Montana VSD Stockwater Examples

Example 1

Given:

The Rancher runs a cow-calf operation with 600 head and grazes the cows from May to October ~ 153 days. He uses only one tank at a time and rotates from pasture to pasture every 45 days. Average water requirement is 20 gallons/day per head.

Well elev. 2400
Static water elev. 2315
Depth of well 212 ft
Pump set at elev. 2200
All pipe is 2" dia. HDPE, 200 psi
Design flow rate 20 gpm

The tanks are supplied by a Red Jacket Big-Flo 28 GPM Series “DC” pump, 3560 rpm
1st. tank, sta. 45+00, elev. 2550
2nd. tank, sta 52+50, elev. 2575
3rd. tank, sta 59+15, elev. 2610
4th. tank, sta. 67+00, elev. 2630

Cost for KWH based on BPH hrs/fuel unit (National Irrigation Guide)
Electric $0.8
Diesel $0.21
Gas $0.33
Solution:

\[ 600 \text{head} \times \frac{20 \text{gallons}}{\text{head}} \times 153 \text{days} = 1,836,000 \text{gallons/season} \]

\[ \text{Total hours of operation} = \frac{1,836,000 \text{gallons}}{20 \text{gpm} \times \frac{60 \text{minutes}}{1 \text{hour}}} = \frac{1,836,000 \text{gallons}}{20 \text{gpm} \times \frac{1 \text{hour}}{60 \text{minutes}}} \]

Calculate Friction loss and total TDH Requirements

<table>
<thead>
<tr>
<th>Station</th>
<th>Friction plus elevation requirements (ft)</th>
<th>Total dynamic head (ft) Friction plus well lift</th>
</tr>
</thead>
<tbody>
<tr>
<td>45+00</td>
<td>209.65</td>
<td>296.37</td>
</tr>
<tr>
<td>52+50</td>
<td>241.11</td>
<td>327.83</td>
</tr>
<tr>
<td>59+15</td>
<td>284.91</td>
<td>371.63</td>
</tr>
<tr>
<td>67+00</td>
<td>311.66</td>
<td>398.38</td>
</tr>
</tbody>
</table>

**Without VFD**

Plot points from manufacturers pump curve. Because of the low efficiency use the 5HP-17DC curve (see Attachment 1 on last page).

<table>
<thead>
<tr>
<th>Q (gpm)</th>
<th>Head (ft)</th>
<th>Efficiency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>560</td>
<td>0</td>
</tr>
<tr>
<td>13</td>
<td>525</td>
<td>47</td>
</tr>
<tr>
<td>28</td>
<td>400</td>
<td>60</td>
</tr>
<tr>
<td>45</td>
<td>170</td>
<td>28</td>
</tr>
</tbody>
</table>

Based on pump curve the pump will supply 20 gpm at 477 ft. of head instead of the 398 ft. needed. The extra head is burned off and wasted.

Water horsepower is equal to:

\[ \text{WHP} = \frac{Q \times H}{3960} = \frac{20 \times 477}{3960} = 2.4 \text{hp} \]

With a pump efficiency of 58% the Brake horsepower is equal to:

\[ \text{BHP} = \frac{Q \times H}{3960 \times \text{Eff}_p} = \frac{20 \times 477}{3960 \times 0.58} = 4.15 \text{hp} \]

The power input for an electric motor with an estimated motor efficiency of 84% is:

\[ \text{Power input} = \frac{4.15 \text{hp}}{0.84 \text{Eff}_m} \times \frac{746 \text{KW}}{1 \text{hp}} = 3.69 \text{KW} \]

Estimated annual operating cost is:

\[ \text{Cost} = 3.69 \text{KW} \times 1380 \text{hrs} \times \frac{80.08 \text{KWH}}{1 \text{year}} = 44,422 \text{KWH} \]

If gas or Diesel are used the respective cost would be $1,854 and $1,179.88.

In this example the motor efficiency was not adjusted for the gas or diesel motors. In a real example the motors efficiencies would need to be adjusted to represent the respective motors.
With VSD

Water would be supplied to each pasture approximately 25% of the time. The VSD would be constant flow-variable pressure and would be controlled with a flow meter or sensor of some kind.

Use affinity laws to plot new pump curves. Data points for the adjusted speeds are shown below.

