PQSoft Case Study

PQ Investigation at a Battery Facility

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Abstract:

This case study presents the results of a power quality investigation at a battery manufacturing facility. The facility had been experiencing a high rate of motor failures and was experiencing problems with its computer control system. Ground noise caused by the ungrounded 480 V system and ground loops was part of the problems identified with the computer control system. A ground fault on the 480 V system was found and removed. The installation of harmonic filters reduced the THD from 19% down to 2%. Some of the motor failures were attributed to the basic nature and risks associated with an ungrounded 480 V system.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

RELATED STANDARDS

IEEE Standard 519
ANSI/IEEE Standard 141-1993 Recommended Practice for Electric Power Distribution for Industrial Plants

GLOSSARY AND ACRONYMS

IEEE	Institute of Electrical and Electronics Engineers
THD	Total Harmonic Distortion

INTRODUCTION

There are concerns about the power distribution system at a typical Battery Facility. Plant personnel perceive a high failure rate of motors, and problems experienced by the installation of a new system to control battery formation are the most immediate concern. This case study addresses the following issues:

- Formation Computer Control
- Grounding of the Distribution System
- Harmonic Distortion

FORMATION ROOM COMPUTER CONTROL

The computer control for the formation room at the current facility has encountered past operational difficulties. A similar system was installed in a sister plant successfully. The following problems occurred with the new system at the current facility:

- Formation room attendants did not trust the system, and a high number of batteries were rejected for improper formation.
- Temperature indications, when compared with manual readings, were often in error +/-10 degrees, and sometimes in error by 50 degrees. The errors were intermittent, with no consistent pattern.
- Current indications that often read low, causing the rectifier unstable operation.

The problems with the system are due to the following factors:

- Lack of ownership for the problem of getting the system corrected. Recently a plant engineer has been added there to address this concern.
- Ground noise caused by the ungrounded 480V system.
- A shared common reference that becomes distorted by noise.
- Inherent lack of accuracy in the Hall Effect sensor boards. Bench tests have shown that under laboratory-type conditions, the best accuracy achievable is on the order of +/-5%.
- Electromagnetic interference to the current signals caused by their proximity to the rectifier reactors.
- Ground loops, exasperated by the installation of a new driven-ground rod at the UPS powering the wall-mounted computers.
- The 30V wiring insulation on the temperature probes failing, and coming into contact with the 300V rectifier circuits. This is in evidence by burned insulation found, and by monitoring which showed a 300V offset (dc) on the ground system.

To date, the following steps have been taken to improve the system:

- A ground fault was isolated from the power system.
- A recorder was used to check the accuracy of the signals going to the wall computers.
- Filter capacitors installed on the Analog Input Boards to the controller, to correct the noise on the current signals.
- The driven-ground rod at the UPS was removed from the system.
- The temperature probes and their associated shield wires were isolated from the system.
- A BMI-8800 Power Disturbance Recorder was installed on the power feed to the wall computers, to monitor for ground noise.

