Itron

The Benefits of a Distribution Transformer Monitoring Solution at Network Waitaki Limited

WHITE PAPER

INTRODUCTION

This white paper reviews the benefits of installing a Distribution Transformer Monitoring solution (DTM) at Network Waitaki Limited (NWL) in New Zealand.

NWL is looking to provide a better quality of service to stakeholders by having more awareness of where issues are on their distribution network and what may be the cause of those issues. There are two important elements to achieving this goal:

- Improve the knowledge of the long-term lifecycle of transformer assets
- Improve awareness of real-time network operations

Although the time scales associated with these two challenges are different, the data requirements are quite similar.

For a solution to be effective, its information must address the following criteria:

- The data must be meaningful
- The data must be in manageable quantities
- The data must be time stamped
- The data must be presented in context along with tools for basic analysis
- Programmable alarms must be reported in a timely manner
- Status queries must be available on demand
- Systems must be simple enough to retrofit into existing equipment
- Systems must deploy without special communications requirements

NWL is facing several issues as listed below:

- Current operational awareness information is unavailable. NWL's SCADA system is limited to high voltage network equipment (11kV and higher). Additionally, getting NWL AMI meter data is difficult for two reasons:
  - Smart meter adoption is low in the service region, AMI data is not available for many consumers.
  - Smart meters are generally owned by retailers or third parties, so sharing of smart meter data/information in New Zealand is problematic due to perceived commercial conflicts between retailers and distributors.
- Outage management needs to be improved to increase customer satisfaction. The utility needs to be more proactive, or at least timely, when an outage occurs. Low voltage outage information is generally "crowd sourced" in that NWL relies on customers calling in to report a fault.
- Load planning is difficult to establish using the current Max Demand Indicator (MDI) data which is read sporadically and provides only one type of data. The MDI reading can also be skewed by a temporary loading situation.
- Analysis framework needs to be improved to take advantage of the transformer assets already in place. This allows NWL to have a better view of when/where a transformer needs to be replaced, or added to the network. Lifecycle information is currently restricted to a physical condition assessment, and the analysis of the remaining life of a transformer requires intrusive and disruptive testing such as Dissolved Gas Analysis (DGA) on the transformer oil.
- Scheduling regular maintenance condition assessment patrols can be problematic since equipment may be installed in locations that are difficult to access.

Network Waitaki
Powering North Otago

DISTRIBUTION TRANSFORMER MONITORING SOLUTION

Itron's DTM solution provides accurate monitoring, supervision, and assessment of a transformer's condition and environment. Seamless integration into the Itron Cloud Services Platform allows data to be analyzed, processed and displayed easily and efficiently. The components delivered as part of the DTM solution are:

» DTM Unit: Itron's three-phase meter is installed on the Low Voltage (LV) side of a transformer. The current sensors provide accuracy over the entire current range of the transformer using Rogowski coils. The DTM unit meets IEC62053-21 requirements for CI0.5 accuracy. Communication between the DTM units and the remote reading system will be provided by cellular modem or direct connect ethernet. The modems are powered by the meter and modular by design, thus, allowing the flexibility to change the modem and communication media without impacting the service.

» Itron Total Outcomes for DTM covers the complete set of use cases and services related to the DTM solution. This service is hosted, flexible and can be provided either as Software as a Service or as Outcomes as a Service. Itron Total Outcomes includes the IT infrastructure, software licenses and system administration and implements the following services:

- Data Collection: Collects, stores and manages data from the DTM unit.
- Analytics Platform: Receives DTM data and calculates transformer loading, phase balancing, transformer life, etc.
- Dashboards and User Interface: Displays the data retrieved from the DTM unit and information processed by the Analytics Platform.

FIELD TRIAL BETWEEN NWL AND ITRON

NWL is currently trialing Itron Total Outcomes for DTM. Eight DTM units were installed in the field (see Figure 1 for an illustrative field configuration) between August and December 2016. The DTM units are each connected to a transformer in the downtown area of Oamaru (see Figure 2.).

The DTM units have been read daily since the installation. During the past year, feedback from the NWL engineering team has helped improve the analytic dashboards. Additionally, feature improvements to the cellular modem allowed NWL to receive real-time alarm information.

