Wind-Diesel Microgrid System For Remote Villages in Kenya

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Outline

- Introduction
  - Motivation
- Objective
  - Analyze the reliability of a remote wind-diesel microgrid system as demand grows over a period of time.
- Method
  - Estimating Load data
  - Determine wind power generated given wind speeds
  - Transmission system layout
  - Power flow modeling and simulation in MATLAB.
- Results
  - Quantify system reliability

Introduction

- Dominant energy source for non-electrified households is wood fuel.
- Associated with adverse health and environmental effects.

Introduction

- National grid electricity supply to low density areas results in high capital outlays, large transmission losses and less reliable electric services.
- Rural Electrification Programs can be **better** achieved through wind-diesel microgrids.

Objective

- Model a wind-diesel system and analyze its reliability as load increases over a period of 8 years
  - Based on the % of wind energy predicted to go into the system compared to the actual % from the wind energy output curve at the same load level as that of the power flow model.
  - Investigate the impact of varying the diesel generator unit size on the contribution of wind energy to the system.

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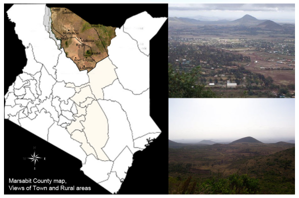
Case study: Marsabit, Kenya

- Located in the Eastern Province of Kenya.
- Population of 37,445 people.
- Trading and Commercial Centre.
- Grid ends 263 km from Marsabit.



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Load Data Analysis

- Based on a survey was done in Fatick, a rural village in Senegal to determine the daily energy demand per household.
- Load analysis broken down into four sectors:
  - Residential load: Homes connected to the grid
  - Commercial load: General and hardware stores, hotels and restaurants
  - Municipal load: Banks, health centers, airports, post offices and government offices
  - Schools

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Load Data Analysis

- 1500 homes connected to the grid
- 6 hotels and 3 hardware stores
- 3 banks, 5 health centers, 1 post office, 1 government office and 1 airport.
- 10 schools, each with 1 lamp operating 9 hours a day

Residential load	660 kWh
Commercial load	54.12 kWh
Municipal load	27 kWh
Schools	7.92 kWh
Total	**749 kWh**

TABLE I. ENERGY CONSUMED BY A RESIDENTIAL BUILDING

Appliance	Number of appliances	Power rating (W)	Operation time (hrs)	Energy (Wh/day)
Electrical lamp	5	11	3	165
Radio	1	15	5	75
Black & White TV	1	40	5	200
		110		**440**

TABLE II. ENERGY CONSUMED BY A MUNICIPAL BUILDING

Appliance	Number of appliances	Power rating (W)	Operation time (hrs)	Energy (Wh/day)
Electrical lamp	8	11	3	264
Radio	1	15	5	75
Black & White TV	1	40	5	200
Refrigerator	1	100	19	1900
		243		**2439**

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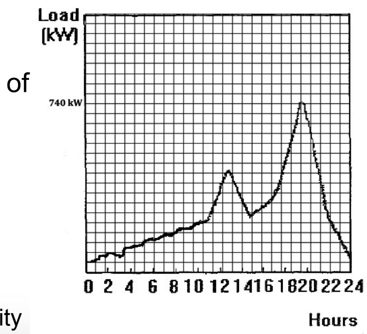
Load Data Analysis

- As of June 2010, maximum load in Marsabit town was reported to be **740 kW***
- The total load based on this estimation is **749 kW**

* Source: S. Mwangangi , W. Koech, J. Akinala, and T. Omwega, "Environmental and social impact assessment project report for proposed two 250 KW wind turbines at Marsabit," unpublished

Load Data Analysis

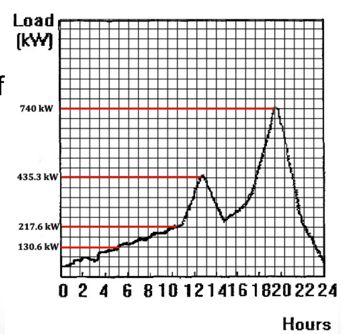
- Peak Load at 7 pm (1900h)
- Annual load growth of 250 connections. (17%)
- Current technology mix:
  - 1200 kW diesel capacity
  - 650 kW wind capacity



Source: M. S Mbogho, C. Wekesa, D. Murage, and J. Toyoda. "Economic analysis of supplying an electro village using alternative electrical power sources." IEEE, vol. 2, pp. 968 - 971, September 1996 [The 1996 4th IEEE AFRICON Conference. Part 2. Stellenbosch, South Africa].

