses of the old, unintelligent transmission and distribution power grid. A more feasible solution for both the short and long term is to be more efficient with the electrical power that is already being generated and distributed over the grid. A step in this direction would make the grid itself more intelligent so that power utilities, governmental regulators, power distribution companies and consumers such as homeowners and businesses could better monitor, analyze and control energy generation, distribution and usage.

With the Smart Grid technology, the energy generation and distribution process will be more robust, efficient and economical rather than higher power generation. In addition to increasing the innate intelligence of the grid itself, the smart grid is rapidly evolving into an intricate network with multimodal communications methods. To address this growing need, more Arm-based solutions are being leveraged to control the smart grid. With low power and energy-efficient designs that are ideal for this market, Arm processors help these complex networks increase security functionality, intelligent support for application and communication stacks, and communications functions for home or building connectivity.

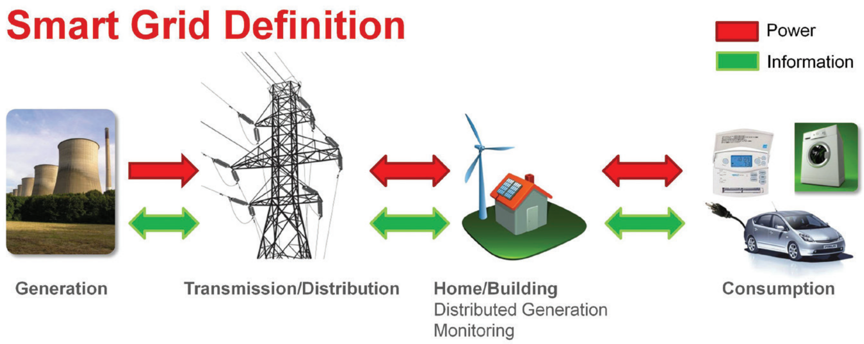


Figure 1. The smart grid with its interconnected nodes of intelligence.

For example, utility providers can detect outages and restore services much faster without the need of contacting the users or sending a crew to confirm restoration, especially in the cases of natural disasters like Hurricane Sandy. Whereas the old legacy grid carried power almost exclusively, communications and intelligence will be integral to the new smart grid that is already emerging.

End-to-end intelligence and communication

The smart grid is far removed from the passive, practically inert infrastructure of power lines and distribution facilities in the past connecting-generation plants to homes, businesses and factories. Instead, the smart grid taking shape today is more like a nervous system that links together nodes of distributed intelligence. Alongside electrical power, extensive communications data will traverse the smart grid. From control systems in generating plants, and transmission and distribution substations, the smart grid will extend to smart meters on homes, businesses and factories. The lifeblood of smart grid will be information and it will pulse with data.

Hierarchically, the smart grid will be comprised of several layers and segments. Beyond the distribution substations will be data concentrators, which will interface substation control systems to a group of smart meters located on residences or businesses in a certain geographic area. A data concentrator would communicate in real time with its smart meters via a wireless link such as sub-1GHz or wired connection like PLC (FSK/G3/PRIME/G1901.2); and for the WAN (Wide Area Network) communication as backhaul GPRS as examples of standards that could be used. The concentrator would gather information from each smart meter at a regular predefined interval. This information would be organized, aggregated and forwarded to a substation according to a sampling rate established by the grid's operator. Sampling intervals could vary, depending on the needs and capabilities of each utility's control system. If the sampling rate must be changed for whatever reason, a simple firmware upgrade to the data concentrators is usually all that is required.

The number of smart meters a particular concentrator interfaces with will depend on the architectural scheme of its segment of the smart grid and the processing capabilities of the concentrator. In urban areas it is expected that concentrators will on average interface with 100 to 150 smart meters, but more powerful concentrators could interface to thousands of meters.