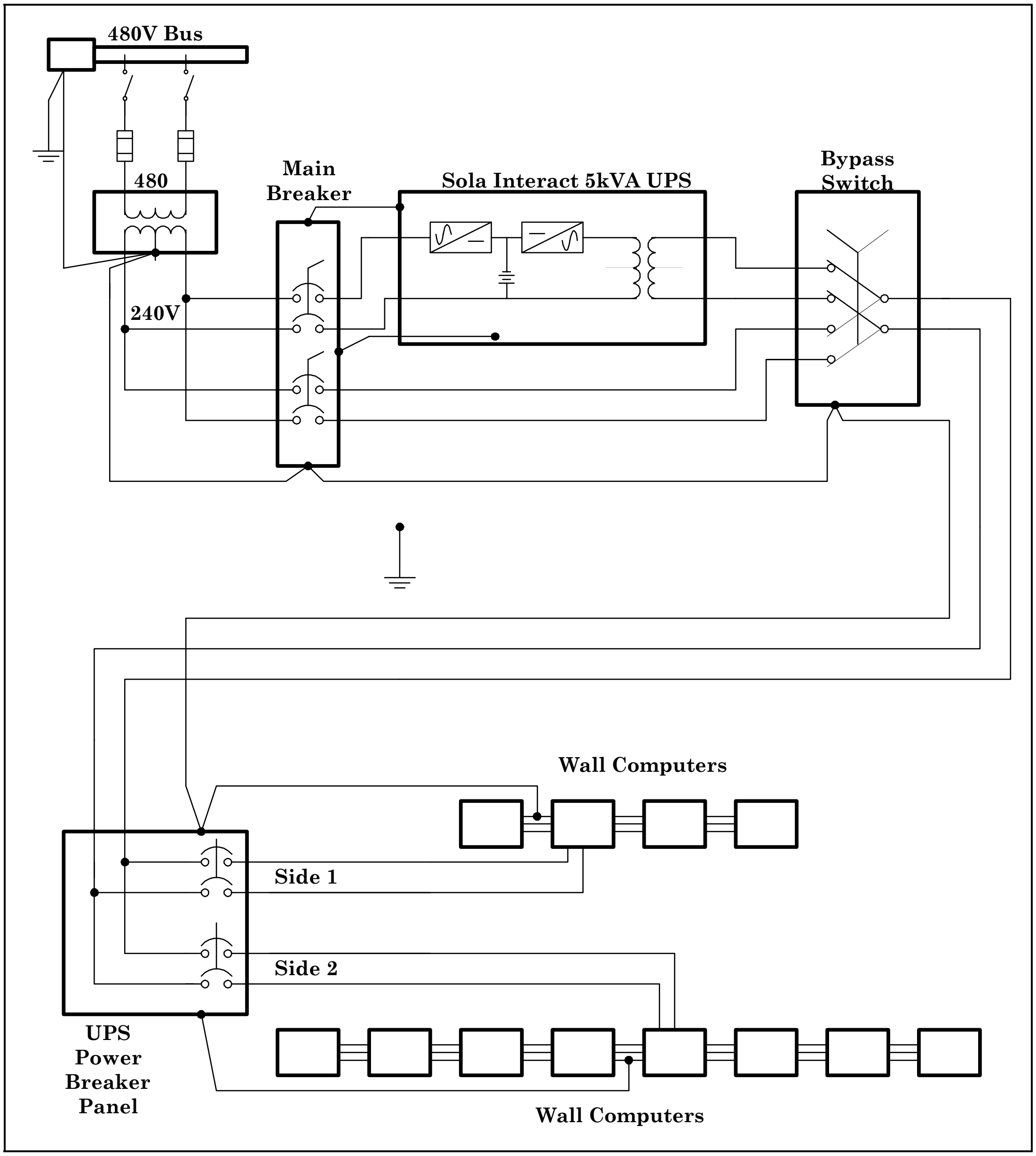

Figure 1 - Powering Arrangements for the Wall Computers

Figure 1 shows how the wall computers are powered. The system lacks a ground reference point -- a single point where all ground wires are connected from. The system would be improved by powering each wall computer from a dedicated circuit, each with an individual ground connection. The improved system would have ground connections run with separate wires that are all tied to a common reference point inside the breaker panel. The common reference point would be a ground bus designed for such a purpose (often a 1/4” copper plate is used).

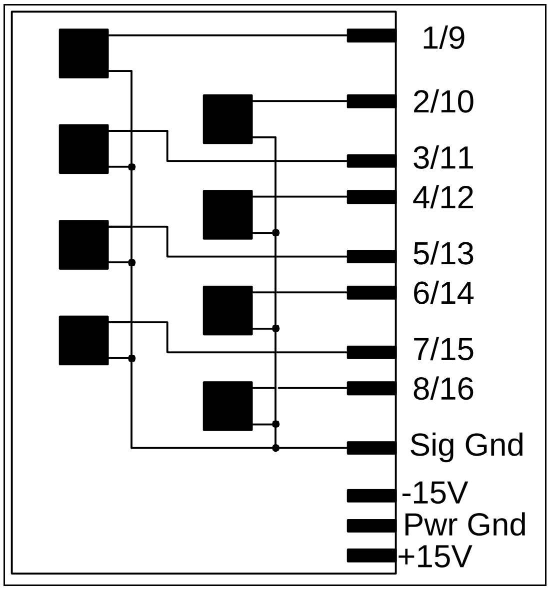

Figure 2 - Current Sensor Board with Shared Signal Return

Figure 2 depicts the current sensor board. The board is used for eight Hall Effect transducers to monitor the current of eight circuits. The board is designed with a signal common for all the signal transducers. Bench tests indicate that the transducers appear to be accurate within 0.5%. However, those tests show that the signal common causes the reference to be corrupted, such that the accuracy of this board is only within about 5%, and the errors are not consistent.

