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Variable Frequency Drives and SCADA – Are they worthwhile investments?

Managers and personnel from Delano-Earlimart Irrigation District, Orange Cove Irrigation District, South San Joaquin Municipal Utilities District, Sutter Mutual Water Company, and Saucelito Irrigation District were interviewed to determine if installing variable frequency drives (VFD) and supervisory control and data acquisition (SCADA) systems were worthwhile investments. All of the districts interviewed installed VFD and SCADA for one main purpose: to increase their level of service to customers. Districts that have had VFDs and SCADA systems for multiple years are also enthusiastic about other benefits that were not expected. Interestingly, some of the major benefits cannot be associated with a dollar value, but do effect the level of service provided by each district.

Analysis of the dollar benefits associated with the installation of VFDs and SCADA systems showed that the simple payback (not including interest) for the districts ranged from 2.1-4.7 years.

Typical Benefits

Although the exact benefits to each district vary, typical benefits from VFDs and SCADA systems in the five districts that were interviewed are:

- **Increased level of service to water users** – One of the main aspects of increased service is flexibility in supplying water to meet water users' demands. The three main components of flexibility – duration, flow rate, and irrigation frequency – can be improved with proper operation of VFDs and SCADA. Increased system reliability was stressed by a majority of the districts as being the number 1 benefit commented on by water users.
- **Reduced stress on operational personnel** – Field personnel no longer have to spend 24 hours a day, 7 days a week, physically monitoring pumping plants and reservoir water level elevations and readjusting flows. The level of automation and data analysis that can be incorporated in a SCADA system has helped to shift water delivery from an art to a science. In addition, water user complaints have decreased dramatically, reducing stress on the management and office personnel.

- **Reduced pump wear and increased pumping efficiency** – Data acquisition allows real-time monitoring of individual pump operating hours, flow rates, and the number of times a pump switches on and off. Trending this information over time allows operators to monitor the relative pump efficiency and determine when pumps should be repaired. In some cases, the data acquisition can be used to balance non-VFD pump hours, prolonging the life of pumping plants.
- **Reduced vehicle wear and fuel use** – Since field personnel no longer have to physically monitor and adjust pumps, they no longer have to drive as many miles per day. Over an entire year the savings in fuel and vehicle wear can be significant.
- **Reduction in labor costs** – Some districts reduced the number of field personnel. Other districts have been able to allow field personnel to perform other tasks they did not have time to accomplish before.
- **Energy Savings** – Prior to the installation of VFDs, pumping stations could only match a set point by either using a valve to throttle down pressure or bypassing water. The pump station would provide excess pressure or flow so that the possibility of a deficit would be less likely to occur. Bypassing or throttling is a waste of electricity. Using a VFD, the set point is matched without the need for bypassing water or throttling down pressure. Therefore, it seems that VFDs have a large potential for energy savings. However, this is not always the case. It depends on the efficiency of the original operation and the operation of the VFD. The VFD also adds an efficiency component into the overall pumping plant efficiency, somewhat decreasing the total operating efficiency. Three of the five districts interviewed showed an annual energy savings per volume pumped. The other two had no significant benefit in this area.

The actual benefit to the districts interviewed will be outlined in the case studies below. The bottom line is that all of the districts are very pleased with the systems they have installed and all are currently expanding, or have

plans to expand, their existing system by adding additional VFD and SCADA sites.

Delano-Earlimart Irrigation District

Delano-Earlimart Irrigation District (DEID) is located on the east side of the San Joaquin Valley near the town of Delano. The district obtains water from the Friant Kern Canal. Approximately one third of the district is uphill from the Friant Kern Canal and the remainder of the district is downhill. Water is pumped from the Friant Kern Canal in both directions, uphill and downhill. A majority of the pumping serves the uphill users. Downhill pumping provides service to water users near the Friant Kern Canal. For the remainder of the downhill section of the district, water flows by gravity to service water users.



