ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 4, April 2014

The Deployment of Microgrid as an Emerging Power System in India and its Simulation using Matlab-Simulink

Jitender Kaushal[1], Prasenjit Basak[2]

Ph.D Scholar, Department of Electrical and Instrumentation Engineering, Thapar University, Patiala, India[1]

Assistant Professor, Department of Electrical and Instrumentation Engineering, Thapar University, Patiala, India[2]

ABSTRACT: This paper presents the importance of deployment of distributed energy resources as a promising aspect which is emerging as a future power system as microgrid in the power community worldwide. The basic concepts of microgrid technology including its operational and control techniques are presented briefly in simplified manner. The application and prospect of microgrid in Indian power scenario are also explored and discussed which justifies that India has a great geographical potential to accept and implement this technology in future. A sample DC microgrid model is simulated using Matlab-Simulink to demonstrate the grid connected and islanded operation of the same. The simulation results are represented, discussed and found satisfactory.

KEYWORDS: Distributed Energy Resource (DER), Consortium for Electric Reliability Technology Solutions (CERTS), Distributed Generation (DG), Ministry of New and Renewable Energy (MNRE), Integrated Energy Policy Report (IEPR).

I. INTRODUCTION

All Renewable energy resources are useful. Each source of renewable energy has an unique benefits. Renewable energy is made from resources Mother Nature can replace like wind, water, and sunshine. These sources are being used all over the world. Renewable energy produces much less air pollution. Obviously it is the best source of energy. It is clean, reliable, Eco friendly. It might cost a lot in the beginning but then it pays off in the long run. Require less maintenance then fossil fuel combustion engines and the fuel source is unlimited. Consumers won't invest in energy unless private industries create the infrastructure. However, private industries won't invest in the infrastructure unless consumers are willing to invest in the alternative source. Therefore, alternative sources won't be developed unless other incentives are in place. The government can make a real difference by placing in these incentives to start alternative sources. The future must be planned by pure fact that oil, coal, and natural gas are not sustainable energies. We know we will eventually run out; why should we rely on them to always be there and be present? We need to focus as much time as possible to dedicating our future to renewable energies such as solar and wind. We have an opportunity to re-imagine and re-engineer our energy infrastructure into clean sources that are widely available and offer wide market participation. It won't always be the easy path, but it is the logical one to deliver energy, economic, and environmental security.

India's cumulative Grid interactive or Grid Tied Renewable Energy Capacity (excluding Large Hydro) has reached 26.9GW, of which 68.9% comes from wind, while solar PV contributed nearly 4.59% of the Renewable Energy installed capacity in India [1]. As announced in November 2009, the Government of India proposed to launch its Jawaharlal Nehru National Solar Mission under the National Action Plan on Climate Change with plans to generate 1,000 MW of power by 2013 and up to 20,000 MW grid-based solar power, 2,000 MW of off-grid solar power and cover 20 million sq metres with collectors by the end of the final phase of the mission in 2020 [2]. The Mission aims to achieve grid parity (electricity delivered at the same cost and quality as that delivered on the grid) by 2020. Achieving this target would establish India as a global leader in solar power generation [3]. Although a relative newcomer to the wind industry compared with Denmark or the US, domestic policy support for wind power has led India to become the country with the fifth largest installed wind power capacity in the world [4].

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 4, April 2014

The Consortium for Electric Reliability Technology Solutions (CERTS) microgrid concept assumes an aggregation of loads and microsources operating as a single system providing both power and heat. The majority of the microsources must be power electronic based to provide the required flexibility to insure operation as a single aggregated system. This control flexibility allows the CERTS microgrid to present itself to the bulk power system as a single controlled unit that meets local needs for reliability and security [5]. Microgrids are the low voltage power generating plants. The network is designed to supply electrical energy for a small community, like a housing estate or a sub-urban locality or an academic community such as a school or university. The generators employed in a microgrid are usually renewable DERs (Distributed Energy Resources) integrated together to generate power at distribution voltage level. Some important differences between a microgrid and conventional power plant are given as:

- The generated power at distribution level can be directly fed to the utility distribution network.
- The sources used in microgrid are of much smaller capacity as compared to large generators in conventional power plants.

