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Increasing Power Production of Small Dam Hydroelectric Plants

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***Abstract*— The United States Army Corps of Engineers (USACE) built and manages the Summersville dam and its recreation area. The USACE's priorities are flood control downstream of Summersville Lake and recreation, not producing power. USACE currently allows the Hydroelectric plant (Hydro) attached to the dam to make power only when enough water is being released to make power. During dry spells or winter months this may only be a few days per week. Gauley River Power Partners (GRPP) owns and operates hydro [2]. GRPP loses significant profit due to the USACE's strict water control regulations. These regulations have not been updated to optimize hydroelectric power production. For this reason, the water control methods employed in the past have been analysis in to determine how certain changes in water control could affect power production, recreation, and wildlife. The Results of this analysis shows that if small changes were made to the current water control techniques, significant increases in profit could be experienced. This can be accomplished without endangering recreation opportunities or wildlife. Flood control capabilities would be reduced. However, enough water storage would still remain to manage flooding downstream.**

***Keywords*— hydroelectric; power production; green energy; renewable energy; small dam**

I. Introduction

The USACE uses Howell Bunger valves to release water from Summersville Lake, as well as releasing water through Hydro. When Howell Bunger valves are used the water is plumed around the hydroelectric plant. This prevents Hydro from producing any power from the thousands of gallons of water that are by passing the plant.

The USACE currently uses an outdated set of technical orders or “tech. orders” to determine how and when water will be released from Summersville Lake. The tech. orders are difficult to understand. Significant procedures are vaguely covered in the tech. orders. This allows the USACE hydrology department or USACE dam tenders to make decisions concerning certain parameters of water control based on personal preference or opinion.

The tech. orders in use have not been updated to maximize power produced by Hydro. Current procedures place heavy emphasis on protecting recreation and wildlife at Summersville Lake and downstream on the Gauley River. The emphasis on recreation and wildlife coupled with personal preference for such has manifest into a major limitation for hydroelectric power production.

II. Purpose

The primary objective is to find a way for the USACE to maintain their water responsibilities while allowing Hydro to produce as much power as possible. This will result in higher power production from Hydro. Higher output from Hydro will lower the need for energy produced by coal plants. As a result, the amount of greenhouse gases emitted by coal plants will be lower. GRPP will also be able to increase profits.

III. Theory

The theory investigated suggested that if slight changes could be made to USACE regulation during the winter months, large increases in profits could be seen by GRPP. The winter months, November through March, have been investigated in this report. Changing the regulations employed during these months presents the greatest possible profit.

The summer months consists of May through August. During this time period the USACE mandates that the lake level during this time be kept within two tenths of a foot of their goal level. The goal lake level is usually designated as 1652.30 feet above sea level.

This level has been determined as the best level for recreation on the lake. It is also best for wildlife. The final key factor used to determine this level is flood control capability. For these reasons, the USACE is unlikely to negotiate regulations regarding summer months.

However, the winter months provide some opportunity for negotiation. During the winter months the lake level is lowered 77 feet to 1575 feet above sea level. This draw down is considered necessary by the UACE in order to be prepared for massive amounts of snow run off. Snow run off can add up to 30 feet to the lake level overnight depending on conditions [2].

When the USACE tech. orders were originally written, before the dam's completion in 1966, the 77 feet of water storage was necessary. Weather forecasting at that time was not very accurate and this large amount of storage was required in order to be prepared for the storm of the century at all times.

For this reason, accumulated snow runoff is evacuated from the dam as quickly as possible through the Howell Bunger valves and Hydro. Hydro is rarely permitted to release this water within its operating limits over time. This is results from Hydro's releases being lower than the Howell Bunger valves. Therefore, Hydro cannot not draw the lake down fast enough for USACE preference.

Today large storms that would cause such a buildup of water can be forecast far enough in advance to prepare. The lake level can be lowered to provide adequate flood storage if necessary. Thanks to today's weather forecasting technology, a 77 foot safety zone is not required at all times in order to be prepared for large storms.