Alternate pump curves

<table>
<thead>
<tr>
<th>RPM</th>
<th>Q</th>
<th>H</th>
<th>Q</th>
<th>H</th>
<th>Q</th>
<th>H</th>
</tr>
</thead>
<tbody>
<tr>
<td>3300</td>
<td>0</td>
<td>481</td>
<td>0</td>
<td>454</td>
<td>0</td>
<td>410</td>
</tr>
<tr>
<td>3207</td>
<td>12</td>
<td>451</td>
<td>12</td>
<td>426</td>
<td>11</td>
<td>385</td>
</tr>
<tr>
<td>3047</td>
<td>26</td>
<td>344</td>
<td>25</td>
<td>325</td>
<td>24</td>
<td>293</td>
</tr>
<tr>
<td>2928</td>
<td>42</td>
<td>146</td>
<td>41</td>
<td>138</td>
<td>39</td>
<td>125</td>
</tr>
</tbody>
</table>

Plot the new pump curves. Then plot the estimated operating points or system curve and plot the approximated efficiency curves. Pump efficiency can now be estimated at the new speeds. Efficiency curves move down and to the left similar to the pump curves. Chances are that the operating points won't fall on the plotted curves but the new efficiency may still be approximated.

The VFD adds another loss in the form of efficiency. The default value for VFD efficiency is approximately 97%. Horsepower and energy input are calculated using the following equation:

\[
\text{Power input} = \frac{Q \times H}{3960 \times \text{Eff}_d \times \text{Eff}_m \times \text{Eff}_{VFD}}
\]
The actual energy cost is based upon the percent of the total hours that the system is operated at each condition; in this case each pasture is operated 25% time. Seasonal cost is estimated using the following equation:

\[
\text{Energy cost} = \frac{\text{HP} \times 0.746 \times \text{KW}}{\text{HP} \times \text{hrs} \times \% \text{ of time} \times \text{cost}}
\]

The results are summarized in the following table:

<table>
<thead>
<tr>
<th>TDH</th>
<th>Efficiency</th>
<th>Power Input</th>
<th>Hours of operation</th>
<th>KW-h</th>
</tr>
</thead>
<tbody>
<tr>
<td>296.37</td>
<td>61</td>
<td>3.06</td>
<td>383</td>
<td>874</td>
</tr>
<tr>
<td>327.83</td>
<td>60</td>
<td>3.40</td>
<td>383</td>
<td>970</td>
</tr>
<tr>
<td>371.63</td>
<td>60</td>
<td>3.89</td>
<td>383</td>
<td>1109</td>
</tr>
<tr>
<td>398.38</td>
<td>60</td>
<td>4.19</td>
<td>383</td>
<td>1196</td>
</tr>
</tbody>
</table>

The seasonal cost of an electric motor would be $332.

The Net savings would be $452 - $332 = $120 per season. The respective cost savings for gas and diesel are as follows once again not adjusting for the different motor efficiencies; $485 and $309.

Compare this value to the cost of the VSD to calculate the payback period. In this case the savings from power alone are relatively small. Other benefits and associated values from using a VFD are much harder to determine. The power savings are also very dependent on the type of pump that is being retrofitted or selected. A steeper pump curve would generate more savings. The number of hours the system is operated also directly affects the cost. In many agricultural situations the operating hours are too low to justify the cost of a VFD from power savings alone.
Example 2

Given:

The Rancher runs a cow-calf operation with 600 head and uses any two pastures at one time as he rotates his heifers and cows. The pipe line runs through the landowner's corral where there is a 12 ft. diameter tank, and is used all the time. From May to October ~ 153 days, 500 head are split between the two rotating pastures and 100 head are rotated through the corral. From October through April all 600 head are at the home corral. The tanks are supplied by a Red Jacket Big-Flo 28 GPM Series “DC” pump, 3560 rpm.

