International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075, Volume-2 Issue-6, May 2013

Dispatch, Control Strategies and Emissions for Isolated Wind-Diesel Hybrid Power System

Bindu U. Kansara, B. R. Parekh

Abstract— Depleting oil reserves and the growing concerns of global warming, have made it compulsory to seek alternative in form of environment friendly technologies like renewable energy sources. The advantage of hybrid power systems is the combination of the continuously available diesel power and locally available, pollution-free wind energy. With the Wind-Diesel hybrid power system, the annual diesel fuel consumption can be reduced and, at the same time, the level of pollution can be minimized. A proper control and dispatch strategy has to be developed to take full advantage of the wind energy during the periods of time it is available and to minimize diesel fuel consumption. The paper presents two dispatch strategies (i) load following and (ii) Cycle charging along with different system controls. For the proposed system, load following dispatch strategy along with its system control performs better than the cycle charging strategy.

Index Terms— Wind Turbine, Diesel Generator, Distributed Generation, HOMER

I. INTRODUCTION

One of the most recognized terms in today's electricity market is decentralization of energy sources. To realize the potential of distribution generation, generation and load must be taken as a subsystem. This system may use any combination of generation, load and storage technologies and can operate in grid connected mode or autonomous mode. Some examples of micropower system or microgrid are solar-battery serving a remote load, wind-diesel system serving an isolated village, a grid connected natural gas microturbine providing heat to a factory. Micropower system consists of electric and thermal load, and any combination of photovoltaic modules (PV), wind turbine, small hydro, biomass power generation, microturbines, fuel cells, reciprocating engine generators, batteries and hydrogen storage.

The analysis and design of micropower system [1] is challenging due to large number of design options and uncertainty in key parameters such as load size and future fuel price. Renewable energy sources add further complexity because the output may be intermittent, seasonal and nondispatchable and the availability is uncertain. The work is a technical, environmental and economic feasibility study [2,3] and dispatch strategies to manage the load demand of a hybrid generating system, composed of wind, diesel and battery interfaces feeding a customer with high reliability requirements of electric supply. Penetration of DG across the country has yet not reached the significant levels. These emerging technologies have lower emission and potential to have lower cost. A better way to realize the potential of distributed generation is to take a system approach where load and generation acts as a subsystem called "microgrid" [4]. This is a decentralized and bidirectional pattern permits electricity import from the grid and electricity export to the grid. A plant that produces electricity less than 500 kW comes under micro generation technologies. Microgrid sources can produce electrical energy and thermal energy both. Hence, the penetration of distributed energy resources both at low voltages and medium voltages in utility have been increased in developed countries like USA, Canada, Japan and Germany. Computer simulation is an increasingly popular tool for determining the most suitable hybrid energy system type, design and control for an isolated community or a cluster of villages. This paper presents the system control combined dispatch strategies, to achieve better performance of wind-diesel system. The main purpose of the control system proposed here is to reduce the participation of the diesel generator in the electricity generation process, taking the maximum advantage of the renewable sources available. The overall load dispatch scenario is controlled by the availability of renewable power, total system load demand, diesel generator operational constraints and the appropriate management of battery bank. The incorporation of a battery bank makes the control operation more practical.

II. SYSTEM SCHEMATIC AND COMPONENTS

The ability to generate electricity is a building block of modern society. The utilization of wind turbines to produce electricity is practiced for over hundred years. Similarly, diesel engines have been a technology to produce energy since 1940s. However, the field of engineering concerned with the coupling of Wind-Diesel systems have just begun recently [6]. The following schematic represents basic Wind-Diesel hybrid system. Hybrid power system incorporates more than one piece of equipment for electricity production as well as storage, power conditioning components and system controls. The system consists of two diesel generators alongwith a wind turbine connected to AC bus side of the network. HOMER power optimization software by NREL is used to simulate and analyze the hybrid systems.

Manuscript received on May, 2013.

Prof. Bindu U. Kansara, Electrical Engineering Department, Sardar Patel University, A.D. Patel Institute of Technology, New Vidyanagar, India.

Dr. B. R. Parekh, Head, Electrical Engineering Department, Sardar Patel University, BVM Engineering College, India.

