Analysis and Scope of Hybrid Renewable Energy System

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Abstract. Shifting to Renewable Energy Sources has become the need of the hour, but the dependency of these sources on natural, uncontrollable factors, poses a great challenge. A stable power supply is necessary for a hundred percent shift to renewable sources of energy. This reliability can be increased in many ways, but here in focus, are Hybrid Renewable Energy Systems (HRES). HRES is an attempt to make a stable energy source that is clean and sustainable. The paper in detail presents the scope of HRESs keeping India in focus.

1. Introduction

Non-renewable sources of energy by definition, are sources of energy that are limited. Meaning, these sources will not be replenished in many lifetimes. Non-renewables mainly refer to coal, oil, petroleum, natural gas, and also include nuclear and biomass. Most power plants that are used to generate electricity on a large-scale burn fossil fuel [1-10]. Being limited is not the only drawback of these fossil fuels, as they also cause a lot of pollution and add to the ever-increasing climate problem. Climate change is real, and its effects, shifting weather patterns and rising sea levels have never been more evident. A fundamental change in the way we generate electricity has become necessary [11-20].

Renewable energy, as the name suggests, replenishes quickly. These sources are more sustainable and the key to solving the climate problem. The need for power in our day to day lives will only increase with technological advancement. Hence, renewables are an obvious solution. To name a few, solar and wind are widely used sources of renewable energy. Though they do come with their own set of problems. As these sources of energy are heavily dependent on natural factors, that humans cannot control and often cannot predict, these systems become very unreliable [21-30].

A hybrid energy system has two or more renewable energy sources working together increasing efficiency [31-35]. The objective is to make an overall system that can be relied upon to generate clean electricity. About 5,000 trillion kWh per year solar energy is incident over India's land area with most parts receiving 4-7 kWh per sq. m per day, and wind power potential of 302 GW at 100 meter above ground level is present [6]. With HRES this potential could utilized better. This paper will discuss the potential and feasibility of Hybrid Renewable Energy Systems.
2. Present Status of energy in India:
India has an estimated renewable energy potential of about 900 GW from sources like Wind – 102 GW, Bio-energy – 25 GW, Small Hydro – 20 GW, and Solar power – 750 GW. Here is a table showing Indian power generation as of April 2020.

| Fuel   | Megawatt (MW) | % of total |
|--------|---------------|------------|
| Coal   | 1,98,525      | 54.2       |
| Lignite| 6,610         | 1.7        |
| Gas    | 24,955        | 6.7        |
| Diesel | 510           | 0.1        |
| Hydro  | 45,699        | 12.4       |
| RES    | 87,269        | 23.6       |
| Nuclear| 6780          | 1.9        |

From the given table it is clear that 62.8% of the energy produced in India comes from thermal generation, that is 2,30,600 MW. There is a lot of renewable potential in India that is currently not being used. For a developing country, electricity plays a key role in enabling the progress of technology and infrastructure. Shifting to renewables will not only accelerate the progress of India, but also facilitate in a more sustainable nation in the long run.

India's electricity sector is very active when it comes to utilization of RES. As of December 2011, India produced 22.4 GW electricity which was beyond the total installed electricity in Austria by all technologies. India was also the first country in the world to set up a Ministry of non-conventional energy resources in early 1980 [4], [5].
3. Problems with RES:
Power generation becomes very much dependant on natural conditions in the case of RES. For example, in the case of solar panels, if it rains or if it is cloudy, the power output will be low. As humans cannot control these conditions, the integration of these sources into the main grid has become a challenge. Other challenges with RES are the dependence on optimum location and large areas of land required for set up. The cost of installation is also high [7].

4. Hybrid Renewable Energy System (HRES):
Hybrid Renewable Energy Systems are setups that integrate two or more renewable energy sources to get a more reliable system. These systems are location dependant and accordingly try to maximize output.

4.1. Different combination of HRES
Here are some examples of HRES combinations.

4.1.1. Solar-wind
Solar-Wind HRES is an integrated system that uses solar panels and wind turbines together to generate electricity. Here is the basic setup of a solar-wind HRES.

4.1.2. Solar-Biomass
A combination of solar energy and biomass energy HRES. This system can have further applications where it is used to in desalination and other applications. This hybrid system has a lot of potential in electrifying rural areas. With its added applications it can accelerate development immensely [8].

4.1.3. Hydro-Wind
A wind-hydro system generates electric energy combining wind turbines and pumped storage. These systems can also be used to meet water supply needs, by using a wind turbine to provide energy for the pumping system, national grid need not be used [9]. Hydro-wind pumped storage power stations are also being developed which could increase wind penetration in islands are also being developed, and discussed in many research papers [10], [11].

4.1.4. Solar-Wind-Biomass
Any type of combination can be developed according to needs. A combination of all three according to the location can also be feasible. For any HRES this basic flowchart is applicable.
This kind of system, where three sources are used can be installed in remote places where it is not feasible to install power grid. It can give independent and constant electricity to that region.

