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State of the Art in Research on Microgrid Applications: A Review

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ABSTRACT

The traditional power systems throughout world or mainly dependent upon the conventional method of power generation of electrical power by the combination of Fossil fuel. But there kind of fuel is being exhausted rapidly which will create huge crises fuel for power generation after few decades. So worldwide research activities have already had being initiated to find out the alternatives source of energy through the maximum utilization of renewable energy resources. It is realize that individual capacity of renewable energy resources such as, Photovoltaic Generator, and Wind turbine, etc. are small compared to the traditional generation technology such as thermal power station. In this scenario microgrid system is emerging as a probable solution to solve the power crises in future. The microgrid is interconnected system of different types of energy resources such as photovoltaic, wind energy, Biomass, small hydroelectric generation statics, Fossil fuel etc. which needs proper coordination for satisfactory operation to meet the load demands. To achieve this coordination, microgrid itself requires good infrastructures so that it can operate in grid and Islanded mode as well as in the situation while same faults have occurred in the power network.

Keywords: Microgrid, economics, operation and control, protection, Communications, DER Distributed energy resource, DG Distributed generation unit, DR Demand response.

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I. INTRODUCTION

The U.S. Department of Energy (DOE) has offered the following description of Microgrids: A Microgrid, a local energy network, offers integration of distributed energy resources (DER) with local elastic loads, which can operate in parallel with the grid or in an intentional island mode to provide a customized level of high reliability and resilience to grid disturbances. This advanced, integrated distribution system addresses the need for application in locations with electric supply and/or delivery constraints, in remote sites, and for protection of critical loads and economically sensitive development. (Myles, et al. 2011).

In the present work a detailed Literature survey has been performed to identify the latest advancements protocols as suggested by many researchers and IEEE/IEC standards also a sample microgrid is modeled and simulated to investigate the basic mode of the operation, the results represented in the form of waveforms which are found satisfactory. Microgrid is a localized grouping of electricity sources and loads that normally operates connected to and synchronous with the traditional centralized electrical grid (macrogrid), but can disconnect and function autonomously as physical and/or economic conditions dictate.[1] By this way, it paves a way to effectively integrate various sources of distributed generation (DG), especially Renewable Energy Sources (RES). It also provides a good solution for supplying power in case of an emergency by having the ability to change between islanded mode and grid-connected mode. On the other hand, control and protection are big challenges in this type of network configuration, which is generally treated as a hierarchical control

Clean energy microgrids offer consistent, affordable, reliable, flexible and resilient local energy generation and delivery. Because a microgrid is localized, it can mitigate power disruptions by continuing to operate – providing electricity to its local customers – when the macrogrid is unable to serve the microgrid customers. A microgrid can either operate as an island (generator power just to its own customers) or as an integral partner into the macrogrid. It serves as a resource for faster system response and recovery. Microgrids add another dimension to the obvious benefits of energy generation by increasing efficiencies and reducing energy losses during transmission and distribution. The ability to produce power locally when the macrogrid is down enhances community resiliency during extreme weather events, protects the safety of the public and reduces incidents leading to economic losses and infrastructure failure.

From the electric grid's perspective, the primary advantage of a Microgrid is that it can operate as a single collective load within the power system. Customers benefit from the quality of power produced and the enhanced reliability versus relying solely on the grid for power. Distributed power production using smaller generating systems – such as small-scale combined heat and power (CHP), small-scale renewable energy resources can yield energy efficiency and therefore environmental advantages over large, central generation. (U.S. Department of Energy 2009) The Microgrid concept also reflects a new way of thinking about designing and building smart grids. Specifically, the Microgrid concept focuses on creating a design and plan for local power delivery that meets exact needs of the constituents being served. The Microgrids efficiently and economically integrate customers and buildings with electricity distribution and generation – and energy distribution such as heat – again at a local level. The Microgrids also enhance power reliability for the users due to redundant distribution, smart switches, intelligence and automation, local power generation and the ability to "island" the Microgrid from the Macrogrid. Hence, blackouts and power disturbances are either eliminated or substantially minimized.

