Smart technologies

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The future of electricity: Diverse, connected, clever

In 2008, South Africans learnt a new term: "load shedding".

Unlike the 2003 "Northeast Blackout" which affected 50 million people in the United States and Canada (or even larger blackouts in Italy, also in 2003, Indonesia in 2005 and Brazil in 2009), load shedding is the planned and scheduled interruption of electricity supply to specific areas or industries in order to make up for a shortfall in generation capacity.

What South Africans experienced was not a "forced outage" or a large-scale blackout, but a "rolling blackout". It has become a common phenomenon in many developing nations. In South Africa, load shedding cost the economy billions and raised a red flag on the state of the country's energy security.

By 2010, South Africa was hosting the world's biggest sports event with power at least temporarily secured. Strides are being made at the policy level to introduce clean energy into the country, not only because of a proactive stance on climate change, but because of the economic security and savings provided by energy efficiency.

Looking forward

Now imagine it is June 2020 and the Olympic Games have come to Durban, South Africa. The sun is just going down as you get home from work. You plug your new "Made in South Africa" hybrid electric car into the garage charge point, keen to kick off your shoes and watch the opening ceremony on your 3D home theatre.

As the house switches on the lights, you cannot tell that there is load shedding going on. But this is not the load shedding of 2008: a smart meter in the house's electrical distribution box has responded to a request from the transmission system operator to save some electricity during the early-evening peak and has switched off the solar geyser's electric back-up system.

Because the car is set to "parked mode" the smart meter decides to only start charging it later in the evening when the price drops to ZAR 0.75 per unit.[1] In fact, at the present peak-time price of ZAR 2.00[2] per unit, it makes economic sense to sell some of the remaining charge in the car's battery back onto the grid, making already-cheap electric mobility even cheaper.

Just like the Football World Cup a decade ago and despite the noticeable impact of climate change, the Summer Olympics are being held during a chilly South African winter – that is to say, cold everywhere but in tropical Durban.

While you are watching the ceremony, you notice that the street lights have gone out. It seems that the load shedding has spread as it often does on energy-thirsty cold nights. Fortunately, your home power monitor tells you that the smart meter was able to divert some of the car's battery power from the grid to the house's LED lights and electronics, so even that goes unnoticed.

Grid computer

This futuristic scenario is but the tip of the iceberg when it comes to the capabilities of a smart grid, of which the smart meter is only one component.

The smart grid embodies the convergence of two types of networked infrastructure: electricity and information and communications technology (ICT). Mobile phones have come to integrate radios, music players, cameras, TVs, email and internet devices. Similarly, smart grids do much more – and do it much more efficiently – than today's grids, which simply pump electricity one way: from power stations to buildings and factories.

In a smart grid, the flow of energy and information is multi-directional: solar panels on rooftops can supply to the grid, while a smart meter monitors and reports on this supply to the system operator and the building's energy management system. If there is a fault on a line or a cable has been stolen or there is a high parasitic load on a specific feeder line, the grid's monitoring systems can notify maintenance teams before anyone has picked up a phone to report it.

With the flexibility that intelligence brings, smart grids are far more robust than today's grid. An intelligent grid can spot problems before they affect or spread through the entire system, and in many cases can self-repair the problem. This includes potential power outages and variations in the quality of supply that cost economies like the United States more than USD 100 billion a year,[3] with commerce and information-based industries suffering the greatest losses.

1 The average wholesale cost of electricity will be ZAR 0.70/kWh by 2013 according to the 2009 Multi-Year Price Determination by the South African energy regulator, NERSA. USD 1 = ZAR 8

2 The marginal cost of peaking electricity (from gas turbines) is around ZAR 3.50/kWh.

3 www.epri-intelligrid.com/intelligrid/docs/Cost_of_Power_Disturbances_to_Industrial_and_Digital_Technology_Companies.pdf

The future is electric

Grids that can predict and plan are also a key enabler for adding large amounts of variable renewable energy to the generation mix. Smart grid applications can predict, for example, the supply of wind power for the next day, the next hour or the next minute based on weather models and real-time data. Other applications can optimise dispatch schedules (how much power is required and when it is required) for different generators.

In addition to electricity supplied from coal, nuclear and renewable energy plants, such a dispatch schedule might include:

- "Dispatchable demand-side management", which reduces demand (as in the example above of an electric geyser that can be turned off on request);
- Drawing electricity into the grid from energy storage (batteries or hydro-pumped storage schemes), which bolsters supply; or, unless it can be avoided
- Bringing quick-but-expensive peaking generators (like gas turbines) online.