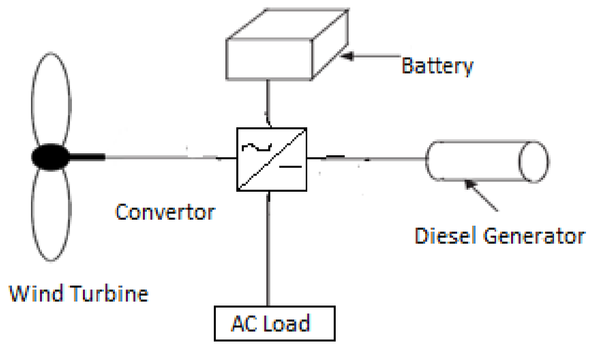

Figure 1 Basic Isolated Wind-Diesel Hybrid System
Submit your manuscript electronically for review.

A. Wind Resource

Utilizing wind mills for various reasons is a practice for several years. Now many nations recognize the shortage of fossil fuels and importance of wind energy. The wind energy has re-emerged as an important source of sustainable energy resource worldwide. As the ratio of installed wind capacity to the system load increases, the required equipment needed to maintain a stable AC grid increases, forcing an optimum amount of wind power in a given system. So the design of individual components must be sized properly. India is enriched with abundant wind energy resources. Tamilnadu and Gujarat have the longest sea coast. So, a remote place of Gujarat, Kutch 24.5^0 latitude and 70.5^0 longitude is taken as a site for data selection. Weather data are important for pre feasibility study of renewable hybrid system for a particular site. In this modeling, 65 kW AC rated power is used for the wind turbine. The power curve and cost curve for wind turbine is shown in figures 2 (a) and (b) respectively.

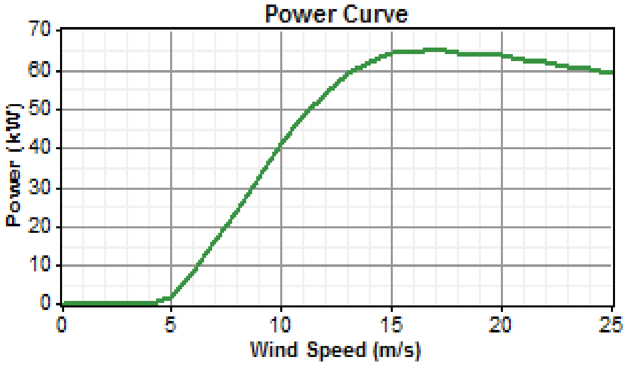

Figure 2 (a) Power Curve of a Wind Turbine

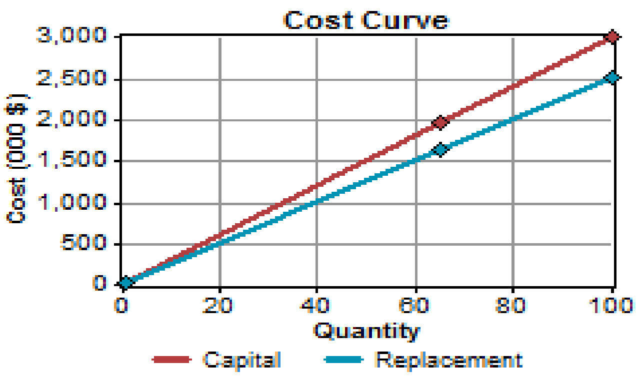

Figure 2 (b) Cost Curve of a Wind Turbine

The life time is taken as 25 years and Hub Height is 25 meters for the wind turbine considered. Figure 3 (a) and (b) shows the wind resource and wind profile. 1 hr auto correlation factor is 0.893.