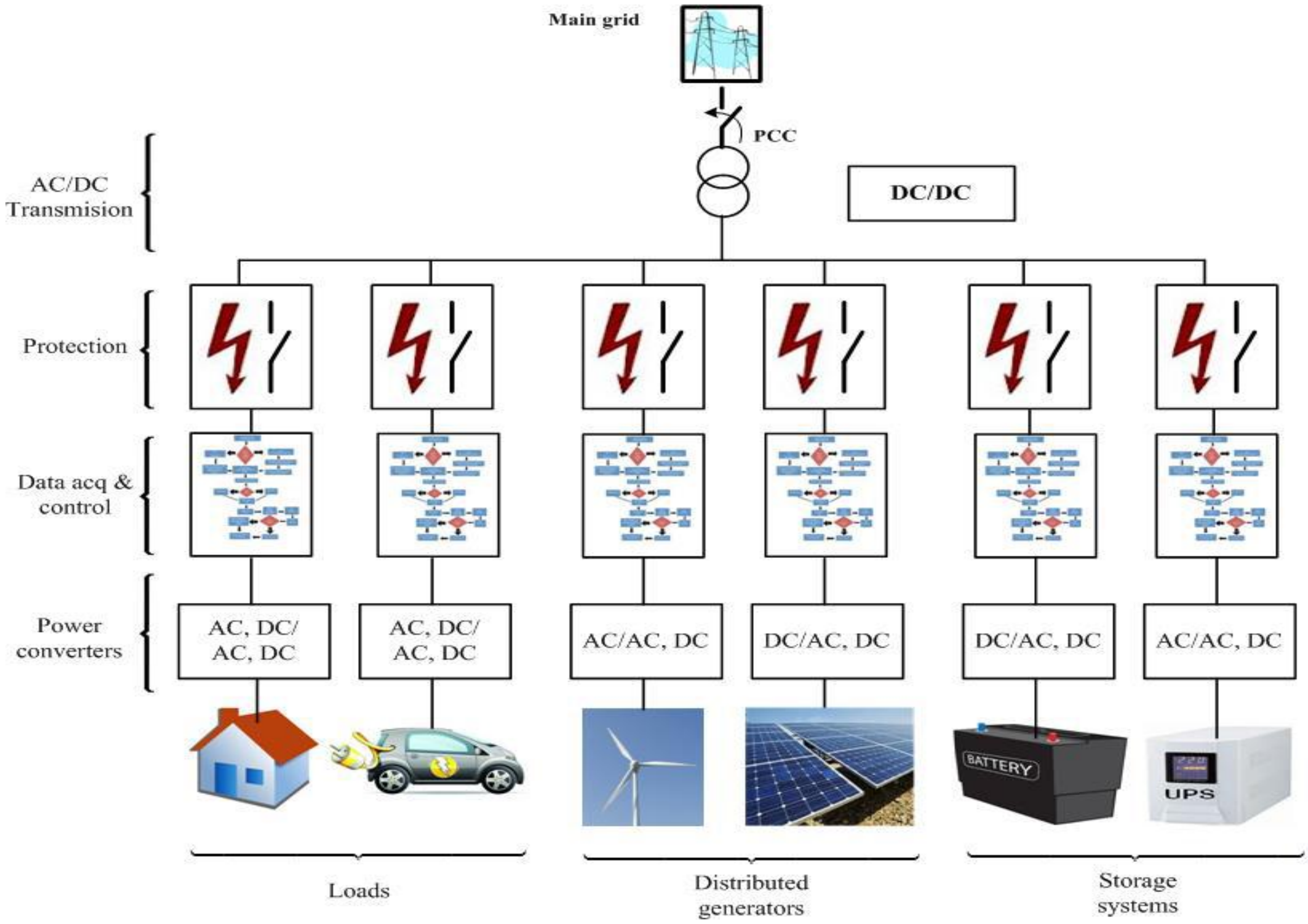

Fig 1: Architecture of microgrid

II. Overview of Microgrid Based On Survey

As energy generation and distribution companies are competing in the market place, we have seen an increasing interest in renewable or non- conventional energy source. A microgrid is an energy community having clean energy sources such as solar power, wind power, and fuel cells and energy storage devices such as batteries. The energy sources and energy storage devices are distributed in the community, and they are called distributed generation systems (DGs) and distributed energy storage devices (DSs), respectively. Recently, attention on the microgrid has been growing as an eco-friendly power system reducing climate change.

