Potential Use of DC Microgrid for Solar and Wind Power Integration in Rural Areas in India: A Review

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Abstract: ***This paper describes the possibilities of the application of DC microgrids to solve the rural areas, energy problem in the country (India). DC Microgrids open a gateway for integration of solar and wind energies which together are efficient and cleaner way of renewable energy generation, which can be integrated into the power distribution network. They have several other advantages, which include - reduction in transmission losses, improvement in power quality & reliability, reduction in emissions and even they are cost effective. The most important characteristic is that it provides a possibility for electrification of remote villages, which are far from the reach of the conventional grid. This paper presents a detailed discussion on the possibility of application of DC microgrids for rural areas in India.***

Keywords: DC microgrid, solar, wind, BESS, supercapacitor, HOMER, State of Charge (SoC).

1. Introduction

Renewable energy plays an important role in the global energy sector. The wind and solar energy sectors particularly have experienced tremendous investment and growth in the last decade and the trend still continues [1]. The global society has not only become increasingly more energy dependent, but has also become more aware of environmental effects. Once the renewable energy technologies become more dominant, then energy would be produced anywhere without polluting the environment.

Ministry of Non-Conventional Energy Sources (MNES) in India has been supporting research and development efforts to upgrade the existing technologies of renewable energy generation[2]. The R&D work mainly focuses on power generation, system design and optimization. The energy systems designed using renewable sources primarily seek to address issues related to electric and transportation sectors. The ideas presented in this paper mainly focus on electrical energy generation and also to analyze usefulness of designing DC microgrids for remote locations in the developing world. A key advantage of DC microgrids is that the low risk of dangerous electric shocks from low voltage DC makes plug-and-play grids a possibility [3]. DC microgrid is one of the new approach to generate and use power in our buildings and also link how to make and distribute power at the national electrical grid level—the "macro grid". The use of microgrids is partly motivated by the increasing concern for the strain on and vulnerability of electrical macro grid system.

The operational controls are designed using different methods in order to support the integration of wind and solar power within microgrids. Reported works in literatures also describe that the engineers design multilevel energy storage systems comprising of Battery Energy Storage System (BESS) and Supercapacitors. Energy can be stored in batteries when it is generated by both wind turbine and the PV array. Later, during peak time the stored energy can be used. Hence DC microgrid with multiple sources can benefit the poor by providing efficient and cost effective energy storage technologies.

2. Basic Structure of a DC Microgrid

Depending on its operational frequency, microgrids are classified into three types, viz., AC microgrid, DC microgrid and hybrid AC/DC microgrid. Compared to the others, DC microgrids have shown more advantages and they are being studied by many researchers these days for different applications. Researchers believed bygrowing number of proponents that "smart" dc microgrids can make better use of the energy generated, stored, and used at a local level. Whether are new on-site energy generation (e.g., solar installations) or adding smart devices to monitor energy use or intelligently connecting power to electric vehicles and battery storage, such approaches added control of energy use at the building level, thus making buildings better "partners" with the nation's smart grid efforts[4]. It also provide a way to buy centrally generated energy at times of the day when it is more abundant, temporarily store it, and then use it during peak demand periods.

A Hybrid energy storage system (HESS) consisting of batteries and supercapacitors, used to meet the highly fluctuating power demands [5]. The main purpose of supercapacitor is that it can take care of high frequency power component in contrast to the batteries which can take care of average power component only. Therefore a hybrid energy system improves system efficiency and reduces the battery cost. It is very important to study the steady state characteristics of the DC microgrid as mentioned by Dong Chen and Lie Xu [6], in order to gain a deep understanding of its effect on the system. Itrequires local and supervisory detection units at the constant power loads (CPLs) to detect the fault.

