Advanced Hydraulic Wind Energy

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Educational Background

- California State University Los Angeles
  - B.S. Electrical Engineering
    - Electronics
  - M.S. Electrical Engineering
    - Communications

Outline

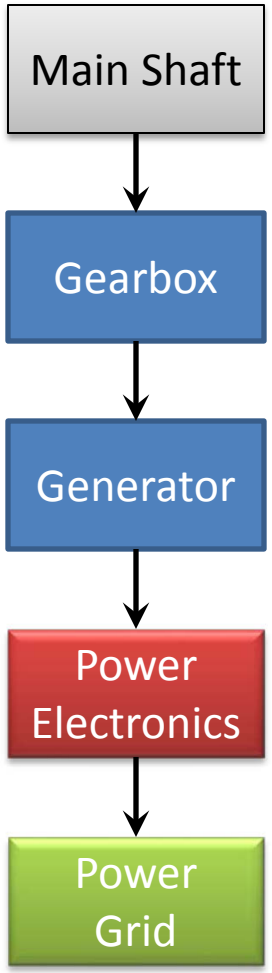
- Project goals
- Current designs and developments
- Proposed configuration
- Performance analysis
- Cost breakdown

Project Goals

- Perform cost and reliability analysis of a novel hydraulic energy transfer (HET) wind turbine system proposed at JPL
  - Cost break-down of wind turbine designs
  - Examine costs of components, installation, maintenance
  - Examine reliability, average breakdown, costs over time
  - Compare efficiencies between proposed HET design and conventional designs

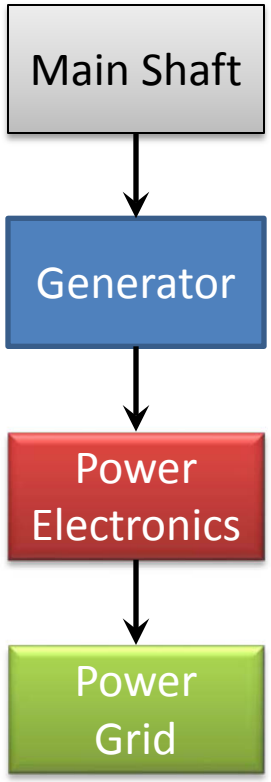
Current Designs

- Conventional turbine configuration
  - Wind turbine shaft connected to gearbox
  - Gearbox provides torque conversion to generator
  - Generator receives lower torque, higher RPM
  - Constant RPM maintained at generator input
- Drawbacks
  - Repair and maintenance must be done at top of tower
  - Replacing components requires heavy lifting equipment
  - Gearbox wears down quickly due to mechanical components



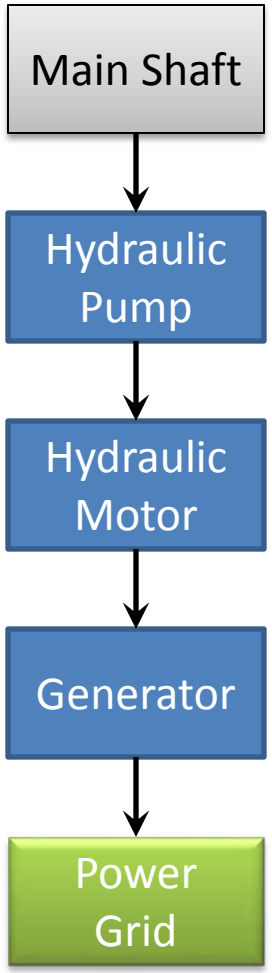
Current Designs

- Direct drive train (gearless) configuration
  - No torque conversion from turbine shaft to generator
  - Removes need for gearbox and has less mechanical components
  - Generator operates at same RPM as turbine
  - Due to slow rotation, generator requires higher number of magnetic poles
- Drawbacks
  - Increased poles lead to larger diameter rotor/stator, increasing size
  - Permanent magnets used to supply magnetic field and reduce weight
    - Rare-earth materials are very expensive