An improved design of this board would have separate commons for all of the eight signals. Twisted-pair, shielded cable would offer the best immunity for electromagnetic and electric field interference. The shield of the cable should be grounded at both ends, to ensure the integrity of an alternative path (rather than through the signal conductors) for electromagnetic interference. The shield of the cable should be tied to the grounding of enclosures, etc., and not to the logic common. Where possible, the logic common of the system should be isolated from the safety grounding system.

Table 1 - Measurements Taken with a Fluke 41 Hand-held Harmonics Meter

	11:00 AM	**1:00PM**	**5:20PM**	**6:30PM**
UPS Input Voltage	240V 2%THD	236V 1.8%THD	234V 2.2%THD	
UPS Input Voltage (L-Ns)	117.8/117.8	118/118	117.2/117.2	
UPS Output Voltage	235V 0.7%THD	235V 3.2%THD	235V 6.5%THD	
UPS Output Voltage (L-Ns)	111.5/121.6	115/119	116.3/118.3	
Common-Earth Voltage	0.1V	0.0V	0.1V	
Ground Wire to Transformer Ground Current	0.16A 40%THD	0.16A 29%THD	0.18A 27%THD	0.18A 26%THD
Ground Wire to UPS (1) Ground Current	0.16A 33%THD	0.19A 30%THD	0.20A	0.19A 25%THD
Ground Wire to UPS (2) Ground Current	0.19A 23%THD	0.2A 24%THD	0.26A 40%THD	0.27A 40%THD
Ground Wire to Wall Units Ground Current	0.07A	0.08A	0.14A	0.14A 35%THD
UPS Input Current	3.11A 6.5%THD	3.85A 6.9%THD	6.12A 12%THD	6.12A 12%THD
UPS Output Current	0.05A	2.0A 120%THD	5.64A 101%THD	5.62A 100%THD

The measurements in Table 1 were taken with the system in an isolated state. The high amount of harmonic distortion in the UPS output current is normal for computer switch mode power supplies. The amount of harmonic distortion in the ground currents is indicative of zero sequence (chiefly third harmonic) frequencies present -- and also is not unusual. In general, the currents flowing through the grounding system were seen to be negligible. These measurements were taken after the ground rod was disconnected from the system. If the ground rod were reconnected to the system, it is possible it would attract other fault current from the plant, generating more noise on the signal reference.

Should difficulties arise in the future, the currents in the ground wires should be checked. The values in Table 1 provide a reference. For example, if the temperature probes are reconnected, it is possible a fault in one of them could cause ground current to flow, and a noisy data reference. Such a problem might be discovered by a relatively high amount of current flowing through the ground wires.