From grid point of view, the main advantage of a microgrid is that it is treated as a controlled entity within the power system. It can be operated as a single aggregated load. This ascertains its easy controllability and compliance with grid rules and regulations without hampering the reliability and security of the power utility. From customer's point of view, microgrids are beneficial for locally meeting their electrical or heat requirements. They can supply uninterruptible power, improve local reliability, reduce feeder losses and provide local voltage support. From environmental point of view, microgrids reduce environmental pollution and global warming through utilisation of low-carbon technology. However, to achieve a stable and secure operation, a number of technical, regulatory and economic issues have to be resolved before microgrids can become commonplace. Some problem areas that would require due attention are the climate-dependent nature of generation of the DERs, low energy content of the fuels and lack of standards and regulations for operating the microgrids in synchronism with the power utility. The study of such issues would require extensive real-time and off line research, which can be taken up by leading engineering and research institutes across the world [6].

Some research works from last decade are given below:

F. Katiraei, *et al.* studied that an appropriate control strategy for the power electronically interfaced distributed generation (DG) unit can ensure stability of the microgrid and maintain voltage quality at designated buses, even during islanding transients. They also concluded the presence of an electronically-interfaced DG unit makes the concept of microgrid a technically viable option for further investigations [7]. After that in the year of 2007, T. K. Panigrahi, *et al.* described the concept of microgrid central controller with local micro source controllers for the efficient participation in future real time markets and also discussed about market pricing, bidding from both source and load sides. Tariff structure may be proposed to make simple according to capacity charge and energy charge. Some incentives or encouragement may also be considered during peak hours when microgrid balances the power of whole system with maximum availability of protection [8]. In the year of 2011, under CERTS microgrid Laboratory test, R. H. Lasseter, *et al.* demonstrated the ease of integrating distributed energy sources into a microgrid, peer-to-peer and plug-and-play functionality, flexibility of control modes and ability to island and re-connect the grid in autonomous manner [9]. Prashant Kumar Soori *et al.* proposed the application of super capacitor energy storage system connected to microgrid. A super capacitor based energy storage system is the best option for microgrid because of its high storage capacity, wide working temperature range, cost effectiveness and eco-friendly [10]. JI Ping *et al.* reviewed on domestic and abroad island microgrids and presently, the planning, optimization, control and operation scheduling of island microgrid development is in laboratory stage or under demonstration projects [11]. R. H. Lasseter suggested that many "Smart Grid" functions such as improved reliability, high penetration of renewable sources, self-healing, active load control and improved generation efficiencies through the use of waste heat can be implements using coupled microgrids. Microgrid technology has maturing to the point that it is possible to design a full range of microgrid functions from high power quality to utilizing PV sources [12]. Wookyu Chae, *et al.* proposed a method to improve the stability of grid-interconnected microgrid using BESS (Battery Energy Storage System) and super capacitor. They conclude that the stability of microgrid can be improved using droop function and if mode of operation is changed [13]. Yih-Der-Lee, *et al.* investigated that for a stand-alone operation of the microgrid with HCPV (High Concentration Photovoltaic) and the microturbine, the operating voltage varied within the operation constraints of the grid-tied inverters due to change of load demand in the microgrid [14]. Muhammad Ali *et al.* studied the safe operation of microgrid to fulfil the supply and demand of the consumer and implemented an automated load management technique by intelligent controller to balance the energy level. After implementing this system, losses are reduced, quality of power is increased and due to reduced losses, tariff rates are reduced that can benefit poor people without interruption

