Homer Tidal Turbine and Marine Instrument Test Station Design

Senior Design Project

Sponsored by: City of Homer

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Acknowledgements

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- NOAA Kachemak Bay Research Reserve
- Homer Electric Association, HEA
- Monty Worthington, ORPC
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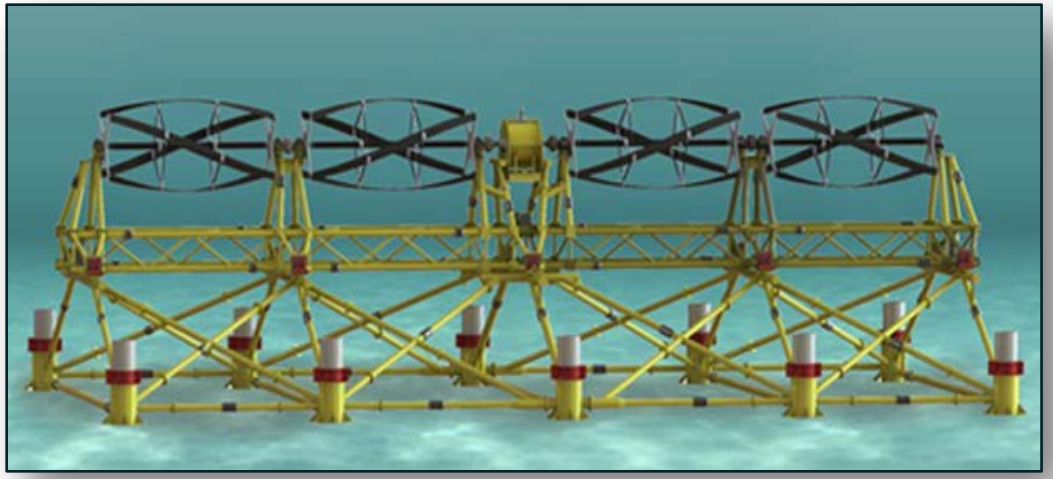
Purpose of this project

- Provide for testing tidal power turbines and marine instruments
  - Generate new industry in Homer
  - Generate revenue

- Encourage tidal power generation in Alaska



ORPC TidGen

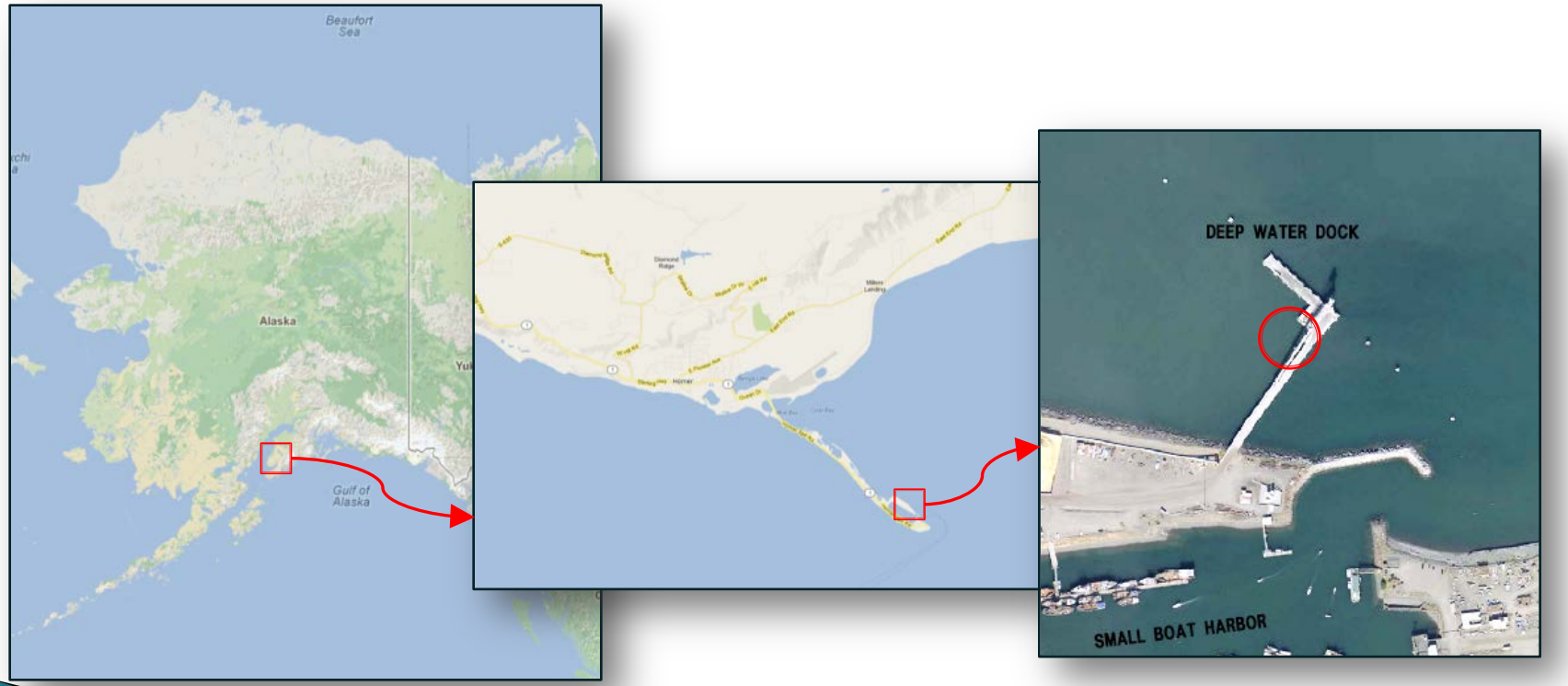
Project Scope

- Identify opportunities
- Develop criteria
- Formulate and compare alternatives
- Provide a 35% design of preferred alternative