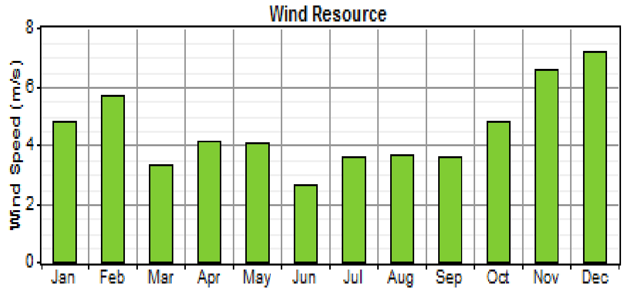

Figure 3 (a)Wind Resource

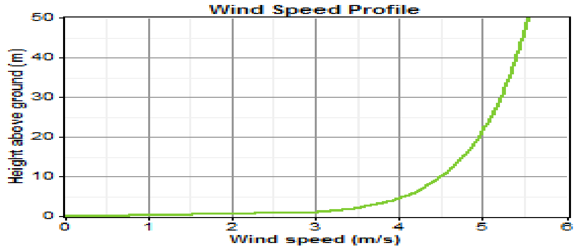

Figure 3 (a)Wind Speed Profile

B. Diesel Engines

Diesel generators and combustion engines are mainly used for off-grid generation, the advantages of combustion engines are low installed capacity, high shaft efficiency, suitable for start-stop operation, and high exhaust heat. These engines convert heat from the combustion into work via rotation of shaft. The shaft is directly coupled to the generator and electricity is produced. They run at a speed defined by the frequency of supply grid. In this modeling 75 kW and 100 kW diesel engines are used alongwith the wind turbine.

In addition to wind turbine and two diesel generators, storage battery, a converter and a primary load is used in the modeling of isolated Wind-Diesel hybrid system. A primary load of 2.1 MWh/day having 189 kW peak, 88.5 kW average and 0.468 load factor is taken for simulation.

III. MODELING OF MICROGRID SYSTEM

After the system components, modeling and simulations of the micro power system is carried out. HOMER, an optimization model is used to simulate the system. Large number of options are available for different sizes of the components used, components to be added to the system which make sense, cost functions of components used in the system. HOMER's optimization and sensitivity analysis algorithms evaluated the possibility of system configuration. Range of different fuel prices and different wind speeds are considered for modeling. The system cost calculations account for costs such as capital, replacement, operation and maintenance, fuel and interest. The simulation is carried out for two different dispatch strategies (i) load following and (ii) cycle charging with diesel generator controls.

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

A. Wind Turbine

A 65 kW, Atlantic Orient make AOC 15/50 wind turbine is chosen for the system. Availability of energy from the wind turbine depends greatly on wind variations. Wind data for a site Kutch, Gujarat with 24.5^0 latitude and 70.5^0 longitude is considered. The parameters considered for wind turbine are : anemometer height : 10 m, Weibull K : 2, auto correlation factor: 0.85, scaled annual averages 4.5 and 5.5 m/sec, turbine life time : 15 years and hub height : 25 years. The capital cost, replacement cost and O&M cost considered for the wind turbine are 30000 $, 25000 $ and 500 $/yr respectively.

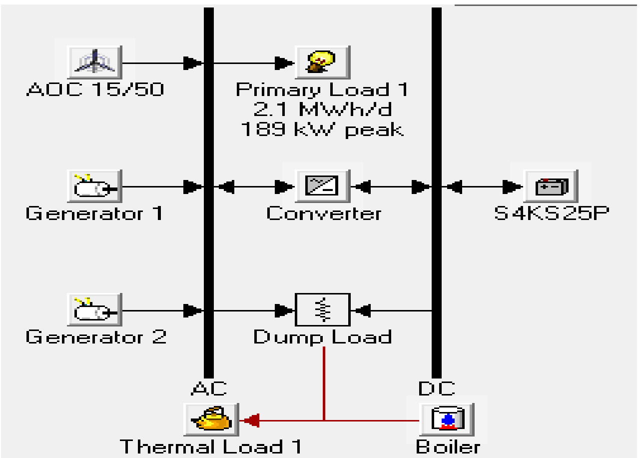

Figure 4 System architecture in HOMER

B. Diesel Generator

Two diesel generators of capacity 75 kW and 100 kW are considered for this system. Operating hours and Minimum load ratio % are 15000 hours and 30% respectively. Capital cost, replacement and O&M costs considered for the diesel generators are 1500 $, 1200 $ and 0.05 $/hr.

C. Battery Bank

In case of excess energy from renewables, storage battery bank is used in the hybrid system design. Commercially available battery models, like Surrett 4KS25P (4V, 1900 Ah, 7.6 kWh) is considered for the hybrid system. Each battery costs capital cost 500$, 500$ to replace the battery and 50$/yr for O&M. The simulation results in optimum size of battery of 36 kW.