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 4, April 2014

of power [15]. Prasenjit Basak *et al.* investigated that it is necessary to identify the feasibility of microgrid operation in the industrial fields and steady and dynamic state studies have been done in a plant equipped with many induction machines. The research teams of CERTS have greatly contributed in the research on the customer adoption of microgrid through proposing customer adoption modelling. This also shows the scopes of power electronic based application like static inverters with storage facilities provided with ‘‘plug-and play’’ functionality to provide required flexibility with the connected grid [16]. Mukundhan Srinivasan, *et al.* designed a system in which a combination of technologies to provide an Energy-on-Demand (EoD) service to enable low cost innovation suitable for microgrid networks and simple Rural Energy Device (RED) Box which serves as an elementary proxy for Smart meters which are typically used in urban areas. The whole system data stored in the cloud will provide valuable insights to the Utility Service Provider (USP) that can be used for Demand-Side-Management (DSM) in isolated/interconnected microgrid networks [17]. In the month of April 2013, Josep M. Guerrero *et al.* reviewed that the advanced control technique to increase the stability of microgrid with decentralized, distributed and hierarchical control of grid connected and islanded microgrids. By implementing the hierarchical control it may leads to energy management system and sets of microgrids can be developed by interconnecting intelligent microgrids for future perspective [18].

II. MICROGRID AS AN EMERGING POWER SYSTEM

The growth in renewable energy installation is a combined effect of regional energy development agencies, ministry of new and renewable energy (MNRE), and private sector participation [19].

A. Components of the Microgrid

Supportive government policies are also driving renewable energy installation. The planning commission of India has published integrated energy policy report (IEPR) which highlights the need to maximally develop domestic supply options and diversify energy sources for sustainable energy availability. According to IEPR, total renewable energy may account for 11-13% of India’s energy mix by the year 2032. It also suggests that the distributed nature of renewable energy sources can provide many socio-economic benefits for the country [20]. A microgrid is a group of interconnected loads and distributed energy resources (DERs) within clearly defined electrical boundaries that acts as a single controllable entity with respect to the grid. A microgrid can connect and disconnect from the grid to enable it to operate in both grid-connected or island-mode. The overview of common components of a microgrid is labeled in figure 1.

B. Operation and Control Techniques Employed in Microgrid Technologies

Renewable or non-conventional electricity generators employed in DG systems or microgrids are known as distributed energy resources (DERs) or microsources. The choice of a DER depends on the climate and topology of the region and fuel availability. This briefly describes the following DER technologies [6]:

- Combined heat and power (CHP) systems
- Wind energy conversion systems (WECS)
- Solar photovoltaic (PV) systems
- Small-scale hydroelectric generation
- Other renewable energy sources
- Storage devices.

i. Combined heat and power (CHP) systems

CHP or cogeneration systems are most promising as DERs for microgrid applications. Their main advantage is energy-efficient power generation by utilisation of waste heat. CHP system allows better usage of energy than conventional generation, potentially reaching an efficiency of more than 80%, compared with that of about 35% for conventional power plants. It is most efficient when the heat is utilised locally. Thus, CHP plants can be located somewhat remotely from their electrical loads, but they must always be located close to the heat loads for better performance.

ii. Wind energy conversion systems (WECS)

WECS convert wind energy into electrical energy. The principal component of WECS is the wind turbine. This is coupled to the generator through a multiple-ratio gearbox. Usually induction generators are used in WECS. The main

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 4, April 2014

parts of a wind turbine are the tower, the rotor and the nacelle. The generator shaft is driven by the wind turbine to generate electric power. The function of the gearbox is to transform the slower rotational speeds of the wind turbine to higher rotational speeds on the induction generator side. Output voltage and frequency is maintained within specified range, by using supervisory metering, control and protection techniques. Wind turbines may have horizontal axis configuration or vertical axis configuration. The average commercial turbine size of WECS was 300 kW until the mid-1990s, but recently machines of larger capacity, up to 5 MW, have been developed and installed.

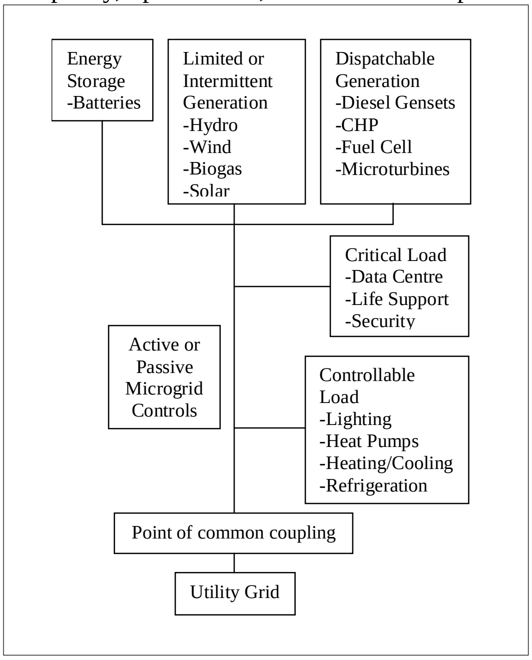

Fig. 1. Overview of common components in a microgrid.