Load Data Analysis

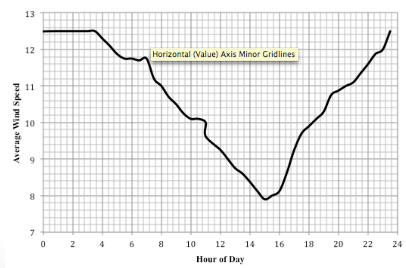
- Peak Load at 7 pm (1900h)
- Annual load growth of 250 connections. (17%)
- Proposed technology mix:
  - 1523.5 kW diesel capacity
  - 650 kW wind capacity



Source: M. S Mbogho, C. Wekesa, D. Murage, and J. Toyoda. "Economic analysis of supplying an electro village using alternative electrical power sources." IEEE, vol. 2, pp. 968 - 971, September 1996 [The 1996 4th IEEE AFRICON Conference. Part 2. Stellenbosch, South Africa].

Wind Power Analysis

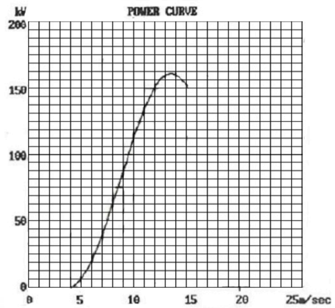
- Wind energy potential of Marsabit averaged over a 6 year period between 2001 and 2006.



Source: J. N Kamau, R Kinyua, and J. K. Gathua. "6 years of wind data for Marsabit, Kenya average over 14 m/s at 100 m hub height; An analysis of the wind energy potential." ELSEVIER, vol 35(6), pp. 1298-1302, June 2010.

Wind Power Analysis

- Nordtank 150 kW XLR wind turbine



Source: Nordtank. "Nordtank 150 kW technical data 7.06," *<http://www.windturbinewarehouse.com/.../ nordtank/Nordtank_150_SAC_DSM_4_20_07.pdf>*

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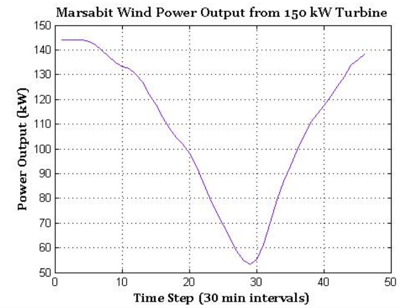
Wind Power Analysis

- Max power output of **144.1** kW.
- Min Power output of **53.23** kW.
- Power output at peak load: **113** kW



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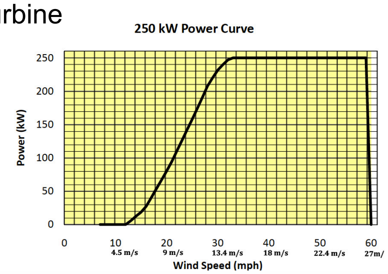
Wind Power Analysis

- Powerworks 250 kW WEG MS-2 wind turbine



Source: PowerWorks Wind Turbines $_{LLC}$. " 250 kW wind turbine sales brochure." <http:// www.powerworksinc.com/PowerWorks_250_kW_sales_brochure.pdf>

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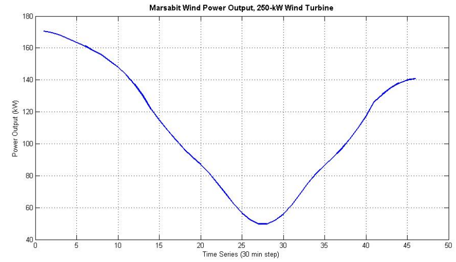
Wind Power Analysis

- Max power output of **170.47** kW
- Min power output of **49.73** kW
- Power output at peak load: **115** kW



