Energy Research and Development Division
FINAL PROJECT REPORT

LOW-COST, SCALABLE, FAST DEMAND RESPONSE FOR MUNICIPAL WASTEWATER AND RECYCLING FACILITIES

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Prepared by: AutoGrid Systems and Lawrence Berkeley National Laboratory

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PREFACE

The California Energy Commission Energy Research and Development Division supports public interest energy research and development that will help improve the quality of life in California by bringing environmentally safe, affordable, and reliable energy services and products to the marketplace.

The Energy Research and Development Division conducts public interest research, development, and demonstration (RD&D) projects to benefit California.

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Low-cost, Scalable, Fast Demand Response for Municipal Wastewater and Recycling Facilities is the final report for the PIR-11-007, conducted by AutoGrid Systems Inc. The information from this project contributes to the Energy Research and Development Division's Industrial/Agricultural/Water End-Use Energy Efficiency Program.

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ABSTRACT

This project demonstrated that existing off-the-shelf information technology and controls equipment, originally developed for energy efficiency and energy monitoring needs, can be used to provide demand response while matching or surpassing the performance of existing devices. The project demonstrated how industrial facilities such as wastewater treatment facilities and recycling plants could provide fast automated demand response in California. The contractor selected Sunnyvale Materials Recovery and Transfer Station and Donald M. Somers Water Pollution Control Plant in Sunnyvale, California as the sites to demonstrate the AutoGrid System Inc.'s Demand Response and Optimization Management System.

The project team analyzed the operations and process at each of the industrial facilities, identified and quantified load shed/shift that could participate in demand response events. At the Donald M. Somers Water Pollution Control Plant in Sunnyvale California, approximately 150 kilowatts of demand response potential was identified (from aerators, pumps, and fans). At the Sunnyvale Materials Recovery and Transfer Station, approximately 200 kilowatts of demand response was identified from two equipment (conveyor belt motor and wood grinder).

After enabling the facilities with the required controls and telemetry, they were linked to AutoGrid's Demand Response and Optimization Management System platform and several demand response tests were carried out. GridView's platform was used to remotely monitor and record the magnitude of load sheds. At the Sunnyvale Materials Recovery and Transfer Station 200 kilowatts were shed. 160 kilowatts were shed at the Donald M. Somers Water Pollution Control Plant.

Keywords: Demand Response, Automated Demand Response, DR, AutoDR, Wastewater, OpenADR, DROMS.

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EXECUTIVE SUMMARY

Introduction

This project demonstrated how industrial facilities such as wastewater treatment and recycling plants could provide fast demand response (DR) within California and, therefore, participate in the regulation and ancillary services market (to maintain power quality and reliability). AutoGrid Systems Inc. and Lawrence Berkeley National Laboratory (LBNL) aimed to demonstrate that through OpenADR2.0b based automated demand response (Auto-DR), industrial facilities are capable of providing fast responding, fast ramping, dispatchable, auditable, and geographically pin-pointed virtual generation to the grid. This virtual generation could be used to solve accuracy, capacity, intermittency, and congestion problems of the grid for a tenth of the cost of existing supply side and storage technologies. These facilities would directly benefit financially, play a crucial role in achieving renewable generation penetration in the grid and provide significant economic and environmental benefit to California.

With economies of scale, GRIDlinkADR, Cellular Gateway, and all other materials, including the sub-meters, will cost about $4,500 and assembly and installation costs are about $5,000 for each unit, for a grand total of under $10,000.

Project Purpose

The Demand Response Optimization and Management System (DROMS) developed by AutoGrid Systems Inc. was demonstrated at Sunnyvale Materials Recovery and Transfer Station and Donald M. Somers Water Pollution Control Plant in Sunnyvale California.

This project provided quantitative and measurable benefits in numerous areas:

Energy Cost and Demand Savings

- Ten percent reduction in peak demand at the industrial sites.
- Ten percent reduction in demand charges during the summer months at the industrial sites.
- Ability to provide ancillary services at less than $100 per kilowatt (kW) for facilities that can shed a load of 100 kW or more and less than $50 per kW for facilities that can shed load of 200 kW or more.

Technology and Innovation

- Identifying and testing telemetry equipment capable of providing ancillary services to the grid at less than $10,000 per site.
- Demonstrate a payback period of 24-months or less to the facility for the cost of equipment.
- Simultaneous support of OpenADR1.0 and OpenADR2.0 protocols.
- Demonstrate Open-ADR's ability to interface with facilities legacy control systems.

Project Process

Sunnyvale Materials Recovery and Transfer (SMaRT) Station and Sunnyvale Water Pollution Control Plant (WPCP), service the cities of Mountain View, Palo Alto, and Sunnyvale. Both industrial facilities serve as reference for other wastewater treatment and industrial plants consuming significant amounts of electricity. These facilities participated in not only traditional utility DR programs targeted at reducing the peak demand, but also new and emerging DR programs designed to provide fast responding ancillary services to the grid to support large scale integration of renewable generation using the DROMS platform.

The operations and processes at each of the industrial facilities were analyzed by LBNL researchers. Load analysis at each facility identified potential power load shed or shift strategies that have minimum or no impact on the facility's normal operations. Load shed potentials were quantified for equipment at each facility. Controls and telemetry were installed at the facilities, then linked to AutoGrid's DROMS platform and several DR tests were conducted at each facility to demonstrate the technology.

Project Results

DR tests were carried out at both facilities using DROMS. At each facility selected equipment was turned off for the duration of the test events. The magnitude of load curtailments was remotely monitored and recorded through GridView's platform. SMaRT Station successfully switched off the wood grinder and sorting room conveyer belt resulting in overall 200 kW of shed. WPCP turned off all four of the pre-selected equipment pieces, pond aerators, pond recirculation pumps, digester pumps, and backwash pumps, resulting in an overall curtailment of 160 kW.

All personnel were notified a day before, and again 30 minutes before each test event. All tests were completed successfully with full automation through AutoGrid's DROMS. No disruption to a facility's core operation was recorded and operators managed to perform labor redistribution with no safety hazard to plant personnel. At the end of the project, the researchers demonstrated that the off-the-shelf information technology (IT) and controls equipment provided DR and surpassed the performance of existing devices at 10-20 percent of the cost proposed in Southern California Edison's (SCE) rate case application (SCE, 2011).

Project Benefits

Deploying Open Automatic Demand Response (OpenADR2.0) at industrial facilities will act as an industry reference for OpenADR2.0 distribution in California. The concepts demonstrated through this pilot project have the potential to transform energy transmission and distribution in California and the United States, improving grid reliability with Distributed Generation. The knowledge and experience gained from the demonstrations encourages exporting this technology from California to the rest of the world, creating jobs and revenue growth for the state.

CHAPTER 1: Background

1.1 Demonstrating Fast, Scalable Automated Demand Response

Demand response (DR) is being considered as a valuable resource for keeping the electrical grid stable and efficient, and deferring upgrades to generation, transmission, and distribution systems. However, simulations to determine how long infrastructure upgrades can be deferred are necessary in order to plan for the upgrades.

To meet renewable energy portfolio standards (RPS) deployment goals, it is forecasted that more than 4 gigawatts (GW) of additional ancillary services will be needed in California alone by 2020 to maintain grid stability (KEMA, 2010). Without more innovative approaches, this demand will be met by fossil fuel based generation, significantly diluting the environmental benefits associated with renewable generation and increasing the overall cost of electricity for the ratepayers. The industrial and agricultural sector within California consumes roughly 30 percent of all electricity in the state. Water treatment comprises about 3 percent of the total annual energy use in the United States and wastewater treatment facilities in California alone consumed 2,012 gigawatt hours (GWh) of electricity in 2001 (Thompson, Song, Lekov, & McKane, 2008)

This project evaluated and demonstrated the capabilities of Auto-DR in wastewater treatment and recycling facilities, facilitated peak load reduction, and enabled participation in grid balancing programs such as ancillary services, which will aid integrating renewable generation into California's energy portfolio.

Through this project, the researchers brought several innovative technologies already proven in laboratory settings at leading academic institutions in California and demonstrated their applicability in mainstream industrial settings. The project demonstrated the use of automated demand response, using AutoGrid's Demand Response Optimization and Management System (DROMS) at two industrial facilities, Sunnyvale's Water Pollution Control Plant and the Sunnyvale Materials Recovery and Transfer Station, SMaRT Station®.

In addition to serving as reference for facilities such as wastewater treatment and recycling plants to provide fast DR within California, this project will also serve as an industry reference for OpenADR 2.0b deployment within California for these and other types of facilities.

Another key goal of this program was demonstrating that off-the-shelf communication technology based on open standards and Internet protocols can be adapted and used for fast DR application and can provide a superior level of security and reliability for mission-critical grid operations. This, along with a cloud-based deployment of the system that eliminates a large upfront IT expense will remove initial barriers to adoption for demand response by significantly lowering the cost of participating in DR programs. By making it more attractive for these facilities to participate in DR programs, the project will foster increased overall market

acceptance for DR and demand side management programs and will provide significant economic and environmental benefit to California.

1.2 Applicable Demand Response Programs

Most customers simply don't have enough time to understand the various rates offered by utilities or the capability to monitor and forecast market prices signals to participate in. Automated DR has already led to over 200 megawatts (MW) of OpenADR implementation in California by the end of 2011[1].

Ancillary services are support services in the power system and are essential in maintaining power quality and reliability. There are typically two types of ancillary services products that DR participates in: contingency and operating reserves. Regulation, the product with the fastest communication requirements in ancillary services markets, allows the system operator to request upward or downward changes in output. Regulation is used to track and balance system-wide generator output with system-wide load on a sub-minute by sub-minute basis (Kiliccote, Lanzisera, Liao, Schetrit, & Piette, Fast DR: Controlling Small Loads over the Internet, 2014). Only in California and the Electricity Reliability Council of Texas, regulation is separated into two products; these are regulation up and regulation down. In all other markets, regulation products are symmetric, meaning the generator signs up to deliver as much regulation up as down product (Kiliccote, Lanzisera, Liao, Schetrit, & Piette, Fast DR: Controlling Small Loads over the Internet, 2014).

Table 1: Summary of Ancillary Services for Fast DR Participation

Service	**Service Description**		
	Response Speed	*Duration*	*Market Cycle*
Operating Reserves			
Regulating Reserves, or Regulation up/down; AGC; Frequency responsive reserves	Online/Spinning reserve, immediately responsive to Automatic Generation Control (AGC) to allow the Balancing Authority to meet the NERC Real Power Balancing Control Performance.		
	<1 minute; must be able to reach max amount of Reg within 10-30 min	*30 min (Real Time); 60 Min (Day Ahead)*	*Hourly; every 15 minutes looking ahead 2 hours*
Load Following or Fast Energy Markets	Similar to regulation but slower. Bridges between the regulation service and the hourly energy markets.		
	~10 Minutes	*10 minutes to hours*	*5 min*
Contingency Reserves			
Spinning Reserves	Online Generation, synchronized to the grid, that can increase output immediately in response to a major generator or transmission outage and can reach full output within 10 minutes		

[1] http://www.openadr.org/assets/docs/understanding%20openadr%202%200%20webinar_11_10_11_sm.pdf

	Instantaneous response; <10 minutes for full output	*30 minutes*	*10 min*
Non-Spinning Reserve	Same as spinning reserve, but need not respond immediately; resources can be offline but still must be capable of reaching full bid within the required 10 minutes		
	< 10 minutes	*30 minutes*	*10 min*

Source: (Kiliccote, Lanzisera, Liao, Schetrit, & Piette, Fast DR: Controlling Small Loads over the Internet, 2014)

1.2.1 CAISO Proxy Demand Response Programs

CAISO permits demand side resources to participate in the ancillary services market under a limited set of conditions[2]. The Proxy Demand Response (PDR) program is the primary means by which larger side resources can participate. For a single load to bid into the market as a resource, it must be able to provide at least 100 kW of shed, and the bid increment past 100 kW is 10 kW (e.g. resource can bid 110 kW into the market but not 105 kW). The following markets can bid into with a demand side resource:

- Day-ahead energy market including Residential Unit Commitment.
- Day-ahead and Real-Time Non-Spinning Reserve market.
- 5-Minute Real-Time Energy market.

To participate in these markets, the resource must provide sufficient telemetry data and also have a CAISO certified meter or settlement. A system for providing PDR to the CAISO must have a hardware profile that meets CAISO requirements and enable the required interactions[3].

1.2.2 Intermittent Renewable Management Pilot Phase 2[4]

Intermittent Renewable Management Pilot Phase 2 (IRM2) is a PG&E Pilot focused on integrating demand-side resources into the CAISO market. The IRM2 enables participants to earn capacity and wholesale payments through direct participation in the CAISO using the PDR product. While the initial phase of the pilot is limited to the Day-Ahead Market, a subsequent phase will add Real-Time markets and services (Olivine Inc., 2014).

SMaRT station and WPCP qualify for this program under the program requirements by meeting the following criteria:

- One or more customers within a single region as defined by the CAISO (Sub Location Aggregation Points or Sub-LAPs) able to be combined into a single demand response resource.

[2] http://www.caiso.com/23bc/23bc873456980.html

[3] http://www.caiso.com/market/Pages/MeteringTelemetry/Default.aspx

[4] http://olivineinc.com/irm2/

- The same load-serving entity (LSE) must serve all customers within a resource.
- The resource able to achieve a minimum curtailment of 100 kW.

1.3 Functional Requirements

1.3.1 Metering and Telemetry

A system for providing Proxy Demand Response to the CAISO must have a hardware, communication, and response profile that meets CAISO requirements. Current requirements are detailed below. For settlement, a meter must meet the following requirements[5]:

- ±0.25 percent at light load (10 percent of rated current) at power factor of 100 percent.
- ±0.20 percent at full load at power factor 100 percent.
- ±0.25 percent at full load at power factor of 50 percent lag.

The meter must also be able to provide five-minute interval data for settlement. A facility's utility meter is usually sufficient for settlement as long as the load shed is observable and quantifiable in the whole facility load data.

For telemetry, the metering requirements are less stringent. Meter accuracy is specified to be within ±2 percent although there is no absolute limit to deviation in energy between the telemetry and settlement meters in any five-minute interval. The CAISO is able to determine on a case-by-case basis if the telemetry meter and settlement meter match well enough. Using a calibrated reference meter, the researchers will need to verify the accuracy of the telemetry meter across load conditions of interest as installed at the facility. This will require the acquisition of a meter known to be accurate to better than 2 percent. In consultation with CAISO, the researchers can determine if this must be done for all meter installations or just a sample to show that the system is reliable by design.

The authors have identified two products lines of meters that are sufficient for their purposes. The first is the Dent Instruments Power Scout[6] line of meters (both 3 channel and 24 channel models). These meters are 0.2 percent accurate nominally excluding errors from the current transducers (CTs). Dent provides a variety of CTs with less than 1percent error to provide an overall system accuracy that should comply with requirements. The second is the Electro-Industries Power Shark 100 meter that provides three channels and has 0.2 percent accuracy nominal hardware. CTs with sufficient accuracy are available with the Power Shark.

The important demonstration questions that need to be addressed are the following: 1) Can researchers reliably control loads simultaneously and with low latency across multiple sites within a specified response time; 2) How reliable is using the internet or 4G cellular network as

[5] http://www.caiso.com/Documents/Specification_ISOLoadMeters_MTR10-99_.pdf

[6] http://www.dentinstruments.com/

the mode of control and metering; and 3) Can off-the-shelf meters provide data for real-time telemetry services. Fast DR is capable of control response in four seconds and loads complete transition in seconds to less than one minute depending on load type. In previous work, LBNL has demonstrated four second regulation services and synchronized load control, and successfully met specifications for ancillary services across the United States. Telemetry via 4G cellular network demonstrated a 94.5 percent success rate, and residential and internet demonstrated a 98 percent success rate (Kiliccote, Lanzisera, Liao, Schetrit, & Piette, Fast DR: Controlling Small Loads over the Internet, 2014).

1.3.2 Communication Protocol

Telemetry can be provided using OpenADR2.0b, and settlement data will be provided through a secondary means to be determined in consultation with the CAISO, the facility, and the serving utility (for the two demonstration sites, the settlement was achieved through Pacific Gas and Electric's [PG&E] normal customer billing procedure).

OpenADR 2.0 is a set of communications signals and systems provided over the internet to allow facilities to automate their demand response with no "human in the loop". OpenADR is intended to standardize DR event information between DR Service providers and consumers.

OpenADR allows DROMS to directly interface with an increasing number of building energy management systems that are already incorporating OpenADR for day-ahead markets, accounting for over 200 MW capacity in California and adopted by over 60 utility and smart-grid vendors.

CHAPTER 2:
Demonstration Sites

2.1 Sunnyvale Materials Recovery and Transfer Station

2.1.1 Description

The Cities of Palo Alto and Mountain View are partners with the City of Sunnyvale for the development and operation of the (SMaRT) Station . Completed in 1993, this permitted facility is being used by the three cities to meet the state mandated goal of 50 percent waste reduction. This facility receives and processes curbside recyclables from the cities of Sunnyvale and Mountain View and will include a buyback recycling center. The facility will also receive and process loads of municipal solid waste and recover materials from the incoming waste stream for the three participating cities. At the SMaRT Station garbage, recyclables and yard trimmings are sorted, processed, and marketed. Unrecyclable material is compacted, loaded, and hauled 27 miles south to the Kirby Canyon Recycling and Disposal Facility in south San Jose (County of Santa Clara, 2011).

Figure 1: Sunnyvale Materials Recovery and Transport (SMaRT) Station

Photo Credit: Google (Left), City of Sunnyvale (Right).

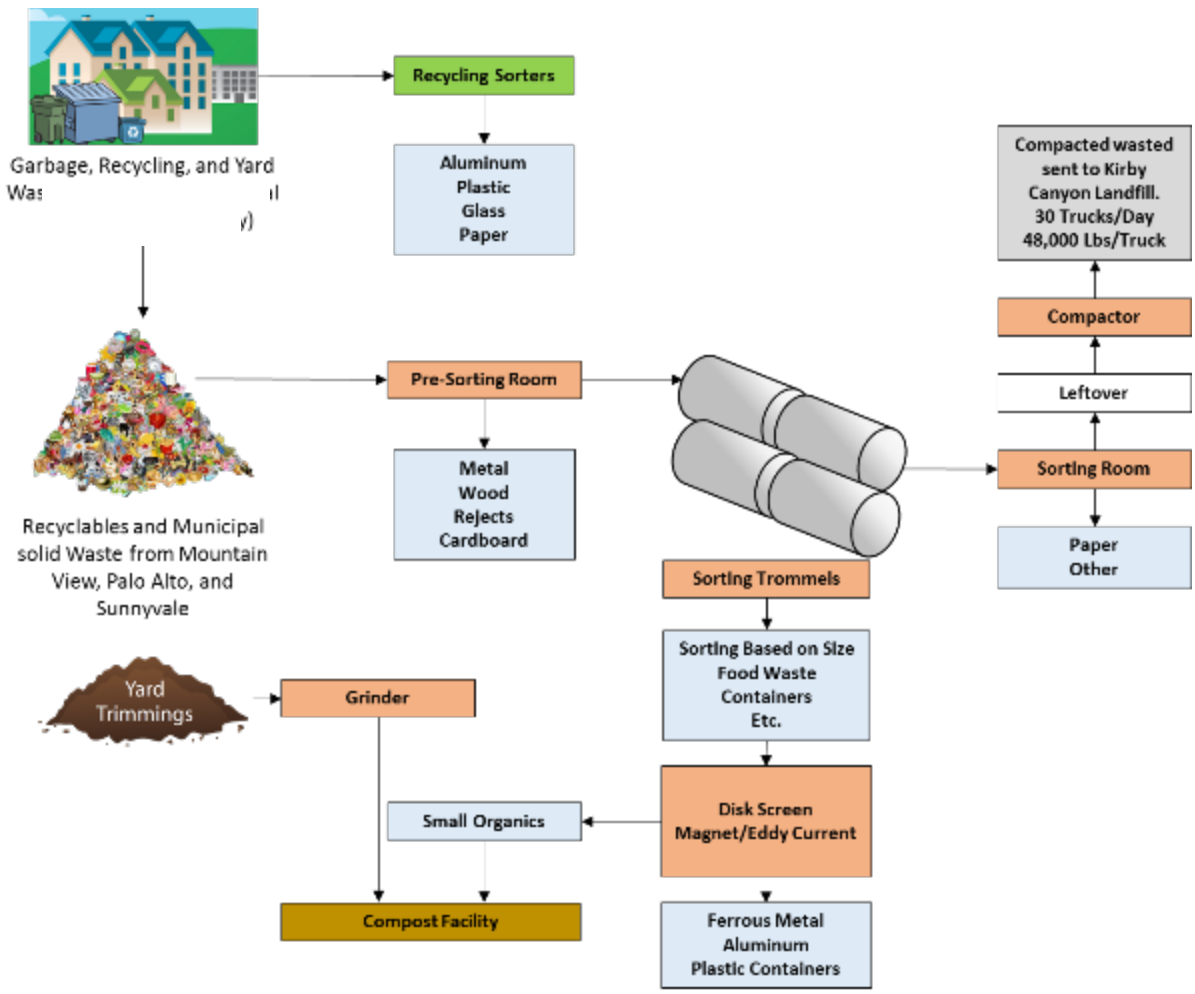
2.1.2 Waste Recycling Process and Plant Operations

Trash and recyclables are brought to the SMaRT station to be sorted and transferred away. Tipping floor is the first stage in the facility. At this stage large items are separated. Then garbage and recyclables go on a dual conveyor belt through a preliminary sorting room where bulky items such as cardboard, carpet and wood are manually separated from the waste stream. Garbage bags are then fed into sorting trommels (large rotating cylinders). In this stage, garbage bags are opened and the contents rotated through the cylinder and separated out by size through a series of holes. Small items, rich in organic material will fall out first; larger items fall out through the larger set of holes including recyclables. Automatic sorting continues by size and type using magnets, disk screen sorter and an eddy current that pulls out steel and aluminum. Plastics need to be manually separated. The stream that emerges at the end of the

trommels contains mostly paper which needs to be manually pulled out and sent to recycling. All the material from this recovery process that cannot be pulled out or recycled will be sent to the compactor where it will be compressed and sent out to Kirby Canyon landfill in South San Jose. The material in the landfill will stay there indefinitely as very little decomposition happens there.

Along with garbage and recycling, yard trimmings are also delivered to the SMaRT station. Yard trimmings are collected and put through a grinder and then transported to a composting facility. Figure 2 summarizes the operations of the SMaRT station in a simple flow diagram.

Figure 2: SMaRT Station Process Diagram

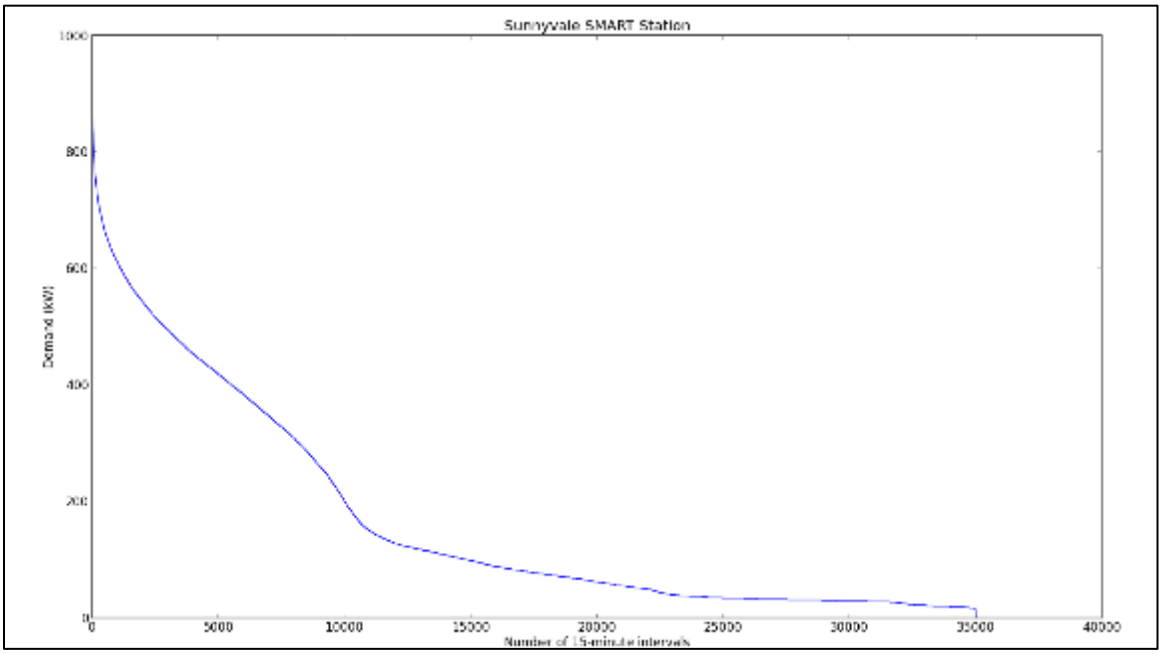


Source: AutoGrid Systems Inc. Study of plant

2.1.3 Load Profiles

The demand seen at the SMaRT station over the sampled interval (01/01/2011-12/31/2011) ranged from 0-965 kW, with an average of 166 kW. Figure 3 represent the annual load duration curve for the SMaRT station.

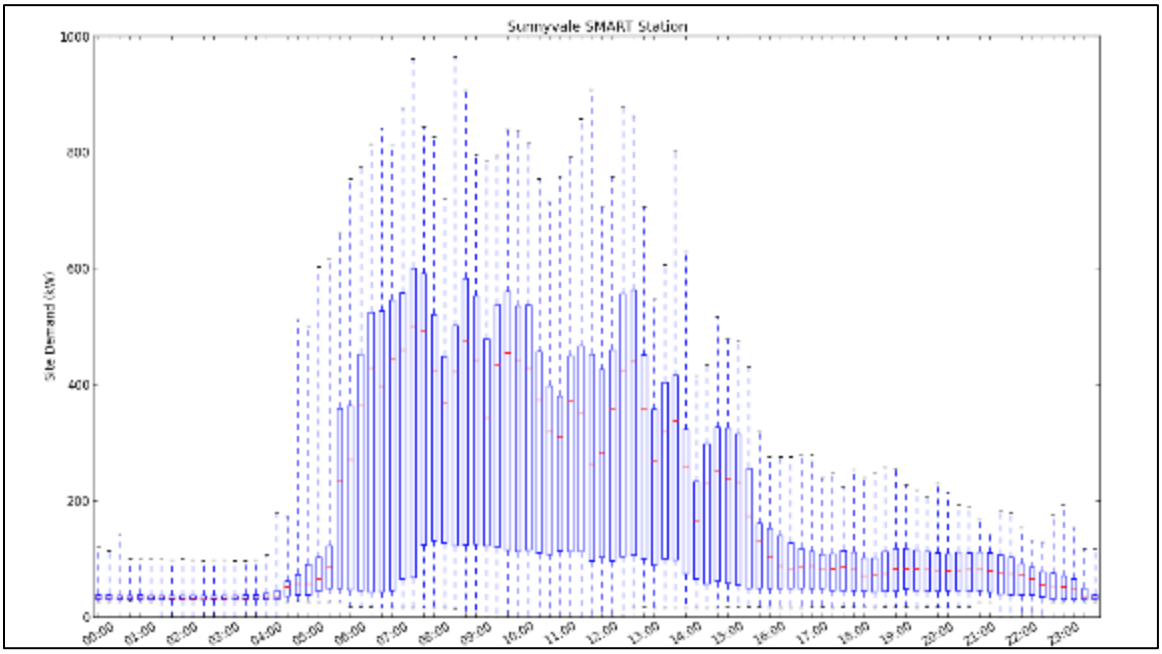
Figure 3: Annual Load Duration Curve for the SMaRT Station



Source: AutoGrid Systems Inc. Study of plant

The typical load profile begins the day around 25 kW, starts ramping up around 4 a.m., and maintains a steady peak from around 6 a.m.-1p.m. before gradually ramping down to standby levels.

Figure 4: Typical Daily Load Profile for Sunnyvale SMaRT station

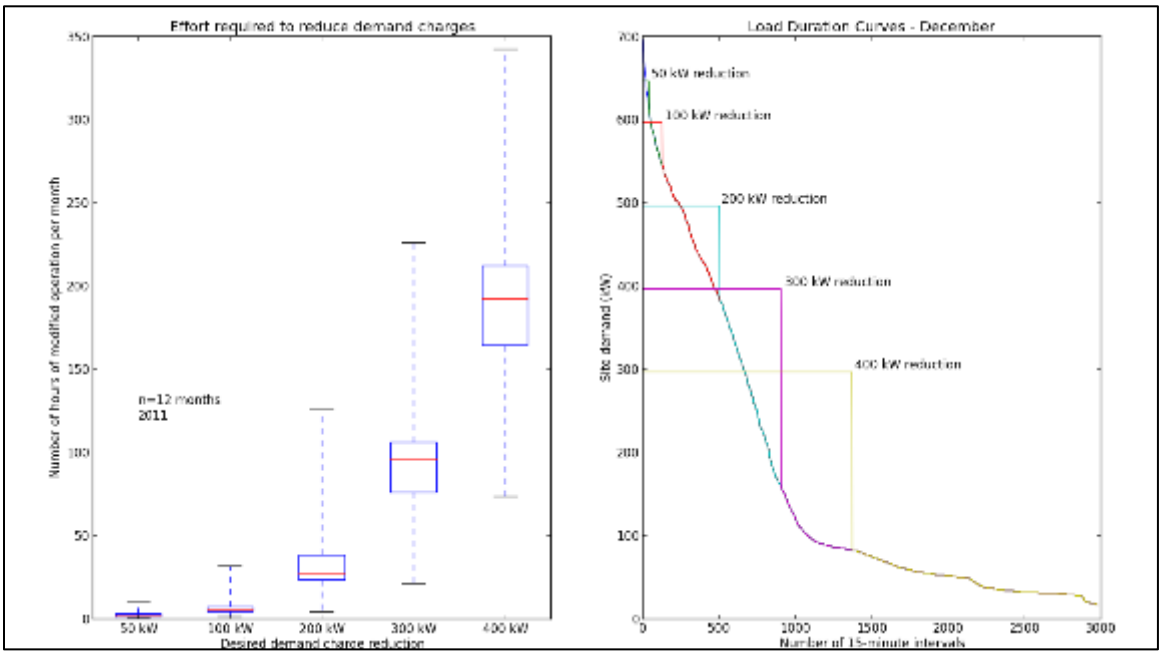


Source: AutoGrid Systems Inc. Study of plant

For each month, a load duration curve was constructed. In addition, an alternate load duration curve was constructed for each of 5 different demand charge reduction levels: 50 kW, 100kW, 200 kW, 300 kW, and 400 kW. The total monthly energy was maintained by shifting the demand from the highest-demand hours to the next-highest hours, flattening the top end of the load curve. The number of hours required to shift this amount of load and the resulting modified load profiles are shown in Figure 5. The month of December is plotted as it is the month with the most effort required to achieve each reduction level.

Little effort seems to be required to shift the first 100 kW of load (<12 hours for all months) but quickly accelerates as larger load reductions are desired. To reduce demand charges by 400 kW, the operation of the station would have to be modified for nearly 50 percent of the time, which would prove challenging considering operation schedules.

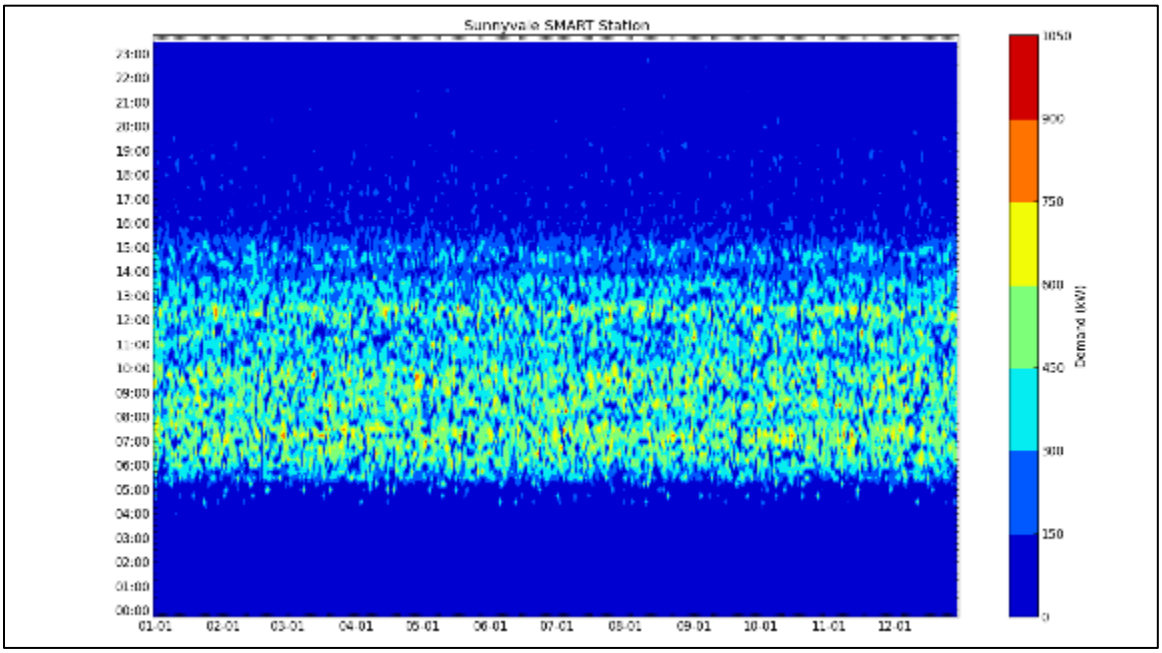
Figure 5: Effort Required to Modify Demand for Reduced Peak Demand (Left) and Load Duration Curves for the Modified Demand (Right)



Source: AutoGrid Systems Inc. Study of plant

By examining the time dispersion of the demand peaks over the course of the analyzed data, as seen in Figure 6, the peak demand intervals seems to be consistently in the windows of 7 .am.-10 .am. and 12-1 p.m., with very few peaks from 10 .am.-12 p.m. This suggests that load can be moved to these times to reduce peak demand.

Figure 6: Dispersion of Demand over the 12 Months of Study



Source: AutoGrid Systems Inc. Study of plant

2.1.4 Demand Response Potential

At the SMaRT station two conveyor belt motors and a large wood grinder were identified to have desirable curtailment potential without any impact on the plant's core operations. These two pieces of equipment were selected based on operation requirements and characteristics of the SMaRT station. Approximately 250 kW of load shed potential was identified at the SMaRT Station, with the wood grinder contributing 80 percent of this load shed.

2.1.5 Controls

The controls for all the selected pieces of equipment are relatively manual as they require presence of plant personnel during their operation. There is a motor control center which operates the conveyor belt. Please refer to Appendix A for detailed electrical diagrams for the control systems.

2.2 Sunnyvale Wastewater Pollution Control Plant

2.2.1 Description

The Donald M. Somers Water Pollution Control Plant was built in 1956 and was expanded incrementally in 1962, 1978, and 1984, and it can currently treat approximately 29.5 million gallons per day. There are two adjacent ponds totaling 440 acres that are used for secondary treatment. The site uses onsite natural gas and biogas for power generation. There are currently multiple different control systems in operation at the plant, each operating on different areas. The plant is a tertiary treatment facility serving the city of Sunnyvale. The objective of the plant is to remove pollutants and produce a high quality effluent suitable either for safe discharge to the South San Francisco Bay or for non-potable uses.

The Sunnyvale Water Pollution Control plant located at 1444 Borregas Avenue, Sunnyvale, California 94089 shows great potential demand response and increased energy efficiency. The site has several key attributes that make it an ideal candidate for enhanced controls and monitoring and optimization based on the OpenADR standards and the AutoGrid DROMS optimization system.

The site has excess electric generation capacity (approximately 110 percent of required), however, it does not have any information feed to wholesale prices, nor the equipment, nor personnel, to optimize the use of their generation and load shedding capabilities. The excess power generated at the WPCP is delivered to PG&E and goes through the CAISO meter. The rate for the exported power is fixed and was negotiated well before the start of the project. The staff at the site is quite interested in the potential to realize improved operations. The site has a 440 acre pond that is used as part of its secondary process. This pond is an asset that could add substantial flexibility in the plants ability to shed and shift electric loads. In addition, its vast surface area provides a natural source of oxygenation to the secondary effluent that is not available at many other wastewater treatment sites. The stable source of dissolved oxygen at the Sunnyvale site removes the challenge of increased turbidity that was observed in the San Luis Rey Wastewater Treatment Plant Case Study (Thompson, Song, Lekov, & McKane, 2008). The site has begun the process of evaluating various major capital improvement strategies. Improved data monitoring and analysis provided by this project could provide data to make better decisions with regard to these capital improvements. In addition to data to analyze energy efficiency, payback periods, environmental compliance, new revenue streams introduced through the use of demand response optimization could influence the choices available to the management team.

The Sunnyvale Water Pollution Control plant shows great potential to participate in traditional demand response programs as well as faster acting ancillary services markets. With relatively modest enhancements to their existing system control and data acquisition (SCADA) systems, large electric loads can be shifted, shed and otherwise modified to participate in various DR programs.

Figure 7: Sunnyvale Water Pollution Control Plant (Left) and Water Storage Pond (Right)

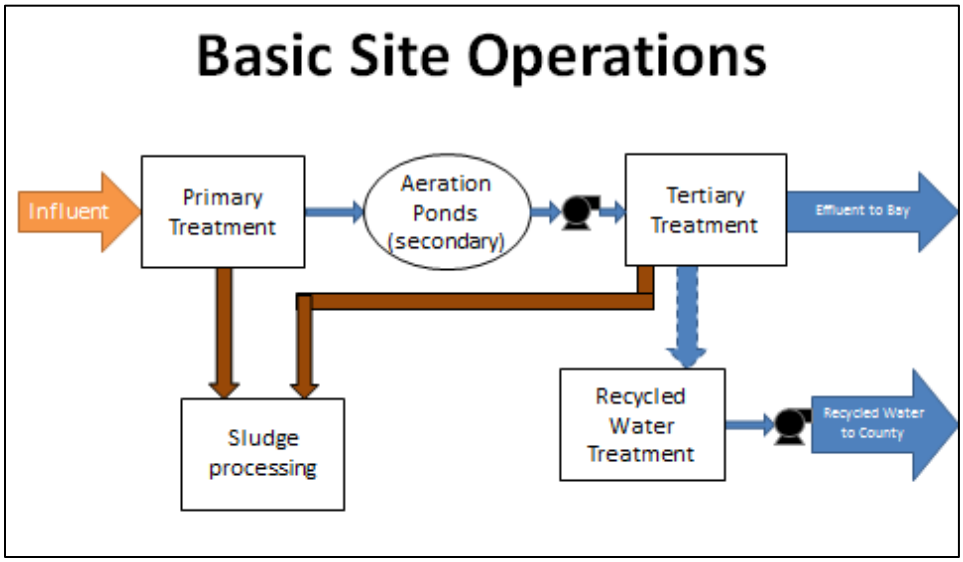
Photo Credit: Google (Left), City of Sunnyvale (Right).

2.2.2 Waste Recycling Process and Plant Operations

Influent enters the plant below ground, and passes through screens and grinders before it is raised above ground by lift pumps, which are fueled by biogas from the plant's digesters. The influent then is sent to sedimentation tanks, where solids settle to the bottom and scum rises to the top (primary treatment). Solids and scum are removed and sent to the digesters, while the wastewater continues to the aeration ponds. Once in the digesters, the solids and scum (sludge) are held at an elevated temperature to enable anaerobic digestion, producing biogas in the process. Eventually, the sludge is de-watered and trucked away from the plant.

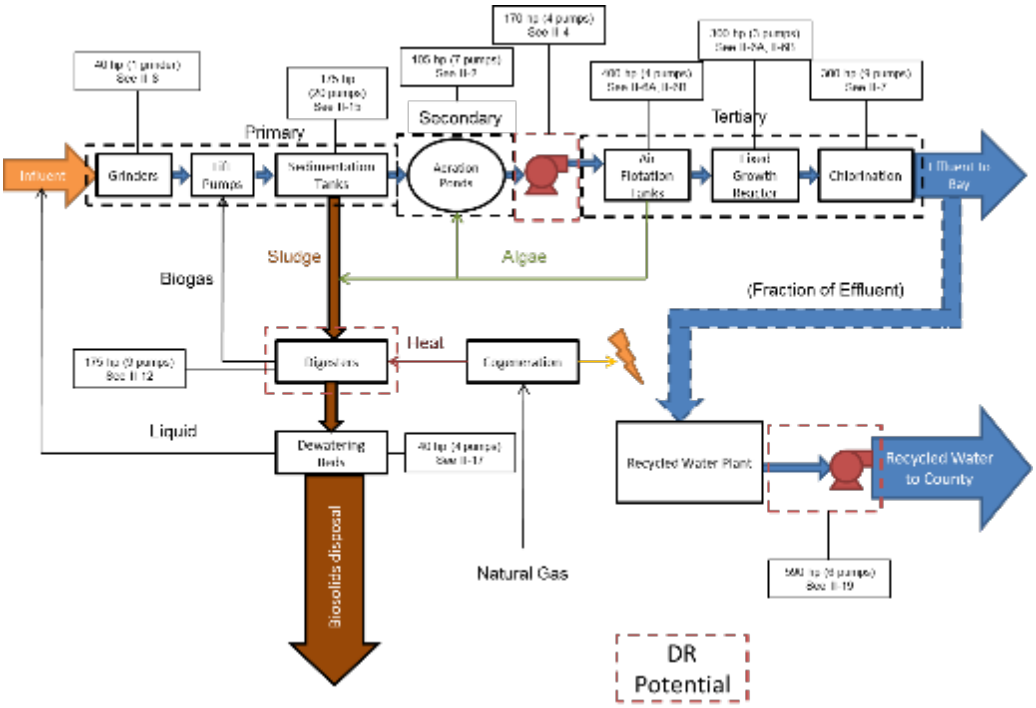
While the wastewater sits in the aeration ponds, it is circulated and oxygenated by pumps and aerators to enable biological breakdown of dissolved solids (secondary treatment). The wastewater is then pumped to air flotation tanks, where algae is removed from the wastewater, then to the fixed growth reactions, where bacteria remove ammonia, and finally to the chlorine contact channels, where the wastewater is disinfected (tertiary treatment). After tertiary treatment, most of the wastewater is discharged into the bay. A fraction of the wastewater is further treated, becoming "recycled water," and is pumped to county holding tanks for distribution to golf courses and other irrigation water users. These operations are depicted in Figure 8 and Figure 9. The plant's electrical system is shown in Figure 10.

