Basic Chapter 7
Rectifier Basics

Appalachian Underground Corrosion Short Course

Introduction

- A rectifier is a device that converts alternating current (AC) electricity from the power grid to direct current (DC) electricity for impressed current cathodic protection.

Topics to be Discussed

- Rectifier safety
- Rectifier components
- Types of rectifiers
- Periodic inspections of rectifiers
- Preventive maintenance of rectifiers
- Basic troubleshooting of rectifiers
- Interrupting rectifiers

Rectifier Safety

- Cathodic protection rectifiers can pose electrical shock and arc flash hazards.
- Only qualified personnel should access cathodic protection rectifiers.
- Most companies have developed safety procedures for personnel accessing cathodic protection rectifiers.
- Qualified personnel accessing cathodic protection rectifiers must follow appropriate safety procedures.
- Not all personnel may be qualified to perform all the tasks described in this text.

Rectifier Safety

- Many companies require that personnel accessing freestanding rectifier installations check the rectifier case to confirm it is not energized before accessing it.
- This can be done by using a non-contact voltage detector or by measuring the rectifier case-to-soil voltage with a voltmeter and a CSE.
- When measuring the rectifier case-to-soil voltage, the voltmeter connection to the case must be made with an insulated clip or probe. If the case-to-soil voltage is less than 15 VAC and 15 VDC it is safe to access.

Rectifier Safety

- At one point in time it was common practice to check to see if the case was energized by “backhanding” the rectifier. This practice is no longer considered acceptable.

What is a Rectifier?

- A rectifier is a device that converts alternating current (AC) electricity from the power grid to direct current (DC) electricity for impressed current cathodic protection.
- The positive terminal of the rectifier is connected to the anode bed.
- The negative terminal of the rectifier is connected to the protected structure.
- Connecting a rectifier with the opposite polarity will cause the structure to corrode rapidly and could have catastrophic consequences.

Rectifier Components

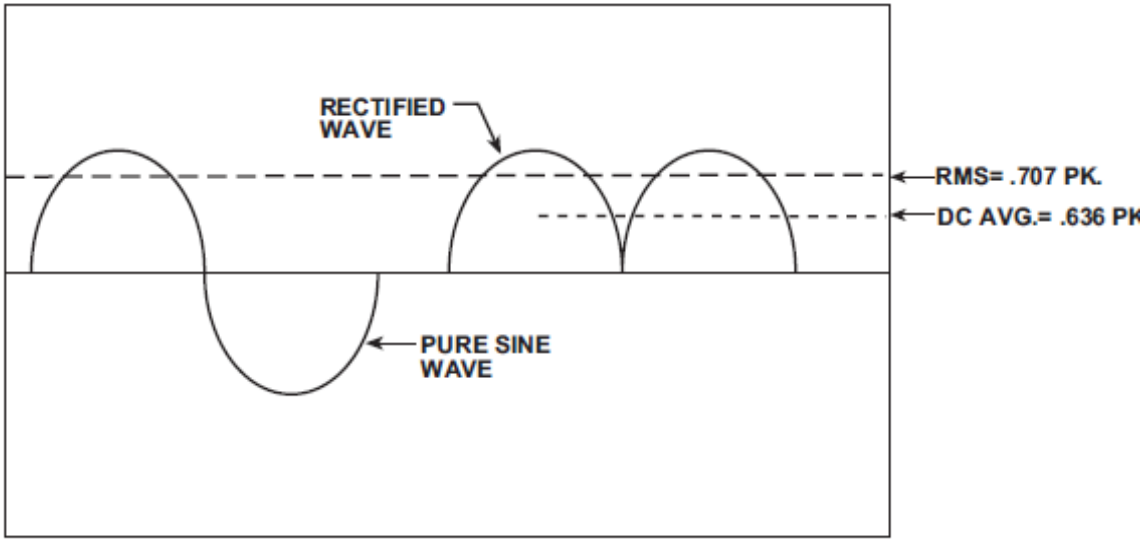
- A standard cathodic protection rectifier is a simple electrical device.
- The heart of the rectifier consists of the transformer and the rectifying element.
- These two components alone could provide the DC power required for a cathodic protection system.
- Other components, or accessories, are added to the unit to enhance its performance and provide safety functions.

Transformer

- A transformer is a device used to step up a voltage, step down a voltage, or to isolate a voltage from its source.
- In a rectifier, the transformer is used to step down the voltage from the power source to a suitable voltage for rectification.
- In most rectifiers, the voltage output of the rectifier is adjusted by changing the tap settings of the transformer.

