Case Histories: Continuous Process Solutions Utilizing Battery Free UPS

Gary P. Rackow, P.E. *Member, IEEE*

***Abstract*—Many continuous manufacturing processes require protection from power abnormalities. In this paper, two such cases are discussed. The first is an edited version of a previously published study illustrating a flywheel based UPS power quality solution for a continuous pipe extrusion process. The second extends this concept for a pharmaceutical freeze-drying process. In addition to correction of short-term power sags and surges, total power outage protection was necessary. The solution was a flywheel based UPS with an integral standby engine.**

***Index Terms*—Flywheels, Uninterruptible power systems, Voltage control, Harmonic distortion, Reactive power, Standby generators.**

I. Case 1: Introduction

An extruder upgrade from 200 to 400 horsepower initiated this UPS project at continuous pipe manufacturer in Florida (Figure 1). The extrusion process is a critical manufacturing step that can take up to 20 hours. No interruption of the extrusion or defect can be tolerated. This manufacturer knew from experience that the extruder's variable speed drive is sensitive to power quality and would require protection, particularly since the factory is subject to a high level of thunderstorm activity. Analysis of protection alternatives started during November of 1996 in cooperation with the local utility. A 1000 kVA battery free UPS was delivered in February 1998, and the project was completed after extensive testing by the beginning of April.

II. Case 1: Continuous Pipe Manufacturing

A. Critical Manufacturing Process

This manufacture supplies flexible pipe for the oil and gas industry. Critical applications include connections from undersea wells, offshore rigs and storage facilities. The pipe consists of concentric extruded polymer and reinforced helical metallic layers. A single piece of pipe may be thousands of meters long, have an inside diameter of 10.75 inches and include between 10 and 20 layers of material. Because high pressures and stresses may act upon the pipe, and because of the severe consequences if a rupture occurs, manufacturing quality control must meet stringent standards imposed by Lloyds Register and the manufacturer's zero-defect policy.

Gary P. Rackow is with Piller, Inc, Middletown, NY 10940 USA (e-mail: grackow@piller.com).

Fig. 1. The factory was subject to frequent thunderstorm activity.

Furthermore, the fast track nature of oil field projects requires tight delivery schedules, and costly provisions for late delivery are frequently included in supply contracts.

In this environment of strict compliance to quality control and schedules it is critical that the extrusion process operates without interruption. A single extrusion flaw can result in the loss of a full day of production, several days delay to complete the pipe, high scrap and rework costs, overtime and added transportation costs for ships and barges waiting to ship the pipe. Therefore, the extruder requires reliable, conditioned power.

B. Needs and Objectives

This plant operated their 200hp extruder exclusively from an onsite 850kW diesel generator. This generator could not support the new extruder due to harmonics caused by the larger 400hp dc drive. Their engineering staff determined that, unless other steps were taken, the diesel plant would have to be expanded by more than 500kVA to provide a sufficiently stable, low impedance source for the extruder. Because it was near coastal resorts, the manufacturer was also concerned about environmental issues associated with the diesel generator. In addition, the operating cost of on-site generation was three times the cost of electricity purchased from the utility. These conditions convinced them that alternatives to on-site generation must be examined in order to achieve the following three primary goals:

- Continue to fulfill the corporate mission statement: "We commit. We deliver. No excuses."
- Reduce operating cost
- Continued environmental responsibility

C. Solution Analysis

This manufacturer worked with the utility in the past to analyze power quality and energy saving issues, so they asked this local utility to help characterize the extruder load, assess its effects on the supply voltage, and help develop alternatives to on-site generation. The utility analyzed the extruder input current and the resulting supply voltage distortion. Waveforms and harmonic spectra were recorded when operating from utility power and while attempting to operate from the 850kW diesel generator *(Figures 2-5)*. It was confirmed that the diesel generator was equipped with a voltage regulator and isochronous governor designed for use with nonlinear loads. Nevertheless, the dc drives could not tolerate the voltage harmonics and the instability that occurred when operating on the existing diesel generator.