Figure 8: Simplified Process Flow Diagram



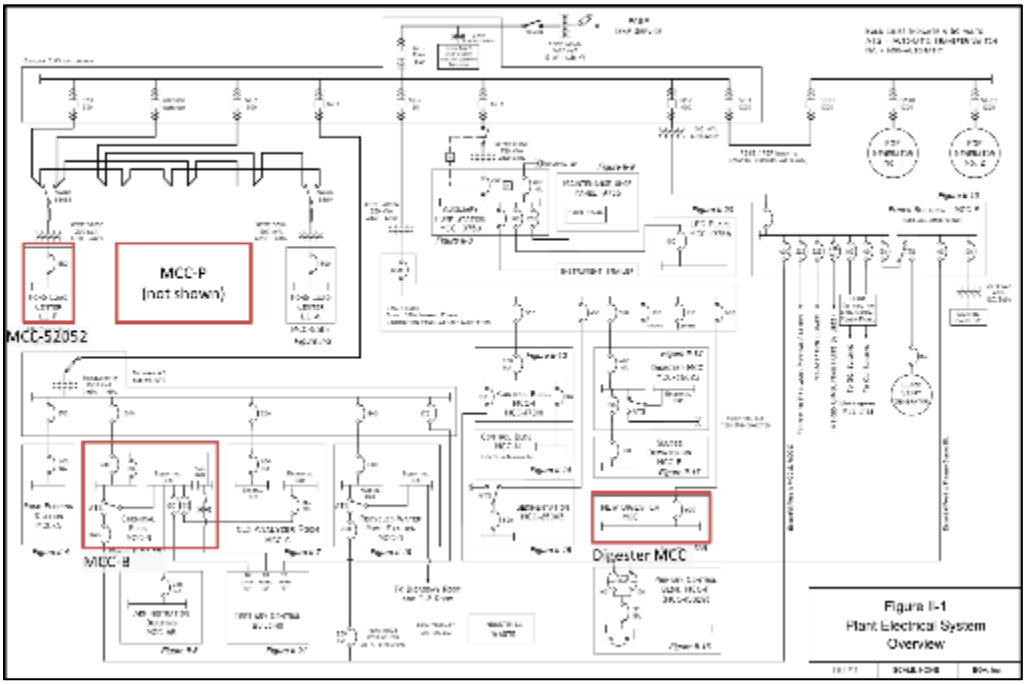
Source: AutoGrid / LBL plant process study

Figure 9: Detailed Process Flow Diagram



Source: AutoGrid / LBL plant process study

Figure 10: Plant Electrical System—Motor Control Centers (MCCs) with Controllable Loads Outlined in Red

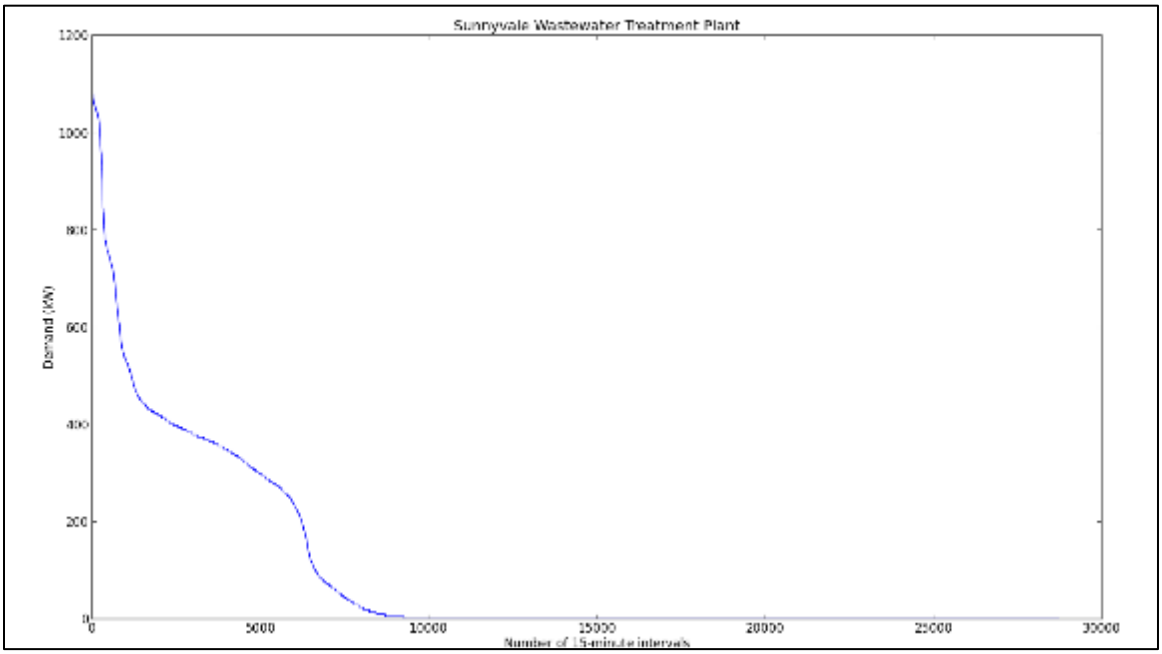


Source: Sunnyvale WPCP Line Diagram

2.2.3 Load Profiles

The demand seen at the Sunnyvale Wastewater Treatment plant over the sampled interval (01/01/2012 - 10/25/2012) ranged from 0-1,114 kW, with an average of 97 kW. Figure 11 represents the annual load duration curve for the WPCP.

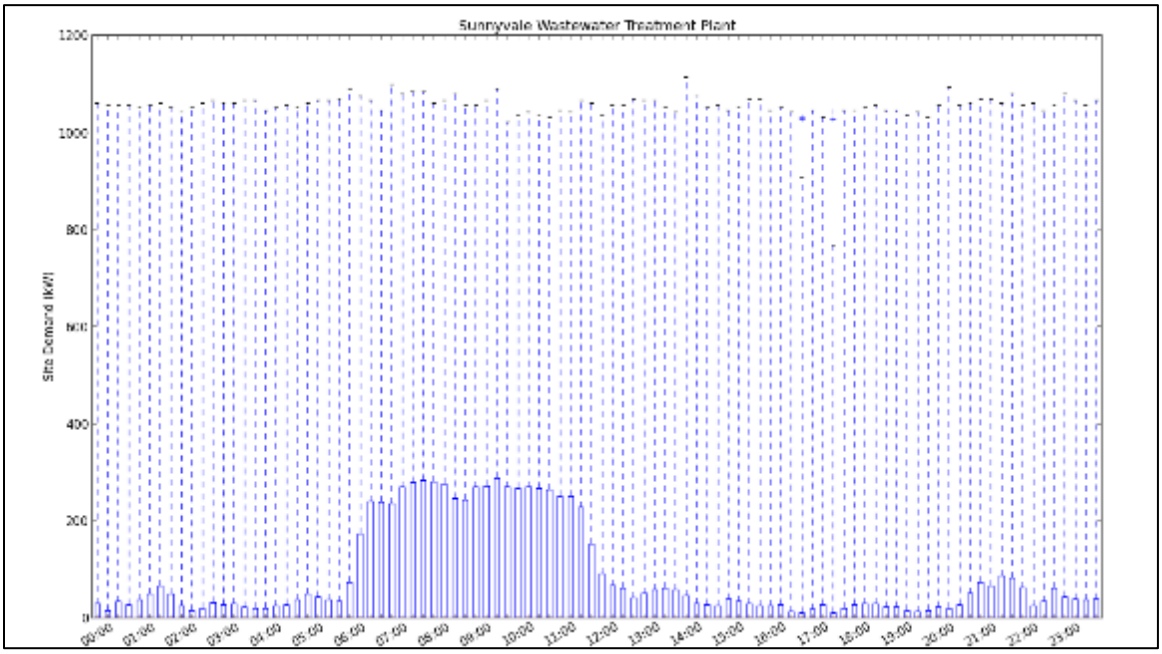
Figure 11: Load Duration Curve for Sunnyvale Wastewater Treatment Plant



Source: AutoGrid Systems Inc.

68 percent of the time there was zero demand. When there was a demand registered, it was typically around 200 kW higher in the 6am-12pm window than during the remainder of the day.

Figure 12: Typical Daily Load Profile for Sunnyvale Wastewater Treatment Plant

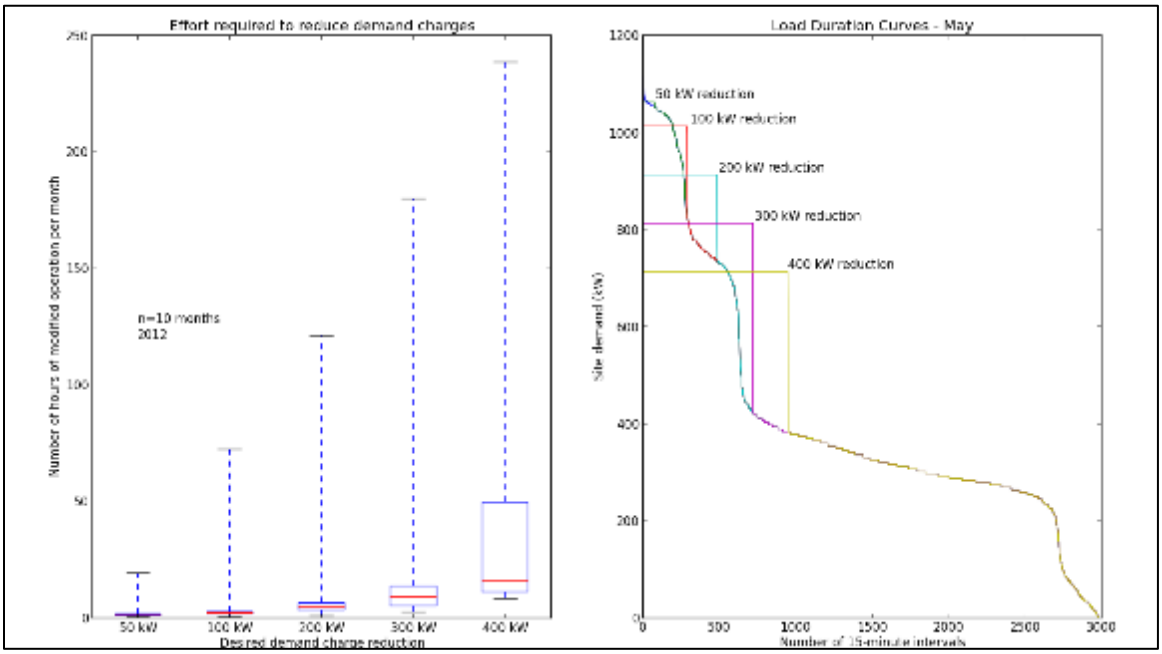


Source: AutoGrid Systems Inc.

For each month, a load duration curve was constructed. In addition, an alternate load duration curve was constructed for each of 5 different demand charge reduction levels: 50 kW, 100 kW, 200 kW, 300 kW, and 400 kW. The total monthly energy was maintained by shifting the demand from the highest-demand hours to the next-highest hours, flattening the top end of the load curve. The number of hours required to shift this amount of load and the resulting modified load profiles are shown in Figure 13. The month of May is plotted as it is the month with the most effort required to achieve each reduction level.

For most months, large peak demand reductions could be accomplished with minimal effort, but the effort required for the hardest month rose with the amount of load reduction desired, and was above 72 hours for each reduction level after 50 kW.

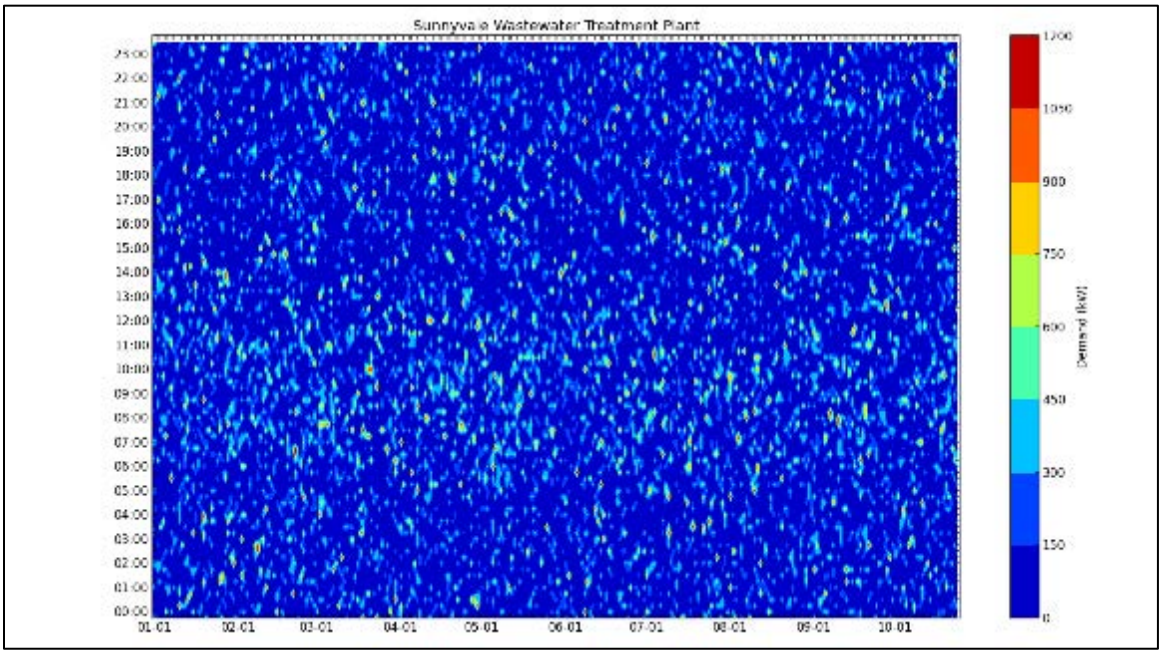
Figure 13: Effort Required to Modify Demand for Reduced Peak Demand (Left) and Load Duration Curves for the Modified Demand (Right)



Source: AutoGrid Systems Inc.

By examining the time dispersion of the demand peaks over the course of the analyzed data, as seen in Figure 14, the peaks appear to be scattered fairly randomly. There does not appear to be any seasonal component to the plant's energy usage.

Figure 14: Dispersion of Demand over 10 Months of Study



Source: AutoGrid Systems Inc.

2.2.4 Demand Response Potential

Traditionally, ancillary services have been provided only by generators, and the infrastructure required to participate was costly. However, advances in technology and market structure have made load participation attractive, provided the equipment needed to participate is not overly expensive. The goals of this project are two-fold: to demonstrate the ability to provide at least 100 kW of ancillary services, and the ability to accomplish this using communications and controls that are less expensive than the traditional set (less than $100/kW for facilities that can shed load of 100 kW or more and less than $50/kW for facilities that can shed load of 200 kW or more).

Based on the analysis done by Ekster and Associates, no equipment manipulation can be attempted upstream of the ponds due to the catastrophic effect of such manipulation on the wastewater conveyance and treatment. Equipment with installed capacities higher than 300 kW and 270 kW are identified as having "significant impact" and "critical impact" by the report. Equipment with "significant" and "critical impact" are recommended to be excluded from the load shedding evaluation and remain as a part of the typical plant operations.

The team investigated whether certain aspects of the plant's operation can be scaled back during a DR event, and whether the plant can simply ramp down operation, rather than completely cut off power to the specified pumps. There are several aspects of wastewater treatment process that allow for load curtailment when events are called. As indicated with red boxes in Figure 10, the following areas were identified as having large demand response potential:

- Pond Aerators: Although there are seven aerators, each rated at 15 horsepower (HP), typically there are only three or four in operation at any given time. All can be shed.
- Pond Circulation Pumps: There are four pond circulation pumps, each rated at 60 HP, and typically two are running at any given time. One must remain on at all times, so typically one pump can be shed.
- Digester Pumps: There are two operational digesters (#s 3 and 4 out of 4), each with a mix pump, rated at 30 HP and 40 HP respectively. Both can be shed.
- Fixed Growth Reactor Fans: There are 12 fans, each rated at 1 HP. All can be shed.

Table 2: Load Shed Summary

Location	Load Type	Shed Capacity	Quantity	Total Shed
Pond Aeration	Aerators	15 kW	3	45 kW
Recirculation	Pumps	45 kW	1	45 kW
Digester	Pumps	25 kW/30 kW	1	25 kW
Backwash	Pumps	15 kW	3	45 kW

Source: Ekster Report.

There are several aspects of wastewater treatment processes that allow for load curtailment when DR events are called. Pond aerators and circulation pumps as well as digester pumps and fixed growth reactor fans were identified as having large demand response potential. In total, there are approximately 175 HP of equipment which are typically on and can be controlled for DR, or approximately 150 – 200 kW. Controlling loads for DR purposes should have a negligible impact on plant operations, as the equipment do not impact the throughput of the plant, and they are somewhat oversized for the functions they serve. Plant personnel conveyed that this equipment could be shut down for four hours at a time without negative consequences.

2.2.5 Controls

Please refer to the Appendix B for detailed diagrams regarding the control systems.

2.2.6 Enabling Demand Response for Demonstration Sites

The researchers designed units that were capable of receiving a signal and converting that to a load shed operation. Due to the sensitivity of the plant operations, the plant operator required a bypass button to cancel a scheduled DR event. The bypass button, along with built in metering system and communications equipment (for equipment status and communication of load shed) were all incorporated into the final designed boxes for each site.

The system required two centrally located VT-IPm2m-113 ADR GRIDlink ADR running Open ADR 2.0b connected on the local area network to five Shark 100 meters, one DENT meter, and

five Red Lion ET-8DI2-8DO2 remote I/O modules. At each location was a 7" G3 Cadet Color touch screen HMI for operator use. For backhaul to the DROMS and the GRIDview Cloud, a Red Lion SN-6621 Verizon Cellular was used.

The entire system communicates using Modbus TCP over Ethernet and due to the size of the plant and the distance between devices; running cable through conduit was economically prohibitive. Industrial Wi-Fi was selected as a better alternative in both cost and ease of installation.

Wi-Fi was found to be highly reliable and secure. All remote devices whether remote I/O or Modbus meters were monitored and logged for connectivity status from the GRIDlink. The remote I/O modules also monitor their connection to the GRIDlink. There are safeguards built into the remote units to revert to a pre-determined failure mode on loss of communication.

In December 2014, a storm rolled through the area over a period of 48 hours. It brought torrential rain and high winds. There was no loss of communication.

Using Ethernet enabled remote configuration of all devices from an IC Systems lab in Irvine, California. When design changes had to be made, there was no need to send an engineer to the plant site reducing costs.

GRIDview is the Cloud backend to GRIDlink. This enables data logging of all the data collected and a view of the overall system. Technicians at IC systems can view the health of the GRIDlink, upgrade software and test. This enables the technician to assist the electrician in testing the installation. This would normally require two persons on site and one would have a deep knowledge on how the system works. This was found to be important on several occasions.

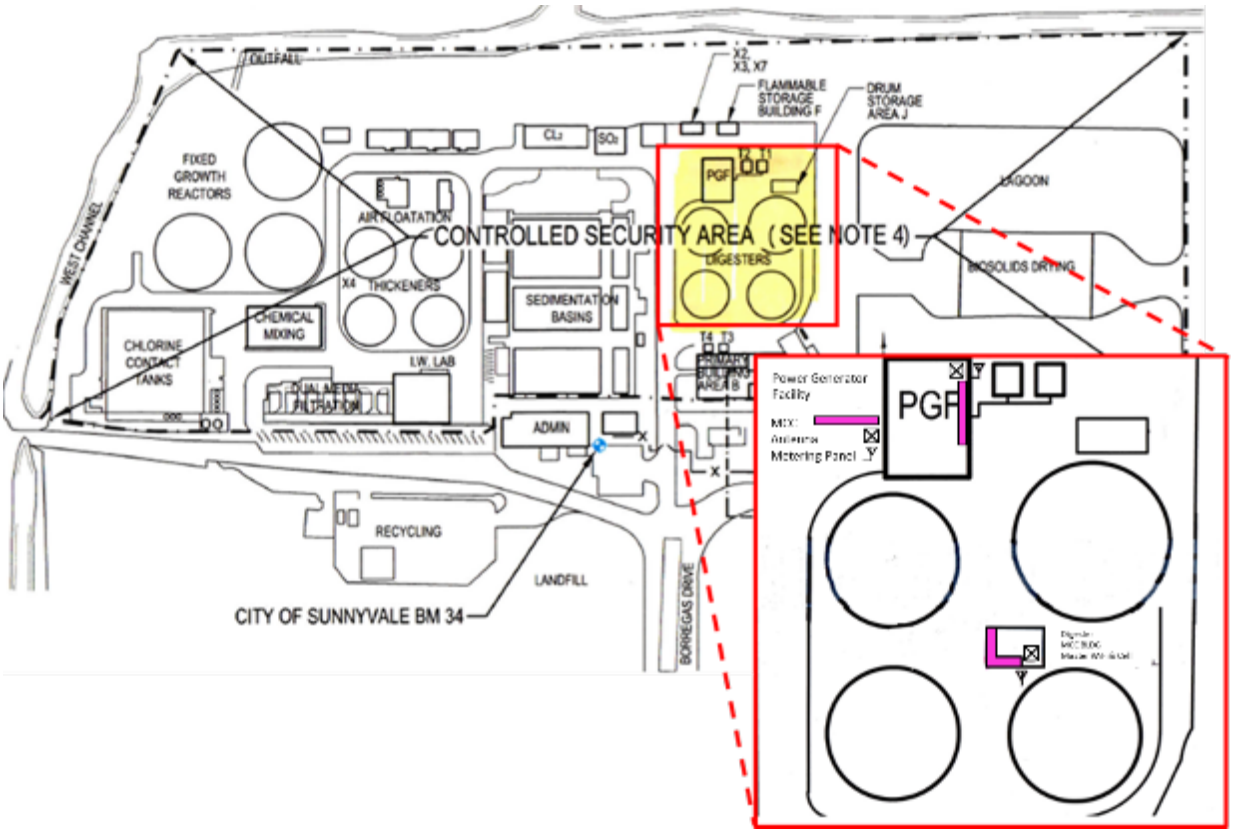
2.2.7 Telemetry

The requirements for telemetry depend on the specific market of interest[7]. For the non-spin market, telemetry data are required every 4 seconds to CAISO. The load must either generate load data every 4 seconds if it is the only load providing the resource or every minute if two or more loads combine to provide the resource. For the water treatment plant, it may be possible to consider individual pumps as sub-resources that are combined together. AutoGrid can provide the needed aggregation services if one minute live telemetry is preferred. The safest system design uses 4 second or faster data for telemetry from the individual loads under control. Non-spinning reserves must fully reach the desired shed within ten minutes and be able to maintain that shed for at least 30 minutes.

One cellular unit and two Wi-Fi units were installed at the plants to enable telemetry. Figure 15 shows the locations of the Cellular/GridLink ADR unit and a Wi-Fi 33/GridLink Extender Module unit at the WPCP. Similarly at the SMaRT station a Cellular/GridLink ADR unit was connected at the controls station for the curb side recycling sorting conveyor belt and was tested successfully. Wi-Fi 33/GridLink Extender Module for the wood grinder was also installed at a separate location.

[7] http://www.caiso.com/thegrid/operations/gcp/index.html

Figure 15: Load Shed Points at WPCP



Source: McIntire Electric drawing

2.2.8 Metering

A combination of Dent Power Scout 3 plus and Shark® 100 meters were used at both facilities. The Shark® 100 monitor is a multifunction power meter designed to be used in electrical substation, panel boards and as a power meter for OEM equipment. The meter is specified as a 0.2 percent class energy meter for billing applications as well as a highly accurate panel indication meter[8].

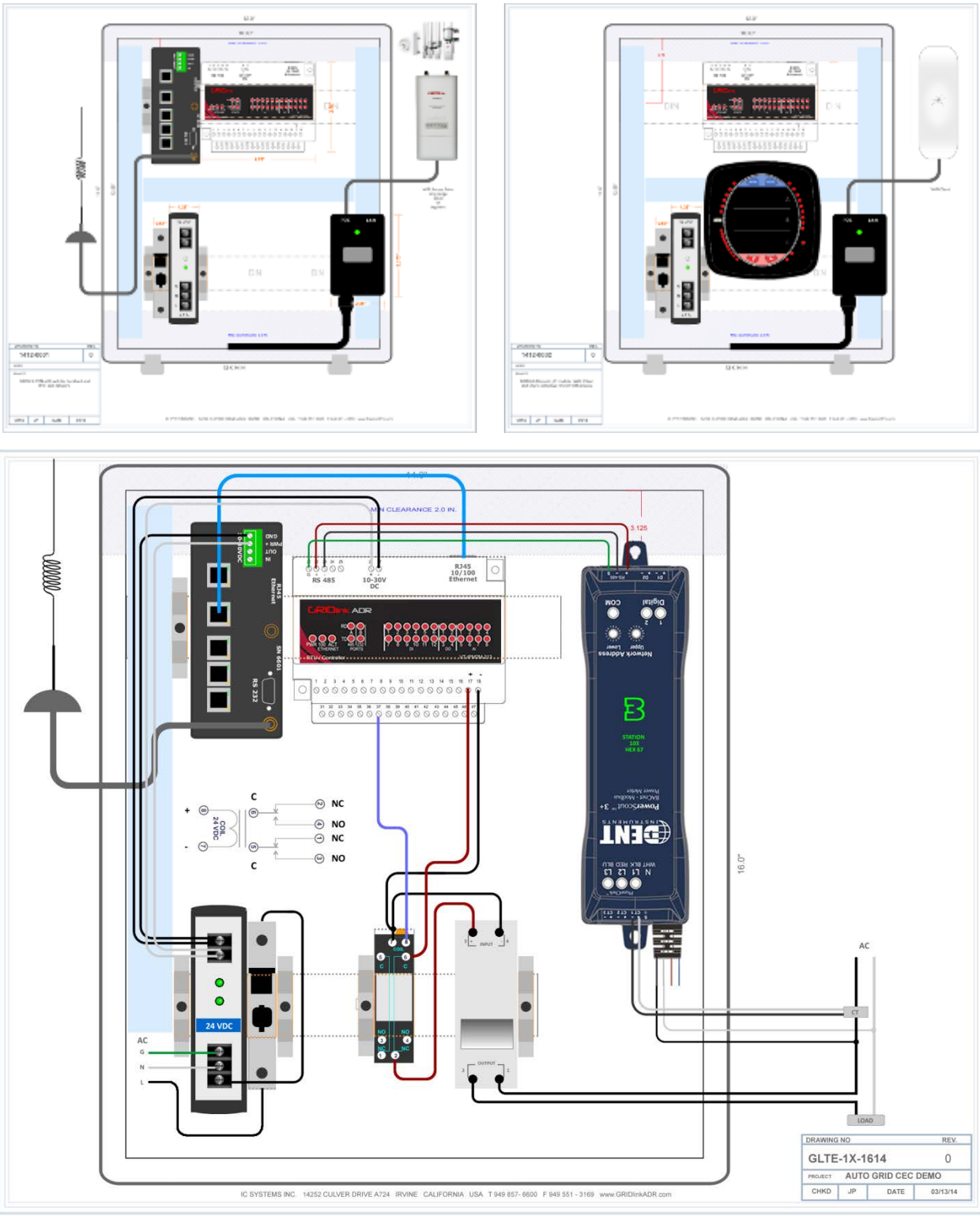
WPCP has its own settlement meter that meets CAISO requirements and is used to meter the exported power from the cogeneration facility. During event hours, this export will increase and that increase will be recorded by the facility meter.

2.2.9 Automation and Controls

GRIDLink ADR® is the first industrially rated, fully compliant custom programmable OpenADR controller on the market. GRIDView® is the backend cloud based interface for remote monitoring and management of multiple sites. Meters and relay switches installed at the control centers for each load allows the automation of demand response.

[8] http://www.electroind.com/pdf/06_29_12/Shark/Brochures/E145702_Shark100_Bro.pdf

Figure 16: Boxes Designed by LBNL



Source: ICSystemsinc.com

CHAPTER 3: DROMS

3.1 DROMS as an Enabling Tool for Fast DR

DROMS is a web-based system that allows industrial energy consumers to be broadly engaged in traditional peak capacity management type of DR programs as well as new fast responding ancillary services programs in an integrated and optimized manner.

3.1.1 DROMS Architecture

DROMS is a scalable, web-based software-as-a-service platform that provides all program design, program implementation, program execution, event management, forecasting, optimal dispatch, and post-event analytics functionality. The architecture and design of DROMS is scalable, reliable, and fault-tolerant and meets the throughput requirements for reliably communicating to millions of end-points in the time-scales necessary for providing ancillary services.

3.1.2 Open Standards

DROMS supports OpenADR2.0b open standards alongside other protocols for near real-time control of customer end-use electric loads using open standards. OpenADR version 2.0b ei-reporting were leveraged to collect sub-meter data from the identified load shed points to enable near real-time control and monitoring requirements of providing ancillary services.

3.1.3 Dispatchability

Ancillary services differ from most traditional DR products in that they are "dispatchable." DR sheds for ancillary services occur with little or no advanced notice, ramp faster and last for shorter durations. DROMS will target a variety of flexible loads for near real-time dispatchability for providing ancillary services.

3.1.4 Capital Costs

Existing DR platforms require extensive hardware installation at the end-user site. Traditionally, major loads and generators must install ISO/RTO approved telemetry devices that can collect 4-second data and cost upwards of $100,000. DROMS will use off the shelf information and communication technology and controls equipment that will match or surpass the performance of existing devices for less than $5,000. These devices have been developed for energy efficiency and energy monitoring needs; the software has been upgraded to support OpenADR2.0b protocol for communication and telemetry.

3.1.5 Advanced Analytics

DROMS uses advanced machine learning and robust optimization techniques for real-time and "personalized" DR-offer dispatch. DROMS keeps a unified view of available demand side resources under all available DR programs and history of participation in different DR events at individual customer locations. The DR resource models are dynamic, they will vary based on current conditions and various advanced notice requirements.

3.1.6 Big Data

A key feature of DROMS is its ability to provide a closed feedback loop so that the system will continue to optimize performance, increase predictability, and minimize loss of service through analysis of ongoing events. For this the system will need the capability to store and analyze petabytes of data in near real time with very high reliability and fault-tolerance. A number of techniques to deal with massive amounts of data with equally stringent requirements have been developed in recent times. These include database systems custom-built to deal with time series data, NoSQL databases and file-systems to store and access massive data-sets as well as highly distributed computing architectures such as Map-Reduce/Hadoop to process this data. DROMS is built on top of the Energy Data Platform which was developed to handle these massive amounts of data within the most stringent throughput and latency requirements.

3.1.7 Removing Barriers to Adoption

Finally, the Software-As-A-Service (SaaS) availability of DROMS will remove another significant barrier to the adoption of DR. Today's DR system require extensive upfront investment in IT infrastructure and personnel to design and implement a new program. At pilot scales these investments are hard to justify, and since most pilots don't reach the scale necessary to payback the upfront expense, utilities are reluctant to make these investments. By lowering the initial upfront investment using the SaaS model, DROMS will not only open up the DR market for thousands of utilities who did not have the means or willingness to make the necessary capital expenditure, but will also spur more innovation by allowing utilities to cost-effectively introduce new experimental programs.

3.2 Value of Supercharging DR with Data Analytics and Real-time Feedback

Continuing advancements in information technology and data science has made aggregation, analysis and visualization of petabytes of data generated by the smart grid not only possible but also extremely valuable. When used DR, it can open up new avenues of value creation—realizing benefits from reduced operational costs, increased customer satisfaction; higher average load shed and increased revenues from market participation. Prediction, forecasting, control, diagnostics and protection of a portfolio of demand-side resources can be done through a single, smart platform and save the utility and the consumer millions of dollars. A data-enabled portfolio approach allows the utility to create customer choice from a variety of DR program options, for example, behavioral, auto-DR, TOU. It also allows the DR program manager the flexibility to call DR resources for different utility needs: for example fast DR for ancillary services; critical peak price events for system peak reduction. As new demand response models emerge, the key business drivers behind the adoption of such DR portfolio platforms are:

3.2.1 Increased DR Load Impact

- Increased reliability of load shed making DR resource-dispatchable for grid operations
- Increased load shed per customer from higher customer satisfaction

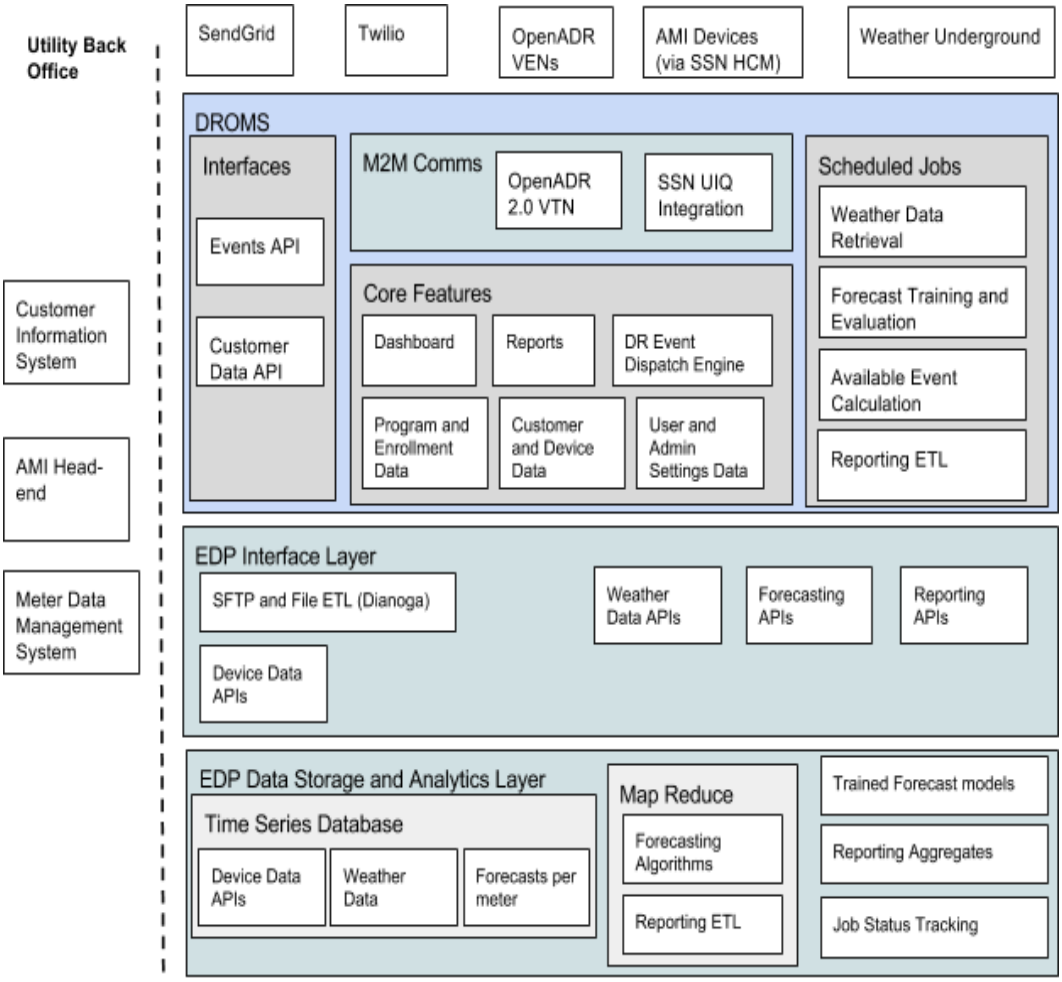
- Increased customer response from optimizing DR schedule and from post event automated feedback

3.2.2 Reduced Program Net Costs

- Reduced recruiting and marketing costs from segmentation
- Reduced churn

Analytics can be used to supercharge the DR resource portfolio through the key value drivers listed above.

Figure 17: DROMS Architecture Diagram



Source: AutoGrid Systems Inc.

3.3 DROMS Features

3.3.1 Dashboard and Reports

- At-a-glance view of load and load shed metrics (Actual and Predicted)

- Intended for System Operators who need to quickly know what DR resources are available so that they can dispatch them in just a few clicks
- Interactive Reporting for slicing and dicing of key load and load shed metrics and event participation metrics

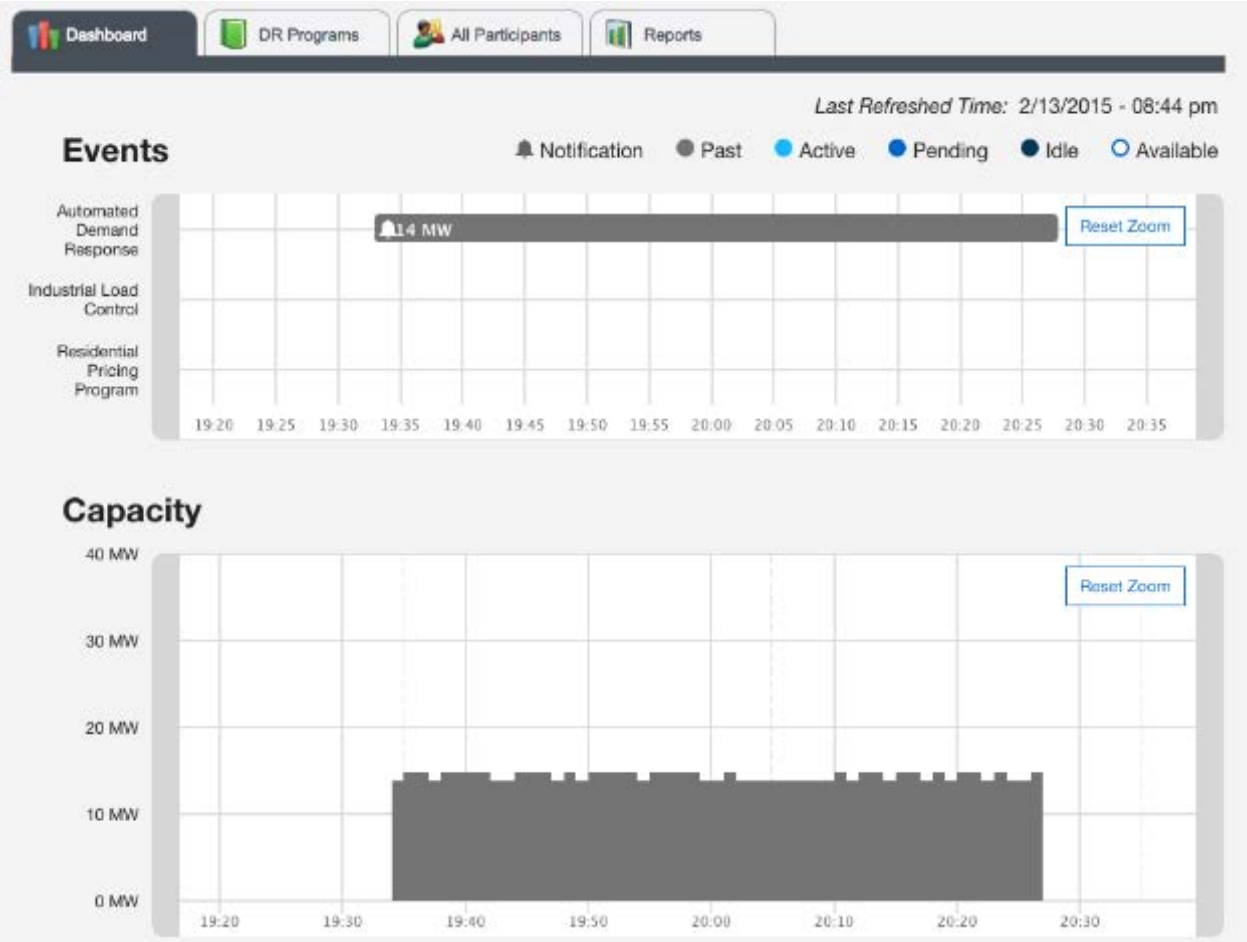
3.3.2 DR Event Dispatch Engine

- Send notifications and DR events to devices

3.3.3 Core Data Management

- Customer and Device Data, Program and Enrollment Data, User and Admin Settings Data

Figure 18: DROMS User Screen



Source: AutoGrid Systems Inc.

3.4 DROMS Interfaces

3.4.1 Event Dispatch API

- Asynchronously dispatches DR events that are either entered by users through the DROMS UI or received via the REST interface for programmatic dispatch

3.4.2 Event Participants and Customer Data API

- Used for Analytics and Reporting

3.5 Customer Data API

3.5.1 M2M Communications

- OpenADR 2.0 VTN
- SSN UIQ Integration

3.6 Supported Analytics

3.6.1 Forecasting

- Forecast model training to improve forecasting of each load based on the most recently available data
- Frequency of training and evaluation can be adjusted per deployment
- Forecasting method can also be configured per program

3.6.2 Reporting ETL

- Reporting ETL takes time series data from the EDP and aggregates it for interactive reporting in the Dashboard
- Forecasts per Meter — time series data is taken for individual meters

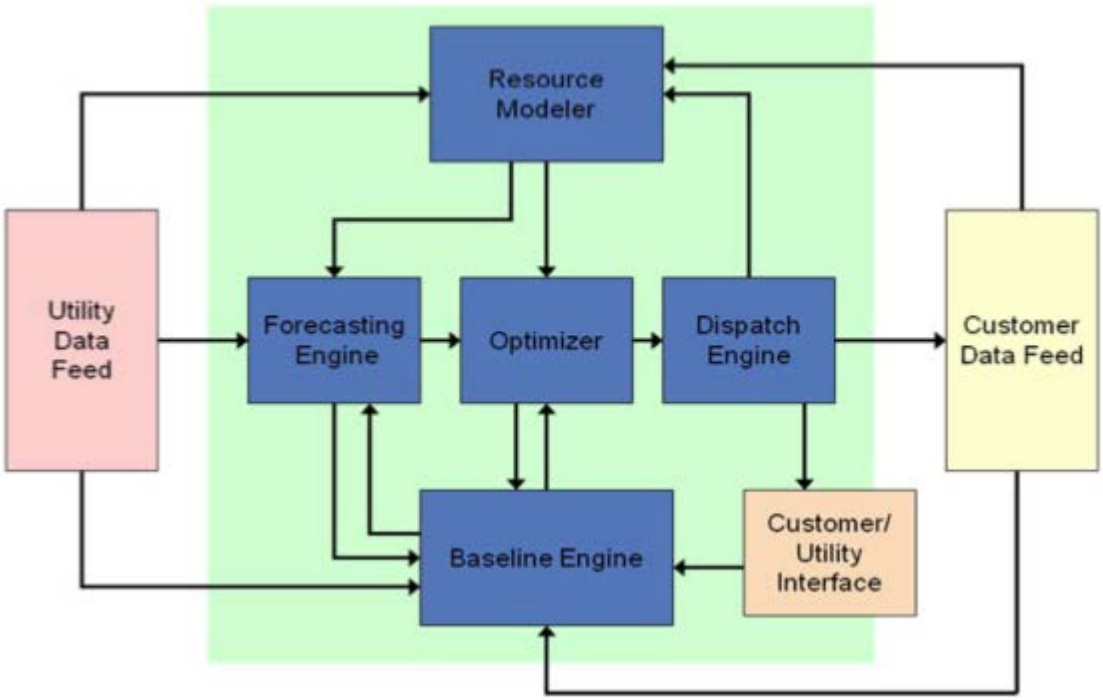
3.6.3 Job Status Tracking

- Auditing and Monitoring

3.7 DROMS Operation

DROMS connects to the utility's backend data system on the one side and customer end-points on the other side. DROMS receives live data-feeds from either or both the customer end-devices and utilities meter data management system to calibrate the forecasting and optimization models as DROMS executes DR events. In case some of the feeds are not available the forecasting engine runs in an "off-line" manner or with partial data feeds. DROMS uses live sub-metering at the load shed points that provide continuous meter data feeds. DROMS provides near real-time DR event and price signals to the customer end-points to optimally manage available DR resources.

Figure 19: DROMS Operation



Source: AutoGrid Systems Inc.

3.7.1 The DR Resource Modeler:

- Keeps track of all the available DR resources, their types, their locations, and other relevant characteristics such as response times, ramp-times, etc.
- Continuously updates the availability of resources affected by commitment to or completion of an event.
- Monitors the constraints associated with each resource such as the notification time requirements, number of events in a particular period of time, and number of consecutive events.
- Monitors user preferences to determine a "loading order" as to which resources are more desirable for participation in DR events from a customer's perspective and the contract terms the price at which a resource is willing to participate in an event.
- Gets data feed from the client to determine if the client is "online" (that is, available as a resource) and whether the client has opted-out of the event.