This provides an opportunity to negotiate. However, the USACE is reluctant to change from what has worked for almost fifty years. The USACE is also intimidated by the possible risk of decreasing flood storage.

In order to be able to weigh the possible positive and negative effects of adjusting the winter pool level an investigation has been conducted. Numerical data has been compiled to show calculated gains in profit if pool levels were changed.

IV. Procedure

Data collected by Hydro's computer system is currently being analyzed to find new ways to improve power production. Permission to use the data had to be obtained from the Enel Green Power regional manager. The data then had to be acquired from the Gauley River Project supervisor. Once the data was received, all the unnecessary recordings had to be filtered out.

An example of data retrieved from the Hydro after all unnecessary data was filtered out can be seen in Table 2. The primary formula that will be used can also be seen in Table 1 [1, 2].

Table 1. Raw Recorded Data from the plant computer.

Spanish									
Fecha	Hora	U1-PQM-R3325	U2-PQM-R3327	PLC-PLC-R3403	PLC-PLC-R3407	PLC-FC-R3126	U1-FC-R3127	U2-FC-R3128	HB-FC-R3129
English		Active Power	Active Power	Lake Level	Tail Race Level	Total Flow	Flow U1	Flow U2	Flow HBV#3
Date yr/month/	Time	Signal U1	Signal U2						total HBV Flow
08/03/01 00:00	00:00:05	22.28000069	21.55999947	1575.429199	1373.19519	3153	1614	1537	0
08/03/01 01:00	01:00:07	21.87999916	21.75	1575.354736	1373.087646	3126	1596	1527	0
08/03/01 02:00	02:00:09	21.61000061	21.77000046	1575.319824	1373.076538	3192	1631	1561	0
08/03/01 03:00	03:00:11	21.87000084	21.54000092	1575.307861	1373.099243	3172	1652	1520	0
08/03/01 04:00	04:00:13	21.95999908	21.70999908	1575.288086	1373.130737	3124	1593	1531	0
08/03/01 05:00	05:00:16	22.12999916	21.56999969	1575.23877	1373.019409	3179	1649	1532	0
08/03/01 06:00	06:00:18	21.72999954	21.64999962	1575.23938	1373.074341	3159	1618	1541	0
08/03/01 07:00	07:00:01	21.80999947	21.36000061	1575.189331	1373.137085	3140	1623	1524	0
08/03/01 08:00	08:00:03	18	17.5	1575.238892	1372.822021	2589	1341	1248	0
08/03/01 09:00	09:00:05	18.09000015	17.45999908	1575.256348	1372.86499	2616	1369	1247	0
08/03/01 10:00	10:00:07	17.95000076	17.48999977	1575.30542	1371.518677	2562	1330	1232	0
08/03/01 11:00	11:00:09	18.10000038	17.55999947	1575.370972	1372.793213	2550	1307	1243	0
08/03/01 12:00	12:00:12	18.12000084	17.59000015	1575.42749	1372.768433	2588	1338	1250	0
08/03/01 13:00	13:00:14	18.26000023	17.80999947	1575.482178	1372.657104	2588	1317	1271	0
08/03/01 14:00	14:00:16	20.29999924	20.04000092	1575.515747	1372.691284	2934	1523	1411	0
08/03/01 15:00	15:00:18	20.44000053	20.31999969	1575.544189	1372.821411	2955	1505	1451	0
08/03/01 16:00	16:00:00	20.30999947	20.14999962	1575.561523	1373.088745	2932	1515	1417	0
08/03/01 17:00	17:00:02	20.48999977	20	1575.557861	1373.005005	2980	1522	1458	0
08/03/01 18:00	18:00:04	20.37999916	20.22999954	1575.5625	1372.998169	2906	1485	1426	0
08/03/01 19:00	19:00:06	20.45000076	20.46999931	1575.61499	1372.984741	2932	1494	1437	0
08/03/01 20:00	20:00:09	20.42000008	20.38999939	1575.61499	1373.045532	2944	1498	1449	0
08/03/01 21:00	21:00:11	20.45000076	20.29999924	1575.623779	1372.982422	2914	1477	1437	0
08/03/01 22:00	22:00:13	17.62000084	17.42000008	1575.677246	1372.802734	2565	1322	1243	0
08/03/01 23:00	23:00:15	17.86000061	17.60000038	1575.739136	1372.84668	2516	1293	1223	0
Power= ω x Q x h x ηoverall									
ω= weight dencity of water									
Q= water volumetric flow rate (m^3/sec)									
h= Head									