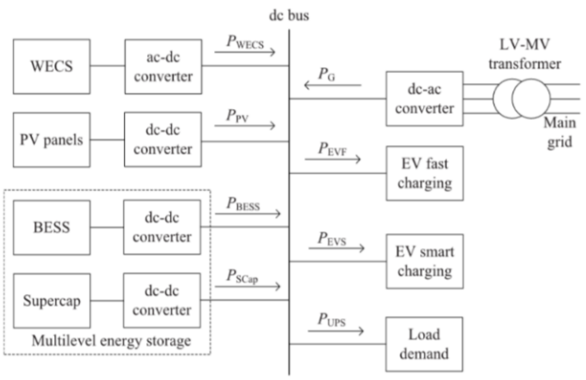

Figure 1: Layout of DC Microgrid [3]

Figure 1, shows the schematic diagram of a typical DC microgrid with conventions employed for power transmission. The primary requirement of DC microgrid is to maintain the DC bus within an acceptable range of voltage. Wind energy conversion system (WECS) connects to dc bus generally through ac to dc converter and PV panel connects to dc bus through dc to dc converter.A multilevel energy storage comprising of Battery Energy Storage System (BESS) and Supercapacitors also connects to dc bus through dc to dc converters. The capacitor has much less energy capacity than the battery, but has the capacity of charging and discharging much faster than a battery. Also dc bus can be connected to Electric Vehicle (EV) charging points through EV charging station and grid interface.

A typical DC microgrid system has four kinds of terminals: generation, load, Energy Storage System (ESS), and grid-connected voltage-source converter (G-VSC). In research works by Dong Chen, Lie Xu and Liangzhong Ya [7] and in another by Xiu Yao [8], these terminals have been classifiedinto two types: power terminal and slack terminal. Power terminals usually operate on their own merits and do not actively contribute to system control. Typical power terminals are variable generations such as wind and photovoltaic systems, which normally operate at maximum power point tracking (MPPT) according to weather conditions, and variable load. On the other hand, slack terminals are controlled to accommodate the power variation coming from the power terminals and maintain a stable system operation with limited DC voltage variation. A DC microgrid should have at least one slack terminal to satisfy the operation. The generation within a DC grid can come from wind, photovoltaic units, diesel generator, etc.

The DC Grids can be cost effective and present a minimal technical risk while addressing energy scarcity in many parts of the world [9].

3. Energy Requirement of Rural Area

Many of India's villages are still un-electrified. Most of the houses in rural areas use kerosene lamp for lighting and fire wood for cooking. Houses are built with local materials such as clay, wood, bamboo etc. Requirement of energy in most of the rural houses are also minimal.

Figure 2 shows a DC village-microgrid [7] with the goal of meeting the dynamic electricity needs of households within a 2 km radius which will integrate the following features:

(a) Line transmission losses will be minimized by using 380V DC and converted to safer 12VDC at the households.

(b) A droop voltage power-sharing scheme is implemented, wherein the microgrid voltage droops in response to low-supply/high-demand.

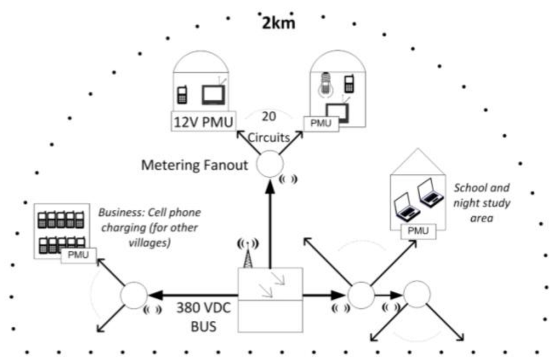

Figure 2: Architectural overview of a DC village-microgrid with a 380VDC transmission bus that is converted to 12VDC for household usage [7]

(c) The household power management units (PMUs) integrate scalable distributed storage that are owned by individual households.
(d) PMU will have good efficient DC-DC converters that provide power to efficient DC appliances.

A technique of prediction of PV inverter current is presented in research work by P. Achintya Madduri *et al.* in 2013[11] when the current exceeds its rated value, due to any grid faults. The objective of this work was to prevent the loss of PV based renewable generation due to fault. The grid code required the DG inverter to stay connected and provide Low Voltage Ride Through (LVRT) capability during fault scenario. The proposed methodology was based on the evaluation of slope and magnitudes of the PV inverter current for short circuit current detection.
The photovoltaics (PV) require an automation surveying over large geographical areas [12]. It is very important to have a good knowledge of roof top characteristics in order to identify where the problems arise in the National Grid and where mitigation measures may be necessary. The research describes that how the required roof characteristics may be obtained together with expected percentage error.

4. Loss Optimization and Cost Effectiveness

The goal of microgrid is to coordinate operation with the large power grid and also to provide an effective complement to the power grid. With large scales of microgrid connected in the distribution grid, the interaction between the DC microgrid and the power grid cannot be ignored [13]. The main backbone of microgrid is DC where DC equipment connect microgrid directly.

