Taylor Ranch Remote Electric Power Generation Feasibility Study and Design

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Abstract- **The article outlines the research and design of a small scale stand-alone electrical power generation system for a remote teaching and research facility. The document describes the process of forming feasible alternatives for the system and the criteria used in selecting and designing the most economical and functional system.**

I. INTRODUCTION

The University of Idaho, College of Forestry currently utilizes Taylor Ranch as a facility for teaching and research. Taylor Ranch is remotely located in the Frank Church Wilderness in Central Idaho. The only modes of transportation into the site are by small airplane or via a 37 mile foot trail.

Current energy requirements at the site are met by using propane, wood and two small solar generation systems. Propane is used for lighting, hot water, refrigeration and cooking, while heating is accomplished using woodstoves. Two buildings utilize solar power for radios and laptop computers, and a few DC lights.

II. PROJECT OBJECTIVES

The purpose of the project was to examine the feasibility of different sources of small-scale power generation to provide electricity for Taylor Ranch. Different system alternatives were to be evaluated to determine if they would meet the generation demands of the site, and determine if they were reliable and cost effective. The final objective was to design a system based on the lowest cost viable alternative.

III. SITE STUDY

The project team traveled to Taylor Ranch to gather information necessary for formulating a system plan. Activities performed during the site study included an inventory of existing and proposed building lighting and equipment, stream measurements, building and site measurements, and interviews with the College of Forestry personnel regarding site operations and the resulting impact on the proposed power system.

The inventory process involved inspecting every building on site and determining what lighting and equipment existed, along with the anticipated lighting and equipment that would be added with the addition of a power generation system. Each building was then measured for dimensions, to use later in determining lighting placement and wiring needs.

Stream measurements were performed on Pioneer creek, a stream in close proximity to the site. Measurements were taken using a sight level to determine the head drop of the creek from different possible source locations to different possible generation locations. Flow measurements were then performed to obtain an idea of the amount of water available at that time of the year. Details of measurement methods are outlined in Appendix F. Since these measurements were performed on the 1st of October, it was not considered a minimum flow, but more of an average representation of the flow for the year. The design team informed the College of Forestry that a stream measurement program should be implemented during the 1996-97 winter to ascertain a minimum flow condition for the creek. A typical procedure that could be used for this program is found in Appendix K.

Site layout measurements were performed by using a 100 ft. steel tape measure. Since an accurate site map was not obtainable at the time of the measurements, it was decided that this would be the best way to determine the distances between buildings and notable reference points. Surveyed drawings were later obtained from Hodge & Associates, Inc. in Moscow, Idaho, and the site measurements were checked for accuracy. The final site layout is Appendix A.

College of Forestry employees were interviewed regarding usage and maintenance of the site, and each individual building. Environmental impact and possible fire system and domestic water system improvements of a possible hydro system were discussed with the Forestry personnel. Environment impacts were also informally discussed with State of Idaho Fish and Game personnel, who were on site for the day. This discussion revealed that Pioneer creek was

The cost for each alternative was summarized and presented to Ed Krumpe and Alton Campbell from the College of Forestry, along with a discussion of each system's features. It was decided at this point to consider the DC hydro system as the system of choice, and pursue this system's design in greater detail. There were several factors that influenced this decision.

A. *Cost*

The DC hydro system was the most cost effective system for several reasons. The system's generator was much less expensive than the AC system's, and required less load control. The generator was also less expensive than the equivalent amount of PV panels, and required much less batteries than the solar alternatives, due to the system's ability to provide continuous charge.

B. *Environmental Impact*

The DC hydro system used less of the stream flow than the AC hydro system. The AC hydro system's usage was over 25 percent of the flow, which is an environmentally unfavorable situation. The DC hydro system can be contained completely in one power house building, resulting in minimal "line of sight" impact for the system. Since there are hiking trails running right by the site, and the location lies in wilderness area, it is important that the system not be highly visible. A large solar array in the wide open field would attract attention, and provide an adverse impact for persons utilizing the recreational area.

C. *System Utility*

The DC hydro system excelled in reliable power production, ease of maintenance and ease of installation. The DC hydro system excelled in reliability where the others didn't. At low stream flow conditions, the DC hydro system was capable of power production, whereas the AC hydro system would be ineffective. If the flow could not produce the synchronous speed required by the AC generator, there would be no power production at all. Solar generation would always be variable, when periods of high cloud cover would halt power production.