D. Power Convertor

A power electronic converter is required for a system in which DC components serve an AC load or vice versa. The installation and replacement cost are taken as 1000$ and 1000$ respectively. O&M cost is considered to be 100$/yr. Lifetime of a unit is 15 years and an efficiency of 85%.

IV. DISPATCH STRATEGIES AND SYSTE CONTROLS

A technical challenge for the isolated hybrid Wind-Diesel system is related to its control and dispatch strategy. The energy distribution for hybrid systems with and without considering energy storage element battery will be different. Energy storage can smooth out the fluctuation of wind power. The dispatch strategy is intended to control the system such that the load requirements (electric and thermal, domestic hot water usage, space heating, and space cooling) are met. A dispatch strategy is a set or rules that govern the operation of the generator(s) and the battery bank. Two dispatch strategies, (i) load following and (ii) cycle charging are proposed for the system with multiple diesel generator controls. Which is optimal depends on many factors, including the sizes of the generators and battery bank, the price of fuel, the O&M cost of the generators, the amount of renewable power in the system, and the character of the renewable resources. The system is simulated with two dispatch strategies and paper discusses the results of control and dispatch strategies.

A. Load Following Dispatch Strategy :

Under the load following strategy, whenever a generator is needed it produces only enough power to meet the demand. Load following tends to be optimal in systems with a lot of renewable power, when the renewable power output sometimes exceeds the load. The load following strategy is a dispatch strategy whereby whenever a generator operates, it produces only enough power to meet the primary load. Lower-priority objectives such as charging the battery bank or serving the deferrable load are left to the renewable power sources. Under the load following strategy, HOMER dispatches the system's controllable power sources (generators, grid, battery bank) so as to serve the primary load and the thermal load at the least total cost each time step, while satisfying the operating reserve requirement. The total cost includes the cost of fuel, operation and maintenance, and replacement.

$P_L = P_{WIND} + P_{BATTERY}$ (P_{DIESEL} OFF) …. When Battery is connected

$P_L = P_{DIESEL}$ …. When battery is not connected

$P_{EXCESS} = P_{DUMPLOAD} + P_{THERMAL}$

A generator's fixed cost is equal to its hourly operation and maintenance cost plus its hourly replacement cost plus the cost of its no-load fuel consumption. Its marginal cost is equal to its fuel curve slope times the fuel price. If waste heat can be recovered from the generator and the waste heat is needed to serve the thermal load, the generator's marginal cost is reduced by the value of the thermal energy it produces (which is equal to the marginal cost of thermal energy from the boiler). If a cost is assigned to carbon emissions, the generator's marginal cost is increased accordingly. Once it characterizes each dispatchable source in this way, the set of combination of generation sources that satisfies the primary load, required operating reserve, and thermal load at least cost are simulated.

B. Cycle Charging Dispatch Strategy:

Under the cycle charging strategy, whenever a generator has to operate, it operates at full capacity with surplus power going to charge the battery bank. Cycle charging tends to be optimal in systems with little or no renewable power. The cycle charging strategy is a dispatch strategy whereby whenever a generator needs to operate to serve the primary load, it operates at full output power. Surplus electrical production goes toward the lower-priority objectives such as, in order of decreasing priority: serving the deferrable load, charging the battery bank, and serving the electrolyzer.

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

$P_L = P_{WIND} + P_{DIESEL}$ (with 100% capacity) + $P_{BATTERY}$ (charging with surplus diesel power)

When using the cycle charging strategy, the controllable power sources (generators, battery bank, grid) dispatches power in a two-step process.

(1) selects the optimal combination of power sources to serve the primary and thermal load according to the load-following strategy.

(2) ramps up the output of each generator in that optimal combination to its rated capacity, or as close as possible without causing excess electricity.

If a setpoint state of charge is applied to the cycle charging strategy, then when the battery state of charge is below the setpoint and the battery was not discharging in the previous time step, HOMER will avoid discharging the battery in this time step. A generator will likely be called upon to serve the primary load and produce excess electricity to charge the battery bank. So once the system starts charging the battery bank it continues to do so until it reaches the setpoint state of charge.