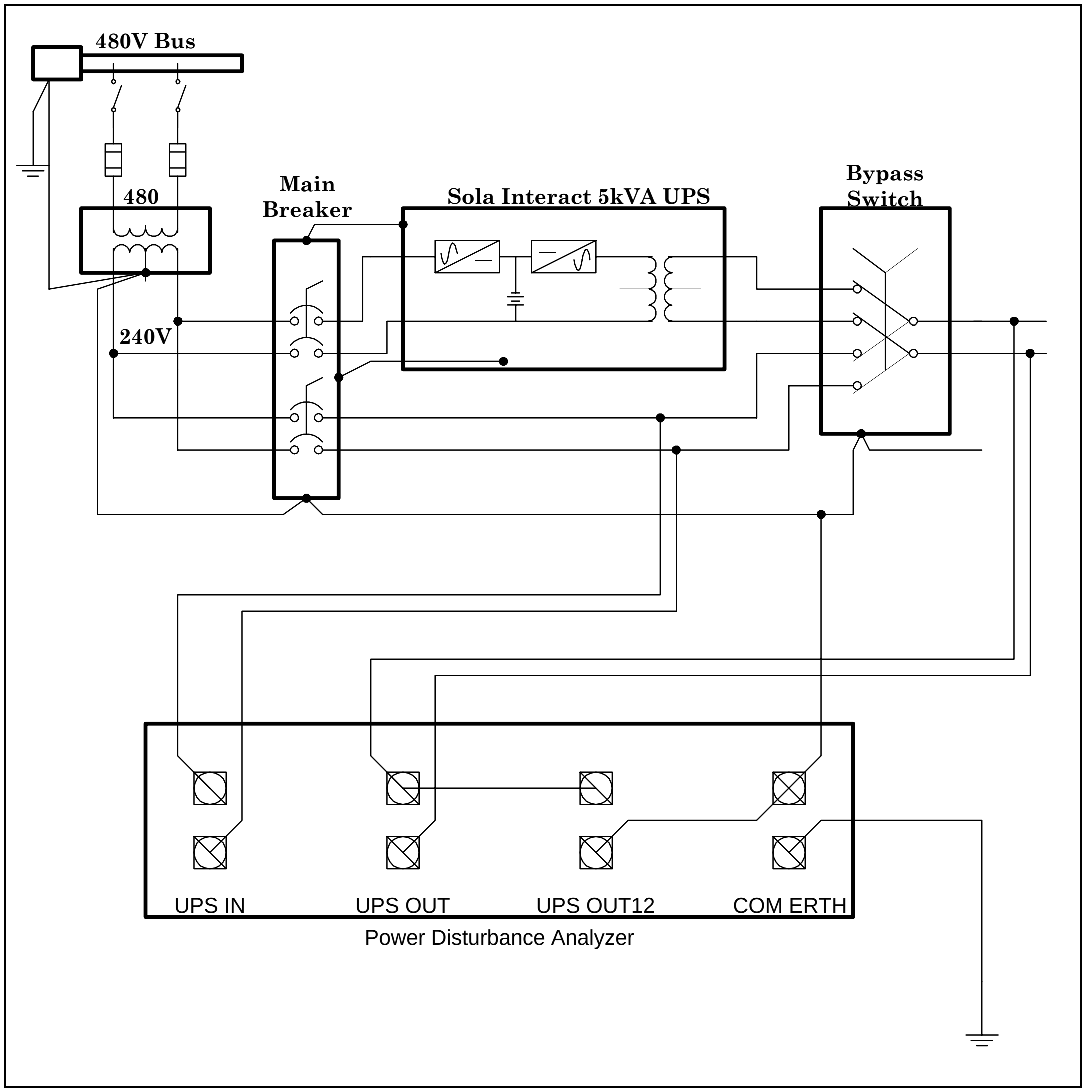

Figure 3 - Power Disturbance Analyzer Connections

A BMI power disturbance analyzer was connected to the system as shown in Figure 3. The purpose of this connection was to determine if there was noise on power (channels 1-2) and the data common signal (channels 3-4). Also the analyzer provides "time stamping" of any disturbances that might be correlated with any operation difficulties of the system.

Table 2 summarizes some of the early results from the disturbance analyzer. The levels recorded should be considered normal. It is important to note that the signal common-to-earth voltage remained at a very low level. Should a ground fault interfere with the signal common, this should show up on this measurement.

Table 2 - Power Disturbance Analyzer Measurement Results

	Feb 1 5:00-6:00 pm	Feb 1 6:00-7:00PM	Feb 2 9:00-12:00Noon
UPS IN 240 RMS Noise	 228.1-235.9V 0.0-0.9Vpk	 227.6-234.9V 0.1-0.9Vpk	 229-233.9V 0.1-0.2Vpk
UPS OUT 240 RMS Noise	 229.5-236.4V 0.1-1.8Vpk	 230.0-236.4V 0.1-0.9Vpk	 233.3-234.8V 0.1-0.1Vpk
UPS OUT 120 RMS Noise	 114.5-117.4V 0.1-1.0Vpk	 113.8-117.2V 0.1-0.9Vpk	 115.7-116.2V 2.7-3.1Vpk
Common-Earth RMS Noise	 0.0-0.2V 0.3-1.1Vpk	 0.1-0.2V 0.3-0.9Vpk	 0.0-0.1V 0.1-0.2Vpk

HARMONICS

During the shutdown of Thanksgiving 1993, harmonic filter capacitors were installed on the 480V mains. Currently the harmonic distortion typically found in the plant is about 2% THD, which is well within the IEEE Standard 519 recommended guideline of 5%.