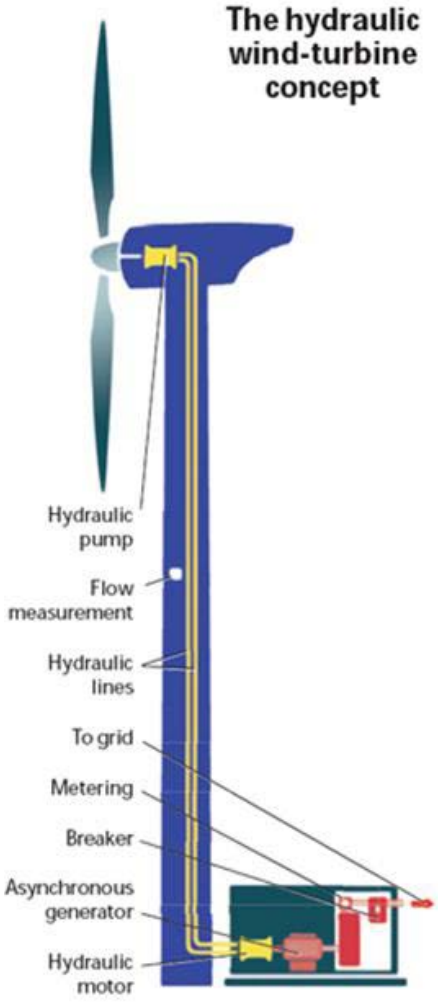
Current Developments

- Hydraulic drive train
  - Turbine shaft supplies torque to a hydraulic pump
  - Pump circulates fluid to a hydraulic motor
  - Hydraulic motor provides torque conversion, replacing gearbox
  - Constant RPM supplied to generator
- Advantages
  - Less mechanical components, increased mean-time-between-failures (MTBF)
  - Hydraulic system has no cut-in wind speed, able to capture energy even at low wind speeds



Current Developments

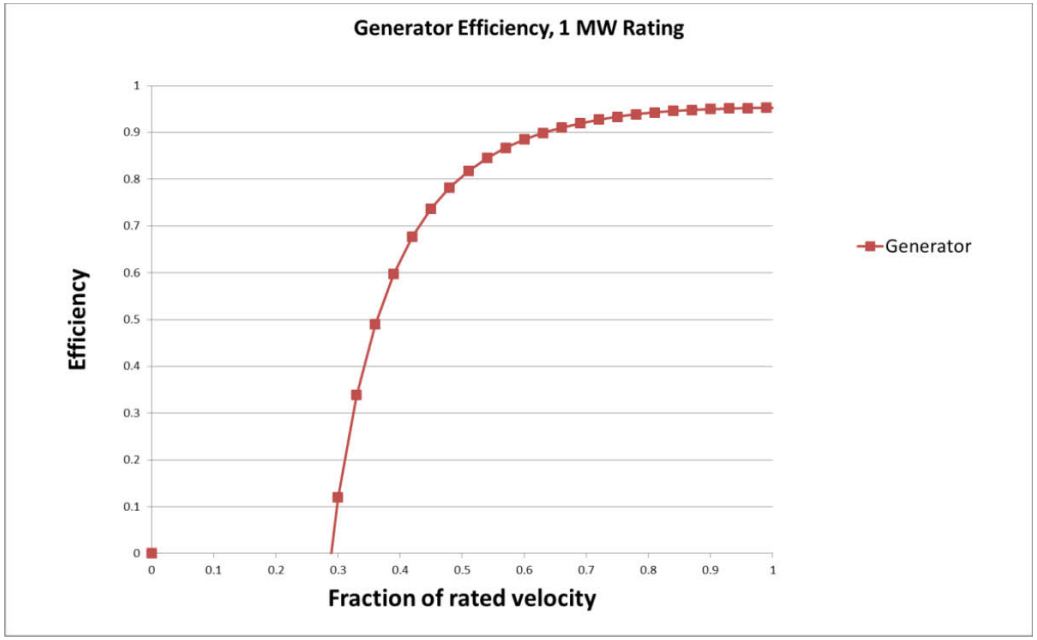
- Alternate configuration
  - Hydraulic motor and generator can be relocated to ground level
  - Energy transferred to ground through hydraulic lines
    - Less restriction on weight and space; conventional asynchronous generator can be used
    - Reduced maintenance cost due to ease of access



Components relocated to ground [1]

Current Developments

- Persisting problems
  - Generators are more efficient when operated near maximum capacity
  - Though hydraulic system can operate at lower wind speeds, generator becomes inefficient in this range

