Halmar Technical Bulletin No. 770B

ON-LINE RECTIFIER ANALYZER

END USER EXPERIENCES

BY
J.J. Demos, Member, IEEE
Halmar Electronics, Inc.
Columbus, Ohio

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Paper No. PCIC-88-52

J.J. Demos. Member. IEEE
Halmar Electronics. inc.
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Abstract

Current balance among paralleled semiconductors of large multiphase rectifier installations is necessary to ensure continued satisfactory operation. Until recently. there were no reliable methods available to accurately measure current carrying capacities of diodes in large multiphase rectifiers. In addition, some methods of determining whether or not a diode was even conducting exposed employees to dangerous conditions.

A measuring system called ON—LINE Rectifier Analyzer (OLRA) Model RDCMS makes these measurements safely and reliably. The system provides more accuracy and reliability and automatically produces better records than any previous method.

OLRAs have been used in selected electrochemical processing installations in various countries for the past two years. Before the introduction of the OLRA, numerous users experienced problems which were traced and attributed to current imbalances in power rectifiers. Historically, electrochemical companies had used conventional methods to measure and monitor conductivity of individual semiconductors within power rectifiers.

Reports detailing the testing, performance, accuracy, advantages, and disadvantages of the OLRA were made available to Halmar Electronics, developer of the new product, by companies that used it during the period 1985 to 1987.

This paper describes the OLRA, compares it with historical methods of rectifier semiconductor current measurement, and summarizes reported findings of companies now using the product.

Introduction

The benefits of proper current balance song paralleled semiconductors in large multiphase rectifiers may be grouped under the heading of cost savings.

Cost savings can be subdivided into the following categories:

- lower rectifier costs
- higher reliability and lower maintenance costs
- lower energy costs.

When a manufacturer designs a rectifier system, the quantities and ratings of components are dependent on the ampere requirements of the user. The manufacturer also considers possible current imbalance among paralleled multiphase rectifier units and among internal semiconductor paths.

Figure 1: Typical ON—LINE Rectifier Analyzer

N Minus One"

There can often be a 20 percent excess capacity allowance by the design engineer to allow for imbalance or N minus one" (N-1) capability. N-1 means a phase group can be operated without one diode because phase current will redistribute through remaining diodes if one fails. However, serious problems multiply quickly when the device ratings are exceeded. This extra current can strain the remaining components until one by one they too fail, and the result is a cascade failure.

Causes of Imbalance

Causes of current imbalance among semiconductors are:

1. non-uniformity of semiconductor forward drop characteristics:
2. non-uniformity of thyristor gate signals as well as variations in thyristor response to gate pulse signals:
3. imbalanced impedance among paralleled current paths:
4. the condition of bolted or clamped joints.

A current imbalance in one diode path, for whatever reason, changes the current distribution through the other semiconductors in parallel with it. Too much current can result in a cascade of burned out rectifier devices. If this occurs. it could mean a shutdown of the rectifier and long—

FUNCTIONAL BLOCK DIAGRAM

DATA ACQUISITION UNIT DATA READOUT UNIT

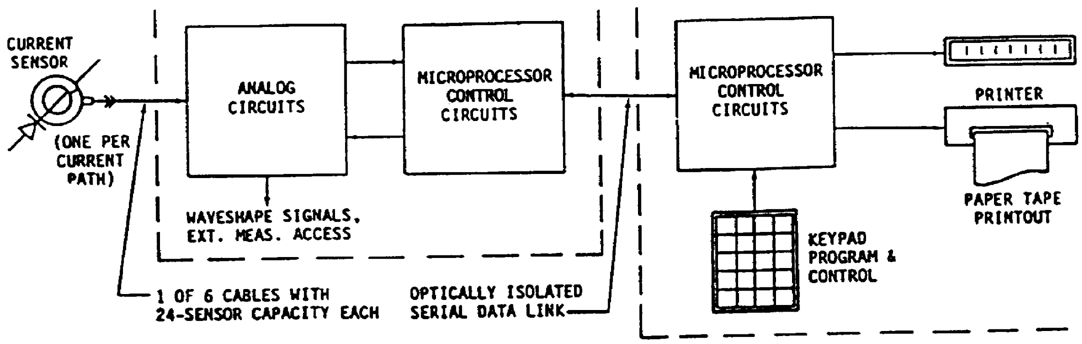

Figure 2: Functional diagram – OLRA

term. expensive repair. Recovering from an extended loss of power rectifier capacity is very costly for many processes

Perfect Current Balance

Theoretically, perfect current balance among paralleled semiconductors would reduce the necessity for excess capacity allowance because there would never be an imbalance among the components. An engineer could use tighter specifications and less expensive, lover-rated components to design a more competitively priced rectifier. In theory, perfect current balance could directly lower the initial cost of a rectifier system.