iii. Solar photovoltaic (PV) systems

The major The major advantages of a PV system are sustainable nature of solar energy as fuel, minimum environmental impact, drastic reduction in customer’s electricity bills due to free availability of sunlight, long functional lifetime of over 30 years with minimum maintenance and silent operation. PV cells can be effectively used as a DER in a microgrid, but they suffer from the disadvantages of high installation cost and low energy efficiency. It has been studied that small PV installations are more cost-effective than larger ones, which indicates the effectiveness of feeding PV generation directly into customer circuits at low voltage distribution networks. However, the nature of PV generation being DC, suitable power converter circuits are to be employed for converting DC power into AC at the specified frequency level. Hence, they can be potential contributors to a microgrid. Solar energy reaches the PV cell in two components, direct and diffuse. The direct component is about 85% and comes through direct radiation. The diffuse component is about 15% and comes through scattered diffusion in the atmosphere.

iv. Small-scale hydroelectric power generation

The small-scale hydroelectric generators are effectively used for generating power onsite in microgrids. Extent of generation depends on the topography of an area and its annual precipitation. These generators suffer from large variations in generation due to variable water flow caused by uneven rainfall. Both synchronous and induction generators may be used for small-scale hydro generation with suitable multiple-ratio gearboxes. However, suitable precautions must be taken during designing a turbine so that its damage due to over speeding can be avoided during sudden loss of load.

v. Other renewable energy sources

The landfill gas, biomass, municipal waste, etc., are treated as other renewable energy sources for generation of electricity. The location of these generators is determined by the availability of these resources. Major drawbacks of

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 4, April 2014

these resources are low energy density, scarcity of resource and difficult to store them in large quantities. Since storage is not cost-effective, these generators are normally of small capacity and operate in load pockets close to the resources. A competitive arrangement, Non-Fossil Fuel Obligation (NFFO) was created in the UK to encourage generation from renewable energy resources in the late 1990s. The NFFO scheme has been replaced by another support mechanism named as Green Certificates in the year 2000, imposing some obligation on the electricity supplier's liability to generate a minimum percentage of their total generation from renewable sources. Other countries have also adopted different strategies and sometimes direct government intervention to encourage similar generation schemes.

vi. Storage devices

The backup energy storage devices that must be included in microgrids to ensure uninterrupted power supply are storage batteries, flywheels and ultra capacitors. These devices should be connected to the DC bus of the microgrid and provided with ride-through capabilities during system changes.

C. Challenges and Issues for DERs

The impacts of DG connection on the utility network protection are listed as follows:

- false tripping of feeders
- nuisance tripping of protective devices
- blinding of protection
- increase or decrease of fault levels with connection and disconnection of DERs
- unwanted islanding
- prevention of automatic reclosing
- out-of-synchronism reclosing

Technical recommendations like G83/1, G59/1, IEEE 1547, CEI 11-20 prescribe that DERs should be automatically disconnected from the medium voltage (MV) and low voltage (LV) utility distribution networks in case of tripping of the circuit breaker (CB) supplying the feeder connected to the DER. This is known as the anti-islanding feature. This is incorporated as a mandatory feature in the inverter interfaces for DERs available in the market. As the DERs are not under direct utility control, use of anti-islanding protection is justified by the operational requirements of the utilities. However, it drastically reduces the benefits of DERs and microgrids improve the service reliability. Therefore, these issues must be critically assessed and resolved, and market participation of DERs and microgrids should be allowed to exploit their full benefits. Although the current power scenario is still quite conservative in providing strong aspects to this new technology, the designers of distribution expansion are trying to realise the full capacity of the distributed generators and microgrids. The utilities may be pressed in this regard to come forward to encourage DER and microgrid deployment from three probable directions, as follows:

- As microgrid owners and DER manufacturers are more comfortable with basic energy production, they would intend to expand their range of operations.
- State regulators would press utilities to accept greater DER penetration.
- ISOs would recognise that microgrids and DERs can sell several ancillary services in the open market.

