Utilizing Energy and Demand Forecasting as a Tool to Develop Energy Procurement Strategies

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Abstract

Energy costs for pumping is typically one of the largest expenses in a water utility's operations budget. The capability to effectively forecast demand profile and schedule production can be beneficially used to guide the utility to procure energy products (electricity, diesel or natural gas) in a manner designed to contain costs.

Many utilities have procurement flexibility for purchasing energy used for pumping. Potential options may include choice of alternative suppliers, tradeoff between electricity, natural gas, and co-generation, or electricity purchases in a deregulated market. The understanding of, and effective use of a properly designed forecasting tool to project near term demand and energy load profiles will give the operations and purchasing managers the updated information required to make complex decisions, minimizing the risks and leveraging the benefits. Possible choices facing the utility may include:

- How much electricity should be purchased on the real time market
- How much should the utility "hedge" and procure on long term contracts
- Should in-house generation be used, and if so, when and for how long
- How much gas should be purchased on the forward market

The capability to leverage a forecasting tool becomes even more critical as the utility employs system wide optimization strategies to move electrical load in response to pricing to minimize costs while maintaining defined boundary conditions in the service area. All this must be

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performed without compromising operational reliability or water quality. As energy tariff structures and policies vary from region to region, and no two water distribution systems are similar, a “one size fits all” energy forecasting tool would not be practical. Any forecasting tool must be custom designed for the specific application.

1 Introduction

When considering energy procurement for a water utility, an understanding of how energy is consumed by treatment, in pumping, and in water distribution is important. In general, water utilities have significant flexibility in how they operate their water distribution system even taking into account strict constraints on minimum fire-fighting storage and water quality requirements For example, it is often preferable to run the water treatment plant at a consistent rate, and let storage tank levels drop and rise during the daily peaks and troughs of water demand respectively. This produces benefits in water quality, assuring water turnover, as well as minimizing disruption at the water treatment plant itself. Many utilities practice the strategy of filling storage tanks overnight to cope with the morning demand, and then refilling them before the evening peak. Such a practice may necessitate pumping during high tariff afternoon hours. The amount of energy consumed by pumps is considerable, and the ability to control when this energy is consumed can have a significant impact on electricity cost. To achieve consistent savings, an automatic pump scheduling system can be added on top of an existing Scada and telemetry system to control the starting and stopping of pumps in response to electricity tariff schedules as well as system production demands and operational constraints.

2 Energy Use in a Water Utility

Energy costs for pumping is typically the second highest cost after labor for a water utility. The price of electricity is also rising at a far higher rate than labor costs making it likely that it will become the dominant cost of production and distribution of water in the near future. This is already the case in the UK for example. Electricity use in water production and distribution is not trivial, it constitutes one of the largest single industry categories in the United States.

"The more than 60,000 water systems and 15,000 wastewater systems in the United States are among the country’s largest energy consumers, using about 75 billion kWh/yr nationally—3 percent of annual U.S. electricity consumption."

Electric Power Research Institute, Energy Audit Manual for Water/Wastewater Facilities, (Palo Alto: 1999), Executive Summary.

As a rule, the largest use of electricity in water and wastewater operations is for pumping. Typically 95% of all energy purchased by a water utility ends up being used to pump water, both raw and finished. The remaining 5% covers office and administration users. A typical breakdown is shown in Figure 1 for a major utility in Maryland.

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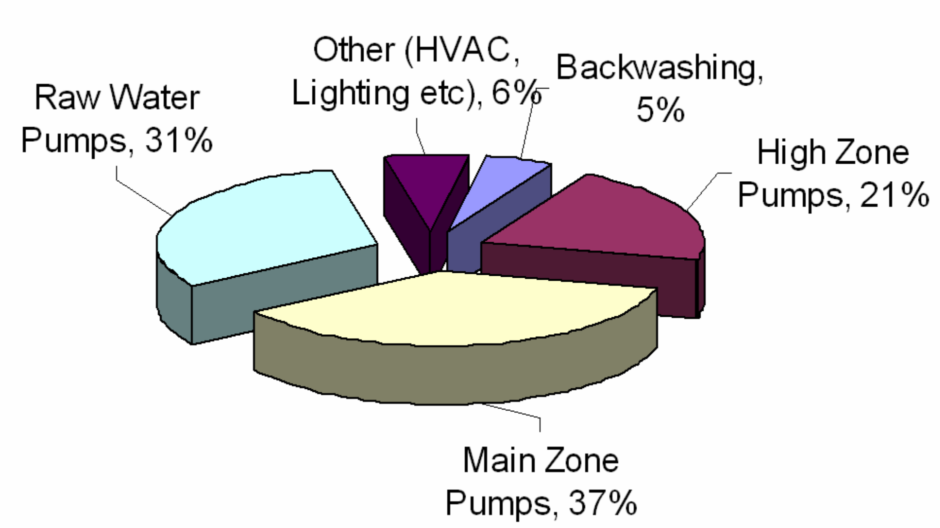

