Research Trends & Challenges in Control of Micro Grid

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RESEARCH TRENDS & CHALLENGES IN CONTROL OF MICRO GRID

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A B S T R A C T:

The interest on micro grid has increased significantly triggered by the Increasing demand of reliable, secure, efficient, clean, and sustainable electricity. A comprehensive review on current control technology is given with a discussion on challenges of micro grid controls. Microgrids (MGs) are new emerging concept in electrical engineering. Apart from their many benefits, there are many problems and challenges in the integration of this concept in power systems such as their control and stability, which can be solved by Energy Storage Systems (ESSs). A discussion about the control methods of ESSs and future trends are also presented Finally, research needs and road map for micro grid control are also described. Under normal operating conditions, a Micro Grid (MG) is interconnected with the Medium Voltage (MV) network. Combining information and power technologies, the efficiency and reliability of the power network have been improved dramatically. The objective is to maximize the use of renewable energy while driving efficiently the storage system.

Keywords:Microgrid,Controllers,microicrosourcesEnergy Storage System (ESS), State of Charge (SoC), dynamic stability, power system restoration.

I. Introduction: The micro grid concept has been researched and implemented intensively by many experts worldwide with significant research conducted in U.S., E.U., Japan, and Canada. [1,2]. Before the microgrid concept was introduced, many researches had been conducted on distributed generation (DG). Research and implementation of micro grid have increased in last few years in several ways. Many aspects of micro grid ranging from architecture to controls have been researched and implemented in laboratory test-beds and field models. MGs usually provide different advantages for consumers and power system operators such as transmission losses reduction, power quality enhancement, and system efficiency increment.

In many countries, small generators can participate in the energy market, and consumers can profit from reliable energy. Normal Interconnected Mode – the MG is connected to main Medium Voltage (MV) grid being either partially supplied from it or injecting some amount of power into it. However, the adverse impact of weather and climatic conditions on the generation output of the solar and wind energy systems cannot be neglected. A Micro grid (MG) is a group of energy sources located in the same local area that is in turn connected into the main grid while also being able to disconnect from it and operate independently, for example in the event of an electricity outage. The MG islanding process may result from an intentional disconnection from the MV grid (due to maintenance needs) or from a forced disconnection (due to a fault in the MVnetwork).

II. Micro grid review: A micro grids is an interconnection of distributed energy sources, such as micro turbines, wind turbines, fuel cells and PVsintegrated with storage devices, such as batteries, flywheels and power capacitors on low voltage distribution systems [6]. A basic micro grid architecture is shown in Fig. 1.

This micro grid consists of a group of radial feeders, which could be part of a distribution system or a building’s electrical system. There are three sensitive-load feeders (Feeders A–C) and one no sensitive-load feeder (Feeder D).

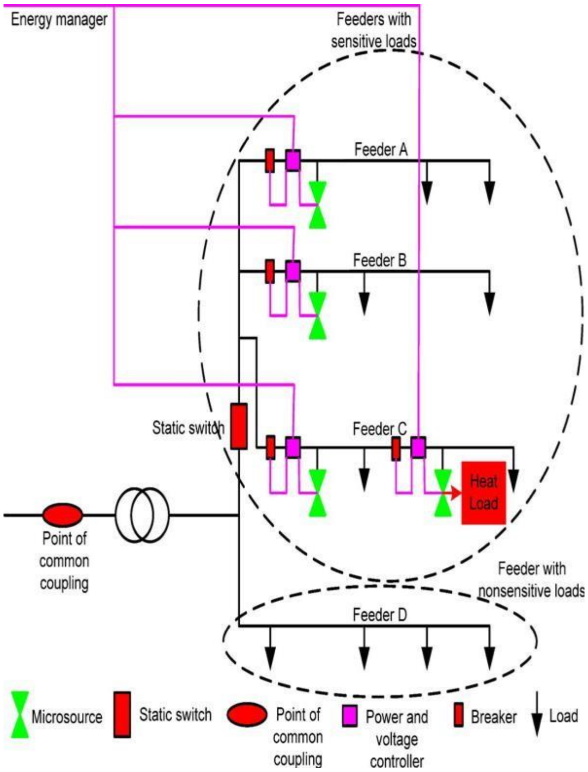

Fig. 1. Microgrid architecture

Post-disturbance, the microgrid will reconnect to the utility and

work normally as a grid-connected system. In this grid-connected, excess local power generation, if any, will supply the non-sensitive loads or charge the energy storage devices for later uses. The excess power generated by the micro grid may also be sold to the utility; in this case, the micro grid will participate in the market operation or provide ancillary services [6,9,10].