The combination of variable renewable energy supply, hybrid and electric vehicles and smart grids are a match made in heaven. By storing the energy from one large (1 MW) turbine in the batteries of 25 electric vehicles,[4] you can get a guarantee of (300 kW of) steady power, even when the wind comes and goes. The car owner, in turn, gets access to clean energy at a very low marginal cost. A smart grid brings all of this – distributed, renewable energy power and energy storage devices like vehicle traction batteries – together, where and when required.

Smart grids are set to revolutionise energy markets by providing real-time information across the grid. This is essential for the implementation of flexible pricing mechanisms like time-of-use tariffs, free basic electricity, escalating block tariffs and electricity quota systems (like that contemplated for the South African government's Power Conservation Programme). You cannot get real-time information from a monthly reading of a meter. You need intelligent systems that can record and transmit usage data in a structured way to multiple users of that data: the user of the electricity (via the building or process monitor), the utility supplying the electricity and the system/network operator who manages it.

Intelligent empowerment

Just as telecommunications networks have given rise to e-commerce, smart grids also support new markets: electricity "users" are empowered to become "participants" in the energy market – they can sell electricity they produced or stored or even electricity they *did not* use back to the system operator.

On top of this, smart grid participants (homes, businesses or factories) can choose to buy and sell electricity at the time when they would benefit most: buying off-peak and selling back excess power during peak times. The mechanics of supply and demand in an open and real-time energy market ensure that prices rise sufficiently when demand is high for additional supply to become available.

Because information on energy usage is also more visible – for example, it can be displayed in real time on an energy-use monitor – smart meters help change consumer behaviour to save more energy. Together, all of the energy-saving effects of smart grids are expected to reduce US consumption by as much as 4.3% by 2030.[5] The accompanying reduction in greenhouse gas emissions would be equivalent to converting 14 to 50 million cars to zero-emission vehicles every year.

A global movement

With all of these advantages, it is little wonder that smart grids are getting a lot of attention worldwide. In the United States, more than thirteen cities[6] have announced roll-out programmes for between one and five million smart meters each. In 2009, the federal government also earmarked USD 4.5 billion in stimulus funding to smart grid projects.

In the European Union, research on smart grids started in 2005 and smart grid policies are now being developed. South Korea plans to roll out a complete smart grid by 2030 and has started developing pilot programmes, Australia has committed USD 100 million to smart grids, and China is rolling out a smart grid focused on the transmission network.

4 A plug-in hybrid electric vehicle (PHEV) with a 100-km range can provide planning reserves of 1.5 kW and operational reserves of 5.8 kW (www.spinnovation.com/sn/Reports/A_Preliminary_Assessment_of_Plug-In_Hybrid_Electric_Vehicles_on_Wind_Energy_Markets.pdf). A wind turbine of 1 MW, at a 30% capacity factor and with a 15% capacity credit (corresponding to medium levels of penetration) requires 150 kW of operating reserve for 300 kW of "firm capacity" (lightbucket.wordpress.com/2009/03/12/the-capacity-credit-of-wind-power). Thus, 150kW/5.8kW=25 PHEVs.

5 www.smartgridnews.com/artman/uploads/1/SGNR_2009_EPRI_Green_Grid_June_2008.pdf

6 David J. Leeds, GTM Research (2009) *The Smart Grid In 2010: Market Segments, Applications and Industry Players*. www.gridwise.org/documents/090901The%20Smart%20Grid%20in%202010%20GTM%20Research(revisedSept09).pdf

Some of the world's leading businesses are developing and selling smart grid products. This includes established engineering companies like ABB, Siemens and General Electric, as well as ICT companies like IBM, HP, SAP, AT&T, Cisco and Google. Upstart "cleantech" companies are also getting a share, including Comverge, Echelon, EnerNOC, GridPoint and Itron.

Companies specialise in different aspects of the smart grid architecture, including the power layer, the information layer and the application layer. Products span the whole power system, from generators to homes or factories, with the entire electrical infrastructure in between.

While there are still some competing standards for home area networks, some smart grid communications are converging on the leading standards in use in the ICT industry. This includes wireless standards like 2G/3G, WiMax and Wi-Fi.

As energy security and climate change continue to bite, we will require an energy revolution. Such a revolution, like many others, must be accompanied by better information, more accurately communicated, and mediated by technology shaped to our needs.[7] ■

7 For comprehensive information on smart grids, see the resources section of the US GridWise Alliance at www.gridwise.org/resources_gwaresources.asp