4.2. Scope of HRES in India

India is a country where 75% of the population lives in rural areas. These areas do not have adequate electricity, water supply, education, and transport. With HRES, electricity can become easily accessible in rural India. Using systems that integrate rain-water harvesting can also help overcome the water problem. Developing villages has been a challenge for India for a very long time. HRESs can be the solution to many of the problems.

Here is the location-wise suitability of HRES.

Table 2. location-wise HRES recommendation [13]

| Geographical feature | Type of HRES | Recommendation          |
|----------------------|--------------|-------------------------|
| High Altitude        | Biomass-wind-fuel cell, photovoltaic-wind, photovoltaic-biomass | Photovoltaic-biomass |
| Mountain             | Biomass-wind-fuel cell, photovoltaic-wind, photovoltaic-biomass | Photovoltaic-biomass |
| Plain                | Photovoltaic-biomass, hydro wind, solar flower, combined HRES plant, biomass wind, photovoltaic-wind | Combined HRES plant |
| Semi Desert          | Wind-fuel cell, wind-photovoltaic, wind biomass, photovoltaic-biomass, photovoltaic wind-biomass | Photovoltaic-Wind-Biomass |
| Desert               | Wind-fuel cell, wind-photovoltaic, wind biomass, photovoltaic-biomass, photovoltaic wind-biomass | Photovoltaic-Wind-Biomass |

The given table is just a recommendation and based on the location a more specific HRES can be applicable.
There are limitations to HRESs as well. There will be converter loss associated, and also a cost of establishment. As HRESs are still upcoming there is a lot of research that can be done to improve these systems.

India with its diversity in weather conditions could benefit a lot with such systems, especially in remote areas where installation and the reliability of the national grid is often not feasible. These systems can independently function and because of their increased reliability can power regions effectively. HRES also exploit India RES potential more effectively, and utilization of such systems could benefit in long term sustainability of the country.

5. Conclusion:
This paper established what Hybrid Renewable Energy Systems are, and analysed their potential. There is still a lot of optimisation required in hybrid systems. Overall, these systems could make Renewable Energy Sources more reliable and help in their integration to the main grid. Rural India could benefit a lot with HRESs and see immense growth and development. HRESs could be very beneficial for remote regions, and can have further applications in water supply, desalination and rain-water harvesting. Systems that could integrate not just power generation, but also have more functionality (as mentioned above: water supply, desalination and rain-water harvesting), can accelerate rural development in India.