After filtering out the unnecessary data the next step was to determine the efficiency of the turbines to use in the power formula. However, this is not as easy as it may sound. Turbine efficiencies change with the flow rate and head level. In order to find these efficiencies the data had to be obtained from the original plant information stored in the plant. The efficiency data required was found in the turbine test report from 1999. This book held vast amounts of efficiency data in spread sheet form, but the book only exists as a paper copy.

The current challenge is how to use efficiency data that is only available on paper in an excel spread sheet. It has been determined that the best way to overcome this is to plot numerous points from an efficiency graph retrieved from the report in excel.

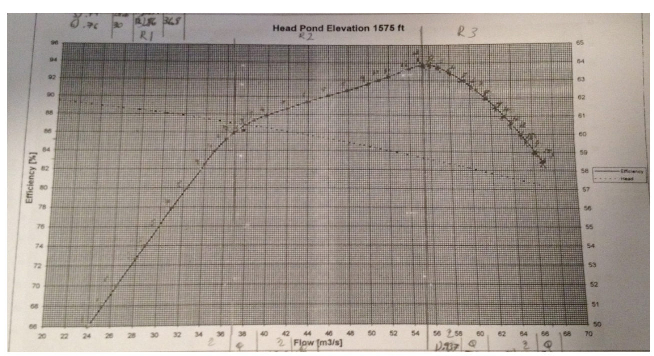

Figure 1. Turbine Efficiency Graph

The turbine efficiency graph is shown in Figure 1. The graph was divided into three region based upon nonlinear changes in the graph. Twelve to fourteen points were taken from each region depending on how linear the graph was in the region. The coordinates of the graph coordinate with an efficiency and flow.

Table 2. Data Points from Turbine Efficiency Graph

Region 1			Region 2			Region 3		
Efficieny	Flow (m3/s)	Flow (cfs)	Efficieny	Flow (m3/s)	Flow (cfs)	Efficieny	Flow (m3/s)	Flow (cfs)
0.66	24	847.5528	0.86	36.8	1299.581	0.937	55.4	1956.434
0.68	25.2	889.9304	0.87	38	1341.959	0.94	56	1977.623
0.7	26.4	932.3081	0.874	38.6	1363.147	0.932	57	2012.938
0.726	28	988.8116	0.88	40	1412.588	0.93	58	2048.253
0.74	28.6	1010	0.886	42	1483.217	0.92	59.4	2097.693
0.76	30	1059.441	0.896	44	1553.847	0.914	60.2	2125.945
0.78	31	1094.756	0.902	46	1624.476	0.91	61.6	2175.386
0.8	32.4	1144.196	0.908	48	1695.106	0.9	62.4	2203.637
0.826	34	1200.7	0.916	50	1765.735	0.89	63.2	2231.889
0.84	35	1236.015	0.92	51	1801.05	0.88	64	2260.141
0.854	36	1271.329	0.924	52	1836.364	0.872	64.2	2267.204
0.86	36.8	1299.581	0.934	54	1906.994	0.86	64.4	2274.267
			0.937	55.4	1956.434	0.852	65.4	2309.581
						0.84	66.2	2337.833
						0.83	66.8	2359.022

The table above shows the data that was extracted from each region. This data was used to reproduce the original efficiency graph as if it was divided into the three regions. Once the regions were graphed the best fit trend line was inserted. An equation to calculate the approximate turbine efficiency was generated from the trend line.

