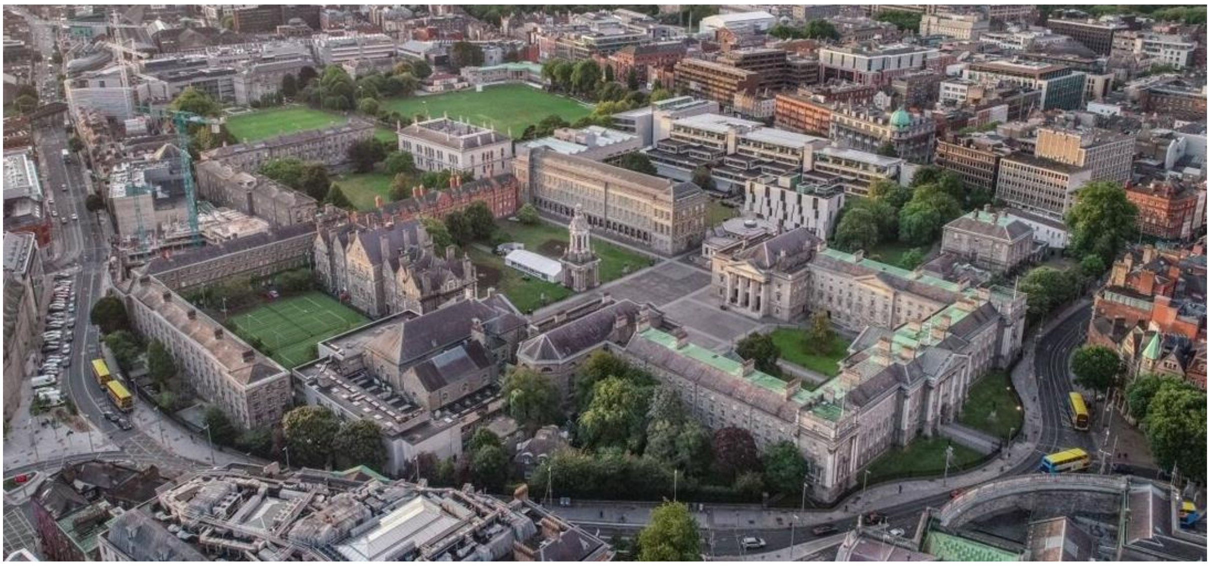
Trinity Smart Grid



Trinity Smart Grid (Oct 2018 to April 2020) was a central part of an SEAI-funded Research & Development project led by the School of Physics in collaboration with Estates & Facilities to monitor at the low-voltage (LV) transformers the power flows within several buildings on the main campus of Trinity College.

As with many large energy users, Trinity receives its electricity from the national power grid at medium voltage (MV) and operates its own local low-voltage power grid assets. We developed a custom grid monitoring technology to collect data on Trinity College's local grid over the course of the project which could identify individual load switching downstream of our technology..

This non-intrusive load monitoring (NILM) technology was developed entirely in the School of Physics and consisted of a multi-channel LV voltage and current signal acquisition hardware unit, a cloud server and a data analytics platform. The cloud streaming electrical power data analytics capabilities of the transformer monitoring technology was designed to produce outputs that have the capability to change how consumers use energy by "disaggregating" (separating) the load at the grid level, which can help in lowering barriers to achieving this goal.

The proposed solution was expected to identify energy saving opportunities. The technology is specifically designed to classify the major power users on a power line. This allowed Trinity College operations staff to make more informed decisions to achieve their energy savings goals. With Trinity's 25,000 staff and students, and 1,000,000 annual visitors (pre COVID-19), this project was one of the first of its kind to implement load disaggregation on this scale, and as such represents the highest standard of international-class RD&D.