Rectifying Element

- The rectifying element is an array of diodes that converts the AC in to DC out.
- A diode is a two-terminal electronic component that conducts current primarily in one direction.
- By arranging multiple diodes in the proper configuration, the AC into the array will be converted to DC.
- The most common rectifying circuit is the single-phase bridge.
- The DC produced will not be pure DC, like from a battery, but rippled. See Figure 7-1.



AC RECTIFICATION
FIGURE 7-1

Rectifying Element

- Most recently built rectifiers use silicon diodes.
- In the 1960's and 1970's selenium bridges were the preferred rectifying element in cathodic protection rectifiers. However, selenium ages and declines in efficiency over time, while silicon does not. Improvements in the ratings of silicon diodes have made them stronger and more durable.
- Some rectifying elements have multiple discreet diodes.
- For lower output rectifiers, one-piece silicon diode bridge rectifier modules can be used.

Circuit Breakers

- The primary function of a circuit breaker is to provide overload protection for the circuit in which it is installed.
- In a rectifier, the built-in breaker also serves as the on-off switch for the unit.
- In most rectifiers, turning off the built-in breaker will de-energize components on the rectifier panel such as the output terminals, the shunt, fuse holders and the transformer taps. It will not de-energize all components in the rectifier.
- To de-energize all components, an external disconnect must be used. It is good practice to have an external disconnect installed near the rectifier.

Shunts

- Almost all rectifiers have shunts to allow a simple way to measure the DC current output.

Accessory Equipment

- Voltmeters and ammeters are commonly installed on the rectifier to facilitate the monitoring of its voltage and current output. Sometimes, only one meter is supplied which, by use of a selector switch, will read both volts and amperes. Built-in voltmeters and ammeters should not be considered accurate or reliable. Portable multimeters should be used to obtain accurate voltage and current output values.
- Lightning arresters are normally installed on both the AC input and the DC output circuits of the rectifier. Lightning surges can enter the rectifier from both the AC and DC sides. Installation of lightning arresters will help prevent damage to the unit and its components due to these surges.

Accessory Equipment

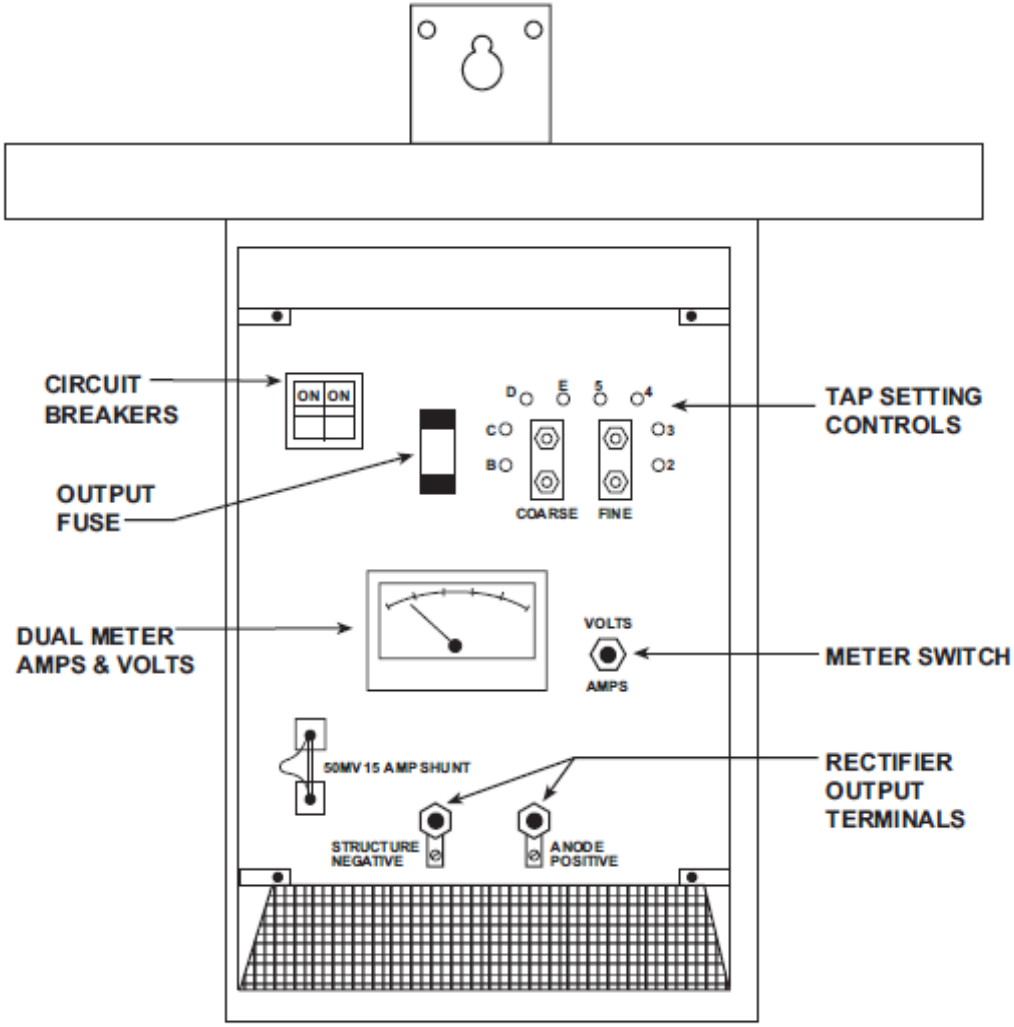
- In addition to the main breaker, fuses or breakers can be installed in the positive and negative DC output circuits and the AC secondary circuit.
- Efficiency filters can be added to some rectifying elements to improve the AC to DC conversion efficiency and save power costs.
- Communications filters can be used to eliminate electronic noise/interference on electronic circuits and at the same time provide increased lightning protection to the DC circuits of the unit.