Proper current balance would increase rectifier reliability because equal load sharing would minimize component stress and deterioration. Maintenance and replacement costs would be reduced.

If total phase currents were balanced, circulating current would be eliminated and ac to dc conversion would be more efficient. Also, low resistance would result in less wattage loss.

In summary, proper current balance among paralleled semiconductors could save initial systems costs. increase production by maximizing current output, increase power rectifier on-stream availability, minimize component deterioration, reduce emergencies, and increase employee safety.

How to Measure Current Imbalance

There are four methods used to measure current imbalance in parallel semiconductor paths:

- infrared scanning.
- millivolt drop measurement.
- current clamp-on devices, and
- the OLRA.

In the first method, infrared scanners are aimed at diodes to determine whether or not they are actively conducting current. Using memory scopes, a heat image trace can be displayed. This relatively simple type of measurement will tell an operator if there is a low, medium, or high temperature in points of interest. Relating this image to current is, at best, relative from one point to another.

There are certain inherent inaccuracies in infrared image testing:

•Operator inaccuracy. No two operators aim the device or take the measurement in the same way:
different operators will frequently produce different readings.

•Instrument inaccuracy. The infrared imaging gun is a sensitive piece of equipment. It will detect heat from semiconductors that are actually warmed from radiated heat rising from the bottom of the rectifier cabinet to the top. Inaccurate conclusions result!

Extreme caution must be used when infrared scanning is used to determine current balance. Operators often must enter the rectifier cabinet to aim the device at the diodes. Even though special suits and shields are required in most plants. the danger from explosive arcs occurring either spontaneously or as a result of personal error is magnified by operator proximity to the diodes.

The second method of determining current balance consists of measuring the millivolt drop across the fuses, using the fuses as shunts. By connecting an indicating meter onto a diode fuse, an operator can determine if a diode is actually conducting current.

One problem experienced with this method is caused by electrical interference or noise. Inaccurately, the meter can indicate the presence of current in a diode, when in reality, the meter is activated by noise-induced energy generated by other devices such as fuses. other diodes, cables, and wires located in close proximity of the meter leads. It is also difficult to be sure of the exact fuse resistance value since partial clearing of the fuse may have been caused by transient conditions since installation.

Finally, clamp-on-current meters are frequently used to indicate semiconductor current-carrying capacities. This method actually measures bus current and places the operator in close proximity of exposed rectifier devices. It leads to a hazardous situation.

The OLRA is the only system available to measure individual semiconductor currents accurately. reliably and safely.

The portable analyzer includes the Data Acquisition Unit. the Data Readout Unit, six phase cables. and up to 192 noncontact, current-measuring sensors.