CRANN Chiller replacement

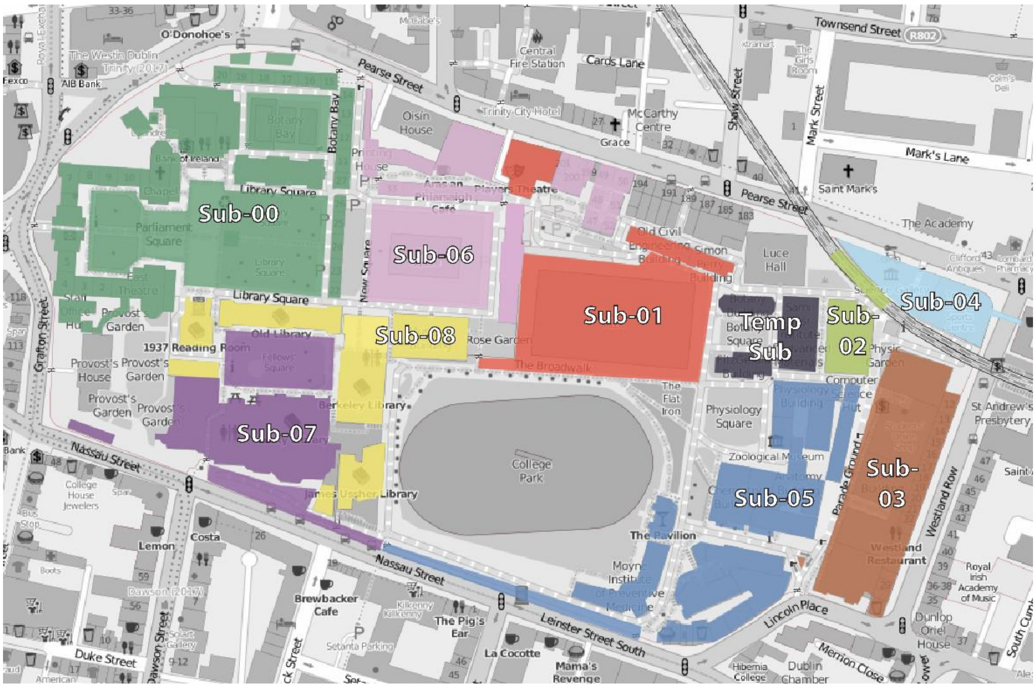


Figure 1: Map of Trinity College Dublin's main campus with the areas served by each of the 10 substations separately coloured and labelled (as of 2018)

The Trinity College Dublin MV/LV network consists of 10 substations that transform medium voltage to low voltage, with the layout shown in Figure 1. The overall campus MV network has undergone a major €4.3M upgrade, with works completed in January 2018. This upgrade has changed the topography of the local grid, with substations moved and/or replaced, cabling reinforced, and the level of the voltage adjusted.

TCD's annual electricity bill is approximately €3.5M, so even very modest energy savings through NILM and human behaviour analysis of up to 5% would result in an annual cost saving of up to €175,000.

Our equipment was installed at a small number of campus locations (Sub-03, Sub-04 and Sub-08) which accounted for around 40% of the total energy consumed on campus and gathered detailed information on power usage and quality over 18 months. During this time, we identified several opportunities for energy savings.

The biggest success of the project was achieved in August 2019, when anomalous electrical behaviour was detected in substation Sub-04. Frequent current spikes were observed, large enough to draw voltage levels down to below statutory levels. Working with Estates & Facilities it was determined that the cause of the behaviour was a large water chiller in the CRANN building, which, according to our disaggregation methods, was responsible for around one quarter of the total power consumed in Sub-04. When the chiller was replaced with a more modern unit, the power quality issues disappeared and consumption in Sub-04 dropped from around 80,000 kWh per week to around 68,500 kWh per week (see Table 1). This amounts to energy savings of over €70,000 per year (2% of the total energy budget), in addition to preventing detrimental knock-on effects that could have been caused by the bad power quality.

	Chiller A	No chiller	Chiller B
Period	Before 16 August 2019	16 – 23 August 2019	From 23 August 2019
Energy consumption	80,040 kWh/wk	58,910 kWh/wk	68,490 kWh/wk
Energy cost [a)]	€9,850/wk	€7,310/wk	€8,490/wk
Proportion of total energy consumed in Sub-04	26%	-	14%
Power factor	Frequent severe pf > 0.95 violations on all phases	Few minor pf > 0.95 violations on a single phase [b)]	Frequent minor pf > 0.95 violations on a single phase [b)]
Power quality	Frequent current spikes (>2000A) detected pulling down voltage below statutory limits	No issues detected	No issues detected

a) Based on a day rate of €0.15/kWh and a night rate of €0.07/kWh incl. VAT, with daytime defined as 8am – 11pm
b) These detected violations may be within calibration inaccuracy and should be confirmed using a commercial power factor analyser

Table 1: Savings realised by replacement of chiller in CRANN

The Berkeley Library

The data for Christmas 2019 was analysed manually in early January. We developed a tool for extracting the on/off event waveforms and with the biggest loads it was easy to track their operation. The following waveform examples represent the switching on of the air system (Figure 2) and the storage heating (Figure 3) in the Berkeley Library.

