

# Power Quality Evaluation of Mobile UPS Installation at S&C Electric Company

Ernst H. Camm<sup>1</sup>

Brad Roberts

S&C Electric Company  
Chicago, IL

## Introduction

A mobile PQ2000 Power Protection System, now known as the PureWave™ UPS system, was installed at S&C Electric Company's Polymer Products Fabrication Building in Chicago, Illinois in May 1999 to provide uninterrupted electrical service to the entire building. See Figures 1 and 2. The unit was designed to supply up to 2 MVA of interrupted power for up to 15 seconds at 480 Volts.

A power quality evaluation of the installation, sponsored in part by the Department of Energy through Sandia National Laboratories<sup>2</sup>, was performed over a six-month period from July 1999 to early January 2000. The project involved two phases, including the collection and review of power disturbance data and the effects on process equipment, and continuous monitoring of utility source and building load voltages and currents over a period of six months. During this time period a circuit breaker was installed between the UPS and the building's supply transformer to simulate utility-side interruptions to the load.



Figure 1: Mobile PureWave UPS installation at S&C Electric Company.

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<sup>1</sup> E-mail address: [ecamm@sandc.com](mailto:ecamm@sandc.com).

<sup>2</sup> Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy under Contract DE-AC04-94AL85000

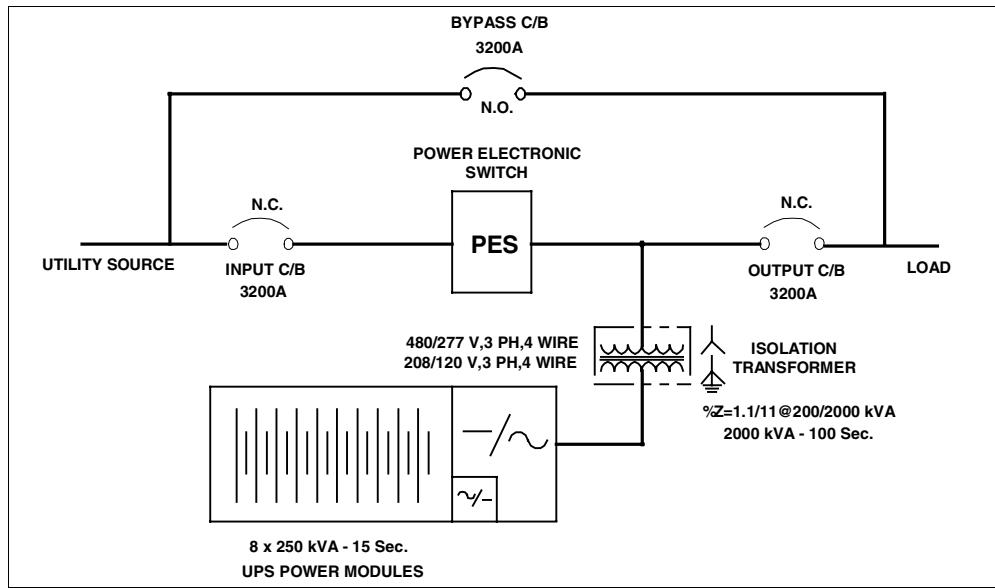


Figure 2: One-line diagram of 480 V, 2 MVA PureWave UPS system.

### Phase I: Data Collection and Review of Power Disturbance Data And Effects on Process Equipment

The first phase of the power quality evaluation involved data collection and review of power disturbance data to determine the effects of power disturbances on process equipment in the Polymer Products Fabrication Building. The data collection and review involved:

- Review of the serving utility's distribution system one-line diagrams for the S&C Industrial Complex.
- Review of the electrical system one-line diagrams for the Polymer Products Fabrication Building.
- Discussions with the facility electrical maintenance personnel and end-users on the effects of power disturbances on the building's electrical equipment.
- Determination of the process equipment that has been affected by power disturbances.
- Review of the ride-through characteristics of the equipment affected by power disturbances.
- Review of existing power-disturbance records for the building to develop a history of the effects of disturbances on process equipment.
- Determination of the production losses associated with power disturbances and the economic impact thereof.

The building's medium voltage system is supplied via two 12-kV feeders through a common-bus preferred-alternate scheme. In the event of an interruption or outage on the preferred feeder, the conventional source-transfer equipment in the medium-voltage switchgear is set to transfer the building and other connected loads to the alternate feeder in approximately 2.5 seconds. The UPS system provides uninterrupted power to the building's load during this time interval, preventing sensitive electrical equipment, including AC contactors, programmable logic controllers (PLCs), and adjustable frequency drives (AFDs) from being affected.