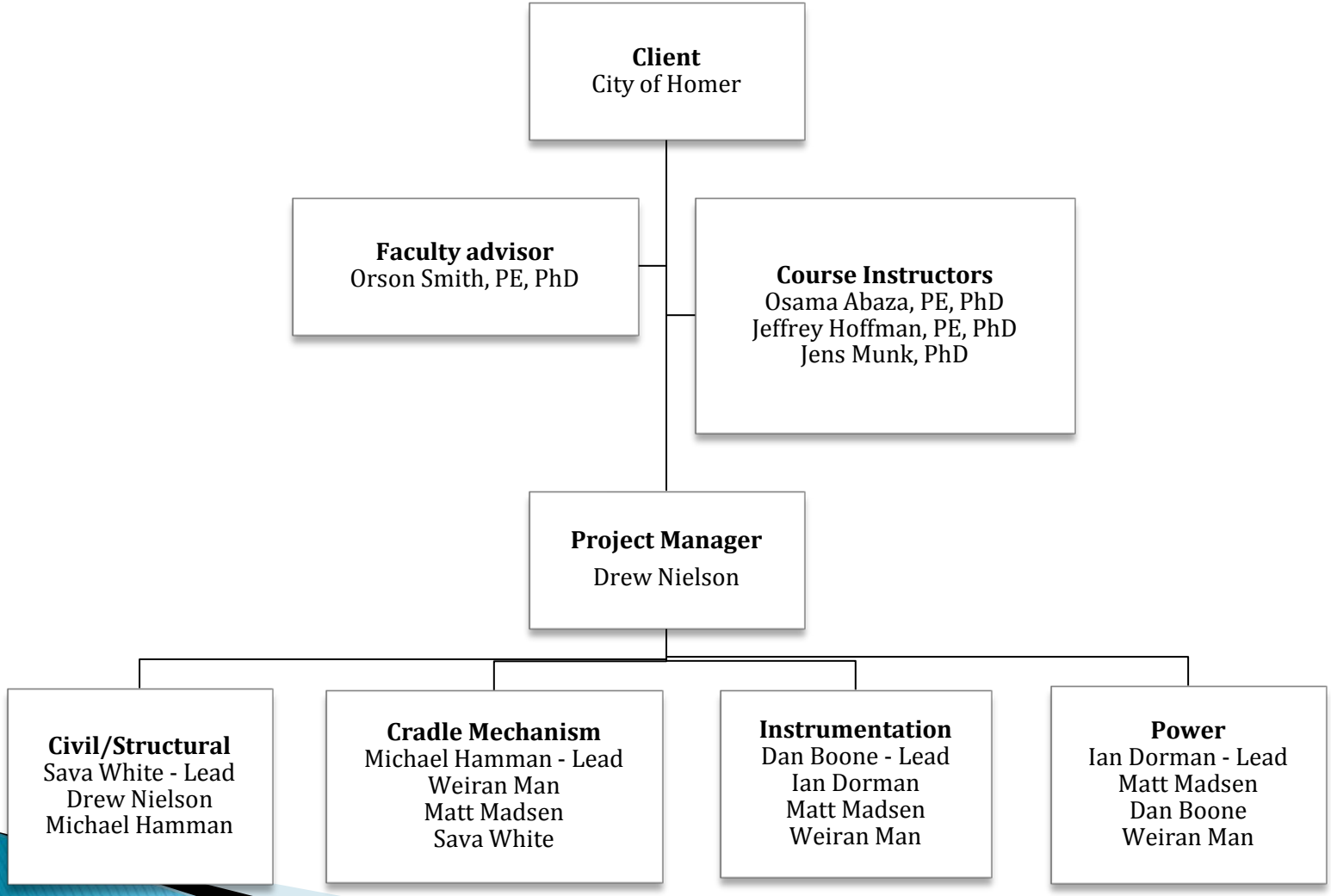
City of Homer, small boat harbor

Location and vicinity

- This project is located at the Deep Water Dock in the City of Homer, Alaska.

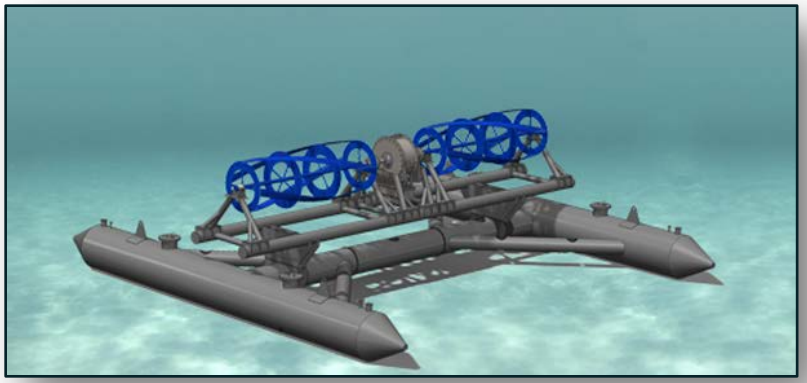


Client and Team Organization



Tidal Energy Overview

- Increasing demand for alternative sources of energy
- Alaska has 90% of U.S. tidal energy potential
- ORPC Bay of Fundy tidal energy project
- ORPC's Cook Inlet Tidal Energy Pilot Project
- Potential to power 2,300 Kenai Peninsula homes



ORPC RivGen

Site Characterization

- Uni-directional current
- Relatively low water velocity (2 knots)
- Tide range average of 18ft in height
- Pilot study on fish survival
- Minimal ecological impact

Existing Site Conditions

- Deep water dock built in 1988
- 2 pilings and beams added for wood chip conveyor

Design and Evaluation Criteria

- Functional Performance
  - Accommodate multiple R/D designs.
  - Easily deploy testing devices.

- Structural Stability
  - Must withstand dynamic and static loads.
  - Protect instrumentation and data collection devices.

Design and Evaluation Criteria

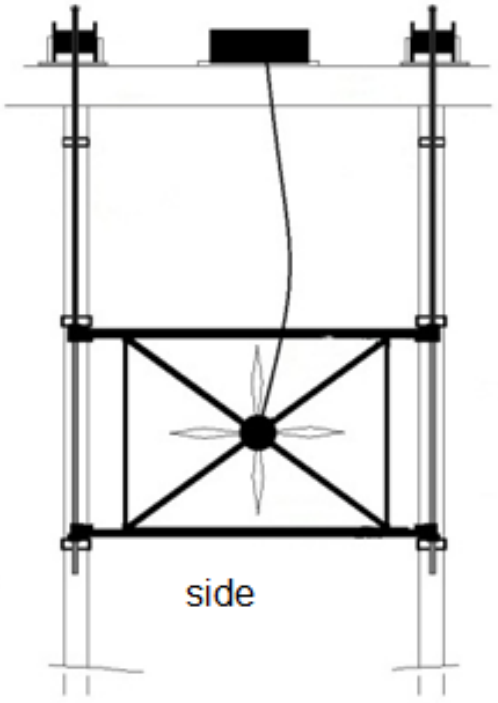
- Economical Profitability
  - Minimize operation and installation costs.