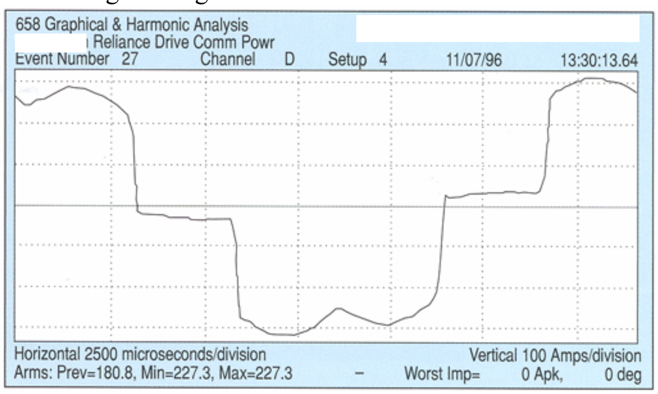

Fig. 2. Distorted utility voltage waveform supplying extruder.

Potential solutions were separated into three categories. The first included options to increase the size of the diesel plant. The second included various extruder modifications that might allow operation with the existing engine generator. The third was to install UPS protection for the extruder. Increasing the size of the diesel plant was quickly eliminated as an option because it entailed the highest capital and operating costs without mitigating the potential for fuel spills. The alternatives for modifying the extruder included input filters for the drive, twelve-pulse rectification instead of six-pulse and a variable frequency ac drive instead of the dc drive.

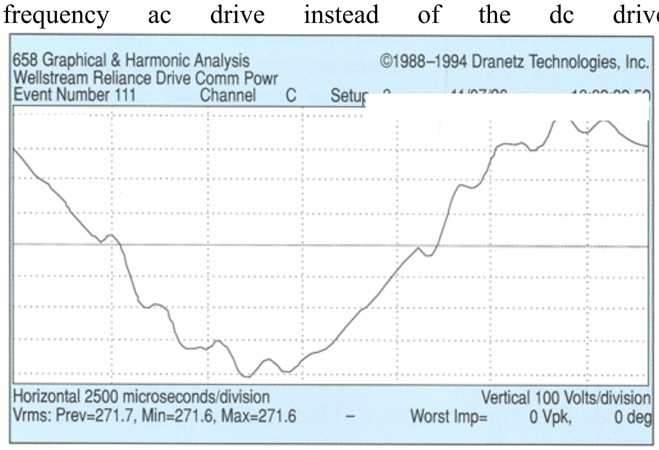

Fig. 3. Extruder input current waveform operating on utility.

Eventually. all of these alternatives were rejected because the modifications could adversely affect extruder operations, or required unacceptable equipment modifications. In addition, all of the alternatives still required operation from an on-site generator. A UPS solution offered the best chance for meeting all of the project goals, but it needed to be determined that the UPS would maintain output voltage and frequency acceptable to the dc drive over the full range of operating speeds and loads. This determination was difficult since the composition of the drive current harmonics and the position of commutation notches change with operating conditions. In *Figure 4,* for example, the notches appear at the peak of the voltage waveform rather than at a more normal position near 30° and 150°. This characteristic can cause high output voltage distortion in PWM inverters frequently used in static UPS systems.

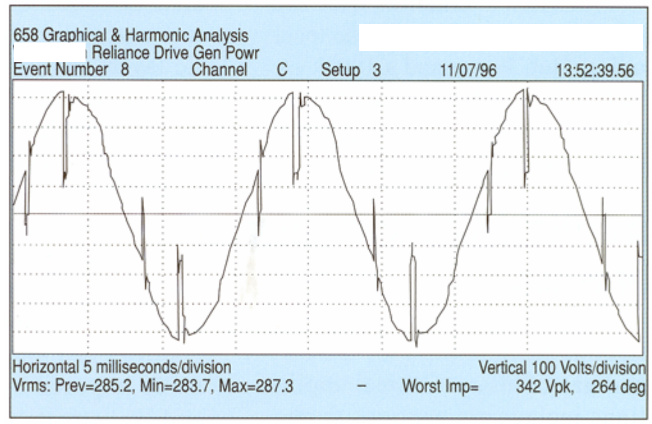

Fig. 4. UPS output current waveform supplying extruder.

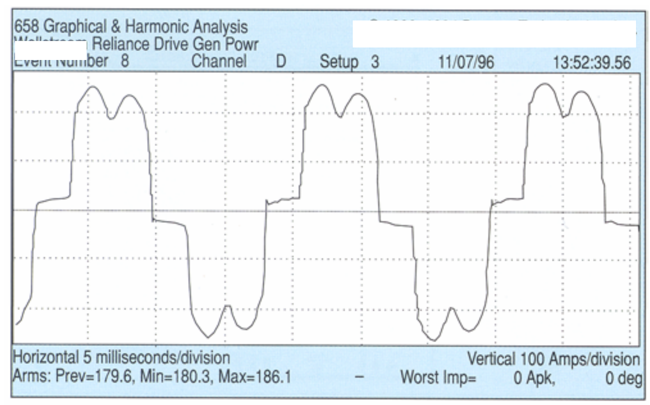

Fig. 5. Extruder input current waveform operating from UPS.

