DELIVERING VALUE THROUGH DESIGN – MANGAWHAI ECOCARE PROJECT

Bart Post – Senior Control Systems Engineer, McKay
Greg Lovell – Manager Business Development, McKay; Managing Director, Greg Lovell Consulting

ABSTRACT

Capital expenditure in Waste Water Treatment represents a long term investment for the asset owner and operator. Often ignored, the through-life cost of the asset is likely to be significantly larger than the initial capital investment. The design of the electrical and control installation is one of the areas that is extremely important in optimising project life cycle costs.

This paper discusses the design aspects and the technology chosen for the electrical and control installation of the Mangawhai Ecocare project, and how it delivers value for Water Infrastructure Group, as the builder and operator of the new Waste Water Treatment Facility at Mangawhai. It will also discuss the enablers that encouraged the design approach, in particular the way in which the electrical, instrumentation and control package was let.

The Mangawhai Ecocare project is a good example of how you can make an electrical and control installation future proof and reduce both capital and running costs by putting more emphasis on the design stage of the project and by implementing smart technology throughout the system without compromising the reliability of that system.

KEYWORDS

Design, Electrical, Control, Life Cycle, Capital, Smart solutions, Waste water.

1 INTRODUCTION

In 2009 Water Infrastructure Group delivered the $60 million Mangawhai Ecocare Wastewater scheme for the Kaipara District Council, a wastewater scheme that WI Group will operate on behalf of the council for at least the next ten years.

The scheme provides a sustainable wastewater system for approximately 1500 homes with capacity to service 3500 in the future. The Ecocare scheme includes a small footprint water reclamation plant, and 180 mega litre storage facility for reclaimed water, and 13 pump stations.

McKay was chosen by Water Infrastructure Group, as the electrical, instrumentation, and control system provider for the new scheme, and owing to latitude given to McKay in the design and build of the electrical and control systems, was able to deliver solutions that provide long term benefits to both WI Group and the Kaipara District Council.

To deliver value through design it is necessary to take a holistic view of the project, understand the client's needs and then provide an engineered solution, rather than delivering a design for the sole purpose of meeting a technical specification. Usability, (ease of maintenance, ease of operations, and ease of getting information) is one of the most important considerations in smart design as this determines the efficiency with which people will interact with the system.

A smart design should consider the wider customer group. This group is not limited to the plant operators, the maintainers and the asset owners, but should also consider the wider community that is impacted by the scheme.

2 CREATING THE ENVIRONMENT FOR INNOVATION

Most capital projects, particularly those for councils, follow a regimented path which can, however unintentionally, introduce inhibiters to innovation.

Figure 1 shows the typical sequence for a waste water treatment project.

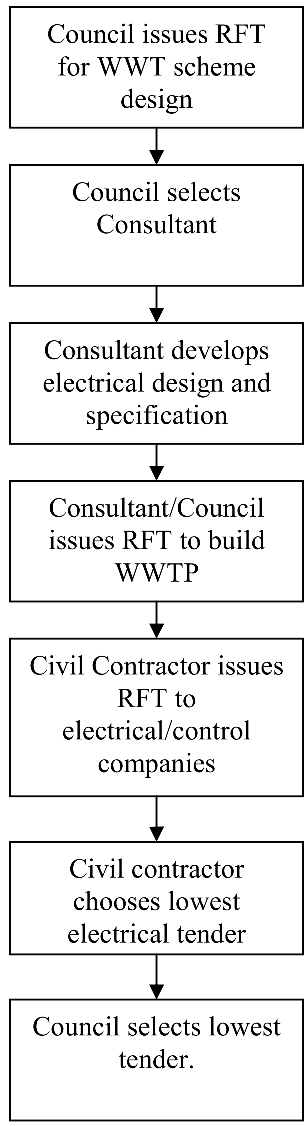

Figure 1: Typical tender process

The approach to tendering, whilst the most common, presents obstacles for smart design, especially for electrical and control installations.

The council's selection of consultant is likely to be made on their experience in process and civil design. The electrical and control side of the project will be secondary.

If the electrical scope of work is let via a prime civil contractor, then the lowest compliant tender will usually dictate the choice of electrical contractor. Sometimes civil contractors call for prices at tender stage, sometimes afterwards, and sometimes both. Usually there is a period of only two weeks to prepare a tender proposal for the electrical and control works. This period of time is often insufficient to prepare both a compliant bid and an alternative.

There are a number of ways in which councils evaluate tenders, such as lowest conforming bid, weighted attribute, quality price. Yet, none of these take into consideration the actual life-cycle cost of the project.

The Mangawhai water scheme project was different, in that WI Group had won the competitive tender to design, build and operate the plant. WI Group focussed on selecting an electrical and control provider that could meet the technical requirements of the project and deliver on time.