The DC hydro system's maintenance requires that the water source remain free and clean, along with periodic maintenance of the storage batteries (see Appendix L for battery maintenance procedures). The water supply is already a maintenance issue for the site, as the proposed new supply would be taken out of the existing domestic water supply's headbox. The water supply maintenance could possibly be less, however, because the new supply to the generator would maintain a constant flow through the pipe, therefore possibly avoiding winter freeze up of the headbox.. Solar panels add additional maintenance routines, as panels must be tilted for optimal winter and summer production, and during heavy snow conditions, the panels must be kept clean to produce power. There was also a concern about high winds possibly causing damage to a large solar array. The AC hydro system includes more mechanical parts than the DC hydro system, invariably making maintenance more difficult.

The DC hydro system affords a clean, simple installation. Each alternative was probably almost equal in this respect, but this did not detract from the advantages of the DC hydro system. Installation of the new water source would be an improvement to the existing water system, and therefore would serve a dual purpose.

VII. FINAL SYSTEM DESIGN

Once the appropriate alternative was selected, finalization began to ensure a complete and accurate system, along with the associated costs. System protection was finalized at this point, battery storage figures were re-checked, along with the generator and water supply sizing. The stream flow potential was found to be slightly less than was originally anticipated, but still provided a more than ample supply for the turbine. Shipping and transportation estimates were obtained to round out the system cost. A finalized cost summary is provided in Appendix I, with a breakdown of the function of each system component provided in Appendix J. The finalized system components are as follows:

A. *Harris Hydro 4 Nozzle Turbine with 24V Alternator*

This generator unit was selected based on it's reputation as a standard for this type of application. The output of the generator falls within the required output power range. Details of generator selection can be found in Appendix H.

B. *Ananda TDR-624A Diversion Controller*

This diversion controller was selected based on several items. The rated wattage of the controller is above the highest expected output from the generator. The controller is UL listed, and enclosed neatly in a NEMA 1 enclosure, ensuring an easy and neat installation.

C. *Ananda Powercenter 5-404*

The Powercenter provides the backbone for the system protection. The dual 400 Amp type-T fuses provide short circuit protection for the charging system as well as the system's load. The DC section breakers provide disconnects for the generator and diversion controller, while the AC section breakers provide individual disconnects for the AC building loads. This panel was selected for several reasons. The main reason was the ease of installation. Since all protection equipment is contained in this one central location, the panel can be mounted, wired and forgotten. This panel is ndeed the only viable hydro stream in the area, as Big creek ınd Rush creek are anadromous fisheries, each supporting hree possibly endangered fish species; steelhead trout, :hinook salmon and bull trout. Pioneer creek does not support ıny fish species.

IV. LOAD DETERMINATION

The individual building and total system loads were :alculated using the information gathered during the :quipment and lighting inventory and interviews with Forestry personnel. These calculations defined the maximum wattage and current draw for each building, as well as for the total system. These calculations were used in sizing the various components of the generation systems researched. For methods and load calculations, see Appendix B.

Most of the loads identified by the inventory and interviews required 120 VAC power. It was therefore decided that the system designed would need to provide 120 VAC power in order to be considered as meeting the system's requirements. Using 120 VAC power would also provide the most flexible voltage source for future equipment connections.

V. PRELIMINARY RESEARCH AND DESIGN

Preliminary research and design was performed on four system alternatives utilizing the information obtained in the site evaluation and the load calculations. Central solar generation, distributed solar generation, alternating current (AC) hydro generation and direct current (DC) hydro generation were all investigated. Appendix D has summaries of all four alternatives used for comparison.

A. *Centralized Solar Generation*

Centralized solar generation was considered to be a viable alternative, as the site has plenty of open building roof space that would allow for mounting a central array of photovoltaic (PV) panels. From the load analysis, the number of PV panels required was calculated for panels of various watt output at peak sun hours. The actual load that had to be supplied daily was greater than the load that would have to be supplied by a hydro source of generation, as five days of power autonomy would need to be stored by the system in the case of bad weather for several days, when little or no power production could take place. The need for this autonomy greatly increased the amount of batteries that would be needed to store the excess back-up power (see Appendix J for battery calculations).

B. *Distributed Solar Generation*

A distributed solar generation scheme was considered to see if providing generation at each individual building would improve the cost outlay of the system. It was found that for a system supplying the complete site load, there was actually a cost increase, due to multiple inverters and fusing packages that needed to be provided at each building. Cutting back on the system by eliminating some of the buildings that would be served was not considered a viable alternative, as the objective of the project was to provide power for the full system load.