D. Initial Conditions

Several existing site conditions strongly influenced the selection of a UPS solution. First, the facility is served by two 12.47kV feeders supplied from different utility substations, and these substations are supplied by separate transmission lines. Second, a primary switch transfers the facility between feeders in 12-cycles. Simultaneous outages of these feeders has only occurred once during an area-wide blackout. Third, installation of a conventional UPS system would require substantial site preparation and construction to provide a suitable location for batteries. The only indoor space available was in the main manufacturing area *(Figure* 6), which is not suitable for batteries and does not readily accommodate construction of a battery room. The plant manager also wanted to

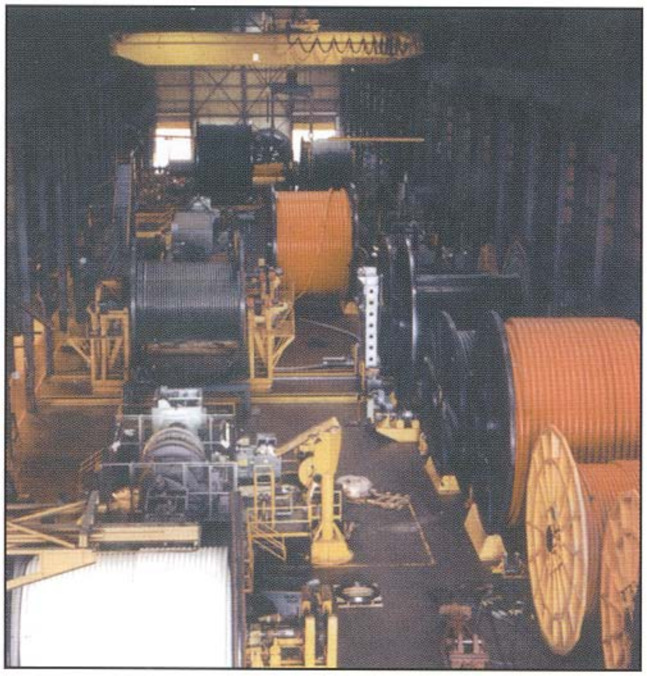

Fig. 6. The main continuous pipe manufacturing area.

avoid the increased maintenance associated with large battery installations. The fourth consideration was limited space in the manufacturing area. The best location for minimizing construction costs required compact equipment that did not require rear access. Finally, the drive was sensitive to voltage variations, harmonic voltages induced by its own nonlinear current and frequency change. Maximum allowable input voltage sag is 30% for less than three cycles, and maximum recommended input voltage THD is below 7%. As delivered from the manufacturer, the drive would not tolerate slew rates greater than 0.21 Hz per second. Subsequent adjustment improved the performance but the slew rate tolerance remained less than 1 Hz per second.

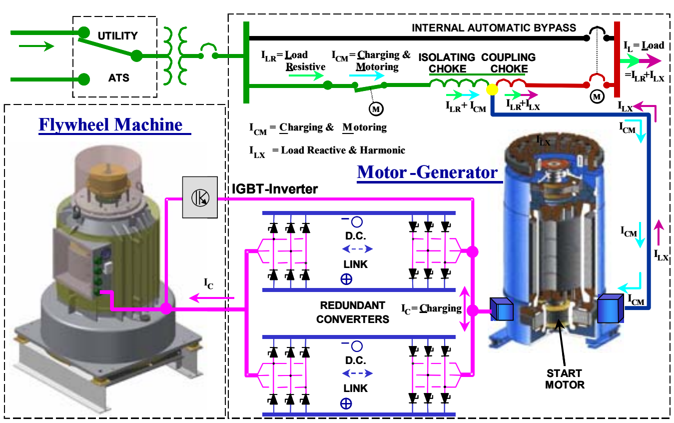

Fig. 8. Internal power diagram of the flywheel UPS

E. UPS Solution

The utility, which already had experience with battery-free UPS systems, facilitated a turnkey solution that was accepted by their customer. Because static UPS systems can have difficulty maintaining well-regulated output voltage for dc drives, the decision was made to use rotary UPS technology.