The last main part of the CERTS architecture is the energy manager which is responsible to manage system operation through power dispatching and voltage setting to each micro source controller. Some possible criteria for the micro grid to fulfill this responsibility are as follows [7].

1. Insure that the necessary electrical loads and heat are fulfilled by the micro sources.

2. Insure that the micro grid satisfies operational contracts with the utility

3. Minimize emissions and/or system losses

4. maximize the operational efficiency of the micro sources.

III. Micro grid controls:

1. Micro sources work properly at predefined operating point or slightly different from the predefined operating point but still satisfy the operating limit.

2. Disconnection and reconnection processes are conducted seamlessly.

3. utilization of heat installation is optimized.

4. In failure case, micro grid is operate through black-start

Local Controls:

Local controls are the basic category of micro grid controls. In most micro grid applications, local controllers will coexist with other type of controllers, while in fully islanded micro grids, as described in [33–

35], the local controllers are the only required controllers. The local controllers must also ensure the ‘‘plug-and-play’’ function of micro sources. Most micro sources require power-electronic interfaces to convert their output to suit power system specifications. The general model for a micro source is shown in Fig. 2. It contains three basic elements: prime mover, DC interface, and voltage source inverter (VSI). The micro source couples to the micro grid using an inductor. The VSI controls both the magnitude and phase of its output voltage, $\overline{V}$, in order to control real and reactive powers. The voltage regulation is crucial for a micro grid with integration of large number of micro sources in order to overcome oscillation caused by high penetration of micro sources. The voltage regulations also used to insure that there are no large circulating reactive current between sources.

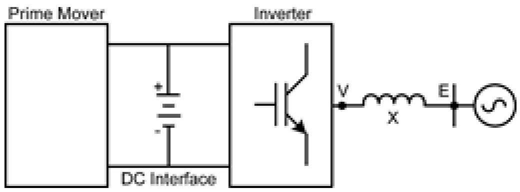

Fig. 2. General model of a micro source connected to a micro grid.

Besides the voltage regulation, micro sources must also regulate active and reactive powers. The most common methods to regulate these powers are droop-based active and reactive power controls. In grid operation it receives the power from both grid and micro source depending on the customer situation. the micro grid is usually

equipped with a capability to intentionally operate in islanded mode of operation [40]

Prime Mover: he source of mechanical energy for a rotating electric generator is known as the prime mover. The prime mover is directly coupled to the generator. Energy sources for prime movers are thermal, hydro, and wind. The prime movers normally are turbines, but some thermal units use internal-combustion engines.

Centralized controls:

1. local controllers consisting of Micro source Controllers (MCs) and Load Controllers (LCs);

2. Microgrid Central Controllers (MGCCs);

3. Distribution Management System (DMS).

Hierarchical systems consists of centralized or decentralized controllers

Decentralized controls:

Decentralized control is used for micro grids with the following properties [10]:

1. Microsources can have different owners in which case several decisions should be taken locally.

2.action of the controllers of each unit participating in the market should have a certain degree of intelligence.

3.local micro sources may have other tasks besides supplying power to the local distribution networks, like producing heat for local installations, keeping the voltage locally at a certain level or providing a backup system for local critical loads in case of main system failure.