The building's utilization voltage is derived from a 12 kV/480 V/277 V delta/wye-grounded transformer supplied from the medium-voltage switchgear. The UPS system is connected to the secondary side of this transformer and to the 480-V bus in the building's main switchboard via the 480-V bus tie circuit breaker.

Review of power disturbance data and equipment power disturbance ride-through characteristics indicated that the hydraulic pumps used for the thermalset molding machines in the polymer products fabrication process are

primarily affected by momentary interruptions and voltage sags. See Figure 3. Momentary power interruptions and voltage sags of sufficient depth and duration result in the AC starter contactors of the motors driving the hydraulic pumps dropping out. The PLCs controlling the molding process can also be affected by momentary power disturbances. Momentary power disturbances also affect adjustable-frequency drives (AFDs) used in the dispersing equipment associated with the molding process. AFDs used to drive the cooling tower fans of the building are also affected, but the shutting down of these drives for brief periods will not affect the fabrication process.



Figure 3: Molding machine with hydraulic system power pack in the foreground.

The tripping of motors driving the hydraulic pumps can affect up to 12 molding machines, each holding up to 4 parts. If all molding machines are affected during momentary power disturbances direct production losses could amount to approximately \$36,000 per disturbance. In 1998 there were 13 power disturbances recorded in the building's electrical system, resulting in direct production losses of approximately \$468,000. In addition, production delays associated with the momentary power disturbances could also severely impact the production schedules of other S&C products containing polymer products, resulting in further losses.

## Phase II: Power Quality Monitoring

During the second phase of the project two Dranetz/BMI PQNode 7100 disturbance analyzers were installed for continuous monitoring of 480-V phase-to-neutral voltages on the source side of the UPS system and the 480-V bus on the load side of the UPS system. The disturbance analyzers were configured to capture waveshape disturbances in voltage waveforms caused by transients, voltage sags and swells, and interruptions, as well as rms disturbances associated with voltage sags and swells, and interruptions. Rms disturbances were triggered on the disturbance analyzers whenever any of the three phase-to-neutral voltages on either the source or load side of the UPS system dropped below 90% of the nominal voltage or increased above 110% of nominal voltage.

During the six-month monitoring period 12 voltage sag events occurred at the facility due to utility-side faults. The phase-to-neutral voltage sags during these events ranged from approximately 70 to 89 percent of nominal voltage, while the duration of these sags ranged from 3 cycles to 11 cycles. Three-phase neutral-to-ground voltages during one of the voltage sags captured on the source-side disturbance analyzer are shown in Figure 4(a). Figure 4(b) shows the three-phase voltages captured on the load-side disturbance analyzer during the same voltage sag. The

UPS system operated as intended, correcting the phase-to-neutral voltages on the load side to nominal voltage during each of the 12 voltage sags.