Fig. 7. The 1000 kVA flywheel based UPS.

By using competitive evaluation and consultation with manufacturers, the utility and the manufacturer decided to use a 1000kVA rotary UPS utilizing integral flywheel energy storage (Figure 7). The UPS manufacturer predicted the output voltage harmonic distortion of its UPS when supplying the dc drive using straightforward calculations based on output impedance and the drive current harmonic spectrum.

The UPS module uses a flywheel to provide 30 seconds ride-through at maximum extruder load. This allows ample backup time to attempt to clear a fault on one utility feeder, transfer to the second feeder and to synchronize to the second feeder at less than 1 Hz per second slew rate and reconnect. This unit has a fast recharge rate, which allows energy to be returned to the flywheel at rates as fast as the discharge rate at rated load. However, in this installation the supply circuit capacity limits the recharge rate to three seconds for every second of discharge at maximum extruder load. The fast recharge rate ensures that the flywheel will not be depleted even if several interruptions are experienced in rapid succession.

The nonlinear load performance of this UPS is exceptionally good because its output impedance is about half of normal synchronous generators of similar rating. The predicted output voltage THD was 5.5% to 6% with the drive in operation. The measured THD after installation was within the predicted range. In this case reliability was a primary concern. The configuration of the UPS contains redundant power electronics and controls to assure high reliability and fault tolerant operations *(Figure* 8). Normal operation with full UPS protection continues even if one of the converters fails. MTBF calculated for the unit is 1.38 million hours.

The vertical design of the flywheel and motor generator allows a compact design. The overall dimensions, including the flywheel, are 182" long X 52" deep X 90" high. No rear access is required. This allowed the unit to be installed against the outside wall of the plant in a location convenient for integration into the existing electrical system. The placement of the unit made integration straightforward with minimum alteration of existing wiring as shown in Figure 9.

Existing transfer switches provided means to completely bypass and isolate the new UPS system if required for maintenance or testing. Open transition bypass was adequate since brief interruption of power to the extruder between product runs does not cause any disruption of operation.

