Taylor Ranch Power System Expansion

Presented by Team Small Scale Sustainable Power (SSSP)

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Background

- Original homestead donated to University
- Surrounded by Frank Church Wilderness
- Only access: small plane or two-day hike
- Current system result of 1995 senior project
Current System One Line

Legend:
- Circuit Breaker
- Main Disconnect
- Electronic Load Governor
- Battery Bank

1. APT Tapering Diversion Regulator
2. Trace SW4024 Inverter
3. Xantrex XW Hybrid Inverter/Charger

Generator:
- H: Hydro
- S: Solar
- G: Gas
Project Phase I: Funding Proposal

- Phase I dates: February 12th – March 10th
- Objective: Conceptual power system design
- Required immediate extensive research
- Funding will dictate entire 2nd half of project
- Result: Completed NSF funding proposal
Proposed System One Line

Legend:
- Circuit Breaker
- Main Disconnect
- Electronic Load Governor
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- Generator:
  - H: Hydro
  - S: Solar
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1. APT Tapering Diversion Regulator
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Phase II dates: March 10th – Present

Objective: Concrete version of Phase I design

Phase II goals:

- Physical design of each subsystem
- Installation procedure & plans
- Identification of critical specifications
- Component selection
- National Electrical Code (NEC) compliance verification
The following slides describe each subsystem of the system expansion proposed by SSSP

Individual subsystems:
- Electrical grid
- Hydroelectric generation
- Solar generation
- Battery storage & backup
- Data acquisition
The Site

- Roof of hay shed
- Slope of roof faces almost due south
Photovoltaic Module

- Sanyo HIP-200BA19, HIT 200 Watt Solar Panel
- Cell efficiency: 19.7%
- Power Output per panel: 200 Watts
- Max Power Output from entire solar field: 3600 Watts
- Size (LxWxH): 51.9in x 34.6in x 1.8in
Layout

- 6 panels in each series string
- 3 strings in parallel
- Total length of solar field is ~22 feet
- Total width of solar field is ~10 feet
Attachment

- At least 4 inches from roof to module frame
- Each cell weighs: 33.07 lbs
- Total solar field system weight: ~675 lbs
Hydroelectric Generation

- Current system: Harris Hydro 4-nozzle system and 24VDC alternator
- High maintenance and low efficiency
- Expansion proposal: full system replacement
- Custom-designed system from Canyon Hydro
  - Designed to match site specific flow and head
  - Generator produces true 120VAC, 60Hz output
  - Governor controls power flow with ballast loads
Hydroelectric Generation
Sample Canyon hydroelectric system

- 15 kW model pictured
- Projected system in 1–2 kW range
- AC output synchronized by Xantrex inverter

Electrical Grid

- Current system: 120VAC, single phase
- AC lines to every electrified cabin
- Expansion proposal keeps current AC system
- Proposed addition: buried DC line
  - ~100m span from hay shed PV array to pump house
  - Medium voltage: ~350–420VDC
  - #4 AWG solid copper conductor
  - Environmentally sealed PVC conduit
**Electrical Grid**

- DC transmission analysis: Line losses

![Power Loss Through Various Gauge Wires](image)

\[
P_{loss}(R_{cu_{avg}8}, V_{dc}) = 100
\]

\[
P_{loss}(R_{cu_{avg}4}, V_{dc})
\]

\[
P_{loss}(R_{cu_{avg}3}, V_{dc})
\]

\[
P_{loss}(R_{cu_{avg}1}, V_{dc})
\]

\[
P_{loss}(R_{cu_{avg4}}, 48V) = 485.136 \cdot W
\]

\[
P_{loss}(R_{cu_{avg4}}, 350V) = 9.125 \cdot W
\]
DC transmission analysis: DC voltage drop

\[ V_{drop} \left( R_{cu_{-}awg4}, V_{dc} \right) = 6.468 \text{ V} \]

\[ V_{drop} \left( R_{cu_{-}awg4}, 350 \text{ V} \right) = 0.887 \text{ V} \]
Electrical Grid

- DC transmission analysis: Efficiency

![Efficiency of Various Wire Gauges](image)

\[
\text{Eff}(R_{\text{cuawl}8}, V_{\text{dc}}) = \text{Eff}(R_{\text{cuawl}4}, V_{\text{dc}}) = \text{Eff}(R_{\text{cuawl}3}, V_{\text{dc}}) = \text{Eff}(R_{\text{cuawl}1}, V_{\text{dc}})
\]

\[
\text{Eff}(R_{\text{cuawl}4}, 48V) = 86.524 \\
\text{Eff}(R_{\text{cuawl}4}, 350V) = 99.747
\]
Electrical Grid

- High power DC/DC converter
DAQ System Overview

- Integrated Data Acquisition System
  - Monitor Power Plant Operation
  - Monitor Site Conditions
  - Connected to Internet
Goals: Power Plant Maintenance

- Efficiencies of Electric Power Generation
  - Track Aging of Components
  - Track wear of mechanical systems
  - Determine when repairs are needed
  - Determine where repairs are needed
Goals: Power Usage Monitor

- Track Power Flow
  - Power Generated by Source
  - Power Used by Load
  - Find/Discipline Wasteful Users
  - Improve Usage Predictions
Data Collection System put in Place

- Connected to Internet
- Monitor performance of Systems
- Gather Data on Field Performance
- Used to Develop New Technologies
Parameters to be Measured

- Photovoltaic Array
  - HVDC Transmission Line
- Hydroelectric Turbine
- Backup Generator
- Battery Energy Storage
- AC/DC Inverter
- LVAC Distribution Network