Hence, state regulatory bodies need to take initiatives for rapid implementation of the new technology for greater benefits to the distribution systems [6].

III. APPLICATIONS OF MICROGRID IN INDIAN-POWER SCENARIO

With an addition of 3,152 MW in 2012-13, the total installed capacity of grid-interactive renewable power reached about 28,000 MW. The total grid-interactive generation capacity in the country of wind power now stands at 19,051 MW, solar power at 1,686 MW, small Hydro power at 3,632 MW and Bio-power at 3,697 MW. In distributed/off-grid renewable energy, the total addition during 2012-13 was 99.13 MW, with a cumulative installed capacity of 825 MW. The Jawaharlal Nehru National Solar Mission, which is aiming at adding 20,000 MW of solar power capacity in the country by 2022. Phase-I of the Mission has been completed this year. Over 745 MW of solar power projects have been installed in the year 2012-13. A major objective of the Mission is to reduce and bring the cost of solar power generation to grid parity levels [21].

India is one of the fastest growing countries in terms of energy generation and consumption. Currently, it is the fifth largest consumer of energy in the world, and will be the third largest by 2030. Present capacity of about 190 GW is set

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 4, April 2014

to grow by 7-10% (to meet growing demands) to about 300GW in 2020 and 800GW by 2032 mostly through coal needing an investment of $150-175b annually. To meet the current deficit, consumers (mostly private) have installed diesel gen-sets of a total capacity of 35,000 MW which is not 'green', all operating in off-grid mode. Balancing this growth with the demand to contain emission is the challenge. One-sixth of the Indian villages are entirely off the electricity grid. Amongst the other 500,000 villages with grid access, more than 50% suffer from infrequent, erratic, low-voltage power [22]. Off-grid power generation augmented by local renewable energy (wind, solar, bio, hydro) in a microgrid mode is therefore an attractive option to energize nearly 125,000 villages currently off-grid [23].

The Ministry would like to step up renewable energy decentralized applications to save a billion litre of diesel annually after 5 years. Telecom towers and industrial power generation are two focus areas to reduce consumption of diesel. Thus off grid power will become a major component of sustainable energy and microgrid may become inevitable. India has initiated a National action plan on climate change through following Missions [24];

- Solar Mission
- Mission on Enhanced Energy Efficiency
- Mission on sustainable Habitat.
- Water Mission
- Mission for Sustaining Himalayan Eco-system
- Mission for Green India
- Mission for Sustainable Agriculture
- Mission for Strategic Knowledge on Climate Change

Kuvam Microgrid Private Limited gives some comparative advantages of microgrid which are listed in Table I. Kuvam has started its operation from West Champaran district of Bihar state in India where more than 400 households have been provided with a 24 hour electricity connection. The electricity has been generated through solar energy and distributed through a microgrid based on pre-paid metering model. Kuvam have 99% repayment rate by the consumers and 100% electricity theft elimination through its unique model. Kuvam's business model is one of the most profitable in solar industry with lowest establishment and maintenance cost [25].

	Lanterns/Home Light System	*Lantern Charging Station*	*Microgrid*
Affordability	One time high cost from Rs. 2000 to Rs. 14500	1 Lantern on rent for 4 Hours at Rs. 10 per day	2 Lights & Mobile charging cost Rs. 6,5 per day
Sustainability	Up to battery's life i.e. 1 year or maximum of 2 years	Up to battery's life i.e. 1 year or maximum of 2 years	Battery life of 5 years with high power Li-Ion batteries
Scaling	User has to buy whole new lantern/system	User can take more than one lanterns on rent	Power can be increased depending on the requirement
Utility	Only Light	Only light and Mobile charging	Beginning with light and go up to any application
Hassles	Movable component which make system difficult to manage	People have to go to charging station to take lantern on rent	Plug and Play, Hassle Free Service

Table 1 Comparative advantages of a microgrid [25]