A loss optimized cost effective droop control schemein some research works [14,15] described a remotely located DC microgrid connected to a weak radial distribution feeder. It provides a loss optimized and cost effective droop control law for the battery energy storage converter (BESC) and bidirectional interfacing converter (BIC). The BIC controller ensures that the drop/rise in distribution grid voltage at the point of common coupling (PCC) due to the active power exchange between DC microgrid and utility grid is as per the Indian voltage regulation standards set by the Central Electricity Authority (CEA).

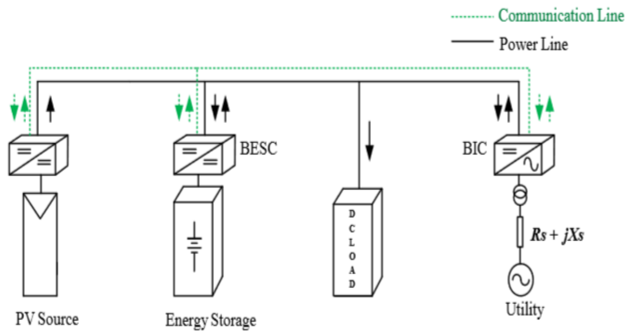

Figure 3: Single line diagram of a DC microgrid connected to the utility grid [14]

The total system losses in dc microgrid are compared with the losses of ac microgrid. The less power conversion stages due to the very nature of the distributed sources, storages, and loads make DC microgrid more attractive than the AC microgrid. The DC microgrid is also preferred over AC microgrid because (i) quality of power supply is high, (ii) has more reliability and higher uninterruptible supply, (iii) the losses are less due to the absence of reactive power, and (iv) has higher efficiency [16].

Microgrids are key elements to integrate renewable and distributed energy resources as well as distributed energy storage systems. The new electrical grid named as Smart-grid (SG) will deliver electricity from suppliers to consumers by using digital technology to control appliances at consumer's homes to save energy, reducing cost and increase reliability and transparency [17,18].
Use of transformer can be eliminated on load side converter by using proper dc voltage of the microgrid (±750V in some study) [19].

Thus a dc microgrid leads to minimization of cost of improvement in efficiency at the same time.

5. Charging and Discharging Status Monitoring of The Battery Bank

The condition of the smart grid to work safely depends on maximum **State of Charge (SoC)** and the lifetime of the battery bank guaranteed by minimum state of charge. In order to maintain the state of charge (SoC) of the storage system within its nominal limits, a storage converter voltage control loop is used, with a correction of the reference voltage as a linear function of the deviation between the desired SoC and the actual one [20]:

$$V_{dc-ref} = V_{dc}^{*} - k.(Q_{storage-ref} - Q_{storage-meas})$$

where,
V_{dc}^{*}= dc reference voltage of the interface converter
$Q_{storage-ref}$ = target state of charge
$Q_{storage-meas}$= measured state of charge
k = proportionality constant

The proportionality constant of the SoC controller is set according to the desired range excursion of the storage system SoC. In this way an automatic self-regulating control of SoC is implemented which guarantees that SoC is brought back to its target value in steady-state conditions.

Also flow of energy from the wind turbine and the battery bank should be done for charge acceptance and discharge rate of batteries [21]. Limitations of state of charge (SoC) depend on the characteristics of battery charging regulator.

Use of voltage regulator also is one of the main tasks to take care of the fluctuating conditions to make the system efficient. To follow all the power fluctuations on the dc bus, the closed-loop bandwidth set for the storage converter is kept as high as possible.In another type of work,green energy storage monitoring system was designed to monitor the lithium iron phosphate battery charging and discharging status for a long time [22]. It is basically used manage diverse power sources from power plants, solar panelsand wind turbines and to coordinate the difference between the peak and average power availability, and also to maintain the consistency of the power quality in the user side. The core of the overall solution for these issues is the use of the energy storage systems efficiently.