There are several reasons why microgrids are increasingly used. First they use alternate energy resources, which are more environmentally friendly commitments and require fewer technical skills to operate as they rely more on automation. Finally, microgrid is the only option if new transmission infrastructure cannot be developed in a timely or cost effective fashion. Alternatively, it can provide high quality, uninterrupted power supply as needed by many companies who use highly sensitive equipment.

The microgrid can be operated by two operation modes: the grid-connected mode and the islanded mode. In the grid-connected mode, a microgrid is connected to a power system, especially a distributed system. On the other hand, the islanded mode means an isolated operation mode from any power system for the case of fault occurrence in the connected power system or geographical isolation such as a small island. In the islanded mode, microgrids should be operated to meet a power balance between supply and demand without power trade. Whenever a power imbalance occurs, the output of DGs is decreased and load shedding is used to solve the power imbalance.

The on-site generation sources give ability to isolate the microgrid from a larger network and provide highly reliable electric power. By product heat from generation sources such as micro turbines could be used for local process heating or space heating and allowing flexible tradeoff between the needs for the electric power and heat. Micrograms may be considered as a solution to 30 and 31 July 2012 blackout in India. This outage affected over 620 million people about 9% of the world population or half of India's population spread across 22 states in Eastern, Northern and Northeast India.

TABLE I
SUNDARBAN REGION MICROGRIDS DETAILS

Technology used	Installed Capacity	Remarks
Solar Power plant	300 kW	Serving more than 1500 consumers
Solar home lightning	3200 kW approx.,	6000 Nos., serving about 30,000 people
Bio-mass Gasifier	1000 kW	Serving around 1000 consumers
Wind farm	1000 kW	Grid connected

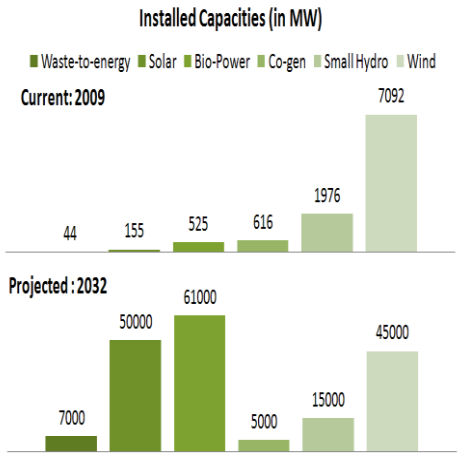

Fig 2: Suburban region microgrids details and installed capacities projected up to 2032

III. BROAD LITERATURE SURVEY REPORT

The concept of microgrids dates back to 1882 when Thomas Edison built his first power plant. Edison's company installed 50 DC microgrids in four years. At that time centrally controlled and operated utility grids were not yet formed. With the utility grid subsequently utilizing large centralized power plants which benefited from the economies of scale, and significantly increasing transmission connections for reliability purposes, the electric grid turned into a monopolistic utility by connecting isolated microgrids, and these microgrids faded away. There is a new wave in recent years, however, to deploy microgrids which is driven in part by the need for higher reliability and power quality, advancements in power electronics and DER technologies, and a more engaging generation of electricity consumers [2].