C. System Controls :

Multiple generators can operate simultaneously, with minimum renewable energy fractions (MRF) considered = 0% and 20%, annual interest rate = 6%, plant working life span = 20 years, diesel price =0.8$/L, wind speed = 0, 4.5 and 5.5 m/s

V. RESULTS AND DISCUSSION

The system shown in figure 4 is simulated for two different dispatch strategies with the system controls. Table 1 shows the comparison of load following and cycle charging dispatch strategies.

The system is simulated for load following and cycle charging with SOC 80%, the analysis is carried out considering technical, electrical and environmental aspects. With the proposed system control and dispatch strategies, Table 1 shows the performance of the system with load following strategy is better than that of cycle charging dispatch.

VI. CONCLUSION

The results of isolated Wind-diesel hybrid system using HOMER modeling shows that if, cost summary, cash flow summary, electrical production or emissions and cost of wind turbine, battery and converter us considered as a whole, load following dispatch strategy is far better than cycle charging dispatch strategy. Considering economic, technical and environmental aspects for both the strategies, Load following strategy is better in cases where renewable penetration is more and cycle charging is effective in cases where renewable energy penetration is less. For this hybrid wind-diesel system, load following dispatch strategy gives better performance in terms of Net Present Cost (NPC), Cost of Energy (COE), renewable fraction and GHG (Green House Gases) emissions.

REFERENCES

1. Rocha M. da., Landa Noronha G., Paula Cardoso A. ,et. al. “Feasibility study for Hybrid Electric Generating with Wind-Diesel and Grid Resources “ RIO 9 – World Climate and Energy Event , 17-19 March, 2009, Brazil
2. Manwel J. F., McGowan J. G., Abdulwahid U., “Simplified Performance model for Hybrid Wind-diesel System” Renewable Energy Laboratory, MA, USA.
3. BJindal A.K., Gole A.M., Muthumuni D., “Modeling and Performance Analysis of an Integrated Wind/Diesel Power System for Off Grid Locations,” 15th National Power System Conference (NPSC), IIT Bombay, December 2008.
4. Lasseter R. H., Paigi P. “Microgrid : A Conceptual Solution” PESC’04, Germany, 20-25 June 2004
5. Getting Started Guide for HOMER Version 2.1, April 2005
6. Shahid S. M., El-Amin I, Ahmed F., “Potential of Off-Grid Wind/Diesel hybrid System for Electrification of a remote Settlement in Saudi Arabia” Wind Engineering, 28 (5) , 621-628, 2004.
7. Frye Jack A. “Performance Objective Design of a Wind-Diesel Hybrid Energy System for Scott Base, Antarctica”, Master’s Thesis, 2006.
8. http://www.academia.edu/1485012/Dispatch_Strategy_and_Model_for_Hybrid_Photovoltaic_and_Trigeneration_Power_Systems accessed on 12 March, 2013
9. J.K. Kaldellis, An integrated model for performance simulation of hybrid wind–diesel systems Renewable Energy 32 (2007) 1544–156 science direct
10. Survey on Microgrid Control Strategies Wei Huanga, Miao Lua*, Li Zhangb elsevier

AUTHORS PROFILE

Prof. Bindu U. Kansara is with Department of Electrical Engineering, A.D. Patel Institute of Technology, New Vallabh Vidyanagar. She has completed her Bachelor and Master degree in Electrical Engineering from Birla Vishvakarma College of Engineering, Gujarat, India. She is currently pursuing Ph.D. Her research interest includes Microgrid, Distributed Generation and Power System Operation and Control, Renewable Energy Resources.

Dr. B. R. Parekh is Professor and Head of Department of Electrical Engineering, BVM Engineering College, Vallabh Vidyanagar, Gujarat, India. He has completed his BE and ME in Power System. He has completed his Ph.D. from IIT, Bombay with specialization in power system. He has published number of papers in national and international journals. His research interest includes HVDC transmission systems, Power System Operation and Control.