The much greater intelligence and communications capabilities of smart meters will bring a new dimension of control, monitoring capabilities and analytical processing power to not just grid operators like utility companies, but also to individual homeowners and businesses. Smart meters give utilities the kind of in-depth information they have never had before on energy usage at the point of consumption. Likewise for homeowners and businesses, smart meters will be a window into detailed information on power consumption patterns down to the level of individual appliances or machines. Homeowners, for example, would have both a macro and a micro view of their energy usage.

From a macro level, users would have detailed knowledge of the total power consumed in the house, revealing when power consumption is the greatest during the day. From the micro perspective, users could be provided data on power usage rates for each individual appliance in the home, such as the air conditioning unit or hot water heater. This level of data would be obtained from different techniques like disaggregation or breaker panel board monitoring. One way of implementing disaggregation is by monitoring the wave form of the current flow in the home power lines and understanding that different equipment, when in use, can generate different shapes. An Arm® processor running a complex algorithm could detect when each different appliance is on. Another possibility is leveraging the circuit breaker panel board monitoring system. Today, most of the homes/buildings have separate electrical circuits for each room or for major appliances such as a refrigerator, freezer or water heater. All circuits are generally aggregated in a circuit breaker panel board where power consumption could easily be measured. Whether it is through disaggregation or circuit breaker panel board, correlating all of this information could lead to significant power savings.

From the standpoint of a grid operator, intelligent data concentrators connected to smart meters can provide tremendous benefits in terms of improved operational controls and management of the grid. Real-time monitoring information will make the grid more reliable by increasing its resiliency. For example, operators will be better able to quickly respond real time to sudden shifts in power consumption or problems with transmission lines. The effective capacity of the grid itself would increase as a result of reducing energy losses on feeder lines. The constant communication with an operator's assets in the field, such as data concentrators and smart meters, will increase the effectiveness of the utility's inventory management systems. Renewable or distributed energy sources can be effectively integrated into the grid without jeopardizing its integrity. And educating consumers with the information gathered from the smart grid will lead to increased awareness of energy issues as well as better decisions on usage.

Home energy gateways

One key component of the smart grid is a home energy gateway, a device that provides homeowners the detailed level of information, albeit on a smaller scale, that the smart grid provides utilities. An energy gateway could communicate with and control all of the home's energy-consuming devices, including appliances like furnaces, air conditioning units, refrigerators and others. Homeowners would then be better able to closely monitor and control power consumption. Home energy gateways will vary greatly in the capabilities built into each one. High-end gateways could be equipped with wireless Internet access, touch displays and other ease-of-use features whereas gateways for the low end of the market could feature simple LCD displays, or without screens, and local connectivity only to the home's appliances and the grid's smart meter.