DEID turnout from the Friant Kern Canal that services an uphill section of the district.

The district currently has 14 variable frequency drives (VFDs) and a supervisory control and data acquisition (SCADA) system in place that allows remote and automatic monitoring and control of all district pump stations and reservoirs. Before this current system was in place, district personnel would manually stage pumps in a pump station to maintain a water level in a standpipe near the pump station. Excess water would be bypassed back to the original source. District personnel would have to physically monitor the reservoirs

and pump stations 24 hours a day, 7 days a week.

Benefits

- Increased level of service
- Reduced downtime
- Reduced pump wear
- Reduction in staff size
- Reduced vehicle wear
- Reduced stress on management and field personnel

Capital Costs vs. Annual Savings

Annual Savings

Vehicle wear	\$2,208
Field Personnel	\$74,880
Management and Office Personnel	\$11,360
Pump wear	\$6,667
Total Annual Savings	\$95,115

Total Capital Cost to District **\$447,041**

Simple Payback (Years) **4.7**

With the VFDs and SCADA system, the pumps automatically match a setpoint in the standpipe just upstream of the pumps. A computer in the district office monitors and collects data from the pump stations. The pumps can also be controlled from the district office. Alarms within the SCADA system ring district personnel pagers, indicating a problem. Using PcAnywhere™, district operations managers can monitor and make changes in pumping operations from their home computers during nights and weekends.

The results from the SCADA system and the VFD installations have been positive. The increased level of service the district has been able to achieve is one of the most important results. District personnel and farmers now have complete confidence that water will be available when it is ordered and that it will be delivered at a relatively constant rate. Previously, they did not have this confidence because of the unpredictability associated with the old system.

The district has been able to reduce inefficiencies and downtime by analyzing system data with SCADA. Analyzing the number of times pumps are turned on and off,

the number of hours each pump is running, and the flow rates delivered has helped indicate problems in the pump, motor or control program, or if someone is taking water when they were not scheduled too. Running hours on motors can be balanced on the district’s large pump stations by changing the rotation (when the motors are turned on, relative to the other motors) of the non-VFD motors in the pump station. The SCADA system also allows the district personnel to quickly troubleshoot farmer complaints, such as not receiving the proper flow rate.

The district has been able to reduce its workforce by two people with the new system. Personnel no longer have to check the pumps in the field unless there is a problem that cannot be solved from a remote computer. They can now concentrate more effort on other tasks that enhance the overall service provided by the district.

District personnel estimate that they drive over 200 miles per week less now than they did before the VFDs and SCADA system were installed.

Problems

The only problem the district has had with the VFDs and SCADA system was some interference in the radio communications. This problem has been solved.

Future Endeavors

Currently, DEID is working on a system that will provide on-demand service to farmers without the need of on-farm reservoirs by eliminating unwanted flow rate fluctuations at the turnouts. A float is placed in a standpipe; this float controls a valve that regulates the flow from the district turnout. As the farmer’s demand increases, the float valve is activated to increase the flow to the farmer. The water level in the standpipe is held constant at any reasonable demand the farmer has. The VFDs and SCADA system allow the district’s conveyance system to automatically react to any changes at the turnouts as long as the system does not exceed capacity.

Orange Cove Irrigation District

Orange Cove Irrigation District (OCID) is located on the east side of the central San Joaquin Valley. The district water is supplied by the Friant Kern Canal. The district’s water distribution system was antiquated and badly in need of renovation. In addition, farmers have been moving towards drip and microspray irrigation methods over the past two decades. The farmers require water on a much more flexible schedule with these methods as opposed to borderstrip or furrow irrigation methods. They need more flexibility in irrigation frequency, irrigation durations, and flow rate.