Figure 1: Energy use profile of a large water utility in Maryland

Water production and distribution utilities have access to many opportunities for innovative purchasing strategies for electricity and also can use alternative fuel sources. The ability to store energy in elevated storage tanks, pumping when electricity is relatively low cost, and letting gravity do the work, drawing down storage when electricity is expensive allows the operator a significant degree of flexibility in the scheduling of when energy is purchased, and at what tariff.

2.1 The Electricity Market

Leveraging flexibility in choice is not without risk. The utility management, operations, and procurement teams must judiciously examine all the procurement options available, as well as the projected demand patterns, and allow for contingencies such as fire flows, growth, extreme weather patterns, etc. Having the capability to effectively forecast water demand and schedule production can be beneficially used to guide a utility to procure energy products (electricity, diesel or natural gas) in a manner designed to contain costs while simultaneously reducing risk.

The are many possible options that may be available to the utility when purchasing electricity. Among them are;

- Standard Offer Of Service (SOS) contracts with flat rates throughout the year
- SOS contracts with demand (kW) charges varying by time of day or day of week
- Time-Of-Use (TOU) energy (kWh) charges with flat demand charges
- TOU energy charges and TOU demand charges
- The Real-Time electricity market (where available)
- Negotiated hedge contracts for fixed blocks of energy use at any time (base energy)
- Time-of-use hedge contracts for fixed blocks of energy use
- Load curtailment or peak-load penalty schemes

- Alternative energy sources to run pumps such as diesel or gas
- On-site electricity generation

Many of these options are complementary, such that part of a distribution system may be running on a flat rate tariff while another neighboring pump station is on a time-of-use contract. Often the water utility has a range of options on offer for each pump station and must choose which type of contract to accept. Knowing your electricity demand profile, i.e. the shape of the daily usage, is very useful in evaluating competing offers. Of even more use is knowing what the water consumption demand profile could be to minimize cost without breaching storage or pressure requirements.

3 Demand Forecasting

3.1 Water Demand Forecasting

Before an electricity demand profile can be created the water demand profile is required. Anyone familiar with hydraulic modeling will know that selecting appropriate water demand profiles to apply to selected nodes in the model is crucial to obtain an overall mass balance for an extended period simulation. The problem is that choosing an appropriate demand profile changes depending on whether it is summer or winter, weekend or weekday. Demand, and more specifically demand shape, is also heavily dependent on weather. Each day is unique. When calibrating a model, it is best to choose a single representative day, and use actual measured demand at each node for that day. This reduces the uncertainty in the model and allows calibration to be made against actual recorded storage tank levels.

While this is appropriate when calibrating models with known historical data, demand prediction requires the use of statistical tools to determine likely future water demand based on expected weather conditions. Only by accumulation of demand profile days over the course of a typical year is it possible to make long-term energy procurement strategies effective. In spring demand may be increasing day by day, billing up towards the peak summer demand. In fall the opposite may be true.

The technique used by Derceto Inc., is to take up to two years of demand data and then categorize into various demands days, including weekdays and weekends. From this, patterns can be developed for a typical weekday in summer, a weekend in summer, and so on. This is just the starting point. As a water demand increases, the diurnal profile changes such that the peaks become higher. On higher water demand days there is less operational flexibility to totally avoid peak energy cost periods and consequently more pumping must be done during the expensive time periods. Just how much load can be shifted to off peak periods will to a large part depend on how much usable storage is available.