McKay was initially invited to offer a proposal with budget estimates using a relatively open specification. Once McKay was chosen as the electrical provider, the design was fine tuned and a fixed price was agreed upon that met the WI Group budget.

3 DELIVERING VALUE THROUGH DESIGN

A lot has been said and written about the definition of design. One definition, offered by designer Richard Seymour in 2002, defined smart design as “making things better for people”. How does this apply to the electrical and control installation of a sewerage scheme?

The electrical and control scope of works is a small proportion of the capital investment in a waste water treatment project (around 10-15%), yet this part of the design has a significant impact on how people will interact with the plant. For example, the operator’s primary means for controlling and monitoring the plant is through the SCADA system and the Process Historian. Considering this, the amount of forethought put into the electrical and control system is quite often woefully inadequate compared with the amount of effort put into the process and the mechanical design.

Several areas can be identified which demonstrate that smart design can make a difference in the performance of an electrical and control installation:

- An installation can be made future proof by making it scalable and modular
- Using open systems will make it easier to integrate with other systems, and will guard against obsolescence
- Using transparent communication throughout the system, including the telemetry, will make monitoring and maintaining the installation more efficient
- Providing the client with tools to fine tune the treatment process can reduce energy and improve the end product
- The use of “smart solutions” can optimise capital and life cycle costs

The following paragraphs will elaborate on each of these areas and will give examples of how design can make things better for people.

3.1 STRUCTURING THE PROCESS

To create a good understanding of the requirements for a process installation, it is often useful to create a hierarchal structure of that process. One of the methods that can be used to structure a process is the ISA S88 standard. Although designed for batch control, this standard can also be used for modelling discrete and continuous processes like waste water treatment. It is a design philosophy for describing equipment and procedures where the hierarchy of equipment used in the process is defined in the physical model. Further, the control that enables the equipment in the physical model to perform a process task is defined in the procedural model.

Figure 2 shows a part of the physical model for the Ecocare Project:

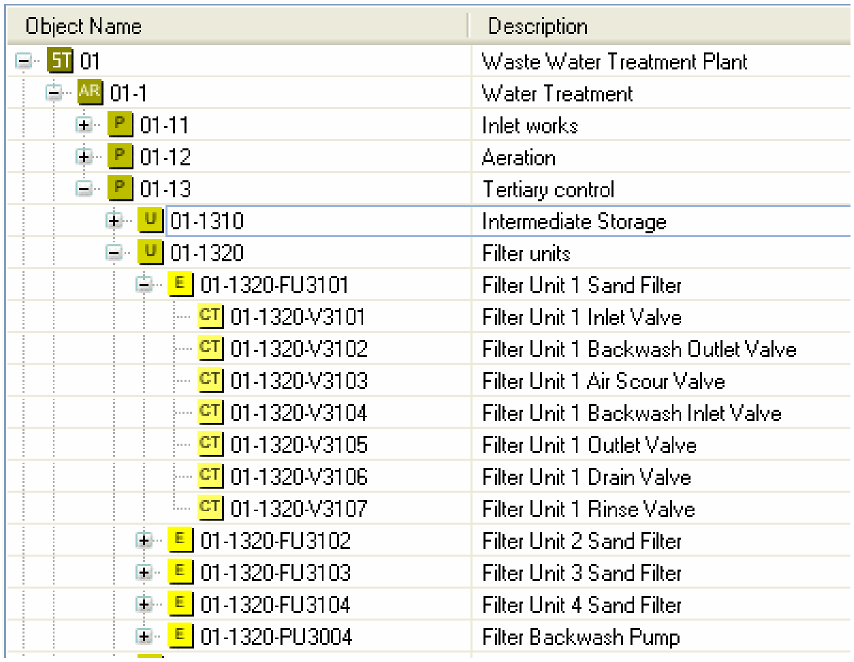

Figure 2; Physical model using ISA S88

The physical model is a decomposition of the process into enterprises (organisation looking after treatment plants), sites (treatment plants, pump stations etc), areas, process cells, units, equipment and control modules. Aside from being able to specify the control requirements in a structured way, the model can also serve as the starting point for software and documentation generation by creating reusable classes which can be linked to the objects.

Amongst other things this method can:

- Improve quality through requirement management
- Improve consistency by linking disciplines like software and hardware engineering
- Shorten the engineering time by making functionality reusable
- Make the software design modular and easy to maintain

3.2 INTERACTION DESIGN

Another activity that, in a smart design process, takes place during the first stages of a project is the specification of the way users interact with an installation. Interaction with an installation can take place in a lot of different ways, ranging from opening and closing valves with a hand wheel to starting/stopping pumps from a remote location using a computer interface. There are many design decisions that can strongly influence user interaction. Variable speed drives (VSD), for example, can be installed next to the pump in the field, in a switchboard room mounted on a wall or inside a switchboard enclosure. The location of a VSD will have a big influence on the way a user can interact with it. If the VSD is installed in the field, the operator can observe the reaction of a manual operation. On the other hand, it would not be practical to use the VSD human machine interface (HMI) for manual operations in case of a programmable logic controller (PLC) failure because of the distance to the central control building. Contrary to this, when the VSDs are installed on a wall in the control building, the user interface of the VSD could replace the hard wired Manual/Off/Auto switches including switchgear in the switchboards.

