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Building a Truly Smart Grid: What Can We Do When There Is No Legacy System?

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"Over 1.2 billion people - 20% of the world's population - are still without access to electricity worldwide, almost all of whom live in developing countries. This includes about 550 million in Africa, and over 400 million in India."[1] Much of this need for electric power will not, and should not, be met by power systems that emulate the infrastructure created in the developed world during the past century. Mature power systems are built around the century-old paradigm of large-scale generation. The economy of scale offered by these systems, which rely primarily on fossil fuels, is now offset by their detrimental environmental effects. Much of the challenge of introducing renewable energy and smart cyber technologies into developed markets has to do with the massive technological and regulatory infrastructures that have evolved to support the existing systems.

Just as mobile telecommunication has flourished in the developing world in the absence of legacy landline systems, the absence of a pervasive existing energy infrastructure offers possibilities for introducing renewable and cyber technologies from the outset, with completely new methods and paradigms for meeting demand for electricity with highly distributed and heterogeneous sources of energy. In Africa, a remarkable variety energy sources are being developed, including hydro, geothermal, solar, biogas, and biomass gasification. A number of pilot projects are underway throughout the continent, creating islands of electrification at different scales. Rural electrification is being achieved through a mixture of on-grid generation and isolated micro-grids, including solar systems that provide low-voltage DC to satisfy basic demands for LED lighting and recharging mobile phones. This is leading to an energy future in Africa based on a diversity of highly distributed small-scale generation. The heterogeneity and distribution of generation in Africa presents the opportunity to explore the application of new cyber technologies and control strategies, without the daunting obstacle of having to retrofit an enormous legacy system predicated on a totally different paradigm.

Infusing emerging energy systems with sensing, communication and distributed control technology is the key to realizing a reliable and sustainable energy future for the developing world. Completely new

[1] World Bank: Energy—The Facts
http://web.worldbank.org/WBSITE/EXTERNAL/TOPICS/EXTENERGY2/0,,contentMDK:22855502~pagePK:210058~piPK:210062~theSitePK:4114200,00.html

thinking and innovation is needed because energy markets in emerging markets will differ so significantly from mature energy markets, both in demand as well as the future nature of the supply. For example, in the develop markets, consumers demand 24/7 access for appliances such as refrigerators, TVs, and washing machines, and air conditioning, and there has been some resistance to increasing sensing and relinquishing control for effective demand response. In contrast, in the developing markets there is a high awareness of energy usage by consumers who are willing to adjust their lives to accommodate intermittent availability.

Introducing a rich cyber infrastructure as the physical resources are being developed will make it possible to design, deploy and evaluate new strategies for managing the radically different energy system that is emerging in much of the developing world. The network of cyber elements should be conceived from the outset to support rapid change as both generation and demand evolve in these emerging markets, where operating objectives and constraints are certain to vary rapidly for the next several years. Initially, operating strategies should focus on managing relatively scare energy resources to deliver power to the most critical loads, such as healthcare and production facilities, while continuing to improve the general standard of living through well-managed and predictable delivery of power to homes and market centers. Given the availability of highly distributed energy supplies, much of which will be created initially as off-grid micro-grids, the cyber infrastructure should make it possible to switch the network topology fluidly between self-sufficient islands and interconnected sub-grids as the demand and availability of power change. New methods will be needed for learning and adapting to the evolving changes in the amount and type of demand, as the availability of power will in turn stimulate new demands for power. There will need to be a much stronger integration of long-term planning and operational tools to take advantage of real-time data for effective forecasting across time scales. The cyber infrastructure and computational intelligence embedded in the power systems for the developing world need to be agile and extensible, rather than static and brittle, to take full advantage of the growth and variety of both generation and demand.

In summary, the energy “green fields” of the developing world offer opportunities to explore not only technologies for renewable generation, but also technologies and strategies for operating this evolving energy landscape in smart ways that are tailored to the specific features and needs of Africa. Just as innovations such as mobile money have emerged from Africa rather than the developed world, we anticipate that the new energy markets have the potential to become the most fertile regions in the world for smart-grid innovation.