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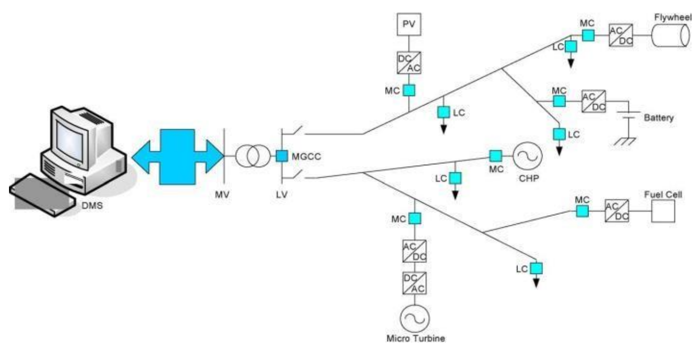


Fig. 4. Hierarchical control of micro grid.

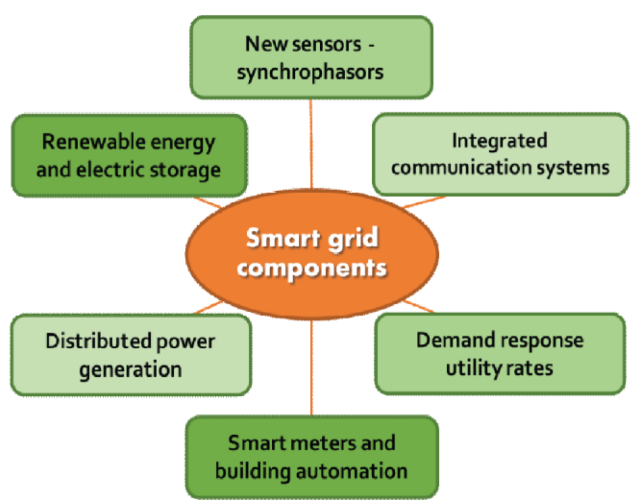


Fig.5 Smart grid ideology

Table I Comparison between the existing grid and smart grid

Existing grid	Smart grid
One-way communication	Two-way communication
Manual restoration	Self-healing
Electromechanical	Digital
Failures and blackouts	Adaptive and islanding
Limited control	Pervasive control
Few customer choices	Manu customer choices
Manual monitoring	Self-monitoring
Centralized generation	Distributed generation
Few sensors	Sensors throughout

IV MICRO GRID CONCEPTS:

It is different connection of small, modular generation sources combined with energy storage components to low/medium voltage distribution system forming a new type of power system feeding local loads. It is interconnection of small, modular generation sources combined with energy storage components to low/medium voltage distribution system forming a new type of power system feeding local loads.

1) To provides penetration of distributed generators into the distribution network.

2) Provision of quality and highly reliable power/energy to key loads.

3) Smoothly interfacing with the available network/grid power system.

4) Provide support to the main grid in the form of export of real power and reactive power

5) The utility of micro grid control systems interacts efficiently and reliability.

V SMART FEATURES OF SMART GRID:

The Field Area Network (FAN) is used for interface for establishing two-way communication to the utility and customers.

This network is a smart and ubiquitous feature of the critical infrastructure designed to support the utility communication. the FAN is used for links for the data communication among the consumers and distribution companies, control centers, operational and head offices, etc.

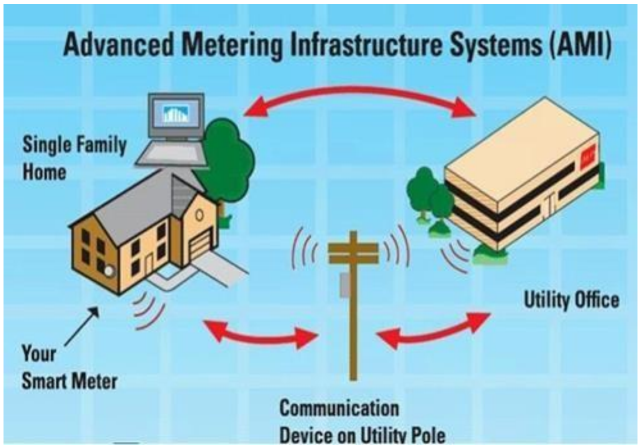


Fig.6 Advanced Metering Infrastructure Systems

A) Smart Protection System

It is used in energy efficiency and demand profile, demand profile shopping, utility, and cost and price, dynamic programming, convex programming