By applying a clear and consistent philosophy regarding operating modes like local Manual/Remote manual/Semi-Auto/Auto, it becomes much easier for an operator to learn how to interact with the plant. Over the life of the asset, a consistent operating philosophy will result in reduced training time, reduced operator error, and, generally, result in an increase in productivity and job satisfaction.

One problematic area is the integration of package units. In treatment plants, installations like inlet screens, filter units, and UV plants often come as a package, including a switchboard with its own local controller(s), an HMI, and in some cases an interface to communicate with the central SCADA system. The user interface of the package unit will, in most cases, be completely different from the plant control system. However, depending on the complexity of the controls and the attitude of the supplier, it might be possible to integrate the control software and user interfaces with the plant control system, by using a remote IO-rack as the demarcation between the supply packages for example.

Potentially this can have many advantages:

- The user interface of the package unit can be fully integrated with the user interface of the central plant control system
- The control system is maintained by one contractor
- Since all systems use the same gear, less spare parts need to be kept in stock

The above will only be possible if a clear demarcation can be defined in the scope of supply of the individual suppliers involved.

3.3 ELECTRICAL DESIGN

Initially taking time to consider how an installation will be used in both the short term and long term, can help to identify areas where design can improve the outcome of a project. Relatively small ideas can have a big impact on the end product.

One of these areas is the cable layout of an installation. Putting a false floor under a switchboard and linking these spaces with trenches covered with floorboards will not only make the installation process very efficient, installing additional cables in the future will be a much simpler process as well. Using cable pits at strategically chosen locations linked by ducts is another way of improving a cable installation.