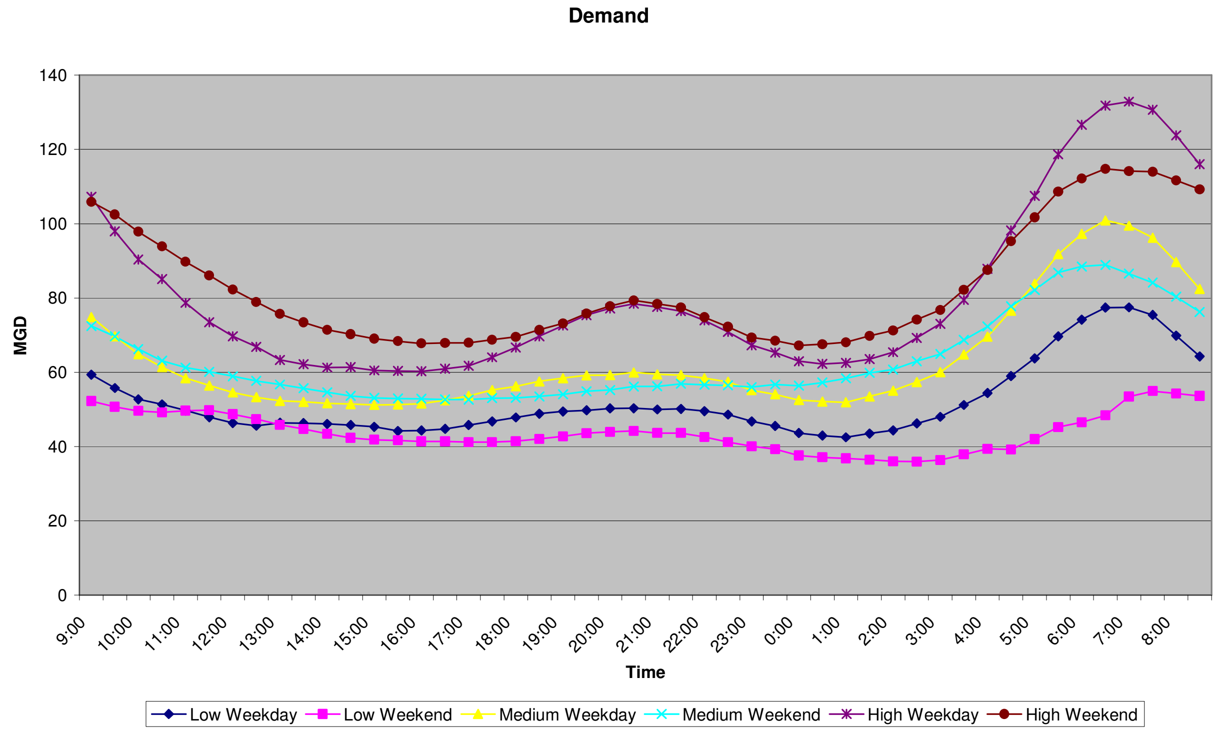

Figure 2 : Typical diurnal profiles showing variation due to demand both on weekdays and on weekends

3.2 Electricity Demand Forecasting

Once water demand profiles have been calculated, then using the historical correlation between water demand and electricity consumption on an hour by hour basis, energy load profiles can be created for the same days. The ability to be able to predict electricity load profiles gives you greater flexibility in purchasing decisions.

4 Eastern Municipal Water DISTRICT: a Case study

In 2005, Eastern Municipal Water District, (EMWD), selected Derceto Inc., to supply an innovative energy management system to automate pump scheduling within a pilot area of their water distribution system. The pilot system selected is the Moreno Valley Subsystem near Perris, California. The pilot system comprises 84 pumps, 25 tanks, 26 pump stations, and 11 control valves. Water for the Moreno Valley Subsystem is procured from a third-party operated water treatment plant. In total, EMWD supplies a population of 570,000 people and has an average daily demand of 70 MGD, peaking at 178 MGD in summer. The Moreno Valley Subsystem comprises roughly one third of the population served and uses 47% of total energy cost as this area has significant variation in topography requiring more pumping than other zones.

