CAES

Compressed Air Energy Storage

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Overview

- Project Introduction
- Constraints
- Design Concept
- Component Analysis
- Conclusion

Project Overview

- What is CAES?
  - Compressed Air Energy Storage
- How can we store Wind Energy
  - Compress Air
    - Simple, available, cheap
    - Highly inefficient
- Store the Compressed Air
  - Man made pressure vessel for small scale
  - Larger scales use caverns
- Use the Compressed Air
  - Turbine, air motor or supply air

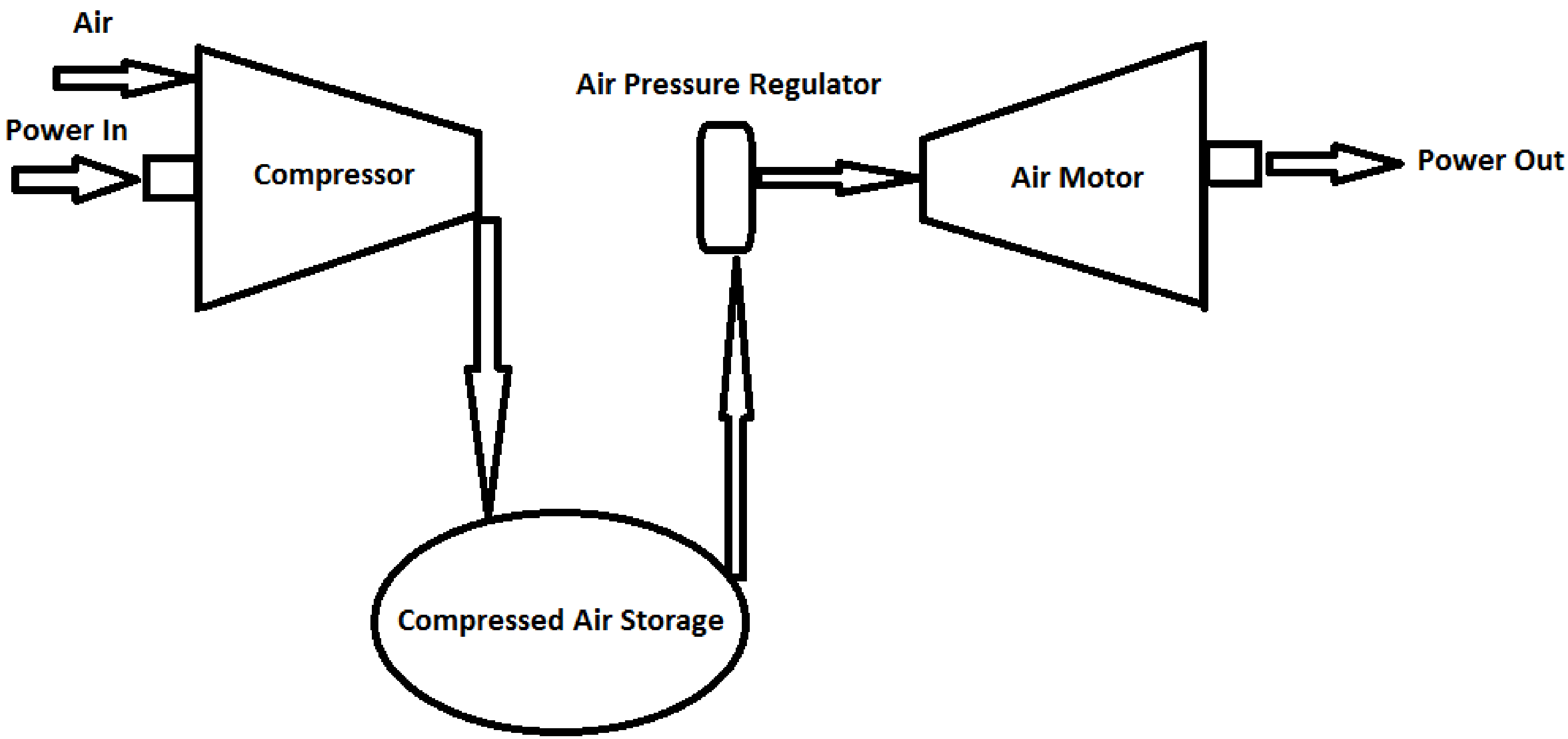
Objectives

- Build small scale CAES
  - 20kW, 50kW, 100kW, 250kW
  - Approximately 30hp, 75 hp, 125 hp, and 350 hp
- Connect Existing Equipment in series to create our system
- Perform analysis on:
  - Overall system performance
  - Overall efficiency
- Is this system feasible for small scale?