6. Tri-Loop Dynamic Error-Driven PI Controller

Research works carried out by O. M. Longe, K. Ouahada, H. C. Ferreira and S. Chinnappen in 2014 [23] and by T. Aboul-Seoud and A. M. Sharaf in 2009 [24,25], present a design of tri-loop dynamic error-driven PI controller. The design is to improve the power quality in the distribution systems that are interfaced with distributed generation (DG), a novel PWM switched DVR and MPFC driven by a Tri-loop Dynamic Error Driven PI Controller are developed.

1) DVR: The tri-loop dynamic error-driven PI controller is the summation of the three basic loops: **(i)** The voltage stabilization loop functions tracking the error of load voltage if there is any fluctuation in the wind speed and regulating it to near unity, **(ii)** The second loop is the load bus current dynamic error tracking loop, which compensate when there is any current change, **(iii)** The Current Harmonic Tracking Loop is the supplementary used for reducing the harmonic ripple content in the distribution system.

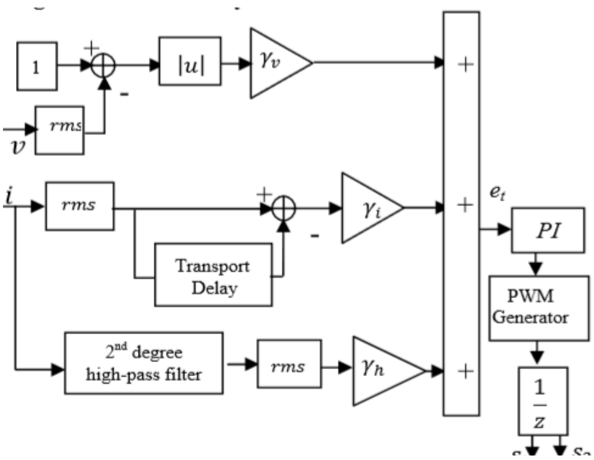

Figure 4: The Tri-loop dynamic error driven controlled PWM layout [23]

2) MPFC: The MPFC tri-loop dynamic error-driven PI controller corrects the global error. It is the summation of the three basic loops for voltage, current, and current harmonic ripple with different assigned loop weights. The scheme introduces significance to the network power factor while decreasing the supply current, and the losses in the distribution feeders. It also decreases the total harmonic distortion in the current. The scheme is cheap and robust.

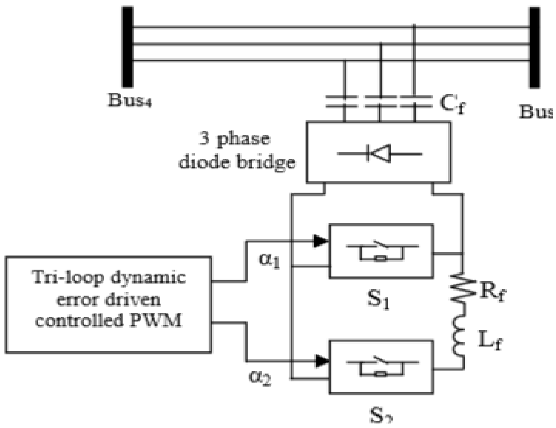

Figure 5: The MPFC layout [24]

7. Hybrid Optimization Model for Electric Renewables (HOMER)

The renewable energy in India has got very high potential, but the total contribution of renewable power as compared to electricity generation is very low. Hence, it is necessary to utilize these resources in optimum manner. One of the excellent solutions for the energy problems in rural areas is the hybrid energy system where grid extension is difficult and not feasible. It is a combination of two or more different types of energy systems which come together to give the optimum output by utilizing the available natural resources in India. The task to design such system is very difficult; hence good planning of such system is important before its construction.

The HOMER software is used to determine the optimal sizing and operational for a hybrid renewable energy system, using the solar radiation data, wind speed data, and load data, based on the three principal steps viz., Simulation, Optimization and Sensitivity analysis [26,27,28]. HOMER simulates the system based on estimation of installing cost, replacement cost, operation and maintenance cost, fuel and interest.

SIMULATION: HOMER performs the energy balance calculations, which determines the best feasible system configuration which can adequately serve the electric demand. HOMER simulates the system based on estimation of installing cost, replacement cost, operation and maintenance cost, fuel and interest.

OPTIMIZATION: Optimization is done after simulation of different combination of hybrid renewable energy system configurations. It is based on Total Net Present Cost (TNPC) to find out number of system configurations.