IV. MICROGRID SIMULATION

To analyse the basic concept of a microgrid here we have considered one main DC grid along with two distributed energy resources (DERs) i.e. DER1 and DER2 and are connected to a common load bus. The main DC grid is connected to load bus through an intelligent bypass switch (IBS) which helps to open the circuit under failure of main DC grid or under islanded mode when the crucial load is taken by the DER1 and DER2. Here DER1 and DER2 may be solar energy plant, wind energy plant, photovoltaic cell, etc. The below mentioned figure 2 is simulated in Matlab-Simulink software to perform the operations of microgrid in grid connected mode and islanded mode. For this simulation model, we have considered one main DC grid with voltage profile of 220 V DC serving 10 kW of load while DER1 and DER2 are connected in parallel to the common load bus with same voltage profile of 220 V DC. For the same model, there are two operating conditions i.e. grid connected mode and islanded mode for this sample microgrid. From figure 3 it is found that the transition period from 0 to 2 seconds, microgrid is working under grid connected mode with equal sharing of power and from 2 to 3 seconds grid is operating under islanded mode. It means main DC grid is failed to supply the load so total load is taken by DER1 and DER2; hence the power is equally distributed in DER1 and DER2. The main DC grid is disconnected by IBS under islanded mode. After 3 seconds system is restored to its grid connected mode and again power is equally distributed by main DC grid, DER1 and DER2. Figure 3.1 shows that the power delivered by main DC grid under grid connected mode as well as islanded

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 4, April 2014

mode. Figure 3.2 and 3.3 shows that the power delivered by DER1 and DER2 under grid connected mode as well as islanded mode, respectively. The figure 3.4 represents the total power delivered to load under grid connected as well as islanded mode for total transition period from 0 to 5 seconds of simulation. It is to be noted that the actual operating time of the above operation is longer compared to the total simulation time of 5 seconds which is assumed just for the simplified simulation of this sample microgrid.