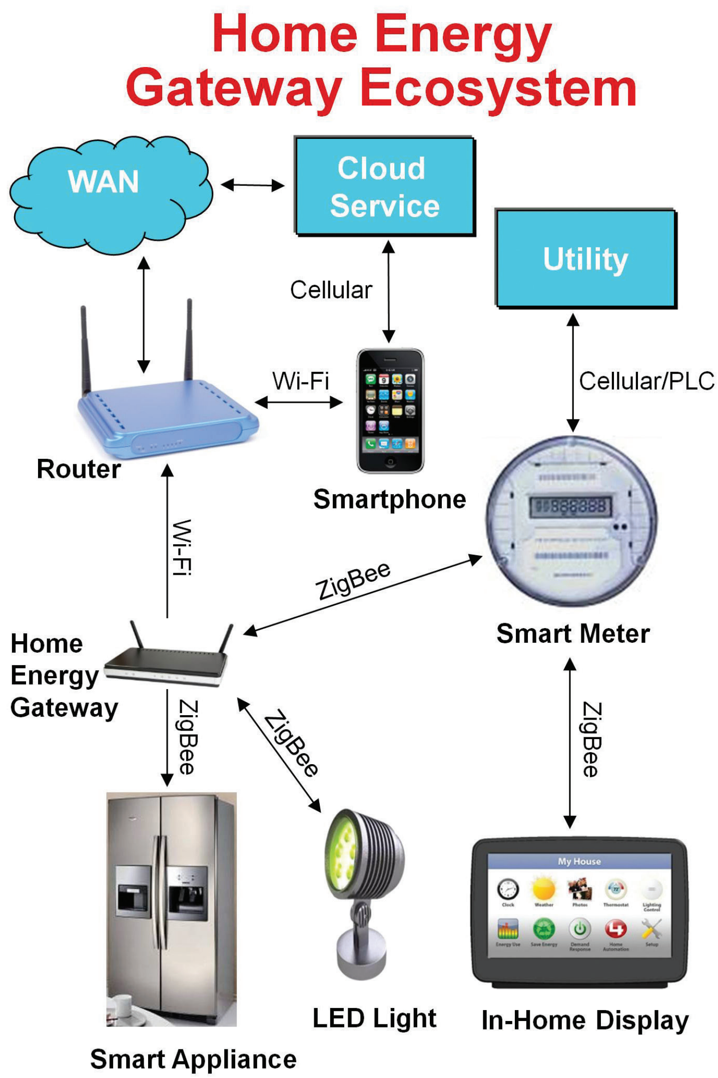


***Figure 2**. A few of TI's communications capabilities for the smart grid.*

Gateways with wide-area connectivity and Internet access would give consumers the ability to control home energy consumption remotely. For example, a home energy gateway might be online with the residence's broadband router via a Wi-Fi® link. The gateway could monitor energy consumption in the home and notify residents of sudden increase in usage via text message to a smartphone. If homeowners are traveling, they could access the energy gateway from a computer or an application on his smartphone to determine the cause of the increase and decide on a course of action.

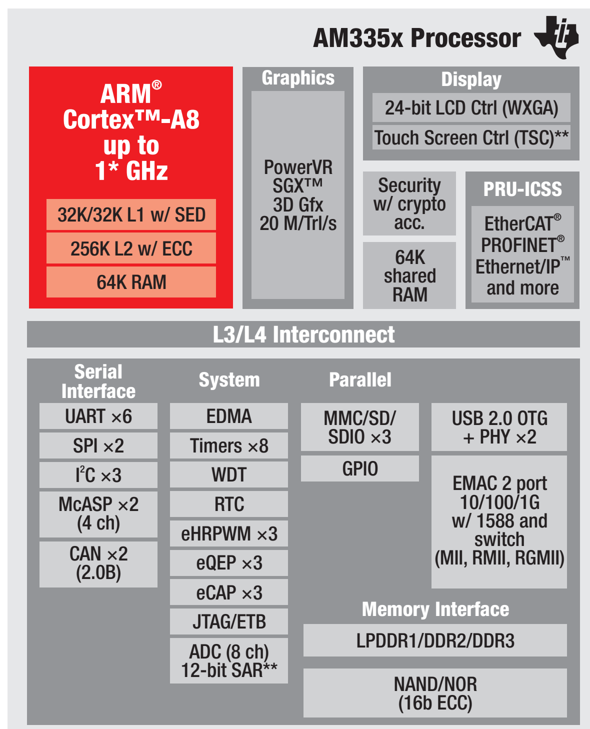
They might decide to turn off several lights in a section of the home where they automatically turn on at night, or increase the thermostat's temperature setting during the heat of the day to reduce energy consumption of the air conditioning unit.

Smart grid solutions

TI is the global systems provider for innovative, secure, economical and future-proof solutions for the worldwide smart grid with the use of a diverse array of technologies. This includes highperformance, low-power and scalable embedded processors and microcontrollers, the broadest portfolio of wired and wireless connectivity solutions, analog front-end technology, power management devices and much more. TI technology and extensive support capabilities, such as reference designs, software development tools, operating systems, cost-effective evaluation modules and an ecosystem of third-party suppliers are being employed at every point in the smart grid, from power plants to substations, homes and businesses.