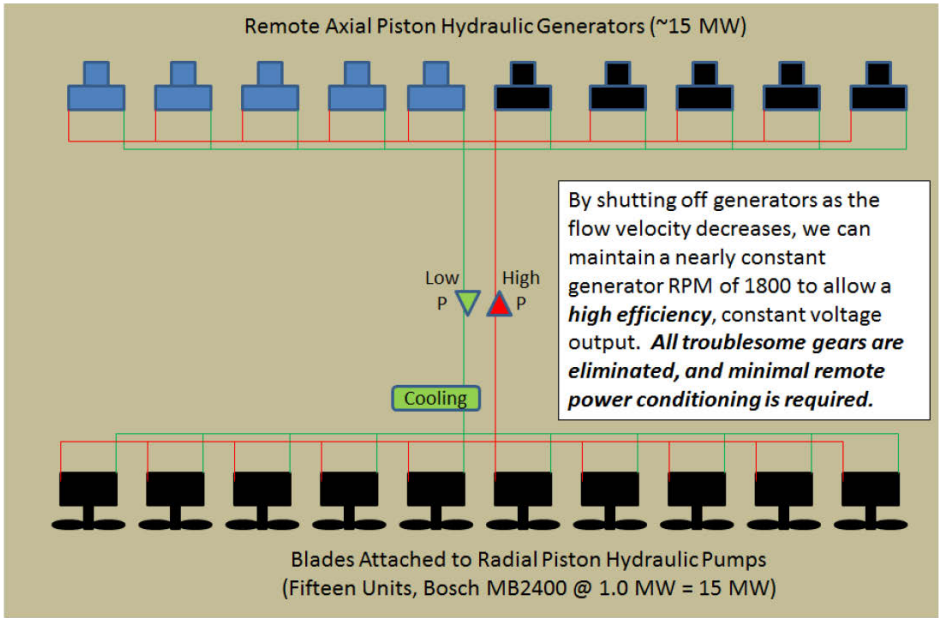


Efficiency is held constant above rated velocity

Proposed Configuration

- Wind turbines and generators connected in unison
  - Rather than individual turbines and generators, multiple turbines transfer energy to multiple generators
  - At lower wind speeds, less fluid pressure is supplied through the hydraulic line

As wind speeds decrease, some generators are shut down so that others can operate near maximum capacity to increase efficiency



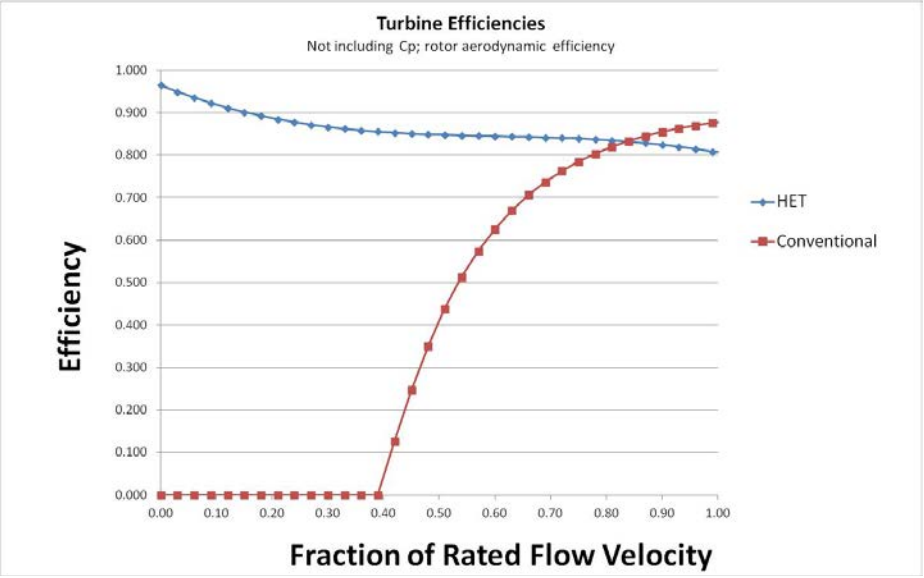
Proposed wind farm concept [7]

Performance Analysis

- Comparison of proposed HET system and conventional turbine

•Hydraulic drive train has higher efficiency below rated velocity

•Gearbox efficiency decreases sharply at lower velocity due to resistance in mechanical parts