As NWL gained insight on the loading of the DTM connected transformers, they took advantage of the versatility of the DTM solution and moved one of the DTM units to a different transformer which needed more detailed analysis. This highlights the potential to monitor high value assets and maintain a "pool" of DTM units which can be used on a rotating basis for lower-value equipment when deploying a DTM solution.
This function was previously achieved by the temporary installation of voltage data loggers, which need to have information manually downloaded and are more focused on voltage quality than the impact on the transformer. Figure 3 displays an illustrative screenshot showing a DTM unit with an alarm.

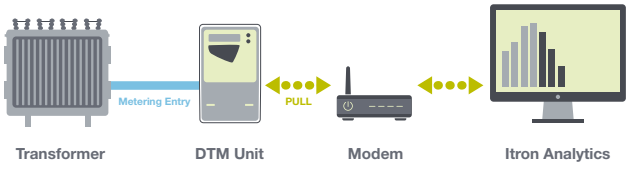


Figure 1 — Field Configuration of DTM Units

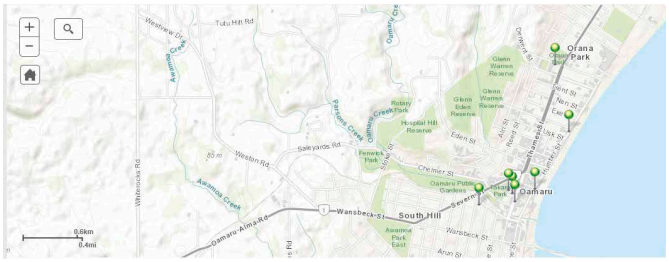


Figure 2 — DTM Unit Map in Oamaru

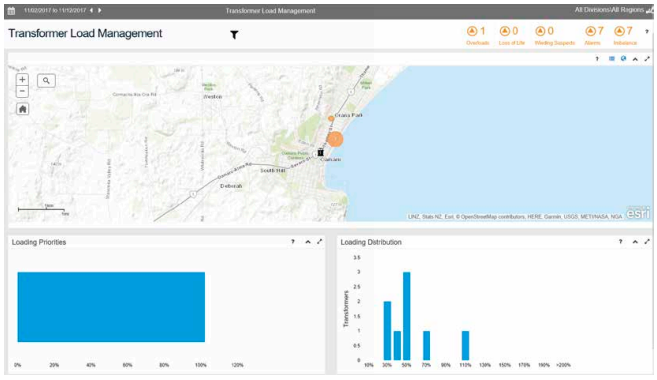


Figure 3 – Map of DTM Unit with Alarm

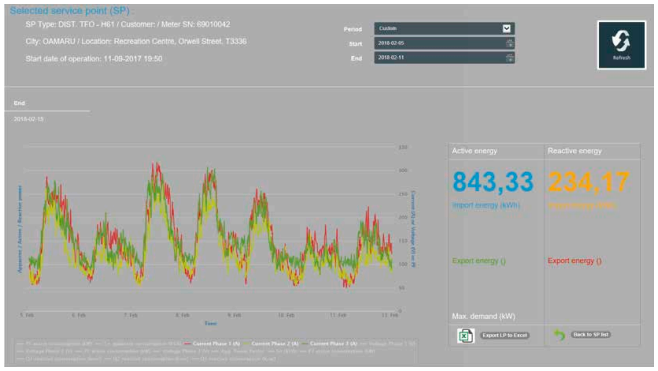


Figure 4 — Illustrative Load Profile

BENEFITS FOR NWL

Better Asset Utilization

The DTM Solution trial demonstrated the fact that some transformers were not used as efficiently as possible. For example, the transformer T69010043 showed that, daily, there were peaks of current happening during the night, up to the nominal current rating of the transformer. However, during the day, the consumption of the transformer was low. Illustrative load profile of the transformer is shown in Figure 4.