C. *AC Hydro Generation*

Generation of direct 120 VAC power using a synchronous generator was considered. This configuration requires that the generator be sized to provide the entire maximum load of the system at any given time. This requires a large, expensive generation package, with load and frequency management controls to assure that as load is shed from the system, the generator is not harmed, or the system in general is not harmed by excessive current supply. Flow calculations (see Appendix G) revealed that in order to provide the maximum load power, a large percentage of the stream would have to be used by the generator, possibly impacting the stream ecosystem in an adverse way. Since the site is environmentally sensitive, this form of generation was a less than desirable alternative.

D. *DC Hydro Generation*

Research into DC hydro generation as an alternative revealed it as a source that would provide some of the best qualities of solar generation and AC hydro generation. This alternative uses a 24 VDC generator to charge a bank of storage batteries, just as an array of PV panels would do. The generator charges the batteries continuously, unlike PV panels, which will only charge when the sun is shining. This greatly reduced the number of storage batteries required by the system. Because the generator charges storage batteries, the generator does not need to be sized to supply the full system load at one time (see Appendix H for generator sizing calculations). As long as the generator provides enough continuous electrical output to meet the charging needs of the system loads, the batteries should be able to be sized to supply the peak load demanded by the system. This system also uses less than 25 percent of the stream flow, which is recommended for minimal impact to the stream environment.

VI. SELECTION OF SYSTEM FOR FINAL DESIGN

The preliminary research and design of the four generation alternatives yielded cost summaries for the basic systems (see Appendix D). These cost summaries did not take into account the common expected costs of supplier freight charges, cabin lighting and wiring and air transportation of system parts to the site. However, since these costs are essentially the same, and would only be estimates of the actual costs, each alternative was judged as an equal viable alternative to supply the needed system power.

also UL listed, and whereas installing separate fuse boxes and breaker panels would probably not be considered as code compliant, this panel is.

D. *Trace DR3624 3600 Watt Inverter*

The DR3624 provides 3600 watts of continuous power, which is well over the system maximum calculated load of 2600 watts. This allows for additional load to be connected in the event that excess power is available from the generation package. It is also better to run the inverter at somewhat less than it's full rated output, as the efficiency of the unit is greater for lower load output.

E. *Trojan TJ-105 6V Deep Cycle Batteries*

The batteries were selected based on cost, local availability, and total weight. The TJ-105's are simply the least expensive, lightest, and they can be purchased at almost any car parts store.

F. *Schedule 40 PVC Pipe*

This type of pipe was selected for it's smoothness, and subsequent low head loss. The pipe was sized to 3" per flow calculations, and can be obtained from any plumbing supplier.

G. *#8 Solid Copper Direct Bury 3 Conductor Cable*

This conductor was selected based on ease of installation, and function. The power loss calculated for the conductor was insignificant (see Appendix C), allowing for future connected amps without have to upgrade conductors.

H. *Building Lighting and Power Systems*

Each building was analyzed to determine the number of fixtures, switches, outlets, utility boxes, circuit breakers and length of wire required to provide power and lighting. An estimate was constructed with a cost breakdown for each building. Prices were obtained directly from the University Shop Stores for an accurate idea of the cost to the College. It should be noted that this portion of the system could be done on a pay-as-you go basis, for example, connect and wire one cabin at a time and allocate the cost over a period of time. This way, not all of the cost would have to be absorbed in one year. Another way to reduce this cost is to limit the use of compact fluorescent lights to high-use lights, while using inexpensive incandescent lighting for low-use lighting.

VIII. SUMMARY AND CONCLUSIONS

The DC hydro system designed should provide adequate power for the existing load at Taylor Ranch and allow for future equipment expansion. All devices were sized to allow room for additional growth of the system. The amount of this growth will inevitably depend on the power output from the generator. Varying stream flow and freeze-up in the winter months could limit production during those months. This is a variable that will inevitably be determined as the system is operated. As long as flow is maintained through the generator, power will be produced.

Electrical power supplied to the site will eleviate the site's propane use for lighting and refrigeration. At the same time, electrical power will make the site more useful by providing adequate power for lighting and equipment used for teaching and research. This design will allow for the power needs of the site and maintain a low environmental impact in line with the standards the College of Forestry wishes to maintain.

IX. ACKNOWLEDGMENT

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X. REFERENCES

For references, see Appendix M.