6. Reference:
[1]. Sitharthan R, Geethanjali M and Pandy TKS 2016 Adaptive protection scheme for smart microgrid with electronically coupled distributed generations Alexandria Engineering Journal 55(3) 2539-2550
[2]. Fathima AH, and Palanisamy K 2014 Battery energy storage applications in wind integrated systems—a review IEEE International Conference on Smart Electric Grid 1-8
[3]. Prabaharan N and Palanisamy K 2015 Investigation of single-phase reduced switch count asymmetric multilevel inverter using advanced pulse width modulation technique International Journal of Renewable Energy Research 5(3) 879-890.
[4]. Jerin ARA, Kaliannan P and Subramaniam U 2017 Improved fault ride through capability of DFIG based wind turbines using synchronous reference frame control based dynamic voltage restorer. ISA transactions 70 465-474
[5]. Sitharthan, R, Sundarabalan CK, Devabalaji KR, Nataraj SK and Karthikeyan M 2018 Improved fault ride through capability of DFIG-wind turbines using customized dynamic voltage restorer Sustainable cities and society 39 114-125
[6]. Prabaharan N and Palanisamy K 2016 A single-phase grid connected hybrid multilevel inverter for interfacing photo-voltaic system Energy Procedia 103 250-255
[7]. Palanisamy K, Mishra JS, Raglend IJ and Kothari DP 2010 Instantaneous power theory based unified power quality conditioner (UPQC) IEEE Joint International Conference on Power Electronics, Drives and Energy Systems 1-5
[8]. Sitharthan R and Geethanjali M 2017 An adaptive Elman neural network with C-PSO learning algorithm-based pitch angle controller for DFIG based WECS Journal of Vibration and Control 23(5) 716-730
[9]. Sitharthan R and Geethanjali M 2015 Application of the superconducting fault current limiter strategy to improve the fault ride-through capability of a doubly-fed induction generator–based wind energy conversion system Simulation 91(12) 1081-1087
[10]. Sitharthan R, Karthikeyan M, Sundar DS and Rajasekaran S 2020 Adaptive hybrid intelligent MPPT controller to approximate effectual wind speed and optimal rotor speed of variable speed wind turbine ISA transactions 96 479-489
[11]. Sitharthan R, Devabalaji KR and Jeas A 2017 An Levenberg–Marquardt trained feed-forward back-propagation based intelligent pitch angle controller for wind generation system Renewable Energy Focus 22 24-32
[12]. Sitharthan R, Sundarabalan CK, Devabalaji KR, Yuvaraj T and Mohamed Imran A 2019 Automated power management strategy for wind power generation system using pitch angle controller Measurement and Control 52(3-4) 169-182
[13]. Sundar DS, Ummamaheswari C, Sridarshini T, Karthikeyan M, Sitharthan R, Raja AS and Carrasco MF 2019 Compact four-port circulator based on 2D photonic crystals with a 90° rotation of the light wave for photonic integrated circuits applications Laser Physics 29(6) 066201
[14]. Sitharthan R, Parthasarathy T, Sheeba Rani S and Ramya KC 2019. An improved radial basis function neural network control strategy-based maximum power point tracking controller for wind power generation system Transactions of the Institute of Measurement and Control 41(11) 3158-3170
[15]. Rajesh M and Gnanasekar JM 2017 Path observation based physical routing protocol for wireless ad hoc networks Wireless Personal Communications 97(1) 1267-1289
[16]. Palanisamy K, Varghese LJ, Raglend IJ and Kothari DP 2009. Comparison of intelligent techniques to solve economic load dispatch problem with line flow constraints IEEE International Advance Computing Conference 446-452
[17]. Sitharthan R, Ponnusamy M, Karthikeyan M and Sundar DS 2019 Analysis on smart material suitable for autogenous microelectronic application Materials Research Express 6(10) 105709
[18]. Rajaram R, Palanisamy K, Ramasamy S and Ramanathan P 2014 Selective harmonic elimination in PWM inverter using fire fly and fireworks algorithm International Journal of Innovative Research in Advanced Engineering 1(8) 55-62
[19]. Sitharthan R, Swaminathan JN and Parthasarathy T 2018 March. Exploration of wind energy in India: A short review IEEE National Power Engineering Conference 1-5
[20]. Karthikeyan M, Sitharthan R, Ali T and Roy B 2020 Compact multiband CPW fed monopole antenna with square ring and T-shaped strips Microwave and Optical Technology Letters 62(2) 926-932
[21]. Sundar D Sridarshini T, Sitharthan R, Madurakavi Karthikeyan, Sivanantha Raja A, and Marcos Flores Carrasco 2019 Performance investigation of 16/32-channel DWDM PON and long-reach PON systems using an ASE noise source In Advances in Optoelectronic Technology and Industry Development: Proceedings of the 12th International Symposium on Photonics and Optoelectronics 93
[22]. Sitharthan R and Geethanjali M 2014 Wind Energy Utilization in India: A Review Middle-East J. Sci. Res. 22 796–801 doi:10.5829/idosi.mejsr.2014.22.06.21944
[23]. Sitharthan R and Geethanjali M 2014 ANFIS based wind speed sensor-less MPPT controller for variable speed wind energy conversion systems Australian Journal of Basic and Applied Sciences 814-23
[24]. Jerin ARA, Kaliannan P, Subramaniam U and El Moursi MS 2018 Review on FRT solutions for improving transient stability in DFIG-WTs IET Renewable Power Generation 12(15) 1786-1799
[25]. Prabaharan N, Jerin ARA, Palanisamy K and Umashankar S 2017 Integration of single-phase reduced switch multilevel inverter topology for grid connected photovoltaic system Energy Procedia 138 1177-1183
[26]. Rameshkumar K, Indragandhi V, Palanisamy K and Arunkumari T 2017 Model predictive current control of single phase shunt active power filter Energy Procedia 117 658-665
[27]. Fathima AH and Palanisamy K 2016 Energy storage systems for energy management of renewables in distributed generation systems Energy Management of Distributed Generation Systems 157

[28]. Rajesh M 2020 Streamlining Radio Network Organizing Enlargement Towards Microcellular Frameworks Wireless Personal Communications 1-13

[29]. Subbiah B, Obaidat MS, Srim S, Manoharn R and Chandrasekaran SK 2020 Selection of intermediate routes for secure data communication systems using graph theory application and grey wolf optimisation algorithm in MANETs IET Networks doi:10.1049/iet-net.2020.0051

[30]. Singh RR and Chelliah TR 2017 Enforcement of cost-effective energy conservation on single-fed asynchronous machine using a novel switching strategy Energy 126 179-191

[31]. Amalorpavaraj RAJ, Palanisamy K, Umashankar S and Thirumoorthy AD 2016 Power quality improvement of grid connected wind farms through voltage restoration using dynamic voltage restorer International Journal of Renewable Energy Research 6(1) 53-60

[32]. Singh RR, Chelliah TR, Khare D and Ramesh US 2016 November. Energy saving strategy on electric propulsion system integrated with doubly fed asynchronous motors IEEE Power India International Conference 1-6

[33]. Sujatha K and Punithavathani DS 2018 Optimized ensemble decision-based multi-focus image fusion using binary genetic Grey-Wolf optimizer in camera sensor networks Multimedia Tools and Applications 77(2) 1735-1759

[34]. Krishnamoorthy S, Punithavathani S and Priya JK 2017 Extraction of well-exposed pixels for image fusion with a sub-banding technique for high dynamic range images International Journal of Image and Data Fusion 8(1) 54-72

[35]. Singh RR, Mohan H and Chelliah TR 2016 November. Performance of doubly fed machines influenced to electrical perturbation in pumped storage plant-a comparative electromechanical analysis IEEE 7th India International Conference on Power Electronics 1-6