Limitations Encountered

- Mechanical or Electrically Driven Compressor
  - Electrical most widely available
  - Compressors are made for non-variable electrical inputs
    - Limits our range
    - May need to normalize power input from wind turbines
- Compressor input Power limited to ±5%
  - Outside of this range, operation is extremely inefficient and damaging to compressor
- We have too wide of a Power Range for one or two compressors for each rating
  - Must use one compressor for each rating
    - Otherwise price gets outrageous
- Pressure Vessel
  - Very limited on range

CAES Design



Air
Power In
Compressor
Air Pressure Regulator
Air Motor
Power Out
Compressed Air Storage

Compressor Data

Compressor Model	QST/B-30-125	QSI-335	QSI-540	QSI-925	QSI-1250
Power Input(hP)	30	75	125	200	350
Full Load Pressure (psi)	125	125	125	125	175
Maximum Pressure (psi)	140	140	140	140	190
Full Load Capacity (acfm)	109	335	540	925	1216
Compressor Manufacturer	Quincy	Quincy	Quincy	Quincy	Quincy

Pressure Vessel

- Steel pipe welded caps
- 12 ft diameter
- 100 ft length
- ¾" thickness
- Yield stress of 30 ksi
- Allowable stress of 16.9 ksi (ASME standards)

$$\sigma_{hoop} = \frac{P * r}{t}$$

$$P = 312.5\ psi = P_{fail}$$

$$P_{allow} = 176.25\ psi$$

$$\sigma_{long} = \frac{P * r}{2 * t}$$

$$P = 625\ psi$$

Pressure Vessel

- Assumptions:
  - Ideal gas law
  - Temperature change negligible
  - Initial fill with P = 0 psig