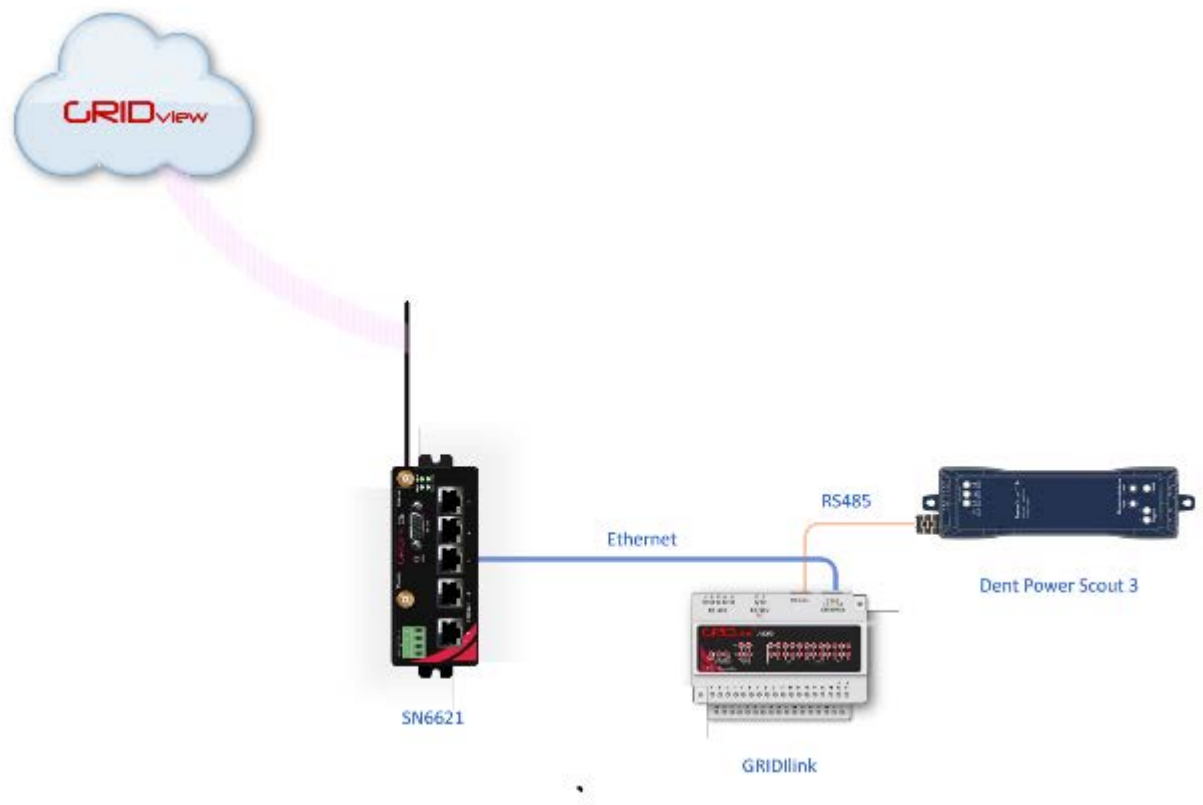
The Forecasting engine gets the list of available resources from the resource modelers to perform short-term forecasts of aggregate load and available load-sheds for individual loads connected to DROMS.

3.8 Performance

Presented in this section are actual performance figures from a couple of real life instances of DROMS in action. Their focus is to look at certain specific performance indicators related to processing times, fastest time, average time, and latencies. The researchers also look at data recording frequencies: fastest possible posting.

Figure 20: Installed System Architecture Showing Communication from Gridview to Unit with Dent PowerScout 3 plus Sub-meter

Example 1: Dent Meter PS3 - RS485



Source: ICSystems Inc.

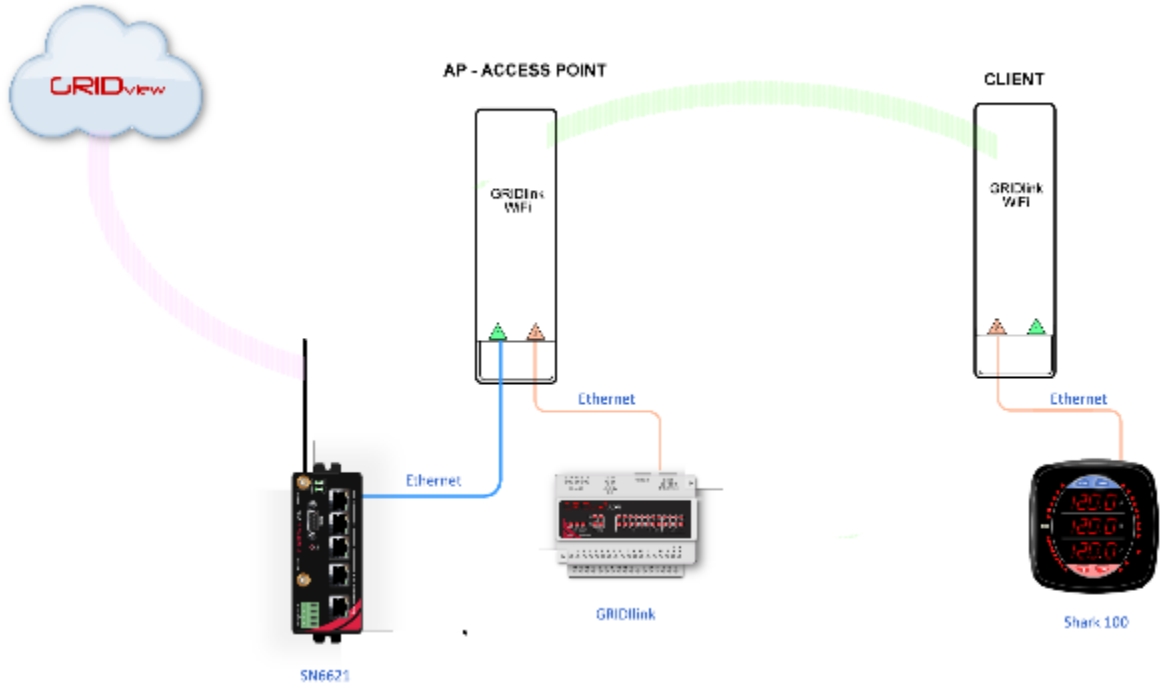
Table 3: Latency Data from Manufacturers

Latency Stack (Dent Meter PS3 - RS485)			
CEC SMaRT (Sunnyvale Water Pollution Control Plant – Device #181, S/N 125933)			
	Min (mSec)	Average (mSec)	Max (mSec)
Dent Power Scout 3 meter Analogue to Digital Conversion (CT to Registers)	500.000	500.000	500.000
RS485 Communication latency - baud rate (1 ms/char at 9600 baud)	16.000	0.000	26.000
Total Latency from meter CT to GRIDlink mSec	516.000	500.000	526.000
Modbus Transfer Poll Cycle (Selectable from 100mS to 5 Sec)			
GRIDlink client reads/writes local I/O db			
Sixnet firmware scans physical, remote I/O to local I/O db	400.000	416.000	434.000
Datalogger (logs local I/O db changes)			
Total Computational instant kW Latency	916.000	916.000	960.000
ISaGRAF Control Program energy calculation (selectable post to GRIDview period from 10 sec to 1 minute)			
GRIDlink to SN6621 Gateway	0.343	0.374	0.500
Ethernet Switching Latency in SN6621 (To Cloud from GL)	0.016	0.016	0.016
SN6621 Gateway to GRIDview Cloud Server or Auto Grid DR Server	65.000	94.960	238.000
Total Latency arriving on GRIDview site mSec :	981.359	1011.350	1198.516
GRIDview Cloud Server data post interval period 5 seconds			
1. Ethernet communication latency values derived from actual testing			
2. Data is posted directly from GRIDlink to the Auto Grid server. The frequency is determined by Open ADR configuration file. The latency should be the same as that for GRIDview.			

Source: ICSystems Inc.

Figure 21: Installed System Architecture Showing Communication from Gridview to Wi-Fi Unit with Shark100 Sub-meter

Example 2: Shark 100 Meter - Ethernet



Source: ICSystems Inc.

Table 4: Latency Data from Manufacturers

Latency Stack (Shark 100 Meter - Ethernet)			
CEC WPCP 1 (Sunnyvale Water Pollution Control Plant – Device #191, S/N 126001)			
	Min (mSec)	Average (mSec)	Max (mSec)
Shark 100 meter Analog to Digital Conversion (CT to Registers)	1000.000	1000.000	1000.000
SN6621 Gateway to Shark 100 meter (Ethernet Comm latency)	0.525	2.648	12.200
Ethernet Switching Latency in SN6621 (To Shark 100 meter from GL)	0.016	0.016	0.016
Ethernet Switching Latency in SN6621 (To GL from Shark 100 meter)	0.016	0.016	0.016
GRIDlink to SN6621 Gateway	0.686	0.748	1.000
Total Latency from meter CT to GRIDlink mSec	1001.243	1003.428	1013.232
Modbus Transfer Poll Cycle (Selectable from 100mS to 5 Sec)			
GRIDlink client reads/writes local I/O db			
Sixnet firmware scans physical, remote I/O to local I/O db	400.000	416.000	434.000
Datalogger (logs local I/O db changes)			
Total Computational instant kW Latency mSec	1401.243	1419.428	1447.232
ISaGRAF Control Program energy calculation (selectable post to GRIDview period from 5 sec to 1 minute)			
GRIDlink to SN6621 Gateway	0.343	0.374	0.500
Ethernet Switching Latency in SN6621 (To Cloud from GL)	0.016	0.016	0.016
SN6621 Gateway to GRIDview Cloud Server	65.000	94.960	238.000
Total Latency arriving on GRIDview site mSec :	1466.602	1514.778	1685.748
GRIDview Cloud Server data post interval period 5 seconds			
1. Ethernet communication latency values derived from actual testing			
2. Data is posted directly from GRIDlink to the Auto Grid server. The frequency is determined by Open ADR configuration file. The latency should be the same as that for GRIDview.			

Source: ICSystems Inc.

3.9 AutoGrid OpenADR Server Latencies and Polling Frequencies

The measured latencies of the different sections of the OpenADR communication are recorded and reported below. Please note that these are based on a 10 second polling frequency. Since the different components operate on an asynchronous clocks they are not perfectly aligned. Synchronized clocks are not a requirement either.

Part of the process of determining the total latency of the system involves determining the latency of the DROMS system processing, especially the latencies of the OpenADR servers.

The authors recorded the latency of each stage of processing involved with the OpenADR server as noted below.

It is important to note that the numbers below also include the programmed polling frequency of their OpenADR server that is currently set at 10 seconds. Since this delay is programmable, it can be set as low as 1 second which would aid in accomplishing the 4 sec total network latency recommended in the ancillary services literature.

Below is an example of the researcher's latency test of OADR VTN (virtual top node) system when interacting with another OADR VEN (virtual end node) with a 10 second polling frequency.

Table 5: OpenADR Server Latency Data (As Measured)

Event received by OpenADR Server from DROMS: 12:59:13
OpenADR Server received oadrPoll request from RAI: 12:59:21
OpenADR Server sent out oadrDistributeEvent to RAI: 12:59:21
OpenADR received oadrCreatedEvent from RAI: 12:59:26
RAI received response for oadrCreatedEvent from OpenADR server: 12:59:26
OpenADR server started receiving oadrUpdatedReport: 13:00:02

Source: AutoGrid Systems Inc.

3.10 Data Sampling, Storage, and Transport

The GRIDlinkADR is capable of scanning between 10 milliseconds to 50 seconds. In this case, the researchers set the sample or scan time to 5 seconds because they wanted to make sure the communications were solid since the researchers were using WiFi in an area where there was no knowledge of possible radio frequency interference. Moreover, since the researchers were gathering one-minute interval data there did not seem to require a faster rate. The GRIDlinkADR is capable of scanning between 10 milliseconds to 50 seconds.
The data is stored in non-volatile ram until it is put into GRIDview. This means that all data is stored indefinitely limited by memory on loss of communication in which it backfills on reconnection. This could be for several days or weeks depending on the configuration.

The data model is flat with 8 fields which show date, timestamp, data type, raw, scaled, Eng Units, and Description. There is an attached sample csv file. The data is pushed up to the GV database via FTP. Both the Shark and DENT publish with an accuracy of 0.2 percent.

3.11 Security, Stability, and Scalability

The communications between GRIDlinkADR and GRIDview is secured through validating the unique serial number which is hashed with 256 bit encryption key. The communication for the backhaul provided by Verizon added additional banking industry level security. GRIDlink ADR Telnet and FTP ports are locked to protect onboard data.

The GRIDlinkADR never required any reboots and maintained consistent connections throughout the test period.

The GRIDlinkADR 113D has the capability to receive up to 8 KYZ meter pulse inputs and network with approximately 250 Modbus devices. This could be a combination of revenue meters, local HMI interface devices and remote in/out (I/O) modules to control loads. The limiting factor would be processing power. A conservative estimate would be 20 meters and 20-30 remote I/Os.

3.12 Asynchronous Architecture

The GRIDlinkADR does synchronize with a time server to provide an accurate time stamp for data collected. All the subordinate devices that the GRIDlinkADR communicated with required no synchronization. The GRIDlink merely polled each device at time periods set forth in the configuration and the GRIDlinkADR time stamped the data replies according to its clock.

3.13 Cost at Scale

At scale GRIDlinkADR, Cellular Gateway and a wide area Wi-Fi Access Point plus antenna make up the basic installation for about $3500. The Wi-Fi enabled remote I/O is about $700 with the opportunity to go down to about $500 in quantity. The cost of sub-metering solutions with the current transformers is about $1000. Installation at the industrial sites costs about $,000 per unit.

In the researcher's current project, the costs were slightly higher and the researchers used more than one unit per site to control different flexible loads. A better strategy needs to be devised to cover more control points with a single GridlinkADR controller to reduce the overall cost.

CHAPTER 4:
Results, Analysis, and Discussion

4.1 Test Plan Summary

All the contacts provided by the plant managers were added to the system notification prior to test events. A notification was sent out 24 hours prior to the scheduled events and reminder notification was sent out an hour before each event.

4.1.1 Pilot & Data Collection

Pilot testing and data collection was accomplished over two and a half months from Dec 2014 - Feb 2015. 10 tests were conducted and data was collected from all available units and used for further analysis, plotting, and reporting. Events of different durations and event notifications were scheduled and conducted from the DROMS system. The events were broadly classified into two categories — utility style events and CAISO type events.

The units were modeled as Direct Load Control (DLC) units capable of receiving OpenADR2.0 notification and had the ability to go into DLC load curtailment without human intervention. Notifications were sent to the units. Notifications were also dispatched to the nominated facilities staff via email, SMS messages, and voicemail. The same information was also available on the DROMS system. Notification times varied from 10 minutes to 24 hours depending on the type of event. The units provided the plant managers ability to opt-out of the event using either a direct Opt-Out button on the units or by accessing the Portal. Additionally a by-pass mechanism was also provided on each unit so that the plant could operate freely during extended periods when they are unable to be part of events.

The researchers had two 2-hour test events on December 22 and 23, 2014, at both WPCP and SMaRT facilities. These events were used to ensure everything was operating normally, notifications were received at all the endpoints and by all the staff members nominated by the plants, load sheds happened automatically and the data collection was smooth. Further, the tests were used to ensure proper data push from GridView to AutoGrid's OpenADR servers and proper recording of the data for further analytics.

The data was continuously received from the plants during the entire period and was used to create baselines and plotting of load sheds.

The plots in the following section are actual data collected on the event days. The event duration is clearly marked with a grey background. The red and blue lines show aggregated data from all units installed at each plant.

The red line represents the system forecast with MOA (morning of adjustment).

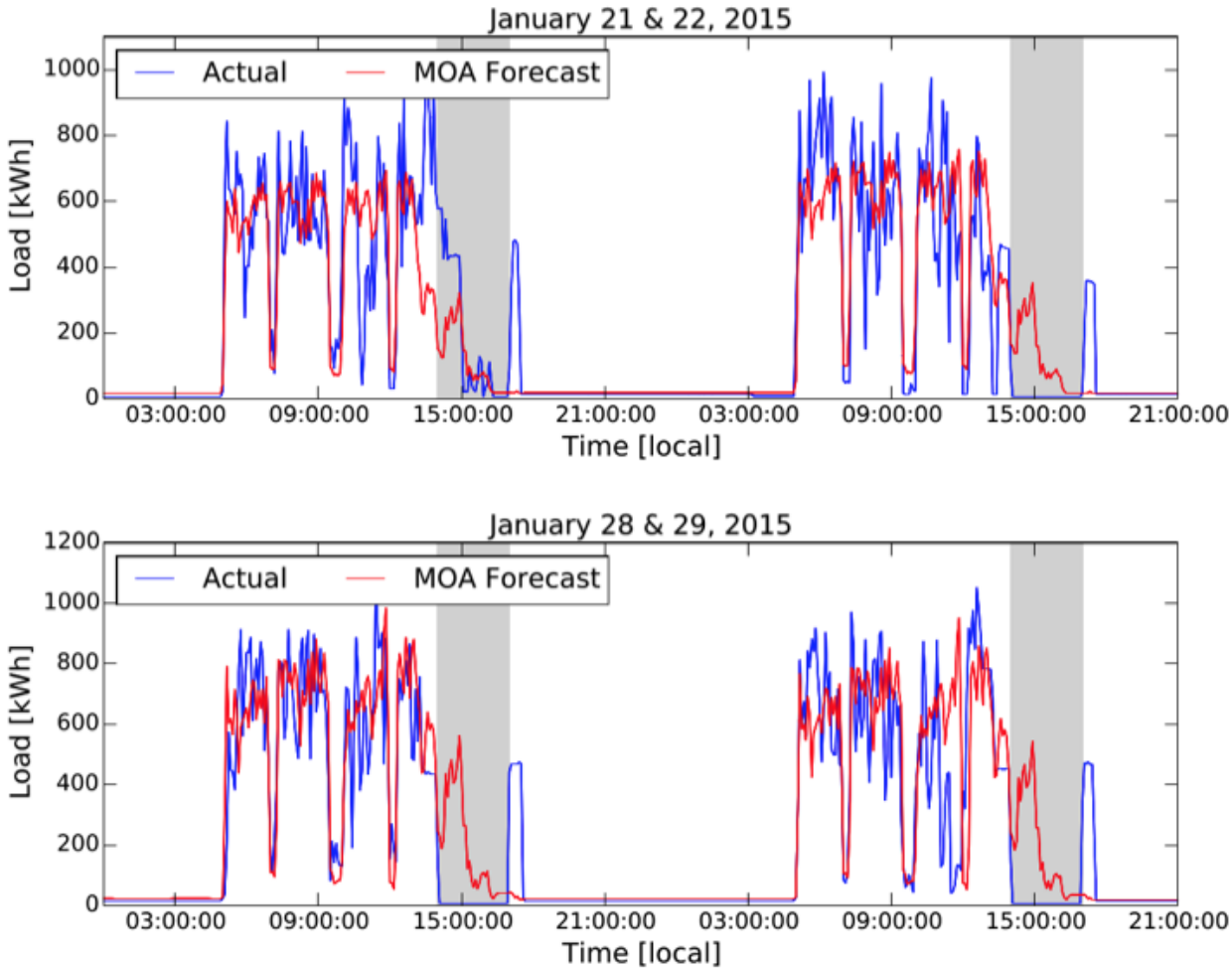
The blue line is the actual load aggregation data received from all units at each plant.

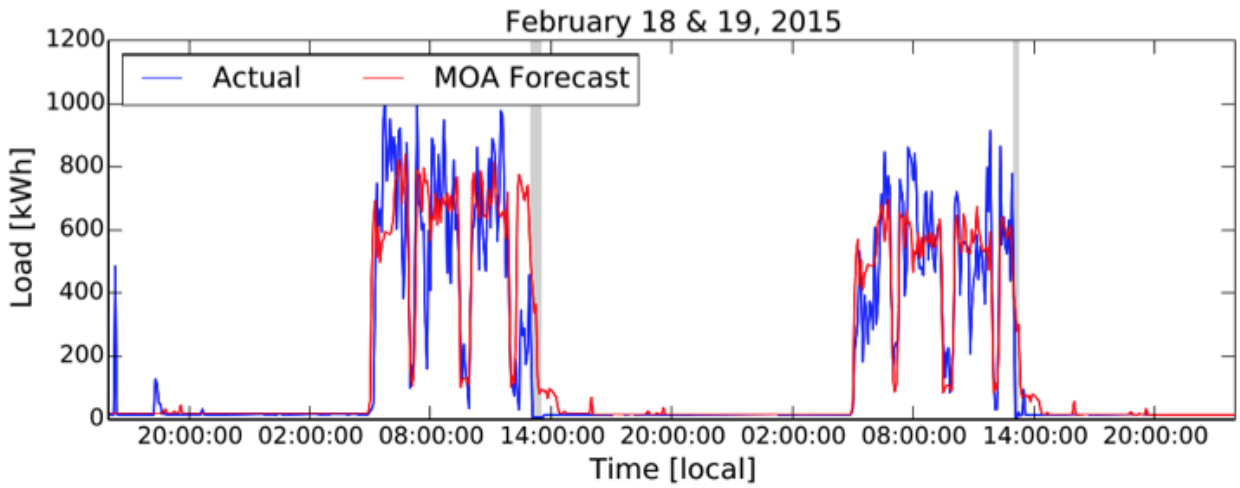
4.2 SMaRT Station DR Test Results

- Predicted baseline is the average of the previous ten operational days

- This method is referred to in the professional literature as XofY
- Baseline estimates for a given day are also scaled by a multiplicative factor such that the average pre-event load matches the previous days' average
- In the following predictions, this scale factor is determined from a seven hour average, capturing the opening of the plant and excluding the two hours prior to the event start
- This timeframe is known as the MOA period

Figure 22: SMaRT Station DR Test Results





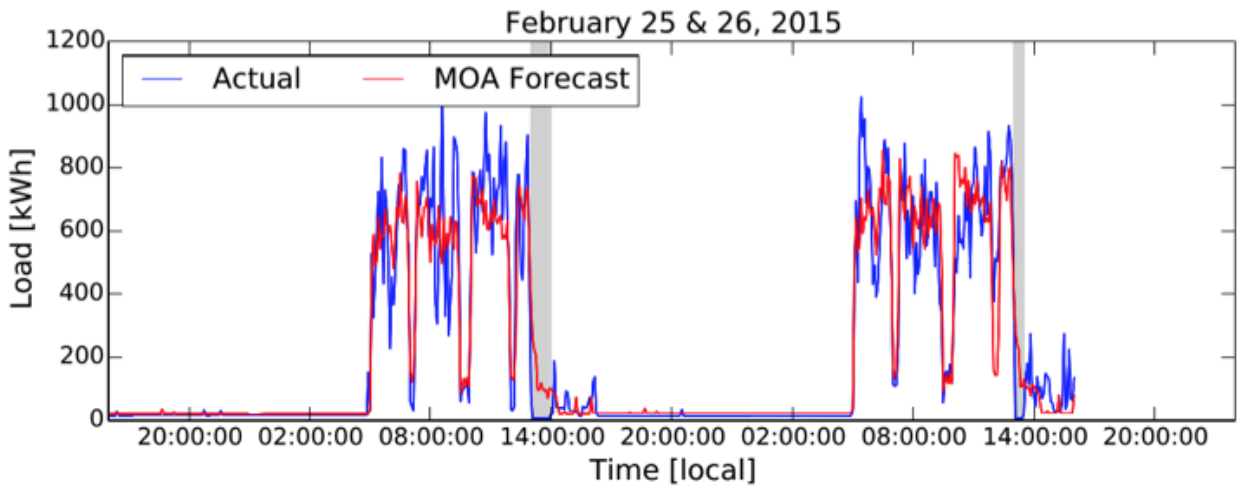


Table 6: Energy Savings Illustration for SMaRT Station

Description	Demand Response (kW)	Benefit	Event Period (Hours)	No. of Events /Year	Savings /Year
Demand Savings	100	$12.11/ kW / month	monthly	12	$14,532
Peak Day Pricing	200	~$7,840 / month in summer, minus $1.20/kWh during events	4	12	$3,600 (Savings will be higher if <12 events called)
CAISO	200	$.008 / kWh	1	8760	$14,016
Total Yearly Savings					$32,148

Source: AutoGrid Systems Inc.

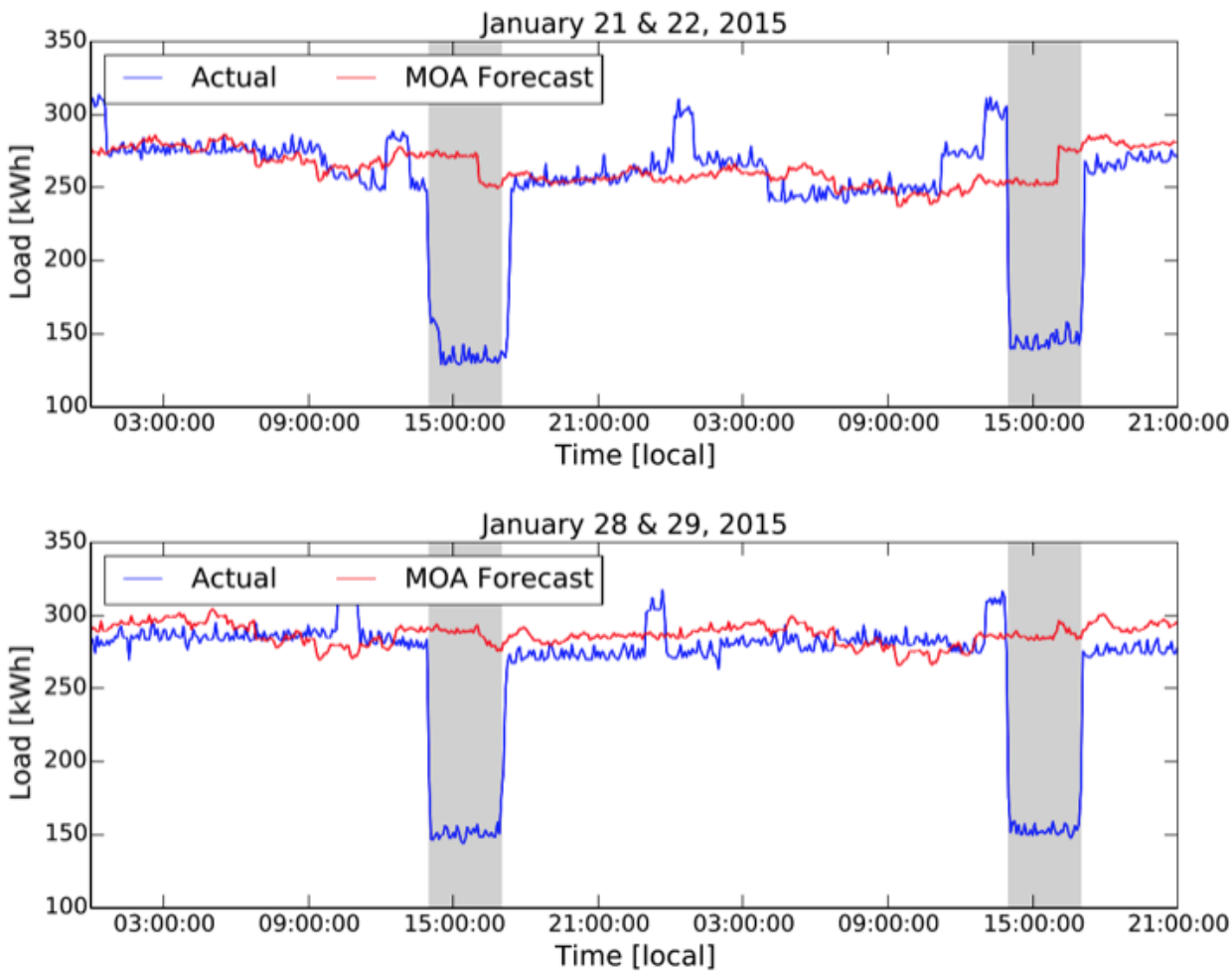
4.3 Donald M Somers WPCP DR Test Results

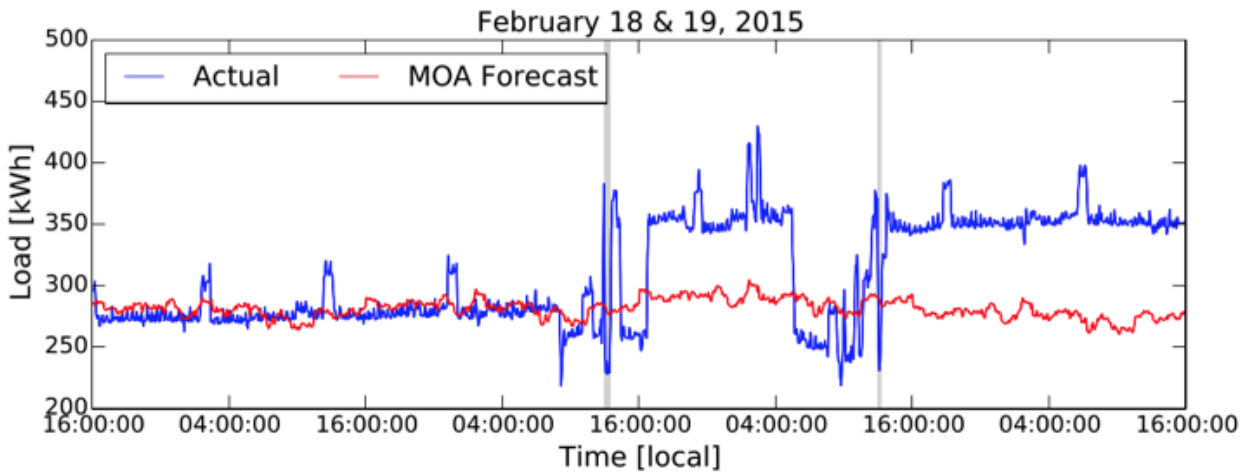
As identified in section 2.2.4 Demand Response Potential, 160 kW of load shed was identified for the WPCP. Three pond aerators, one pond recirculation pump, one digester pump, and three backwash pumps took part in the DR tests shown in 23.

WPCP DR Test Results

- Currently, same XofY methodology applied as in SMaRT forecasting case
- Unlike the SMaRT data, the WPCP load profile does not show a prominent hour-of-day pattern
- Quasi-periodic, hour-long increases in baseline load are observed approximately twice daily but currently no attempt is made to forecast them
- This functionality may be added in the future

Figure 23: Sunnyvale WPCP DR Test Results





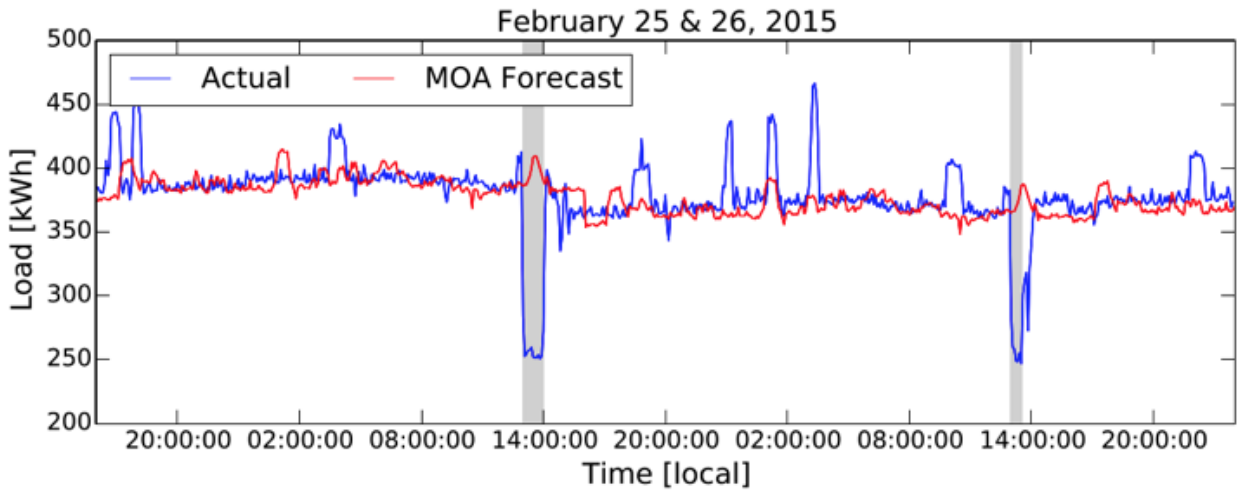


Table 7: Energy Savings Illustration for WPCP

Description	Demand Response (kW)	Benefit	Event Period (Hours)	No. of Events/Year	Savings per Year
Demand Savings	150	$12.11/ kW / month	monthly	12	$21,798
Peak Day Pricing	160	~$7,840 / month in summer, minus $1.20/kWh during events	4	12	$2,880 (Savings will be higher if <12 events called)
CAISO	160	$.008 / kWh	1	8760	$11,212.80
Total Yearly Savings					$35,890.80

Source: AutoGrid Systems Inc.

4.4 Challenges

4.4.1 Barriers for Fast-DR Implementation

One of the main barriers in the way of industry wide adoption of Demand Response practice is the high cost of enablement. Exiting DR platforms require extensive proprietary hardware installation at the end-user site. For ancillary services, loads and generators must install ISO/RTO approved telemetry devices that can collect 4-second data and cost upward of $250,000 per site today. Because the telemetry systems are complex and must provide 4-second updates to the CAISO Energy Management System, these installations are costly (SCE, 2011). The researcher's total cost for all telemetry was under $32,000 for both facilities combined. This is still on the high side as available choices of Open AutomatedDR compliant devices that offer actuation and control is limited at the moment. These costs are expected to come down over time as additional choices become available. Also the researchers had to add additional controls and sub-metering in the current design for multiple loads. These can be further optimized and equipment cost can be reduced to under $10,000 per site.

4.4.2 Redistribution of Labor

Since many operations at the SMaRT Station requires the presence of workers, a labor shift is required during a demand response event. Conveyor belts at the sorting facility and the wood grinder require presence of at least two personnel during normal operations. Following a demand response event, the labor present at the equipment taking part in the event should be redirected to other parts of the facility still undergoing normal operations. The researchers discussed the challenges with labor redistribution with the SMaRT station operators. The operators were open to labor redistribution as other parts of the facility were not impacted by the load curtailment.

4.4.3 Safety

Due to human interaction at certain parts of the facility, it is important to notify the personnel pre- and post-DR events. While all equipment can be called for a DR event remotely, not all can be brought back online in the same manner. As an example, pond aerator pumps require the presence of the operator at the control switch and needs to be manually turned on. At the SMaRT station the wood grinder also needs an operator to manually turn back on when the DR event is over. While automatic recovery could be a convenience it can be a safety hazard and can put workers in the vicinity of the equipment in great risk, especially if they are not aware of the DR event. Strobe lights were added on top of each ADR control unit. The strobe light was left flashing for the duration of the DR events to alert operators and other staff members that the loads were curtailed in response to the DR event.

4.4.4 Bidding the curtailed load in CAISO Regulation markets

The plants can benefit financially and recoup their investment in equipment if they were able to bid their flexible load capacity in a CAISO regulation market. The WPCP can benefit from selling the excess capacity in the regulation market as a generating facility. More investigation needs to be done in how they can maximize the revenue from such bidding.

CHAPTER 5:
Conclusions and Next Steps

This project demonstrated that the researchers provided DR and surpassed the performance of existing devices at 10-20 percent of the cost of what is proposed in SCE's rate case application (SCE, 2011).

This demonstration project built on previous years of industrial demand response research to bring low-cost, scalable, fast demand response to municipal wastewater and recycling facilitates. This demonstration project leveraged several findings of the DR research previously identified.

1. **Auto-DR opportunity validation:** The team determined that there is a wide range of sometimes substantial opportunities for Auto-DR in wastewater and recycling industries through load shedding/shifting. This finding was supported by case study and field test examples. Several wastewater treatment facilities documented the implementation of load management and energy efficiency measures. As result of this project WPCP in Sunnyvale, California reduced average demand by 150 kW or 50percent of total demand by implementing AutoGrid System's Inc. DROMS.
2. **Control capabilities matter:** The team determined that Auto-DR is compatible with energy efficiency and load management in industrial facilities, but many industries have limited controls capabilities, especially for supporting or non-core systems that may be suited for Auto-DR. This demonstration project enabled automatic controls with minimum human interaction and set a new standard for Auto-DR at wastewater facilities. In addition LBNL and AutoGrid built and tested integrated control and metering panels. This allows the facility to participate in CAISO markets directly.
3. **Characterization and strategies to support participation:** The team developed studies and DR strategies for better DR participation at wastewater facilities. Market studies supported by field tests helped the team to identify effective shed/shift strategies, while the guides helped users understand Auto-DR event impacts on their processes and better positioned them for Auto-DR participation.
4. **Identified areas for future work at wastewater treatment facilities:** Conducting a further study to understand the prevalence of cogeneration in wastewater treatment facilities and its relationship to Auto-DR potential, including utilizing schedulable self-generation and a self-starting generation unit to contribute to Auto-DR.

GLOSSARY

Term	Definition
AGC	Automatic Generation Control
API	Application Programming interface
Auto-DR	Auto-Demand Response
CAISO	California Independent System Operator
CT	Current Transducers
DLC	direct load control
DR	demand response
DROMS	Demand Response Optimization and Management System
DRRC	Demand Response Research Center
EDP	Energy Data Platform
EPIC	Electric Program Investment Charge
ERCOT	Electricity Reliability Council of Texas
Fast DR	Fast Demand Response
FE	Forecasting Engine
GW	Gigawatt hour
HP	horsepower
ICT	Information and Communication Technology
I/O	input/output device
IRM	Intermittent Renewable Management
IRM2	Intermittent Renewable Management Pilot Phase 2
ISO	Independent System Operator
IT	Information Technology
kW, kwh, GWh	Kilowatts
kWh	Kilowatt hour
LBNL	Lawrence Berkeley National Laboratory

LSE	load-Serving Entity
M2M	Machine to Machine
MCC	motor control center
MOA	Morning of Adjustment
mS	millisecond
MW	megawatt
NERC	North American Electric Reliability Corporation
OpenADR2.0	Open Automatic Demand Response module version 2.0
PDR	Proxy Demand Response
PG&E	Pacific Gas and Electric
PIER	Public Interest Energy Research
RD&D	Research, development and demonstration
RPS	Renewable energy Portfolio Standards
RTO	Regional Transmission Organization
SaaS	Software As-A System
SaaS	Software-As-A-Service
SCADA	Supervisory Control and Data Acquisition
SCE	Southern California Edison
SMaRT	Sunnyvale Materials Recovery and Transfer station
Smart Grid	Smart Grid is the thoughtful integration of intelligent technologies and innovative services that produce a more efficient, sustainable, economic, and secure electrical supply for California communities.
Sub-LAP	Sub Location Aggregation Points
TOU	Time of Use
VTN / VEN	Virtual Top Node, Virtual End Node
WPCP	Water Pollution Control Plant

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Kiliccote, S., Lanzisera, S., Liao, A., Schetrit, O., & Piette, M. A. (2014). Fast DR: Controlling Small Loads over the Internet. *ACEEE.*

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APPENDIX A:
SMaRT Station Electrical Diagrams