Sitara™ AM335x Arm® Cortex™-A8 processors, for example, are well suited for data concentrators and other smart grid applications. Some of the key benefits of Sitara AM335x processors include:

- Frequencies ranging from 300 MHz to 1 GHz, which allow designers to select the right device according to the performance needed.
- A scalable platform with pin-to-pin compatible devices.
- 1GB total addressable space, which allows the implementation of large and complex programs.
- An EMAC module that provides an efficient interface between the Arm processor and the networked community.
- 2× port industrial Gigabit Ethernet (10/100/1000 Mbps) with integrated switch – MII/RMII/RGMII and MDIO interfaces that support 1588 time-stamping, AV sync and industrial Ethernet protocols.
- USB 2.0 – 2× OTG controllers with integrated PHYs provide a mechanism that complies with the USB 2.0 standard for data transfer between USB devices up to 480 Mbps. Its dual-role feature allows the capability to operate as a host or peripheral.
- LCD controller/Touch screen controller – The liquid crystal display controller (LCDC) is used to interface to character display panels for text message display or to graphical display panels for image/video display up to WXGA.
- Support for numerous serial peripherals like I2C, general-purpose I/O, two Multichannel Audio Serial Ports (McASPs) and seven UARTS (one via Programmable Real-Time Unit).
- Programmable Real-Time Unit and Industrial Communications Subsystems that supports protocols like IEC61850, EtherNet/IP™, PROFIBUS®, EtherCAT®, PROFINET® and more.
- Out-of-box support for ZigBee®, Wi-Fi® and Bluetooth® solutions.



** 1 GHz only available on 15×15 package. 13×13 is planned for 600 MHz.*
*** Use of TSC will limit available ADC channels.*
SED: Single error detection/parity.

***Figure 3**. Sitara AM335x Arm processor block diagram.*

TI's AM335x Arm® Cortex™-A8-based processor offers the highest DMIPs per dollar while delivering optional 3D graphics acceleration. These features enable easy integration with other equipment and very low stand-by power consumption, less than 7 mW.

TI reference designs are also available for smart meters and home energy gateways. In addition, TI embedded processors can be found throughout many of the control systems that utilities have deployed in their substations and generating plants.

Table 1: A few examples of TI's communications capabilities for Smart Grid.

Wired connectivity

- Power line communications (PLC): G3, PRIME
- Ethernet 10/100/1000

Wireless short-range connectivity

- ZigBee®
- Bluetooth®
- Near field communications (NFC)

Wireless local and wide area connectivity

- Wi-Fi
- Cellular protocols

Industrial connectivity

- CAN 2.0, EtherCAT®, PROFIBUS®, PROFINET®, HSR, PRP

Peripheral interfaces

- USB with PHY
- LCD controller with optional touch interface

Conclusion
Energy's new normal

In the decades ahead, it seems inevitable that demand for electrical energy will continue to increase while supply struggles to keep up. Governments, utility companies and users are already coming to grips with this new normal. Fortunately, technology is rapidly being deployed in the smart transmission and distribution grid to help balance the relationship between demand and supply. Although a smart grid will not add a kilowatt of electricity to the supply of energy, it can help ensure that electricity will be available to consumers by increasing conservation, reducing wasteful usage patterns, and increasing the efficient operation of the grid itself, effectively increasing the supply of electricity to users.

Technical advancements such as TI's line of Sitara™ Arm®-based embedded processors have formed the basis for a host of advanced intelligent systems, which are becoming the backbone of today's smart grid. Smart meters, home energy gateways, data concentrators and advanced substation control systems can now deliver the power of real-time information from one end of the smart power grid to the other, resulting in intelligent generation, distribution and consumption decisions.

References

[1] U.S. Energy Information Administration: “Annual Energy Outlook 2018”

[2] Bloomberg.com: “Sandy Cuts Power to More Than 8 Million in U.S. Northeast”

[3] NYTimes.com: “2nd Day of Power Failures Cripples Wide Swath of India”

[4] Reuters.com: “UPDATE 3–Brazil hit by new blackout, infrastructure in spotlight”

[5] Daily News and Analysis (dnaindia.com): “Human error caused blackout in Brazil”