Smart Infrastructure System is used in

1. Smart energy subsystem
2. Power generation
3. Transmission grid
4. Distribution grid
5,New grid paradigm: Micro grid and grid-to vehicle
6. Smart information subsystem
7. Information metering and measurement
8. Smart meter
9. Sensor
10. Phasor measurement unit
11. Informationmanagement
12. Data modeling
13. Information analysis, integration and optimization

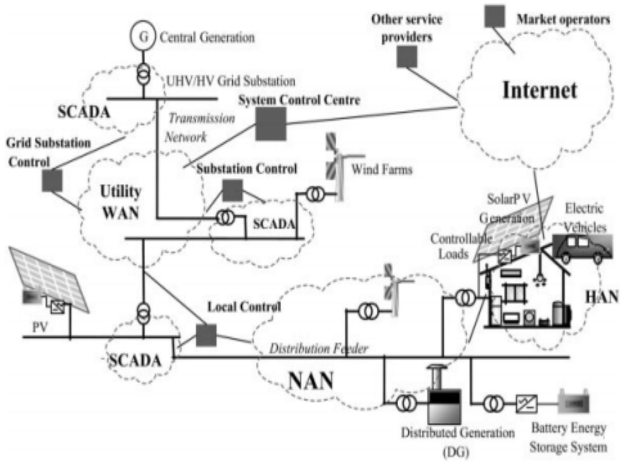


Fig.7 Network connectivity through advanced techniques in the smart grid

VI. INFORMATION &COMMUNICATION TECHNOLOGY

It mainly consists of the Supervisory Control And Data Acquisition (SCADA) and the Wide Area Network (WAN). The SCADA consists of more part in the communication technologies. The WAN is used to business activities and commercial purposes[8-10]

Table I Advantages of of smart metering system [5, 11, 12]

Stakeholder	**uses**
Utility Customers	1) Better access and datato manage energy use 2) More accurate and timely billing 3) Improved and increasedrate options 4) Improved outage restoration 5) Power quality data
Customer Service & Field Operations	1) Reduced cost of Metering reading 2) Reduced collections and connects/disconnects
Revenue Cycle	1) Early detection of
Services- Billing, Accounting, Revenue Protection	meter tampering and theft 2) Reduced estimated billingand billing errors
Transmission and Distribution	1) Improved transformer load management 2) Improved capacitorbank switching 3) Data for improved efficiency, reliability of service, losses and loading 4) Improved data for efficient grid system design
Marketing & Load Forecasting	Reduced costs for collecting load research data
Utility General	1) Reduced regulatory complaints 2) Improved customer premise safety & risk profile 3) Reduced employee safety incidents

Table II Parameters for communication technologies [13, 14]

Sub Network	**Communication Technologies**
WAN	**M**ulti **P**rotocol **L**abel **S**witching (MPLS), WiMax, LTE, Frame Relay
HAN	Ethernet, Wireless Ethernet, **P**ower **L**ine **C**arrier (PLC), **B**roadband over **P**ower **L**ine (BPL), ZigBee
NAN	PLC, BPL, Metro Ethernet, **D**igital **S**ubscriber **L**ine (DSL), EDGE, **H**igh **S**peed **P**acket **A**ccess (HSPA), **U**niversal **M**obile **T**ele-communications **S**ystem (UMTS), **L**ong **T**erm **E**volution (LTE), WiMax, Frame Relay

VII. FUTURE SCOPE IN MICRO GRID

The installation of Microgrids and integration in LV distribution systems will increase significantly in future. Micro grid control aim is to optimize production and consumption of heat, gas and electricity to improve overall efficiency [22].

controlling a large number of micro sources consists of different characteristics are very challenging due to the possibility of conflicting requirement and limited communication [6].

In decentralized or centralized controllers, control action required with probable lost input parameters will be surely challenging.

From grid-connected stations now a day's operation large mismatches between generation and loads due to severe variation of voltage and frequency. The plug in and plug out also introduce severe problem by the connected and disconnected of micro sources at a time.[6]. Communication technologies are based on the IEEE: 802 standards. These standards are applied to NANs in distribution network, WANs in SCADA and HANs in domestic locations.