Figure 22: Latency Diagram Dent

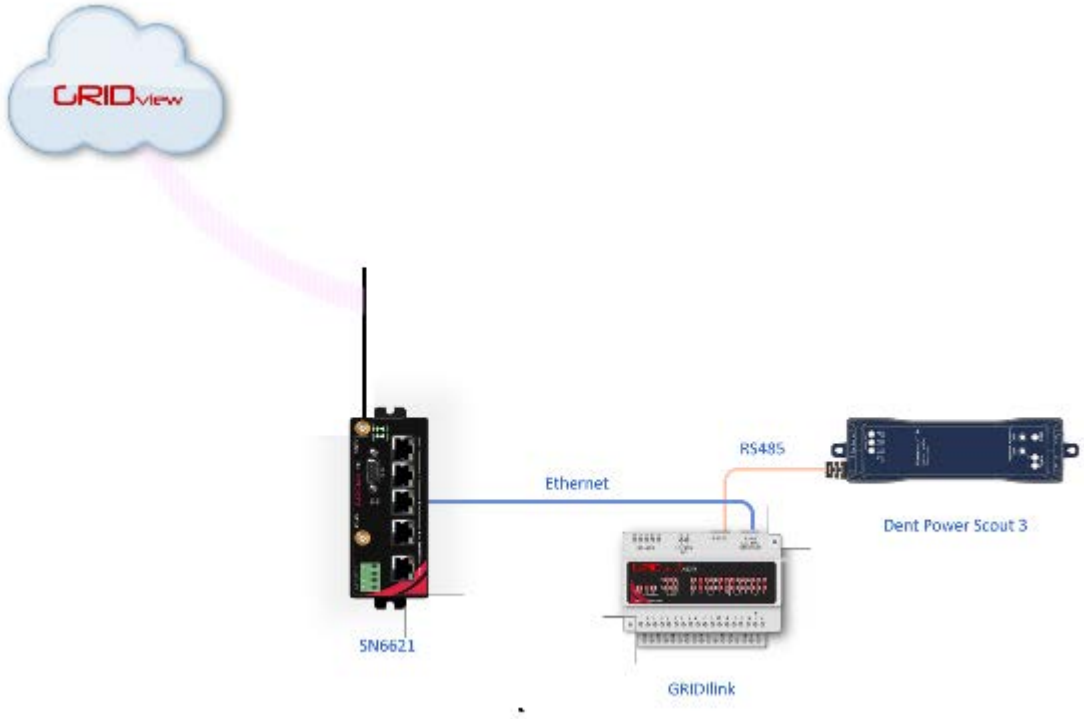


Figure 23: Latency Diagram Shark

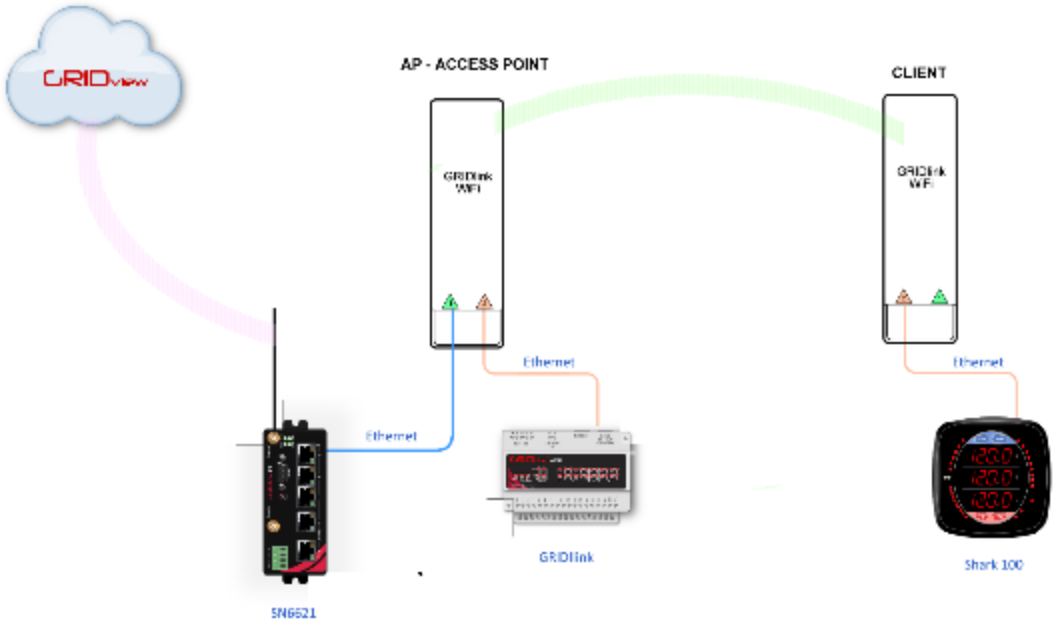


Figure 24: Shark® Meter's Front Panel Display

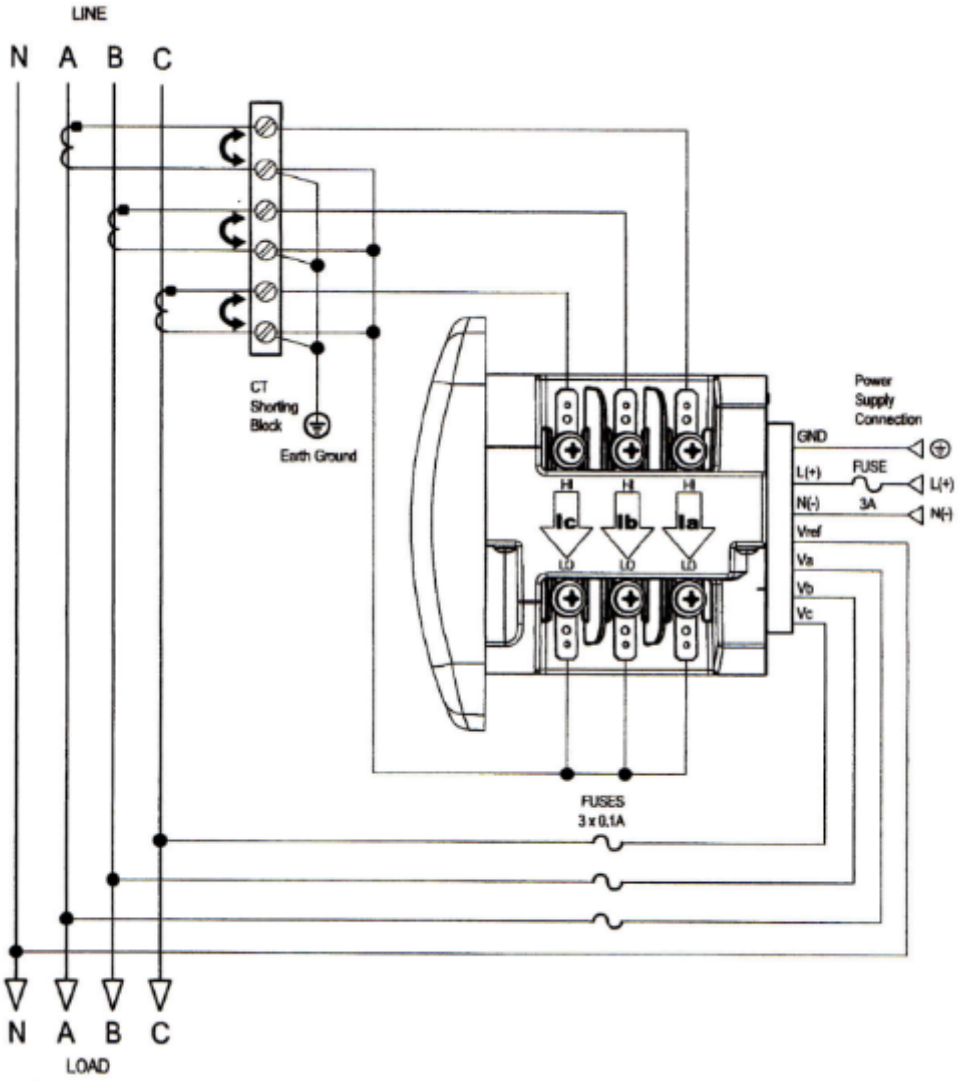


Figure 25: SMaRT Station – Client Curb Side Master Load Shed Control Panel

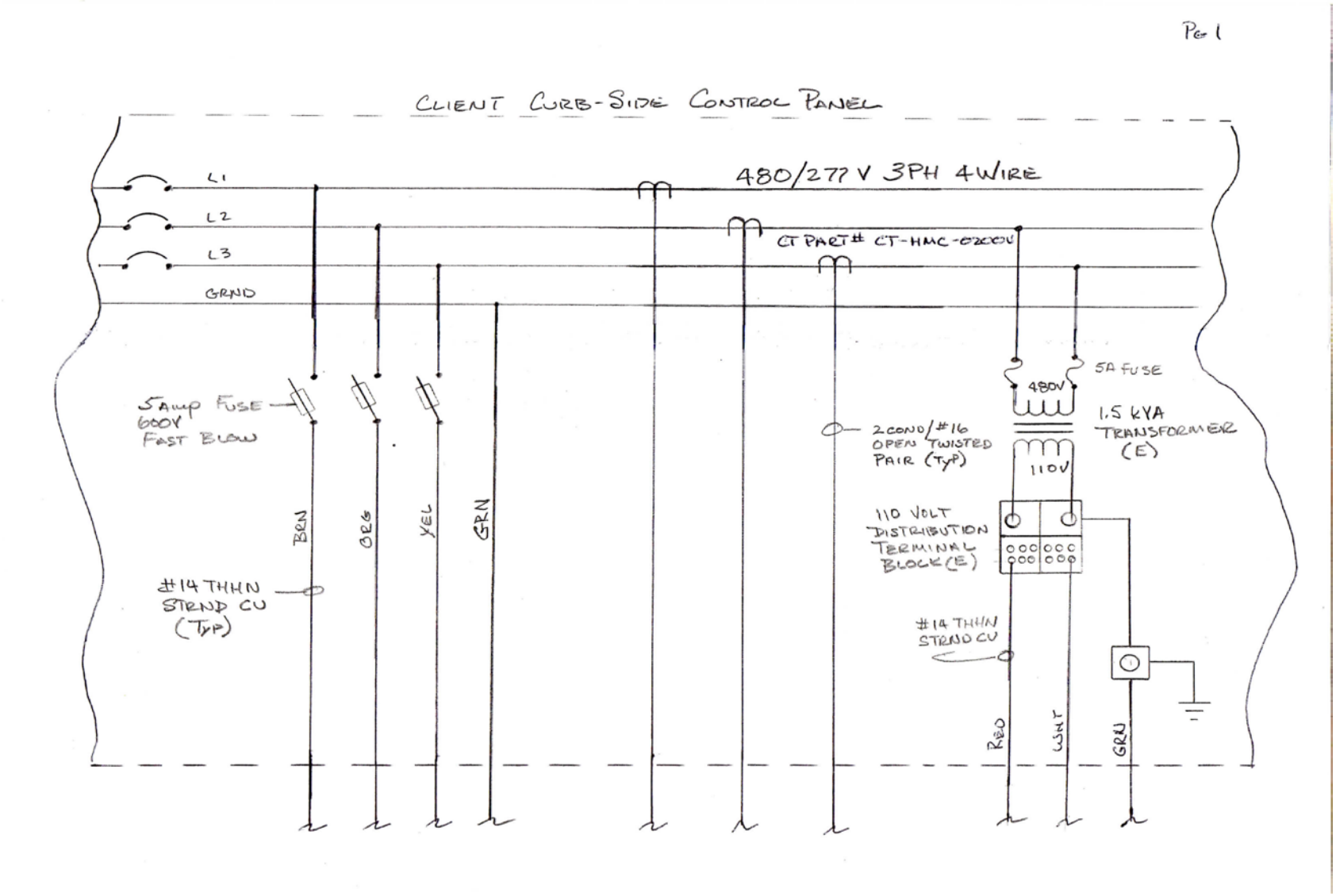


Figure 26: SMaRT Station – Load Shed Control Panel

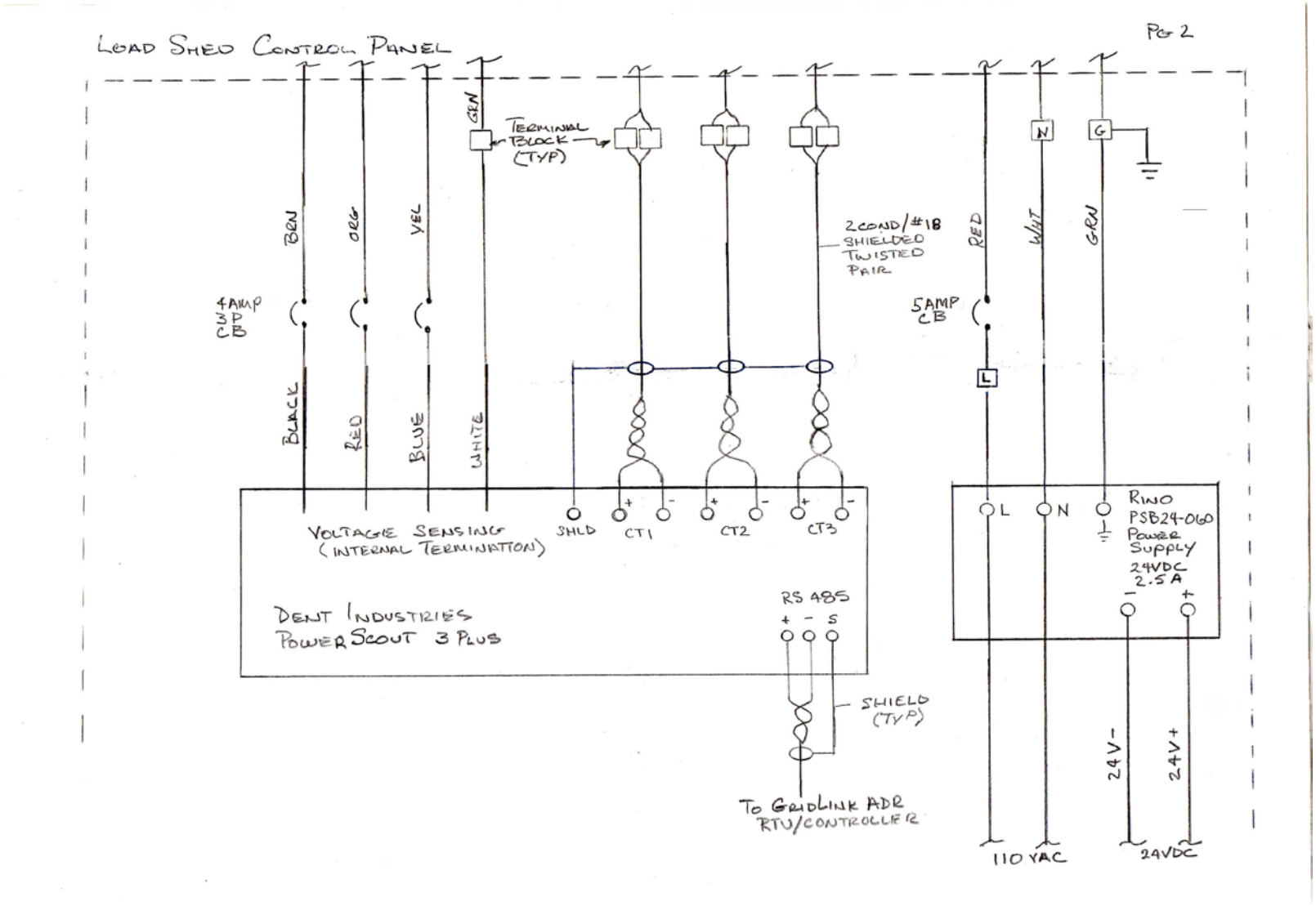


Figure 27: SMaRT Station – Communications

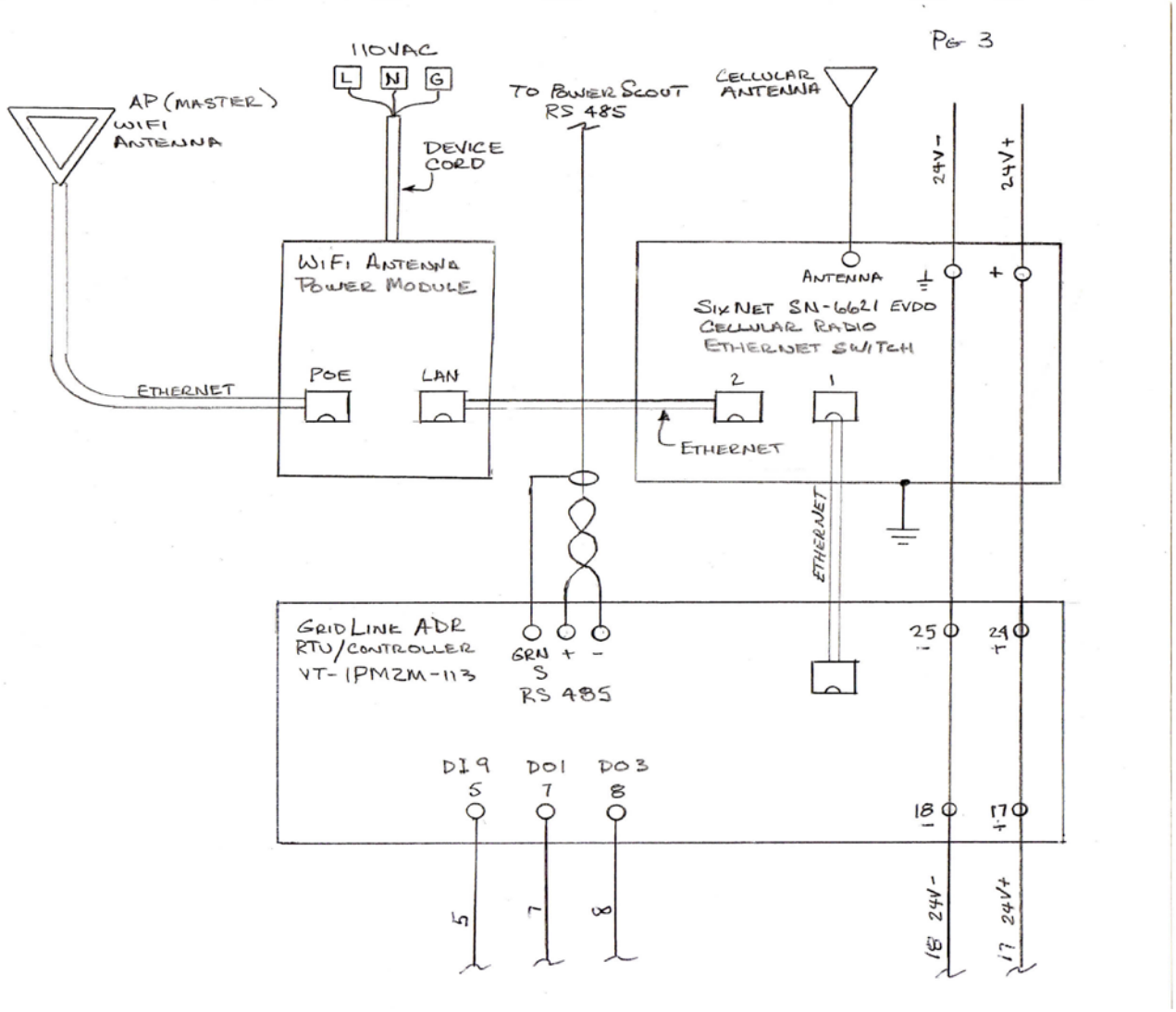


Figure 28: SMaRT Station – Load Shed Control

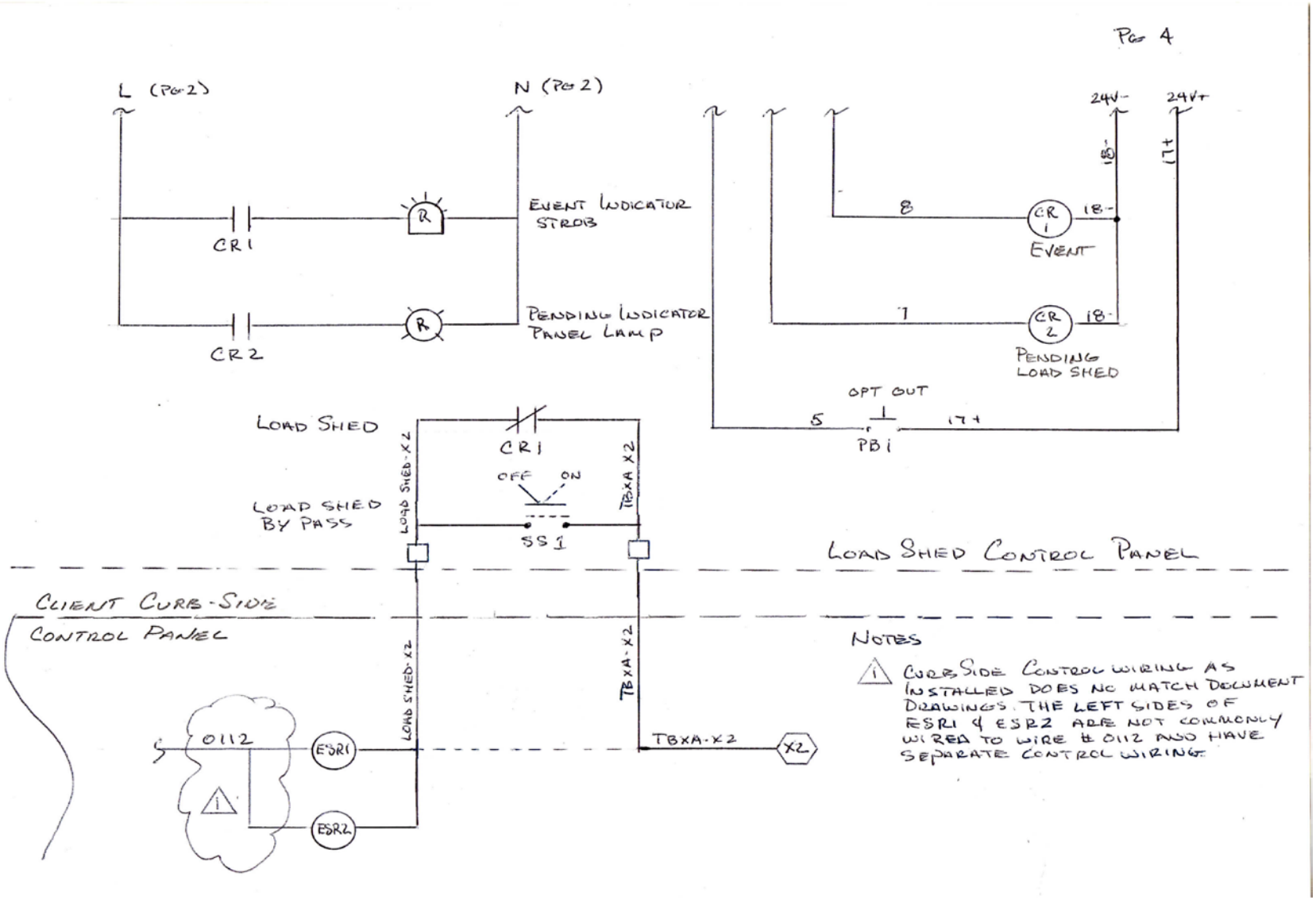


Figure 29: SMaRT Station – Wood Hog Load Shed Panel

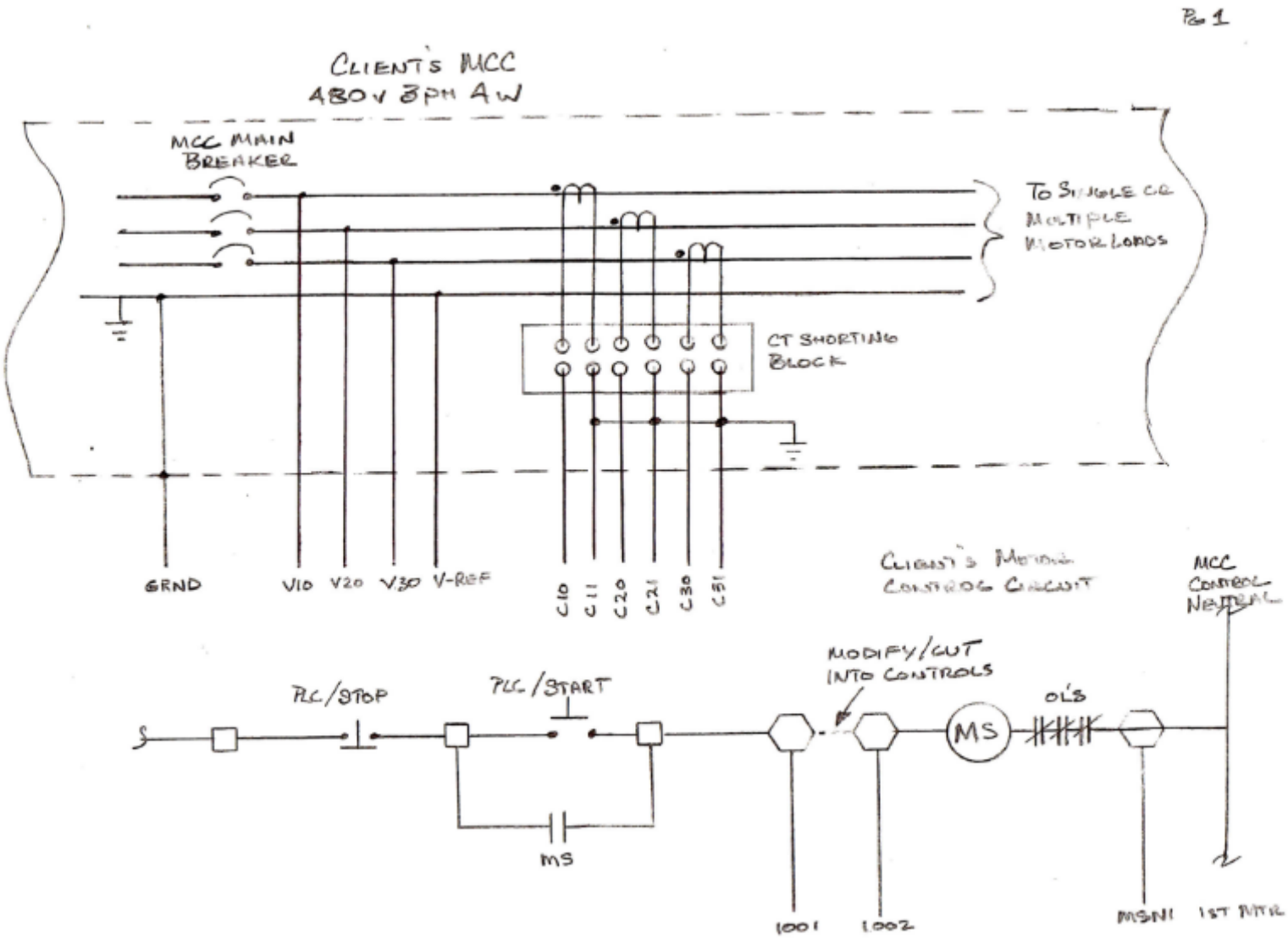


Figure 30: SMaRT Station Wood Hog Client MCC

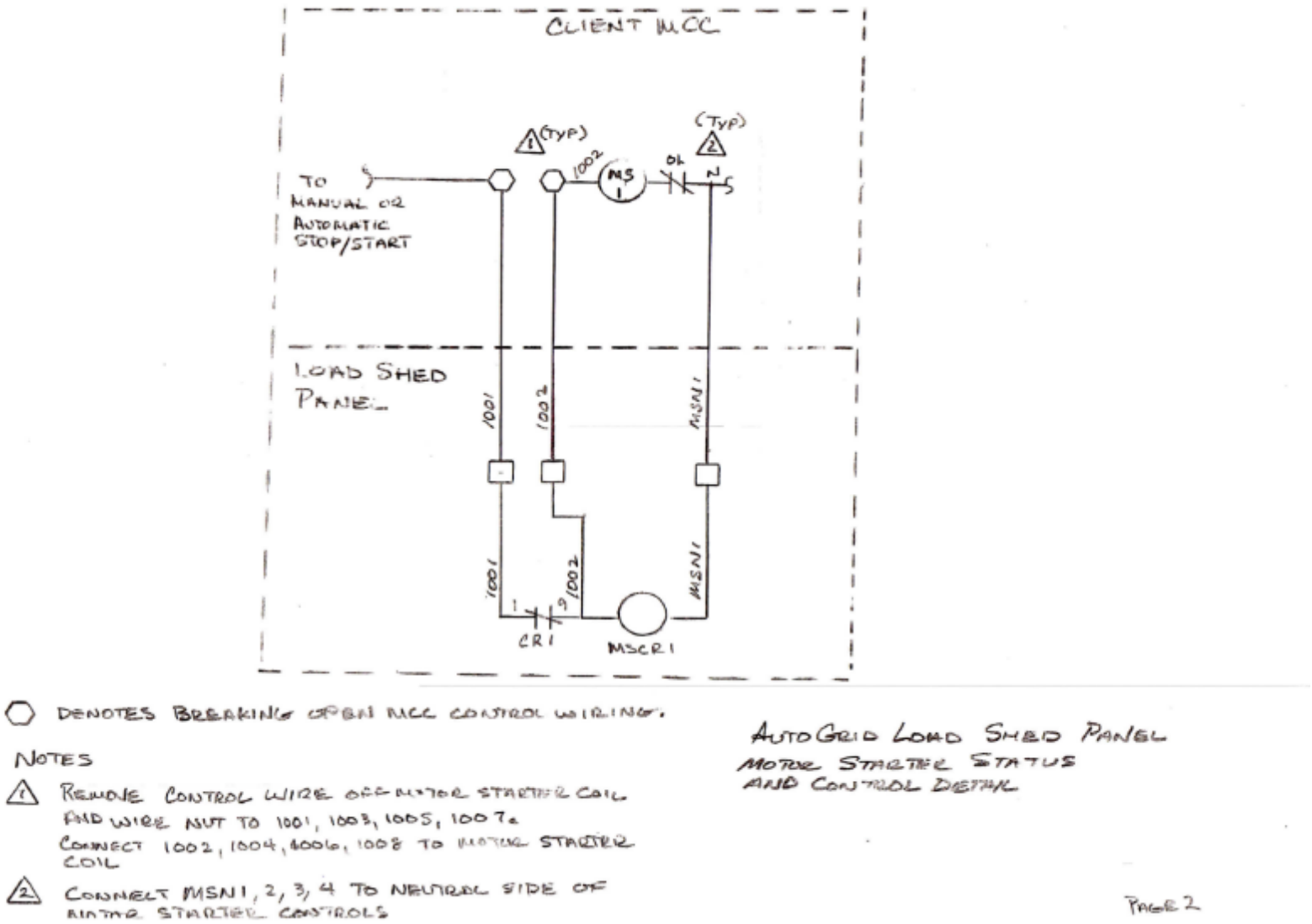


Figure 31: SMaRT Station Wood Hog - AutoGrid Load Shed Panel

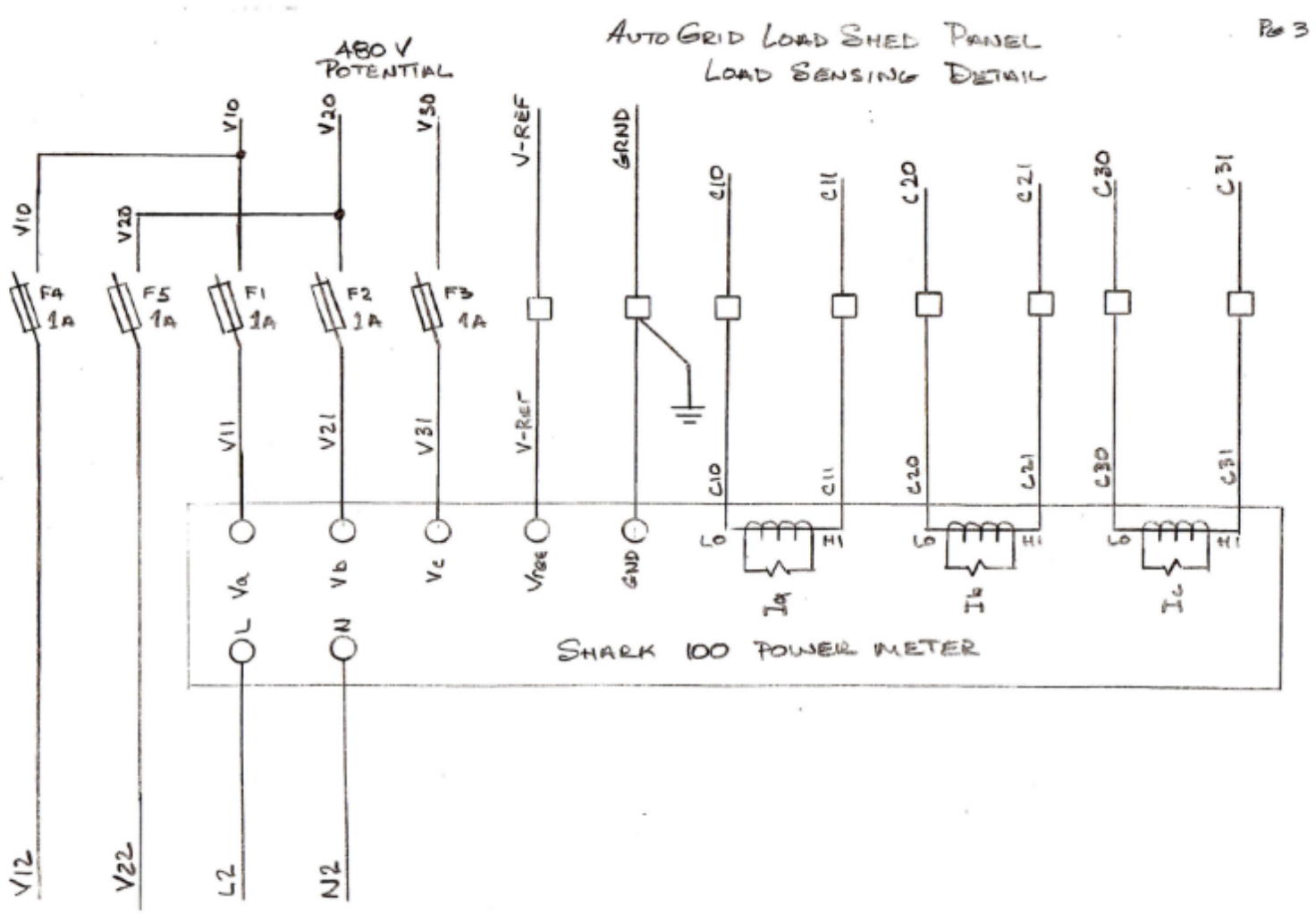


Figure 32: SMaRT Station Wood Hog Control

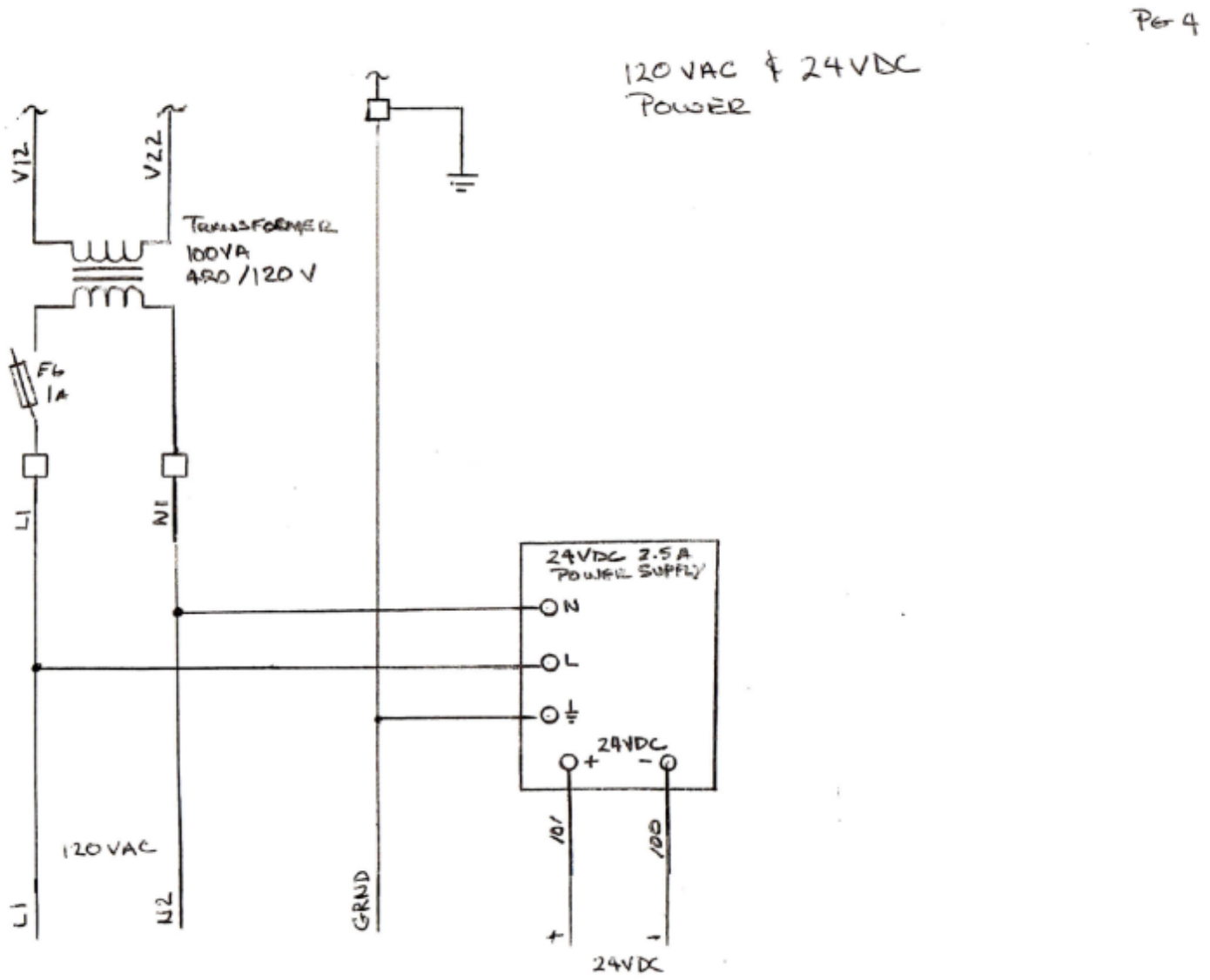


Figure 33: SMaRT Station Wood Hog Bypass Switch Wiring

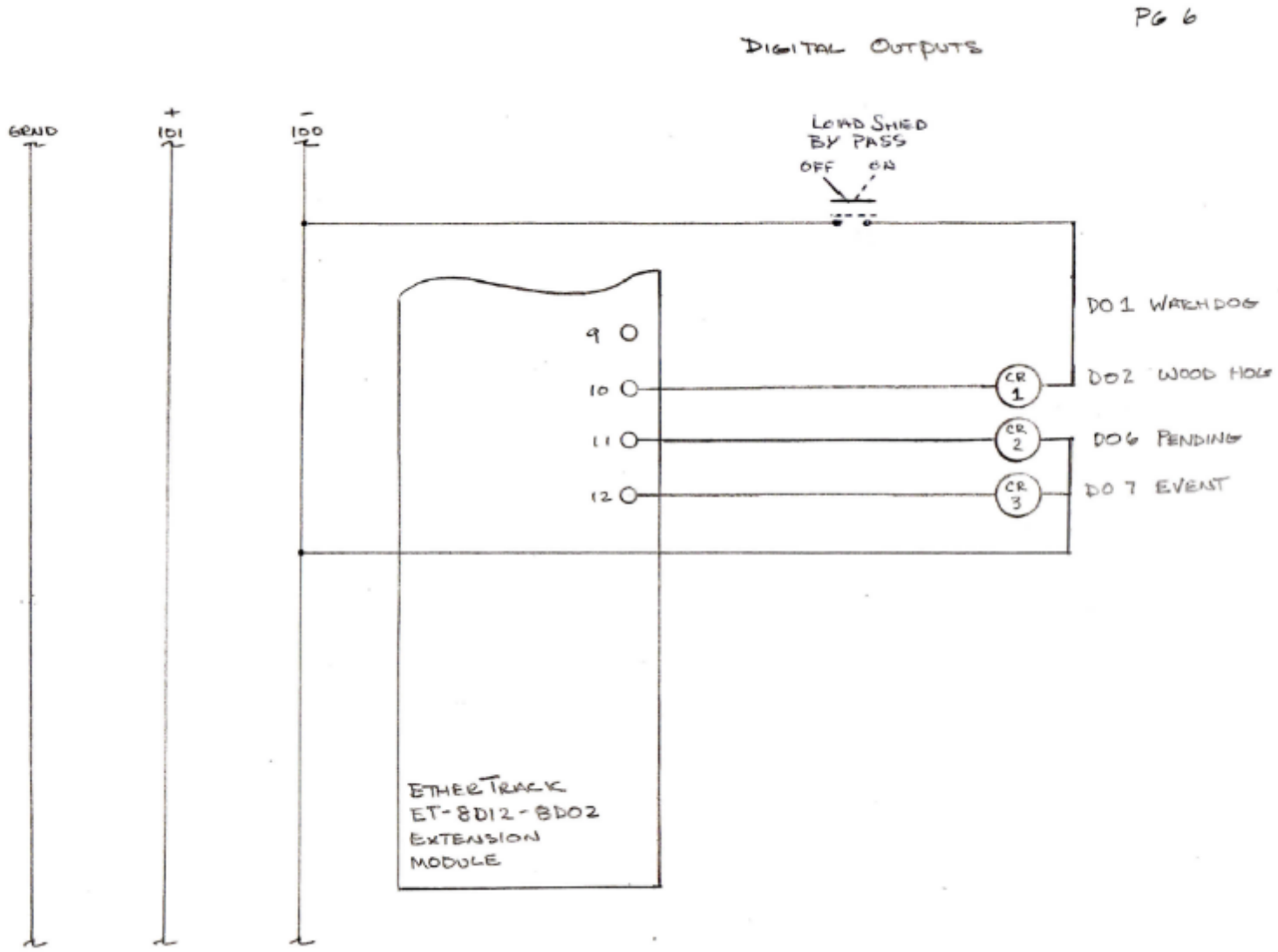
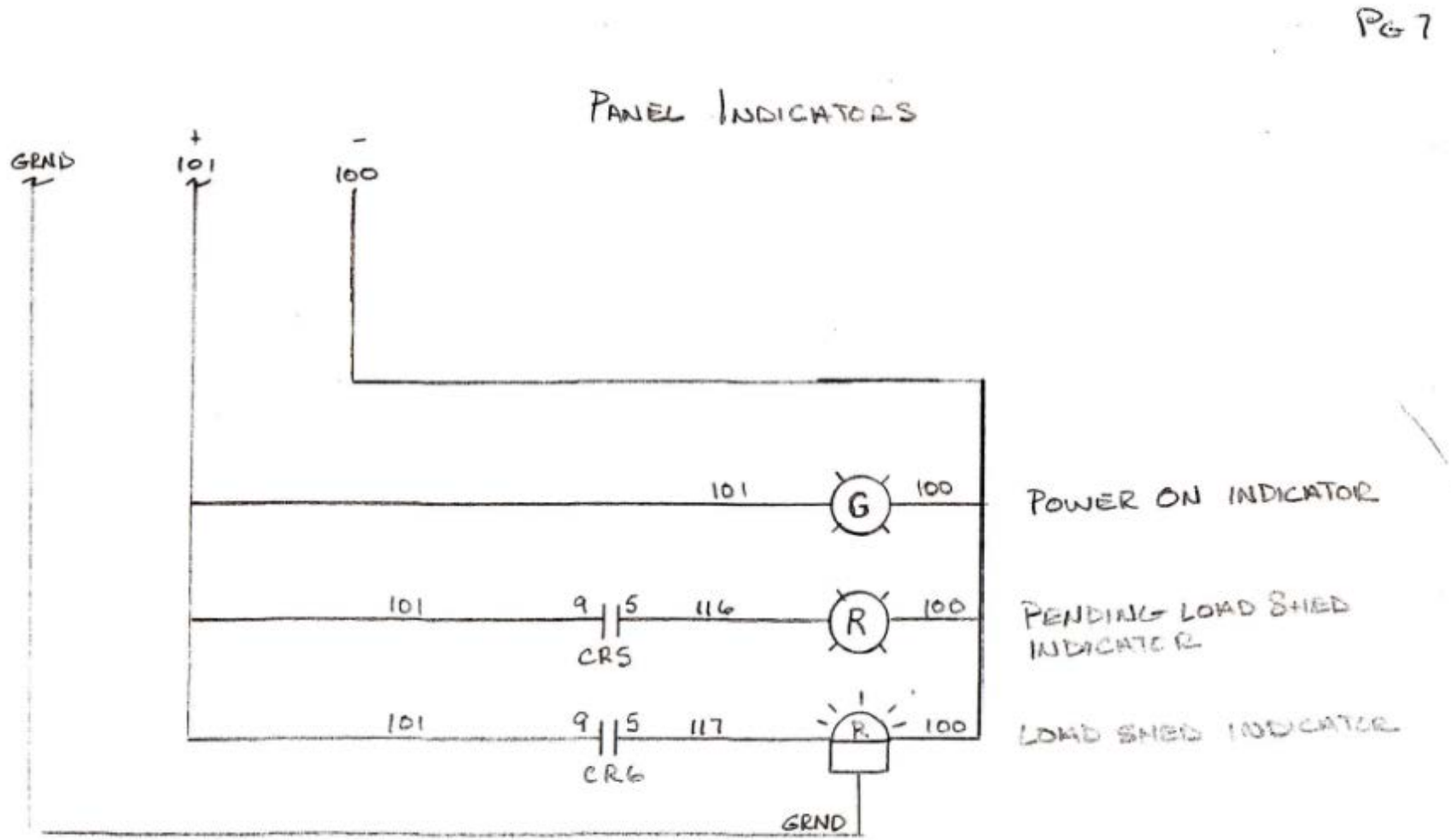


