Text of article published in *IEEE Smart Grid*, March 2012.
http://smartgrid.ieee.org/march-2012/527-microgrids-an-emerging-technology-to-enhance-power-system-reliability

Title: **Microgrids: An emerging solution to combat reduced power reliability**

Authors: **Siddharth Suryanarayanan, Elias Kyriakides**

Catastrophes, natural or man-made, that affect any critical infrastructure have a profound effect on the society. Such recent international events include: the major power outage in the San Diego area that caused approximately 3 million gallons of sewage spilling into the Los Penasquitos lagoon following the tripping of a 500 kV line in Arizona in September 2011; the disaster in the wake of hurricane 'Irene' in the US that left more than 50 dead in August 2011; the tragic explosion at the 'Evangelos Florakis' naval base in Cyprus, in July 2011, that killed 13 and injured several dozens more; and the Fukushima nuclear disasters in Japan in March 2011. In the aftermath of such events, large portions of the centralized electricity grid are compromised, thus subjecting huge sections of the population to erratic supply, with prolonged and frequent power cuts, and lowered electricity supply reliability- e.g., over 7 million customers suffered power cuts in the areas affected by 'Irene'. Rebuilding efforts from the effects of such disasters are hugely affected when a critical infrastructure like electricity becomes unpredictable. No society will be able to recover and rebuild with efficiency when critical sources are compromised.

How can customers make themselves less vulnerable to such widespread unreliability in electricity supply? The answer lies in an emerging paradigm of the electricity grid known as *the microgrid*. This, in its broader sense, refers to a smaller electricity grid with access to all the essential assets of a larger grid such as generators, transmission lines, substations and switchgear. Imagine an electricity infrastructure that is highly decentralized, i.e., with many microgrids catering to clusters of end-user loads, as opposed to one centralized generating station serving as the supply center. Initially microgrids have been realized at the distribution voltage level. This idea may be extended to higher voltage levels. If, or when, a disastrous system event strikes a part of this decentralized infrastructure, then this infrastructure is inherently capable of isolating that damaged or compromised part, while keeping the rest of the system isolated from the catastrophic event. This can be achieved by the use of evolving control and communication systems in engineering. A cluster of microgrids avoids single-points-of-failures in the electricity grid, thus increasing the reliability and security of electricity supply to the end-users. The part that is compromised can then be rectified with greater help from the parts of the electricity grid that are not affected.

The US Department of Energy views the microgrid as an entity that could support several of the recommendations of the Smart Grid Initiative [1]. While the microgrid may possess several advantages, including the opportunity to integrate some ‘greener’ but smaller rated electricity sources such as photovoltaics in the grid, it comes with challenges too. A major socio-economic challenge is the concerted change in the electricity grid infrastructure. Historical evidences for such fundamental changes to any critical infrastructure point to subsidies and influx of funding from governmental sources (e.g., the internet, cell phone revolution in telecommunications). Such governmental stimuli must also be accompanied by active participation from the for-profit private business sector. According to a study published in 2012 by Pike Research, the worldwide market opportunity in microgrids is expected to reach USD 17.3 billion by 2017 – this corresponds to an increase in total installed capacity of microgrids from 1.1 GW to 4.7 GW [2]. Increased governmental funding and active policy making with the engagement of the private sector and utilities are imperatives for this change.

The most significant challenges on the technical front are the development of standards for operating these decentralized microgrids and studies to convince utilities that intentional islanding of the larger grid into smaller self-sustainable microgrids, during system events, is non-detrimental. The IEEE 1547.4 is one such forward-looking standard for engaging microgrids or electrical island resources with electric power systems.

Currently, North America has the largest share in the microgrid market; this should not come as a surprise to the reader as the US has promoted grid modernization through the Smart Grid Initiative, as an Act of the 110th Congress. Several billions of dollars have been allocated for achieving the Smart Grid through the Stimulus Act of the 111th US Congress. The United States Department of Defense, through the Smart Power Infrastructure Demonstration for Energy Reliability and Security (SPIDERS) program, is engaged in investigations on supplying various US bases by means of microgrids [3]. Europe is also investing significantly in a modernized electricity grid. For example, the More MicroGrids project has been pursued via the 6th Framework Programme of the European Union [4].

Subsequent to the blackouts due to 'Irene' in the US and the naval base explosion in Cyprus, experts have pinpointed the applicability of microgrids to provide emergency power to localized customers by intentional islanding. In Japan, the inability to deliver power across the uniquely structured electricity grid, with both 50 Hz and 60 Hz supplies, contributed to the lack of electricity supply to the parts affected by the tsunami in March 2011. Specifically, the microgrid located at the Tohoku Fukushi University in Sendai performed remarkably well in keeping the loads supplied when the rest of the system was compromised in the aftermath of that tsunami [5]. While it may be premature to comment on the details of the September 8th, 2011 outage in the Western US grid at the time of writing this article, it appears that self-sufficiency in the affected areas may have helped in tiding over the outage. If the electricity supply in such scenarios worldwide had not been so dependent on centralized power stations and assets, rather on an aggregate of geographically disperse microgrids, it is apparent that the customers would be experiencing a greater reliability of electric supply, thus being in better position to aid the parts of the system with compromised reliability. It is time for utilities to consider an evolutionary change in the electricity infrastructure, and microgrids may hold that key to modernization and the realization of the Smart Grid.

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Bio of authors:

Siddharth Suryanarayanan (S'00, M'04, SM'10) is an Assistant Professor in the Department of Electrical Engineering and a Resident Faculty Fellow in the School of Global Environmental Sustainability (SoGES) at Colorado State University. His research and teaching interests lie in the area of design, operation, and economics of advanced electric power systems. He has over 50 publications in journals and conference proceedings. He received the IEEE Power & Energy Society's T. Burke Hayes Faculty Recognition Award in 2009. In 2011, he was invited to participate in the US Frontiers of Engineering Symposium conducted by the US National Academy of Engineering.

Elias Kyriakides (S'00, M'04, SM'09) is an Assistant Professor in the Department of Electrical and Computer Engineering at the University of Cyprus, and a founding member of the KIOS Research Center for Intelligent Systems and Networks. He is the Action Chair of the ESF-COST Action IC0806 "Intelligent Monitoring, Control, and Security of Critical Infrastructure Systems" (IntelliCIS). His research interests include the security and reliability of the power system network, optimization of power system operation techniques, energy generation from renewable sources, and the design of future power networks. He has over 70 publications in journals and conference proceedings.