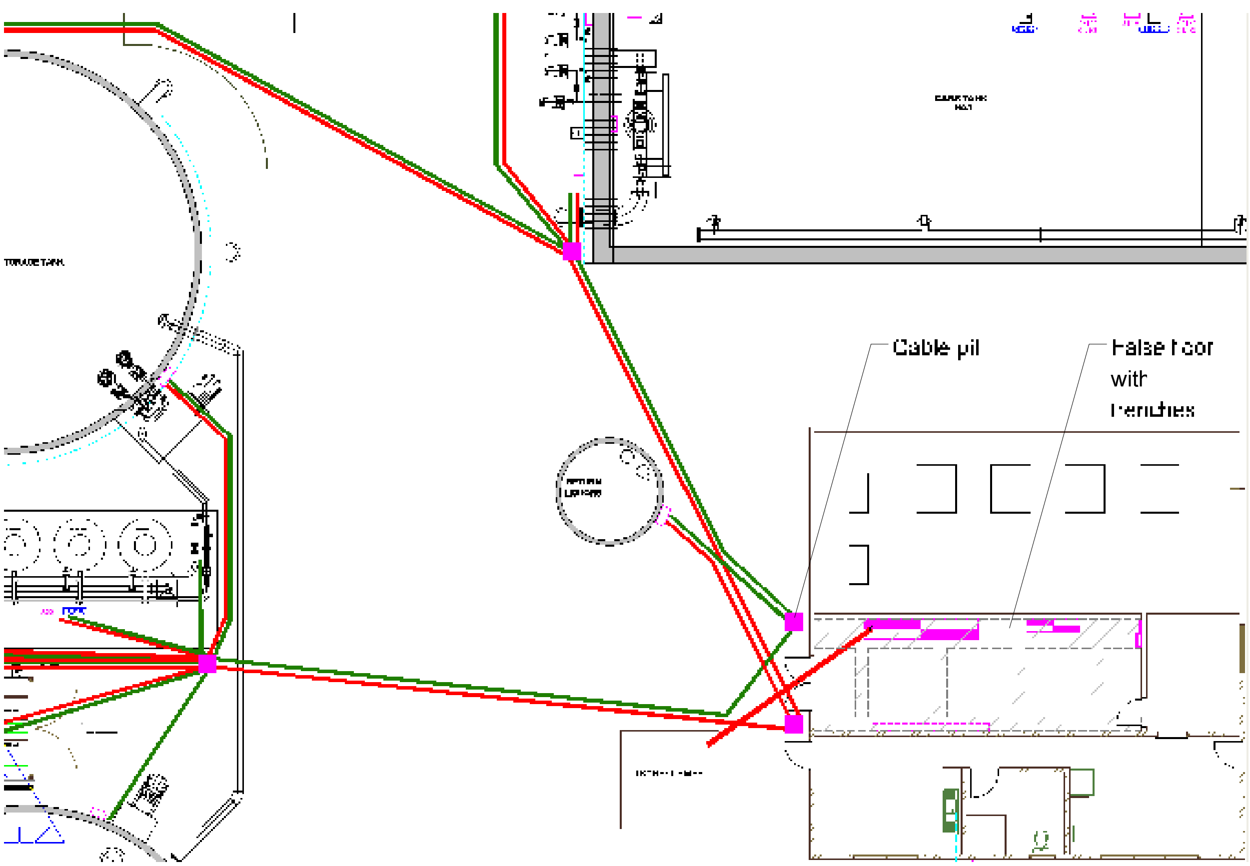

Figure 3; Cable layout

Another example of a way to simplify an installation is to omit features that were commonly used in the past, but are not necessarily needed in today's installations. With the introduction of reliable network interfaces, in conjunction with excellent HMIs on speed drives, one can question whether it is really necessary to terminate hardwired control signals to speed drives. There will be cases where the answer is "yes", but if it is possible to omit hardware control, the savings can be significant. One way of finding this out is to do a FMEA (Failure Modes and Effects Analysis). This is a procedure that classifies the severity and likelihood of a failure within a system and, by doing so, makes it possible to design these failures out of the system with minimal effort and resource expenditure. In relation to the wiring of VSDs, the outcome in the Ecocare project was a configuration where the VSDs are automatically controlled and monitored through an Ethernet connection, and manual operation takes place on the drive itself. This way, there is no need for manual control on the switchboards (Auto-Off-Manual switches, pot-meters etc), thus reducing wiring, space and generally simplifying the switchboards. (See Figure 4)

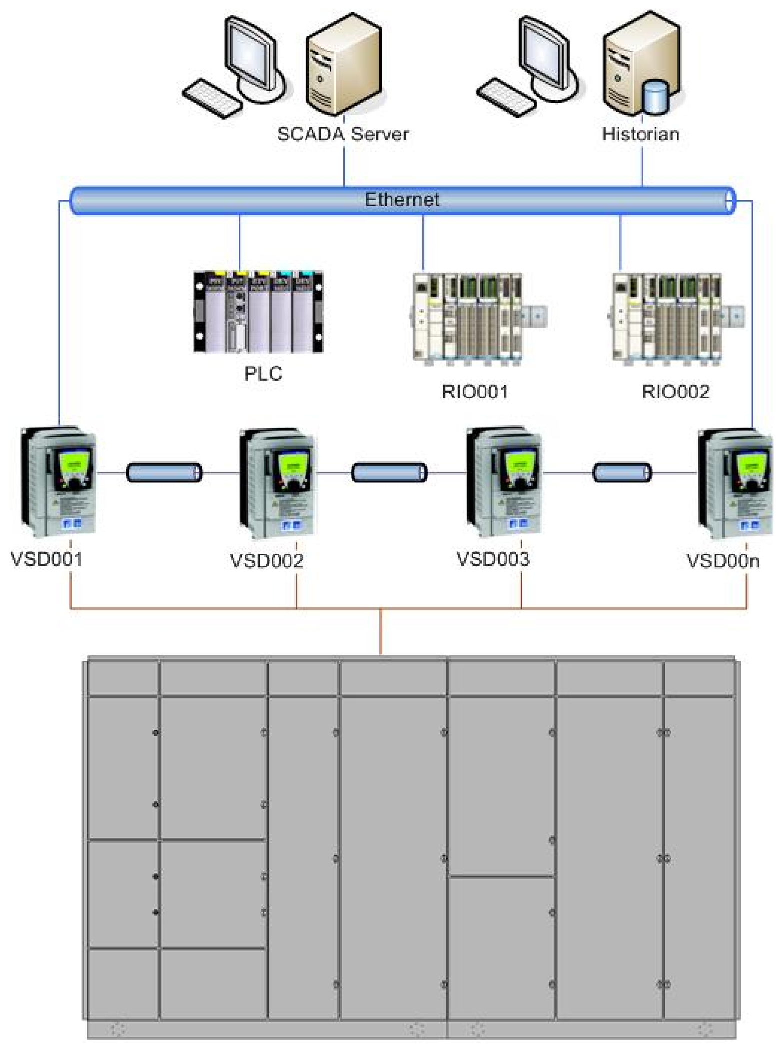

Figure 4; VSD cabling Ecocare project

3.4 SWITCHBOARD DESIGN

3.4.1 PUMP STATIONS

Designing a pump station switchboard that is going to be installed in the field where it is exposed to the elements can be challenging. It has to be protected against the weather (sun, rain, high and low temperatures) and sewerage gases without compromising ventilation. There are environmental considerations such as size and noise emission, and the board must be secure and robust to protect against vandalism.