To respond to these issues, OCID began a major rehabilitation project in 1992. The district replaced 116 miles of mortar joint concrete pipelines with higher pressure PVC pipe, replaced 154 pumping units with 40 high efficiency pumps and motors and installed over 1100 flow meters to replace old flow measuring devices. The system capacity was increased by 150 percent to provide the needed flexibility and to supply frost protection water for citrus, the primary crop in the district. Once the rehabilitation project was complete, the district began installing variable frequency drives (VFDs) and a SCADA system in late 1997. To date, the district has installed 11 VFDs and a SCADA system to monitor and control 16 sites (including the 11 VFD sites) within the district. The last VFD and SCADA installation occurred in September 2001, which added electric load management capabilities for the district.

The rehabilitation project provided farmers the opportunity to operate their own deliveries since the system is designed to operate as a demand system. However, the district still requires water users to schedule their water deliveries in order for the district to coordinate daily demands with the Friant Kern Canal operations. Before the installation of the VFDs and SCADA system, field operators would have to continually monitor and manually adjust pumping stations throughout the day, trying to match supply with demand, including systems with small regulating reservoirs. The increased system capacity and reservoirs at the downstream end of the pipelines helped buffer

the differences; however, flow rate fluctuations were still a major problem.



Water level monitoring and control devices in an OCID reservoir. There is a staff gauge on the left and a float device set in the PVC pipe on the right. The float device is connected to the telemetry system so that the water level can be monitored and controlled remotely or automatically.

Benefits

- Increased level of service
- Reduced downtime
- Reduced pump wear
- Reduction in labor
- Reduced vehicle wear
- Reduced stress on management and field personnel

Capital Costs vs. Annual Savings

Annual Savings

Vehicle wear	\$6,900
Field Personnel	\$56,160
Management and Office Personnel	\$11,360
Pump wear	\$10,000

Total Annual Savings **\$84,420**

Total Capital Cost to District **\$312,619**

Simple Payback (Years) **3.7**

In 2001, the district elected to add more VFDs and SCADA with new features to the system for electric load management purposes. The system’s new capabilities will allow the district and participating water users to shift over 600 kW of electric load off-peak. The system

upgrade cost is \$273,439 and is estimated to save the district an additional \$40,000 per year in energy cost. (Note: no new reservoir construction at this time) The VFDs and SCADA system automatically match supply with demand so that district field personnel no longer physically operate pump stations. The two district field operators have computers with PCAnywhere™ in their homes. The operator that is on call (responsible for off-hours operations) that week can monitor and make changes without leaving his house or desk. Alarms set up in the SCADA system are set up to page the district operators if anything goes wrong in the system. The alarms send a code number to the operators pager that identifies the type of problem and its location.

Another benefit is that pipelines can be charged (filled and pressurized) manually by operating the pumps and monitoring the system from office or home computers. The pipeline systems are dewatered from time-to-time for various reasons but can be refilled in a timely and safe manner if an operator has a demand on the system. Field operators can troubleshoot and solve farmer complaints from the home or office. If the power goes out and shuts down a pump station, the VFD automatically restarts when the power comes back on, minimizing service downtime.



Enclosure and variable frequency drive panel at OCID.

The VFDs and SCADA system have reduced the number of hours district personnel work during nights and weekends provided there is no long term power outage. One district field

operator is on call 24 hours a day, 7 days a week. Before the VFDs and SCADA system were installed, the on call operator may have to make multiple trips to the field throughout the nights and weekends to respond to water shortages by the user, pump outages or check water levels in the reservoirs. Currently, one district field operator remains on call but rarely has to go to the field to solve problems. Work during normal operating hours has also been reduced. It is estimated that the VFDs and SCADA system has saved the District $\frac{3}{4}$ of a person-year per year in labor cost. The district also estimates the mileage on vehicles for the two field operators has been reduced 10,000 miles per year per vehicle (20,000 miles/year total). This is half of what it was before the VFDs and SCADA system were installed on the rehabilitated system.