Figure 34: SMaRT Station Wood Hog – Panel Indicator



APPENDIX B:
WPCP Electrical Drawings

Figure 35: WPCP Back Wash Pump – Client's MCC

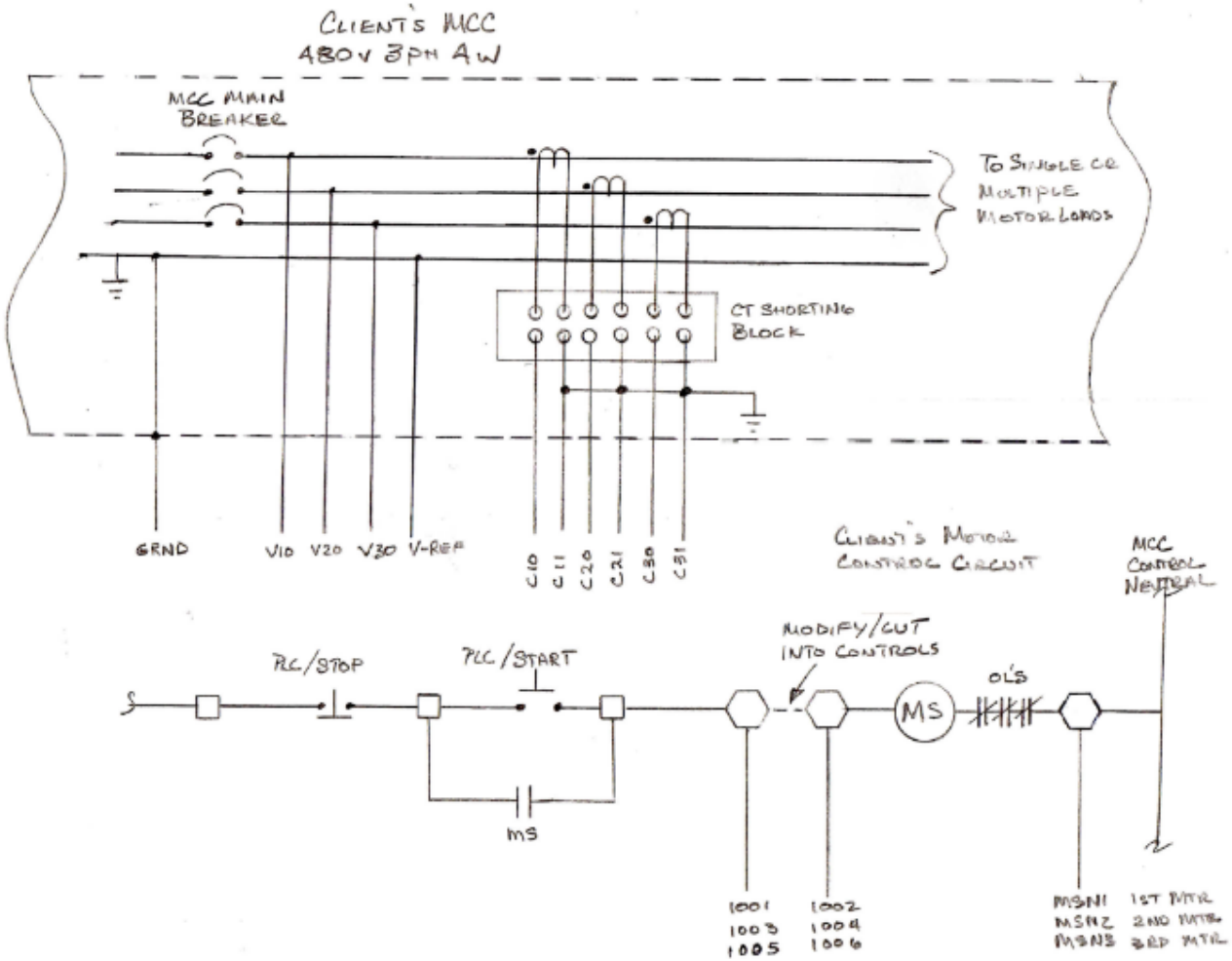


Figure 36: WPCP Back Wash Pump – Motor Starter Status and Control Detail

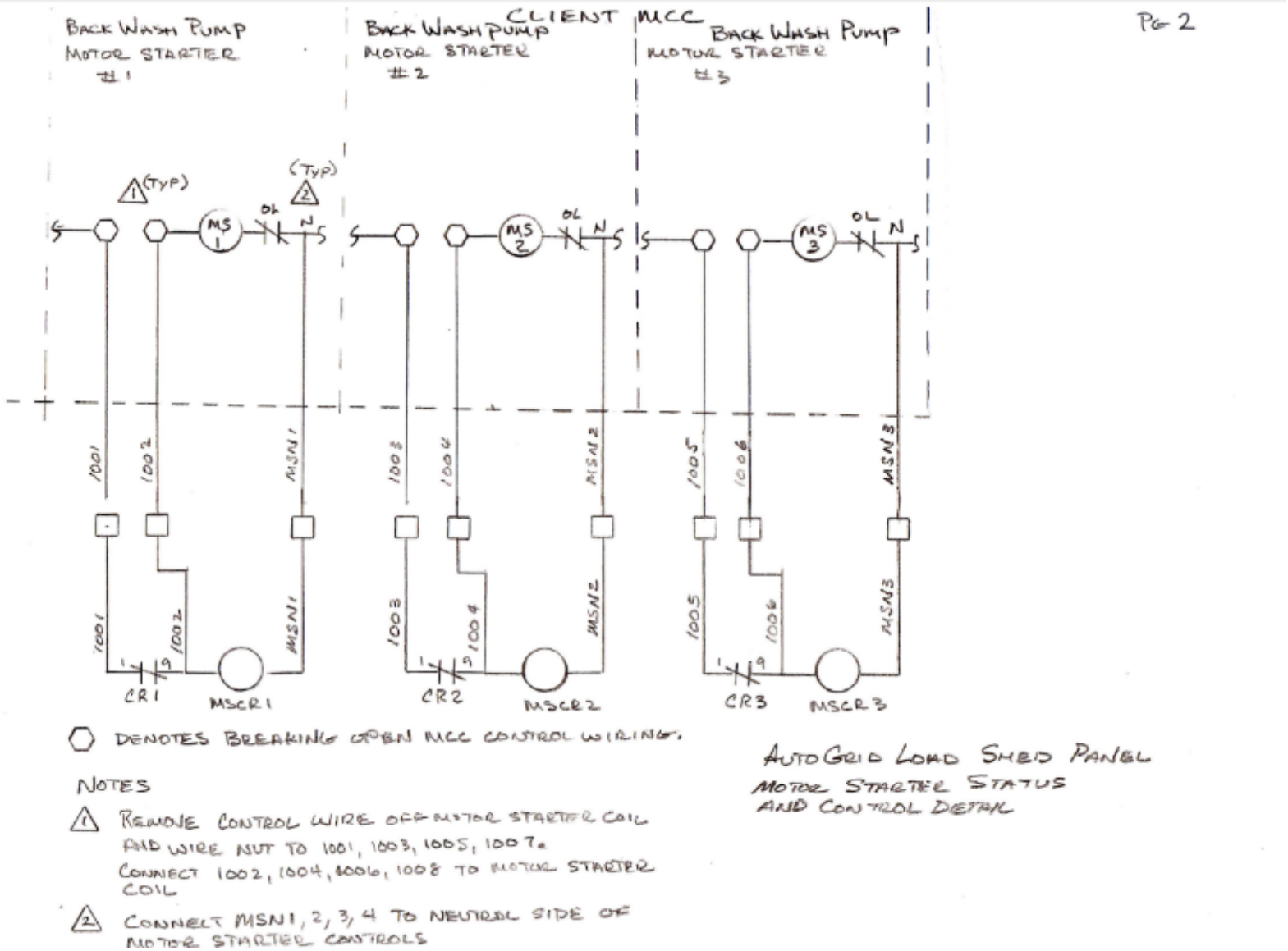


Figure 37: WPCP Back Wash Pump – AutoGrid Load Shed Panel, Load-Sensing Detail

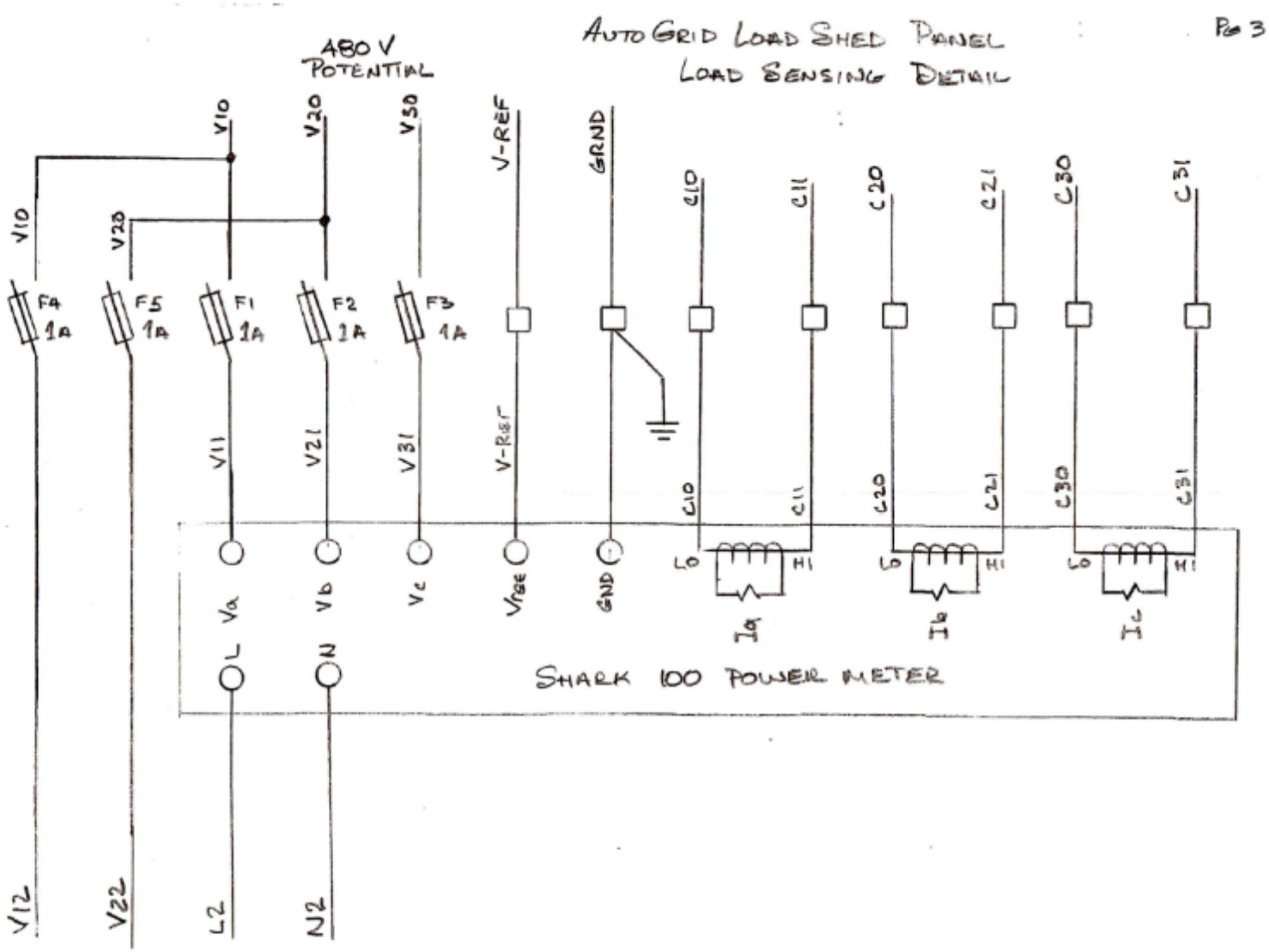


Figure 38: WPCP Back Wash Pump – 120VAC & 24VDC Power Supply

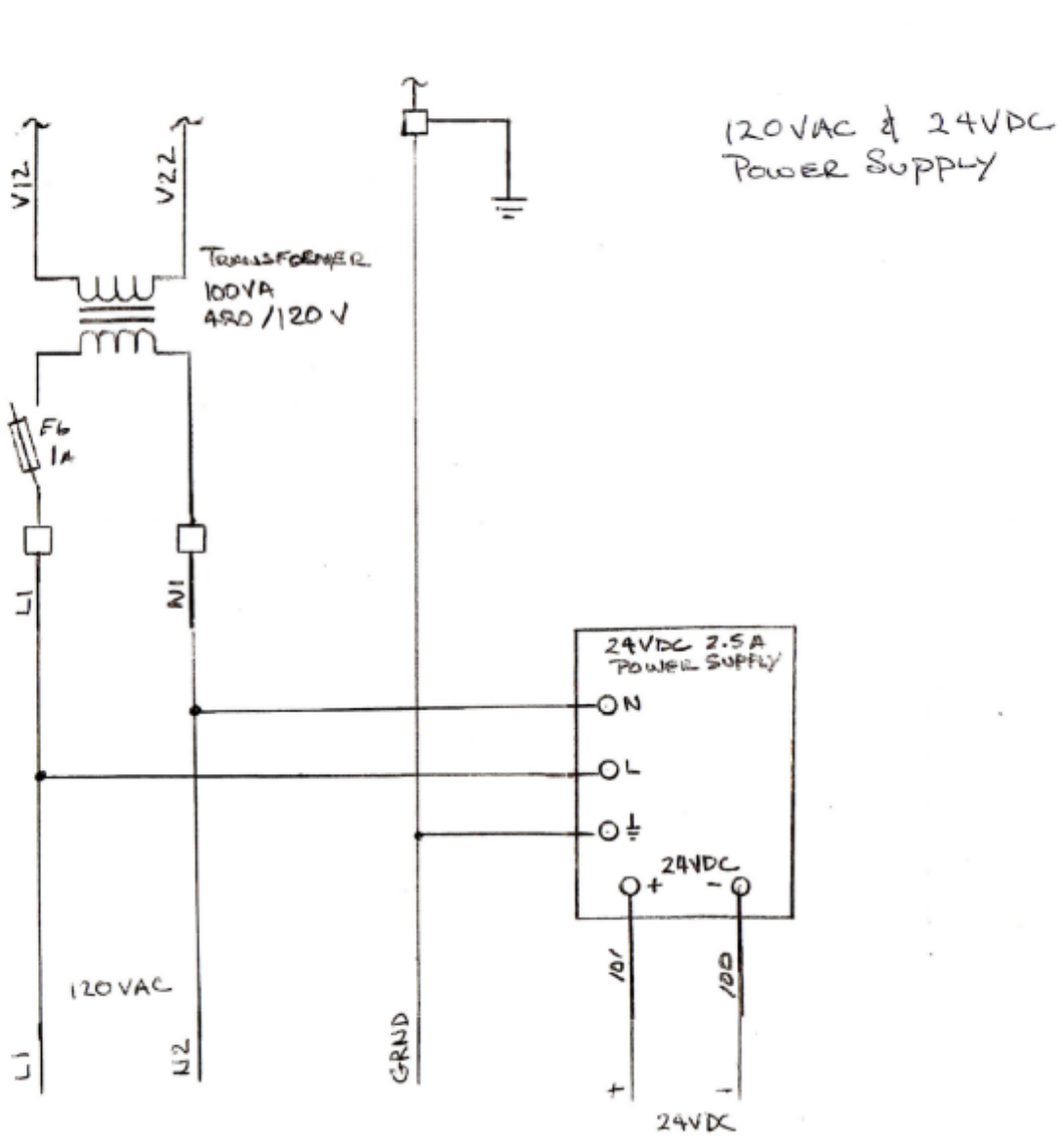


Figure 39: WPCP Back Wash Pump – Digital Input

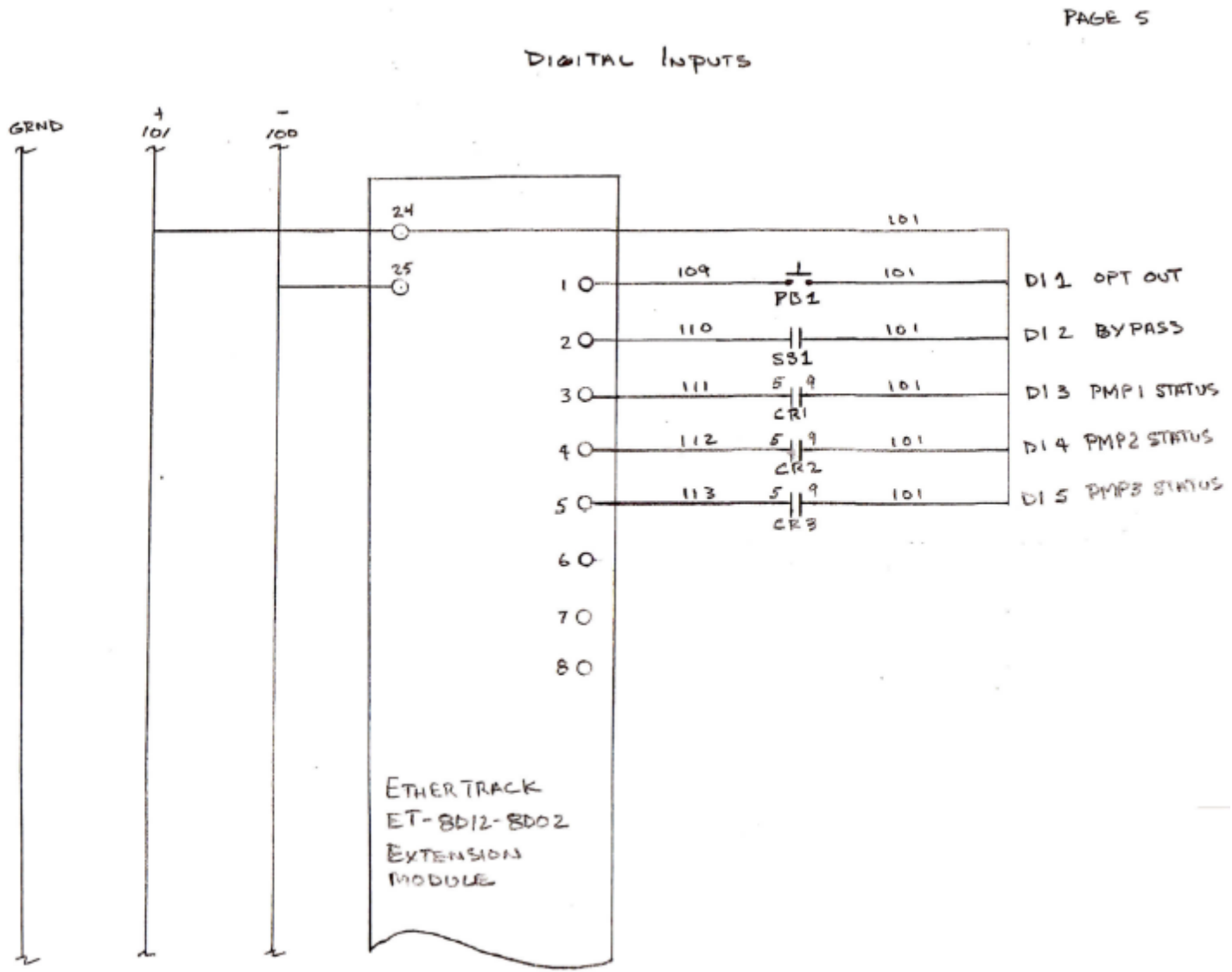


Figure 40: WPCP Back Wash Pump – Digital Output

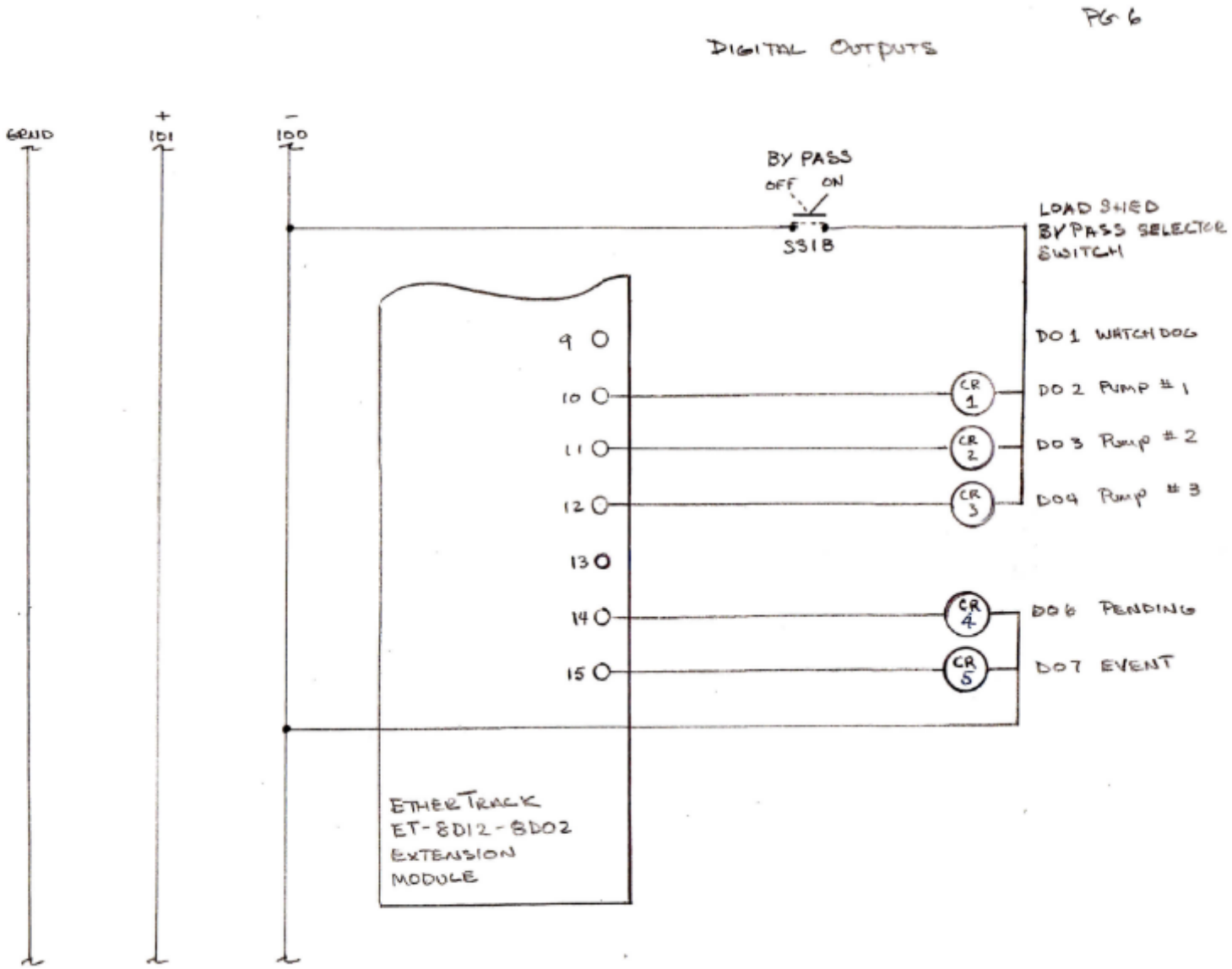


Figure 41: WPCP Back Wash Pump – Panel Indicators

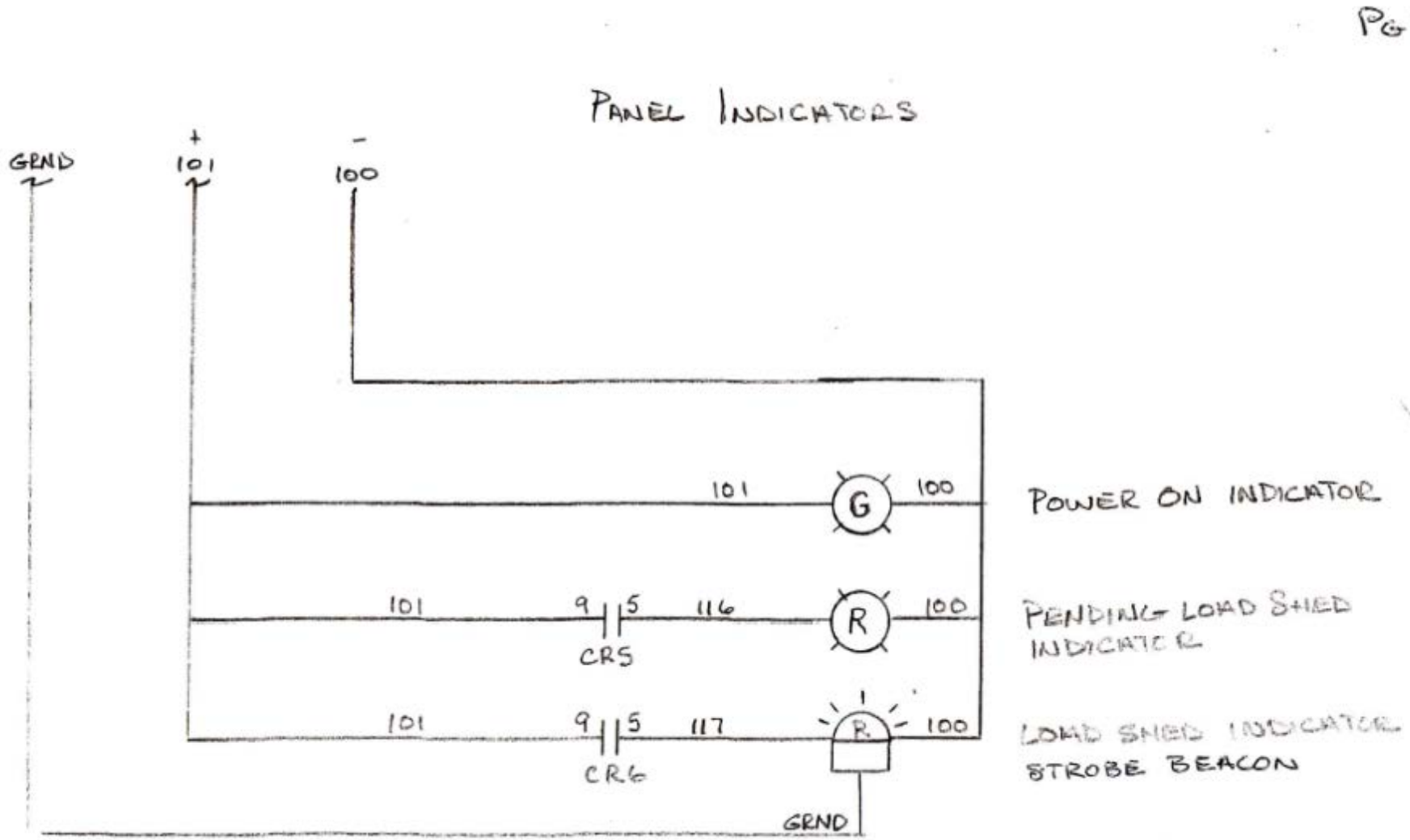


Figure 42: WPCP Power Aeration Pumps – Client's MCC

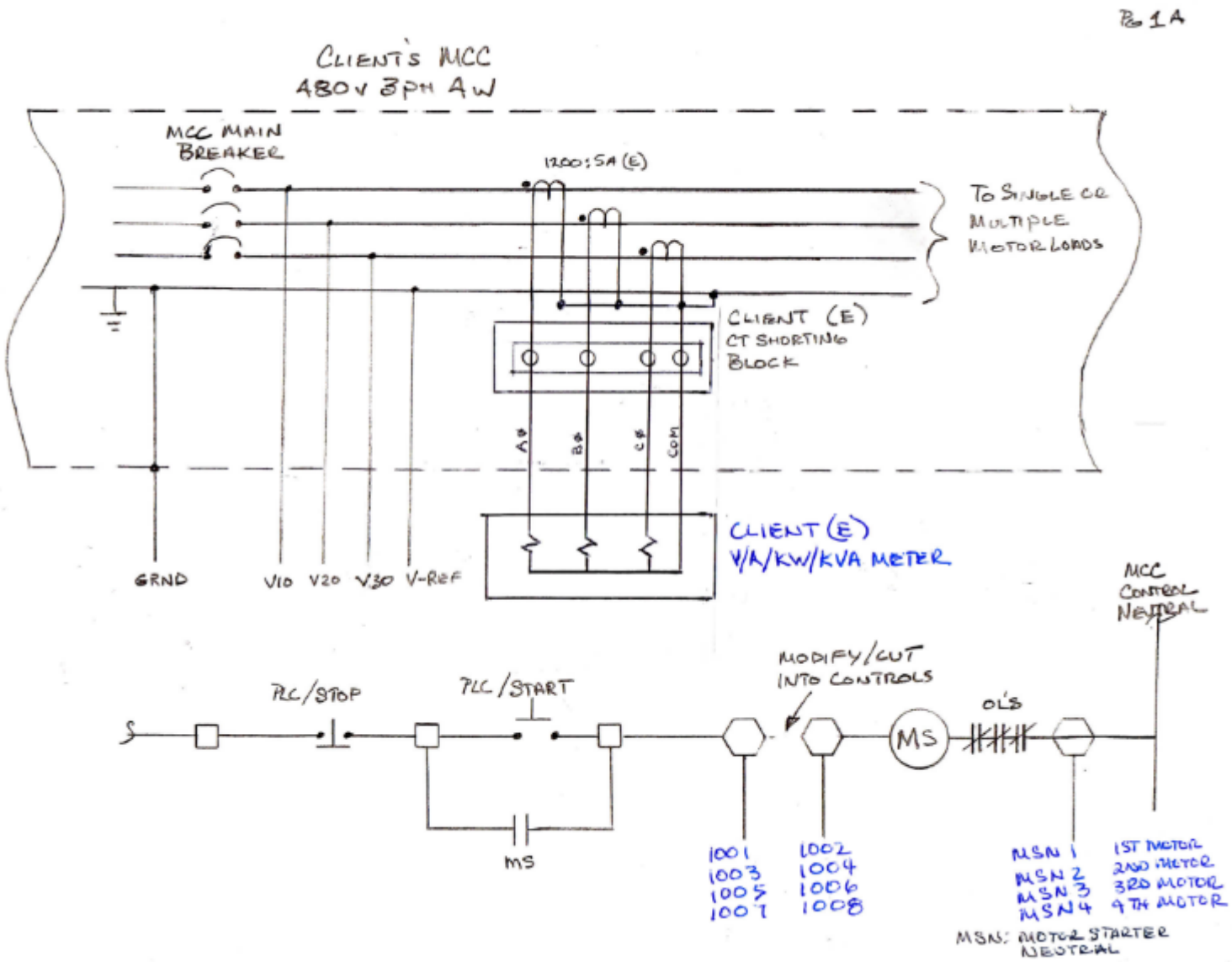


Figure 43: WPCP Power Aeration Pumps – PGF MCC

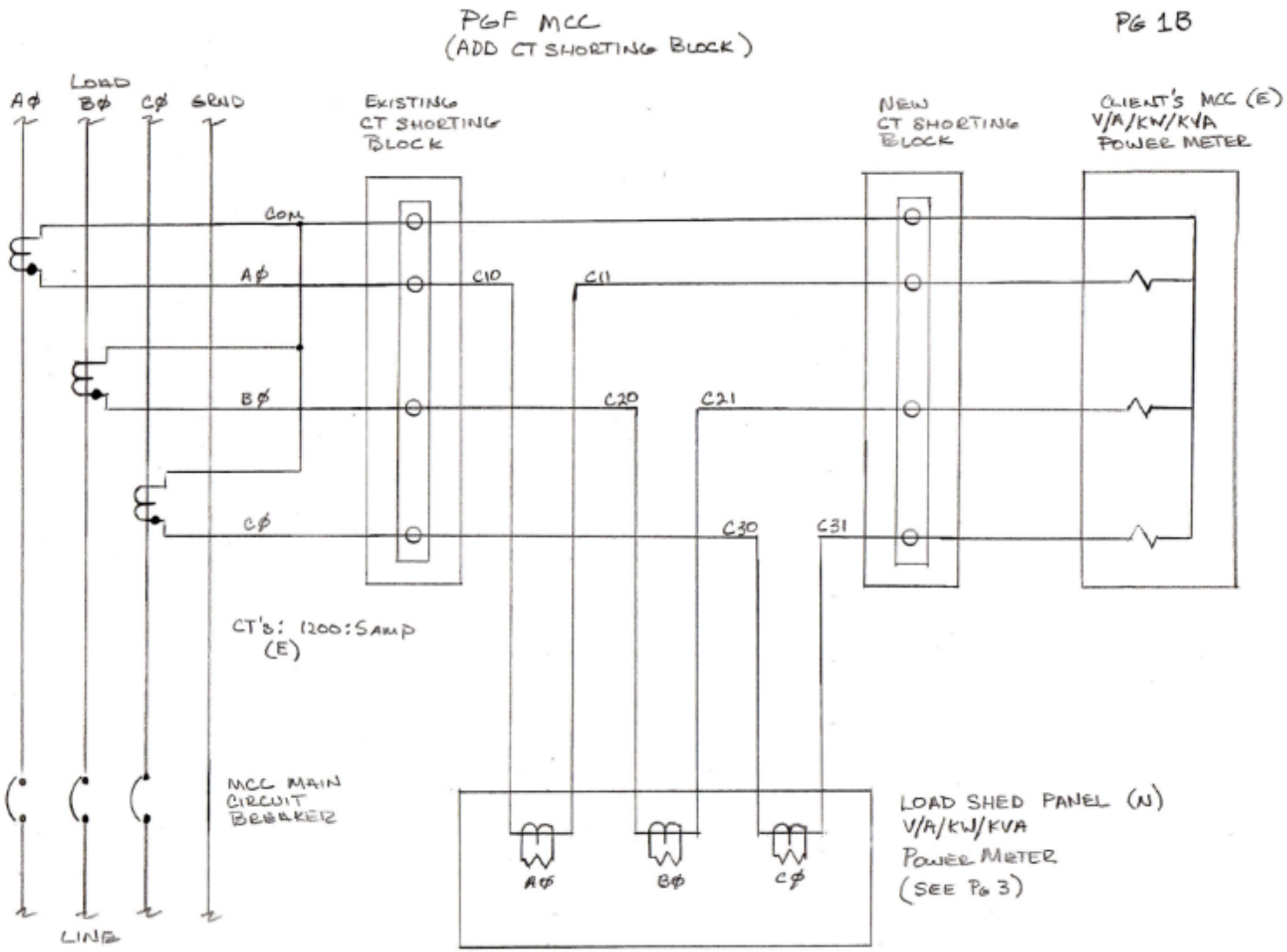
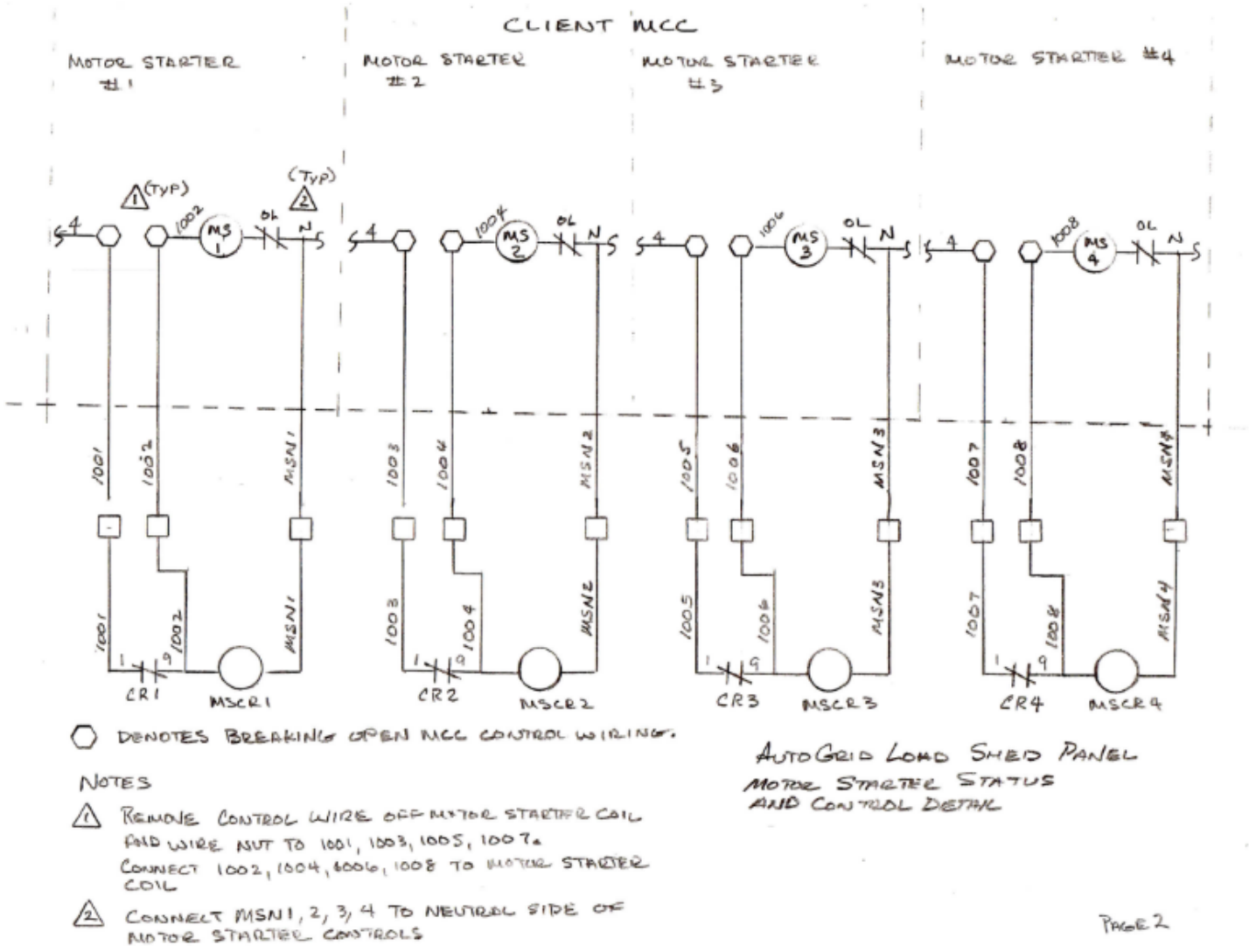


Figure 44: WPCP Power Aeration Pumps – Client MCC



e

Figure 45: WPCP Power Aeration Pumps – AutoGrid Load Shed Panel, Load-Sensing Detail