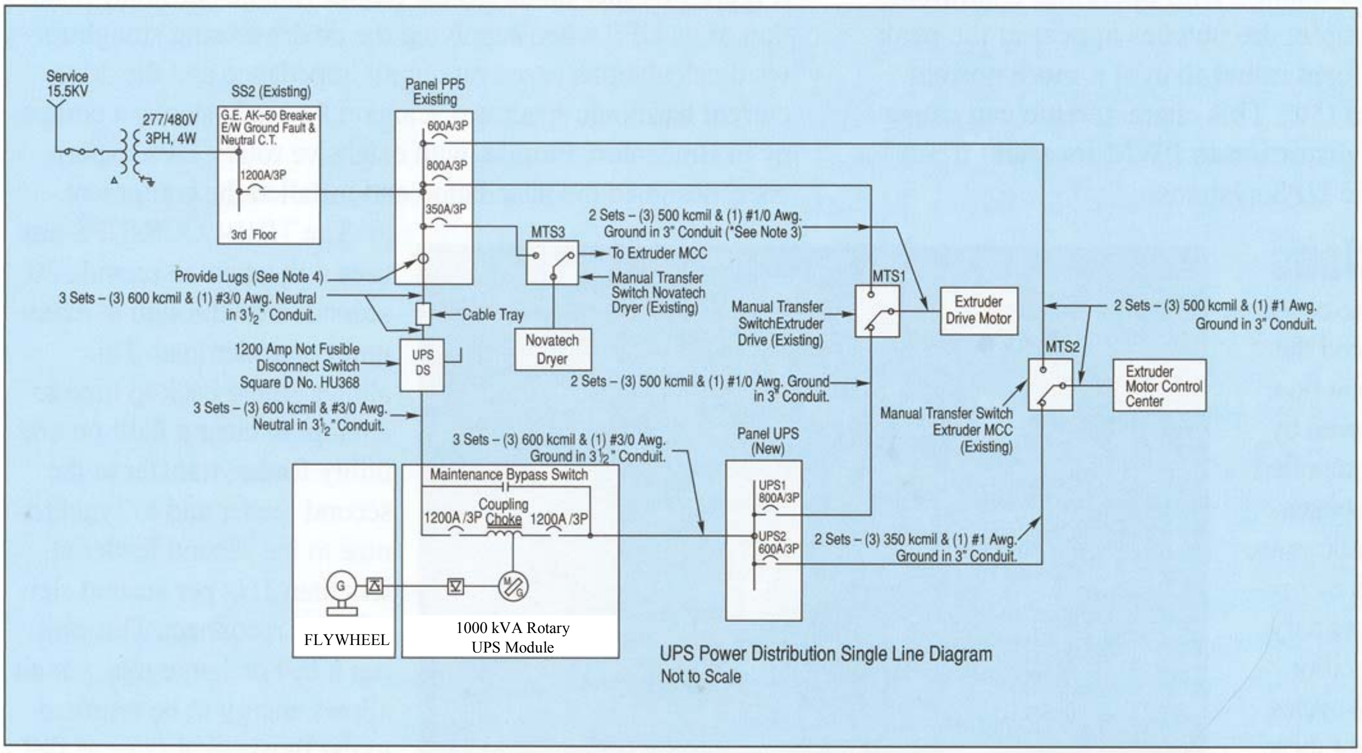

Fig. 9. Overall UPS system One-Line diagram.

Finally, the 95% efficiency and 0.94 input power factor were important characteristics in meeting the goal of reducing operating costs.

F. Results

The UPS system protected the extruder as planned. Initial tests were run to adjust the system, confirm correct operation of the extruder and collect test data. The UPS protected the extruder from seven severe sags and transfers - six caused by lightning and one by a car accident - between medium voltage feeders in a period of just four months after installation. The potential of a fuel spill was eliminated and their operating cost reductions were greater than expected, due to the high efficiency of the UPS. Finally, a $400 per month reduction in utility power factor charges resulted from the UPS system's high input power factor.

III. CASE 2: PHARMACEUTICAL FREEZE DRYING PROCESS

A. Critical Manufacturing Process

Biological materials often must be dried to stabilize them for storage or distribution. Drying always causes some loss of activity or other damage. Lyophilization, also called freeze-drying, is a method of drying that significantly reduces such damage. Because lyophilization is the most complex and expensive form of drying, its use is usually restricted to delicate, heat-sensitive materials of high value.

B. Needs and Objectives

Due to an unacceptable number of weather and power grid related utility interruptions, this pharmaceutical company located in Puerto Rico was experiencing a significant loss of product, with a corresponding impact on revenue. The main area of concern was the Lyophilization process. An industry expert consulting firm was hired to analyze the existing power system and recommend a solution.

Fig. 10. Typical Pharmaceutical freeze-dryer (Lyophilizer)

C. Solution

It was determined that due to the sensitivity of the Lyophilization (Figure 10) equipment to power disturbances, the only practical solution was the addition of a UPS system. Due to motor inrush load characteristics, space limitations, environmental concerns, and lower cost of ownership, a battery-free rotary UPS technology was chosen.