SIMULATIONS RESULTS & DISCUSSIONS

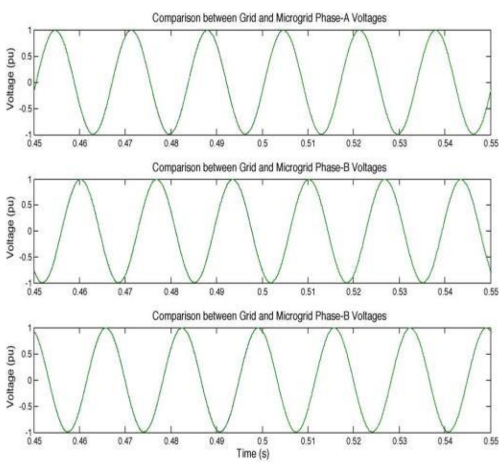


Fig. 8. Phase A, B, and C of the microgrid and grid voltages.

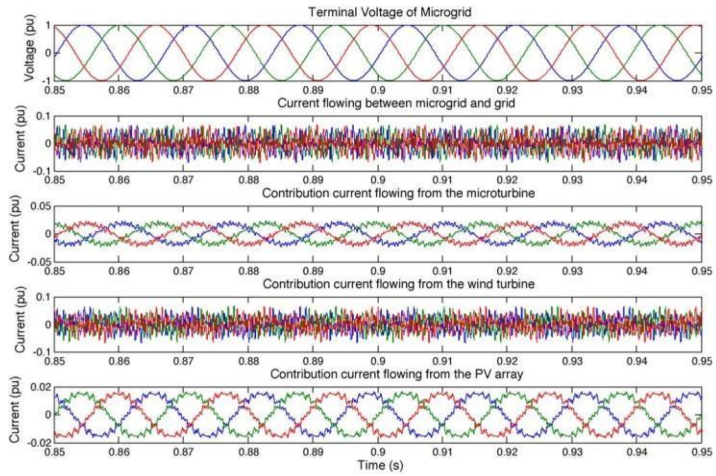


Fig.9. Microgrid voltage and current and micro source contribution currents for grid-connected operation.

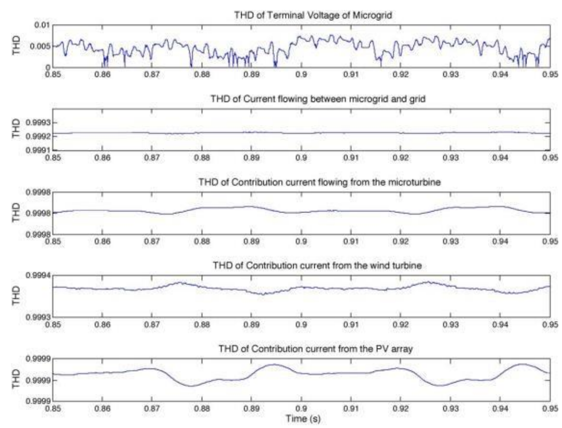
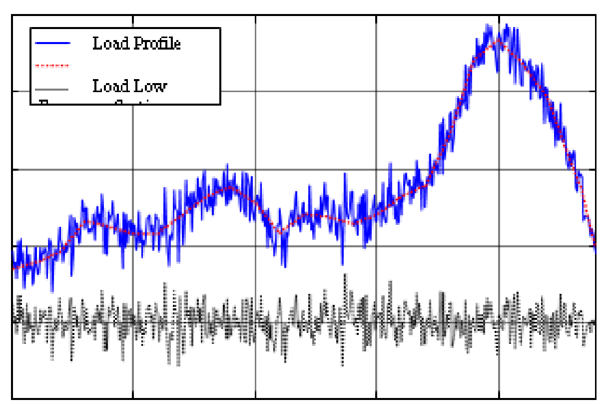


Fig. 10. THD of the microgrid voltage and current and microsource contribution currents for the grid-connected operation.