SENSITIVITY ANALYSIS: The HOMER software repeats the optimization process for every selection of sensitivity variables for the hybrid renewable energy system. The sensitivity variables are the global solar irradiation, wind speed and the price of diesel fuel. The various configurations of hybrid renewable energy are tabulated from the lowest to the highest TNPC. The optimal solution of hybrid renewable energy system is referring to the lowest TNPC.

Hence HOMER software is designed which is used for the simulation and optimization analysis because it limits the input complexity, performs fast enough computation [29].

The work done by Vlado Ostovic in 2014 [10], shows the Harmonic Fields (HF) Generator which is a new electric machine topology for wind. The Harmonic Fields (HF) Generator is perfectly suited for wind applications. A wind turbine drive built around an HF generator has a higher energy yield than a turbine with conventional generator and frequency converter. It is cheaper to build and requires less maintenance.

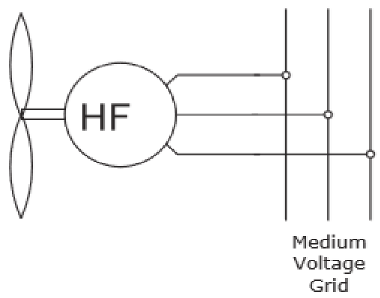

Figure 6: HF generator schematics

Besides low maintenance costs, the wind turbine with HF generators are characterized by low investment cost because they do not requirepermanent magnet, frequency converter, gearbox, transformer and slip rings to generate electric energy from wind.

8. Conclusion

A detailed review of the scope and advantages in using DC microgrid from rural areas has been done. The DC grid shows marked advantages over AC grids in terms of their efficiency and cost effectiveness. The latest trend in controlling the voltages and used of HOMER software in simulation, optimization and sensitivity analysis are also discussed. Overall, the DC microgrid is a viable option for distributing power in both rural and urban households, utilizing solar and wind power available freely.

References

[1] N. Aspinall, L. Mills, D. Strahan, R. Boyle, V. Cuming, K. Stopforth, S. Heckler and L. Becker, “Global Trends in Renewable Energy Investment 2014: Key Findings”, Global Trends Reports, *UNEP Collaborating Centre for Climate & Sustainable Energy Finance, Frankfurt School of Finance & Management*, Germany, April 2014. Retrieved from http://fs-unep-centre.org/publications/gtr-2014

[2] D. P. Kothari, “Renewable Energy Scenario in India”, *Conference Proceedings of 2000 IEEE Power Engineering Society Winter Meeting*, (Cat. No.00CH37077), Vol.1, Jan 23-27, 2000, pp. 634-636. Doi: https://doi.org/10.1109/PESW.2000.850112

[3] K. Strunz, E. Abbasi and D. N. Huu, “DC Microgrid for Wind and Solar Power Integration”, *IEEE Journal of Emerging and Selected Topics in Power Electronics*, Vol. 2, Issue No. 1, March 2014, pp. 115–126. Retrieved from https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=6681907

[4] B. T. Patterson, "DC, Come Home: DC Microgrids and the Birth of the "Enernet" ", *IEEE Power and Energy Magazine*, Vol. 10, Issue No. 6, Nov.-Dec. 2012, pp. 60-69. Doi: 10.1109/MPE.2012.2212610

[5] S. K. Kollimalla, M. K. Mishra, A. Ukil and H. B. Gooi, "DC Grid Voltage Regulation Using New HESS Control Strategy", *IEEE Transactions on Sustainable Energy*, Vol. 8, Issue No. 2, April 2017, pp. 772-781. Doi: 10.1109/TSTE.2016.2619759

[6] D. Chen and L. Xu, "Autonomous DC Voltage Control of a DC Microgrid with Multiple Slack Terminals", *IEEE Transactions on Power Systems*, Vol. 27, Issue No. 4, November 2012, pp. 1897-1905. Doi: 10.1109/TPWRS.2012.2189441

[7] D. Chen, L. Xu and L. Ya, "DC Voltage Variation Based Autonomous Control of DC Microgrid", *IEEE Transaction on Power Delivery*, Vol. 28, Issue No. 2, April 2013, pp. 637-648. Doi: 10.1109/TPWRD.2013.2241083

