ARTICLE IN PRESS

The Electricity Journal xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

The Electricity Journal

journal homepage: www.elsevier.com/locate/tej

Special Issue: Contemporary Strategies for Microgrid Operation & Control

An integrated reconfigurable control and self-organizing communication framework for community resilience microgrids

Lei Wu[a,*], Jie Li[a], Melike Erol-Kantarci[b], Burak Kantarci[b]

[a] Electrical and Computer Engineering Department, Clarkson University, Potsdam, New York, United States
[b] School of Electrical Engineering and Computer Science, University of Ottawa, Ottawa, Canada

ARTICLE INFO

Keywords:
Community resilience micrgrid
distributed energy resource
resilience
integrated control and communication

ABSTRACT

CRMs can effectively share distributed energy resources of multiple owners and enhance resilient electricity supply in communities during disruptions. However, in contrast to single-entity microgrids, CRMs present a unique structure and bring new challenges for operations and control, which can often be interrupted due to cascaded failures in interconnected electrical/communication components. An installation in Potsdam, New York, incorporates some control/communication solutions for resilient and economic operation of CRMs.

1. Introduction of community resilience microgrids

There is an increasing frequency of catastrophic weather events in the United States and globally, which inflict serious social and economic impacts. The critical issue associated with such catastrophes is the availability of electricity for recovery efforts. In fact, according to a report by the National Oceanic and Atmospheric Administration (NOAA), the U.S. has sustained 188 weather and climate disasters since 1980, more than 80% of them bringing damages to the nation's electricity infrastructure (NOAA, 2014). The most notable example is Hurricane Sandy in 2012, which cost some 8.5 million customers their power during the storm and its aftermath (NOAA, 2013). Similar incidents, mostly due to ice storms, were also observed in Canada (Canadian Disaster Database, 2017) and other places around the globe.

Fortunately, as an emerging technology, community resilience microgrids (CRM) can enhance resilient electricity supply to critical loads in the community during such disruption events. A CRM includes multiple distributed energy resources (DER) and critical loads that are owned and controlled by individual entities within a clearly defined electrical boundary, which are connected via primary distribution lines owned by a local regulated power company. Indeed, as shown in Fig. 1, CRMs extend benefits of traditional single-entity, behind-the-meter microgrid systems by effectively sharing DERs among multiple partners within a community, which could enhance energy resiliency by reducing the overall impact of and improving response and recovery to critical events for the entire community.

However, a CRM presents a unique structure and brings new challenges for its operation and control. Specifically, DERs owned and controlled by individual partners can either represent individual stakeholders' financial interests when the CRM is operated in grid-connected mode, or collaborate as a single controllable entity for enhancing resilient electricity supply to critical loads when CRM is islanded. That is, in grid-connected mode, each CRM partner acts as a self-interested entity and operates DERs/flexible loads according to its specific objectives; during disruption events, on the other hand, CRM partners can coordinate with each other by sharing onsite generation capacities and flexible load curtailment/shifting capabilities, in order to supply community critical loads based on certain agreements. Thus, in different CRM operation modes, partners in a CRM would act as either self-interested competitors or as altruistic collaborators following the guidance of the CRM operator.

Furthermore, CRMs are complex networked systems, which not only interconnect DERs and loads of multiple owners through distribution lines but also are overlaid with a communication and control system that gathers inputs and sends out control signals to multiple owners for enabling resilient and economic operation. Indeed, CRM operations can often be interrupted or halted due to the cascaded growth of failures in interconnected electrical/communication components or unwillingness/inability of individual CRM partners to respond. Thus, in order to enable the full functionality of CRMs, an integrated control and communication framework is needed for facilitating CRM operations while complying with system control and communication requirements under different operation modes.

This article discusses the unique operational characteristics of CRMs across multiple timescales in different operation modes, and presents coordinated system control and communication solutions for enhancing resilient and economic operation of CRMs. Section 2 discusses a practical CRM project that is underway for serving the city of Potsdam, N.Y.

* Corresponding author.
E-mail address: lwu@clarkson.edu (L. Wu).

http://dx.doi.org/10.1016/j.tej.2017.03.011

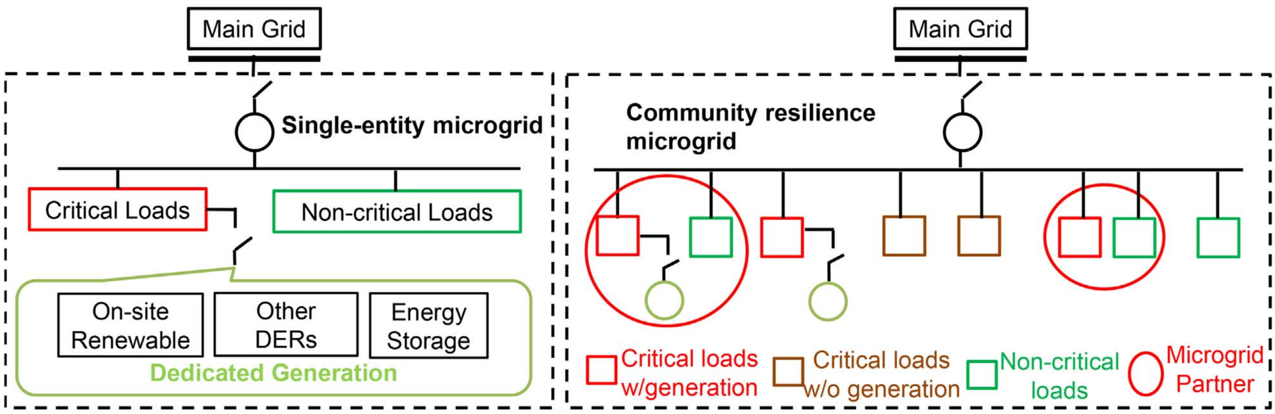

Fig. 1. Single-entity microgrid versus CRM.