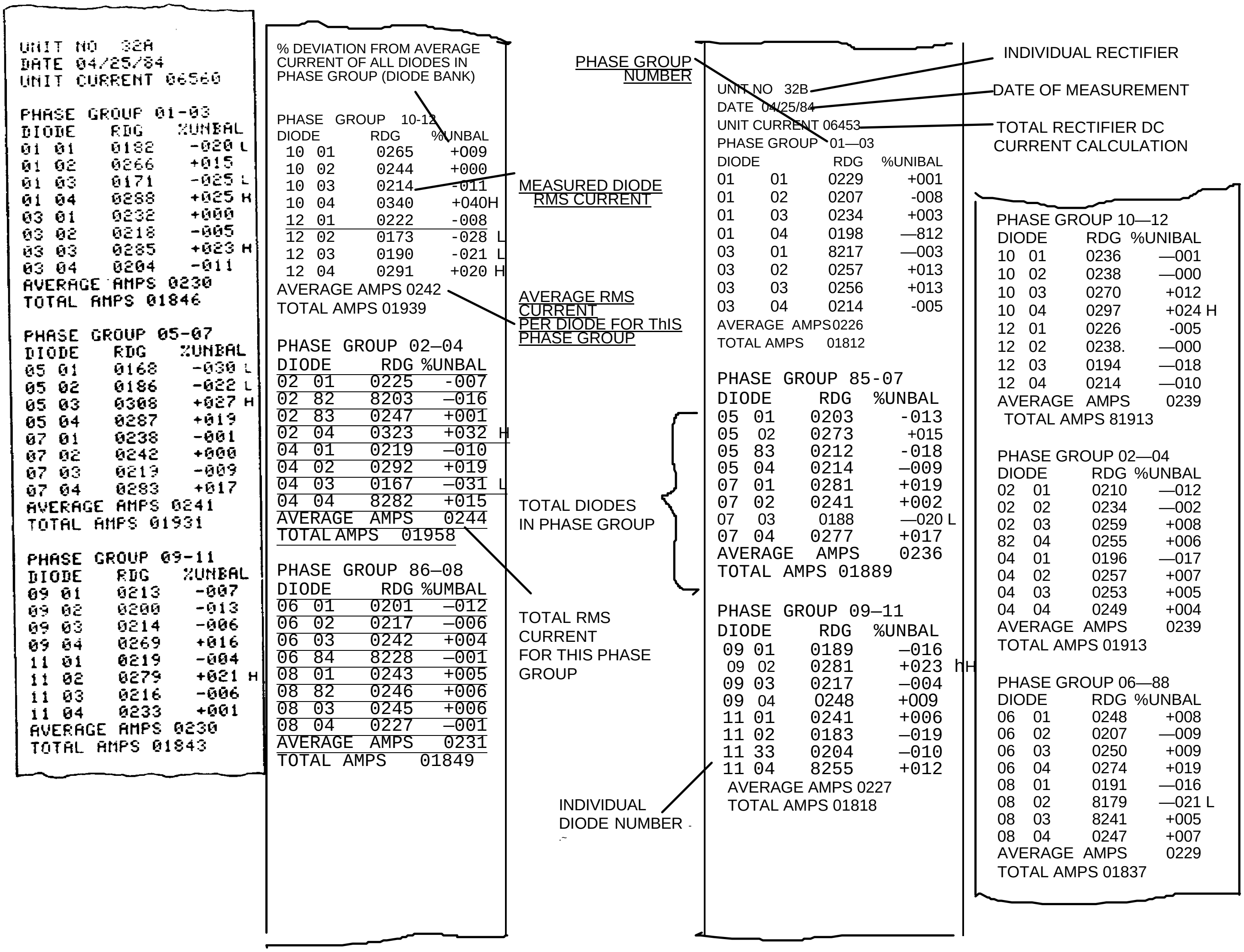

Figure 3: Tape readouts – typical sample

The OLRA is installed in this manner:

1. rectifier is taken off—line:
2. current measuring sensor is placed on each diode path:
3. sensor cables are connected to the six phase-cables:
4. six phase-cables are connected to the Data Acquisition Unit:
5. the Data Acquisition Unit is connected to the Data Readout Unit using an interconnecting cable:
6. both the Data Acquisition Unit and the Data Readout Unit are connected to the ac power supply.

The Data Acquisition Unit acquires analog current signals from all of the current sensors via the six phase cables. The Data Acquisition Unit converts the signals from analog to digital and transmits the data to the Data Readout Unit where readings for any selected diode are displayed.

Additionally, the Data Readout Unit is equipped with a thermal printer for hardcopy records that contain:

- rectifier number:
- date of measurement:
- total rectifier dc current calculation:
- phase number:
- device number:
- measured rms current for each device:
- percent deviation from phase average for each device:
- average rms current per device in each phase: and
- total rms current for each phase.

The Safety Factor

Before comparing the OLRA with other methods of semiconductor current balance measurement. . it is important to discuss employee safety.

Currently. the OLRA is the only method of measuring current balance that allows the measure sent process to be conducted from a location remote from the rectifier enclosure. It is no longer necessary for employees to be in close proximity of a rectifier while it is on line. The Data Acquisition Unit of an OLRA may be placed up to 90 feet away from a power rectifier enclosure. The danger to maintenance personnel from explosive arcs occurring either spontaneously or as a result of personal error is eliminated.

Continuous Monitoring

The case histories presented here will demonstrate the capabilities of a portable OLRA as a maintenance tool used periodically to troubleshoot semiconductor current paths in multi-phase power rectifier systems.

It is also possible to permanently install an OLRA on a rectifier and use a centralized process control system to continuously monitor semiconductor current paths.

Two potential benefits of a permanent installation are:

- increased production, and
- reduced maintenance.

In a permanent installation, the Data Acquisition Unit (DAU) would be connected to the centralized process control computer. Setpoints indicating high or low current would be programmed into the unit and annunciators added. Current sensors would be permanently installed inside the rectifier and connected to the computer. Continuous, automatic monitoring of all internal rectifier currents would now be possible.

Continuous monitoring of all current paths would allow operators to increase the amount of rectifier current. This is possible by taking advantage of the N-1 capability built into rectifiers. (N-1 simply means that each diode is actually conducting current at some percentage less than its rated capacity.) Control systems with automatic monitoring would allow operators to take advantage of the extra component capacity with reasonable safety.

Alarms would alert operators if conduction dropped below a preset level for any current path, and the control system would decrease total current to save stress on remaining components.

Taking advantage of the N-1 capacity of rectifiers to run them at higher currents translates into increased production. Permanent installation of an OLRA promises swift return on investment.