Data gathering and analysis with the SCADA system is becoming an important component of district operation. The district has been able to crack down on water users who take water without ordering water by matching flow with ordered demand. A new program that the district is planning to implement during the 2002 irrigation season is monitoring of district pump efficiencies on a real time basis. Flow meters and hour meters have been added to each pump and access to the pumping station's electric load from the utility now allows the district to monitor pumping plant efficiencies, which are trended with time. This helps the district to respond to pump problems in a timely manner.

The district claims it is most impressed with the reliability and flexibility it has experienced with the VFDs and SCADA system. The district now has the ability to guarantee a turnout flow rate, while providing on-demand service to their customers.

Problems

The district has had a few minor problems with the SCADA system. A radio was damaged during an electrical storm and pressure transducers were damaged during a freeze.

Future Endeavors

With rising power costs, the district is starting a new program in 2002 to shift a majority of their power use to off-peak. The

VFDs and SCADA system, as well as excess system capacity, will allow the system to operate effectively with a district wide shift to off-peak power. The district is giving incentives for peak load reduction to individual farmers that turn off their irrigation systems during the peak period (Monday – Friday, 12-6pm). Farmers will receive a one-time payment of \$100 per kilowatt load they are able to take off peak, as well as a lower cost per acre-ft of water supplied. The district’s conveyance system has the capacity to handle all water deliveries within 18 hours of operation, rather than 24 hours, allowing the district to consider this program. Nevertheless, the program could not be implemented without the VFDs and SCADA system to automatically match the supply with demand and reduce electric loads during the weekday afternoons. The CEC Agricultural Peak Load Reduction Program administered by ITRC is assisting OCID in this project by providing cost sharing grants to help pay for timers on individual growers’ pumps, additional SCADA sites, one VFD, and construction of a reservoir.

Southern San Joaquin Municipal Utility District (SSJMUD)

SSJMUD is located on the east side of the Southern San Joaquin Valley near Delano, California. The district receives water from the Friant Kern Canal. The district is uphill and downhill from the Friant Kern Canal.

Over the past 4 years, the district has installed five VFDs throughout the district and a SCADA system so that all the pumps can be controlled automatically and monitored from the district office. The SCADA system monitors and controls 81 pumps in SSJMUD. The district has also installed softstarts on all of the pumps that do not have a VFD.

The district installed the VFDs, SCADA, and softstarts to improve the level of service to its customers. Water hammer problems in the original system damaged pipeline, resulting in district downtime during the irrigation season. Before the VFDs and softstarts were installed, Randy Elam, district operations manager, estimated that some part of the system went down (or lost water) 15 to 20 times per year. The second reason for the installations was to

minimize flow rate fluctuations at district turnouts.

Benefits

- Increased level of service
- Reduced downtime
- Energy savings
- Field personnel have been able to perform other duties
- Reduced stress on management and field personnel

Capital Costs vs. Annual Savings

Annual Savings

Energy Savings from 4 VFDs*	\$21,060
Field Personnel	\$56,160
Management and Office Personnel	\$14,080
Pump wear	\$4,700
Total Annual Savings	\$96,000

Total Capital Cost to District	\$244,000
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Simple Payback (Years) **2.5**

*Since the fifth VFD became operational at the end of 2001 there was not sufficient data to estimate its energy savings.

Water hammer problems and flow rate fluctuations at turnouts have been minimized with the installation of VFDs, SCADA, and softstarts. In 2001, no customer lost water because of a system failure. Randy Elam claims “reliability has gone through the roof.” Customers have made a number of positive comments regarding the district’s increased level of service and reliability. Reliability, not only in the assurance that water will be available when requested, but also that it will be supplied at a constant flow rate.

The system can now automatically match inflow with outflow. Prior to installation, district personnel would set the water in the morning, turning turnouts on and off and adjusting pumps. Water users can now request the turnout to be turned on or off nearly anytime throughout the day without field personnel making changes at the pump stations.