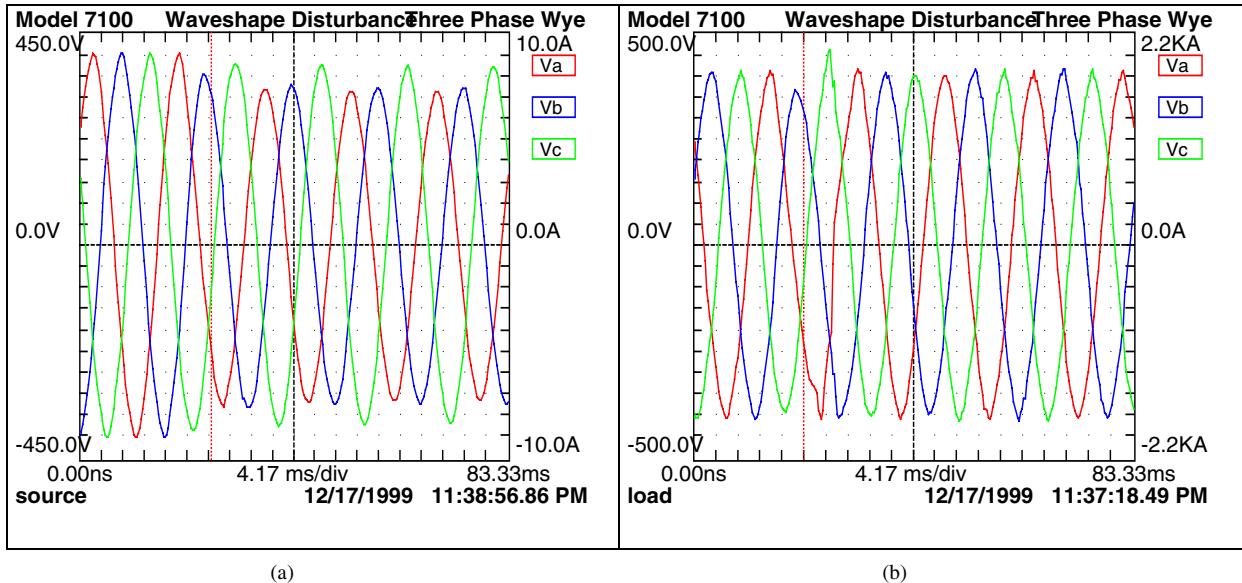


Figure 4: Three-phase phase-to-neutral voltages on (a) the source and (b) load sides of the PureWave UPS system during a voltage sag caused by a utility-side fault.

A large number of additional disturbances were recorded during product demonstrations where utility-side interruptions were simulated by opening a 480-V circuit breaker installed on the source side of the PureWave UPS system. The circuit breaker controls were equipped with a timer circuit to automatically reclose the circuit breaker approximately 6 seconds after interruption. The UPS system operated as intended during each of these simulated interruptions to protect the building's load. See Figure 5 for source and load side voltages captured during one such interruption.

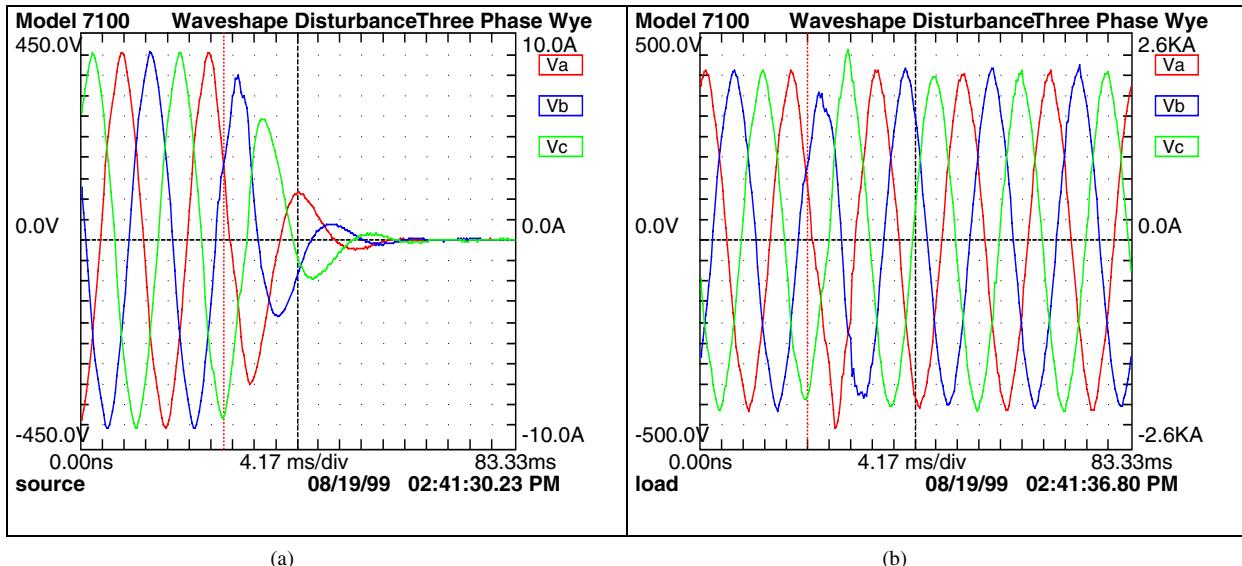


Figure 5: Three-phase phase-to-neutral voltages on (a) the source and (b) load sides of the PureWave UPS system during a simulated interruption.

## **Summary**

The power quality evaluation of the mobile PureWave UPS system at S&C Electric Company's Polymer Products Fabrication Building demonstrated that:

- Momentary power disturbances can affect the fabrication process through the tripping of AC motor contactors and PLCs associated with the hydraulic system used in the thermalset molding machines.
- The economic impact of power disturbances based on direct production losses only can be as high as \$468,000 per year.
- The PureWave UPS system can be effectively applied to provide uninterrupted power to the building's load during momentary power disturbances, including voltage sags and swells, as well as interruptions.

The power quality evaluation further provided valuable information to demonstrate that battery energy-storage technology can be successfully applied for large commercial and industrial type loads.

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