Often, switchboard designs for pump stations are based on a main enclosure in combination with a number of inner boxes that hold the electrical equipment. Although this is a good way to keep the weather out, ventilation is often poor and the dimensions of the enclosure are greater than a board with a single shell. By looking at the way the operators interact with a pump station board, one can identify the most commonly used functions. In most cases, this will be limited to the manual operation and isolation of the pumps. By grouping these functions in one compartment and giving the components in this compartment an IP54 rating (ingress protection against dust and splash water), the other equipment, which only needs to be accessible for maintenance or in case of faults, can be installed in another compartment that remains closed during normal operation.

Figure 5 shows the configuration used for Ecocare project, where one compartment holds the control gear and instruments, another one the mains, generator and pump circuit breakers and a third the IP54 rated VSDs. There are two external doors, one for the control and instrumentation compartment and one for the other side. The circuit breaker compartment is protected by an internal door.

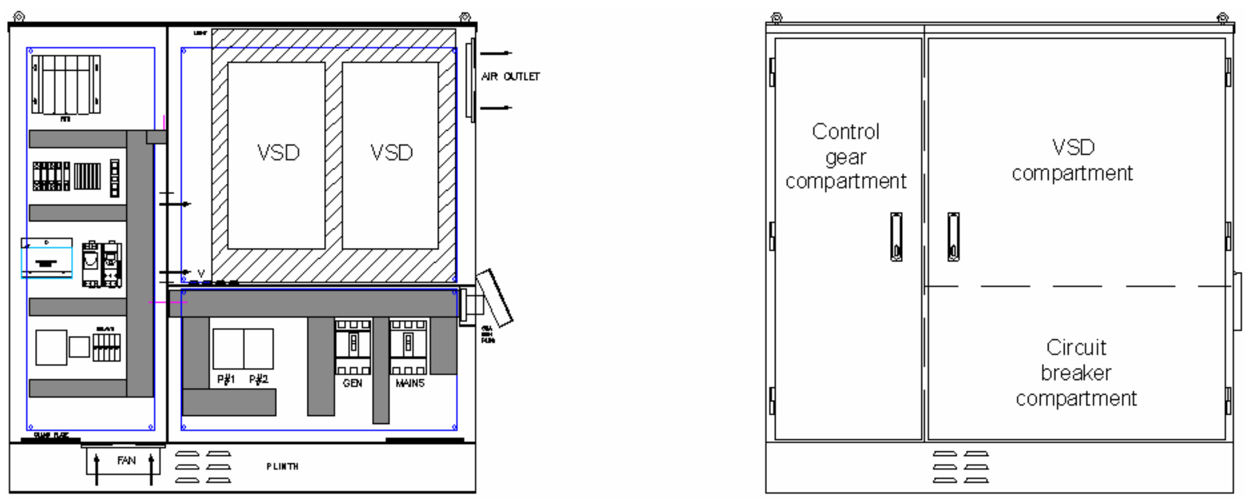

Figure 5; Pump station switchboard layout

This configuration allows the operator to fully control the pumps by opening the VSD compartment and use the HMI on the VSDs to switch between auto and manual operation, start/stop pumps and choose the manual speed. The control and instrumentation compartment, as well as the circuit breaker compartment, can stay closed.

The switchboard fan is built into the bottom plate and sucks air in through a duct connected to a vent in the plinth of the board. In combination with the fact that all cable ducts are sealed, this guarantees that no sewerage gases can ingress into the board. The air is blown through the control compartment and the vertical separation into the VSD compartment where it leaves the board at the top.

3.5 NETWORK DESIGN

3.5.1 PLANT NETWORK

Over the last decade, the use of Ethernet in industrial environments has become common practice. Ethernet is used from the administrative systems level through to the device level. There is no longer any reason why Ethernet cannot be used to build deterministic, open and inexpensive automation network solutions. The choice of network for a new treatment plant is, therefore, an easy one to make. For the Ecocare project the Ethernet network inside the buildings is configured as a redundant copper ring and the connection between buildings are glass fibre. Reliable and predictable data communication is not the only goal when it comes to choosing networks. Devices like PLC's, remote IO, VSDs, managed Ethernet switches etc. are increasingly equipped with web servers and support SNMP (Simple Network Management Protocol) for diagnosing the devices from a central location, for example by using the SCADA system. Solutions, like the Schneider Electric Transparent Ready network that McKay implemented in the Ecocare Project, allow the establishment of transparent communication between field, process and plant, providing the efficient sharing and distribution of information between sensors, instrumentation, devices, controllers, operator workstations and other enterprise systems. It also offers significant savings in the design, installation and maintenance of the plant system and reduces training requirements.