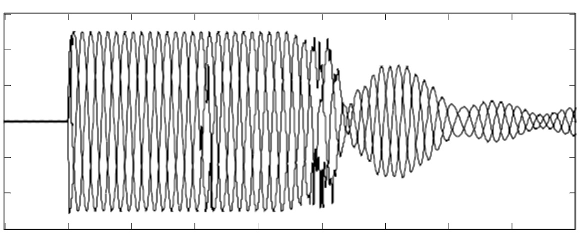
0 5 10 15 20

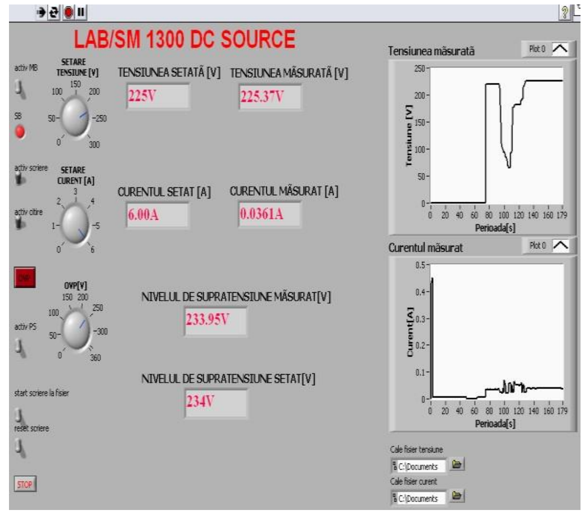
Fig. 11. Typical 24-hour load profile of MG

Network behavior during BS initial stages was evaluated with the EMTP-RV platform described in [3], including in this case the fast inverter commutation transients. The VSI shown in Fig. 13 was selected for energizing the LV network and the MV/LV transformer, at t=0.2s, using a voltage ramping control during 0.5s to reduce the magnetizing current of the DT. The inverter current thus obtained is presented in Fig. 12 where it is possible to observe that the DT magnetizing current was kept at low values.

- Synchronizing the SOFC with the LV network (t=10.8s)
- Synchronizing the SSMT with the LV network (t=25.6s)
- Starting-up of a motor load (t=45s)
- Connecting the wind generator (t=85s)
- Connecting controllable loads (t=94s)
- Connecting the PV (t=140s)
- Connecting controllable loads (t=160s)
- Changing the SSMT and SOFC inverters to PQ control (t=175s and t=170s respectively)
- Synchronizing the MG with the MV network

Fig. 12. VSI current and voltage during and after the fault





Labview main menu (a) interface for the data acquisition (b).

VIII CONCLUSIONS:

This paper has presented a comprehensive review of microgrid and discussed several aspects of controls, energy storage applica- tons within microgrids and specific challenges. A case study simulation was conducted to evaluate the microgrid operation either in islanded or grid-connected systems. The simulation results shows that the microgrid improve reliability of the distribution system by providing power to the sensitive loads when there is no supply from the grid. Several research problems need to be solved in future to keep up with planned renewable energy. The objective is decreasing the energy cost by maximizing the power of PV cells, when operating efficiently with ESS.

References:[1] Lasseter B. Microgrids [distributed power generation]. In: Proceedings of the IEEE PES winter meeting, vol. 1; 2001. p. 146–9.

[2] Hatziargyriou N, Asano H, Iravani R, Marnay C. Microgrids: an overview of ongoing research, development, and demonstration projects. IEEE Power Energy Mag 2007;5(4):78–94.

[3] Dell RM, Rand DAJ. Energy storage—a key technology for global energy sustainability. J Power Sources 2001;100(1–2):2–17.

[4] Lasseter RH. Microgrids and distributed generation. J Energy Eng.; 2007. Available http://www.pserc.wisc.edu/ecow/get/publicatio/2007 public/lasse- ter_asceg2-colum_2007.pdf.

[5] Lasseter RH, Piagi P. Microgrid: a conceptual solution. Proc the 35th IEEE Annual PESC 2004;6:4285–90.

[6] Hatziargyriou N. MICROGRIDS – large scale integration of micro-generation to low voltageGrids.Availablehttp://microgrids.eu/micro2000/presentations/ 16.pdf.