Types of Rectifiers

- Air Cooled
- Oil Cooled
- Explosion Proof
- Constant Current
- Automatic Potential Controlled

Air Cooled Rectifiers

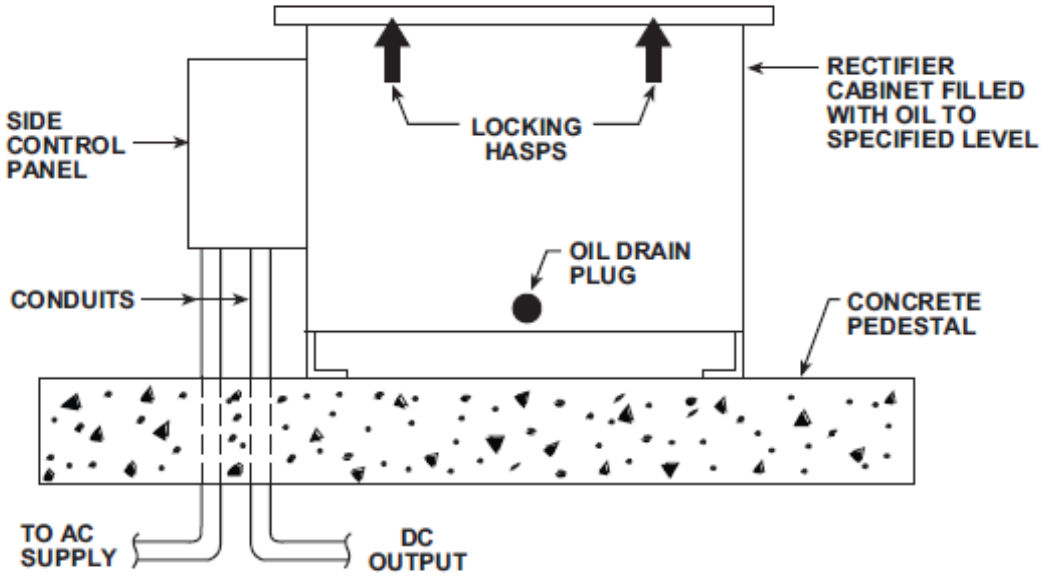
- This type of rectifier and its components are enclosed in a steel enclosure with doors that provide access to the unit for testing and repairs.
- The bottom of the enclosure is usually constructed of steel screening to allow for the circulation of air.
- This type of unit can either be wall, pole, or pedestal mounted depending on the size and weight of the unit.
- See Figure 7-2 for a typical air cooled rectifier.