The district has not reduced its labor force since the installation, but the personnel have been able to complete other jobs and provide better service to customers. Prior to the

installation, field operators would have to work most of the day adjusting pumps, taking care of system failures and farmer complaints. Only in their spare time could they work on system maintenance. To keep up with the maintenance, each day an additional person would be brought from the district shop to help for half a day in the field. Now this no longer occurs. Three of the field operators now spend part of their workday on system operation and maintenance and have time for other jobs such as a graffiti control program. Removing graffiti immediately has dramatically reduced the occurrence of graffiti in the district. Randy Elam estimates that with the old system it would have taken an additional 1 to 2 field personnel to complete the work that is currently being completed.



Computer screen that allows district personnel to monitor and control pumps throughout the district with the SCADA system.

Randy Elam stated that the number of calls he receives from customer complaints have been more than cut in half. Moreover, a majority of the problems can be checked and solved without leaving his desk or sending someone out to the field.

The softstarts and VFDs reduce the shock to the motor because there is no longer an initial in-rush current at startup. The SCADA system also makes it simpler for the district to monitor and balance the number of hours that non-VFD motors are running in a pump station. The staging of the motors can be adjusted from the office computer. The district is hoping to

increase the time between motor rebuilds from every 10 years to every 15 years.

Problems

SSJMUD had some problems with VFDs. The district tried installing VFDs on some of their smaller pumps in the early 1990's. The district claimed these earlier models did not operate correctly, and therefore are no longer being used. In addition, one of the five VFDs currently operating did not function properly from the factory, but it was under warranty and replaced with no further incident.

Future Endeavors

The district is planning to install four additional VFDs in the near future.

Sutter Mutual Water Company

Sutter Mutual Water Company (SMWC) is located near Robbins, California in the Sacramento Valley. The district water supply is pumped from the Sacramento River.

SMWC has installed one VFD and a SCADA system to remotely monitor and control canal water levels at one site. SMWC had two main reasons for the installation:

1. To automatically match supply with demand without excess energy loss from bypassing the extra water from the pump station.
2. The water level in the Sacramento River can fluctuate dramatically throughout the day. The way the bypass was set up led to the pumps losing their prime when the water level in the river dropped below a certain level. As a result, water would no longer be supplied to the canal and the district customers.

The VFD has solved these problems since its installation. The VFD automatically matches supply with demand so that the bypass is no longer necessary.

The installation of the VFD and SCADA system was completed in stages. First, the VFD and SCADA system were installed, but not automated. A district operator would physically change the speed of the VFD motor in the field to match supply with demand. In the second stage of the installation, a simple control algorithm was used to automatically control the

water level in the downstream open channel. The final stage of the project was completed in October of 2001. It included a Proportional-Integral-Filtered (PIF) algorithm with finely tuned constants that were supplied by the Irrigation Training and Research Center to automatically control the VFD.

Benefits

- Increased level of service
- Reduced downtime
- Energy savings
- Reduced the number of field personnel
- Reduced stress on management and field personnel
- Reduced vehicle wear

Capital Costs vs. Annual Savings

Annual Savings

Energy Savings	\$10,311
Vehicle wear	\$3,450
Field Personnel	\$37,440
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Total Annual Savings	\$51,201

Total Capital Cost to District	\$140,000
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Simple Payback (Years) **2.7**

With the addition of the VFD and SCADA system, the district has been able to reduce its field staff by one person. Before the VFD and SCADA system, a field operator was assigned to that pumping station and the area it served. The district has been able incorporate that section of the district into another section so that both sections are operated by one person. The estimated saving in vehicle mileage is 10,000 miles per year.

The district predicts the energy savings will increase with the new control algorithm and finely tuned constants.

Problems

One of the major problems SMWC has had with their VFD is cooling the unit. It is very important to keep the VFD temperature below its rated operating temperature. The district is hoping this problem has been resolved with the installation of a new cooling system this past fall (2001).

Two other problems that have been resolved were: (1) inadequate radio signal between the pump station and office, (2) the necessity of a proper siphon breaker.

Future Endeavors

SMWC is planning to install at least one additional VFD at another pumping plant.