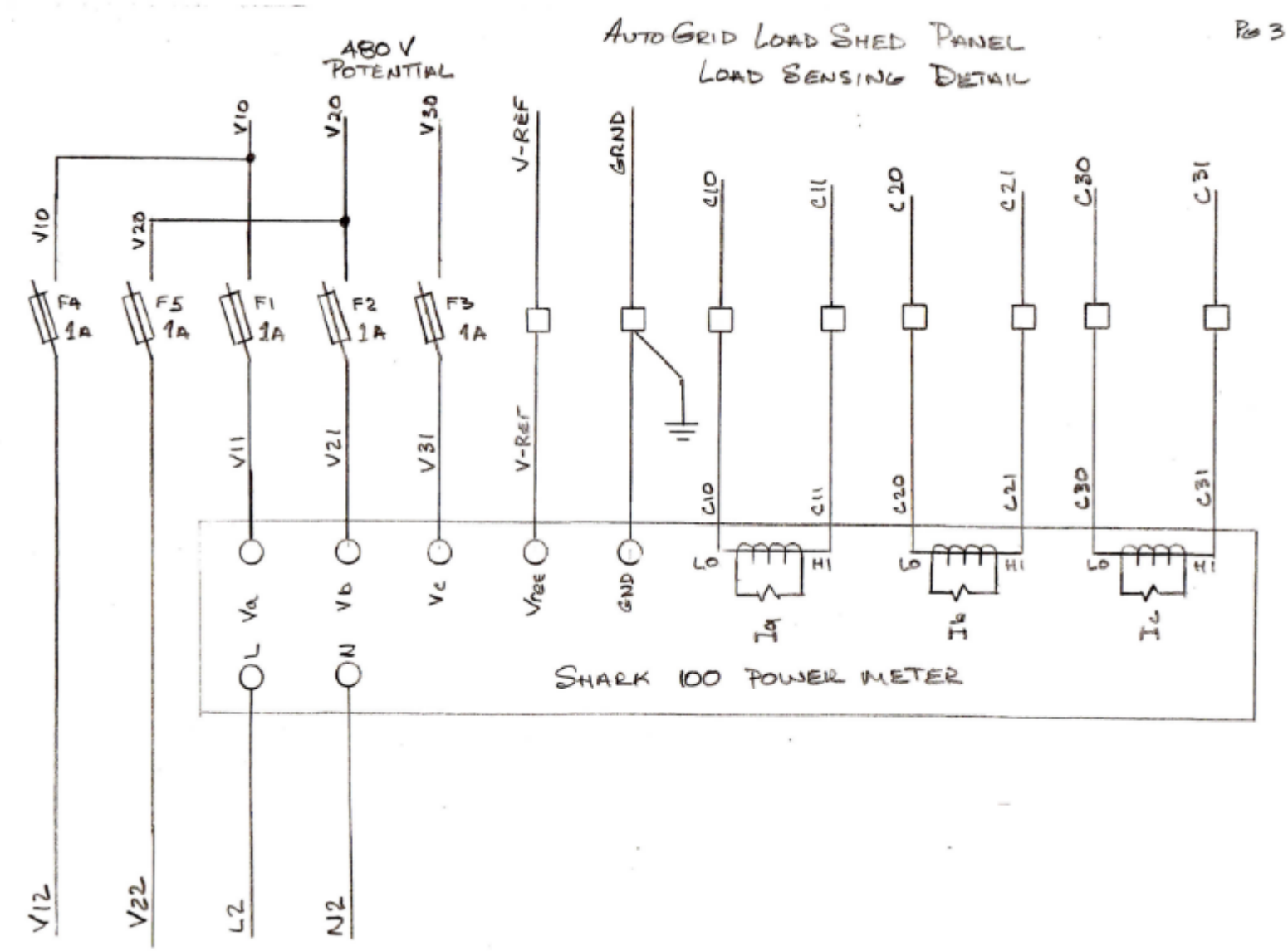


Figure 46: WPCP Power Aeration Pumps – Digital Input

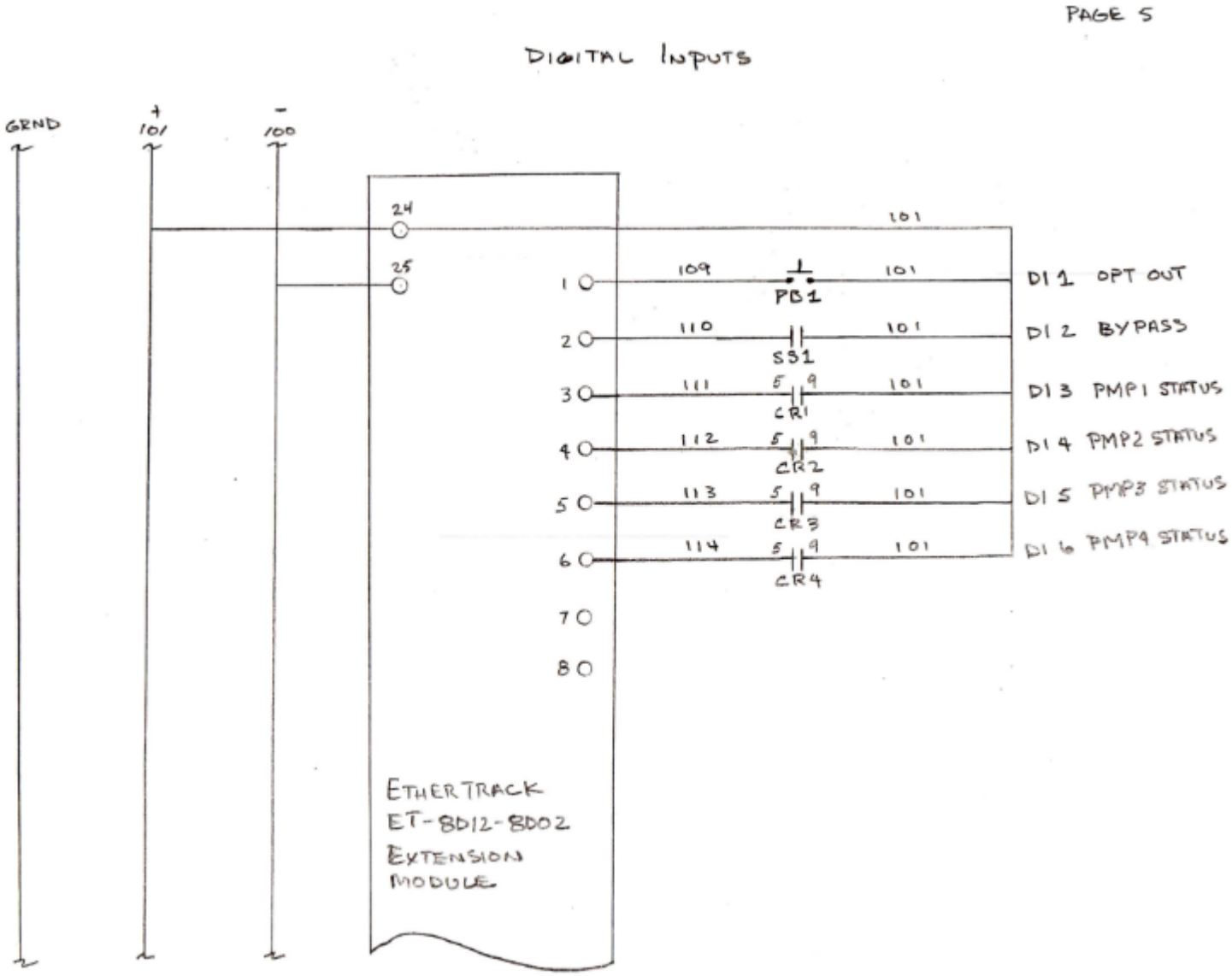


Figure 47: WPCP Power Aeration Pumps – Digital Outputs

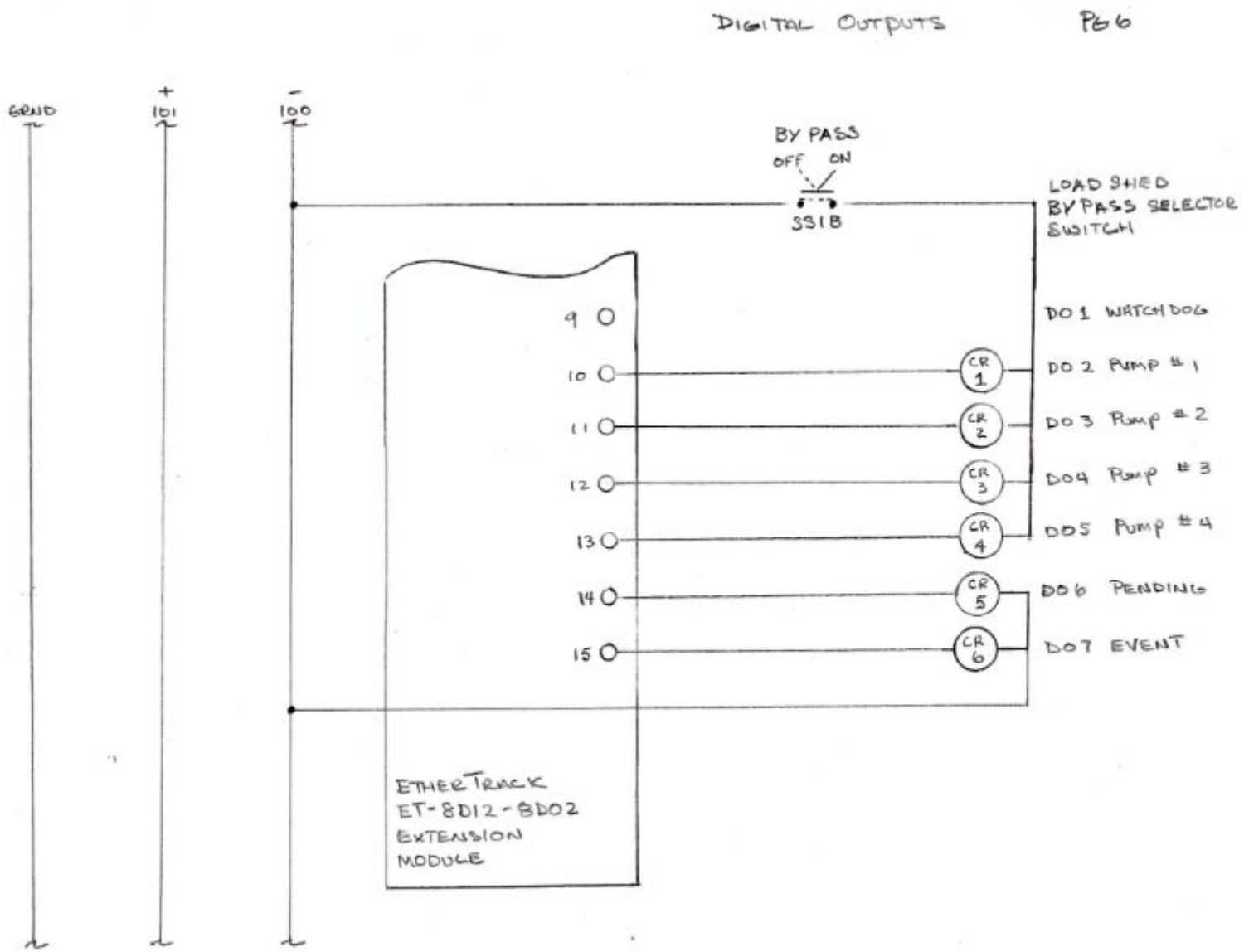


Figure 48: WPCP Power Aeration Pumps – Panel Indicators

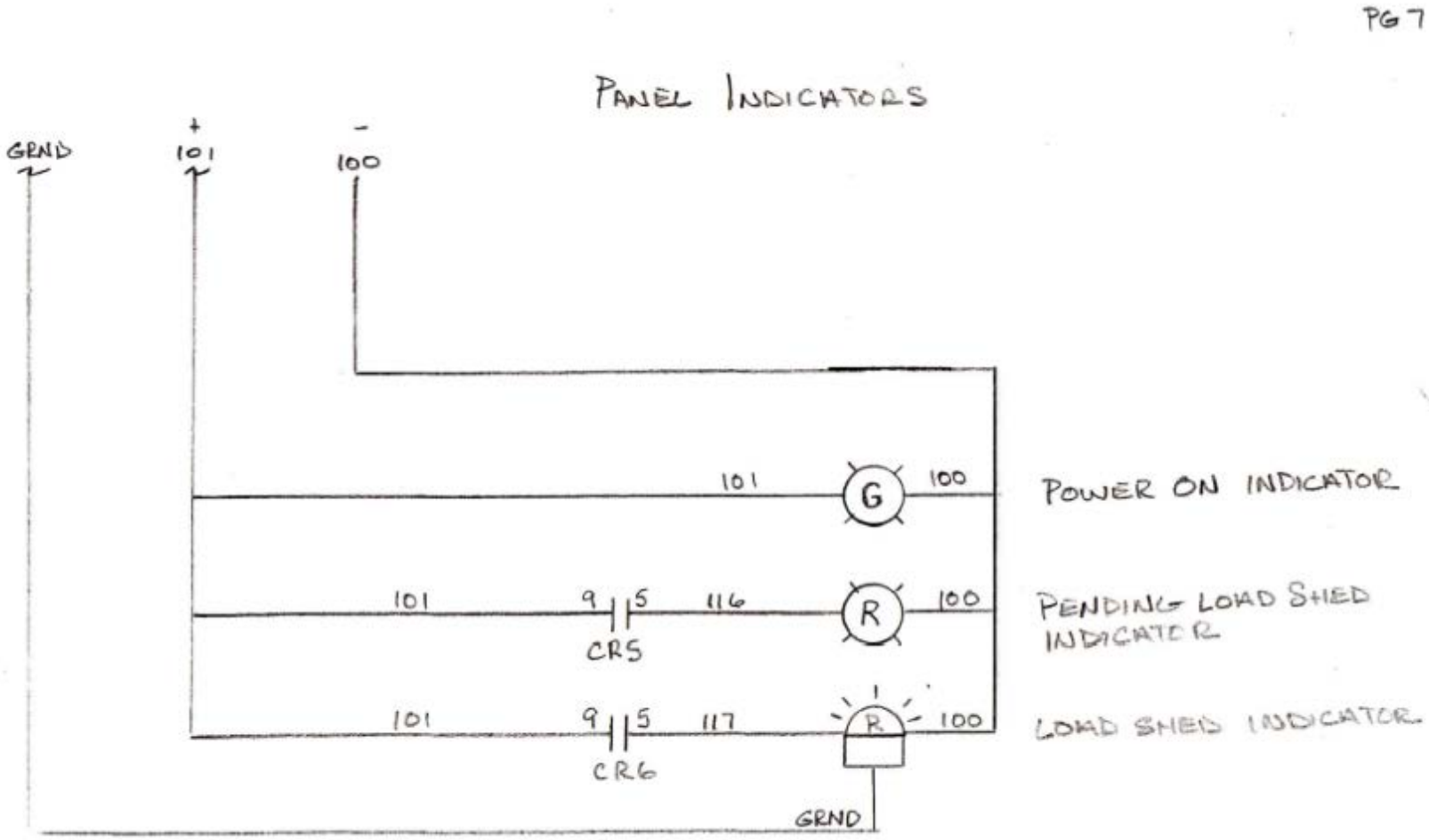


Figure 49: WPCP Digester Circulation Pump – Client's MCC 480V

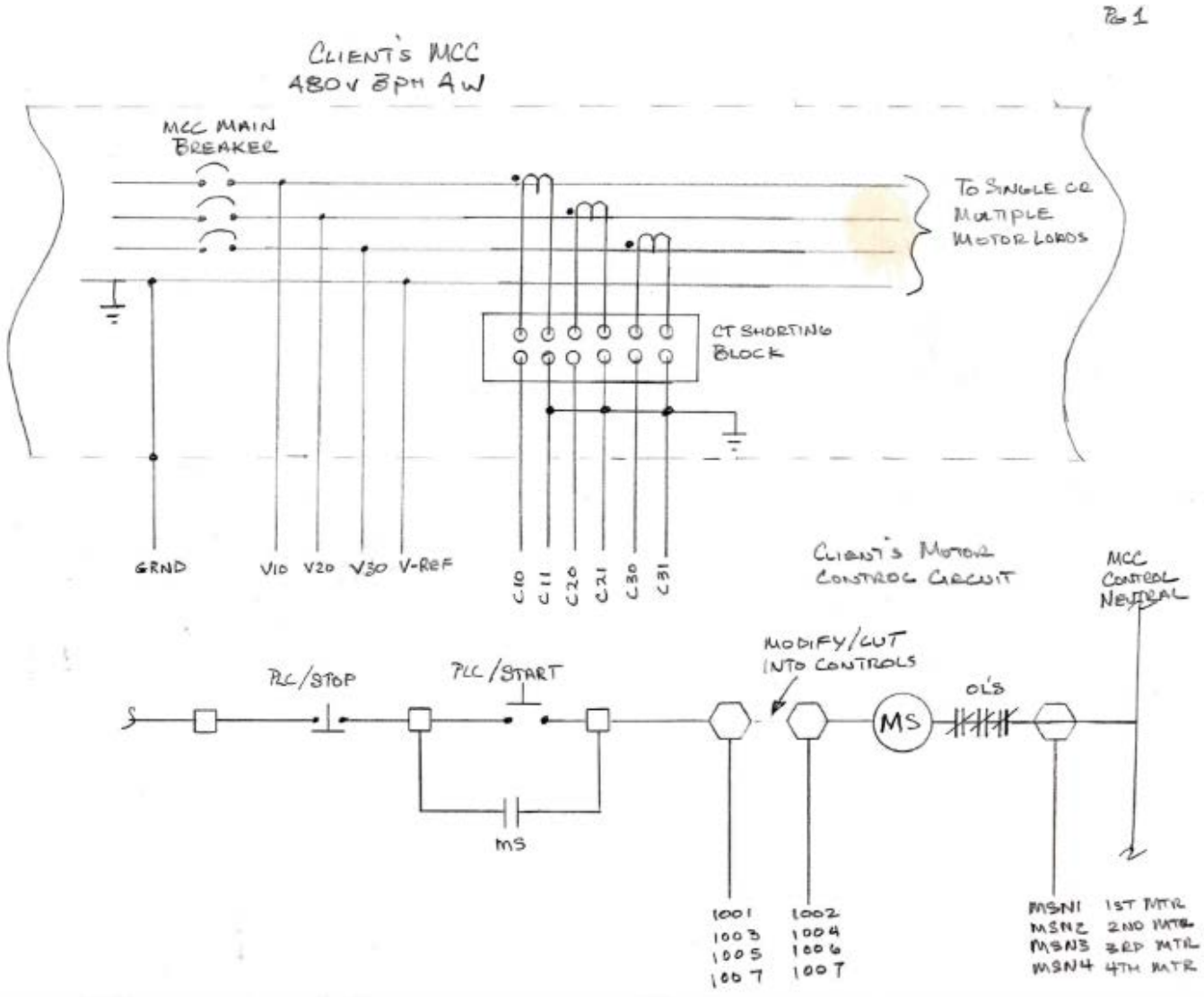


Figure 50: WPCP Digester Circulation Pump – Client MCC

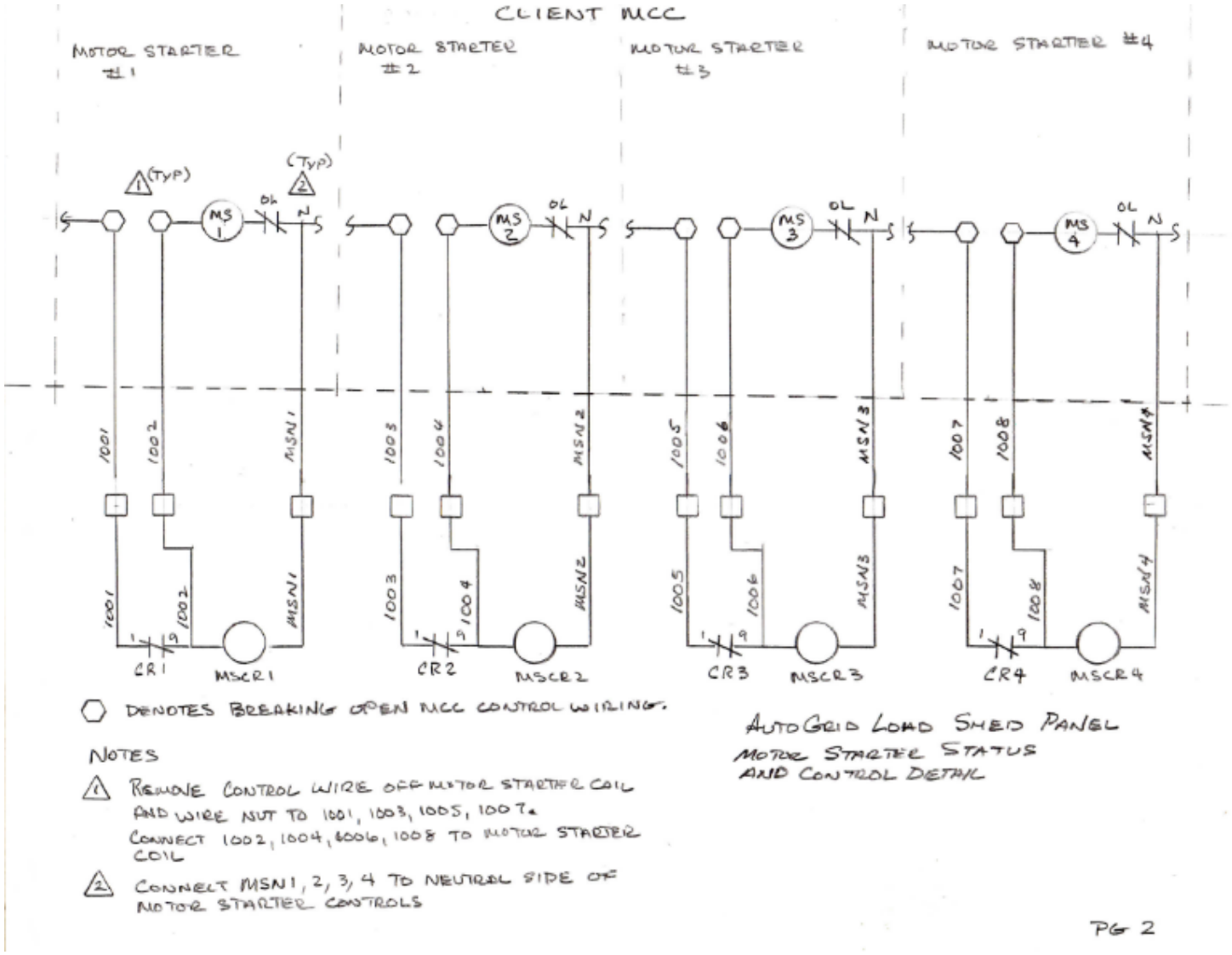


Figure 51: WPCP Digester Circulation Pump – AutoGrid Load Shed Panel, Load-Sensing Detail

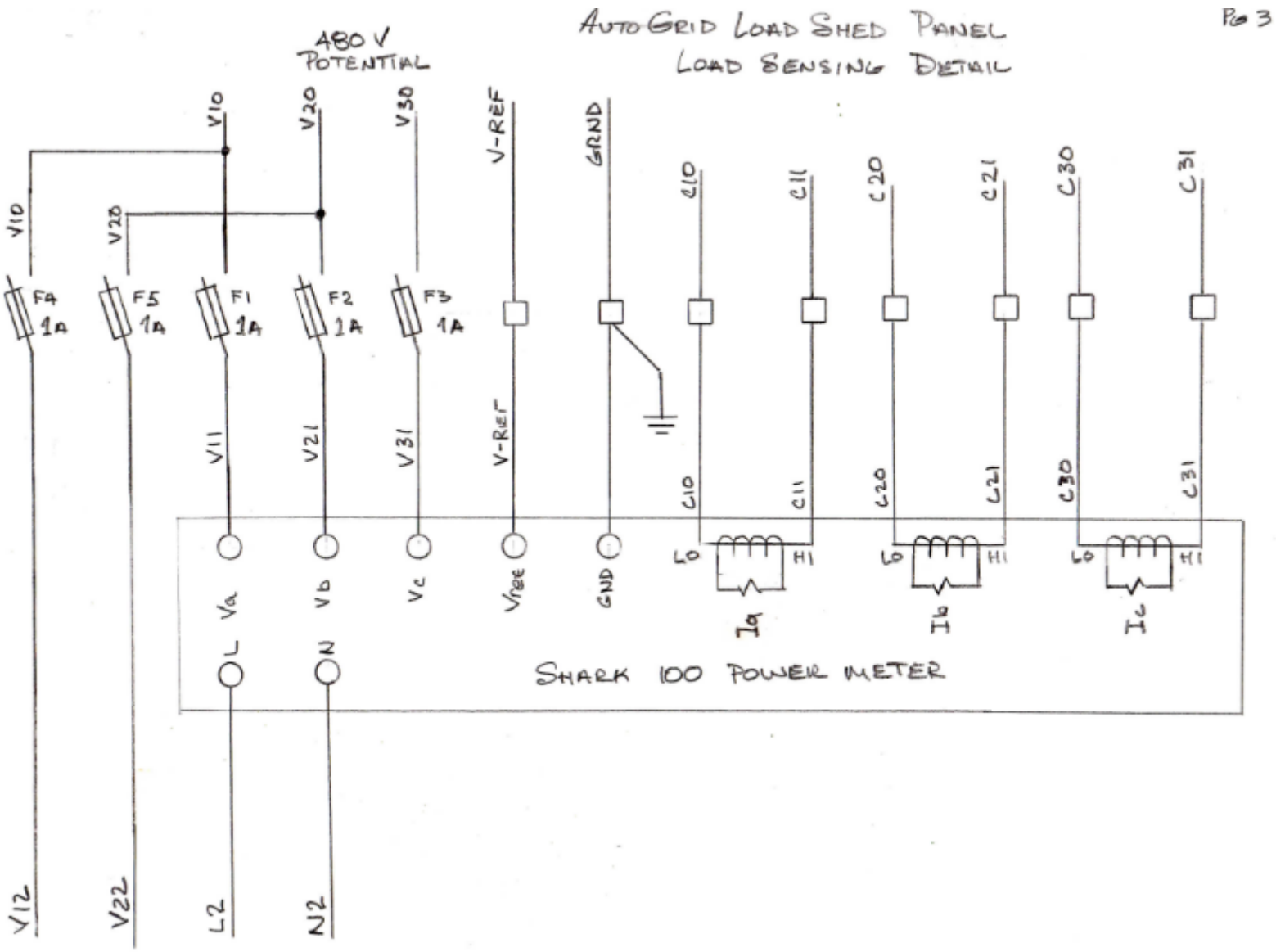


Figure 52: WPCP Digester Circulation Pump – AutoGrid Load Shed Panel 120 VAC and 24 VDC Power Detail

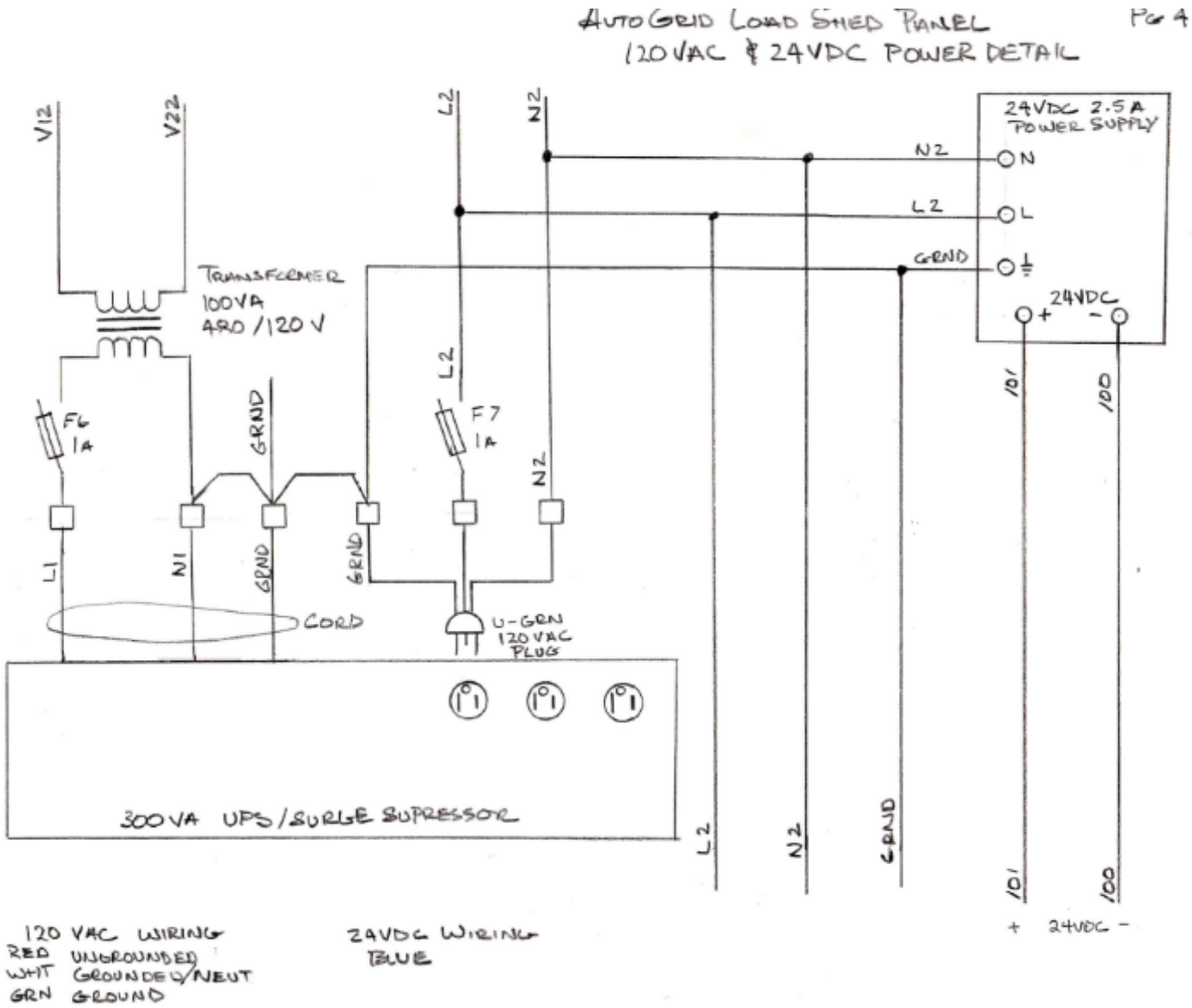


Figure 53: WPCP Digester Circulation Pump – Unit Wiring

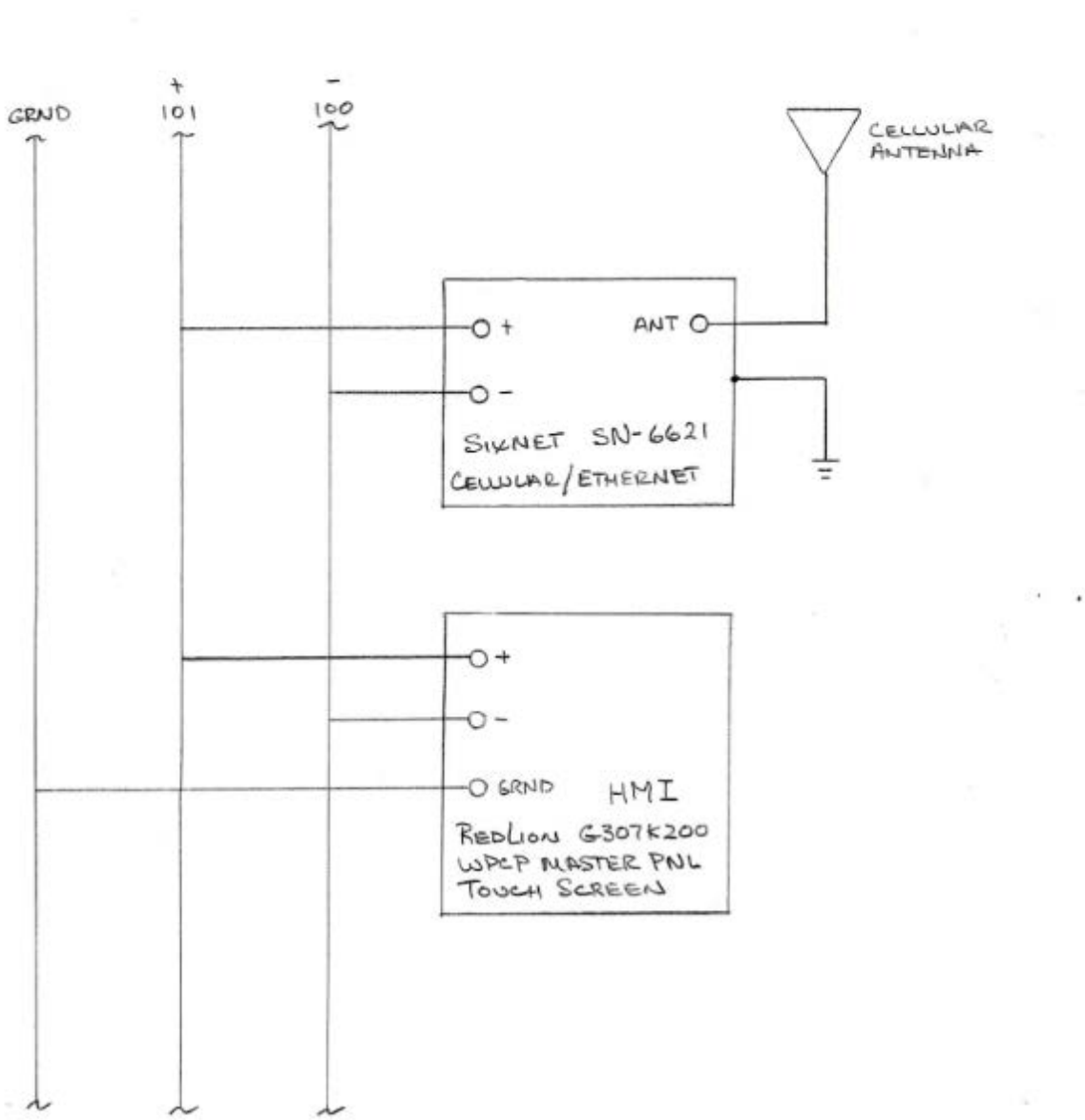


Figure 54: WPCP Digester Circulation Pump – Extension Module Digital Inputs

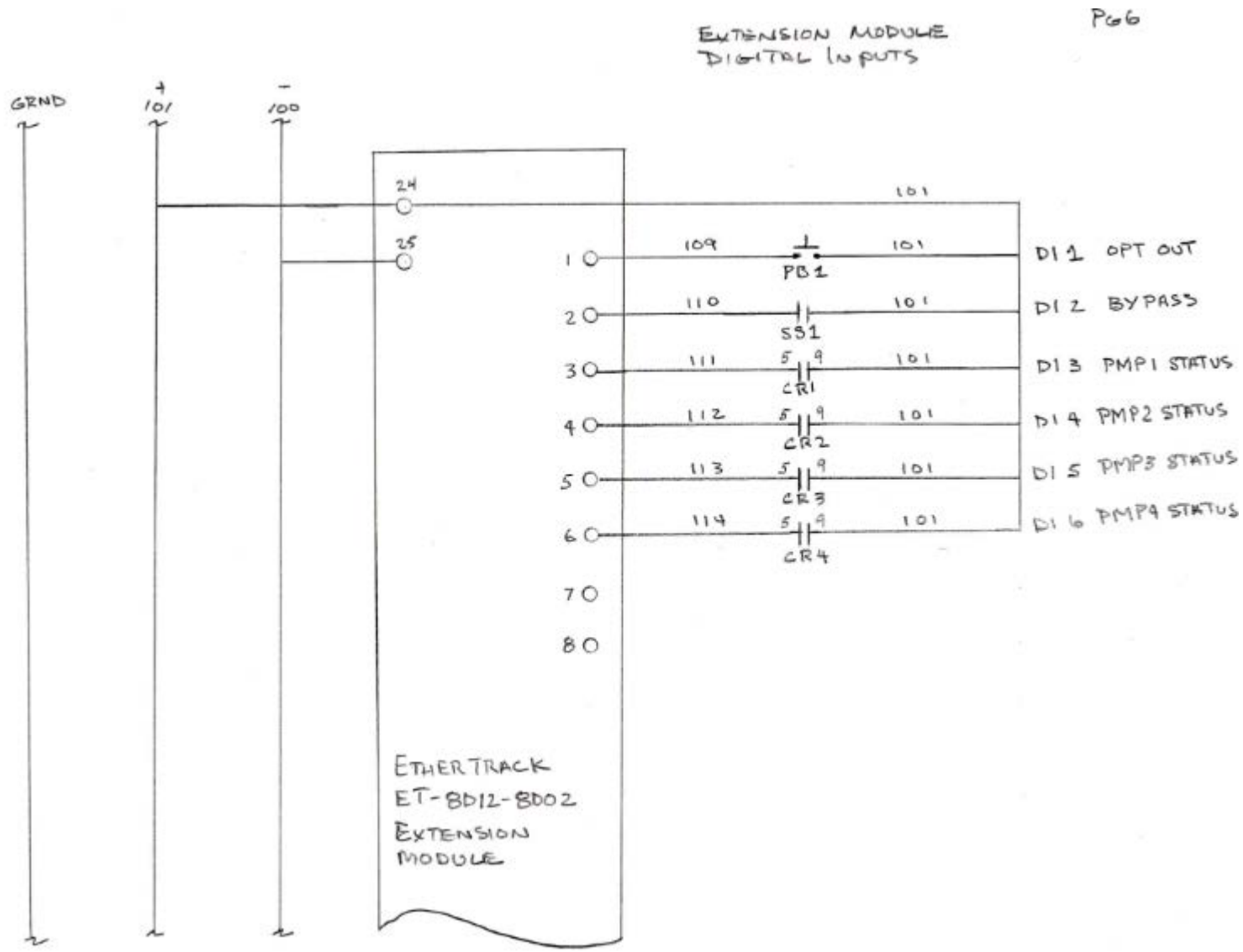


Figure 55: WPCP Digester Circulation Pump – Extender Module Digital Outputs

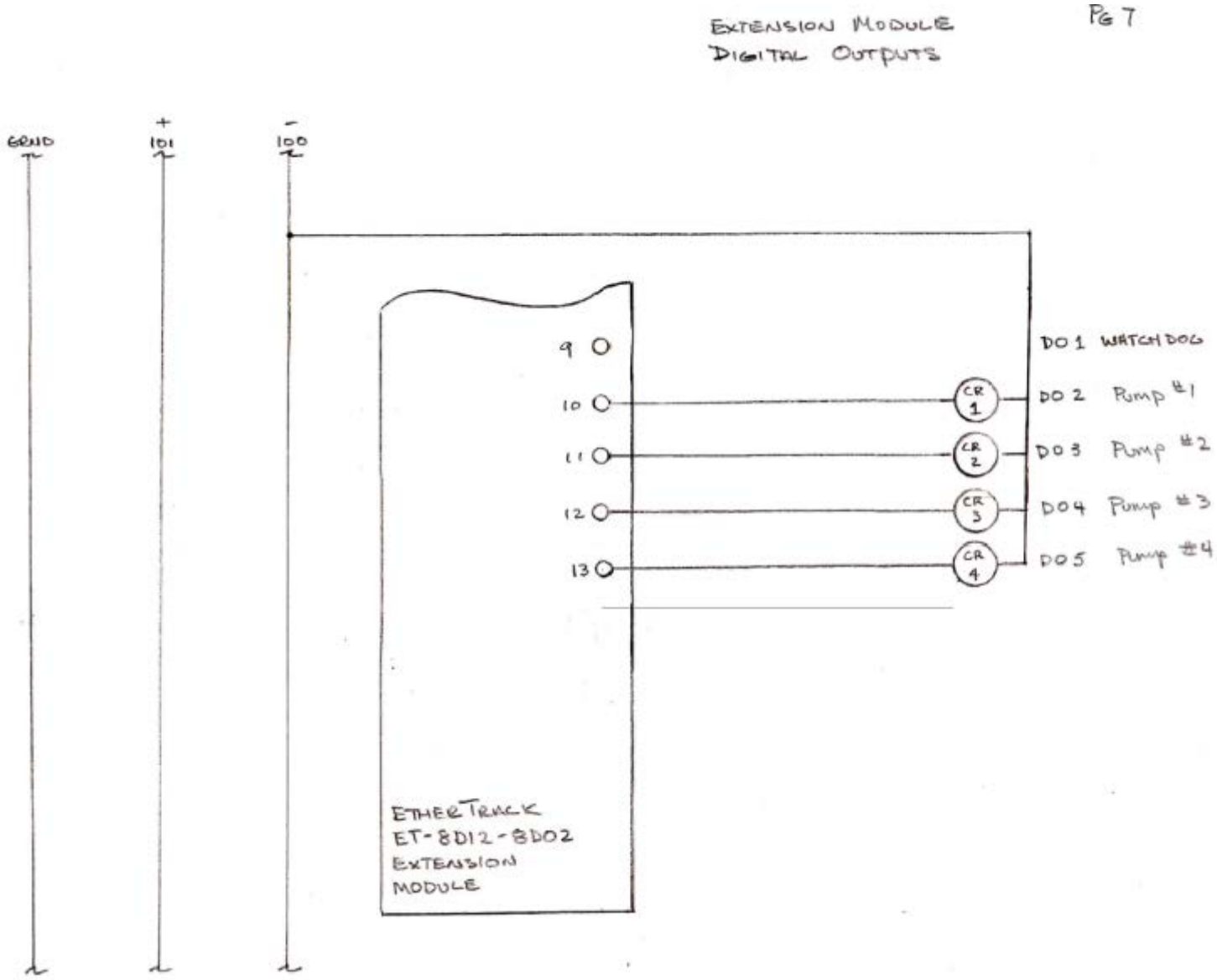


Figure 56: WPCP Digester Circulation Pump – RTU/Controller Digital Outputs

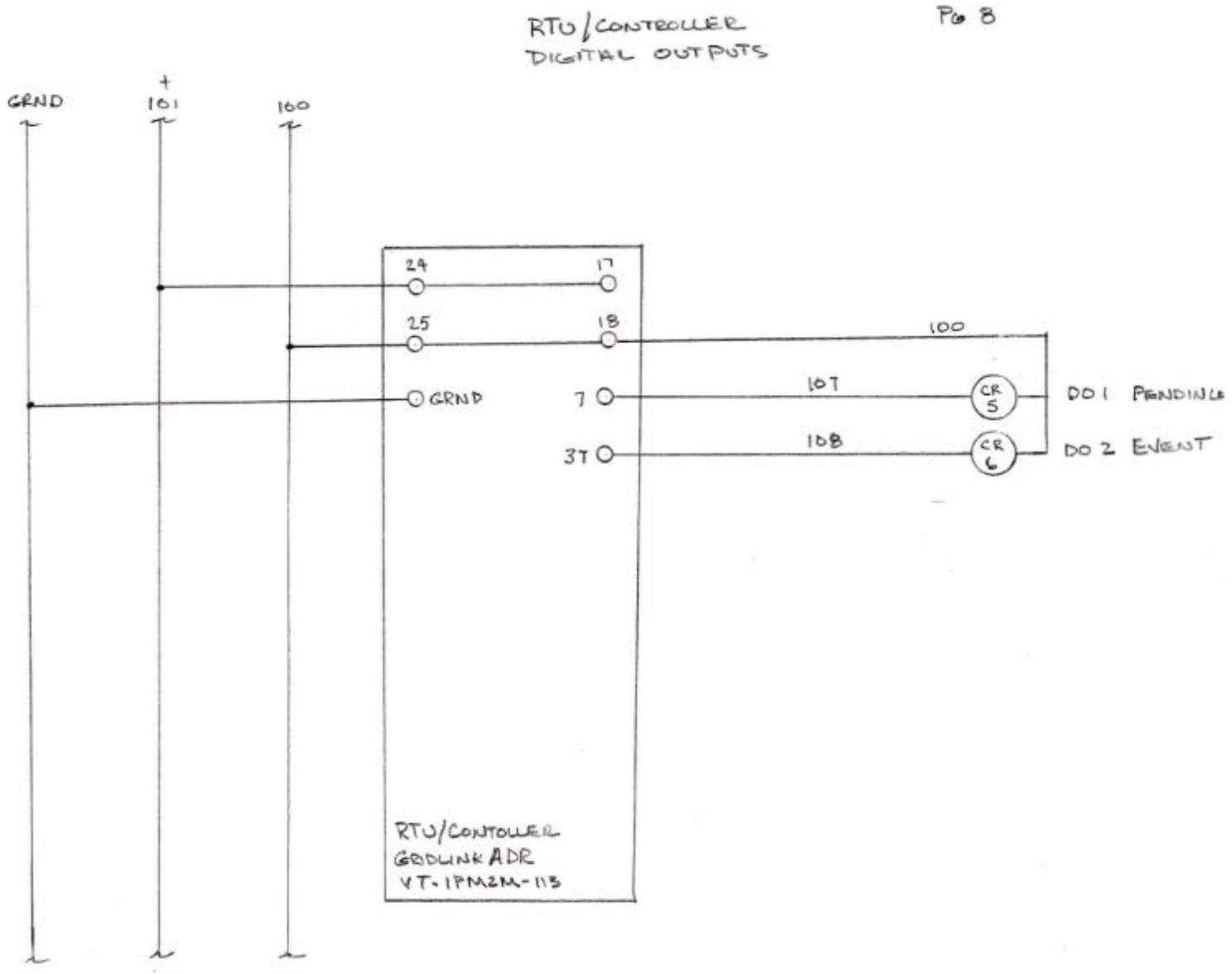


Figure 57: WPCP Digester Circulation Pump – Panel Indicator

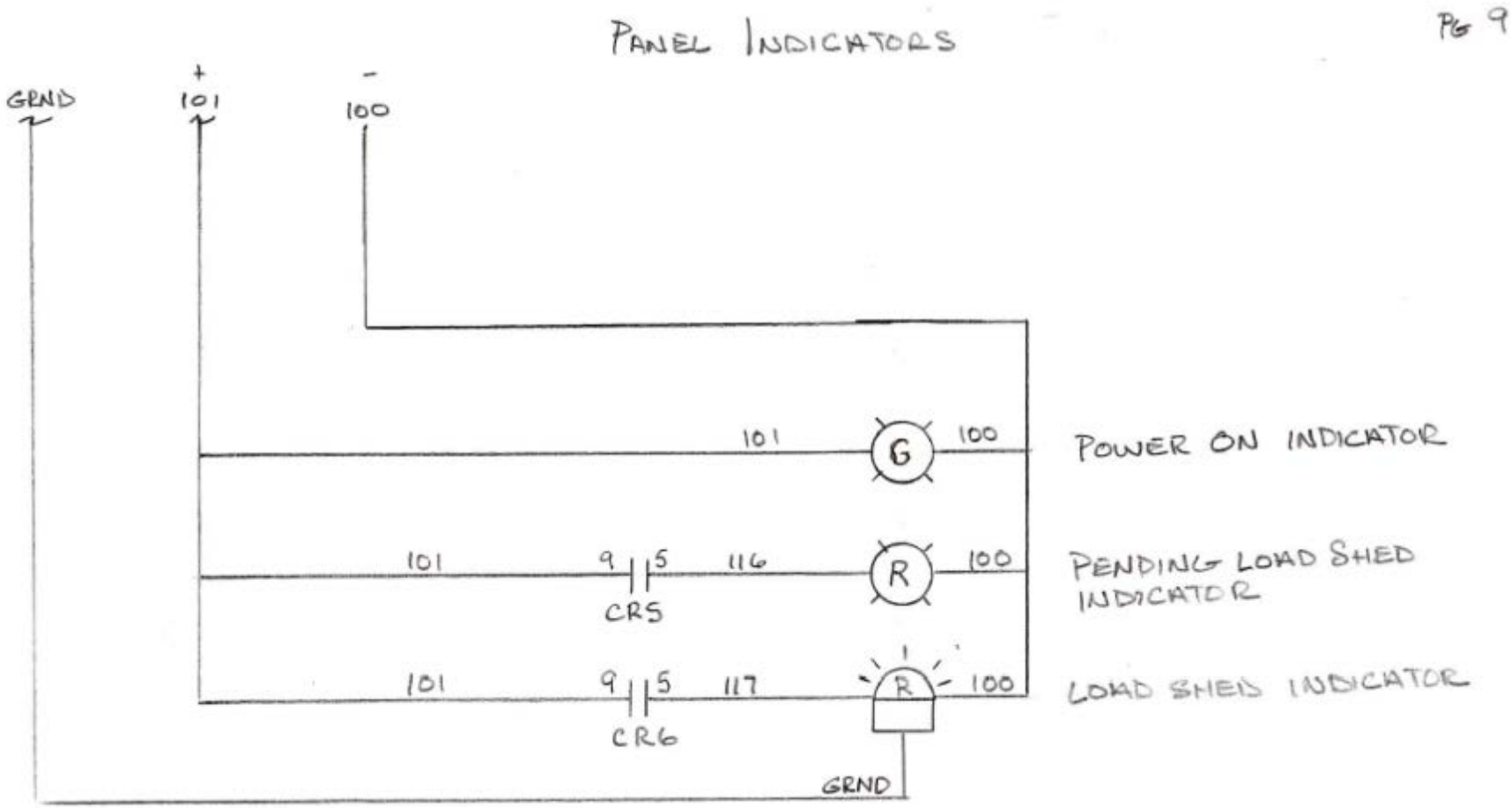


Figure 58: WPCP Pond Aeration Ponds – Client's MCC

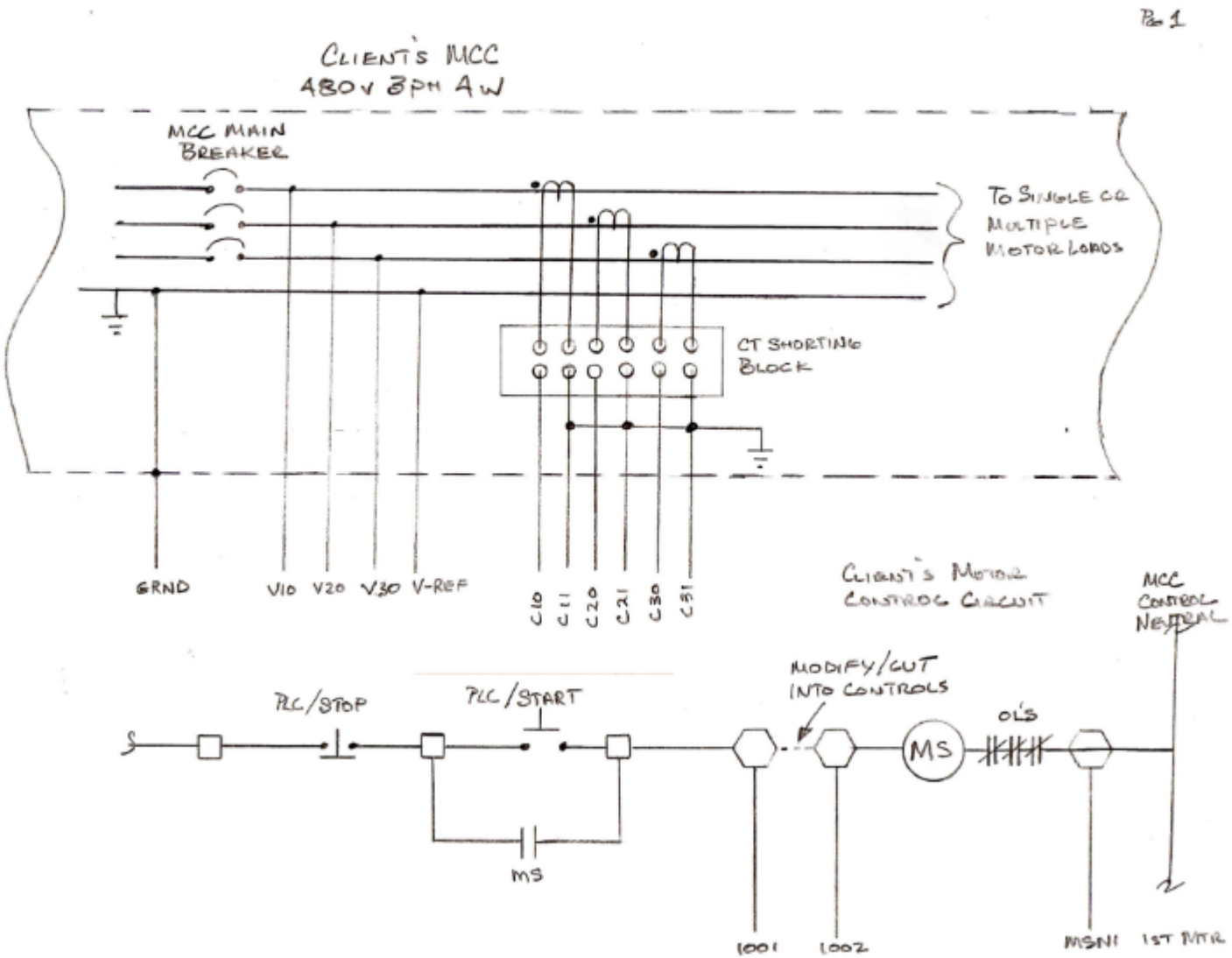
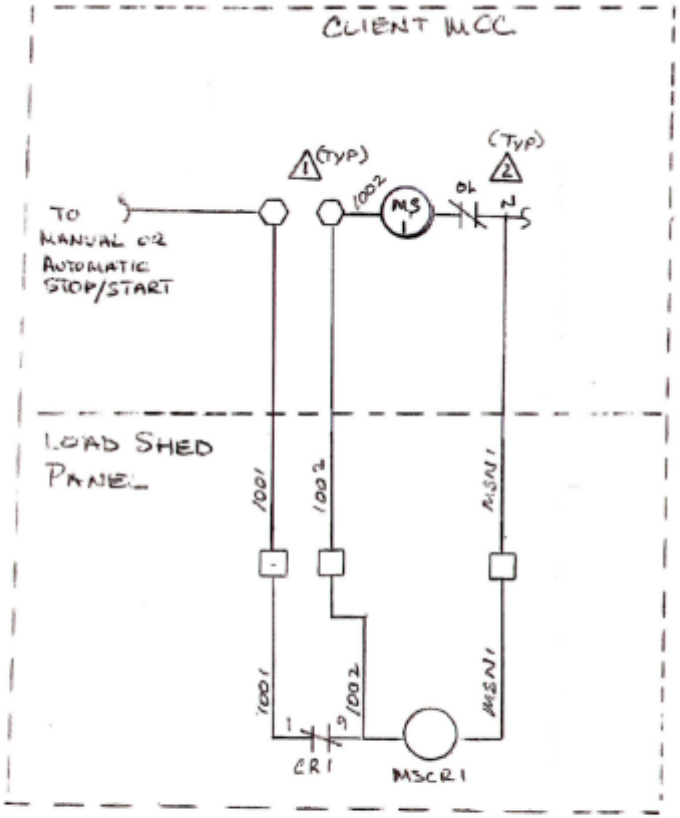


Figure 59: WPCP Pond Aeration Ponds – AutoGrid Load Shed Panel

PG 2



⬡ DENOTES BREAKING OPEN MCC CONTROL WIRING.