The islanded microgrid would be resynchronized with the utility grid once the disturbance is removed [3], [4] facilities. A comprehensive review on DERs and current practices in microgrids as well as the interaction problems arising from the integration of various DERs in a microgrid can be found in [6] and [7], respectively. As discussed in detail in [8], DERs include a variety of technologies. Two common and widely-used DERs, which are considered in this section, are renewable DGs and ESSs. There has been an increasing emphasis on the utilization of renewable DGs, such as wind and solar energy resources, in recent years. The main drivers for this trend include the clean and sustainable nature of such resources compared to the polluting and limited fossil fuels that have traditionally been used to generate power. State and governmental mandates, that push for a broader integration of renewable energies and enforce the environmental agenda to mitigate greenhouse gasses generated by the exhaustion of fossil fuels and combat climate change, are also among factors resulting in increased renewable energy proliferation. Renewable DGs are commonly dependent on meteorological factors Renewable DGs offer several benefits including sustainability, being emission free, and benefiting from an almost ubiquitous primary source of energy [9], [10].

As detailed in [11], there are numerous policies and regulations applied by various states within the U.S. to support investments on renewable DGs, such as renewable portfolio standards, public benefit funds for renewable energy, output-based environmental regulations, interconnection standards, net metering, feed-in tariffs, property assessed clean energy, and financial incentives. The application of renewable DGs in microgrids is one of the extensively studied topics in the literature. A microgrid that utilizes controllable prime movers, such as gas engines, to compensate fluctuating demand and output of renewable energy is presented in [12]. In [13], a building integrated photovoltaic (PV) for urban areas is proposed that can run in isolation from the utility grid while being connected to the grid at all times. In [14], a simulation framework utilizing sequential Monte Carlo simulations is developed to investigate the performance of autonomous microgrids that have the ability to interconnect to achieve adequate load service and shows the sensitivity of a small microgrid assembly to large amounts of wind generation, which can have a significant negative impact on its reliability. The paper concludes that to mitigate the effects of the high variability in the power output of the wind turbines, much greater amounts of storage, aggregate wind generation, or both are needed. In [15], the challenges facing the operation of intermittent power sources, such as wind power, in capacity-limited microgrids are discussed. In [16], the planning of micro hydro power plants and micro wind power turbines into mountainous regions with weak natural energy is discussed. The discussions indicate that regions with relatively weak natural energy may be developed by applying the microgrid with possible compensation between micro-sources. The studying [17] examines the feasibility of applying a micro hydropower generation system in a microgrid as part of the various regional energy programs underway in Africa.

In [18], a fuzzy-logic controller is used for maximum power point tracking of PV systems and implemented by fuzzifying the rules of hill-climbing search methods to reduce its drawbacks. In [19], a survey of perturb and observe techniques is presented which shows that existing techniques suffer from oscillations, complexity, designer dependency, and high computational load The study in [20] uses neural network to estimate the optimal tilt angle at a given location and thus an estimate of the amount of energy available from the PV in a microgrid. It is demonstrated that the neural network is able to estimate the optimum tilt angle with an accuracy of 3_ and the optimized irradiation at the microgrid with negligible error. The study in [21] shows that including a diverse set of renewable energy generation technologies and optimizing the mix of renewable units could potentially reduce energy balance fluctuations in a small-scale microgrid. In order to address this concern, a new concept called ``provisional microgrid'' is outlined in [22], proposing a microgrid without islanding capability. According to [23], benefits could be in the form of either avoided costs or additional revenue received by the operator. For an electricity end-user employing ESS for reducing electricity bill, the benefits would be lower costs of energy [24], [25]. In [26], an algorithm is proposed to manage the devices in real-time in order to mitigate pulsed loads effects on the system performance in microgrids involving ESS. The study in [27] presents a control strategy for the PV source integrated in a microgrid allowing it to operate at maximum power point at all times except for times that the frequency needs to be stabilized. In [28], microgrids are classified based on their value proposition into three types: reliability, energy arbitrage, and power quality.