TYPICAL AIR COOLED RECTIFIER
FIGURE 7-2

Oil Cooled Rectifiers

- This type of rectifier is used in areas where dust, salt air, corrosive fumes or excessive moisture may shorten the operating life of an air-cooled unit.
- The rectifier and its components are installed in a steel enclosure and are completely immersed in oil, isolating them from extreme environments.
- Oil cooled rectifiers are normally pedestal mounted due to their weight.
- See Figure 7-3 for a typical oil cooled rectifier.



TYPICAL OIL COOLED RECTIFIER
FIGURE 7-3

Explosion Proof Rectifiers

- Modified oil cooled rectifiers are available with explosion proof fittings.
- These explosion proof rectifiers are suitable for use in areas where explosive or flammable vapors, liquids or powders are present.

Constant Current Rectifiers

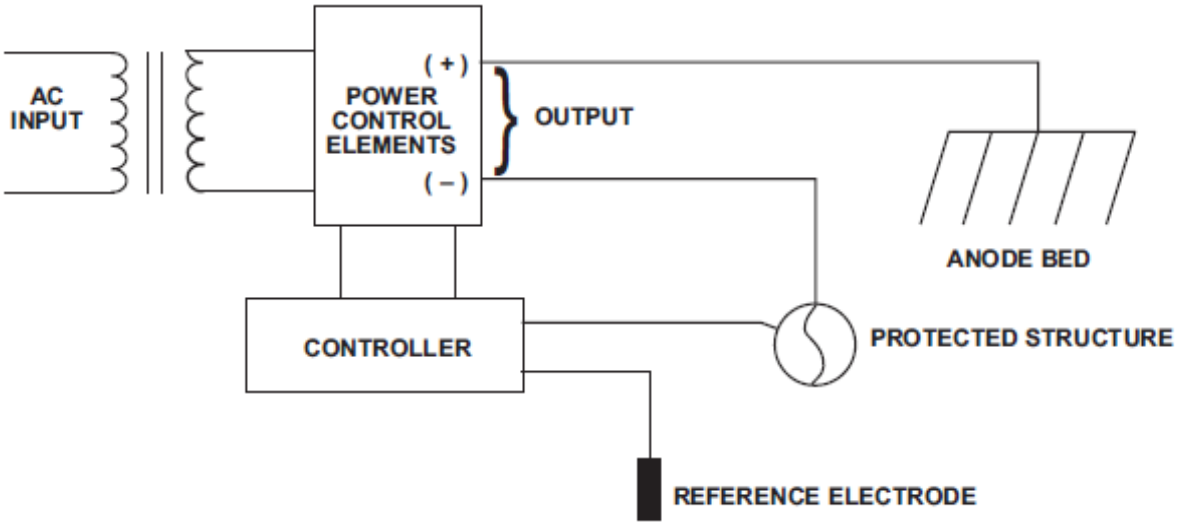
- Constant current rectifiers have a special circuit that enables them to provide a nearly constant current output regardless of circuit resistance.
- This type of rectifier is used in applications where the circuit resistance changes drastically and the output current would be exceeded with a normal rectifier.
- A rectifier having an anode bed installed in a tidal location is an example of a place a constant current rectifier might be used.

Automatic Potential Controlled Rectifiers

- Automatic potential controlled rectifiers monitor the structure-to-electrolyte potential and maintains it at a desired level.
- The use of this type of rectifier requires the use of a permanently installed reference electrode and an additional test wire connection to the structure. Both are connected to a transistorized control circuit as shown in Figure 7-4.
- The controller adjusts the output voltage to keep the reference cell potential at a preset level.

Automatic Potential Controlled Rectifiers

- Automatic potential controlled rectifiers are very useful in the control of corrosion on structures such as water storage tanks, harbor structures and structures affected by dynamic stray currents.



TYPICAL AUTOMATIC POTENTIAL CONTROLLED RECTIFIER CIRCUIT
FIGURE 7-4

Periodic Inspections of Rectifiers

- In order to insure proper operation, rectifiers must be inspected on a regular basis.
- Rectifiers that are subject to PHMSA regulations must be inspected at least six times each year with no more than 2½ months between inspections to insure the units are operating properly.
- Inspecting a rectifier at least every 2 months is a good practice even if it is not subject to any regulations.

Inspecting Rectifiers

- A routine inspection of a rectifier should include, at the least, measuring and recording the DC voltage and current output of the unit.
- These values can be determined by reading the built-in voltmeter and ammeter, but it is more reliable to use a portable voltmeter.