Case History #1

In 1985 the first Case History plant used Halmar's OLRA as one of several devices tested during a search to find a safe. more accurate method of taking diode current measurements.

Previously, engineers at the plant had used a clamp-on current-probe. It proved inadequate and contributed to some rectifier damage over the years because of inaccurate readings.

On September 9, 1985, a company research team set up and tested the Halmar OLRA system. Set-up and initial testing required approximately four hours to complete.

After preliminary testing was completed, actual current measurements were taken on 18 rectifiers consisting of six phase groups per rectifier. 20 diodes per phase group, for a total of 2,160 diodes. Each rectifier required approximately 3 hours to test. Phase I of the testing was completed in four days.

Initial reaction to Halmar's OLRA was positive. Engineers reported the system was the safest, most accurate, and most efficient of all they had tested.

The following excerpts are taken from their report to management:

"Conclusions: The use of this (device) in multiphase rectifiers could provide numerous benefits and improvements." These benefits include: "enhancement of personnel safety. The measurements are electrically isolated from the bus potential" and "the installation and removal of the sensors are done while the unit is completely de-energized." Also, "Data Acquisition and Data Readout are installed remote. In case of an explosion or flash-over on the diodes, the personnel can be safeguarded against injury."

"The current balance measurements are very accurate and indicate the actual current flow through the diodes. No multiplying and recalculation of the readings and unbalances are needed."

"The relative current balance measurements are done in less than 3 seconds in one cubicle over 120 diodes. Installation and removal of the sensors including the entire test on one cubicle is not taking more than 30 minutes. This means that with two men. one man-hour is required. The previous method required two man-hours per cubicle."

Case History #2

In 1986, the company described in Case History #2 rented Halmar Electronics OLRA to determine the cause of frequently blown fuses and damaged diodes in two rectifiers at their Chlor-Alkali plant. The problem was resulting in considerable loss of production time and money.

Testing revealed significant current density imbalance among a few diodes in the two rectifiers and all other diodes in the system. Probable causes for the. imbalance were analyzed. and two remedies were tried.

The first method, cleaning the fuse connections only, failed to restore the current balance. The second method, cleaning the diode faceplates and applying a small amount of silicon-based heat transfer compound before reconnecting the diodes proved to solve the problem.

In their report. plant engineers concluded that during a routine cleaning procedure five years before, a heat transfer compound was used on the diode faceplates. This compound had deteriorated and was now an electrical insulator.

The result of cleaning the diode faceplates and using a new heat transfer compound resulted in equalizing distribution between individual diodes within the groups and between diodes groups.

Case History #3

In the third case history, another Chlor- Alkali plant experienced problems with blown fuses and diode damage when engineers tried to run the rectifiers at more than 60 percent capacity.

Maintenance engineers used infrared scanners to measure diode current conduction levels for each rectifier, and the devices consistently indicated that all diodes in each phase were operating at capacity. The problem of the blown fuses continued to puzzle the engineers for over ten years after the rectifiers were installed.

In 1986, engineers from the ChIor-Alkali plant agreed to a proposal from Halmar Electronics to rent Halmar's OLRA and test their equipment. Halmar engineers went to the plant to demonstrate equipment set-up, how to conduct the tests, and interpret the readings.

During the tests. it was discovered that the OLRA showed that an entire phase group in a particular problem rectifier was not conducting any current. After checking the obvious problems (loose connections. malfunctioning equipment. etc.). the readings continued to indicate total lack of current through the phase group.

POWER RECTIFIER CURRENT BALANCE SENSING TECHNIQUES COMPAR1SON CHART

Method / Advantages	ON-LINE Rectifier Analyzer	Clamp-on Ammeter	Millivolt Probe	Infrared Scan	Diode Blown Fuse Indicator
Personal safety	Yes	No	No	Yes	Yes
Safe for equipment being tested	Yes	No	No	Yes	Yes
Measure path overcurrents	Yes	Yes	No	No	No
Measure path undercurrents	Yes	Yes	No	No	No
Find faulty devices: SCR/diode not gating properly Faulty fuses	 Yes Yes	 ? ?	 ? ?	 ? ?	 ? ?
Calculate phase current unbalance	Yes	No	No	No	No
Isolate faulty electronics (e.g. — control circuitry)	Yes	No	No	No	No
Automatic printed record	Yes	No	No	No	No
lime to repeat measurements	3mm	120mm	120mm	120mm	?
Measurement precision	High	Mid	Mid	Low	Very Low
Reading type	Absolute	Absolute	Relative	Relative	Absolute
Operator influence	Low	Mid	Low	High	Low
Susceptibility to electrical noise	Low	Low	High	Low	High

Table 1 — Power Rectifier Current Sensing Techniques