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There are a number of complications in the Moreno Valley Subsystem. Many of the pump stations comprise one or more electric pumps and one gas powered reciprocating engine driven pump. Choosing the most appropriate pump to use requires careful evaluation of the competing cost of gas versus electricity which changes month to month. Also, judicious use of gas powered pumping to contain electrical demand charges must be entered in to the equation. Water demand forecasting became an important part of the project to deliver a pump scheduling optimization system.

4.1.1 Water demand at Eastern Municipal Water District

EMWD is located about 1 1/2 hours to the east of L.A. and has a semi-desert climate. Summer water demand is significantly higher than winter water demand. Summer daytime temperatures regularly exceed 100°. Growth in the areas served by EMWD is also significant, leading to a steady stream of ongoing capital improvement projects. Water is obtained from a number of sources including both treated and untreated water procured from the Metropolitan Water District of Southern California as well as potable and brackish ground water sources, the later requiring energy intensive desalination.

4.1.2 Electricity tariffs

Southern California Edison, (SCE), is the electricity providers for EMWD. SCE has a range of different tariff categories and offers time-of-use (TOU) tariffs for larger accounts. Most pump stations have very large pumps and therefore have the option of TOU tariffs. TOU tariffs offered by Southern California Edison have three time-of-use bands in summer and two bands in winter. There are also significant demand charges that apply during peak periods in summer.

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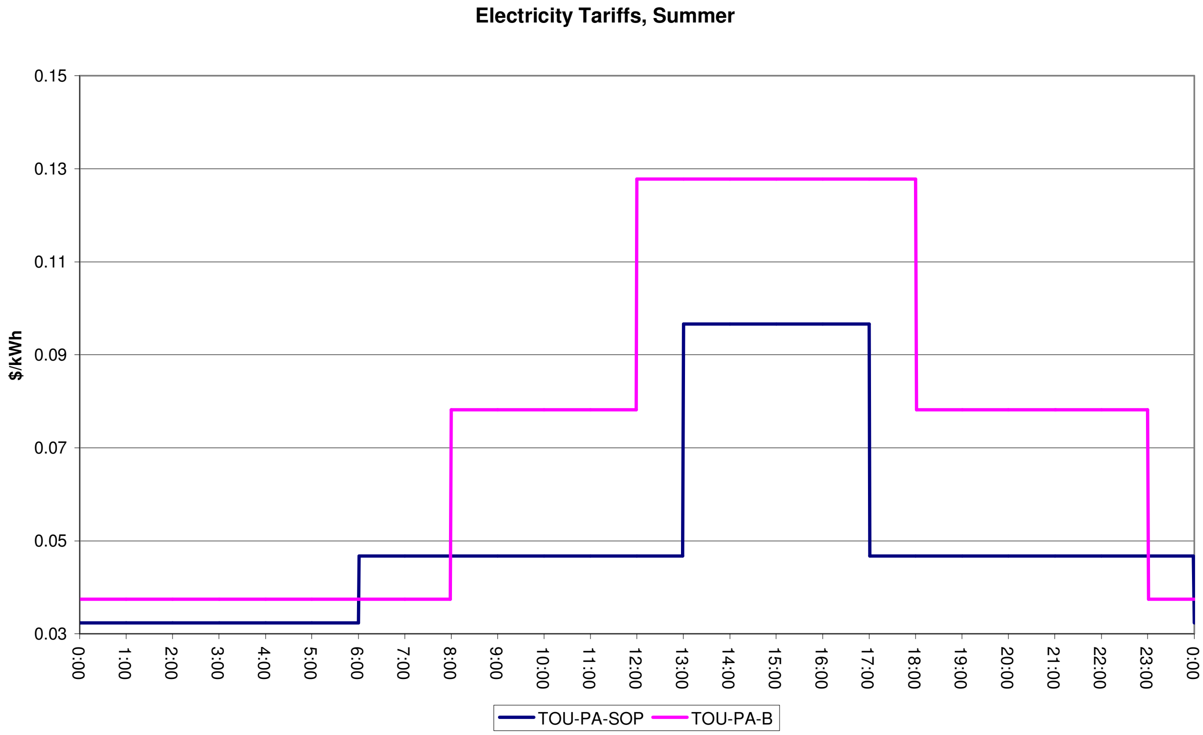

Figure 3: Southern California Edison, summer tariffs

When looking at the pricing data from Southern California Edison, figure 3, it is obvious that it is preferable to avoid pumping between 1 p.m. and 5 p.m or between 12 noon and 6 p.m. depending on the specific tariff. Significant demand charges also exist within these time windows. in fact, demand charges can exceed 40% of the monthly costs. The TOU-PA tariff has a demand charge of $45 per kilowatt, adding thousands of dollars in energy cost per month at the pump stations utilizing this tariff.