Average water requirement is 20 gallons/day per head
Well elevation 2400
Static water elev. 2315
Depth of well 212 ft
Pump set at elev. 2200
All pipe is 2" dia. HDPE, 200 psi
Design flow rate 20 gpm

Corral tank, sta. 5+15, elev. 2410
1st. tank, sta. 35+40, elev. 2715
2nd. tank, sta. 39+75, elev. 2770
3rd. tank, sta. 49+50, elev. 2685
4th. tank, sta. 54+50, elev. 2675

Solution:

\[
600 \text{ head} \times 20 \text{ gal/day/head} \times 365 \text{ days} = 4,380,000 \text{ gals per Season}
\]

\[
\text{Total hours of operation} = \frac{4,380,000 \text{ gallons}}{20 \text{ gpm} \times 60 \text{ minutes/hr}} = 3650 \text{ hours}
\]

Calculate Friction loss and total TDH Requirements

<table>
<thead>
<tr>
<th>Station</th>
<th>Friction plus elevation requirements (ft)</th>
<th>Total dynamic head (ft) Friction plus well lift</th>
</tr>
</thead>
<tbody>
<tr>
<td>5+15</td>
<td>16.82</td>
<td>103.54</td>
</tr>
<tr>
<td>35+40</td>
<td>347.83</td>
<td>434.55</td>
</tr>
<tr>
<td>39+75</td>
<td>388.61</td>
<td>475.33</td>
</tr>
<tr>
<td>49+50</td>
<td>331.99</td>
<td>418.71</td>
</tr>
<tr>
<td>54+50</td>
<td>328.62</td>
<td>415.34</td>
</tr>
</tbody>
</table>
Without VFD

Plot points from manufactures pump curve. Because of the low efficiency use the 5HP-17DC curve (see Attachment 1 on last page).

<table>
<thead>
<tr>
<th>Q (gpm)</th>
<th>Head (ft)</th>
<th>Efficiency (%)</th>
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<tbody>
<tr>
<td>0</td>
<td>560</td>
<td>0</td>
</tr>
<tr>
<td>13</td>
<td>525</td>
<td>47</td>
</tr>
<tr>
<td>28</td>
<td>400</td>
<td>60</td>
</tr>
<tr>
<td>45</td>
<td>170</td>
<td>28</td>
</tr>
</tbody>
</table>

Without a VSD, the pump should be designed based on the maximum TDH of 475 ft. The pump will supply 477 ft. of head. The extra head is burned off and wasted.

Water horsepower is equal to:

\[
\text{WHP} = \frac{Q \times H}{3960} = \frac{20 \times 477}{3960} = 2.4 \text{hp}
\]

With a pump efficiency of 58% the Brake horsepower is equal to:

\[
\text{BHP} = \frac{Q \times H}{3960 \times \text{Eff}_p} = \frac{20 \times 477}{3960 \times 0.58} = 4.15 \text{hp}
\]

The power input for an electric motor with an estimated motor efficiency of 84% is:

\[
\text{Power input} = \frac{4.15 \text{hp}}{0.84 \text{Eff}_m} \times \frac{746 \text{KW}}{\text{hp}} = 3.69 \text{KW}
\]

Estimated annual operating cost is:

\[
\text{Cost} = 3.69 \text{KW} \times 3620 \text{hrs} \times \frac{50.08 \text{c/KWh}}{\text{KW}} \times \frac{810 \text{c/yr}}{\text{c/KWh}}
\]

If gas or Diesel are used the respective cost would be $4,423 and $2,815.

In this example the motor efficiency was not adjusted for the gas or diesel motors. In a real example the motors efficiencies would need to be adjusted to represent the respective motors.
With VSD

The VSD would be constant flow-variable pressure and would be controlled with a flow meter or sensor of some kind.

Determine what percentage of the time each TDH will be needed. Because the last two stations are so close; use the same TDH. That will give four different TDH conditions that can occur three for the pastures and one for the corral.

The four main pastures are used equal amounts of time for the spring and summer grazing:

\[
\frac{200 \text{ head} \times 20\text{ gallons}}{20\text{ gpm} \times 60\text{ minutes}} = 8.33 \text{ hrs/day} \times 152 \text{ days} = \frac{1274 \text{ hrs}}{4 \text{ pastures}} = \frac{318.5 \text{ hrs}}{\text{ pasture}}
\]

Since there are only three TDH possibilities for the pastures we would have 318.5 hrs, 318.5 hrs, and 637 hrs.