- Environmentally Safe
  - No site contamination.
  - Must not adversely affect marine life.

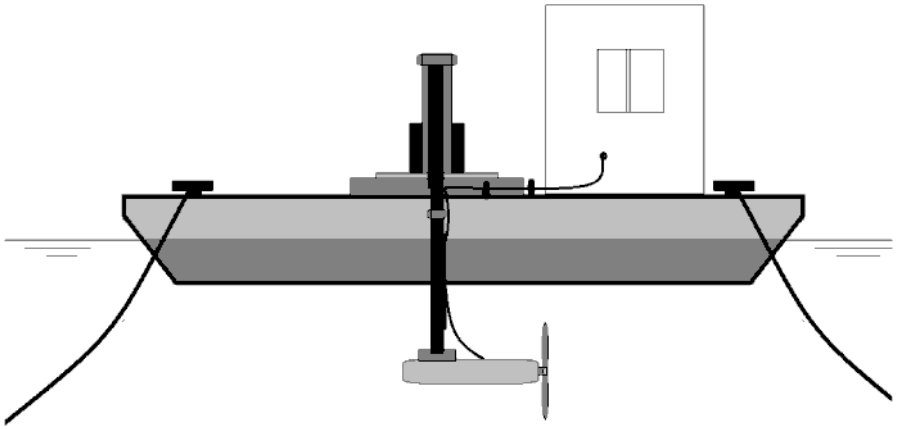
Design Alternatives

Three alternatives were developed

- Dock mounted
- Barge mounted
- Pontoon mounted



Dock mounted



Barge mounted

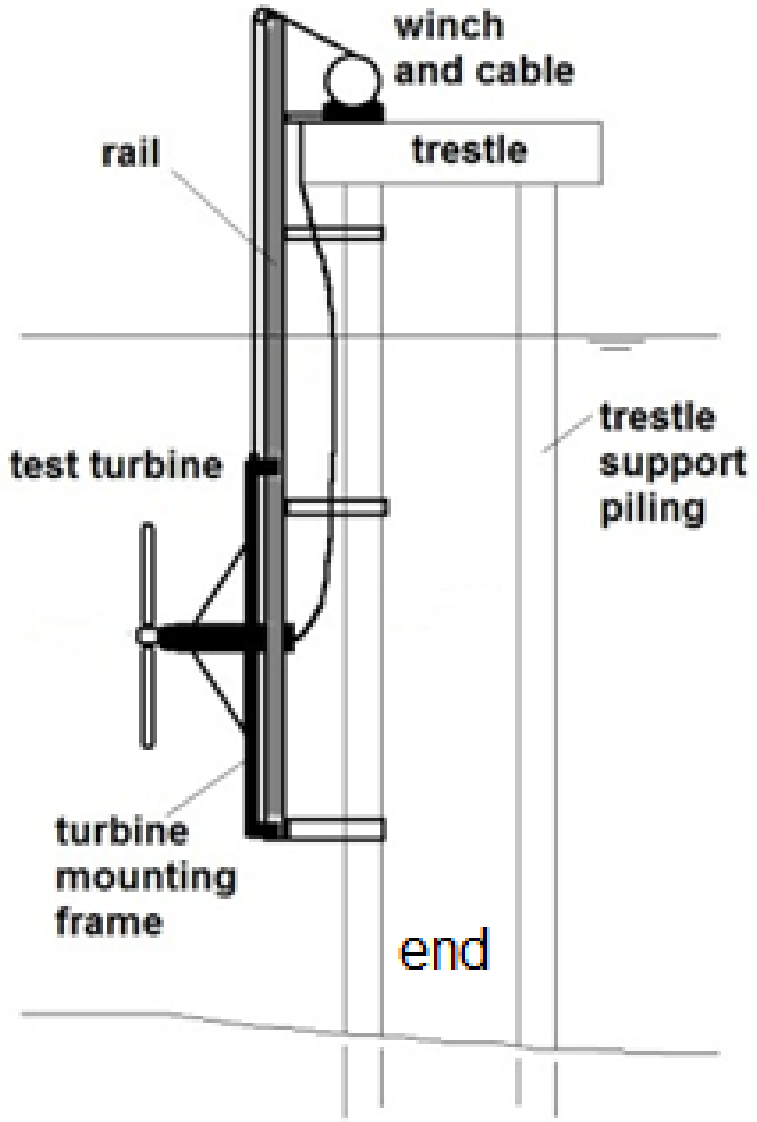
Dock mounted

Advantages

- Revenue
- Interconnection compatibility
- Increased range of generators that could be tested
- Available electric power
- Enclosure options
- Available structure
- Client preferred
- Long-term site monitoring

Disadvantages

- Moderate and unidirectional current
- Higher freeboard
- Maintenance of deployed ocean sensors



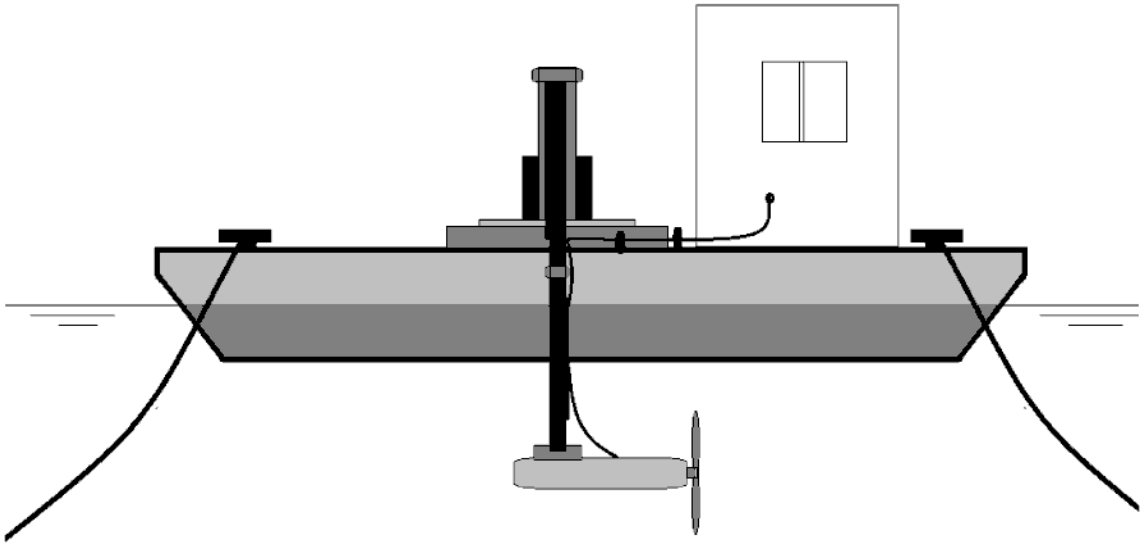
Floating

Advantages

- Transportation
- Instrumentation access
- Access to higher currents
- Access to different environments