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Transmission System Layout

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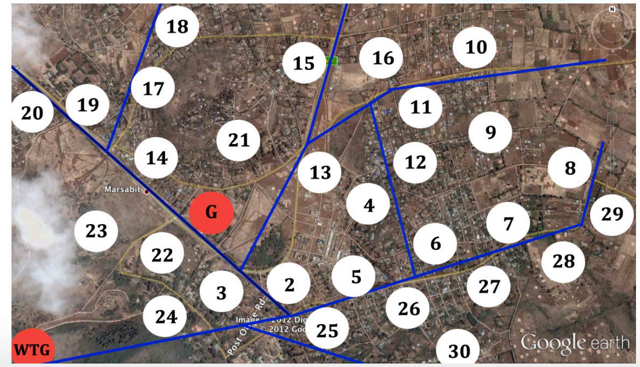
Transmission System Layout



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Transmission System Layout

- Transmission line resistance:
  – 0.1576 Ω/km
- Transmission line reactance:
  – 0.0968 Ω/km

Source: The Kenya Power and Lighting Company. " Design, supply and installation of substation & transmission line: volume II," unpublished

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Power Flow Simulation

- Scenario 1:
  - Diesel generator capacity from 2 of the 4 units, the 740-kW and the 435.3-kW generator (Total: 1,175.3 kW)
  - Wind capacity of 650 kW, only 485 kW of this is actual wind power output
  - Additional wind capacity of 500 kW added after 4 years to meet the growing demand

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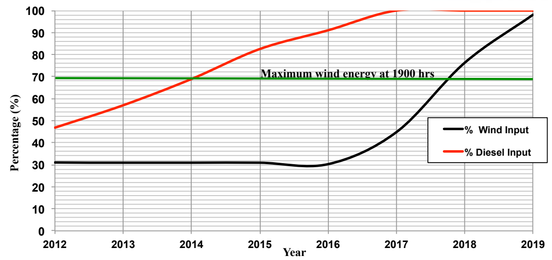
Results

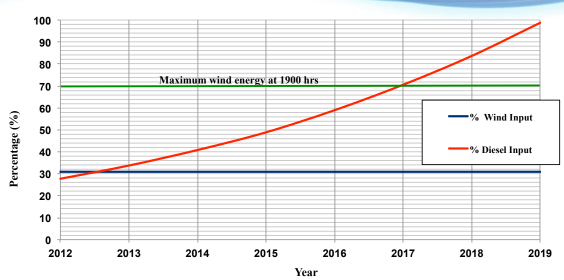


- % Actual Wind Power Input to System at Peak hour:
  Actual Wind gen/Max wind gen*100 = 70.87 %
- % Predicted Wind Power Input to System at Peak hour:
  Predicted Wind gen/Max wind gen *100

Power Flow Simulation

- Scenario 2:
  - Diesel generator capacity from all 4 units. (Total: 1983.5 kW)
  - Wind capacity of 650 kW, only 485 kW of this is actual wind power output
  - No Additional wind capacity added

Results

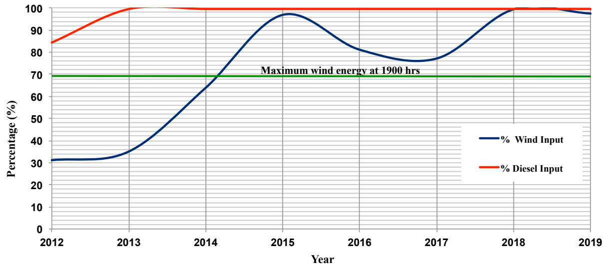


- % Actual Wind Power Input to System:
  Actual Wind input/Max wind output *100 = 70.87 %
- % Predicted Wind Power Input to System:
  Predicted Wind Input/Max wind output *100

Power Flow Simulation

- Scenario 3:
  - Diesel generator capacity from 2 smaller units, the 435.3-kW and the 217.6-kW generator. (Total: 652.9 kW)
  - Wind capacity of 650 kW, only 485 kW of this is actual wind power output
  - Additional wind capacity of 1000 kW added after 4 years to meet the growing demand

Results



- % Actual Wind Power Input to System:
  Actual Wind input/Max wind output *100 = 70.87 %
- % Predicted Wind Power Input to System:
  Predicted Wind Input/Max wind output *100

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Conclusion

- Wind-diesel microgrid systems tends to be more reliable if the diesel generator capacity is increased as opposed to wind capacity during power system expansion to meet the growing demand.

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Questions?

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