[8] X. Yao, "Study on DC arc faults in ring-bus DC microgrids with constant power loads", *Proceedings of 2016 IEEE Energy Conversion Congress and Exposition (ECCE)*, Milwaukee, WI, Sept. 18-22, 2016, pp. 1-5. Doi: 10.1109/ECCE.2016.7855474

[9] F. Sharp, D. Symanski and M. S. Dudzinski, "Scalable DC Micro Grids provide cost effective electricity in regions without electric infrastructure", *Proceedings of IEEE Global Humanitarian Technology Conference (GHTC 2014)*, San Jose, CA, Oct. 10-13, 2014, pp. 18-24. Doi: 10.1109/GHTC.2014.6970255

[10] V. Ostovic, "Harmonie fields machine-The low cost, high efficiency alternative to a conventional generator with frequency converter for wind energy applications", *Proceedings of 2014 International Conference on Renewable Energy Research and Application (ICRERA)*, Milwaukee, WI, 19-22 Oct. 2014, pp. 48-54. Doi: 10.1109/ICRERA.2014.7016453

[11] P. A. Madduri, J. Rosa, S. R. Sanders, E. A. Brewer and M. Podolsky, "Design and Verification of Smart and Scalable DC Microgrids for Emerging Regions", *Proceedings of 2013 IEEE Energy Conversion Congress and Exposition*, Denver, CO, Sept. 15-19, 2013, pp. 73-79. Doi: 10.1109/ECCE.2013.6646683

[12] R. K. Varma, S. A. Rahman, V. Atodaria, S. Mohan and T. Vanderheide, "Technique for Fast Detection of Short Circuit Current in PV Distributed Generator", *IEEE Power and Energy Technology Systems Journal*, Vol. 3, Issue No. 4, Dec. 2016, pp. 155-165. Doi: 10.1109/JPETS.2016.2592465

[13] J. M. Guerrero, M. Chandorkar, T. L. Lee and P. C. Loh, "Advanced Control Architectures for Intelligent Microgrids-Part I: Decentralized and Hierarchical Control", *IEEE Transactions on Industrial Electronics*, Vol. 60, Issue No. 4, April 2013, pp. 1254-1262. Doi: 10.1109/TIE.2012.2194969

[14] J. M. Guerrero, P. C. Loh, T. L. Lee and M. Chandorkar, "Advanced Control Architectures for Intelligent Microgrids—Part II: Power Quality, Energy Storage, and AC/DC Microgrids", *IEEE Transactions on Industrial Electronics*, Vol. 60, Issue No. 4, April 2013, pp. 1263-1270. Doi: 10.1109/TIE.2012.2196889

[15] D. Palmer, I. Cole, T. Betts and R. Gottschalg, "Assessment of potential for photovoltaic roof installations by extraction of roof tilt from light detection and ranging data and aggregation to census geography", *IET Renewable Power Generation*, Vol. 10, Issue No. 4, April 2016, pp. 467-473. Doi: 10.1049/iet-rpg.2015.0388

[16] G. Melath, D. Kapse and V. Agarwal, "A Loss Optimized and Cost Effective Droop Control Scheme for a DC Microgrid Integrated with a Weak Rural Distribution Grid", *Proceedings of 2016 IEEE International Conference on Power Electronics, Drives and Energy Systems (PEDES)*, Trivandrum, 14-17 Dec. 2016, pp. 1-6. Doi: https://doi.org/10.1109/PEDES.2016.7914272

[17] H. Kakigano, M. Nomura and T. Ise, "Loss evaluation of DC distribution for residential houses compared with AC system", *Proceedings of The 2010 International Power Electronics Conference - ECCE ASIA*, Sapporo, 21-24 June 2010, pp. 480-486. Doi: https://doi.org/10.1109/IPEC.2010.5543501

[18] L. Zhang, T. Wu, Y. Xing, K. Sun and J. M. Gurrero, "Power Control of DC Microgrid Using DC Bus Signaling", *Proceedings of IEEE Applied Power Electronics 26th Annual Conference and Exposition (APEC)*, Fort Worth, TX, April 2011, pp. 1926-1932.

