Real Time Reconfiguration and Multi-Level Control for Microgrid

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Motivation

- To maintain the availability of energy to the connected loads and to interrupt the smallest portion of the microgrid under any abnormal conditions
- To minimize problems due to relatively slow reconfiguration algorithms that cannot overcome real-time dynamics following any disturbance/fault
- To improve power system reliability for sensitive loads by better multi-level control mechanism for different operating sceanrios
- To optimize renewable energy and local power resources to supply local load demand

Objectives

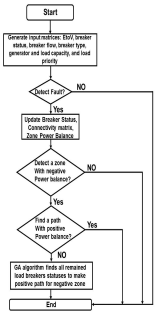
- To design a reconfiguration algorithm that can provides solution to maintain power to key loads
- To validate developed reconfiguration algorithms in real time before implementation using hardware in the loop setup and commercial automation controllers
- To model a microgrid that consists of DER as well as sensitive and non-sensitive loads
- To design controller that can regulate power sharing among DGs in an islanded and connected microgrid
- To design controller that can manage power exchange between grid and microgrid as well as among adjacent microgrids

Real-Time Reconfiguration of Microgrid

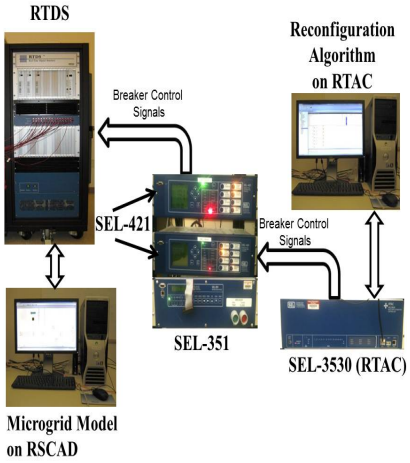
Intelligent Reconfiguration Algorithm (IRA)

- Using graph theory and genetic algorithm
- Graph Theory
  - Model system and utilizes required matrices
- GA
  - Find optimal solution for breaker status in order to maximize served load w.r.t. load priority
- Components of power system are elements of graph representation
  - Vertex of graph
    - Generator - Load - Cable - Bus
  - Edge of graph
    - Circuit Breaker
- Fitness Function for GA
  - λ_{M_i} is priority for i^{th} load
  - x_i is i^{th} load CB status
  - P_{L_i} is power served to i^{th} load

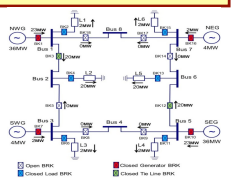
$$Maximize\ f(x) = \sum_{i=1}^{n} \lambda_{M_i} x_i P_{L_i}$$



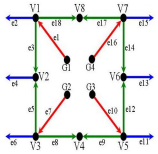
Hardware Setup



8-BUS System



Graph Representation



Real-Time Result

Test case	Faulted Bus Number	Negative power bus	Possible power supply path	Load Shedding	Breaker reconfiguration	MW Served
Case1	B1	B2	B2-B3-B4-B5-B6-B7-B8	L4	BK 11, 1, 2, 3, 18 (O) BK 5, 8, 9, 14 (C)	44
Case4	B1, B7	B2	B2-B3-B4-B5-B6	L3, L4	BK 1, 2, 3, 18, 17, 14, 15, 16, 11 (O) BK 5, 8, 9, 14 (C)	40

Multi-Level Control for Multiple Microgrids

Algorithm

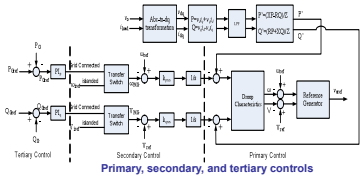
Multi-Level Control of Microgrid

Level 0 (inner loops):	Level 1 (primary):	Level 2 (secondary):	Level 3 (tertiary):
- Internal current loop - External voltage loop	- Power sharing among DGs	- Voltage magnitude and frequency restoration - Synchronization	- Power exchange between grid and microgrid or among adjacent microgrids
(PI and PWM)	(Droop and PI)	(PI)	(PI and MAS)

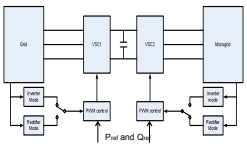
Example of Simulated Scenario

Islanded	Power sharing among DGs	Level 1 control
Grid-connected	Power exchange between grid and microgrid	Level 3 control
Transition	Seamless transition between grid-connected and islanded operation	Level 2 control (Synchronization)
Multiple microgrids	Power sharing among adjacent microgrids	Level 3 control

Control implementation



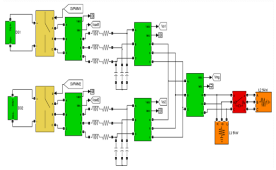
Primary, secondary, and tertiary controls



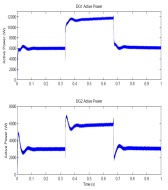
Back-to-back bidirectional converter for tie-line control

Note: Pref and Qref are from DMS or MMS or manually set

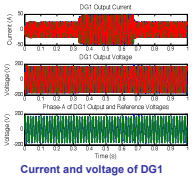
Example of Simulation Results



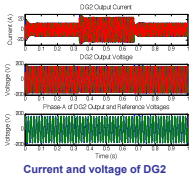
Microgrid is in islanded operation.
Generators: DG1: 15kVA, 480Vdc, DG2: 7.5kVA, 480Vdc
Loads: Two lumped 9kW.
Load changes: a) 9kW to 18kW at 333ms, b) 18kW to 9kW at 666ms



Active Power of DG1 and DG2



Current and voltage of DG1



Current and voltage of DG2

Summary

- Reconfiguration algorithm is fast enough in real-time to maintain maximum load under all possible conditions
- IRA can handle multi-objective functions and successfully implemented in real-time
- Droop control can share power between two parallel DGs based on their rated powers and local measurement only.

References

[1] F. Shariatzadeh, R. Zamora, and A. K. Srivastava, "Real Time Implementation of Microgrid Reconfiguration," presented at 2011 North American Power Symposium, Boston, MA, Aug. 2011.
[2]J.M. Guerrero, J.C. Vasquez, J. Matas, L.G. de Vicuña, and M. Castilla, "Hierarchical Control of Droop-Controlled AC and DC Microgrids—A General Approach Toward Standardization," *IEEE Trans. Ind. Electron.*,vol. 58, no. 1, pp. 158-172, Jan. 2011.

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