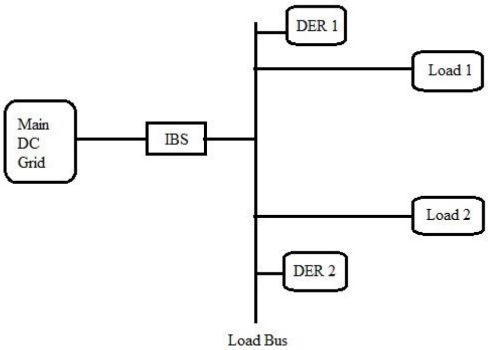

Fig. 2. A typical microgrid simulation model

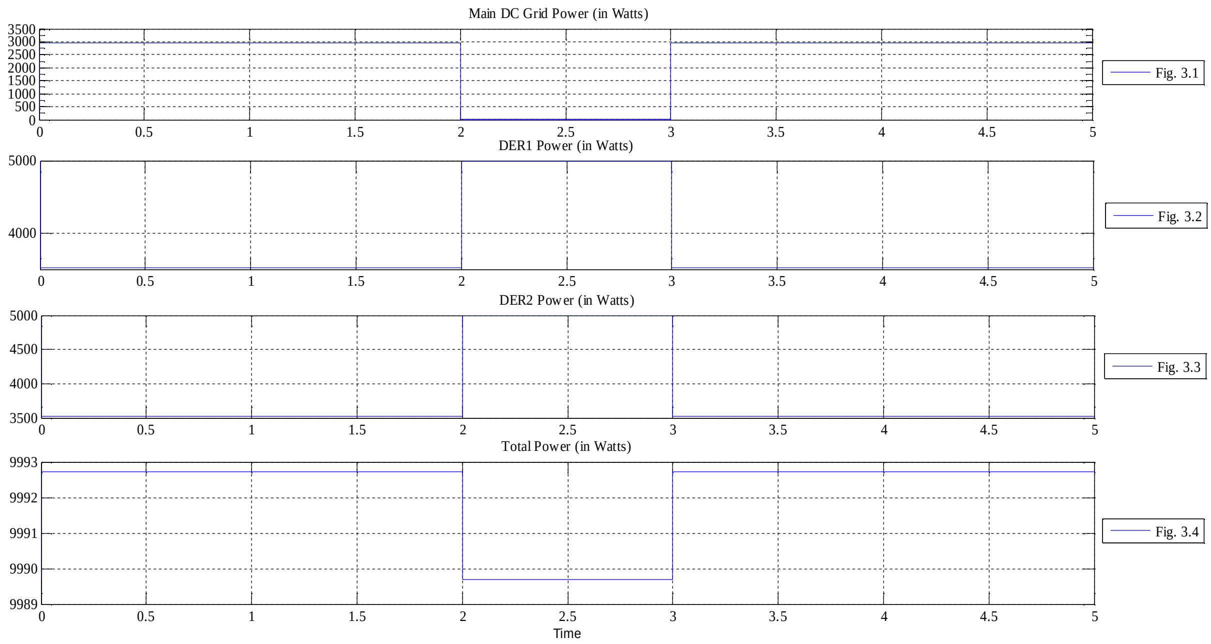

Fig. 3. Waveforms obtained from simulation of DC microgrid during transition from grid connected to islanded mode

IV. CONCLUSION

It is realized that India has significant growth in renewable energy generation. It also suggests that the distributed nature of renewable energy sources can provide many socio-economic benefits for the country. Grid interactive energy sources developed so far in India are Solar, Wind, Small Hydro and Bio Energy. The benefits of interconnecting multiple DERs are investigated in this work in a smaller scale by the simulation of a sample microgrid operating in grid connected and islanded mode and the results found satisfactory. The economic analysis of microgrid at planning stage is generally the function of various aspects like distance to grid, fuel availability, choice of technologies, subsidies, and the regulatory policies. In addition, the key points for success of microgrid are development and utilization of safe and dependable communication infrastructure and control strategies. The present work may be considered as an initial endeavour of the authors to investigate the feasibility of microgrid technology based on the above remarkable factors in future research work.

