A Case for Microgrid Architectures for a More Effective Use of Renewable Energy[1]

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This position statement considers electric powering of cyber-controlled infrastructures (called hereafter "smart infrastructures") from a majority of renewable sources. Example cases for smart infrastructures may be a system of charging stations capable of serving a large deployment of electric vehicles (the future analog to a present network of gas stations), or a telecommunications network, like a wireless cellular network. An increased and more effective use of renewable energy faces the challenge of its variable availability. In this position statement we argue that this challenge can be addressed through the use of microgrid architectures that allow for a tight integration of the load in the smart infrastructure and its associated electric power generation and energy storage system. This tight integration results in a more sustainable single cybernetic energy-smart infrastructure system.

With the adoption of a microgrid architecture, the power generators based on renewable energy are located near or within the smart infrastructure load. A goal to power the smart infrastructure from renewable energy also implies the deployment of energy storage systems within the energy-smart infrastructure system. Consequently, this configuration enables a single cyber-physical system where input from the existing and predicted load from the smart infrastructure and the availability of renewable energy can be jointly processed to manage the smart infrastructure so that powering from renewable energy is maximized. Realization of this approach necessitates research into algorithms that manage the load presented by the smart infrastructure based on renewable energy availability and models for dynamic load presented by the smart infrastructure in the context of the power generation and energy storage subsystems being configured in a microgrid configuration. Also, the realization of this cyber-physical system will require investigation into sensing and data networking technologies that allow for the integration of measurements indicating the status of the microgrid and the smart infrastructure and the distribution of the consequent adaptation commands to the system components.

The central element in the integrated microgrid-smart infrastructure system is an operation and management platform which receives and integrates operating conditions data from the smart infrastructure, the microgrid and renewable energy availability, processes this data and issues management commands to all the system components. Within the operation and management platform, a

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“dynamic availability estimator” (DAE) performs real time evaluation of system status in order to produce the decision commands that aim at maximizing resources availability within the microgrid-smart infrastructure system. The realization of effective DAEs will require research into automatically generated flexible availability model for the elements in the integrated microgrid-smart infrastructure system. This model should consider both historical and present data in order to adjust components failure rates. Also, modeling should consider variable renewable energy sources, energy storage, fuel supply for sources requiring external provision of fuel, and the dynamic characteristics of the different smart infrastructures loads, including the dependence on adaptable parameters that have an impact on the presented load. The second part involves synthesizing data networking approaches in order to identify how to manage the microgrid resources effectively. This modeling looks at the integrated microgrid-smart infrastructure system from a reliability perspective, including the study of the availability of stochastic sources, such as photovoltaic sources, the impact of operational profiles on components unavailabilities through variable failure rates, and the characterization of local energy storage resources. With respect to the integrated management of all elements in the integrated microgrid-smart infrastructure system, it is very interesting to note the straightforward analogies between the management of traffic in a computer network and the management of energy flow and storage within a microgrid: flows are limited by transport capacity and buffers need to be managed both in terms of storage capacity, in-out flow and stability. In this sense, a valuable research direction is one that studies analytical framework that integrates concepts of data networking into resource management in local power systems.

More importantly, the tight integration between the load in the smart infrastructure and its associated electric power generation and energy storage system, which is enabled by the microgrid, presents the important advantage of enabling the adaptation of the smart infrastructure in ways that would not be possible otherwise. For example, in [1] and [2], we presented work recently supported by the National Science Foundation under award No. CCF-1331788 where the level of compression associated with video traffic in a cellular network is adapted based on the availability of renewable energy within the system. In essence, the traffic serviced by a cellular base station is shaped by managing the active wireless applications so that power consumption is reduced when necessary based on the renewable energy availability. Today’s wireless networks achieve the high level of performance based in a significant part on very sophisticated radio resources management. In this approach, energy and load (radio resources in this case) are managed as a single cyber-physical system. Moreover, this approach enables to consider all components of the system as, for example in the case of a cellular base station, the air conditioning/cooling subsystem. This perspective emphasizes how the integration between load and power generation enabled by the microgrid configuration expands the level of control on the smart infrastructure both in depth and in breath, which opens multiple potential tracks for further research.

Moreover, there exists a growing body of evidence that indicates that an increased use of renewable energy to power smart infrastructures using a microgrid configuration results in higher levels of resiliency for the infrastructure. For example, this was observed in the case of telephone switches affected by hurricanes, [3]. As such, research into microgrid architectures for powering from renewable energy smart infrastructures relate also to the study of technologies to increase the reliability and resiliency of the infrastructure.

References

[1] Kwasinski, A.; Kwasinski, A.; *"Traffic Shaping for Extended Operation of Green Mobile Network Powered from Renewable Energy"*, submitted to 2014 IEEE Wireless Communications and Networking Conference (WCNC).

[2] Kwasinski, A.; *"The Role of Video Coding Efficiency in Green Cellular Networks"*, submitted to 2014 IEEE International Conference on Audio, Speech and Signal Processing (ICASSP).

[3] Kwasinski, A.; *"Lessons from Field Damage Assessments about Communication Networks Power Supply and Infrastructure Performance during Natural Disasters with a focus on Hurricane Sandy,"* FCC Proceeding Docket number 11-60 "In the matter of reliability and continuity of Communications Networks, Including Broadband technologies effects on Broadband Communications Networks of Damage or Failure of Network equipment or severe overload." February, 2013.