4.1.3 Gas and Electric Pump Combinations

The EMWD water distribution network makes use of both gas and electric pumps to deliver water. For a given tariff, the overall cost of production per gallon of water pumped must be computed. For example, the “wire to water:” cost per gallon for electric pumps needs to be determined. Although the nominal price of gas energy (between $0.62 – $1 per Therm or 2.1 – 3.5 cents per kWh) is often cheaper than electricity (3.2 to 12 cents per kWh depending on the time of use), the relative inefficiency of gas engines versus electric motors must be compared before deciding upon the most favorable form of energy. Electric motors are remarkably efficient at converting electricity to mechanical work and can often achieve better than 90% efficiency. Gas reciprocating engines on the other hand waste most of their input energy as heat. The gas engines used at EMWD had an average efficiency of around 18% which is typical for such a device. The best measure of performance is therefore cost per unit of water pumped, typically specified as dollars per MG. The purchase price of gas also varies every month, and EMWD was required to specify how much gas they would purchase in the coming month. Additionally, use of gas does not incur demand charges. As gas is procured in bulk, there is no time of use component.

The economic objective of a foreword purchasing strategy is obvious. Gas should only be used if it is cheaper than electricity to deliver the same volume of water. Derceto, Inc analyzed the comparative cost of electricity versus gas over a range of gas contract prices and for each gas pump in the Moreno Valley Subsystem. There are two issues to be solved. The first is to determine when gas is cheaper to use than electricity. The second issue is to determine how much pumping is required in the periods when gas is cheaper.

The first problem appears to be the easiest to solve, but in fact it is not. Electricity demand charges are applied to the highest demand at a pump station, over a 15 minute period in a billing month. This means running a single pump for half an hour will incur the same demand charge as running the same pump all day of the entire month. When you consider that the volume of water delivered in half an hour compared with the volume of water delivered over a whole month have the same demand cost, then the cost per MG delivered using electricity can vary significantly.

The second problem is closely aligned to the first. When looking at peak electricity prices and comparing them with gas prices, we readily note that it is always desirable to avoid pumping during the peak pricing band for electricity, if this is possible without compromising operational requirements. This is especially true when demand charges are taken into account, Therefore it is always preferable to run a gas engine if pumping is required during these peak periods. Note that during low demand days in winter running gas or electric pumps during these periods may not be required at all.

During the shoulder, or part-peak periods, the picture is not as clear. In figure 4, below, the actual gas price is currently just below the threshold at which it is cheaper to use electricity over gas. Even if the gas engine is cheaper to run during the part-peak periods we need to know just how many run hours we require during these same periods to keep the water distribution storage tanks within safe operational bounds. There is a small further complication. Once started it is desirable to run a gas engine for at least two hours, as, in a similar way to a car engine, most wear and tear occurs at start-up.