Section 3 evaluates different operation strategies of a CRM in order to optimally manage dispatches of DERs in grid-connected mode and enhance resiliency in islanded mode. Section 4 presents a self-organizing, small cell-based infrastructure for ensuring flexible, fast, and reliable communication requirements of CRM operations. Section 5 describes an integrated reconfigurable control and self-organizing communication framework to study the interdependency and interaction between control strategies and communication requirements. The paper is concluded in Section 6.

2. Current efforts of the CRM Project in Potsdam

The development of CRM technology to address disaster response is currently underway through multiple projects across the U.S. One of such projects is the "Design of a Resilient Underground Microgrid in Potsdam, NY," (Clarkson University prime contractor, 2014) jointly funded by the New York State Energy Research and Development Authority (NYSERDA) and National Grid. This project is unique in that it involves four electrical generation owners and as many as six additional entities served by the CRM, with interconnections owned by National Grid, the regulated utility serving the area. A preliminary plan for the Potsdam CRM is shown in Fig. 2.

Catastrophic weather events in Upstate New York, such as ice storms, major snow events, and micro-burst wind events, have historically caused widespread damages. The risks posed to residents and the coordination of emergency services are extremely challenging. One of the most devastating events was the ice storm of 1998, which affected most of northern New York State, southern Canada, and northern New England, and caused over $1.4 billion in damages/costs and 16 deaths in the U.S. (Ross and Lott, 2016). In fact, the availability of a functioning CRM after the disruption of the main grid during these events can enable operations of critical services and mobilization of first responders. Such a CRM can also furnish a functional staging area for teams to perform disaster recovery tasks in the region and address the immediate needs of the most affected population.

The Potsdam CRM project is led by Clarkson University, partners with GE Energy Consulting, Nova Energy Specialists, and National Grid. Subsequently, during 2014 to 2017, four synergistic projects have been funded by U.S. DOE, NSF, and New York State Department of Public Service (NYDPS). The DOE project led by GE Global Research funds the development and testing of a microgrid controller, in which Clarkson is subcontractor. One NSF project led by Clarkson University focuses on the human-machine operational impacts of the CRM during normal operations and disaster response, while the other NSF project led by

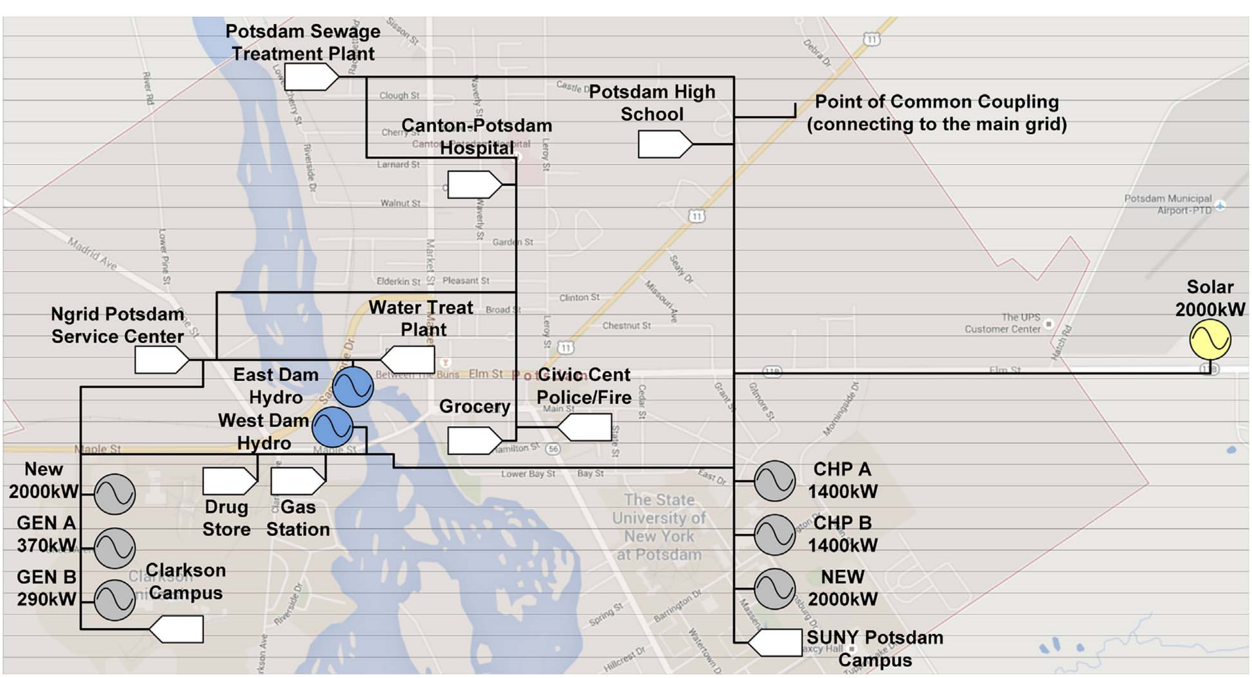

Fig. 2. Conceptual diagram of the Potsdam CRM.