REFERENCES

[1] http://www.renewindians.com/2013/02/indian-renewable-installed-capacity-has-reached-27.7GW.html
[2] Sethi, Nitin (18 November 2009). "India targets 1,000 MW solar power in 2013". Times of India.
[3] http://cdkn.org/resource/cdkn-inside-story-transforming-india-into-a-solar-power/?loclang=en_gb
[4] "World Wind Energy Report 2008"
[5] White Paper on "Integration of Distributed Energy Resources, The CERTS Microgrid Concept", prepared by Robert Lasseter, Abbas Akhil, Chris Marnay, John Stephens, April, 2002.
[6] S. Chowdhury, S. P. Chowdhury and P. Crossley, "Microgrids and Active Distribution Networks", published by The Institution of Engineering and Technology, London, UK, 2009.
[7] F. Katiraei, M. R. Iravani and P. W. Lehn, "Micro-Grid Autonomous Operation During and Subsequent to Islanding Process", IEEE Transactions on Power Delivery, Vol. 20, No. 1, pp. 248-257, January 2005.
[8] T. K. Panigrahi, A. K. Basu, S. Chowdhury, S. P. Chowdhury, N. Chakraborty, A. Sinha and Y. H. Song, "EMERGING POWER MARKET IN A MICROGRID SCENARIO", UPEC, pp. 1079-1085, 2007.
[9] R. H. Lasseter, J. H. Eto, B. Schenkman, J. Stevens, H. Volkommer, D. Klapp, E. Linton, H. Hurtado and J. Roy, "CERTS Microgrid Laboratory Test Bed", IEEE Transactions on Power Delivery, Vol. 26, No. 1, pp. 325-332, January 2011.
[10] Prashant Kumar Soori, Subhas Chandra Shetty, Sibi Chacko, "Application of Super Capacitor Energy Storage in Microgrid System", IEEE GCC Conference and Exhibition, pp. 581-584, February 19-22, 2011.
[11] JI Ping, ZHOU Xiao Xin, WU ShouYuan, "Review on Sustainable Development of Island Microgrid", The International Conference on Advanced Power System Automation and Protection, pp. 1806-1813, 2011.
[12] R. H. Lasseter, "Smart Distribution: Coupled Microgrids", Special Issue Proceedings of the IEEE, The Smart Grid, pp. 1-8, 2011.
[13] Wookyu Chae, Hakju Lee, Jungsung Park, Wonwook Jung, "Cooperative Operation Method of Two Battery Systems at Microgrid System", 3rd IEEE International Symposium on Power Electronics for Distributed Generation Systems, pp. 872-877, 2012.
[14] Yih-Der-Lee, Yung-Ruei Chang, Chen-Min Chan, Yuan-Hsiang Ho, "Preliminary Implementation of Microgrid with Photovoltaic and Microturbine for Stand Alone Operation", IEEE, 2012.
[15] Muhammad Ali, Hafeez ur Rahman, Waheed ur Rahman, Haseeb ur Rahman, "Trends and Overview Regarding the Involvement of Micro-Grids in Modern Power Systems", Smart Grid and Renewable Energy, Vol. 3, pp. 83-84, 2012.
[16] Prasenjit Basak, S. Chowdhury, S. Halder nee Dey, S. P. Chowdhury, "A literature review on integration of distributed energy resources in the perspective of control, protection and stability of microgrid", Renewable & Sustainable Energy Reviews, Volume 16, Issue 8, pp. 5545-5556, October 2012.
[17] Mukundhan Srinivasan, Sabarigirish Vijaykumar, Ramesh Rajesh, Vineeth Vijayaraghavan, "Low-Cost Cloud-Based Design of Smart Rural Energy Device in Microgrid: Perspective India", 1st IEEE Conference on Technologies for Sustainability, pp. 244-249, 2013.
[18] Josep M. Guerrero, Mukul Chandorkar, Tzung-Lin Lee, Poh Chiang Loh, "Advanced Control Architectures for Intelligent Microgrids – Part I: Decentralized and Hierarchical Control", IEEE Transactions, Vol. 60, No. 4, pp. 1254-1262, April 2013.
[19] Available: www.mnre.gov.in/.Nov. 2009.
[20] V. S. K. Murthy Balijepalli, S. A. Khaparde and C. V. Dobariya, "Deployment of Microgrids in India", IEEE, pp. 1-7, 2010.
[21] "Government of the United Progressive Alliance", Report to the People, 2012-13.
[22] IFMR Center for Development Finance- World Resources Institute, "Power to the People: Investing Clean Energy for the Base of the Pyramid in India", 2010.
[23] S. S. Murthy, "Micro-Grid Integration with Renewable Energy in Indian Perspective", Life Senior Member, IEEE, pp. 1-8.
[24] A. Ramachandran, "Technology and the Challenge of Sustainable Development", 54th Sir M Visvesvaraya Memorial Lectue at The Institution of Engineers (India), Bangalore, 15-18 Dec. 2011.
[25] "Kuvam Micro-Grid Private Limited", Centre for Science and Environment- Chattisgarh, presented on 19th August, 2013.

BIOGRAPHY

Jitender Kaushal is a Ph.D research scholar in Electrical and Instrumentation Engineering Department of Thapar University, Patiala, Punjab, India. He received his Master of Engineering in Power System and Electric Drives from Thapar University, India and Bachelor of Technology in Electrical Engineering from Institute of Engineering and Emerging Technology under Himachal Pradesh University, India in the year 2012 and 2008 respectively. He is also working as a Lecturer in Electrical and Instrumentation Engineering Department of Thapar University. From the year 2009 to 2010, he had served as Trainee Engineer in M/s Aartech Solonics Limited in the field of automatic bus transfer system. His research interest is on microgrid, renewable energy resources, distributed generation technology and their penetration in conventional power system. E-mail: jitender.kaushal@thapar.edu

Prasenjit Basak received his BEE and PhD degree in the year 1999 and 2012 respectively from the Jadavpur University, India. He served several industries from the year 1999 to 2004. He started his academic career from the year 2005 and he is currently working as Assistant Professor in the Electrical and Instrumentation Engineering Department of the Thapar University at Patiala in India from 2013. He has published research papers in several international journals including international and national conferences, mainly in the areas of operation, control, power quality, protection and stability of microgrid systems. Email: prasenjit@thapar.edu