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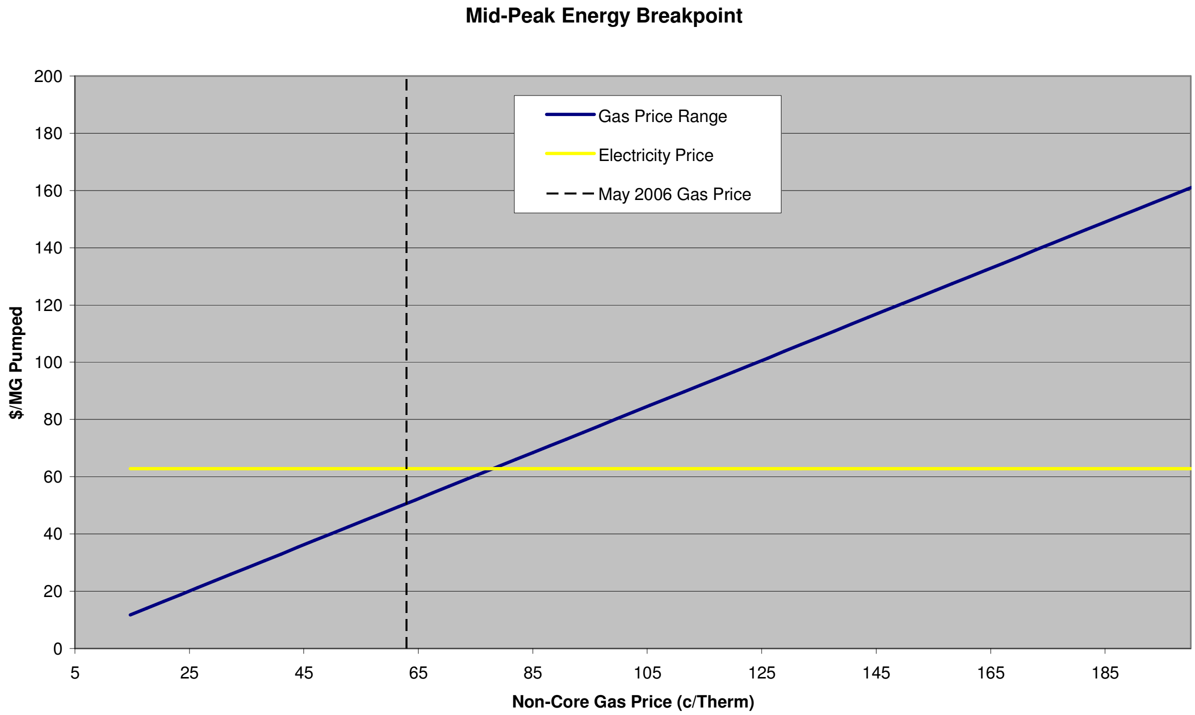

Figure 4 : When gas prices exceeds around 80 cents per Therm, electricity is the cheaper energy source

5 The solution

The Derceto pump scheduling optimization software package was installed at EMWD to work in conjunction with the existing Scada system. The software reads information coming in from the telemetry system and uses this to determine in real-time the water demand for each pressure zone. It takes the monthly forward gas price and then calculates on a pump by pump basis the breakpoint or yield point, where use of gas is cheaper than use of electricity. Finally, Derceto uses its knowledge of operational minimum and maximum storage requirements to determine how many pumps should run and when they should run at each of the 26 pump stations.

The primary goal of optimization is to deliver water to the customers at desired pressure, while keeping in mind water quality requirements, primarily turnover in storage tanks. The secondary goal of the optimization software is do this at the lowest combined cost for procurement of electricity and gas. The software runs on a standard office PC located in the control room. This is a monitorless and keyboard less box, connected across the local area network to the Scada system.

While solving the very complex scheduling problem is of interest to many academics it is in fact only one part of many steps required to create a usable robust and fully automatic optimizer.

The main steps are;

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- Initialize any long term settings such as annual water extraction limits
- Read data from the Scada system, detect and correct any errors
- Set the target volumes required in storage to achieve security of supply and turn-over
- Read any changing third party data such as electricity real time prices (where applicable)
- Calculate schedules for all pumps and valves
- Write commands to the Scada system to start/stop pumps or open/close valves as required.
- Update any analysis such as predicted demand, costs, water production estimates

Most steps in this process require a few seconds to complete. The solver is the most time consuming step, but is still fast enough to be run interactively by EMWD operators with update times of around 1 minute. The water distribution operators can view the Derceto predictions and outputs on a Windows based display screen. In the screen shot below the top graph shows demand, the middle graph shows storage tank level and the bottom row of dots is the pump schedule. The yellow bars indicate current time; anything before the yellow bar is history, anything after is future prediction. The predicted storage tank level rise in response to the pumps running (green dots) is evident.