Efficiency including generator and gearbox

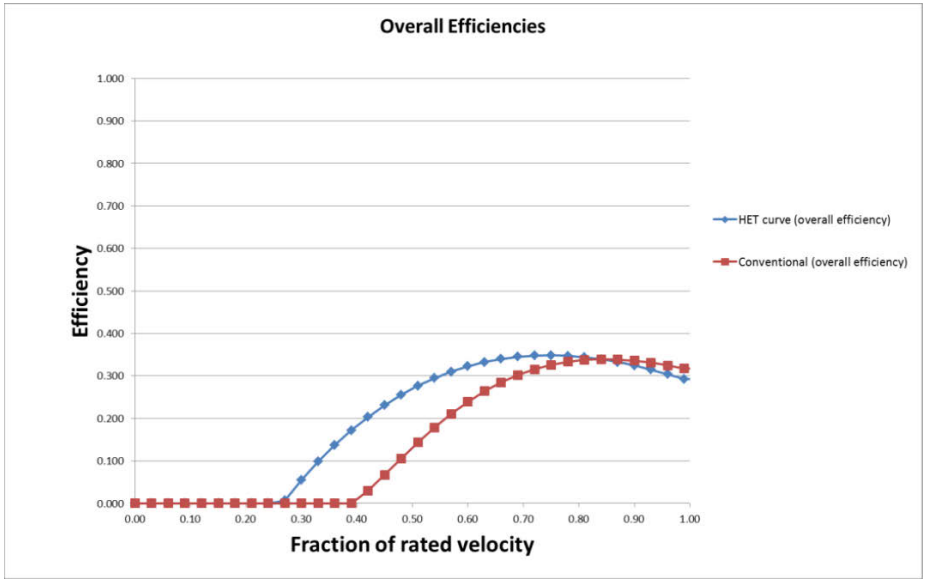
Performance Analysis

- Overall efficiency for both systems, including rotor aerodynamics

•Efficiency including rotor aerodynamics

•Hydraulic drive train is able to produce power at lower wind speeds

•Conventional system requires higher velocity to generate power

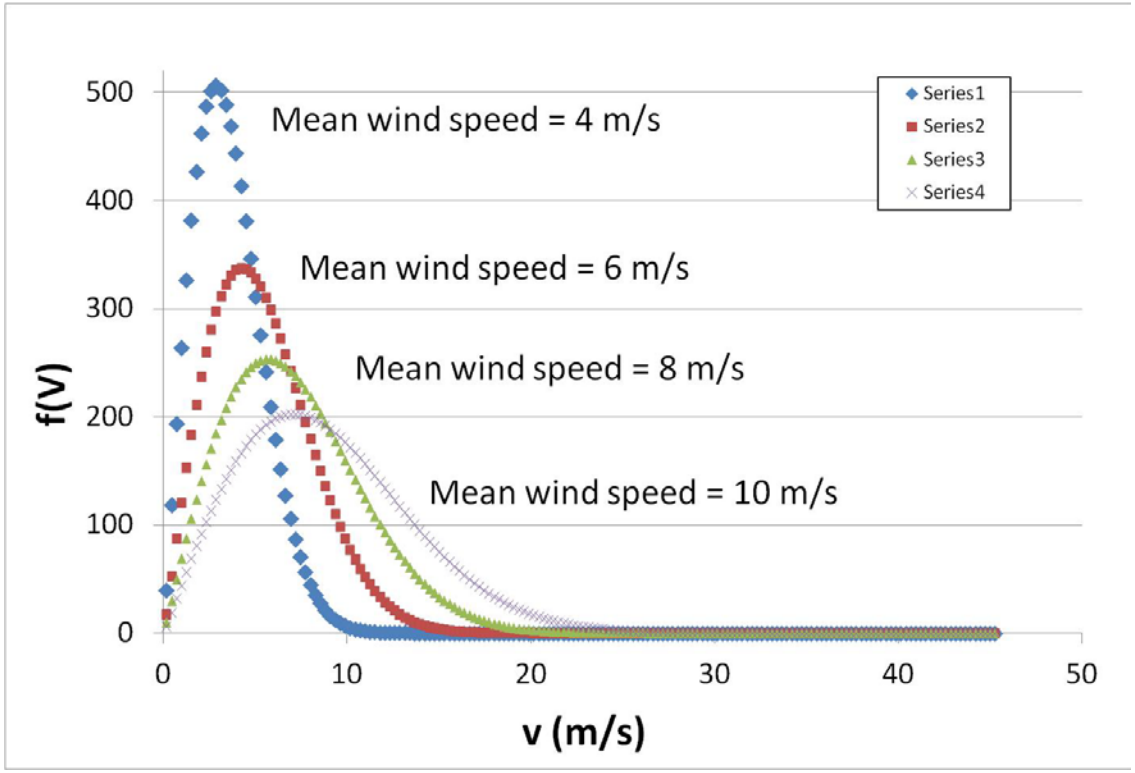


Efficiency including rotor aerodynamics

Performance Analysis

- Weibull distributions used to simulate wind data

Distributions vary based on average wind speed, with an optimal rated turbine speed for each case