Prior to the installation of the filters, the harmonic distortion on the system was reported to be as high as 19%, dominated by the 5^{th} harmonic frequency. These conditions were clearly caused by the Bitrode rectifiers in combination with the power factor correction. The power factor correction is required for voltage support. The Bitrode rectifiers are a six-pulse design, which would be expected to generate high amounts of 5^{th}, 7^{th}, 11^{th}, and 13^{th} harmonic frequencies. These past conditions would have exceeded the amount of harmonic voltage distortion (generally thought to be around 10% THD) that can cause electric motors to run at higher temperatures, and may have weakened the insulation of some of the motors at the facility.

UNGROUNDED DISTRIBUTION SYSTEM

The system at the Plant utilizes a 480V, three-wire ungrounded power system. Although the system is intentionally ungrounded, a reference to ground normally exists due to distributed capacitance between the phases and ground, and also due to the presence of the ground detection lights. Normally, this will allow each phase to be 277V above ground. When one phase of the three-wire system comes into contact with ground, while some capacitive charging current may flow, there is no substantial fault current. This condition causes one of the phases becomes grounded, while the other phases rise to 480V above ground. Additionally, this condition can also lead to an arcing ground fault, which has the potential to cause damaging overvoltage conditions.

Several of the drawbacks of ungrounded power systems are described in the book, Industrial Power Systems Handbook, edited by Donald Beeman, 1955 McGraw-Hill. In one particular instance cited in the book, a plant failed 40-50 motors during a two-hour period due to an arcing fault. In that instance a test instrument revealed voltages above 1200V phase-to-ground on a 480-volt system.

The ANSI/IEEE Std 141-1993 Recommended Practice for Electric Power Distribution for Industrial Plants makes the following statements (page 365):

“It is generally conceded that this practice (ungrounded systems) introduces potential hazards to insulation in apparatus supplied from the ungrounded system.”

“Because of the capacitance coupling to ground, the ungrounded system is subject to dangerous overvoltages (five times normal or more) as a result of an intermittent contact ground fault (arcing fault) or a high inductive reactance connected from phase to ground or phase to phase”

Accumulated operating experience indicates that, in general-purpose industrial power distribution systems, the overvoltage incidents associated with ungrounded operation diminish the useful life of insulation in such a way that electric circuit and machine failures occur more frequently than they do on grounded systems.”

It is possible to ground the 480-volt power system. Since the 480-volt system originates at a single bus in the substation, it would be possible to apply a single grounding transformer there. The required size of the grounding transformer would be approximately one-tenth the size of the overall transformer supply. However, ground fault protection would also be required at the switchgear, at a cost which has been estimated to be around $100,000.

The building schematics show the existing switchgear connected to a ground grid, while the new switchgear panel in the substation is connected to separate earth electrodes. Improved lightning performance would result from bonding both earth connections together. One method of doing this would be to ensure they are both connected to the ground grid.

The 300-volt dc circuits for the battery formation process are also ungrounded. However, none of the potential overvoltage situations possible with the ac system exist with the dc system. The ungrounded dc system has the support of years of operating without serious injury to personnel, and should be continued.

SUMMARY

The difficulties with the formation computer system are primarily due to the following factors:

- Lack of electrical isolation between the input sensors (temperature and current)
- Noise on the grounding system due to arcing faults.
- Inherent inaccuracies present in the original design.
- Grounding of the reference signals that does not originate at a “single point."

The following measures have already been undertaken to improve the performance of the formation computer controls:

- The signals from the current sensors are filtered.
- A ground fault removed from the power system
- The temperature probes are isolated from the system.
- The driven ground rod at the UPS has been eliminated

Specific recommendations to consider for improvement of the formation control system:

- Run a separate power circuit and ground wire to each process computer. Have each of the 12 ground wires connected to a common ground bus (1/4” copper plate or similar) and make sure this ground bus is tied to building steel, and to the ground lug at the 480V bus duct.
- Tie the shield (of the cable from the current sensor board) to ground at both ends. This will restore the electromagnetic shielding. Do not connect it directly to data common. Assure it has good contact with building steel, via conduit, etc.

Although the ungrounded power system causes some overvoltage conditions that occasionally cause motors to fail, it is probably not justifiable to expend $50-100k to change it. The harmonic distortion levels at the plant are currently acceptable.

REFERENCES

Industrial Power Systems Handbook, edited by Donald Beeman, 1955 McGraw-Hill.