3.5.2 TELEMETRY

Of all electrical systems in a treatment process, the telemetry system is in many cases the hardest system to design and implement, predominately because of its specialised character. Even for new installations, quite often people prefer to use systems that have worked reliably in the past. This is unfortunate as often this one area of control system design that, if implemented correctly, can result in a significantly improved system, in terms of transparency, speed and, most importantly, cost effective upgrades as technology improves. Using open systems allows the asset owner a choice of maintenance provider, rather than restricting them to the OEM of a proprietary system.

The main goals of a good telemetry system are:

- High reliability. Alarms need to be sent to an operator within a short time frame. Process and reporting data are less important because of the buffering inside the RTUs (Remote Terminal Unit)
- Easy to scale. The addition of a pump station should have no effect on the existing telemetry system
- Capable of running multiple protocols
- Enough bandwidth to support real-time data-acquisition, but also provide enough room for the use of programming and diagnostic tools
- Good security
- Cost effective
- Vendor independent

The ultimate fast and reliable network is a fibre optic network which can be installed together with the reticulation. Planning a network like this is, in most cases, a complicated task. When you add to this the high capital cost, it explains why fibre optic networks for pump station communication are not very popular. The rollout of a national fibre optic network might change that in the future.

Another wired solution, relevant for more urban areas, is the use of ADSL. Nowadays ADSL is reliable, relatively fast and the capital investment is low. The downside of ADSL is the running cost. Even a "naked" ADSL line costs around the $80 per month which, when multiplied by the number of pump stations, can add up to high costs.

In many cases wireless communication is the best solution. The table below shows the most commonly used:

Technique	Type	Range	Speed
VHF and UHF Radio (Analogue or digital)	Licensed	Good.	1200-9600bps
Digital wide-band 900 MHz and 2400 MHz Spread Spectrum network	Unlicensed	Line of sight required. Distances up to 50 km	0.5 Mbps
Digital wide band General Packet Radio Service (GPRS)	Public	Depends on network provider	56 – 114 kbps
3G cellular data network	Public	Depends on network provider	1.5 Mbps

Table 1; Commonly used wireless communication

Nowadays, the VHF/UHF bands can be used in combination with Ethernet radios, thus providing transparency and also reliability. The main disadvantage of this type of network is communication speed, making tasks like maintenance and diagnosing problems through the data network a tedious process.

900MHz and 2.4 GHz spread spectrum networks are relatively fast but the topology in New Zealand is often a problem. These radios need line of sight and even if the pump stations are installed in a flat area, obstacles like trees and buildings can be a problem. A link that has high signal strength during the install may become a lot weaker in the future as new buildings or growing trees become greater obstacles. Finally, the 900MHz and 2.4Ghz networks are shared networks which, in combination with the restricted capacity in New Zealand, can cause problems in urban areas. For the Ecocare project McKay did a theoretical path study on the use of this band which showed reasonable signal strengths. However, a radio survey in the field showed that, in the real world, only half of the connections were working.

In recent years, 3G/4G cellular networks have increasingly become a good platform for telemetry. They provide more than enough speed; run both data-acquisition and maintenance diagnostics at the same time; prices are dropping and, in combination with a VPN (virtual private networking), provide appropriate data security. The disadvantage is the reliability (failure of the cell phone network). Although these services are improving, using a backup SMS service for alarming is sometimes recommended. (This can be integrated into the same cellular modem and even use an alternative network provider) Another important aspect is the significant knowledge that is required to setup a system based on cellular networks. It is by no means just a matter of putting a sim card in a modem like with a cell phone. It is essential to understand the local situation (fluctuations of people using the same network in the area), how the network is operated and what kind of policies are being used (for example some providers require the support of dormancy mode). It is, therefore, important to first talk to the technical staff of the network provider before making any decisions.

After exploring all options and conducting a lot of testing, a 3G cellular network was selected for the Ecocare project.

3.5.3 CHOICE OF PROTOCOL

When it comes to the choice of protocols for data-acquisition and control, it is abundantly clear that open protocols are the way forward. Even open protocols like Modbus and Profibus, which were originally developed on networks other than Ethernet, are today IP-based (Modbus/TCP, Profinet) and are widely supported by most control system manufacturers. This does not necessarily mean that choosing a protocol is a straightforward process. Many aspects need to be considered for example ease of implementation, supported features like time stamping and quality information, the availability of gear that supports the protocol etc. From an implementation point of view it is best to stick with one protocol throughout the installation. There is one area, however, that will require a different approach because of its unique nature. Although communication speed for telemetry systems is on the rise, there are still several reasons to keep data throughput as low as possible. Sometimes the reason is cost, for example when using broadband. Sometimes, there are technical reasons. For telemetry systems, it is therefore recommended to choose an open telemetry protocol like DNP, IEC60870 or IEC 61850. They are all designed to optimise traffic and provide many features to tune communication in general.