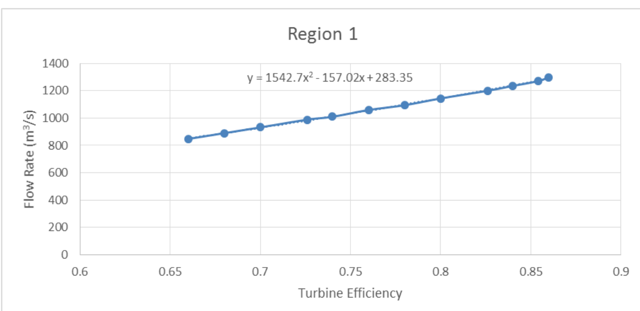

Figure 3. Lowest efficiency region

The plant flows contained in region 1 are below the optimal flows the turbines were designed for. This region shows the turbine efficiency increasing from the lowest manufacture recommended flows.

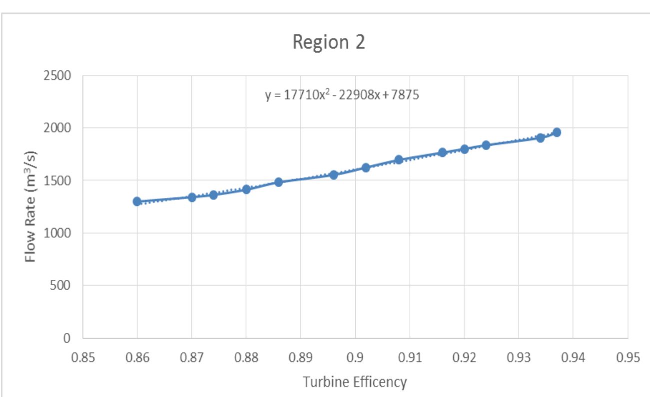

Figure 4. Middle Efficiency Region

Region 2 exhibits the same trend as region 1. Here the efficiency continues to increase as the flows approach the optimal flows the turbines were designed for.

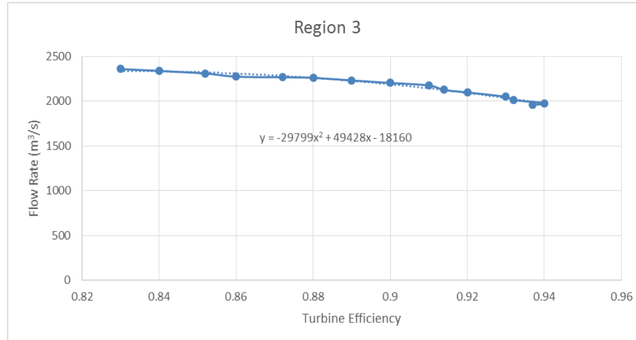

Figure 5. Highest Efficiency Region

Maximum efficiency is reached in region 3. This region also shows the plant efficiency decreasing once the optimal flows are surpassed.

The next step in this project is to use the equations from the graphs in a visual basic (vba) program. By using the vba program the efficiency can be sorted automatically based upon the outflow of the plant. This step has achieved some progress.

Currently, the program can sort a given flow rate into the proper region. It can also use the given flow rate in the region's equation to estimate power production. However, at this time the program can only process one flow rate at a time. The program must now be configured to process the recorded flow rates over a specified period of time.

V. Conclusion

Once this is completed the program can analyze data from any winter month to predict the output of the plant in mega Watts at different flows. If the results are found to be accurate the program can be used to predict future scenarios with different flows and head levels. This will allow the power production and profit limitations caused by strict USACE water control to be shown in an easy to understand format.

References

[1] Abdullah, Mohammad Omar. Applied Energy: An Introduction. Boca Raton, FL: CRC/Taylor & Francis, 2013. Print.

[2] Ackison, Clark, and John Morris. "Hydro Operations." Personal interview. 15 Oct. 2013.

[3] Hicks, Tyler Gregory. Handbook of Energy Engineering Calculations. New York: McGraw-Hill, 2012. Print.