Disadvantages

- Generator system required
- Anchoring system
- Data collection
- Long term testing

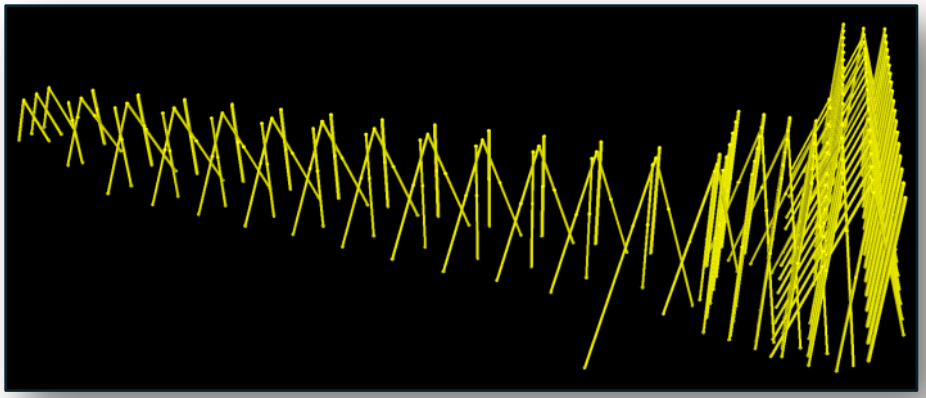


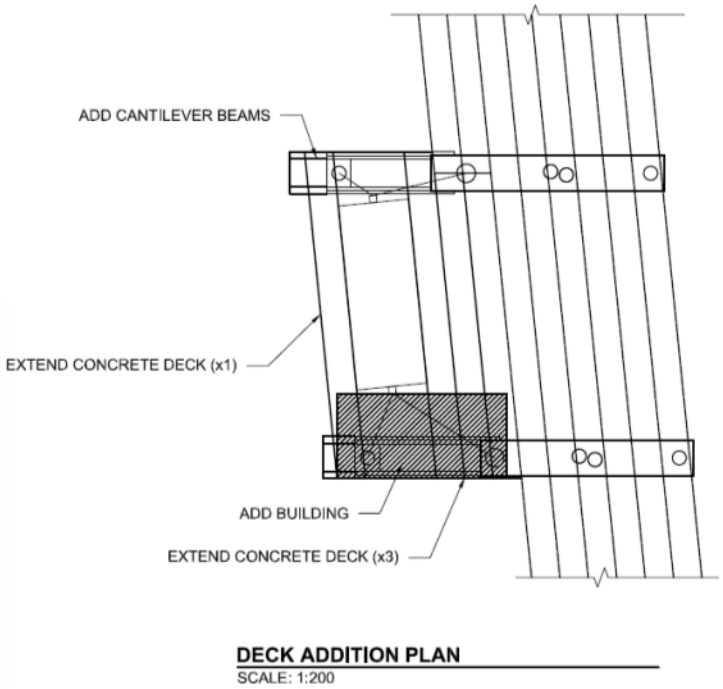
Final Test Station Design

- Dock-mounted option selected for final design
- Test turbine assumptions
  - 10ft length and diameter cylinder
  - Max weight = 30,000 lb
  - Electrically similar to a wind turbine

Structural support

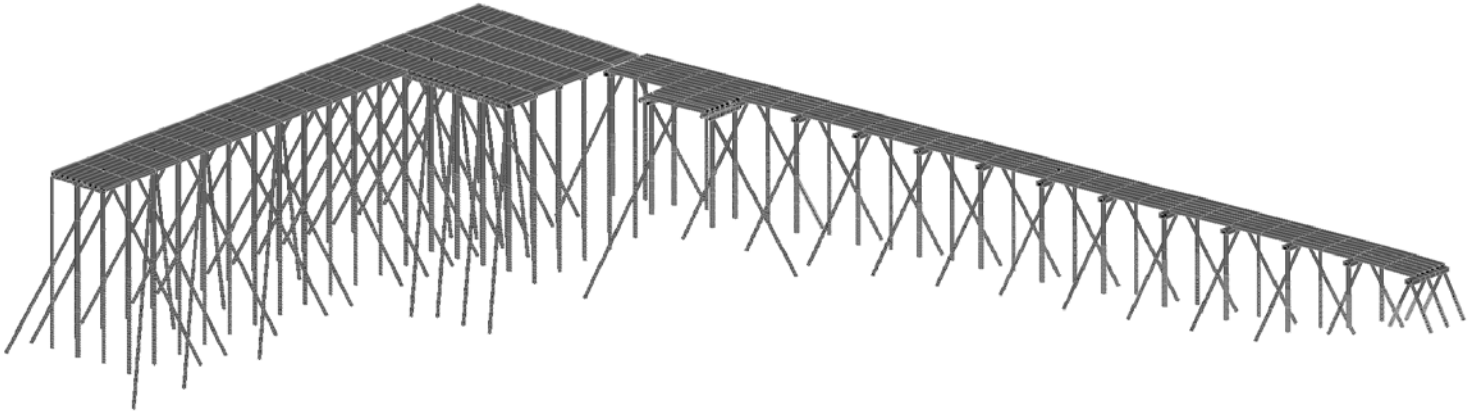
- SAP 2000 model of Deep Water Dock
- Cantilevered extensions
- Connections
- Decking design