3.6 CONTROL SYSTEM DESIGN

3.6.1 USER INTERFACE

As mentioned above, the user interface of a SCADA system is the primary interface for an operator to monitor and control a treatment plant, including its pump stations. Despite this, user interfaces often do not get the attention they deserve. First of all, the SCADA system interface needs to be ergonomical, which includes a whole raft of concepts like intuitiveness, consistency, use of fonts and colours to emphasise information, etc. Also, a SCADA system should not be restricted to the monitoring of the process. Monitoring the health of the equipment is equally important. Providing features like SNMP and web interfaces for PLC's; remote IO racks and VSDs can make tasks like fault finding a lot easier. A SCADA system must be a tool which makes the daily task of an operator easier, more efficient and satisfying.

Now that most treatment plants have remote access through broadband, resulting in multi-site operation, it becomes increasingly important to develop a standardised user interface for a cluster of sites. This will result in one look and feel for all systems.

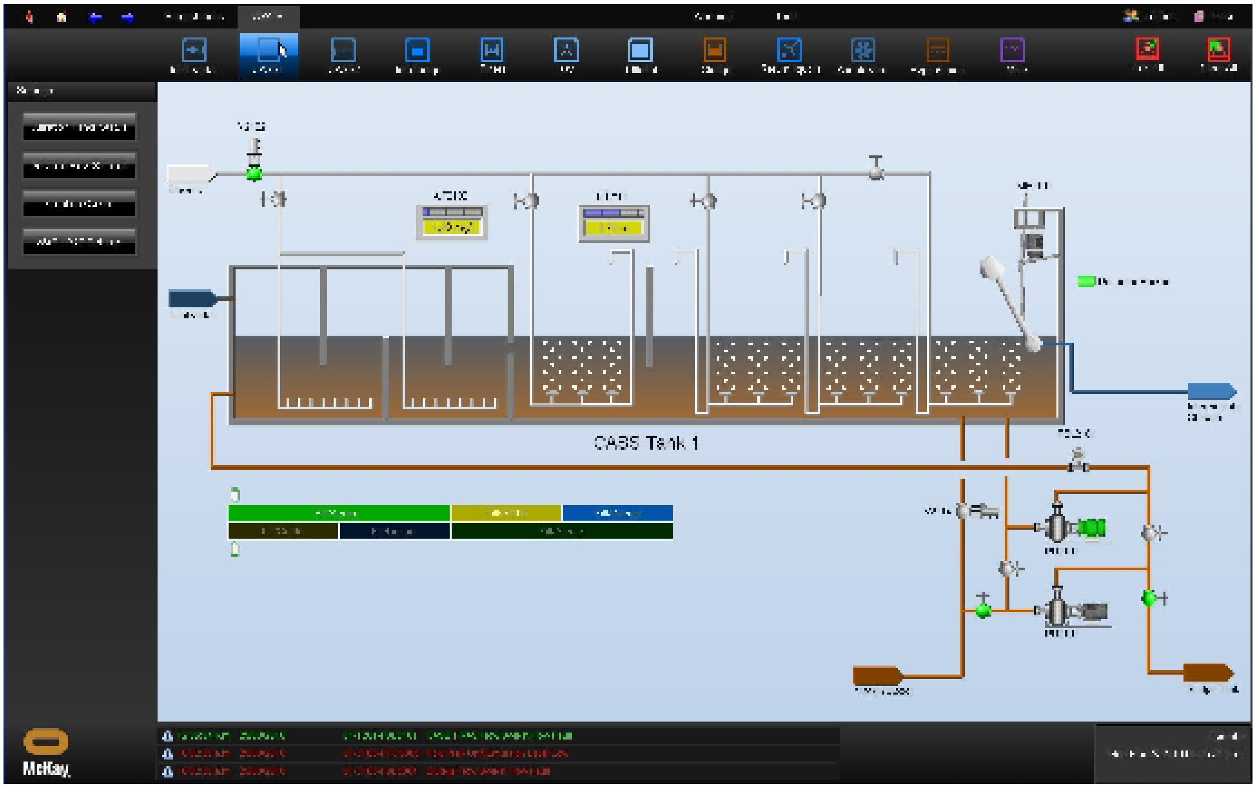

Figure 6; SCADA User interface for Ecocare project

3.6.2 PROCESS HISTORIAN

In recent years, there have been many discussions regarding the use of Process Historians versus the use of relational databases for long term data storage and analysis. One camp argues that relational databases are too slow for fast process data and that only Process Historians are up to the job. The other camp is of the opinion that Process Historians are too complicated and too expensive for tasks that can be executed by a relational database.