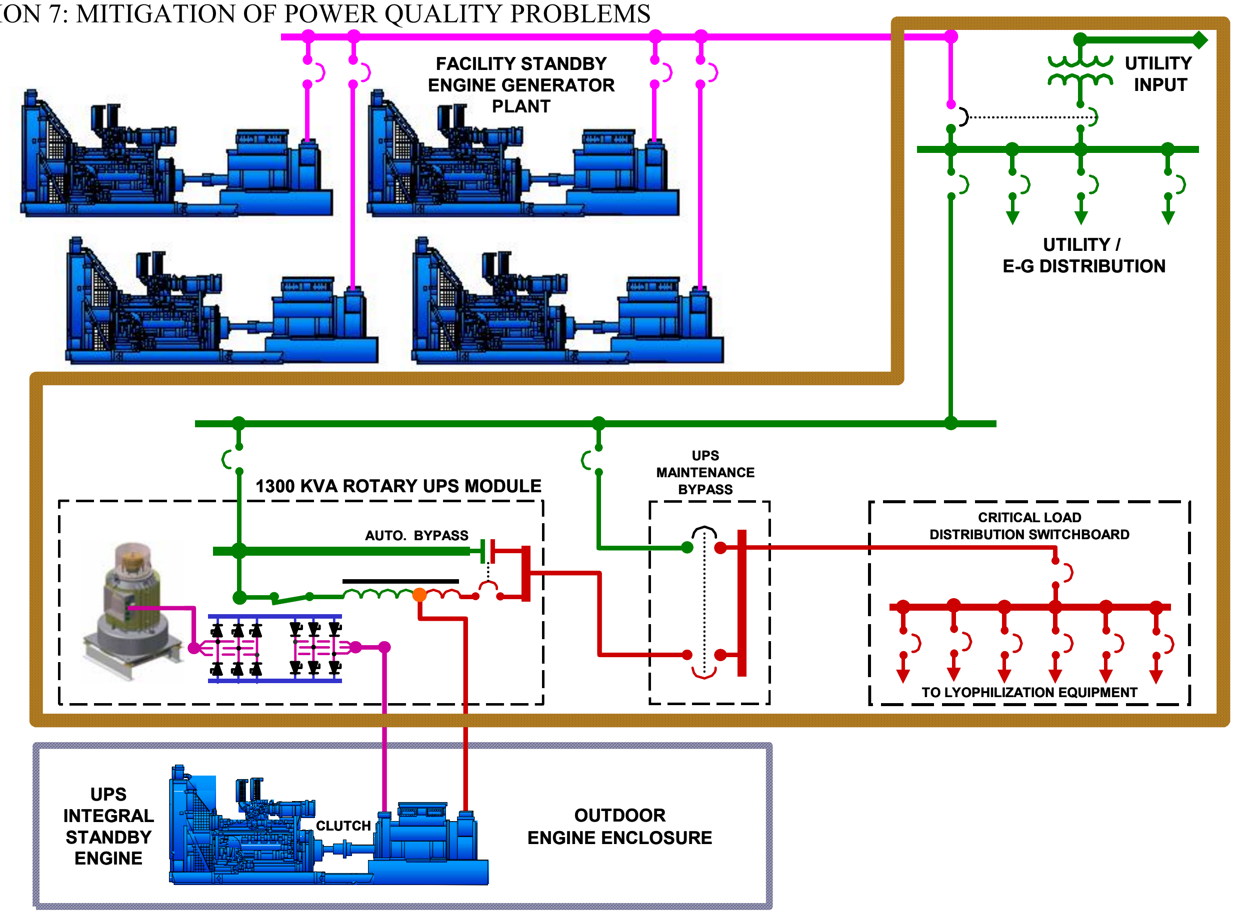

Fig. 11. Total Emergency / Critical Power System One-Line Diagram

The need for additional standby engine capacity was recognized due to planned plant expansions. This, coupled with the fact that environmental code restrictions limit the amount of run time for the main standby engine plant, drove the selection of a flywheel based UPS with integral standby engine support. The basic power quality correction and short-term power protection characteristics are the same as described in the preceding Case I. These capabilities are expanded to include continuous power protection with the addition of an integral standby engine. This dedicated engine is engaged through a clutch to power the primary rotary power conditioner in approximately 5 seconds. This is well with in the flywheel's full load stored energy capability of 15 seconds. The main engine plant then does not need to be put in service except for extended outages. This system *(Figure 11)* is currently being installed on a fast track schedule in order to be in service before the approaching storm season.

IV. Acknowledgment

The author gratefully acknowledge the contributions of M. Mahalak, S. Richbourg, W. Cannon, Sr., and B. S. Walter, for their work on the original version of this document.

V. References

Periodicals:

[1] J M. Mahalak, S. Richbourg, W. Cannon, Sr., and B. S. Walter, "Case History: Continuous Pipe Manufacturer's Solution – Battery-Free UPS," *Power Quality Assurance®*, October 1999. Copyright 1999, PRIMEDIA Business Magazines & Media, Inc. All rights reserved. PQA-06-LA

[2] Snowman, John W. **Downstream Processes: Equipment and Techniques**, pages 315-351, 1988 Alan R. Liss, Inc.

VI. Biographies

Gary Rackow was born in Queens, New York on July 23, 1953. He received the B.S. degree in electrical engineering from the Polytechnic Institute of Brooklyn in 1975.

From 1975 to 1985 he was with General Electric as an application engineer. Product scope included power distribution equipment, motor drives, Uninterruptible Power Systems, and process control. Since 1985 he has been with Piller, Inc., a manufacturer of rotary power conditioning products, and is engaged in the specification and proper application of these in critical power systems.

Mr. Rackow is a member of IEEE Industry Application Society (IAS) and has served as the Atlanta local chapter secretary. He is a registered P.E. in the state of Georgia since 1983.