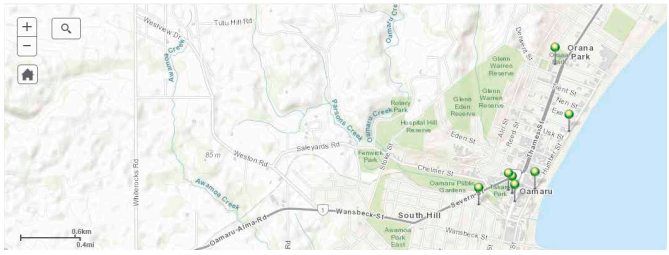
The subsequent analysis provided insight into the utilization and lifecycle of the transformer. With a standard MDI meter, the transformer would have been marked as overloaded and scheduled for replacement with a larger transformer. The information obtained from the DTM solution provided a detailed profile showing the load cycling in a manner which is well within the rating of the transformer (20% overload for less than four hours in a 24-hour period).

Armed with this data, NWL's operations staff proposed to use the available transformer capacity outside of the high load periods to offload other transformers in the area during planned or reactive shutdowns. With recent concerns in the New Zealand electrical industry around the use of live line work, there are additional shutdowns being planned. The DTM solution will enable better and more effective planning when LV network offloads can be performed with minimal impact on customers and assets.

In addition to the peak load information, the DTM solution can provide information regarding phase balancing of the transformer. Figure 5 shows a quick snapshot showing the transformer list in the NWL trial and relevant data for each one. As is shown in Figure 5, the user can see which transformers are unbalanced and by what percentage.

In this case, transformer 69010200 shows a phase imbalance of 58.1%. By drilling down into the imbalance investigation further, additional information on the transformer loading can be displayed by clicking the hyperlink associated with the transformer. After clicking on the hyperlink, and selecting Amps as the display parameter, Figure 6 shows the individual current phases, and Phase A seems to be slightly out of balance when compared to Phase B and Phase C.

However, due to the underloading of the transformer, this imbalance is not affecting the transformer lifespan. Any additional growth should be concentrated on Phase C and then Phase B, while continuing to monitor the transformer performance. Continuous monitoring allows maximum use of the service potential.



List of Transformers

Locate	Transformer ID	Nameplate Rating (kVA)	Peak kVA	Peak Utilization (%)	Imbalance (%)	Percent Loss (%)	Loss of Life (%)	Hot Spot Temp (deg C)
	Trnsfmr_690100	500.0	217.0	43.4	11.6	0.0	0.00	58.1
	Trnsfmr_690100	500.0	511.0	102.2	25.3	0.0	0.00	101.2
	Trnsfmr_690101	500.0	222.0	44.4	21.3	0.0	0.00	54.7
	Trnsfmr_690101	750.0	224.0	29.9	23.7	0.0	0.00	55.1
	Trnsfmr_690102	300.0	92.0	30.7	54.6	0.0	0.00	49.9
	Trnsfmr_690102	300.0	82.0	27.3	18.9	0.0	0.00	47.1
	Trnsfmr_690102	300.0	205.0	68.3	12.6	0.0	0.00	65.5

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Figure 5 — Transformer Balancing Detail

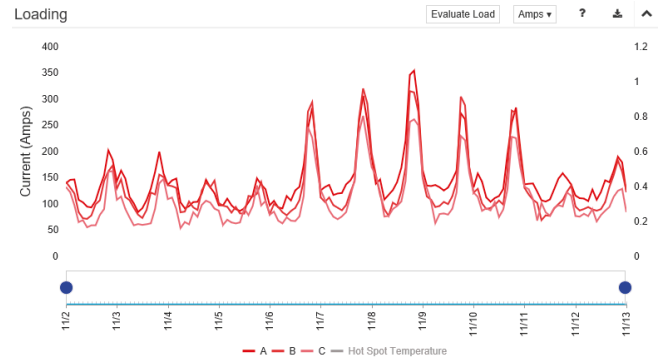

Figure 6 - Individual Current Phases

Monitoring of Underground Transformers

Several of NWL's transformers are installed in underground substations. These locations are under a main highway or at customer premises which can be very difficult to access for maintenance (almost impossible to visit them). As a result, these transformers cannot be maintained easily so monitoring them is critical. The DTM solution provides visibility to these transformers, and the information received helps to plan maintenance when alarms are activated or the load utilization causes concern.