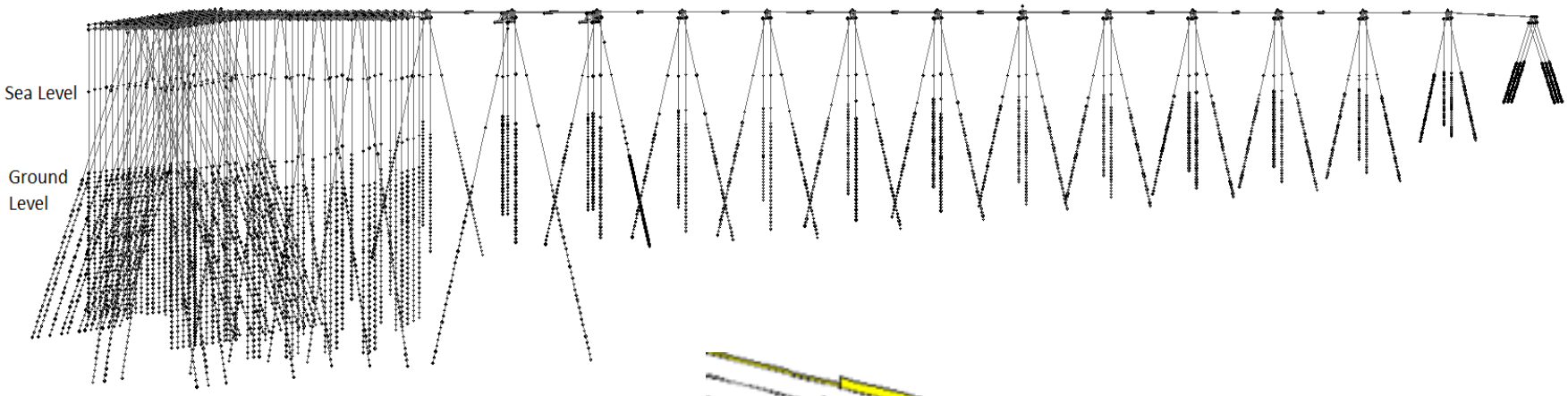


SAP2000 Model

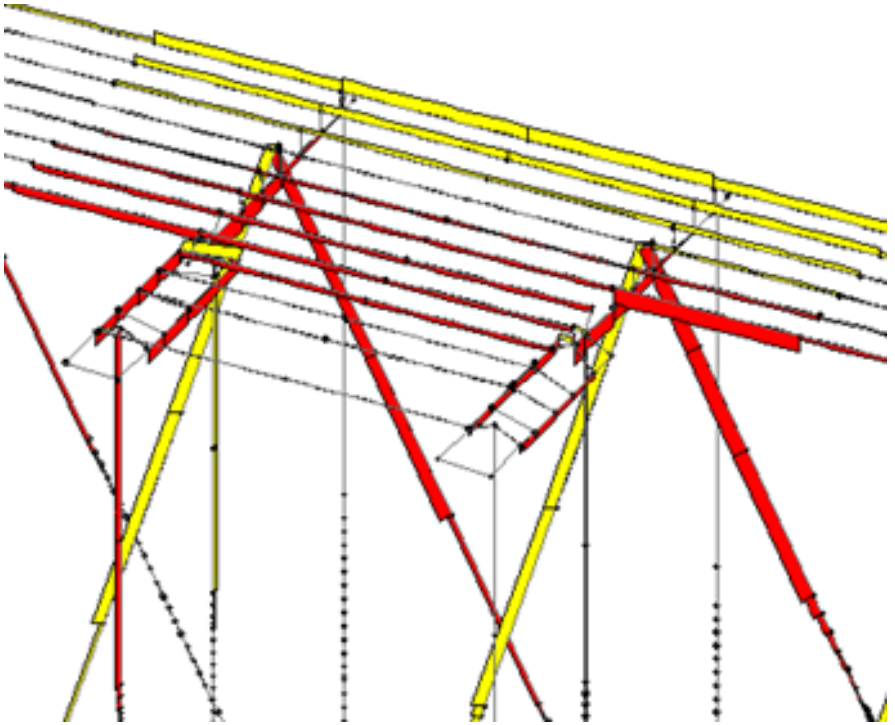
- Utilized to ensure structural stability under the increased load
- Entire load supporting structure of dock modeled
- Close to same properties as real structure



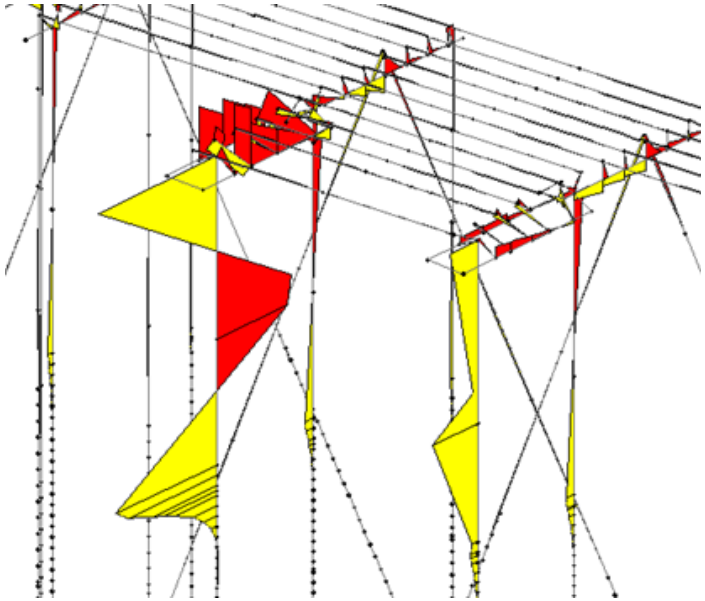
SAP2000 Model Cont.