For most water treatment schemes, however, speed is not really an issue anymore because of the size of an average treatment process combined with the increase in processing speed of relational databases. Choosing a SQL Server for long term data storage will, in most cases, be a good solution. On the other hand, this approach will require a lot of engineering time to create the connectors to the SCADA system and to develop the reports.

Nowadays there are several products on the market that combine an open relational database platform with tools conventionally provided by a Process Historian. They are a good compromise between cost and performance.

Although the specification originally asked for a relational database to store reporting data, McKay decided to use VijeoHistorian, which is the information management component of PlantStruxure™ , based on the Microsoft SQL server relational database platform. It comprises the historian and portal functionalities of the solution, enabling access to all process data, directly from within the SCADA system. Supporting the plant manager to make the right decision, the Historian software is focused on resolving issues and making all control system information available to operators and applications throughout the plant.

3.6.3 SMART SOLUTIONS

Sometimes it pays off to take a completely different approach to the implementation of a control system. In the Ecocare project, for example, the pump stations are controlled by the VSDs instead of a PLC or RTU. Each drive is equipped with an add-on card that functions as a PLC. This “controller inside” card can be pre-ordered with a number of fixed programs, like “Multi-pump” or “Wet well”. The program itself is fixed, but the control can be adjusted through parameterising the VSD using the HMI or by means of the communication port. The “controller inside” card in each VSD communicates with the other through a redundant CANOpen link, thus behaving as a single control unit. When one of the speed drives is taken offline, the other will be able to control the level in the wet well autonomously. This out-of-the-box control redundancy makes it possible to delete hard wired backup circuits and, by doing so, cutting on the number of components in the switchboard, reducing complexity.

3.7 FINANCIAL IMPLICATIONS OF USING DESIGN

3.7.1 CAPITAL COST

Implementing a smart design does not have to result in an increase in capital expenditure. It will most definitely result in an increase in the initial design cost, but the overall expenditure will balance out due to efficiencies gained in reduced programming, installation and commissioning time. Other savings can be achieved in reduction of components, cabling and even switchboards.

It is vital to take a holistic view of the project, rather than breaking the contract down into individual items. It is common to have separate contracts for switchboard supply, electrical installation, control system integration, and Telemetry. Structuring a project in this way not usually allow for both a cost effective installation and a smart one. If one contractor is made responsible for the whole electrical, instrumentation, and control scope, additional expenses incurred in one area can be offset against reductions in others.

The Ecocare project was structured this way, allowing McKay to offer a fixed price for the complete works and at a cost that met the client’s budget.

3.7.2 OPERATING AND MAINTENANCE COSTS

A smart design of the type implemented in the Ecocare project yields many advantages for operating and maintaining the facility.

The operator interface provides quality, real-time information, making it easier for the operator to monitor the performance of the plant, and provides useful alarms, allowing the operator to take corrective actions.

The modular design allows for a reduced spare parts inventory and standardising components means the repair and maintenance training is reduced.

The use of open systems in combination with the 3G network for telemetry makes remote diagnostics simple. Technicians can log on to the treatment plant or the remote stations from any location that has an internet connection, and perform diagnostics without the need to go to site.

The use of open systems means the asset owner or operator isn’t tied to using one company to maintain, modify and upgrade the operating systems; this gives the client flexibility in the choice of provider for ongoing support.

4 CONCLUSIONS

Cost effective, smart electrical and control system design is not only possible, it should be an important consideration in waste water treatment projects (or any project for that matter). A smart design should involve a holistic view of the project, and consider how people will interact with the entity.

For the Ecocare project McKay specifically focussed on:

- Making the installation future proof through a scalable and modular design.
- Using open systems to make it easier to integrate with other systems and to guard against obsolescence
- The use of “smart solutions” to optimise capital and life cycle costs
- Using transparent communication throughout the system, including the telemetry, making monitoring and maintaining the installation easier

- Providing the client with tools to fine tune the treatment process to reduce energy and improve the end product

There are several important considerations that need to be made to encourage smart design:

- Ensure that the tendering process is structured in a way that encourages and evaluates the use of smart design
- Package the electrical, control, instrumentation and telemetry supply contracts together to allow for a complete solution to be implemented and total system gains to be yielded.
- Consider life cycle cost evaluations of tender proposals
- Engage the electrical specialists early in the process

ACKNOWLEDGEMENTS

Richard Coulter - National Sector Manager Water, Schneider Electric

Robin Johnson – Technical Advisor, Water Infrastructure Group

REFERENCES

[1] Writing a functional specification for an S88 batch project, Christie Deitz, Todd Ham and Steve Murray.

[2] ANSI/ISA-88.01-1995 Batch Control Part 1: Models and terminology