The DTM solution also can integrate simple digital I/O (Input/Output) with the DTM unit which allows provisioning of additional "non-meter" alarms such as enclosure security, water sump level alarms and enclosure temperature alarms.

Load Planning

Itron Total Outcomes for DTM provides network load information daily. This addresses several transformer concerns raised by NWL:

» Load and peak time information is provided, at 10-minute intervals, confirming the exact time when the peak load happens in the network. The existing system, MDI, does not provide this type of granular information. MDI systems have a 30-minute hysteresis and are only read once per year. Moreover, MDI data can be corrupted when extra load is shifted to a transformer for fault restoration or in maintenance situations.

» Over- or under-utilized transformers: Itron Total Outcomes for DTM provides clear and concise information on the load of the connected transformer., Based on this, NWL can decide to replace assets based on lifecycle information, upgrade capacity at a distribution substation or use assets more efficiently, depending if the transformers are over or under-utilized.

» The DTM solution allows a better capital renewal planning process, thanks to the accurate, timely and periodic data on asset performance. This solution enables NWL to be better positioned for long-term planning by analyzing data on the day-to-day use of the transformer assets in the field. As DTM units are rolled out across their network, NWL can develop and improve transformer load profiles based on the type of connected load. This will, in turn, allow NWL to focus asset management resources where they are most needed and ensure greater network operational efficiency.

Network Quality and Bad Power Factor

A DTM unit in the trial group revealed an unacceptable power factor at one of the transformer sites (See Figure 7). This information prompted NWL to carry out a detailed investigation with the connected customers and identify the cause of the problem and a solution was implemented to solve this quality issue.

Response to Outage Incidents in the Field

Having real-time and historical data from the DTM solution provides a window into the operational characteristics of the Low Voltage distribution network. This information can be used to provide early and targeted response to faults or power quality issues in the distribution network that would have previously only come to light when customers complained about a service outage. Not only does this improve the quality of service for NWL customers, in many cases, it also allows a response to a situation before it escalates into something larger. This can reduce the effect on SAIDI[2] and SAIFI[3] and the potential cost of the response.

The ability to look at historical loading and transformer data allows NWL engineers to revisit site conditions in the wake of an intermittent supply quality complaint. This can help identify the source of the problem, which can sometimes be problematic to track down after the fact.

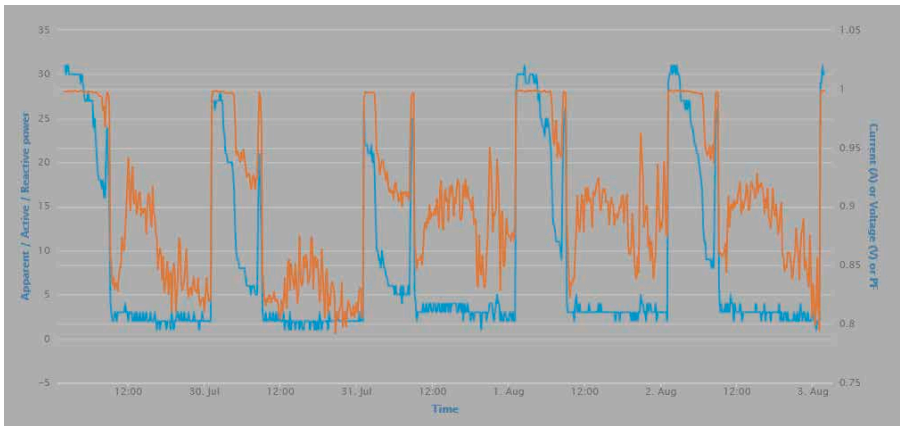

Figure 7 — Unacceptable Power Factor Detail

NEXT STEPS

Some features of the Itron Total Outcomes for DTM solution were not initially deployed at the start of the field trial but have been added to the DTM solution installed at NWL. Additional features will be installed as they become available.