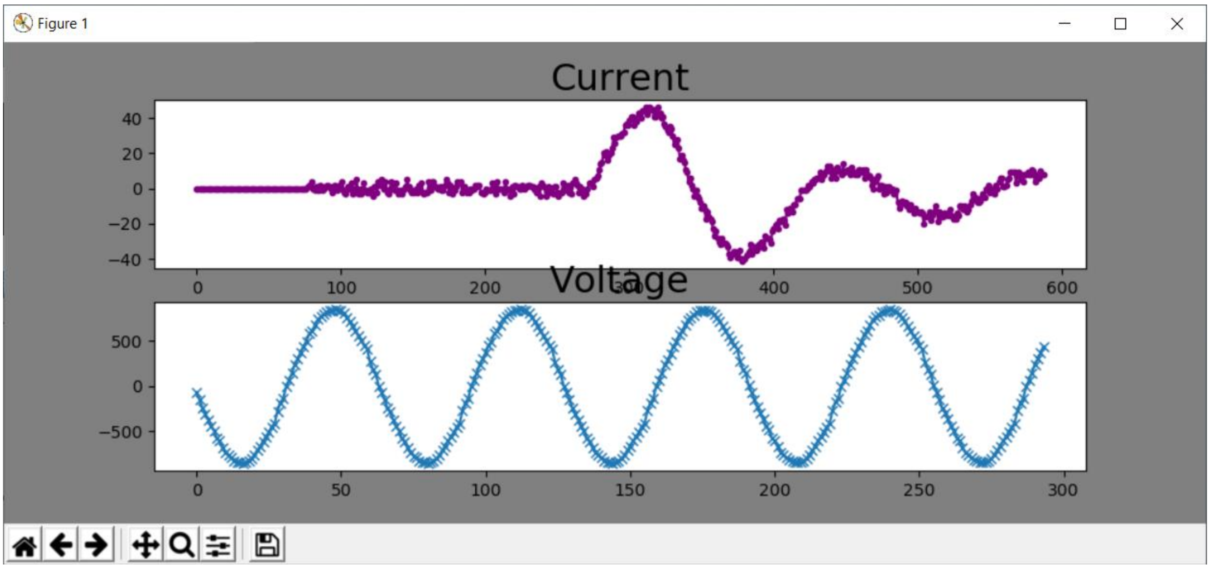


Figure 2: Switch-on signature of the ventilation system in the Berkeley Library

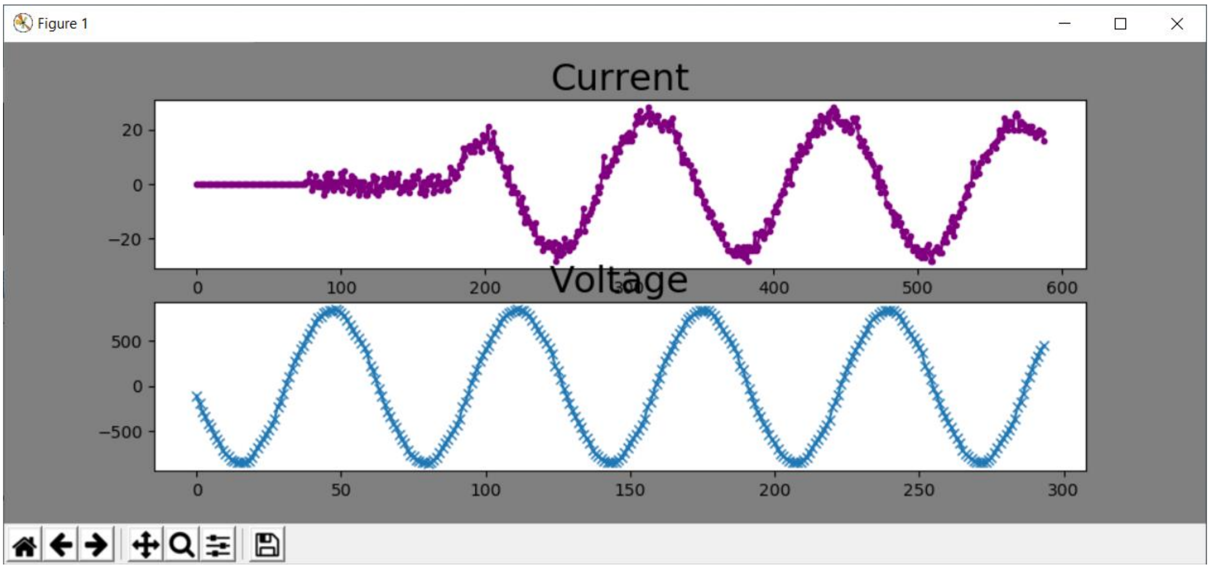


Figure 3: Switch-on signature of the storage heating system in the Berkeley Library

It was realised that the air system had been running during the Christmas shutdown. When this was presented to Estates and Facilities the problem was identified within the controls. Though the energy waste was only of the order of €1,000, if unaddressed the problem could have cost significantly more during the subsequent Covid-19 shutdown.

Further Work

One of the learnings from this project was that a great deal of the load on the campus and in industry is made up of induction motors. We have since progressed to installing a unit with a major American pharmaceutical plant in South Dublin. We are now advancing the system to focus on the electrical signatures of induction motors for the purpose of condition monitoring to allow for predictive maintenance.

Acknowledgement

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