Saucelito Irrigation District

Saucelito Irrigation District (SID) is located near Porterville, California in the Central San Joaquin Valley. The district water supply is pumped and gravity fed from the Friant Kern Canal.

SID has installed four VFDs but has not installed a SCADA system at this time. The VFDs were installed on pump stations that pump water from the Friant Kern Canal into pressurized pipelines that distribute water throughout the district. SID installed the VFDs so that:

- a. Water did not have to be bypassed back to the source, wasting energy.
- b. Field personnel did not have to continuously monitor and change the pumping configuration throughout the day and night.

The VFDs have solved these problems at their respective pump station since installation. The VFD automatically matches supply with demand so that the bypass is no longer necessary and field personnel do not have to continually monitor each station. This has improved the level of service provided to water users by increasing the flexibility they have in water deliveries. The water ordering procedures are still the same, with the exception that on Sundays and part of Saturdays the water user is allowed to operate his or her own turnout.

The district has installed 1 to 2 VFDs per year since 1998. The latest VFD was installed in late 2001 and is currently operational.



Two variable frequency drives at pump station C1. The station services two pipelines, with one VFD per pipeline.

Benefits

- a. Increased level of service
- b. Energy savings
- c. Field personnel have Sundays and part of Saturdays off.
- d. Reduced stress on management and field personnel
- e. Reduced vehicle wear

Capital Costs vs. Annual Savings

Annual Savings

Energy Savings from 3 VFDs*	\$19,900
Vehicle wear	\$720
Field Personnel	\$9,360
Total Annual Savings	\$29,970

Total Capital Cost to District**	\$62,720
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Simple Payback (Years) 2.1

*The fourth VFD installed in late 2001 was not included in the energy saving analysis because data was not yet available.

**The district has received cost sharing grants for each VFD project through the U.S. Bureau of Reclamation. The total capital cost to the district is the total cost of the installation and equipment. The grant was not considered.

With the addition of the VFDs, the district has experienced significant energy savings. This is attributed to the reduction in pumped water that is bypassed. The district also attributes some of the energy savings to the past operation of the pump stations. If a relatively low flow was demanded and the water user was near the pump station, the district would at times operate

a pump at a lower head than was designed. This caused the pump to operate less efficiently than normal.

Problems

In 1991, the district installed a VFD that did not operate properly. This VFD has since been removed.

The district also had one motor driven by a VFD go out. James Akins, SID District Manager, attributes this to the motor not being rewound and double dipped before the VFD was installed. He recommends that before a VFD is installed on an existing motor it should be rewound and double dipped.

Future Endeavors

SID has plans to install three additional VFDs and a SCADA system within the next several years.

Conclusion

The districts interviewed for this report are enthusiastic about the VFDs and SCADA systems that were installed. In fact, each one has plans to expand their current system.

When considering the addition of VFDs and/or SCADA to your distribution system consider all of the benefits listed in this report and how they can enhance the level of service your district currently provides. Of course, it is important to look at the economics of the installation, but it's not possible to place a dollar value on every benefit the district may receive.

VFDs have the potential to save energy. The amount of energy saved will depend on the current operation of the pumping system as well as the future operation. It is difficult to predict exactly how much savings, if any, will occur.

However, there are many other benefits from VFDs and SCADA. We are in a new day and age, where irrigation water delivery is shifting from an art to an industrial process. Pressures from increasing energy costs and environmental issues are forcing this shift. VFDs and SCADA are tools that are assisting districts throughout California in making this shift.

Assumptions used for Annual Savings Analysis

- Gross cost for field and office personnel = \$18/hour
- Gross cost for management = \$35/hour
- Annual savings from vehicle wear assumed \$0.345/mile (IRS mileage reimbursement 2001).

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- **Additional Links**
 - <http://www.itrc.org/papers/ModernizingSMWC/ModernizingSMWC.pdf>
 - <http://www.itrc.org/reports/DEID/deidvfd.pdf>
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