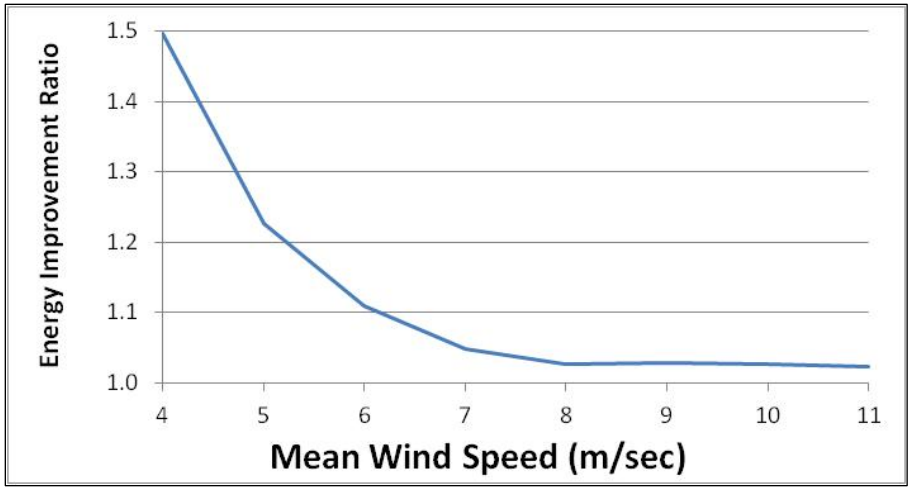


Wind data uses scale factor of 2 with varied averages

Performance Analysis

- Optimal turbine ratings selected for each wind speed

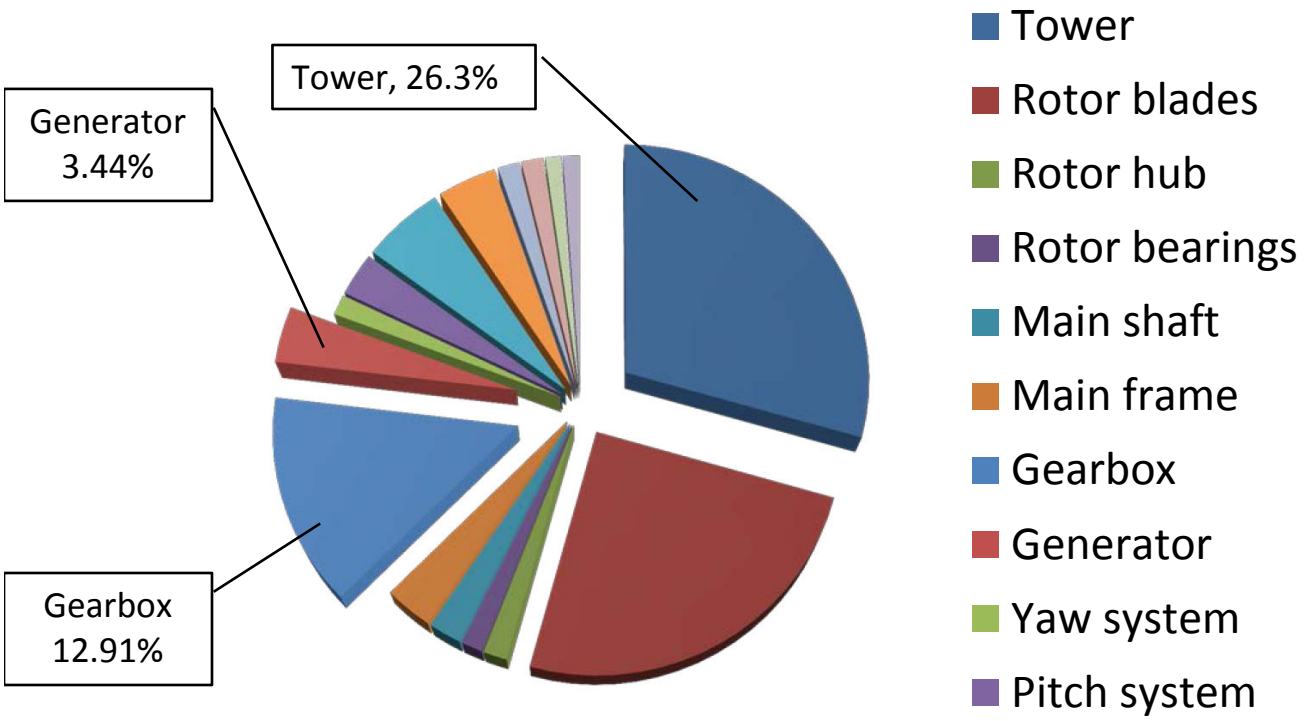
The improvement in energy generation is examined for each mean wind speed, with a minimum of 11 m/s