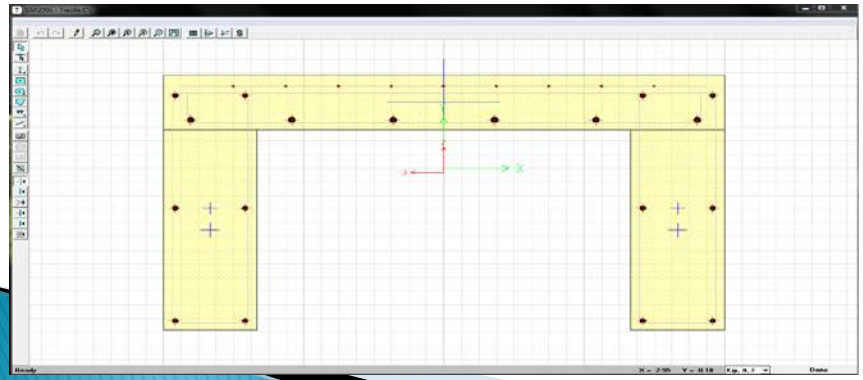
- Included loads
  - Dead
  - Fendering energy
  - Live
  - Ice
  - Breaking wave
  - Current
  - Forklift
  - Cradle mechanism

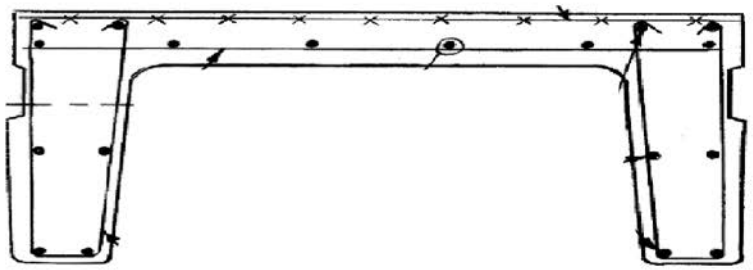


SAP2000 Model Cont.



- Maximum of each element type considered for moment and axial
  - Trestle C – 2.5% Max.
  - Diagonal Pile – 2.5% Max.
  - Vertical Pile 5% Max.
- Increase of force negligible compared with nominal strength





Cradle Mechanism

Options:

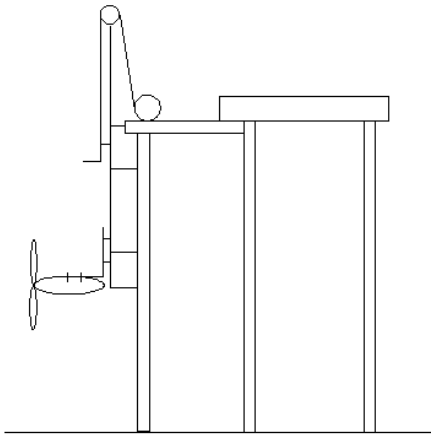
- Rack and Pinion
- Worm gear screw lift
- Chain lift
- Scissor lift
- Cable lift
- Hydraulic ram

Cradle Mechanism

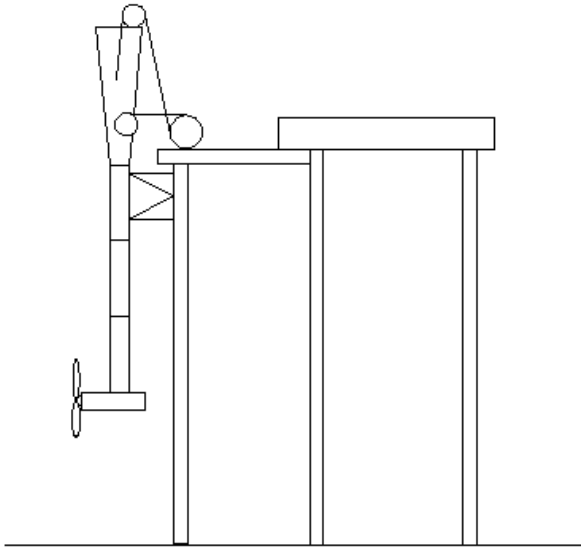
- We chose the cable lift system:
  - Simple Construction.
  - Cost Effective.
  - Reliable.
  - Available technology.

Structural System

- Evaluated two structural systems.



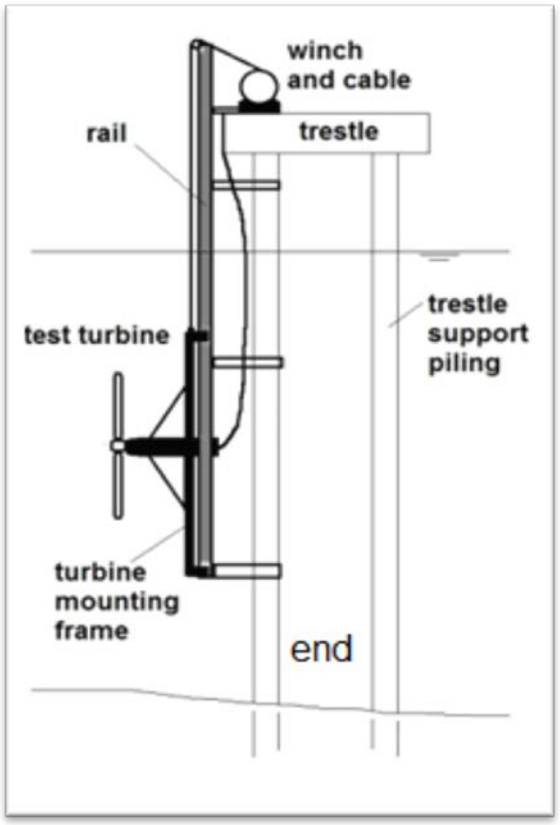
Static Rail



Telescoping Rail

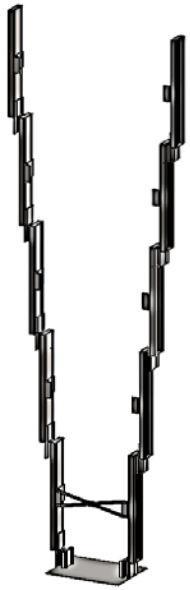
Cradle Deployment System

- Static Rail System:
  - Simple construction.
  - Stability.
  - Minimal material.

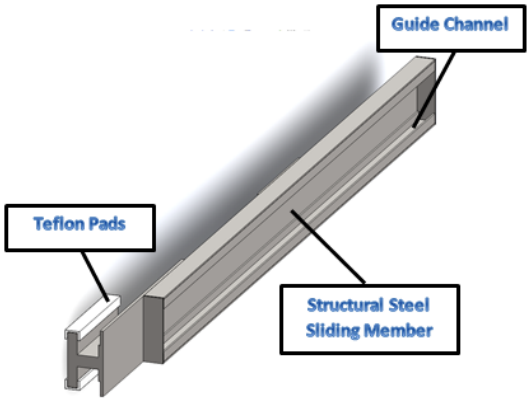


Cradle Deployment System

- Telescoping Rail System:
  - Limiting factors.
    - 50 to 60 foot vertical span.
    - High stress concentrations for pads.
    - Harmonic loading.