$$t_{20kW} = 89.92\ min = 1.49\ hr$$

$$t_{50kW} = 29.26\ min$$

$$t_{250\ kW} = 10.59\ min$$

$$P_{max} = 130\ psi \qquad V = 11{,}310\ ft^3$$

$$P_{min} = 0\ psi \qquad \dot{V} = 540\ \frac{ft^3}{min}$$

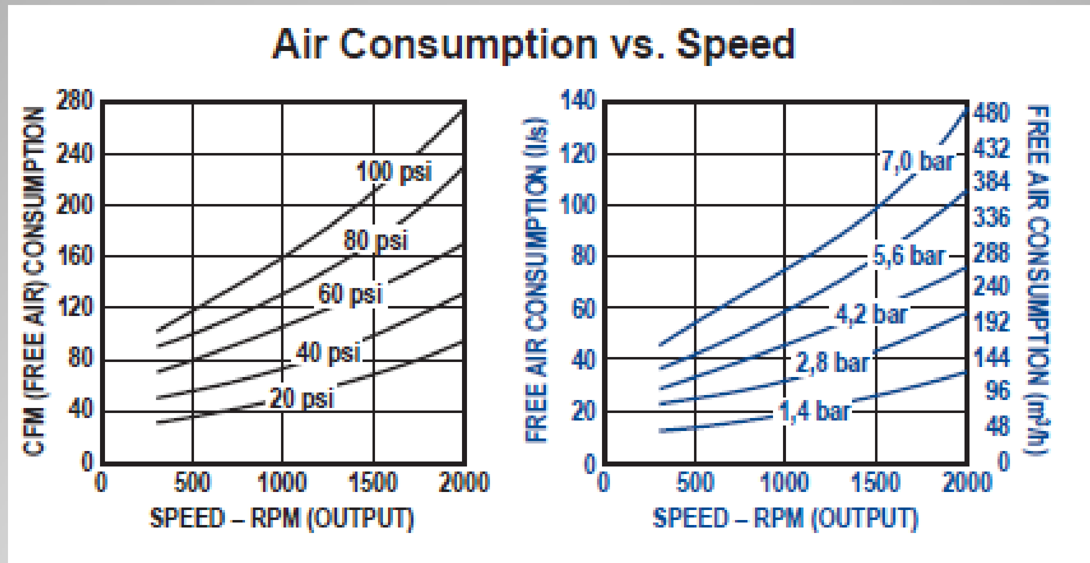
$$P_{in} = 150 psi$$

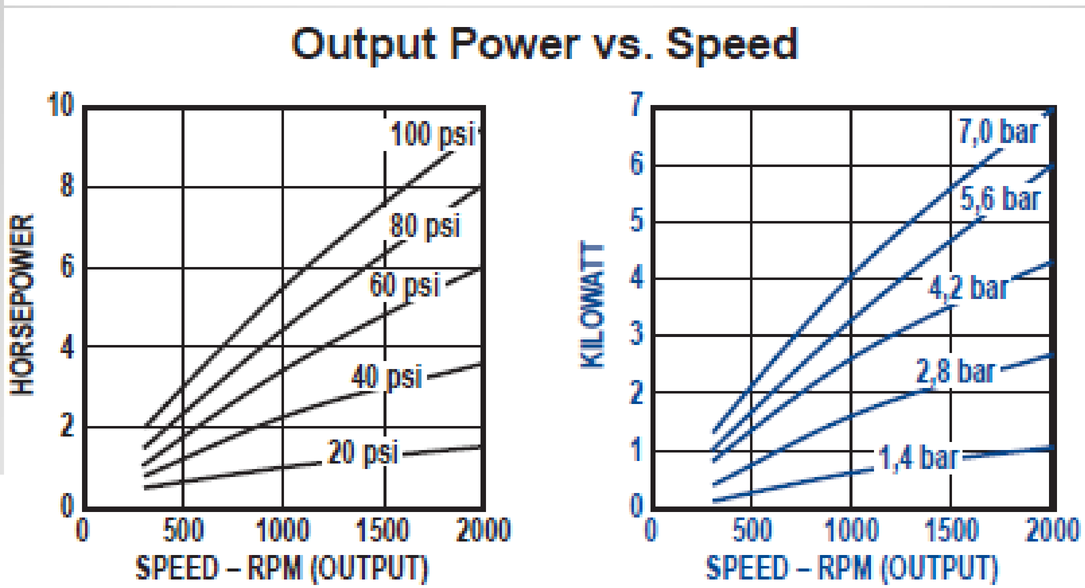
$$dP = \frac{P_{in}}{V} * \dot{V} * dt$$

$$t = \frac{(P_1 - P_2) * V}{P_{in} * \dot{V}} = 18.15\ min$$

Calculation done using 100kW Turbine

Power Generation





Power Generation

- 4 HP (~3kW) Vane Air Motor
  - Max Air pressure 100 psi
  - Max Flow Rate 130 CFM
  - Temperature Range 0-250°F
  - Torque Range 7-9 ft-lb
  - Max RPM 3000
- $341-$455
  - Depends on which mounting we choose

Courtesy Grainger

Power Generation

- Operating Pressure will be 60 psi
  - Higher Operation pressure means shorter time
- Cut off Pressure will be 40 psi
  - Efficiency of motor
  - Useful work out

$$P_{max} = 130\ psi \qquad V = 11{,}310\ ft^3$$

$$P_{min} = 40\ psi \qquad \dot{V} = 130\ \frac{ft^3}{min}$$

$$P_{in} = 60psi$$

$$dP = \frac{P_{in}}{V} * \dot{V} * dt$$

$$t = \frac{(P_1 - P_2) * V}{P_{in} * \dot{V}} = 130.5\ min = 2.18\ hr$$

Efficiency

- Energy is defined in kW hr
  - Power used multiplied by time
- Keep air motor constant
- Assumptions
  - Ideal Gas Law
  - Vessel has constant temperature

$$\eta_{20kW} = \frac{6.45}{29.8} * 100 = 21.64\%$$

$$\eta_{50kW} = \frac{6.45}{24.38} * 100 = 26.45\%$$

$$\eta_{250kW} = \frac{6.45}{44.125} * 100 = 14.61\%$$

$$\eta_{100kW} = \frac{Energy_{out}}{Energy_{in}} * 100 = \frac{6.45}{33.3} * 100 = 19.36\%$$

Conclusion

- Need to take a trip to Kueka Wind Farm
  - Inspect equipment, get model number for existing compressor
- Recommend the chosen compressors to Kueka Wind for the chosen Power Ratings
  - Need to work on normalizing power due to tolerance of compressors
- Purchase Air Motor and Pressure regulator
- Integrating components for CAES system

Sponsors

- Dr. Srinivas Kosaraju
- Dr. Rob Hovsapian
- Keuka Wind

Questions?