NOTES

1. REMOVE CONTROL WIRE OFF MOTOR STARTER COIL FOLD WIRE NUT TO 1001, 1003, 1005, 1007. CONNECT 1002, 1004, 1006, 1008 TO MOTOR STARTER COIL
2. CONNECT MSN1, 2, 3, 4 TO NEUTRAL SIDE OF MOTOR STARTER CONTROLS

AUTOGRID LOAD SHED PANEL
MOTOR STARTER STATUS
AND CONTROL DETAIL

Figure 60: WPCP Pond Aeration Ponds – AutoGrid Load Shed Panel, Load-Sensing Detail

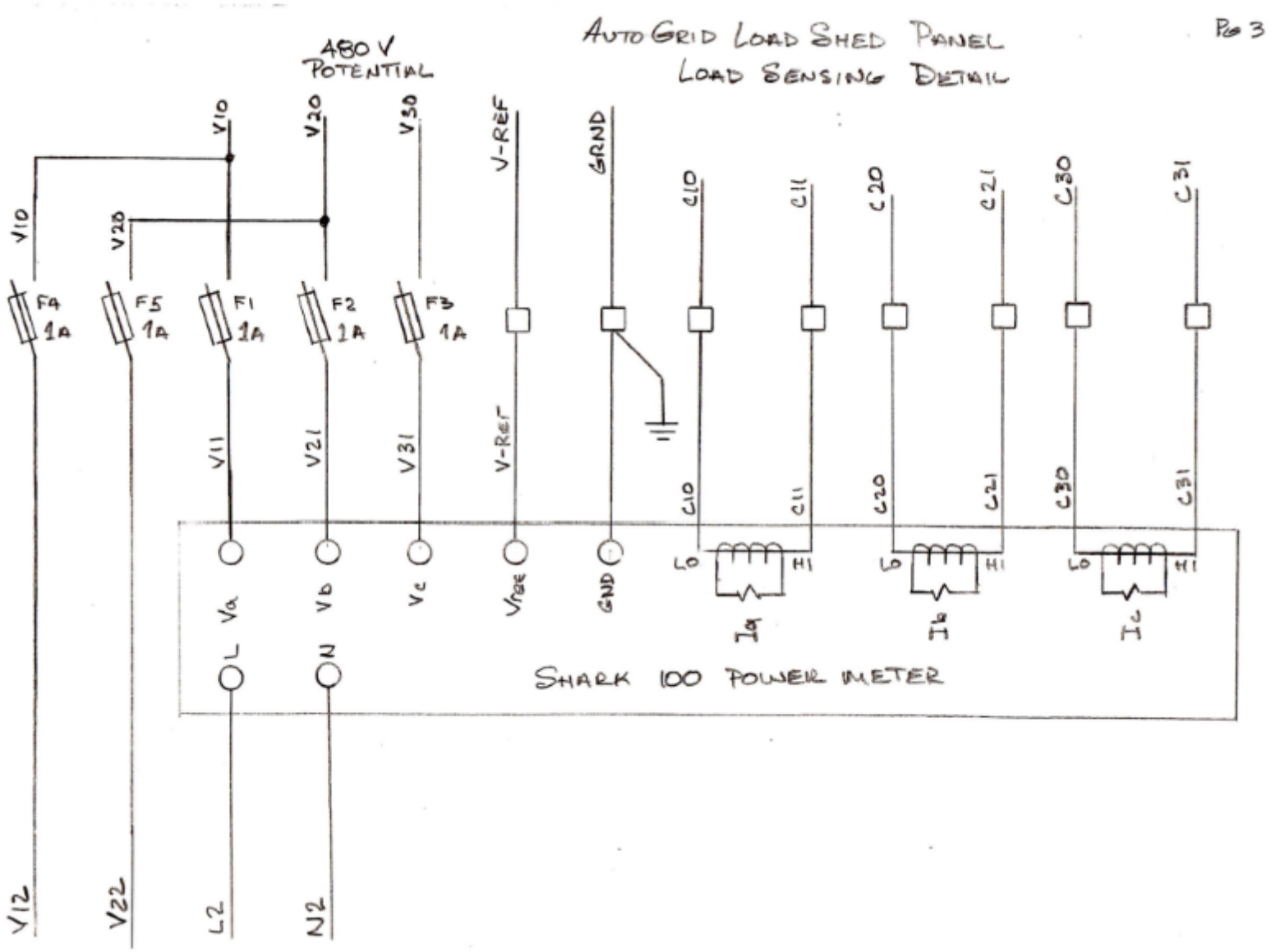


Figure 61: WPCP Pond Aeration Ponds – Power 120VAC and 24VDC

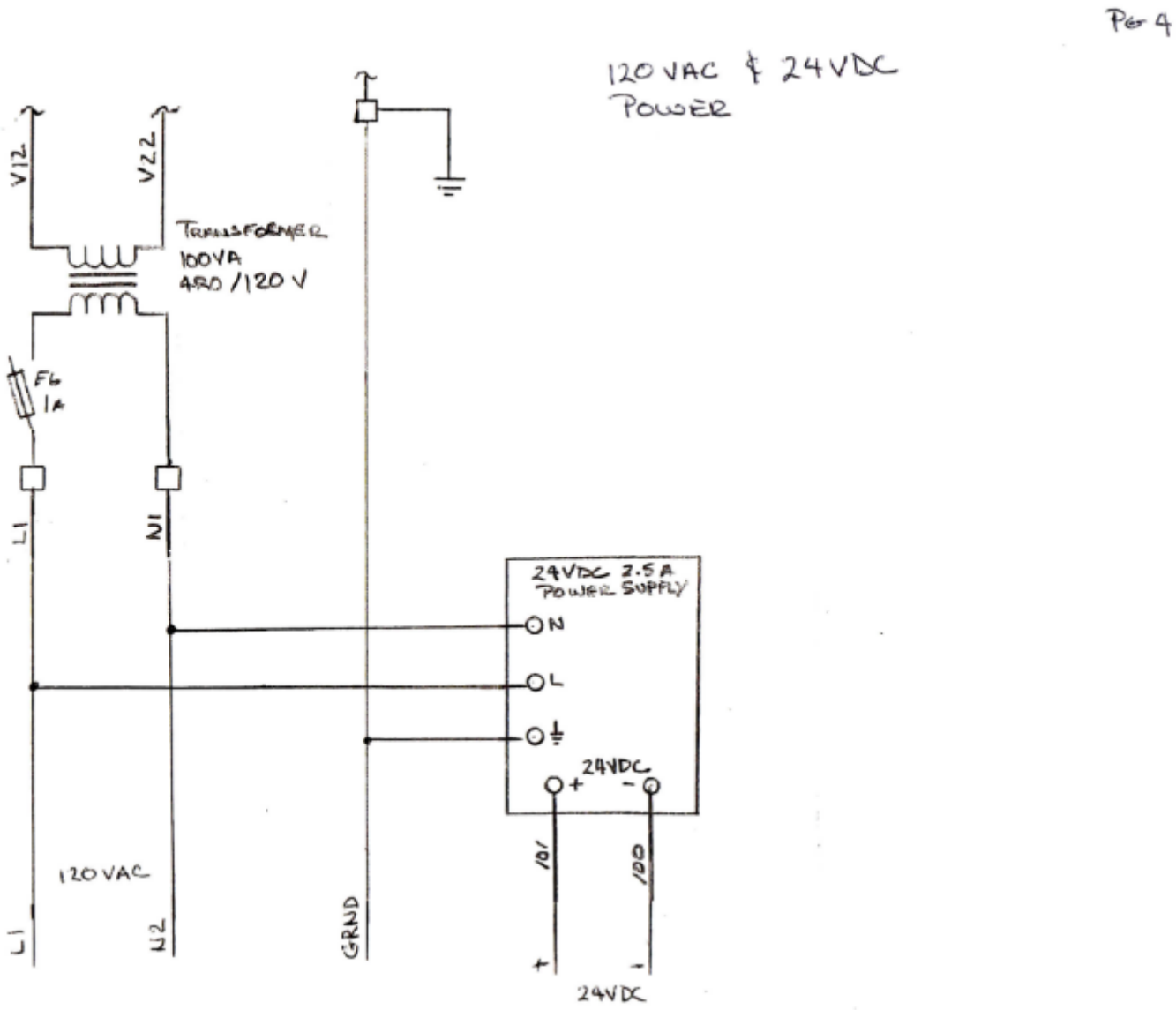


Figure 62: WPCP Pond Aeration Ponds – Digital Inputs

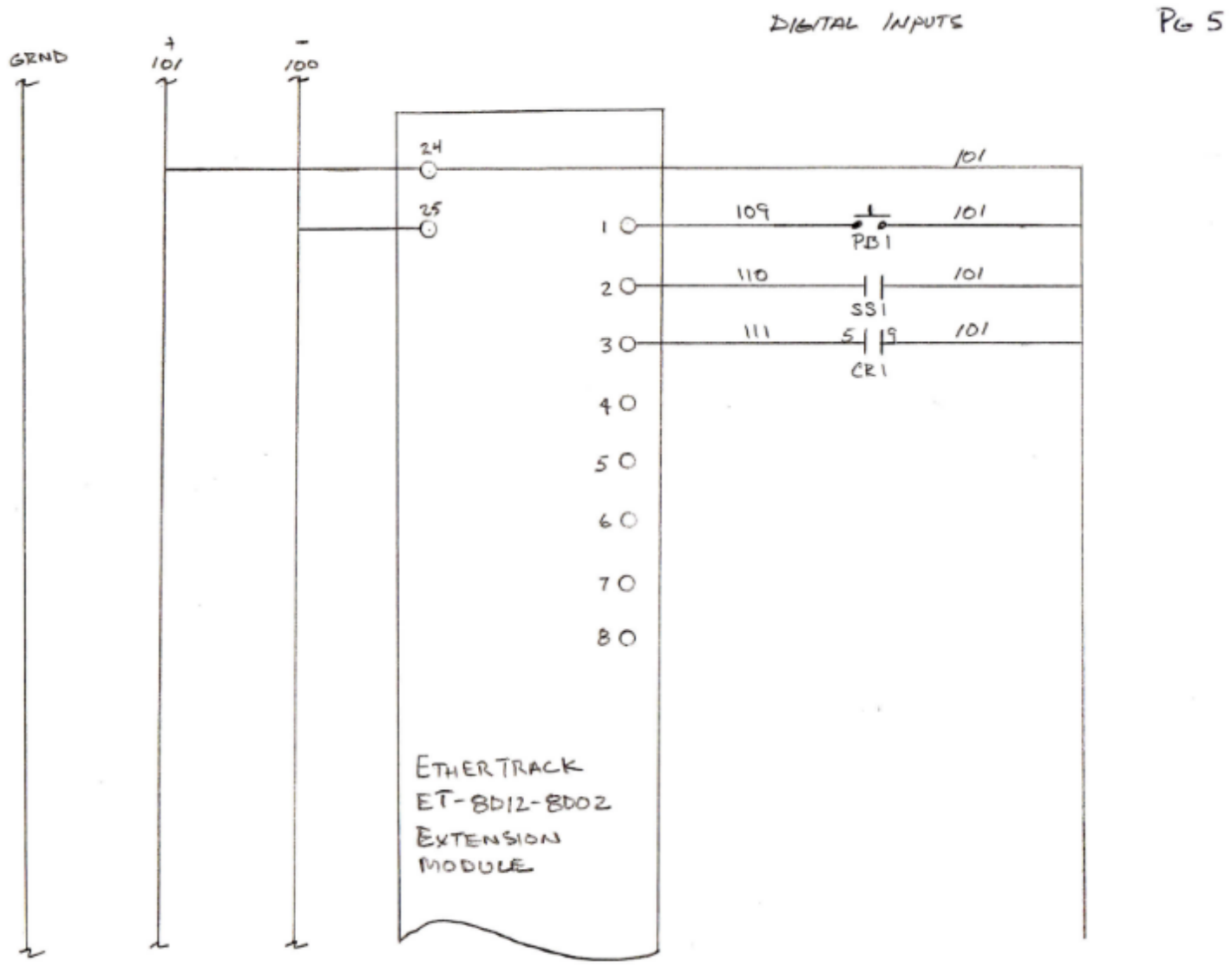


Figure 63: WPCP Pond Aeration Ponds – Digital Outputs

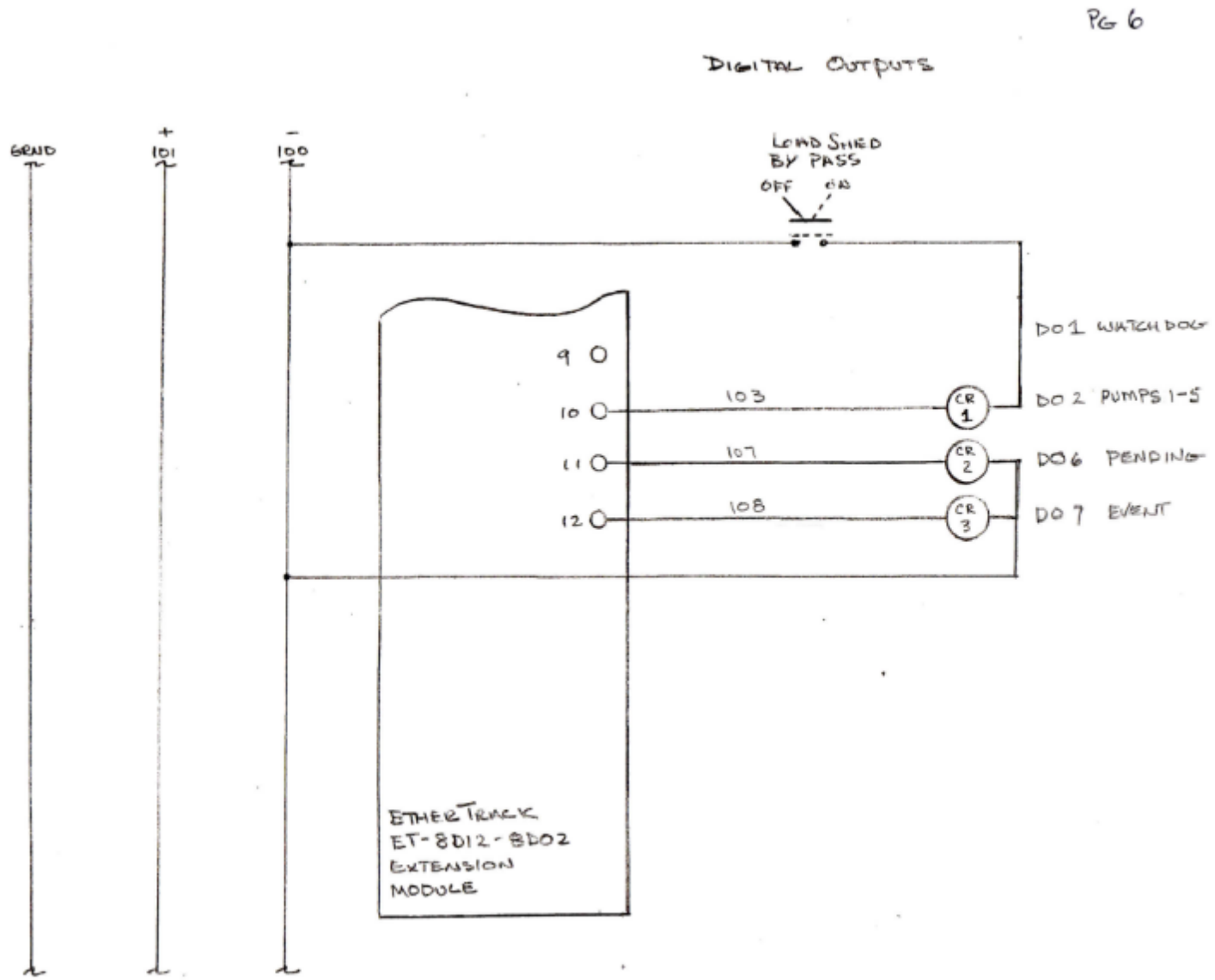
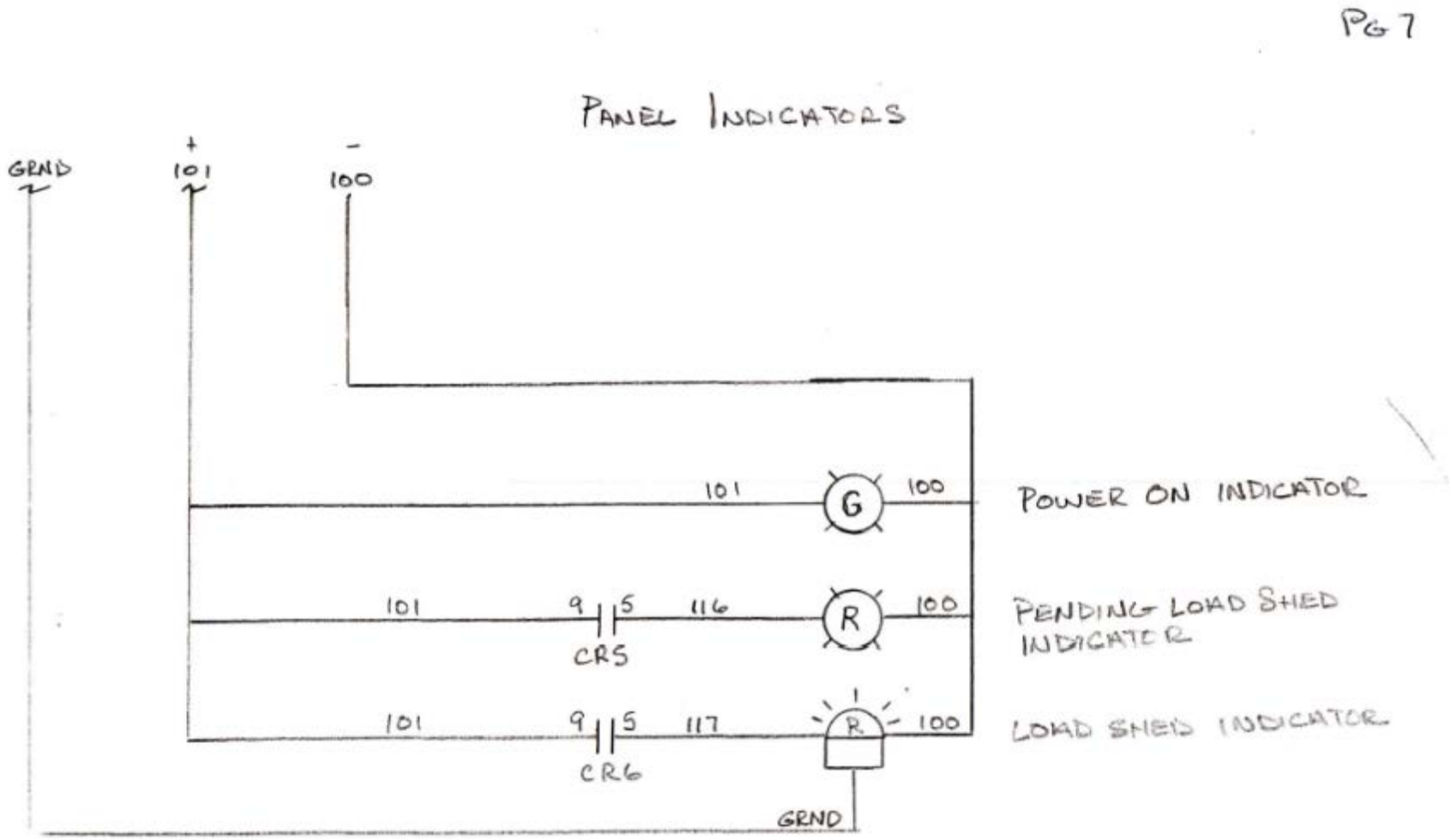


Figure 64: WPCP Pond Aeration Ponds – Panel Indicators



APPENDIX C:
Field Measurement Results from Ekster & Associates

EKSTER AND ASSOCIATES

1904 Lockwood Ave, Fremont, CA 94539

www.srtcontrol.com

MEMORANDUM#3

FROM: ALEX EKSTER Ph.D., P.E., B.C.E.E.

EKSTER AND ASSOCIATES

TO: VIJAY ISRANI

AUTOGRID

SUBJECT: Tasks 3,4

DATE: 9/17/2013

Field measurement results

In memorandum 1 equipment that potentially can be turned off during the DR event was identified and divided into four groups. Group 1 consisted of equipment that is operating 24 hours a day at the same electrical load independently of plant flow. Groups 2 and 3 consisted of constant speed pumps that can be taken out service only in blocks and only together with process units they service. Group 4 consisted of two pump stations each of which has both constant and variable speed pumps.

Memorandum 2 described methodology for measuring electrical demand under various process conditions for each group. Results of this measurements will be discussed in this memorandum.

Table 1 contains the summary of the performed measurements.

Table 1. Results of field measurements

Group #	Equipment list	Nominal motor size, kW	Measured motor energy demand, kVA	Total for each equipment type on a regular day of Summer operation, kVA
1	Aerator	15	14.94	2X14.94=29.88 (constant demand)
	Digester#3, mixing pump	22.3	23.1-24.8	23.1-24.8 (constant demand)
	Digester #4, mixing pump	30	N/A	>30 (constant demand)
	Pond recirculation pump	45	67.2-68.9	2X67=134
2	DAF pressurization pump	75	84	2*84=168 [1](constant demand).
3	FGR recirculation pump	74.6	115 (two pumps	217 (measured constant

			operated in parallel)	demand)
4	Pond effluent pumps	3X30,1X37.5	34-42 See Fig.1	57-78[2] See Fig.1
	Water filtration pumps	30	27-42 See Fig.2	35-57 See Fig.2

1. After the measurements have been performed the plant started using one FGR unit instead of two and energy demand is reduced down from 168kW to 84kW.
2. After the measurements have been performed the plant started using 4 pond recirculation pumps instead of 2 to maintain population of nitrifiers in FGR. Energy demand with 4 pumps in operation is estimated at around 110 kW.

The nominal safety factor for each motor listed in the Table 1 was 1.15. Digester #4 mixing pump was out of service during the measurement campaign due to catastrophic failure of Digester #4. Based on data obtained for digester #3 it is reasonable to assume that energy demand for the digester #4 mixing pump will be at least equal to the installed motor size, i.e. 30 kVA.

It is interesting to notice that all equipment consumes more energy that nominal size of the motors. One of the reason for that, probably, is the fact that operating voltage is larger than nominal voltage printed on the name plate of the individual motors (485V vs.460V). Another reason for high kVA values is low power factor (0.8).

EKSTER AND ASSOCIATES

1904 Lockwood Ave, Fremont, CA 94539

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Figure 1. ENERGY CONSUMPTION BY POND EFFLUENT PUMPS

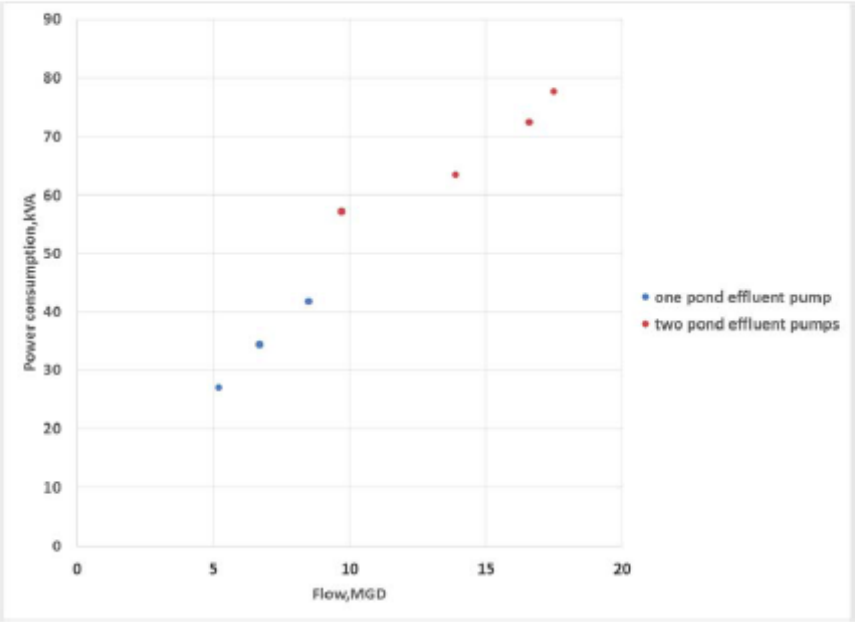
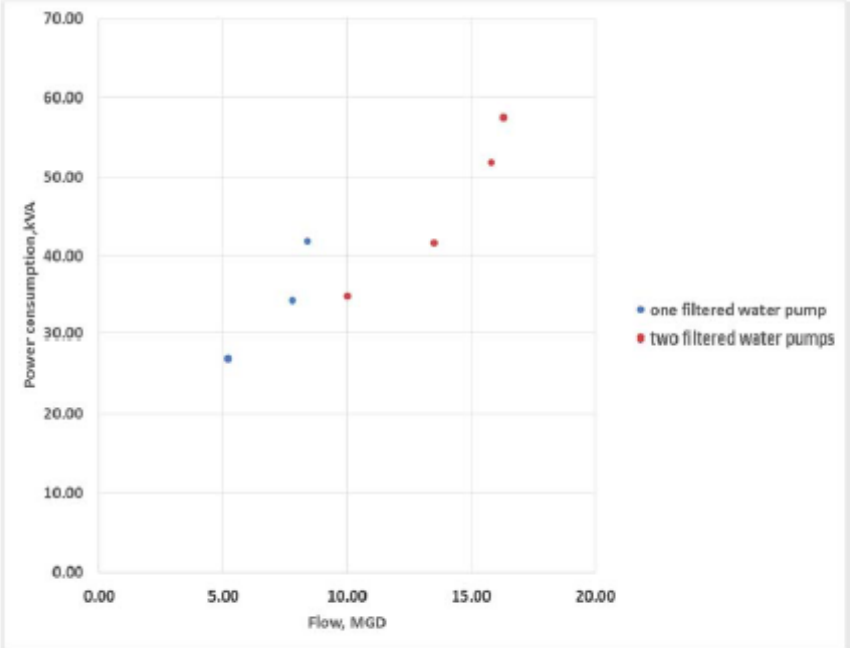


Figure 2. POWER CONSUMPTION BY FILTERED WATER PUMPS



Process impact

Each piece of equipment listed in Table 1 serves a certain purpose within a wastewater treatment train. Certain risks exists that could potentially cause process performance to deteriorate when equipment is taken out of service, even for a couple of hours. Table 1 describes potential process problems that could be caused by taking groups 1-4 equipment out of service.

Table 2. Potential Process Problems

Group #	Equipment to be taken out of service	Potential problems	Chances for problem to occur
1	Two aerators	Depleted DO concentration in the pond	Low
	Digester#3, mixing pump	Reduction of biogas production, digester going sour, grit accumulation	Low
	Digester #4, mixing pump	Reduction of biogas production, digester going sour, grit accumulation	Low
	1 pond recirculation pump	Solids settling	Low
2	One DAF pressurization pump, if two DAF units are in operation.	Increased filter influent turbidity	Minimal at flow less than 10 MGD (only one pond effluent pump in operation)
3	One FGR recirculation pump	Reduced ammonia removal	Minimal at flow less than 8MGD (only one pond effluent pump in operation)
4	1-3 pond effluent pumps	1.High energy consumption per MGD if groups 2,3 stay in service 2.High polymer consumption per MGD if groups 2,3 stay in service	High High

	One water filtration pump	1. High energy consumption per MGD if groups 2,3 stay in service 2. Pump damage if filter flow exceeds pond effluent flow 3. NPDES chlorine limit violation	High High Low

Due to large motor sizes and treatment process complexity none of the equipment listed in Table 2 can be taken out of service without permission of plant management even for a short period of time. However, with permission of plant management and at least an hour of advanced notice, there is a good chance that some of the pumps and two aerators listed in Table 1 can be taken out of service for as long as four (4) hours with minimum impact on plant reliability.

Energy reduction during DR event.

Effects of recommended energy reduction measures on energy consumption during a demand response (DR) event are summarized in Table 3.

Table 3. Effect of energy reduction measures on energy consumption.

Group #	Potential energy reduction measure	Energy consumption before the event, kW	Projected energy consumption during the DR event, kW	Reduction, kW
1	Turning off both aerators	29.88*0.8=24	0	24
	Turning off digester #3 mixing pump	23.1*0.8=18.5	0	18.5
	Turning off digester #4 mixing pump	30*0.8=24	0	24
	Turning off one out of two pond recirculation pumps	134*0.8=107	107/2=53.5	53.5
2	Turning off one out of two DAF pressurization pumps, if two DAF units are in operation.	(1-2)*84*0.8=67-134	67	0-67

3	Turning off one out of two FGR recirculation pumps	217*0.8=173.6	115*0.8=92 (measured when 2 FGR pumps were in operation)	81.6
4	Turning off all but one pond effluent pump	(57-110)*0.8=45.6-88 (not repeatable from day to day)	36*0.8=29	16.6-59
	Turning off one out of two FGR recirculation pumps water filtration pumps	(35-57)*0.8=28-45.6 (usually around 33)	28	5

Implementation logistics. As it was mentioned before, equipment listed in group #1 is flow independent and can be currently switched off/switched on remotely.

Taking DAF and FGR units out of service by pumps of groups 2 and 3 is labor intensive. Significant investment into plant infrastructure and automation is required to make these actions more manageable.

Switching from two pond effluent pumps and from two filtered water to one of each (group 4) is a task which can be automated with minimum capital expenditures. According to Fig.1 maximum flow of one pond effluent pump equipped with VFD is 8.5 MGD. Thus operation of one pond effluent pump will require taking out of service the second to avoid imbalance between incoming and leaving the plant flow, i.e. only one filtered water pump will be in service during DR event.

If only one pond effluent pump is to be used, then only one DAF unit and only two FGR units would be needed, i.e. only one DAF pressurization pump and only one FGR recirculation pump can be in service. At the same time taking DAF and FGR units out of service is not a requirement for single pond effluent pump operation.

Table 4 summarizes complexity of implementation of each of the listed energy reduction measures.

Table 4. Implementation complexity

Group #	Equipment list	Method of Implementation	Ease of implementation
1	Aerator	Automatically turn off both aerators	Simple
	Digester#3, mixing pump	Automatically turn off	Simple
	Digester #4, mixing pump	Automatically turn off	Simple
	Pond recirculation pump	Automatically turn off one pump	Simple
2	DAF pressurization pump	Take one DAF unit out of service	Labor intensive without additional automation
3	FGR recirculation pump	Take one FGR unit out of service	Labor intensive without automation
4	Pond effluent pumps	Automatically turn off a constant speed pump and adjust speed of a pump with VFD (if needed)	Manageable
	Water filtration pumps	Automatically turn off a constant speed pump and adjust speed of pump with VFD (if needed)	Manageable

As it can be seen from Table 4, implementation of the DR program for group 1 equipment is fairly simple. This implementation will reduce energy consumption by 120 kW during DR event for as long as 4 hours. Group 4 is a second candidate for implementation of energy reduction actions during the DR event, although more complex equipment manipulation will be required and overall daily energy and chemicals consumption maybe increased (see Table2). Taking pumps out of service within this group needs to be coordinated using PLC or any other similar device. Implementation of the DR program for group 4 will reduce energy consumption by 21-64kW during DR event. The most labor

intensive is implementation of the DR program for groups 2,3 due to lack of automatic control capability (i.e. motorized valves) for DAF and FGR. In addition, taking equipment out of service within groups 2,3 and 4 requires complex sequence coordination that also needs to be PLC coded. So, while implementation of the DR program for groups2,3 will reduce energy consumption by as much as 186 kW, implementation of the DR program for these groups may not be feasible at this time due to logistical problems.

Start/stop logistics

There are certain delays associated with equipment start/stop. First delay is associated with time for operator to react and reach a pump control device. The plant does not have a computer room with an operator who constantly controls/operates the process remotely. As a result, it may take up to 30 minutes for an operator to reach a motor control device. Due to relatively small motor sizes there is no delay in termination power consumption after the "stop" signal is initiated. Exact logistics of taking group #1 equipment off line will be determined during the next (testing) phase of the study.

There is an additional delay in bringing motors on line. Based on our experience acceleration time (time required to reach full motor speed) for these sizes of motors does not exceed 10 seconds.

Number of motors starts/stops is limited by NEMA standards MG10-2001 for these sizes of motors to five per hour. Considering that the equipment is very old we recommend to limit number of starts/stop to three per hour. Based on results of the next phase of the study, Plant may choose to impose stricter or relax three times per hour restriction.

Recommendations.

Based on information provided in Tables 3,4, implementation of the DR program in the near future for group 1 is both effective and feasible. However, as it can be seen from Table 2, turning off equipment of group #1 may cause significant process problems in both ponds and digesters. Despite the fact that chances of these problems to occur, in our opinion, are low, it is prudent to verify our assumption during field testing. We recommend to develop and implement a two months testing program related to group 1 equipment.

APPENDIX D:
ROI

ROI Savings Illustration for WPCP

Description	Demand Response (kW)	Benefit	Event Period (Hours)	No. of Events/Year	Savings per Year
Demand Savings	150	$12.11/ kW / month	monthly	12	$21,798
Peak Day Pricing	160	~$7,840 / month in summer, minus $1.20/kWh during events	4	12	$2,880 (Savings will be higher if <12 events called)
CAISO	160	$.008 / kWh	1	8760	$11,212.80
Total Yearly Savings					$35,890.80

Source: AutoGrid Systems Inc.

ROI Savings Illustration for SMaRT

Description	Demand Response (kW)	Benefit	Event Period (Hours)	No. of Events/Year	Savings per Year
Demand Savings	100	$12.11/ kW / month	monthly	12	$14,532
Peak Day Pricing	200	~$7,840 / month in summer, minus $1.20/kWh during events	4	12	$3,600 (Savings will be higher if <12 events called)
CAISO	200	$.008 / kWh	1	8760	$14,016
Total Yearly Savings					$32,148

Source: AutoGrid Systems Inc.

APPENDIX E:
SHARK 100 DATA SHEET

SHARK®100

MULTIFUNCTION POWER AND ENERGY METER

Revenue Grade

Features

- 0.2% Class Energy and Demand Metering
- Measurements including Voltage, Current, Power, Frequency, Energy, etc.
- Optional KYZ Pulse and IrDA Port
- Power Quality Measurements (%THD and Alarm Limits)
- V-Switch™ Technology - Field Upgrade without Removing Installed Meter
- Large Bright Red LED Display
- % of Load Bar for Analog Meter Perception
- Optional RS485 Modbus and DNP 3.0 Protocols
- Optional 100BaseT Ethernet
- Fits Both ANSI and DIN Cut-Outs
- Available in a Transducer-Only Version

Applications

- Utility Metering
- Commercial Metering
- Substations
- Industrial Metering
- Power Generation
- Campus Metering
- Submetering
- Analog Meter Replacement

Introduction

Electro Industries introduces one of the industry's highest performance revenue grade panel meters. Based on an all new platform, this low cost meter significantly outperforms other devices many times its price. This unit is perfect for new metering applications and as a simple replacement of existing analog meters. The Shark® meter excels in metering energy accurately, exceeding ANSI C12.20 (0.2%) and IEC 687 (0.2%) energy measurement standards. The unit utilizes high speed DSP technology with high resolution A/D conversion to provide revenue certifiable accuracy for Utility Billing, Substation Metering, Submetering and Critical Metering applications.

High Performance and Economical Pricing for High Volume Deployment

Electro Industries/GaugeTech
The Leader in Power Monitoring and Smart Grid Solutions

www.electroind.com

Superior Accuracy and Virtual Upgrade Switches

V-Switch™ Technology

The Shark® 100 meter is equipped with EIG's exclusive V-Switch™ technology. This technology allows users to upgrade and add features as needed by using communication commands, even after the meter is installed.

Available V-Switches:

- V-Switch 1 – Volts and Amps Meter – Default
- V-Switch 2 – Volts, Amps, kW, kVAR, PF, kVA, Freq.
- V-Switch 3 – Volts, Amps, kW, kVAR, PF, kVA, Freq. kWh, kVAh, kVARh and DNP 3.0
- V-Switch 4 – Volts, Amps, kW, kVAR, PF, kVA, Freq. kWh, kVAh, kVARh, %THD Monitoring, Limit Exceeded Alarms and DNP 3.0

Measured Parameters	Accuracy % of Reading	Display Range
Voltage L-N	0.1%	0-9999 Scalable V or kV
Voltage L-L	0.1%	0-9999 V or kV Scalable
Current	0.1%	0-9999 Amps or kAmps
+/- Watts	0.2%	0-9999 Watts, kWatts, MWatts
+/-Wh	0.2%	5 to 8 Digits Programmable
+/-VARs	0.2%	0-9999 VARs, kVARs, MVARs
+/-VARh	0.2%	5 to 8 Digits Programmable
VA	0.2%	0-9999 VA, kVA, MVA
VAh	0.2%	5 to 8 Digits Programmable
PF	0.2%	+/- 0.5 to 1.0
Frequency	0.01 Hz	45 to 65 Hz
%THD	5.0%	0 to 100%
% Load Bar	1-120%	10 Digit Resolution Scalable

Note: Typical results are more accurate. Applies to 3 Element WYE and 2 Element Delta Connections. Add 0.1% of Full Scale plus 1 digit to Accuracy specs for 2.5 Element connections.

Traceable Watt-Hour Test Pulse for Accuracy Verification

The Shark® 100 device is a traceable revenue meter. It contains a utility grade test pulse allowing power providers to verify and confirm that the meter is performing to its rated accuracy. This is an essential feature required of all billing grade meters.

Additional Features Include:

- Utility Block and Rolling Average Demand
- Adjustable Demand Profiles
- Max and Min Available on Most Other Parameters
- Voltage Provides Instantaneous Max and Min for Surge and Sag Limits

Measured Values	Real-Time	Avg	Max	Min
Voltage L-N	•		•	•
Voltage L-L	•		•	•
Current Per Phase	•	•	•	
Watts	•	•	•	•
VAr	•	•	•	•
VA	•	•	•	•
PF	•	•	•	•
+Watt-hr	•			
-Watt-hr	•			
Watt-hr net	•			
+VAR-hr	•			
-VAR-hr	•			
VAR-hr net	•			
VA-hr	•			
Frequency	•		•	•
%THD	•		•	•
Voltage Angles	•			
Current Angles	•			
% of Load Bar	•			

Advanced Communication Capability with IrDA Interface

The Shark® 100 meter provides two independent communication ports with advanced features.

Back Mounted Communication Port with KYZ Pulse

- RS485 (Option 485P) – This port allows RS485 communication using Modbus or DNP 3.0 Protocols. Baud rates are from 9600 to 57.6k.
- KYZ Pulse – In addition to the RS485, the meter also includes a KYZ pulse mapped to positive energy. This is a fixed energy pulse. Pulse values are:

Voltage Level	Class 10 Models	Class 2 Models
Below 150V	0.2505759630	0.0501151926
Above 150V	1.0023038521	0.2004607704

Optional 10/100BaseT Ethernet

Ethernet (Option INP10) – 10/100BaseT Ethernet with Modbus TCP protocol.

Front Mounted IrDA Communication

Uniquely, the Shark® meter also has an optical IrDA port, allowing the unit to be set up and programmed using a remote laptop PC without need for a communication cable. To configure the meter, just point at it with an IrDA-equipped PC.

Rugged and Safe Voltage and Current Inputs

The Shark® 100 meter is ruggedly designed for harsh electrical applications in both high voltage and low voltage power systems. This is especially important in Power Generation, Utility Substation and Critical User applications. The structural and electrical design of this meter was developed based on the recommendations and approval of many of our utility customers.