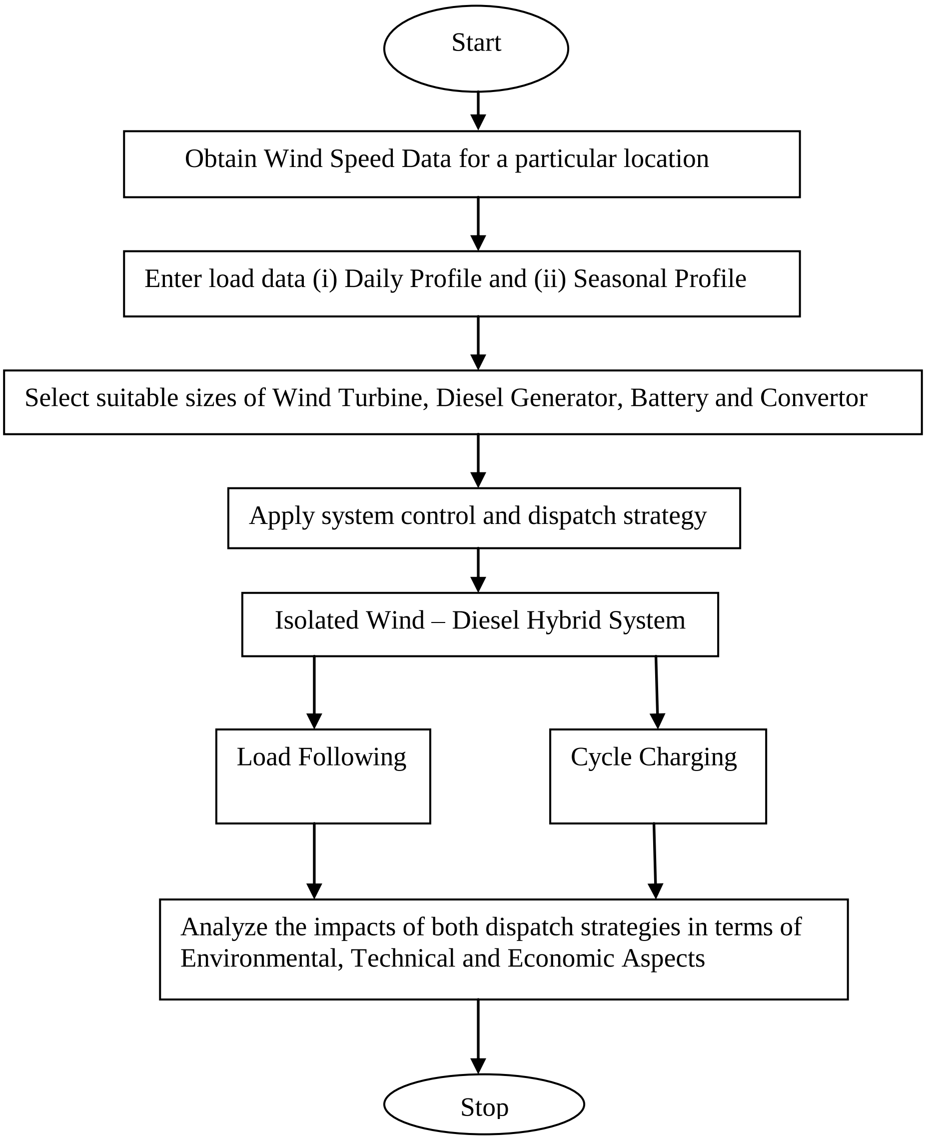

Figure 5 Flowchart of the Proposed System

Table : 1 Comparison of dispatch strategies for Wind-Diesel-Battery System

Parameters	**Dispatch Strategies**	
	Load Following	**Cycle Charging**
Total net present cost (NPC)	$ 5,732,866	$ 5,812,497
Levelized cost of energy (COE)	$ 0.574/kWh	$ 0.582/kWh
Operating cost	$ 268,346/yr	$ 274,576/yr
Wind turbines	8,325,531 kWh/yr - 97%	8,325,531 96%
Generator 1	73,499 kWh/yr -1%	70,729 1%
Generator 2	215,000 kWh/yr - 2%	258,679 3%
Renewable fraction	0.629	0.578
Carbon dioxide	334,355 kg/yr	359,157 kg/yr
Carbon monoxide	817 kg/yr	878 kg/yr
Unburned hydocarbons	90.5 kg/yr	97.3 kg/yr
Particulate matter	61.6 kg/yr	66.2 kg/yr
Sulfur dioxide	672 kg/yr	721 kg/yr
Nitrogen oxides	7,288 kg/yr	7,836 kg/yr