Corral - May to October

\[
\frac{100 \text{ head} \times 20\text{ gallons}}{20\text{ gpm} \times 60\text{ minutes}} = \frac{1.67 \text{ hrs/day}}{128 \text{ days}} = \frac{288 \text{ hrs}}{4 \text{ pastures}}
\]

Corral - October through April

\[
\frac{400 \text{ head} \times 20\text{ gallons}}{20\text{ gpm} \times 60\text{ minutes}} = \frac{10 \text{ hrs/day}}{212 \text{ days}} = \frac{2120 \text{ hrs}}{4 \text{ pastures}}
\]

Use affinity laws to plot new pump curves. Data points for the adjusted speeds are shown below.

\[
\frac{H_2}{H_1} = \left(\frac{\text{RPM}_2}{\text{RPM}_1}\right)^{3/4}
\]

Alternate pump curves

<table>
<thead>
<tr>
<th>RPM</th>
<th>3555</th>
<th>3422</th>
<th>3369</th>
<th>2038</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q</td>
<td>H</td>
<td>Q</td>
<td>H</td>
<td>Q</td>
</tr>
<tr>
<td>0</td>
<td>558</td>
<td>0</td>
<td>517</td>
<td>0</td>
</tr>
<tr>
<td>13</td>
<td>523</td>
<td>12</td>
<td>485</td>
<td>12</td>
</tr>
<tr>
<td>28</td>
<td>400</td>
<td>27</td>
<td>370</td>
<td>26</td>
</tr>
<tr>
<td>45</td>
<td>170</td>
<td>43</td>
<td>157</td>
<td>43</td>
</tr>
</tbody>
</table>

Plot the new pump curves. Then plot the estimated operating points or system curve and plot the approximated efficiency curves. Pump efficiency can now be estimated at the new speeds. Efficiency curves move down and to the left similar to the pump curves. Chances are that the operating points won’t fall on the plotted curves but the new efficiency may still be approximated.
The VFD adds another loss in the form of efficiency. The default value for VFD efficiency is approximately 97%. Horsepower and energy input are calculated using the following equation:

$$\text{Power Input} = \frac{Q \times H}{3960 \times \text{Eff}_\text{r} \times \text{Eff}_\text{m} \times \text{Eff}_\text{VFD}}$$

The actual energy cost is based upon the percent of the total hours that the system is operated at each condition. Seasonal cost is estimated using the following equation:

$$\text{Energy cost} = \frac{\text{HP} \times 0.746W\,KW}{\text{HP} \times \text{hrs} \times \% \text{ of time} \times \text{Cost}}$$

The results are summarized in the following table:

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<th>Power Input</th>
<th>Hours of operation</th>
<th>KW-h</th>
</tr>
</thead>
<tbody>
<tr>
<td>475</td>
<td>58</td>
<td>5.11</td>
<td>318.5</td>
<td>1252</td>
</tr>
<tr>
<td>435</td>
<td>59</td>
<td>4.62</td>
<td>318.5</td>
<td>1131</td>
</tr>
<tr>
<td>419</td>
<td>59</td>
<td>4.43</td>
<td>637</td>
<td>2050</td>
</tr>
<tr>
<td>104</td>
<td>53</td>
<td>1.23</td>
<td>2375</td>
<td>2219</td>
</tr>
</tbody>
</table>

The seasonal cost of an electric motor would be $532.

The Net savings would be $1077 - $532 = $545 per season. The respective cost savings for gas and diesel are as follows once again not adjusting for the different motor efficiencies; $2,228 and $1,418.

Compare this value to the cost of the VSD to calculate the payback period. Price range for VFD (electric) controls range from $200-$900; this would give anywhere between a 2 and 9 year payback. Other benefits and associated values from using a VFD are much harder to determine. The power savings are also very dependent on the type of pump that is being retrofitted or selected. A steeper pump curve would generate more savings. The number of hours the system is operated also directly affects the cost. In many agricultural situations the operating hours are too low to justify the cost of a VFD from power savings alone.
28 GPM SERIES "DC" PUMPS

DESIGNED FOR COMMERICAL CAPACITIES FROM WATER LEVELS TO 500 FEET

The efficient design of the 28 GPM Series allows it to pump from deeper than average wells and deliver rated capacity. Ideally suited for farms, dairies, and commercial establishments. All fit 4" wells.

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GUARANTEED AS MINIMUM PERFORMANCE ONLY IF CERTIFIED

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