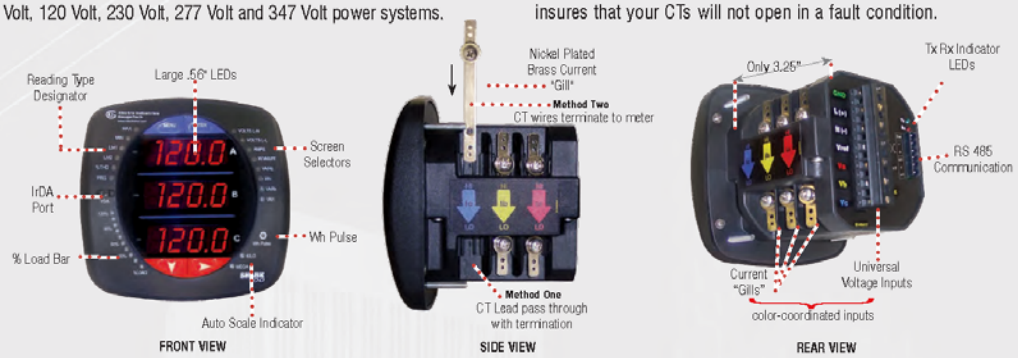
High Isolation Universal Voltage Inputs

Voltage inputs allow measurement of up to 416 Volts Line to Neutral and 721 Volts Line to Line. This insures proper meter safety when wiring directly to high voltage systems. One unit will perform to specification on 69 Volt, 120 Volt, 230 Volt, 277 Volt and 347 Volt power systems.

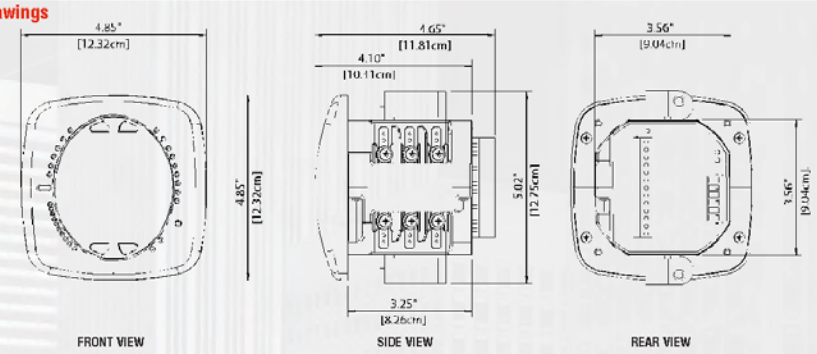
Short Circuit Safe Current Inputs

Current inputs use a unique dual input method:

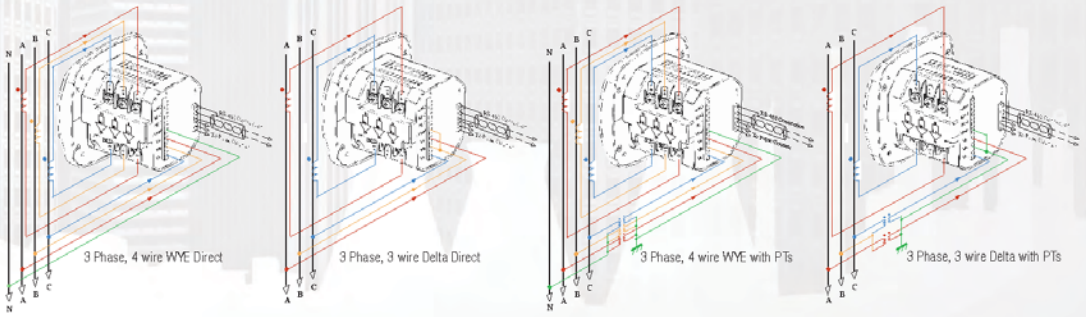
- **Method One** – CT Lead Pass Through. The CT Lead passes directly through the meter without any physical termination on the meter. This insures that the meter cannot be a point of failure on the CT circuit. This is preferable to utility users when sharing relay class CTs. No Burden is added to the secondary CT circuit.
- **Method Two** – Current "Gills." This unit additionally provides ultra-rugged termination pass-through bars, allowing the CT leads to be terminated on the meter. The Shark® meter's stud-based design insures that your CTs will not open in a fault condition.



Dimensional Drawings



Wiring Diagrams



Easy to Use and Install

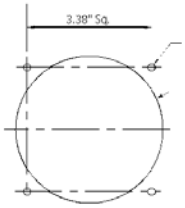
From user interface to mechanical construction, the Shark® 100 Meter was designed to be easy and intuitive, so an installer with minimal meter experience and training can easily install and use this product.

- Easy to use faceplate programming
- PC setup
- Phasor diagram showing wiring status
- Auto scroll feature
- Analog style % of Load Bar
- Shallow panel depth
- Color coordinated voltage and current inputs

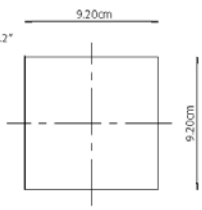
Shark® 100 meter ANSI and DIN Mounting

The unit mounts directly in an ANSI C39.1 (4" round form) or an IEC 92mm DIN square form. This is perfect for new installations and for existing panels. In new installations, simply use DIN or ANSI punches.

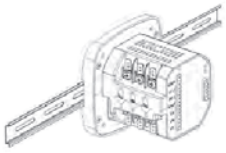
- Perfect for switchgear panel direct retrofits panel
- Mounts in only 3.5" panel depth
- Uses minimal panel space
- Use standard CT or PT wiring



ANSI Mounting



DIN Mounting



Shark® 100T - DIN Rail Mounted Transducer

Specifications

Voltage Inputs
- 20-416 Volts Line To Neutral, 20-721 Volts Line to Line
- Universal Voltage Input
- Input Withstand Capability – Meets IEEE C37.90.1 (Surge Withstand Capability)
- Programmable Voltage Range to Any PT ratio
- Supports: 3 Element WYE, 2.5 Element WYE, 2 Element Delta, 4 Wire Delta Systems
- Burden: 0.36VA per phase Max at 600V, 0.014VA at 120 Volts
- Input wire gauge max (AWG 12 / 2.5mm²)

Current Inputs
- Class 10: (0 to 10) A, 5 Amp Nominal
- Class 2: (0 to 2) A, 1A Nominal Secondary
- Fault Current Withstand (at 23°C): 100 Amps for 10 Seconds, 300 Amps for 3 Seconds, 500 Amps for 1 Second.
- Programmable Current to Any CT Ratio
- Burden 0.005VA per phase Max at 11Amps
- 5mA Pickup Current
- Pass through wire gauge dimension: 0.177" / 4.5mm
- Continuous current withstand: 20 amps for screw terminated or pass through current connections

Isolation
All Inputs and Outputs are galvanically isolated to 2500 Volts AC.

Environmental Rating
Storage: (-20 to +70)° C

Operating: (-20 to +70)° C

Humidity: to 95% RH Non-Condensing

Faceplate Rating: NEMA12 (Water Resistant)

Mounting Gasket Included

Sensing Method
- RMS
- Sampling at 400+ Samples per Cycle on all channels measured readings simultaneously
- Harmonic %THD (% of Total Harmonic Distortion)

Update Rate
- Watts, VAr and VA-100msec
- All other parameters-1second

Power Supply
Option D2:
- (90 to 265) Volts AC and (100 to 370) Volts DC. Universal AC/DC Supply

Option D:
- 18-60VDC Burden: 10VA max.

Communication Format
- 2 Com Ports (Back and Face Plate)
- RS485 Port (Through Back Plate)
- 10/100BaseT Ethernet Modbus TCP (INP10)
- IrDA (Through Faceplate)
- Com Port Baud Rate: (9600 to 57,600)
- Com Port Address: 0-247
- 8 Bit, No parity
- Modbus RTU, ASCII or DNP 3.0 Protocols

KYZ Pulse
- Type Form A
- On Resistance: 23-35 Ohm
- Peak Voltage: 350 VDC
- Continuous Load Current: 120 mA
- Peak Load Current: 350mA (10ms)
- Off Stat Leakage Current @ 350VDC: 1 mA
- Opto-Isolation: 3750V (60Hz, 1min)

Dimensions and Shipping
- Weight: 2 lbs
- Basic Unit: H4.85 x W4.82 x L4.25
- Shark100 – mounts in 92mm DIN and ANSI C39.4" Round Cut-outs
- Shark100T-DIN rail mounted transducer
- Shipping Container Dimensions: 6" cube

Meter Accuracy
- See page 2

Compliance:
- IEC687 (0.2% Accuracy)
- ANSI C12.20 (0.2% Accuracy)
- ANSI (IEEE) C37.90.1 Surge Withstand
- ANSI C62.41 (Burst)
- IEC1000-4-2 – ESD
- IEC1000-4-3 – Radiated Immunity
- IEC1000-4-4 – Fast Transient
- IEC1000-4-5 – Surge Immunity

Ordering Information: To order, please fill out ordering guide:

	Model		Frequency		Current Class		V-Switch Pack		Power Supply		COM		Mounting (Shark100 Only)
Option Numbers:		-		-		-		-		-		-	
Example: Shark 100		-	60	-	10	-	V2	-	D2	-	X	-	X
	Shark100 (Meter/Transducer)		50 50 Hz System		10 5 Amp Secondary		V1 Default V-Switch Volts / Amps		D2 (90-265)VAC or (100-370)VDC		X No Com		X ANSI Mounting
	Shark100T (Transducer Only)		60 60 Hz System		2 1 Amp Secondary		V2 Above with Power & Freq		D 18-60V DC		485P RS485+Pulse (Standard in Shark® 100T Transducer)		DIN DIN Mounting Brackets
							V3 Above with Energy Counters				INP10 10/100BaseT + Pulse		
							V4 Above with %THD & Limits						

Additional Accessories

Communication Converters
9PINC – RS232 Cable

CAB6490 - USB to IrDA Adapter

Unicom 2500 - RS485 to RS232 Converter

Unicom 2500-F – RS485 to RS232 to Fiber Optic Converter

Modem Manager, Model # MM1 – RS485 to RS232 Converter for Modem Communication

Compliance Documents
Certificate of Calibration, Part # CCal – This provides Certificate of Calibration with NIST traceable Test Data.

Electro Industries/GaugeTech
1800 Shames Drive • Westbury, NY 11590
1-877-EIMETER (1-877-346-3837) Tel: 516-334-0870 • Fax: 516-338-4741 • E-Mail: sales@electroind.com • www.electroind.com

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APPENDIX F:
POWERSCOUT 3PLUS DATA SHEET

POWERSCOUT™ FEATURES

DEPENDABLE & PRECISE ENERGY MEASUREMENT

DENT's PowerScout series networked power meters are submetering devices designed to provide timely and accurate consumption data necessary to gain the upper hand on electrical costs in today's escalating energy market. These meters can capture kWh/kW energy and demand data as well as virtually all relevant energy parameters for diagnostics and monitoring on three-phase or single-phase circuit installations. The PowerScout's flexibility, size, and ease-of-use make them ideal tools for gathering detailed consumption information in commercial, industrial, government, and retail environments.

VERSATILE PERFORMANCE

The PowerScout uses direct connections to each phase of the voltage and various interchangeable CT options such as split-core current transformers or flexible RoCoils (for large loads or large cables and busbars) to monitor current on each phase. Every PowerScout has embedded Rogowski coil CT amplifier/integrator circuitry—no need to provide external power to the CTs.

All DENT CTs are internally shielded and carry UL or ETL certification and CE Mark for intrinsically safe operation on energized conductors. Special high accuracy CTs are available for existing CT secondary monitoring.

The PowerScout makes over 50 total electrical measurements which are derived from the voltage and current inputs, including energy and demand values.

FOOL-PROOF INSTALLATION

The PowerScout series instruments are line powered and do not require external power. Its power supply can accommodate service voltages ranging from 80-600V (phase-to-phase). The simple installation is accomplished by connecting the color-coded voltage leads and clearly labeled CTs. DENT's patented PhaseCheck™ circuitry includes a 3 LED indicator display that confirms proper CT to phase installation.

FLEXIBLE CONFIGURATION

The PowerScout 24 (far right, pictured in optional NEMA rated enclosure) can utilize up to 24 current transformers and monitor a combination of three-phase and single-phase loads simultaneously. The meter also provides eight digital outputs, two digital inputs, and a 5V 200mA power output.

The PowerScout can accommodate a wide range of voltage services (80-600V phase-to-phase).

The Next Generation PowerScout 3 Pro with Flexible Rogowski Coils (CT) provides easy installation, accuracy and ease.

A wide selection of CTs are available. Pictured is Mini Hinged, Mi Split-Core, and 61 Flexible RoCoil (Rogowski) CTs.

Typical PowerScout 24 Setup.

POWERSCOUT™ TRANSFORMERS

PowerScout instrumentation can easily connect with a wide selection of current transformers. Choose from conventional and electronic Split Core CTs or the versatile Rogowski Flexible CTs. Each type offers its own particular advantages concerning cost, accuracy, ease of installation, and meeting your varying project requirements.

	MINI HINGED	MIDI HINGED	HIGH ACCURACY	SMALL SPLIT CORE	MED SPLIT CORE	LARGE SPLIT CORE	ROCOIL	ROCOIL
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
KEY SPECIFICATIONS								
WINDOW SIZE	1 in (0.4")	2.5 in (0.8")	1.0 in (0.4")	1.9 in (0.75")	3.2 in (1.25")	5.1 in (2.0")	16": 11.5 cm (4.5") 24": 17.0 cm (7.0") 36": 21.5 cm (10.0") 47": 27.0 cm (14.0")	72": 56.0 cm (22.0")
OUTPUT SIGNAL	333 mV at rated current	333 mV at rated current	333 mV at rated current	333 mV at rated current	333 mV at rated current	333 mV at rated current	131 mV/1000A @ 60 Hz 133 mV/1000A @ 50 Hz	131 mV/1000A @ 60 Hz 133 mV/1000A @ 50 Hz
USEFUL CURRENT RANGE	0.25-40 Amps 0.25-80 Amps	1-200 Amps 1-200 Amps	0.05-7 Amps, 0.15-20 Amps	1-65 Amps 2-130 Amps	5-120, 6-250, 8-320 12-780 Amps	20-780 Amps 20-1300 Amps	75A/75A: 5-5000 Amps	75A/75A: 5-5000 Amps
ELECTRICAL SPECIFICATIONS								
NOMINAL RATING	20, 30 Amps	100, 200 Amps	5 Amps, 15 Amps	50, 100 Amps	100, 200, 400, 600 Amps	600, 1000 Amps	5000 Amps	5000 Amps
ACCURACY	+/-0.5% at rated current	+/-1.0% at rated current	+/-0.5% at rated current	+/-1% at 10% to 110% of rated current	+/-1% at 10% to 110% of rated current	+/-1% at 10% to 110% of rated current	+/-1%**	+1%
PHASE SHIFT	+1.5 at rated current	+0.5 at rated current	+0.5 at rated current	+2 at rated current	+2 at rated current	+2 at rated current	+-0.2 at 50/60 Hz	+1 at 50/60 Hz
FREQUENCY RANGE	50 Hz to 400 Hz	50 Hz to 400 Hz	10 Hz to 10 kHz	50 Hz to 400 Hz	50 Hz to 400 Hz	50 Hz to 400 Hz	20 Hz to 5 kHz	40 Hz to 5 kHz
DIELECTRIC STRENGTH	2500 VAC for 1 minute	5000 VAC for 1 minute	5000 V rms for case 500V rms max	5000 V rms for case 500V rms max	5000 V rms for case 500V rms max	5000 V rms for case 500V rms max	7400 VAC rms for 60 2000 VAC rms max	7400 VAC rms for 60 1000 VAC rms max
MECHANICAL SPECIFICATIONS								
DIMENSIONS	2.6 x 2.0 x 4.2 cm (1.04 x 1.05 x 1.64")	4.7 x 4.7 x 7.0 cm (1.85 x 1.85 x 2.75")	6.4 x 2.5 x 5.1 cm (2.5 x 1.0 x 2.0")	5.08 x 3.56 x 1.55 cm (2.0 x 2.1 x 0.6")	8.26 x 8.6 x 2.54 cm (3.3 x 3.4 x 1.0")	12.07 x 12.70 x 3.05 cm (4.8 x 5.0 x 1.2")	Length 16" (40 cm) Length 24" (60 cm) Length 36" (90 cm) Length 47" (120 cm)	Length 72" (183 cm)
WEIGHT	91 g (3.2 oz)	245 g (8.6 oz)	136 g (4.8 oz)	136 g (4.8 oz)	340 g (12 oz)	748 g (26 oz)	16": 136 g (5 oz) 24": 181 g (6 oz) 36": 227 g (8 oz) 47": 272 g (10 oz)	544 g (19 oz)
POLARITY	Write arc is positive	Write arc is positive	Write arc is positive	Write arc is positive	Write arc is positive	Write arc is positive	Write arc is positive	Write arc is positive
OUTPUT LEAD	Jacks 2.7 m (8 ft) for direct use; 20 AWG	Jacks 2.7 m (8 ft) for direct use; 22 AWG	Jacks 2.7 m (8 ft) for direct use; 22 AWG	Jacks 2.7 m (8 ft) for direct use; 20 AWG	Jacks 2.7 m (8 ft) for direct use; 20 AWG	Jacks 2.7 m (8 ft) for direct use; 20 AWG	2 m (79") to electrical case	2 m (79") to electrical case
OPERATING TEMPERATURE	-15 to 60 C (5 to 140 F)	-15 to 60 C (5 to 140 F)	-20 to 55 C (-4 to 131 F)	-20 to 55 C (-4 to 131 F)	-20 to 55 C (-4 to 131 F)	-20 to 55 C (-4 to 131 F)	-20 to +70 C (-4 to +158 F)	-20 to +80 C (-4 to +176 F)
STORAGE TEMPERATURE	Maximum 105 C (220 F)	Maximum 105 C (220 F)	Maximum 80 C (176 F)	Maximum 80 C (176 F)	Maximum 80 C (176 F)	Maximum 80 C (176 F)	Maximum 80 C (176 F)	Maximum 80 C (176 F)
CASE PROTECTION	Write specs. JL 94 V0	Write specs. JL 94 V0	Epoxy encapsulation, housing ABS/PC3 JL 94 V0	Epoxy encapsulation, housing ABS/PC3 JL 94 V0	Epoxy encapsulation, housing ABS/PC3 JL 94 V0	Epoxy encapsulation, housing ABS/PC3 JL 94 V0	PVC polyolefin JL 94 V0	Polyolefin JL 94 V0
SAFETY SPECIFICATIONS								
SAFETY REQUIREMENTS	JL Recognized JL STL 60950-1 Certified to CAN/CSA STD C22.2 No. 60950	JL Recognized JL STL 60950-1 Certified to CAN/CSA STD C22.2 No. 60950-1	CAN/CSA-C22.2 No 61010-1-2007 Ch 14.2 ANSI/IEC C37.13, IEC C39.13.2	Certified to IEC C37.13-1995 CE Mark	Certified to IEC C37.13-1995 CE Mark	Certified to IEC C37.13-1995 CE Mark	Certified to JL STL 60950-1 Certified to CAN/CSA STD C22.2 No. 60950	Certified to JL STL 60950-1 Certified to CAN/CSA STD C22.2 No. 60950
WORKING VOLTAGE	600 VAC Category	600 VAC Category	Maximum 600 V rms JL 300	Maximum 600 V rms Category	Maximum 600 V rms Category	Maximum 600 V rms Category	Maximum 1000 V rms Category	Maximum 1000 V rms Category

FOCUSED ON ENERGY MEASUREMENT

DENT Instruments designs and manufactures data loggers and energy recorders for today's energy professionals. Our products are often the first step in developing strong energy strategies, for maintaining peak operations, and for lowering operating costs. Our company has built a reputation for providing instruments of the highest quality whose robust design, small size and remote data acquisition make them the loggers of choice for companies large and small.

Since the company's emergence in 1988, we have performed energy measurement studies for a wide range of utility, government, and private clients. This unique customer perspective has strongly influenced the design of our products, reflected in their ease of installation and use.

DENT products provide meaningful energy data that is used to accurately allocate energy costs, identify energy cost-savings opportunities and lower utility bills. Our versatile instruments help pinpoint electrical usage and quantify consumption.

APPENDIX G:
GRIDLINK SPEC R6.11

Product Data Sheet
February 2015
0215-113 r2

VT-IPM2M-113 ADR

Open ADR 2.0 Certified Demand Response Virtual End Node

GRIDlink will change the way you look at Demand Response from now on ...

GRIDlink
Energy Control & Monitoring

BEYOND Open ADR

An adaptable, intelligent tool to help manage Energy Consumption.

GRIDlink is the first industrially rated Open ADR Certified device with advanced communications and programming capabilities. It provides all the functionality envisioned by the OpenADR architects with much more.

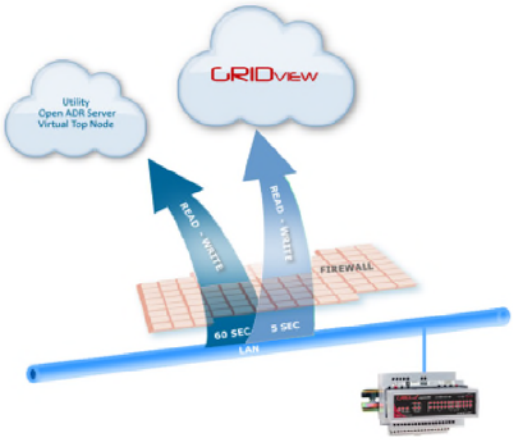
POWERFUL

Advanced communications

- Modbus (TCP, RTU)
- DNP3 (Optional)
- BACnet (Optional)
- Fast Ethernet 10/100
- RS232 & RS485
- And more ...

SECURE

How GRIDlink works



A Utility's Demand Response server which schedules DR Events is referred to as the Virtual Top Node (VTN). The GRIDlink which sheds loads based on the VTN notification is a Virtual End Node (VEN).

GRIDlink initiates a two way communication link with the VTN every 60 seconds using port 443 (SSL). The GRIDlink serial number is hard coded in its firmware and is unique. The VTN uses the serial number to identify it as a valid VEN. With each data exchange the hashed serial number is validated to a 256 bit encryption key.

The VTN constructs a file in a very specific schema or format referred to as a payload. When an Event is scheduled, all the details about notification time, start time and duration are contained in the payload.

Once received, the payload is parsed, the Event is stored in non-volatile RAM and begins counting down. The slightest deviation in syntax from the Open ADR specification will result in a failure.

In Open ADR 2.0a the Event is confirmed back to the VTN, in 2.0b meter data is also provided.

GRIDlink has successfully undergone extensive Cyber Security Penetration Testing by several Utilities and 3rd party consultants.

SIMPLICITY

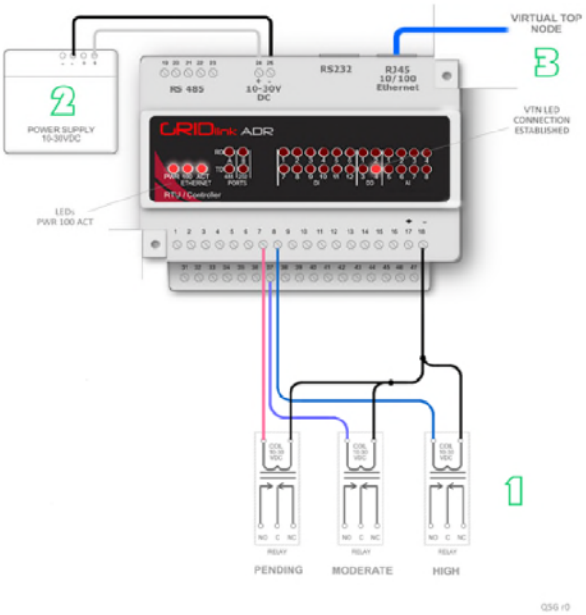
Simple Installation

Three steps:

1. Connect relays to load
2. Provide power
3. Connect to Internet

GRIDlink makes it easy for the installer to quickly complete the job with no special training. Once powered, LED's indicate successful connection to the Local Network and to the Utility's VTN server.

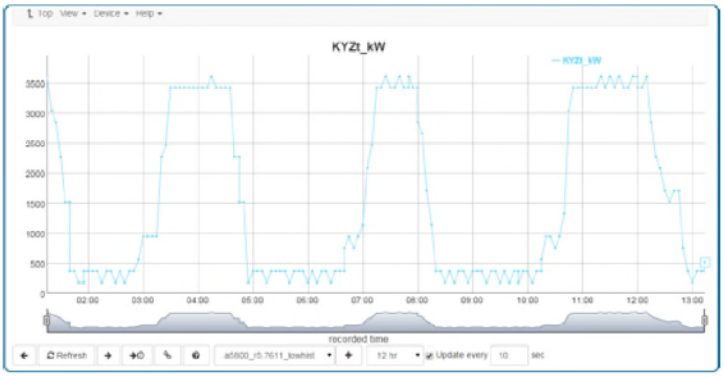
Our technical support group can access all GRIDlinks over our GRIDview Cloud server and easily support the installation by phone.



EXPANDIBILITY

Connect Power Meters

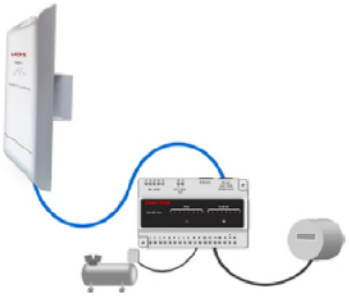
GRIDlink provides easy connections to most Revenue Meters through KYZ pulses or Modbus. Through an easy user configuration page, set up to 4 meters and begin data logging and see trend screens within minutes.



SCALEABILITY

Remote I/O

Extend GRIDlink's reach to multiple loads over distances using remote I/O modules. Connect via RS485 or Ethernet. The remote I/O modules have 8 Digital Outputs and 8 Digital Inputs. The DR signal is sent to as many devices as needed and equipment state and communication status is returned to the GRIDlink's Watch Dog status bit.



GRIDlink WiFi can save on expensive wire runs and conduit costs. Connect multiple I/O modules and Revenue Meters over a distance of 2 miles or more.

ACCESSIBILITY

GRIDview is the backend missing in all other AutoDR products on the market today. It is a cloud based interface for remote monitoring and management of one or more sites. As AutoDR matures and advances, firmware and software upgrades can be easily made to existing sites over the Internet without sending a technician out or taking the unit out of service.

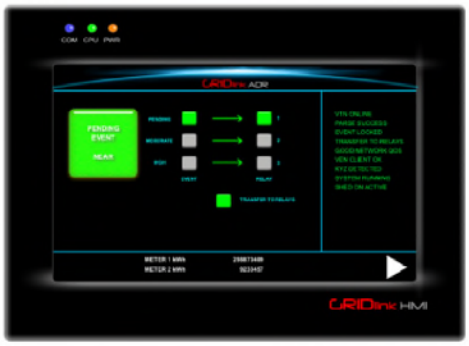
*GRIDview enables remote upgrade of software and firmware which prevents GRIDlink from ever becoming a **stranded asset**.*

Software in the GRIDlink registers itself with GRIDview cloud server and downloads its configuration. Authenticated users can use any web browser to securely view or change current values and configurations. The software provides alarms, including links back to the site, by email or SMS message. Historical data and charts are available to view and download in a CSV file format.

*View the health of GRIDlink and Event status which gives the user full **situational awareness** and significantly **reduces risk of failure on any project**.*

Easily customize information, monitor equipment status, alarms and any other data accessed by GRIDlink such as motor run time and meter data.

GRIDlink HMI offers the user local access and additional features. Rugged industrial interface provides a graphic rich display and easy management of the GRIDlink at the touch of a finger.



Allows Data logging, Email and SMS Texts on Alarms from the Local Network.

It has over 30 communication protocols available and can communicate over 4 simultaneously. This makes GRIDlink HMI an ideal universal interpreter.

FLEXIBILITY

Stand Alone

As part of a Utility's Auto DR Program or automating an existing Demand Response program, GRIDlink can be a complete stand-alone solution shedding automatically one or more loads.

As Part of a Larger System

GRIDlink can also be an easily integrated gateway into a building automation system, lighting controls or SCADA system.

GRIDlink does not require an Open ADR Server (VTN) to operate.

DR Event Scheduler

*With **DRES** software, GRIDlink can schedule load multiple shed events on its own yet be fully compatible with a future Open ADR VTN.*

This is handy for small pilot programs or testing feasibility prior to investing in a DR Server.

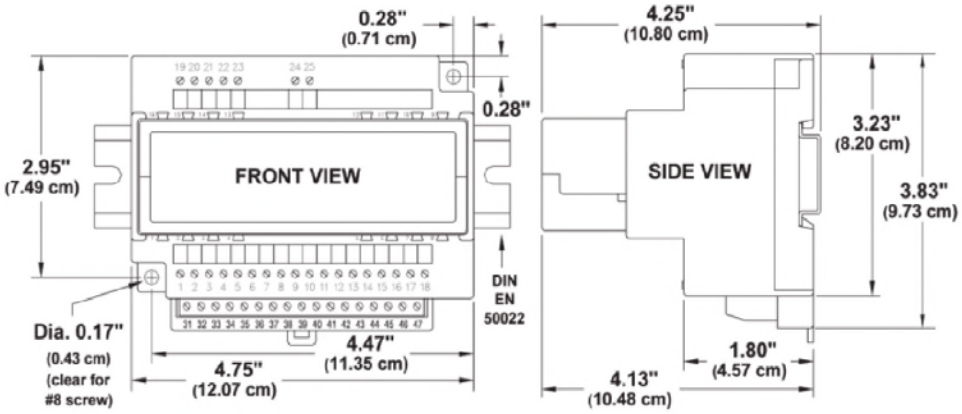
VERSATILITY

Imagine harnessing GRIDlinks to perform functions in concert with a larger Open ADR strategy communication to a VTN but also having an independent local strategy.

Frequency Control – Rate Limiting

GRIDlink can be configured to shed loads based on Power Meter parameters such as frequency or instantaneous kW. It becomes useful in controlling these elements by shedding loads ear marked for DR without the intervention of the Utility's VTN.

DIMENSIONS



SPECIFICATIONS

Industrial powerPC (32 bit data bus)

- Operating system embedded Linux
- Dynamic memory (RAM) 32 Mbytes - 32bit, 0 wait states
- Program memory (Flash) 32 Mbytes
- Retained memory (RAM) 512K (battery-backed)
- Local I/O (on-board) 26
- Limit placed on expansion 256 per I/O type
- Data logging (OPTIONAL)
- IEC 61131 programming
- High Level C programming, Linux open source

ETHERNET PORT

- 10/100BaseTx (auto-detecting) RJ45 connection (auto-crossover)
- Protocols TCP/IP, ARP, UDP, ICNP, DHCP, Modbus/TCP, SIXNET, and more

SERIAL PORT

- RS485 port A screws (485+, 485-, GND) 2-wire half-duplex
- RS232 Port B RJ45 (TD, RD, CTS, RTS, CD, DTR,DSR, GND)
- Protocols (master & slave) Modbus RTU/ASCII
- Flow control hardware, software, RTS-party (for radios and RS485)

DISCRETE INPUTS

- 12 channels (sinking or sourcing) for manual input and force load shed
- Guaranteed ON voltage 9 VDC
- Maximum voltage 30 VDC
- Guaranteed OFF voltage & current 5.0 VDC & 1.5 mA DC
- Input resistance 10K Ohms
- Input current @ 24 VDC 3 mA
- Filtered ON/OFF delay 25 mS (20 Hz max. counting)
- Fast ON/OFF delay 4 mS (100 Hz max. counting)
- Count rate (channels 1 - 8) High Speed Counter (10 KHz on channel 1)

DISCRETE OUTPUTS

- 4 channels (10-30 VDC) 3 for Event Load Shed, 1 for Off Line Indication
- Maximum output per channel 1 Amp
- Maximum output per module 4 Amps
- Max. OFF state leakage 0.05 mA
- Minimum load 1 mA
- Inrush current 5 Amps (100 mS surge)
- Typical ON resistance 0.3 Ohms
- Typical ON voltage (@1A) 0.3 VDC

ANALOG

- 8 Input channels (4-20 mA)
- 2 (optional) output channels (4-20mA)
- A/D resolution 16 bits (0.003%)
- Full scale accuracy +/-0.1% (@20°C)
- Span and offset temp. coef. +/-50 ppm per °C
- Input impedance 100 Ohm
- Current protection Self-resetting fuses
- DMRR (differential mode rejection) 66 dB at 50/60 Hz

ENVIRONMENTAL

- Input power 10-30 VDC
- Input current 100 mA @ 24 VDC (typical)
- Operating Temperature -40 to 70°C (-40 to 85°C storage)
- Shock: IEC60068-2-27
- Vibration: IEC60068-2-6
- Humidity 5% to 95% RH (non-condensing)

CERTIFICATIONS

- Flammability UL 94V-0 materials
- Electrical safety UL 508, CSA C22.2/14; EN610101; (IEC1010)
- EMI emissions FCC part 15, ICES-003,
- Class A; EN55022; EN61326-1
- EMC immunity EN61326-1 (EN61000-4-2,3,4,6)
- Surge withstand IEEE-472 (ANSI C37.90)
- Vibration IEC68-2-6

IC Systems

IC Systems 14252 Culver Dr. A724 Irvine, CA 92604 T 949 857-6600 F 949 551-3169 www.ICSystemsInc.com

APPENDIX H:
SN-6000 DATA SHEET

IndustrialPro® SN 6000 Cellular Routers

Sixnet Networking Series

red lion®

▸▸▸ Cellular Automation

Red Lion's Sixnet series IndustrialPro SN 6000 cellular routers with 4G LTE provide a rugged, reliable solution for monitoring and controlling remote assets and processes in extreme conditions.

IndustrialPro SN 6000 industrial cellular routers offer a cost-effective alternative to leased-line or dial-up networks utilizing secure 4G LTE wireless communication. Built-in Ethernet and serial interfaces provide easy communication between SCADA servers and remote RTUs, PLC/controllers and other automation devices. Convenient VPN capabilities, data encryption and stateful firewall configuration can be used to secure remote networks. Ideal for deployment in industrial M2M networks such as oil and gas, water/wastewater, utility, transportation and mining applications, our industrial cellular routers provide a reliable network extension to remote locations. The end result helps customers save wiring time, space and cost by combining separate functions into one cellular device.

APPLICATIONS

- Oil & Gas
- Water/Wastewater
- Utility
- Transportation
- Mining

PRODUCT HIGHLIGHTS

- High-performance 4G LTE cellular connectivity
- Multiple communication ports
- Routing capabilities provide secure, reliable communication

FEATURES & BENEFITS

- Multiple Communication Ports
  - One RS232 serial port, and up to five Ethernet ports provide seamless connectivity to remote devices
- Rugged, High-Performance Design
  - Reliable operation in rugged environments
  - -40° to 75°C operating temperature*
- Compact Form-Factor Enclosure
  - DIN-rail mounting option
  - Deploys easily in space-constrained locations
- Out-Of Band Management (OOBM)
  - Secure remote CLI access via RS232 port
  - Pre-loaded with many console port configurations
- Secure Ethernet Connectivity
  - Routing capabilities for reliable communication
  - Stateful firewall, SSL, GRE and VPN services and deep packet inspection reduce the risk of unwanted access
- Easy Configuration Options
  - Streamlined web-browser interface

industrial networking

▶▶▶ IndustrialPro SN 6000 Specifications

WIRELESS INTERFACE
AT&T LTE with fall back to HSPA+
Bell Mobility LTE with fall back to HSPA+
Generic LTE with fall back to HSPA+
Manitoba LTE with fall back to HSPA+
Rogers LTE with fall back to HSPA+
Sprint EVDO Rev. A with fall back to 1xRTT
TELUS LTE with fall back to HSPA+
Verizon LTE with fall back to EVDO
Dual-band CDMA2000 EVDO Rev. A
(backward compatible with 1xRTT)
GSM/HSPA+ (backward compatible with EDGE)

PROGRAMMABLE PLATFORM
Software Development Kit (SDK)
C/C++/Perl

SYSTEM PERFORMANCE
32-bit ARM9 400 MHz CPU
512 MB NAND
128 MB RAM

TUNNELING
IPsec, GRE, OpenVPN

Routing Protocols
OSPF, BGP, RIP

Clustering
VRRP

IP
NAT, port forwarding, dynamic DNS, DHCP
Stateful inspection firewall, IP transparency

ETHERNET INTERFACE (10/100 AUTO-SENSING)
1x or 5x RJ45

SERIAL INTERFACE
1x RS-232 serial DB9 115200bps

USB INTERFACE
1x USB 2.0 device mini

POWER INPUT
Range: 8-30 VDC (12 or 24 VDC nominal)
Standby: 1.4W - 3.3W (typical)
Transmitting:
6401: 2.0W – 5.0W
6421: 3.4W – 6.4W
660x: 2.0W – 2.9W
6621: 3.6W – 4.5W
680x: 2.6W – 5.0W
6821: 4.2W – 6.6W
670x: 2.6W – 6.9W
6721: 4.3W – 8.7W
Heat dissipation: 30 BTU/hour max

MECHANICAL
SN-6x0x
Dimensions: 120 x 96 x 32 mm (4.7" x 3.77" x 1.25")
Weight: 453g (1 lb)
SN-6x21
Dimensions:120 x 96 x 51 mm (4.7" x 3.77" x 2.0")
Weight: 500g (1.1 lbs)

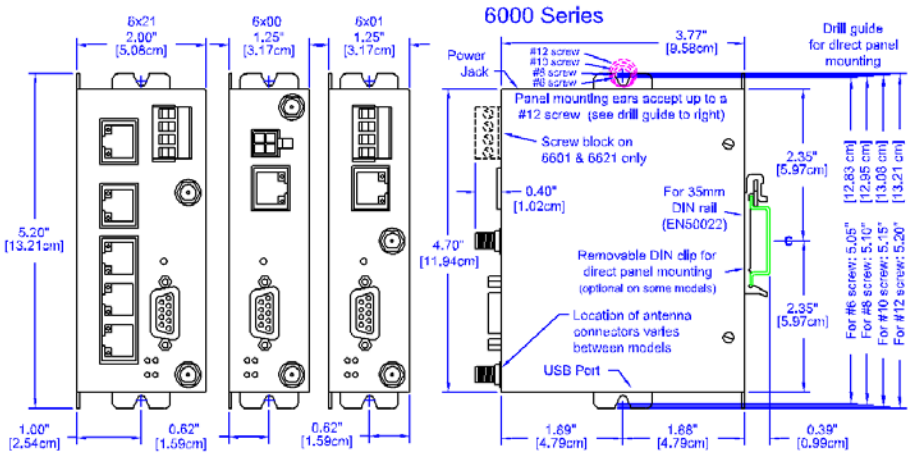
ENVIRONMENTAL
Operating temperature: -40° to +75°C*
Shock: IEC60068-2-27
Vibration: IEC60068-2-6
Humidity: 5 to 95% non-condensing

CERTIFICATION
EMI/EMC:
Emissions: FCC, Part 15 and Industry Canada, ICES-003; Class A; EN55022, IEC61000-6-4
Immunity: IEC61000-6-2 (EN61000-4-2,3,4,5,6,8)
Hazardous locations: Class I, Div. 2, Groups A, B, C, D, ISA 12.12.01
Electrical safety: UL508/CSA22.2/14 (CUL); IEC61010-1
Carrier specific approvals
RoHS compliant

WARRANTY
3 years on design and manufacturing defects

** See Hardware Manual for thermal considerations.*

DIMENSIONS *in inches (mm)*



▶▶▶ IndustrialPro SN 6000 Specifications

ORDER GUIDE

PART NUMBER	PRODUCT LINE	SERIAL RS-232	ETHERNET 10/100	CELLULAR	POWER CONNECTOR	SUPPORTED CARRIERS
SN-6600-(Carrier Code)	SN	1	1	3G/CDMA	Molex end connector cable	(SP) Sprint; (VZ) Verizon
SN-6600-(Carrier Code)-AC	SN	1	1	3G/CDMA	AC adapter	
SN-6600-(Carrier Code)-MX	SN	1	1	3G/CDMA	AC adapter/Molex end connector	
SN-6601-(Carrier Code)	SN	1	1	3G/CDMA	DC powered	
SN-6601-(Carrier Code)-AC	SN	1	1	3G/CDMA	AC adapter	
SN-6601EB-(Carrier Code)	SN	1	1	3G/CDMA	PoE (Power Over Ethernet)	
SN-6621-(Carrier Code)	SN	1	5	3G/CDMA	DC powered	
SN-6621-(Carrier Code)-AC	SN	1	5	3G/CDMA	AC adapter	
SN-6700-(Carrier Code)	SN	1	1	4G LTE	Molex end connector cable	(AT) AT&T; (BM) Bell Mobility; (GE) Generic*; (MTS) Manitoba; (RO) Rogers; (TE) TELUS; (VZ) Verizon
SN-6700-(Carrier Code)-AC	SN	1	1	4G LTE	AC adapter	
SN-6700-(Carrier Code)-MX	SN	1	1	4G LTE	AC adapter/Molex end connector	
SN-6701-(Carrier Code)	SN	1	1	4G LTE	DC powered	
SN-6701-(Carrier Code)	SN	1	1	4G LTE	AC adapter	
SN-6701EB-(Carrier Code)	SN	1	1	4G LTE	PoE (Power Over Ethernet)	
SN-6721-(Carrier Code)	SN	1	5	4G LTE	DC powered	
SN-6721-(Carrier Code)-AC	SN	1	5	4G LTE	AC adapter	
SN-6800-(Carrier Code)	SN	1	1	3G/GSM	Molex end connector cable	(AT) AT&T; (BM) Bell Mobility; (GE) Generic*; (MTS) Manitoba; (RO) Rogers; (TE) TELUS
SN-6800-(Carrier Code)-AC	SN	1	1	3G/GSM	AC adapter	
SN-6800-(Carrier Code)-MX	SN	1	1	3G/GSM	AC adapter/Molex end connector	
SN-6801-(Carrier Code)	SN	1	1	3G/GSM	DC powered	
SN-6801-(Carrier Code)-AC	SN	1	1	3G/GSM	AC adapter	
SN-6801EB-(Carrier Code)	SN	1	1	3G/GSM	PoE (Power Over Ethernet)	
SN-6821-(Carrier Code)	SN	1	5	3G/GSM	DC powered	
SN-6821-(Carrier Code)-AC	SN	1	5	3G/GSM	AC adapter	

* See Band/Frequency table for compatability

FREQUENCY SPECIFICATIONS

PART NUMBER	PRODUCT LINE
SN-66XX-SP/VZ	EVDO: 800/1900 MHz CDMA: 800/1900 MHz
SN-67XX-AT/BM/GE/MTS/RO/TE	LTE: Bands 1, 4, 17; Frequencies 700/2100MHz, AWS (1700/2100) MHz HSPA: Bands 1, 2, 5, 8; Frequencies 800/850/1900/2100 MHz GSM: 850/900MHz
SN-67XX-VZ	LTE: Band 13; Frequency 700 MHz WCDMA: 850/900/1900/2100 MHz
SN-68XX-AT/BM/GE/MTS/RO/TE	HSPA: Bands 1, 2, 5, 6, 8; Frequencies 800/850/900/1900/2100 MHz GSM: 850/900/1800/1900 MHz

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As the global experts in communication, monitoring and control for industrial automation and networking, Red Lion has been delivering innovative solutions for over forty years. Our award-winning technology enables companies worldwide to gain real-time data visibility that drives productivity. Product brands include Red Lion, N-Tron and Sixnet. With headquarters in York, Pennsylvania, the company has offices across the Americas, Asia-Pacific and Europe. For more information, please visit www.redlion.net. Red Lion is a Spectris company.

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