Average Wind Speed	Optimal ratings for each condition		Efficiency Increase (HET/Conv.)
	Conventional Rating	HET Rating	
4	11	11	1.496
5	11	11	1.227
6	11	11	1.109
7	11	11	1.048
8	11	12	1.027
9	13	14	1.028
10	14	15	1.026
11	15	17	1.024

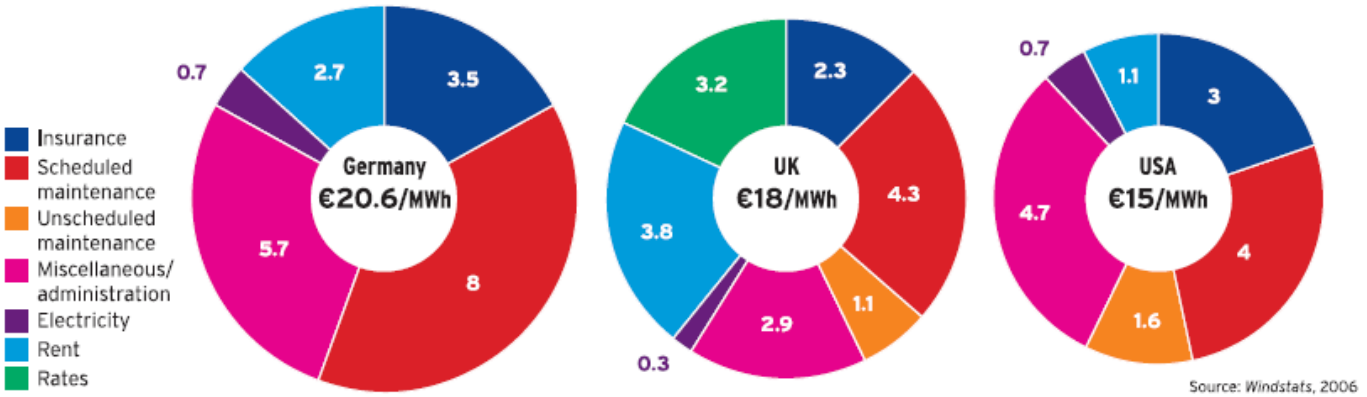
Cost Breakdown

- Capital cost of a conventional wind turbine

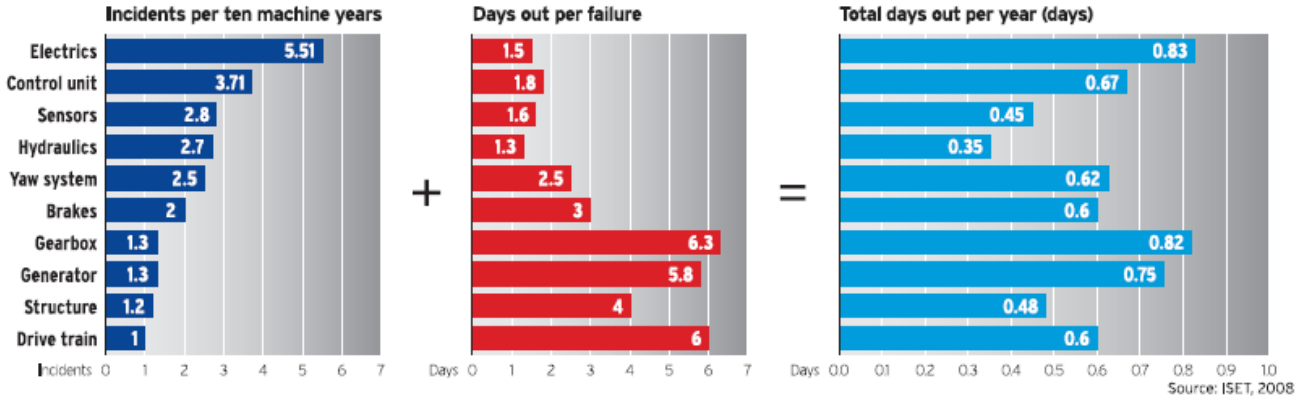


Cost of components [5]

