Estimating the Payback
for an
Electrical VFD (Variable Frequency Drive) Application
in a Pumping Plant Which Presently Spills Excess Pumpage

Farm Energy Assistance Loan Program
California Energy Commission

By

Irrigation Training and Research Center
BioResource and Agricultural Engr. Dept.
California Polytechnic State University (Cal Poly)
San Luis Obispo, CA 93407
(805) 756-2434

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A.   Pump Selection Criteria
1.   The pump to automate with a VFD (in a location with multiple pumps supplying the same pipeline) is the smallest which will meet both of the following criteria:
   a.   (Flow Rate of the VFD pump
        + Sum of the flow rates of all the smaller pumps)

        must be greater than or equal to

        (The flow rate of the next bigger pump)

        ie, $(Q_{VFD} + [\text{sum of all } Q_{smaller pumps}]) >= Q_{Next bigger pump}$

   b.   No larger pump flow can exceed the combined flow of all pumps which are smaller than it (including the VFD at full speed)

2.   There is generally little or no energy savings associated with converting to VFD control for more than one pump at an installation.

B.   Estimation of a annual KW-HR savings for a VFD installation.

1.   Estimating the maximum potential savings.
     An estimate of savings requires an estimate of the historical amounts of spilled water. If, for example, the spilled water is 5% of the total pumped water, then the maximum KW-Hr savings can be:
                  Max. KW-Hr savings = .05 x Annual KW-Hr

     If pumping amounts vary significantly from year to year, an average of 3 years of data should be used.

     The savings may be somewhat less than this (if the VFD operation puts the pump into a less efficient operating range) or somewhat more than this (if the new controlled water level is lower than the previous spill level). An examination of pump efficiencies may show the greatest savings possible can be obtained by simply improving the efficiencies of existing pumps.

     a.   The following information is necessary in most cases:
        - Monthly power bills or pump test data providing KW-Hr per Acre-Foot (AF) pumped for
          each pump
        - Monthly hours of operation per pump
        - Monthly water deliveries (as opposed to pumped amounts)

- Pump test data, providing Acre-Feet (AF) pumped per hour of operation for each pump

b. Compute AF pumped per month for each pump

$$AF = \frac{AF}{hour} \text{ x Hours of operation}$$

c. From district delivery records, determine the total AF delivered to users (plus seepage and conveyance losses) supplied by the pumping station, by month

d. Sum the monthly totals

e. For each water year, find the % spilled

$$\% \text{ Spilled} = \frac{AF \text{ Pumped - AF Delivered}}{AF \text{ Pumped}} \text{ x } 100$$

f. Compute the total KW-Hr savings possible

$$\text{Annual KW-Hr savings possible} = \frac{\% \text{ Spilled}}{100} \text{ x (Annual KW-Hr consumed)}$$

2. <u>Estimating KW-Hr which would have been consumed if one of the pumps had been converted to VFD</u>.

This second step should serve as a check on the first step, in which the "possible" savings were computed. By doing this computation, the effect of the overall pump efficiency of the selected VFD-controlled pump is accounted for.

Again, use historical data to make these "what-if" computations.

a. Estimate the AF which will be pumped by the VFD unit

$$AF = \frac{(\text{Hours}) \text{ x GPM}}{5428}$$

where

Hours = The total hours per year that water is delivered from the pump station (the VFD will operate continuously)

GPM = 67% of the maximum GPM of the pump with the VFD controller (the actual percentage can be determined with a detailed analysis, but it is probably not warranted. The 67% provides a weighted average for a typical condition, accounting for the KW-Hr consumed at various flow rates)

b. Estimate the annual KW-Hrs which would be used by the VFD

$$\text{Kw-Hrs}_{VFD} = \frac{\text{GPM x TDH x 0.0188 x Hours}}{\text{Efficiency}/100}$$

where

TDH = The total dynamic head of the pump, in feet.

Efficiency = The total efficiency of the pump (generally in the range of 40 - 70), which depends upon:

Panel Efficiency (Panel) -about 97
Motor Efficiency (Motor) - depends upon motor size and model;
  typically somewhere between 85 - 93
Impeller Effiency (Impeller) - the efficiency of the impeller and bowls.
  The Impeller Efficiency to use will occur at a flow rate of about
  67% of the maximum flow rate
Losses (Losses) - a measure of the losses which occur due to bearings;
  typically about 98 on a short lift.

$$\text{Efficiency} = \frac{\text{Panel x Motor x Impeller x Losses}}{10^6}$$

c. Estimate the annual KW-Hrs used by the other pumps at the station.

  1. Estimate the AF delivered by the other pumps
    AF_{other} = (Total AF delivered to users plus conv. losses) - AF_{VFD}

  2. Compute the average pump efficiency (Eff_{other}) for the other (non-VFD) pumps.
    The information from individual pumps will come from a pump test. Ideally, the
    average efficiency should be determined by taking a weighted average after
    considering the KW and the Hours of each pump, as anticipated after the VFD is
    installed. In practice, a simple average may be sufficient because the pumps with the
    lowest KW will be cycled on and off more often than the larger pumps, so they will
    have more hours of operation than the larger KW pumps.

  3. Make the final KW-Hr computation for the other pumps

    $$\text{KW-Hr}_{other} = \frac{\text{TDH x 102 x AF}_{other}}{\text{Eff}_{other}}$$

d. Find the total annual KW-Hrs to be used by all pumps

  Total KW-Hr = KW-Hr_{other} + Kw-Hrs_{VFD}

e. Compute the total KW-Hr savings possible

  Annual KW-Hr savings possible = (KW-Hr actually consumed] - Total KW-Hr