Table 1

Power electronics system for power conversion

Power electronics systems for power conversion			
Power Conversion	Definition	Common Module Names	Application
AC-AC	These converters are used to adjust AC output voltage regarding to AC input voltage. The variable firing angle controls the output voltage of TRIAC. These type converters are known as AC voltage regulator	Cycloconverters, Hybrid Matrix Converters, Matrix Converters, Frequency Converter, Voltage Control Converters	Lighting /Heating Controls, Large Machine Drives, Voltage/Frequency level changer,
AC-DC	An AC to DC converter circuit can convert AC voltage into a DC voltage. The DC output voltage can be controlled by varying the firing angle of the thyristors. The AC input voltage could be a single phase or three phase.	Rectifier(Single or Three Phase, Half Bridge or Full Bridge)	DC Machine Drive, Energy Storage Systems, DGs Technologies interfacing, High Voltage DC (HVDC) Transmission
DC-AC	Variable AC output voltage, frequency & phase; and overall power handling, depending on the design of the specific device from DC input power	Inverter (Current Source Inverter, Voltage Source Inverter, Resonant Inverter)	AC Machine Drive, UPS, Induction Heating, Locomotive Traction, Static Var Generation, PV or Fuel Cell Interface with utility
DC-DC	These kinds of converters are used to adjust DC output voltage regarding to DC input voltage. The variable duty cycle controls the output voltage.	Boot Converters, Buck Converters, Buck-Boost Converters, Chopper, Cuk Converters	Power supplies for electronic equipment, Robotics, Automotive/Transportation, Switching power amplifiers, Photovoltaic systems
AC-DC-AC	AC/DC/AC converters, namely DC Link Converters, performs the conversion of AC input to AC output by using DC link between the stages (rectifier, DC link & inverter)	Back to Back Converter, Rectifier-Inverter Converters	For single or multiple applications of electrical machines, DGs application, Microgrid application

REFRENCES

[1]. “Clean Alternative Fuels: Fischer-Tropsch”, United States Environmental Protection Agency, EPA420-F-00-036, March 2002.

[2]. Lasseter, R.H., A Akhil, C. Marnay, J Stephens, J Dagle,R Guttromson, A. Meliopoulous, R Yinger, and J. Eto(2002a). “The CERTS Microgrid Concept,” White paper for Transmission Reliability Program, Office of Power Technologies, U.S. Department of Energy, April 2002

[3]. Lasseter, R. (2002b).” Microgrids,” IEEE PES WinterMeeting, January 2002

[4]. Lopes, J.A. Peças , J. Tomé Saraiva , N. Hatziargyriou , N. Jenkins(2003). “Management of

Microgrids" JIEE Conference 2003, Bilbao, 28-29 October 2003

[5]. S. Suryanarayanan and E. Kyriakides, ``Microgrids: An emerging technology to enhance power system reliability," IEEE Trans. Smart Grid, Mar. 2012. [Online]. Available: http://smartgrid.ieee.org/march-2012/527-microgrids-an-emerging-technology-toenhance-powersystem-reliability, accessed Nov. 13, 2014.

[6]. H. Jiayi, J. Chuanwen, and X. Rong, ``A review on distributed energy resources and MicroGrid," Renew. Sustain. Energy Rev., vol. 12, no. 9, pp. 2472_2483, 2008.

[7]. Y. Zoka, H. Sasaki, N. Yorino, K. Kawahara, and C. C. Liu, ``An interaction problem ofdistributed generators installed in a MicroGrid," in Proc. IEEE Int. Conf. Electr. Utility Deregulation, Restruct. Power Technol.,vol. 2. Apr. 2004, pp. 795_799.

[8]. S. Chowdhury, S. P. Chowdhury, and P. Crossley, Microgrids and ActiveDistribution Networks. Stevenage, U.K.: IET, 2009.

[9]. Why is Renewable Energy Important? [Online]. Available: http://www.renewableenergyworld.com/rea/tech/home, accessed Feb. 13, 2015.

[10]. Renewable Energy, Forms and Types of Renewable Energy.[Online]. Available: http://www.altenergy.org/renewables/renewables.html, accessed Feb. 13, 2015.

[11]. U.S. Environmental Protection Agency. State and Local Climateand Energy Program. [Online]. Available: http://www.epa.gov/statelocalclimate/state/topics/renewable.html, accessed Feb. 13, 2015.

[12]. H. Asano and S. Bando, ``Load _uctuation analysis of commercial andresidential customers for operation planning of a hybrid photovoltaic and cogeneration system," in Proc. IEEE Power Eng. Soc. General Meeting,Jun. 2006.