Extended Cantilevered Channel System



Basic Member

Final Cradle System Design

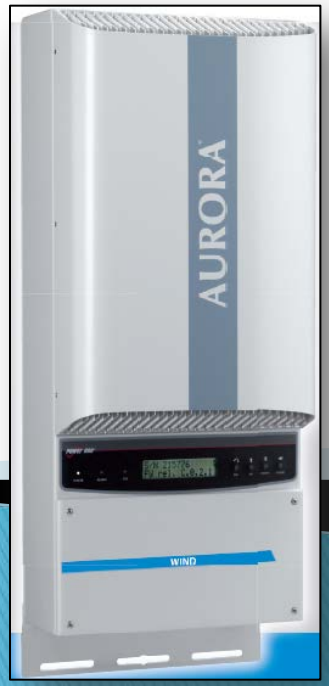
- Chose the static rail system:
  - Supported by structural webbing between piles.
  - Cable winch system.

Interconnection Characteristics

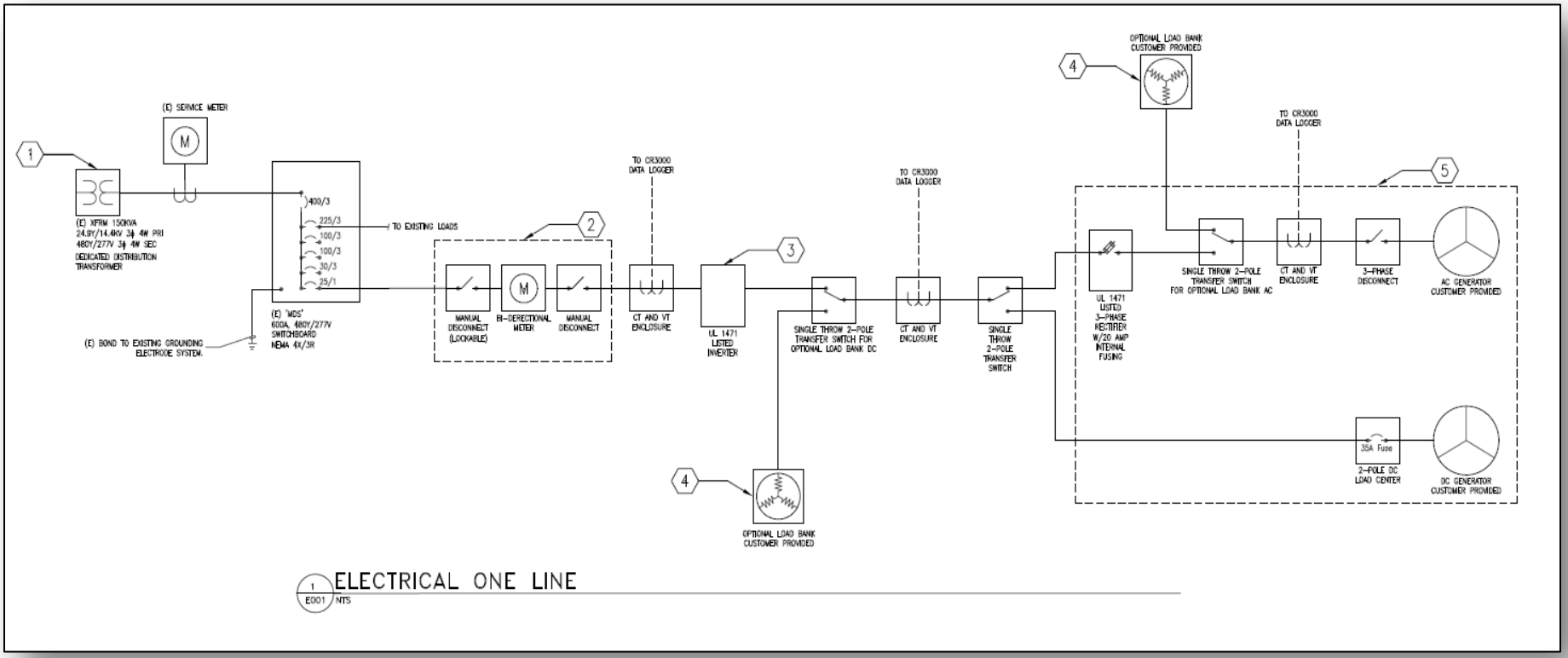
- Accommodates both AC & DC machines
- Interconnection rated for generators with:
  - ~4kW peak power output
  - Up to 400VAC or 50 - 580VDC
- Utilizes wind turbine technologies
- Must meet requirements of:
  - HEA's "Electric Service Requirements (Service Assembly Guide) 2009"
  - IEEE standards 1547: IEEE Standard for Interconnecting Distributed Resources with Electric Power Systems.
  - UL 1741 Inverters, Converters, and Controllers for Use in Independent Power Systems.
  - As well as NEC, NECS, IEEE 1547.1-6, IEEE 519

Interconnection Components

- Site Transformer
- Manual Disconnects & bi-directional meter
- Inverter
- Optional Load Bank Connections
- AC or DC generators



Interconnection One-Line



Interconnection Considerations

- When new machine connected, must have commissioning tests preformed (IEEE 1547.1)
- HEA requires 45 days of notice

Oceanographic Instrumentation

- Deployment System
  - Oceanscience Sea Spider
  - Mounting for multiple instruments
  - Placed in two locations