Real-time Notification

The real-time notification feature, allows NWL to receive real-time information from field assets for the critical alarms that need to be tracked:

- Voltage cuts, sags, swells
- Hot spot temperature
- Fraud events
- Reverse flow of energy
- Current over limit
- Unbalanced load or voltage detected

This information is critical in improving response time from NWL, and will lead to greater customer satisfaction and increased SAIDI performance.

On-demand Reading

The on-demand read feature is particularly important when an initial level of investigation is needed on a transformer. Getting this information allows NWL to retrieve instantaneous values of the DTM unit, and perform a quick analysis of the transformer when an error occurs.

This capability is also useful when transformer loads are adjusted. As loads are removed from the transformer, it is critical to ensure that the appropriate amount of load is removed in real time. Conversely, if additional load is being added to the transformer, the amount of load can be adjusted easily to keep the loading within the transformer usage parameters.

When used in combination with voltage regulation, on-demand reading allows to verify in real time that the voltage levels remain inside the voltage thresholds after a regulation, thus avoiding possible quality issues.

Non-technical Losses

Non-technical losses or energy balancing can be linked to possible theft of energy. Although not being used currently by NWL, Itron Total Outcomes for DTM can load the usage information of all the consumer service points linked to each transformer and compare this data to the energy being supplied by the transformer as recorded by the DTM unit. Using this data, Itron Total Outcomes can provide an energy efficiency rating for each transformer. Going further, Itron Total Outcomes can provide a list of potential theft candidates associated with this efficiency rate, and prioritize the investigation. To further assist in the investigation, another DTM unit can also be installed temporarily as a check meter which is in parallel to the existing consumer billing meter. Comparing the check meter billing data with the existing consumer billing data can provide evidence that a theft has occurred.

Data Integration with Other Network Information Systems (Future)

Integration with an asset management system means that data can be automatically stored with individual asset records to allow better asset management, which may include automatic scheduling of maintenance and/or replacement of transformers. This is done via a web services interface.

Data from Itron Total Outcomes for DTM will be stored in the GIS system of record. This data will provide long-term trend information which can be combined with other data sets such as census or income data to allow predictive load growth planning. NWL engineers will have access to this information to provide more certainty about equipment capacity when planning new connections to the network. This is expected to become an increased area of concern with the proliferation of embedded solar, battery storage and electric vehicle loads. Maintaining realistic energy usage profiles showing peaks will be key when planning network expansion.

Transformer Ageing Rate (Future)

Thermal algorithm calculations embedded inside the DTM unit use standard mathematical models defined in IEC60076-7 to determine:

- Oil temperature of the transformer
- Hot spot temperature
- Ageing rate of the transformer

This will allow NWL to list and prioritize the replacement of transformers with the highest ageing rate, as well as estimate the transformer replacement date, based on the history of the ageing rate.

Medium Voltage Monitoring (Future)

The DTM solution uses the transformer tap setting as well as the information gathered on the low voltage network to provide visibility into the medium voltage network. Itron Total Outcomes can provide load profile information as it relates to high voltage feeders on the 11kV network.

CONCLUSION

As the NWL DTM solution trial winds down, the information gathered to date has allowed NWL to make informed decisions as it relates to their transformer assets. NWL is currently planning on deploying additional DTM units into their network to continue monitoring their assets and low voltage distribution network.

[1] Network Waitaki owns and operates a predominantly rural network, supplying the North Otago, Hakataramea and Ahuriri regions. Its core business is the provision, operation, and management of electricity infrastructure. Network Waitaki services approximately 12,700 consumer connections across a network of 1,800 km of power lines.

[2] The System Average Interruption Duration Index (SAIDI) is commonly used as a reliability indicator by electric power utilities. SAIDI is the average outage duration for each customer served, and is calculated as:

$$\text{SAIDI} = \frac{\text{Sum of all customers interruption durations}}{\text{Total number of customers served}}$$

[3] The System Average Interruption Frequency Index (SAIFI) is commonly used as a reliability indicator by electric power utilities. SAIFI is the average number of interruptions that a customer would experience, and is calculated as:

$$\text{SAIDI} = \frac{\text{Total number of customer interruptions}}{\text{Total number of customers served}}$$

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