[7] Lasseter R, Akhil A, Marnay C, Stephens J, Dagle J, Guttromson R, et al. The CERTS microgrid concept. White Paper on Integration of distributed energy resources, prepared for Transmission Reliability Program, Office of Power Technologies, U.S. Department of Energy, April 2002. Available http:// certs.lbl.gov/pdf/50829-app.pdf.

[8]Lasseter RH.MicroGrids. In: Proceedings of the IEEE PES winter meeting, vol. 1; 2002. p. 305–8.

[9] European Research Project MicroGrids [Online].Available: http://microgrids.power.ece.ntua.gr/

[10] J. A. Peças Lopes, C. L. Moreira and A. G. Madureira, "Defining control strategies for analyzing microgrids islanded operation", in Proc. IEEE St. Petersburg Powertech 2005, Russia [17] Draft Guide to Conducting Distribution Impact Studies for Distributed Resources Interconnection, P1547.7TM.

[11] Meiqin M, Chang L, Ming D. Integration and intelligent control of micro-grids with multi-energy generations: a review. In: Proceedings of the IEEE inter- national conference on sustainable energy technologies; 2008. p. 777–80.

[12] Lasseter RH. Extended CERTS technology. In: Proceedings of the IEEE PES general meeting – conversion and delivery of electrical energy in the 21st century; 2008. p. 1–5.

[13] Nigim KA, Lee W-J. Micro grid integration opportunities and challenges. Proc IEEE PES general meeting 2007;1–6.

[14] Basu AK, Chowdhury SP, Chowdhury S, Ray D, Crossley PA. Reliability study of a micro-grid power system. In: Proceedings of the 43rd international uni- versity power engineering conference; 2008. p. 1–4.

[15] Chicco G, Mancarella P. Distributed multi-generation: a comprehensive view. Renew Sustain Energy Rev 2009;13:535–51.

[16] Omer AM. Energy, environment and sustainable development. Renew Sustain Energy Rev 2008;12:2265–300.

[17] Kaygusuz K. Energy and environmental issues relating to greenhouse gas emissions for sustainable development in Turkey. Renew Sustain Energy Rev 2009;13:253–70.

[18] Pereira OS, Reis TM, De Araujo RGB, Gongalves FF. Renewable energy as a tool to assure continuity of low emissions in the Brazilian electric power sector. In: Proceedings of the IEEE EIC climate change technology; 2006.

[19] Costa PM, Matos MA, Lopes JAP. Regulation of microgeneration and micro- grids. Energy Policy 2008;36(10):3893–904.

[20] Bando S, Sasaki Y, Asano H, Tagami S. Balancing control method of a microgrid with intermittent renewable energy generators and small battery storage. In: Proceedings of the IEEE PES general meeting – conversion and delivery of electrical energy in the 21st century; 2008. p. 1–6.

[21]Youli S, Litifu Z, Nagasaka K. Efficiency of microgrid with storage battery in reliability, economy and environment assessments. Int J Electr and Power Eng 2009;3(3):154–62. [41] Piagi P. Microgrid control. PSERC Tele-Seminar Presentation; 2005. Available http://www.pserc.org/ecow/get/generalinf/presentati/psercsemin1/2pserc-semin/piagi_seminar_slides_june_2005.pdf.

[22] Pec¸as Lopes JA, Moreira CL, Resende FO. Control strategies for microgrids black start and islanded operation. Int J Distr Energy Resour 2006;2(3):211–31.

[23] Pec¸as Lopes JA, Moreira CL, Madureira AG, Resende FO, Wu X, Jayawarna N, et al. Control strategies for MicroGrids emergency operation. In: Proceedings of the international conference on future power systems; 2005.

[24] Hatziargyriou N. Active distribution network. The Effect of Distributed and Renewable Generation on Power Systems Security Round Table; 2005. Avail- able: http://www.microgrids.eu/micro2000/presentations/21.pdf.

[25] Tsikalakis AG, Hatziargyriou ND. Centralized control for optimizing microgrids operation. IEEE Trans Energy Convers 2008;23(1):241–8.