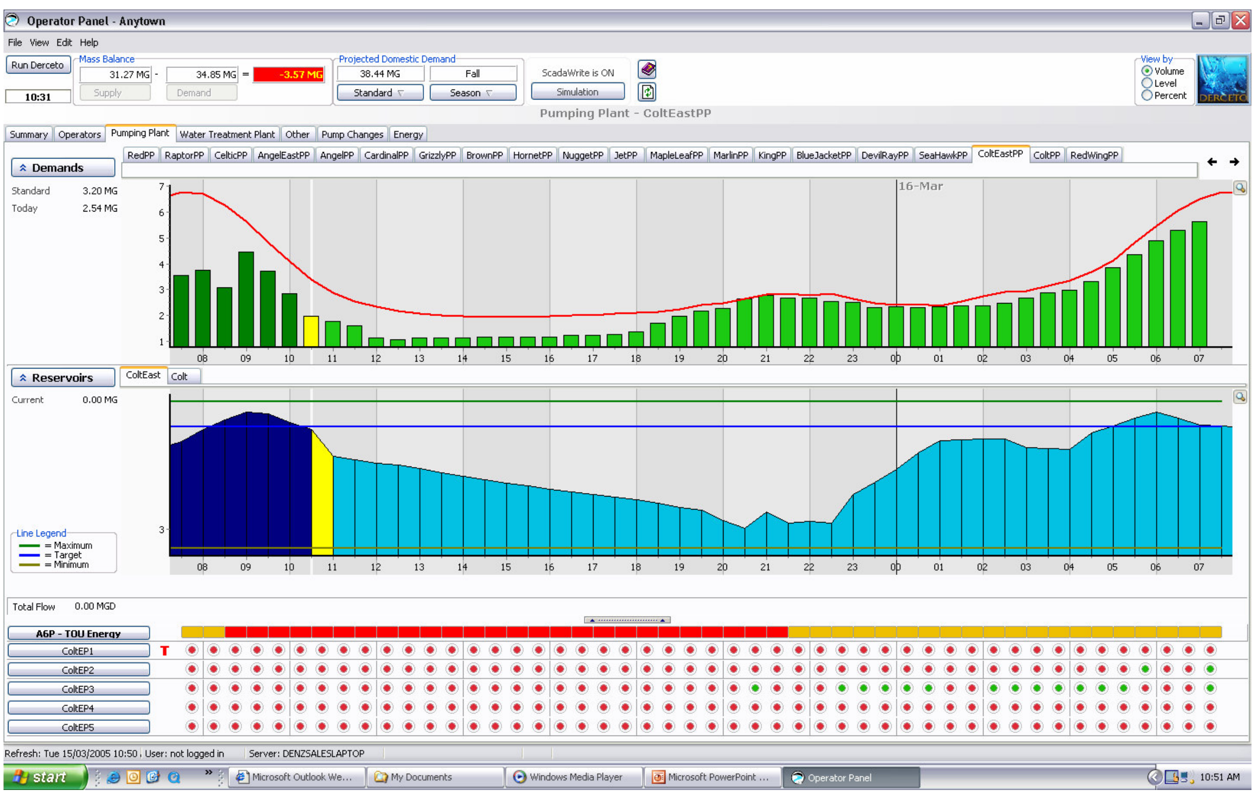

Figure 5: The Derceto operator panel, a thin client GUI which can run across low bandwidth LANs or WANs

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The gas pumps and some of the electric pumps are variable speed drives, and the optimizer must choose the appropriate speed to run these pumps. A new solution is calculated every half an hour, with an entire 48-hour future pump schedule produced. For safety of operation, the schedule is also transferred to the Scada system. If the server ever failed, the Scada system would still have a new 48-hour schedule to run while the PC was being replaced.

At EMWD, the optimiser came online in July 2006 and was in control of 15 of the 26 pump stations in the Moreno Valley Subsystem by the start of August. All pump stations and pumps were under optimizer control by the 11th of August. During this period of time record high temperatures and record high demands were experienced placing extra stress on the commissioning of this complex software. During this high demand period the operators were busy answering and issuing service requests via radio and phone, leaving the optimizer to look after the control of pumps in the system. This significantly reduced the workload of the operators during this very busy time.

Results from using the Derceto software at the DSS conference in September 2006 in Phoenix, Arizona.

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