[13]. M. Sechilariu, B. Wang, and F. Locment, ``Building integratedphotovoltaic system with energy storage and smart grid communication, "IEEE Trans. Ind. Electron., vol. 60, no. 4, pp. 1607_1618,

[14]. M. Giacomoni, S. Y. Goldsmith, S. M. Amin, and B. F. Wollenberg, ``Analysis, modeling, and simulation of autonomous microgrids witha high penetration of renewables," in Proc. IEEE Power Energy Soc.General Meeting, Jul. 2012, pp. 1_6.

[15]. H. Chowdhury, H. T. Ma, and N. Ardeshna, ``The challenge of operating wind power plants within a microgrid framework," in Proc. Power Energy Conf. Illinois (PECI), Feb. 2010, pp. 93_98.

[16]. Z. Litifu, N. Estoperez, M. Al Mamun, K. Nagasaka, Y. Nemoto, and I. Ushiyama, ``Planning of micro-grid power supply based on the weak wind and hydro power generation," in Proc. IEEE Power Eng. Soc.General Meeting, 2006, p. 8.

[17]. L. Wang et al., ``A micro hydro power generation system for sustainable microgrid development in rural electri_cation of Africa," in Proc. IEEE Power Energy Soc. General Meeting, Jul. 2009, pp. 1_8.

[18]. B. N. Alajmi, K. H. Ahmed, S. J. Finney, and B. W. Williams, ``Fuzzylogic-control approach of a modi_ed hill-climbing method for maximum power point in microgrid standalone photovoltaic system," IEEE Trans. Power Electron., vol. 26, no. 4, pp. 1022_1030, Apr. 2011.

[19]. K. Abdelsalam, A. M. Massoud, S. Ahmed, and P. N. Enjeti, ``High-performance adaptive perturb and observe MPPT technique for photovoltaic-based microgrids," IEEE Trans. Power Electron., vol. 26,no. 4, pp. 1010_1021, Apr. 2011.

[20]. Chatterjee and A. Keyhani, ``Neural network estimation of microgrid maximum solar power," IEEE Trans. Smart Grid, vol. 3, no. 4, pp. 1860_1866, Dec. 2012.

[21]. D. Quiggin, S. Cornell, M. Tierney, and R. Buswell, ``A simulation and optimisation study: Towards a decentralised microgrid, using real world fuctuation data," Energy, vol. 41, no. 1, pp. 549_559, 2012.

[22]. Khodaei, ``Provisional microgrids," IEEE Trans. Smart Grid, vol. 6, no. 3, pp. 1107_1115, May 2015.

[23]. Energy Storage Association. Unleashing the Power of Energy Storage. [Online]. Available: http://energystorage.org/energy-storage, accessed Feb. 13, 2015.

[24]. X. Tan, Q. Li, and H. Wang, ``Advances and trends of energy storage technology in microgrid," Int. J. Electr. Power Energy Syst., vol. 44, no. 1, pp. 179_191, Jan. 2013.

[25]. Z. Xu, X. Guan, Q.-S. Jia, J. Wu, D. Wang, and S. Chen, ``Performance analysis and comparison on energy storage devices for smart building energy management," IEEE Trans. Smart Grid, vol. 3, no. 4,pp. 2136_2147, Dec. 2012.

[26]. Mohamed, V. Salehi, and O. Mohammed, ``Real-time energy management

[27]. algorithm for mitigation of pulse loads in hybrid microgrids," IEEE Trans. Smart Grid, vol. 3, no. 4, pp. 1911_1922, Dec. 2012.

[28]. Marnay, C. and O. Bailey (2004). "The CERTS Microgrid and the Future of the Macrogrid. " LBNL-55281. August 2004

[29]. Venkataramanan, G., Illindala, M. S., Houle, C., Lasseter, R. H. (2002). Hardware Development of a Laboratory-Scale Microgrid Phase 1: Single Inverter in Island Mode Operation. NREL Report No. SR-560- 32527 Golden, CO: National Renewable Energy Laboratory.