[26] Logenthiran T, Srinivasan D, Wong D. Multi-agent coordination for DER in Micro Grid. In: Proceedings of the IEEE international conference on sustainable energy technology; 2008. p. 77–82.

[27] De Brabandere K, Vanthournout K, Driesen J, Deconinck G, Belmans R. Control of microgrids. In: Proceedings of the IEEE PES general meeting; 2007. p. 1–7.

[28] Binduhewa PJ, Barnes M, Renfrew A. Standard microsource interface for a microgrid. In: IET-CIRED seminar SmartGrids for distribution; 2008.

[29] Bhatia RS, Jain SP, Jain DK, Singh B. Battery energy storage system for power conditioning of renewable energy sources. In: Proceedings of the IEEE inter- national conference on power electronics and drives systems; 2005. p. 501–6.

[30] Salam AA, Mohamed A, Hannan MA. Technical challenges on microgrids. ARPN J Eng Appl Sci 2008;3(6). Available www.arpnjournals.com.

[31] Methuku SR, Srivastava AK, Schulz N. Comprehensive modeling and technical- economic impact of biomass generation. In: The MSU energy workshop; 2009.

[32]Zhong Q-C, Blaabjerg F, Cecati C. Power-electronics-enabled autonomous power systems. IEEE Trans Ind Electron 2017;64:5904–6.

[33] Gayatri M, Parimi AM, Kumar AP. A review of reactive power compensation techniques in microgrids. Renew Sustain Energy Rev 2018;81:1030–6.

[34] Suntio T, Messo T, Puukko J. Power electronic converters: dynamics and control in conventional and renewable energy applications. John Wiley & Sons; 2018.

[35] Li W, Joos G. A power electronic interface for a battery supercapacitor hybrid

energy storage system for wind applications. Power Electronics Specialists Conference, 2008. PESC 2008. IEEE; 2008. p. 1762–8.

[36] Amjadi Z, Williamson SS. Power-electronics-based solutions for plug-in hybrid electric vehicle energy storage and management systems. IEEE Trans Ind Electron 2010;57:608–16.

[37] Navarro-Rodríguez Á, García P, Georgious R, García J. Adaptive active power

sharing techniques for DC and AC voltage control in a hybrid DC/AC microgrid. Energy Conversion Congress and Exposition (ECCE), 2017. IEEE; 2017. p. 30–6.

[38] Akter MP, Mekhilef S, Tan NML, Akagi H. Modified model predictive control of a bidirectional AC–DC converter based on Lyapunov function for energy storage systems. IEEE Trans Ind Electron 2016;63:704–15.

[39] Bayat M, Sheshyekani K, Hamzeh M, Rezazadeh A. Coordination of distributed energy resources and demand response for voltage and frequency support of MV

microgrids. IEEE Trans Power Syst 2016;31:1506–16.

[40] Radwan AAA, Mohamed YA-RI. Modeling, analysis, and stabilization of converter- fed ac microgrids with high penetration of converter-interfaced loads. IEEE Trans Smart Grid 2012;3:1213–25.

[41] Sanchez S, Molinas M. Large signal stability analysis at the common coupling pointof a DC microgrid: a grid impedance estimation approach based on a recursive method. IEEE Trans Energy Convers 2015;30:122–31.

[42]Kwasinski A, Onwuchekwa CN. Dynamic behavior and stabilization of DC micro- grids with instantaneous constant-power loads. IEEE Trans Power Electron 2011;26:822–34.

[43] Serban E, Serban H. A control strategy for a distributed power generation micro-grid application with voltage-and current-controlled source converter. IEEE Trans Power Electron 2010;25:2981–92.

[44] Friedli T, Kolar JW, Rodriguez J, Wheeler PW. Comparative evaluation of three- phase AC–AC matrix converter and voltage DC-link back-to-back converter sys- tems. IEEE Trans Ind Electron 2012;59:4487–510.

[45] Majumder R, Ghosh A, Ledwich G, Zare F. Angle droop versus frequency droop in a voltage source converter based autonomous microgrid. Power & Energy Society General Meeting, 2009. PES'09. IEEE; 2009. p. 1–8.

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