[19] M. Kumar, S. N. Singh and S. C. Srivastava, "Design and Control of Smart DC Microgrid for Integration of Renewable Energy Sources", *Proceedings of 2012 IEEE Power and Energy Society General Meeting*, San Diego, CA, 22-26 July 2012, pp. 1-7. Doi: https://doi.org/10.1109/PESGM.2012.6345018

[20] J. M. Andújar, F. Segura and T. Domínguez, "Study of a Renewable Energy Sources-based Smart Grid. Requirements, Targets and Solutions", *Proceedings of 3rd IEEE*

Conference on Power Engineering and Renewable Energy (ICPERE), Yogyakarta, Indonesia, 29-30 Nov. 2016, pp. 45-50. Doi: https://doi.org/10.1109/ICPERE.2016.7904849

[21] M. Narayana, "Demand and Supply Analysis of Community Type Wind power System at Gurugoda Village in Sri Lanka", *Proceedings of 2007 International Conference on Industrial and Information Systems*, Penadeniya, 9-11 August 2007, pp. 117-121. Doi: https://doi.org/10.1109/ICIINFS.2007.4579159

[22] C. B. Tzeng and C. H. Tzeng, "Green Energy Storage Monitor System: Electricity storage", *Proceedings of 2017 2nd International Conference Sustainable and Renewable Energy Engineering (ICSREE)*, Hiroshima, 10-12 May 2017, pp. 67-72. Doi: https://doi.org/10.1109/ICSREE.2017.7951513

[23] O. M. Longe, K. Ouahada, H. C. Ferreira and S. Chinnappen, "Renewable Energy Sources Microgrid Design for Rural Area in South Africa", *Proceedings of 2014 IEEE PES Innovative Smart Grid Technologies Conference (ISGT 2014)*, Washington, DC, 19-22 Feb. 2014, pp. 1-5. Doi: https://doi.org/10.1109/ISGT.2014.6816378

[24] T. Aboul-Seoudand A. M. Sharaf, "A Novel Dynamic Voltage Regulator Compensation Scheme for a Standalone Village Electricity Wind Energy Conversion System", *Proceedings of IEEE Canadian Conference on Electrical and Computer Engineering (CCECE'09)*, NL, Canada, 3-6 May 2009, pp. 117-121. Doi: https://doi.org/10.1109/CCECE.2009.5090103

[25] T. Aboul-Seoud and A. M. Sharaf, "A Novel Modulated Power Filter Compensator Scheme for Standalone Wind Energy Utilization Systems", *Proceedings of IEEE Canadian Conference on Electrical and Computer Engineering (CCECE'09)*, NL, Canada, 3-6 May 2009, pp. 390-393. Doi: https://doi.org/10.1109/CCECE.2009.5090160

[26] A. M. Sharaf, A. S. Aljankawey and I. H. Altas, "Dynamic Voltage Stabilization of Stand-Alone Wind Energy Schemes", *Proceedings of 2007 IEEE Canada Electrical Power Conference*, Montreal, Que.,Oct. 25-26, 2007, pp. 14-19. Doi: https://doi.org/10.1109/EPC.2007.4520299

[27] J. B. Fulzele and M. B. Daigavan, "Optimization of PV-Wind Hybrid Renewable Energy system for Rural Electrification", *Proceedings of 2015 7th International Conference on Emerging Trends in Engineering & Technology (ICETET)*, Kobe, Japan, Nov. 18-20, 2015, pp. 101-105. Doi: https://doi.org/10.1109/ICETET.2015.47

[28] R. Huang, S. Low, U. Topcu and K. Chandy, "Optimal design of hybrid energy system with PV/Wind Turbine/ Storage: A Case study", *Proceedings of 2011 IEEE International Conference on Smart Grid Communications (SmartGridComm)*, Brussels,17-20 Oct. 2011, pp. 511-516. Doi: https://doi.org/10.1109/SmartGridComm.2011.6102376

[29] N. Razak and M. Othman, "Optimal sizing and operational strategy of hybrid renewable energy system using HOMER", *Proceedings of 2010 4th International Power Engineering and Optimization Conference (PEOCO)*, Shah Alam, 23-24 June 2010, pp. 495 – 501. Doi: https://doi.org/10.1109/PEOCO.2010.5559240

[30] J. Ahmed and S. Chanana, "Trading Opportunities for Wind Generators in Indian Electricity Market", *ADBU Journal of Engineering Technology*, Volume 2, Issue No. 1, June 2015, 0021104(6pp). Retrieved from http://journals.dbuniversity.ac.in/ojs/index.php/AJET/article/view/70

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