Cost Breakdown



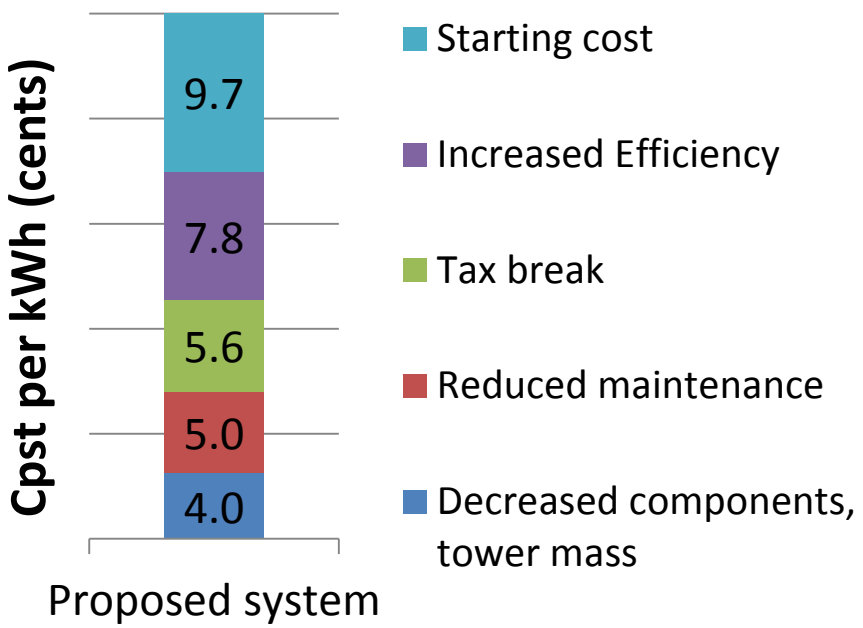
Total operation and maintenance costs, per MWH [6]

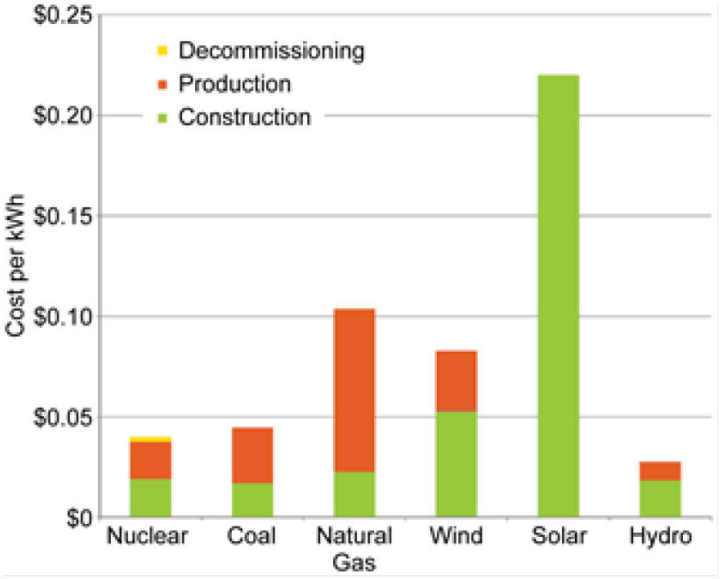


Failure rates and down time of components [6]

Cost Breakdown

- Cost improvement of proposed system
  - Levelised cost is comparable to coal





Levelized cost of energy for various sources [7]

Conclusion

- Overall increase in efficiency of power generation
  - Ability to shut down generators allow others to operate at full capacity
  - Hydraulic drive train begins generating power at lower rated speeds
- Overall reduction of costs
  - Less frequent breakdown of components
  - Ease of maintenance for components on ground
  - Decreased amount of components and tower mass
  - Removes need for gearbox and power electronics

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Questions