Oceanscience Sea Spider

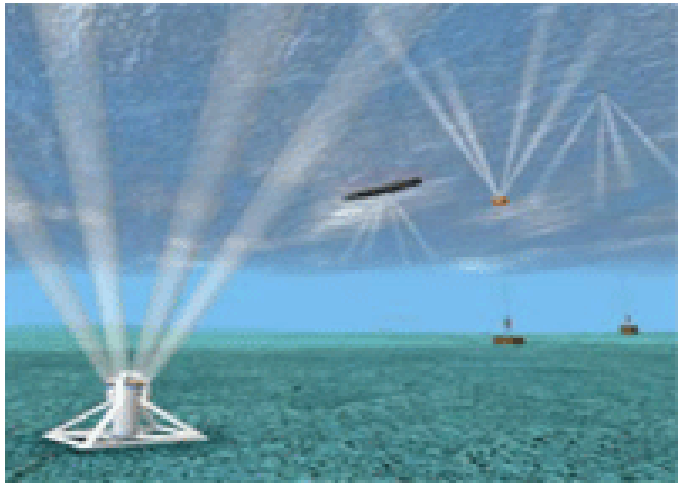
www.oceanscience.com

Oceanographic Instrumentation

- Water velocity
  - Placed in two locations
  - Measured with Acoustic Doppler Current Profiler (ADCP)

- Water conductivity, temperature and depth
  - Used to determine water salinity
  - Monitored with a CTD sensor

Teledyne Workhorse ADCP
www.rdinstruments.com



Conceptual view of ADCPs
www.pge.com

Oceanographic Instrumentation

Picture taken by Scott McMurren. Commons.wikimedia.org

- Water turbidity – the cloudiness of the water
  - Amount and size of suspended particulates
  - Measured with an Optical Backscatter Sensor (OBS)

- Scouring of the seafloor
  - Monitored with underwater camera system

Oceanographic Instrumentation

- Noise produced by the hydrokinetic device
  - Assessed with hydrophone

- Wildlife activity near the test site
  - Monitored with camera & hydrophone
  - Humpback whales
  - Orcas
  - Beluga whales
  - Salmon

www.makoswatertaxi.com

Power Instrumentation

- Determine the power output of the generator.
- Monitor the interconnection system.
- Electrical properties to be monitored:
  - AC voltage and current
  - DC voltage and current

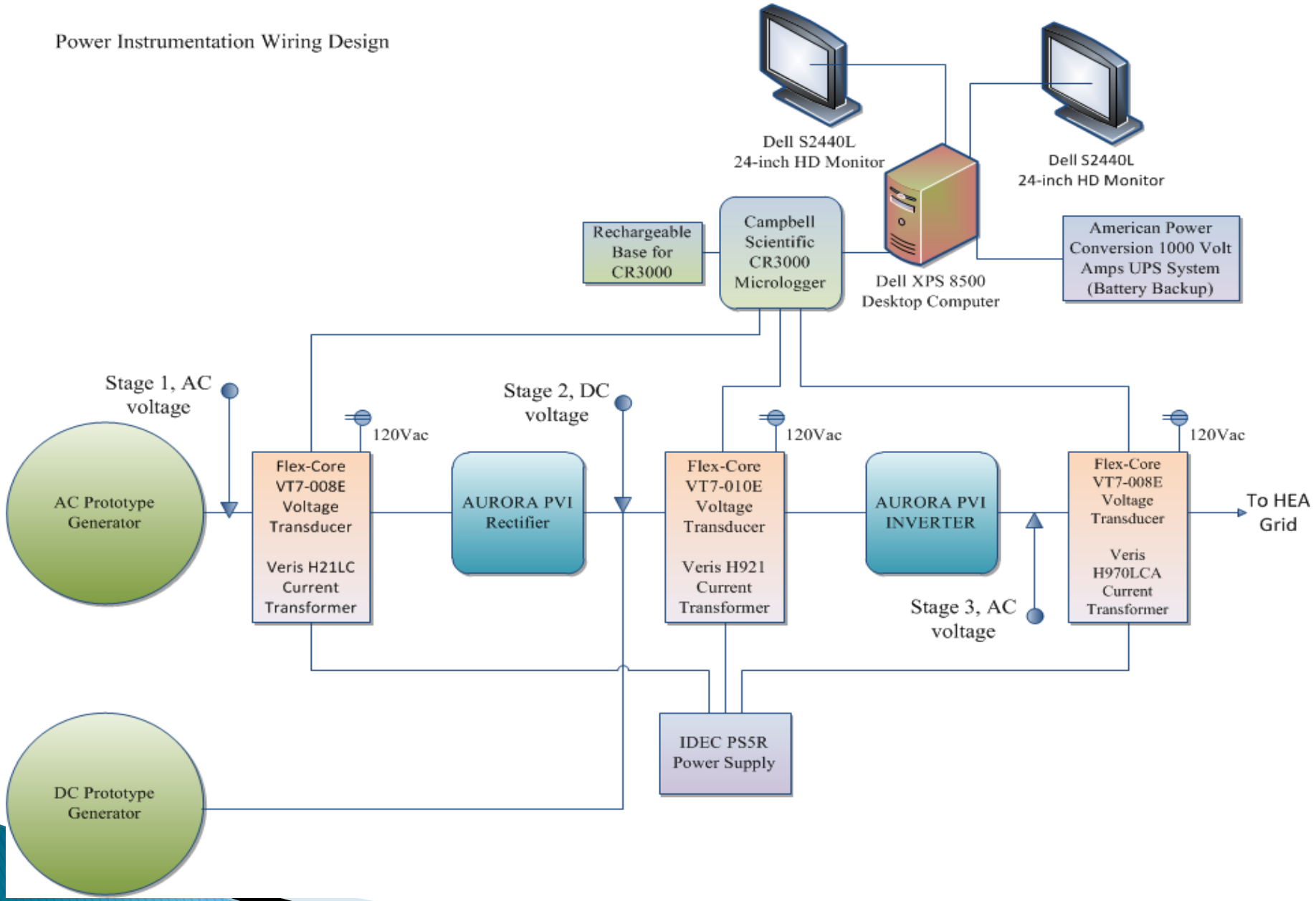
Veris H721LC
www.veris.com

Power Instrumentation

- Interface with a data logger.
- Accommodate either AC or DC generators.
- Measure a wide range of voltage, and current:
  - Stage 1: 400V, 20A
  - Stage 2: 600V, 40A
  - Stage 3: 300V, 30A
- Instruments used:
  - Voltage Transducers
  - Current Transformers

Veris H970LCA
www.veris.com

Power Instrumentation Wiring Design



Conclusion and Recommendations

The Deep Water Dock at the City of Homer is an ideal location for a tidal turbine and marine instrumentation test station.

- Complete site characterization
- Biological activity monitoring
- Full site and structural inspection
- Detailed cost estimate

Questions