Remote Monitoring of Rectifiers

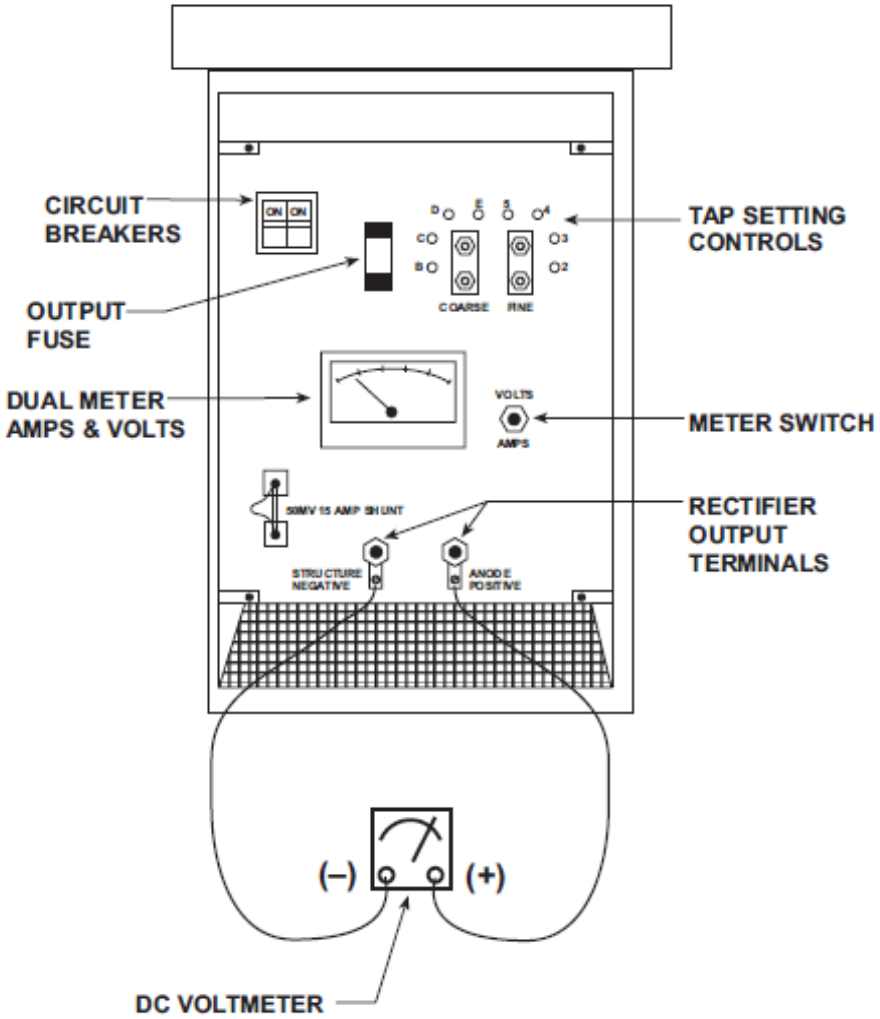
- Rectifiers can also be fitted with remote monitoring units (RMUs).
- RMUs are devices that will measure the operating parameters of a rectifier and allow that information to be accessed remotely.
- RMUs are available in radio, satellite and cellular communication configurations.
- Some systems allow the measurement data to be accessed through an internet web interface.
- Some systems will send notification of rectifier operating anomalies by email or text messaging.

Prior to Touching the Rectifier Case

- Follow your company's safety procedures before opening the rectifier. This may include checking to see if the case is energized as described previously.
- Before accessing a rectifier, perform a visual check of the rectifier. Look for unusual conditions such as loose wires, scorch marks or holes in the case. Look for insects, rodents and other wildlife. Note any unusual smells or sounds that may indicate an issue with the rectifier.
- When opening the rectifier, take appropriate care based on your observations. If your observations suggest it may not be safe to access the rectifier, contact your supervisor for guidance before proceeding.

Measuring Rectifier Voltage

- The DC voltage output is determined by measuring the DC voltage between the rectifier output terminals with a voltmeter. See Figure 7-5.
- Set the voltmeter to volts DC.
- Connect the positive lead of the voltmeter to the positive output terminal of the rectifier.
- Connect the negative lead of the voltmeter to the negative output terminal of the rectifier.
- Use insulated clips or probes to avoid skin contact with the terminals.



MEASURING RECTIFIER VOLTAGE
FIGURE 7-5

Measuring Rectifier Current

- The DC current output is best determined by measuring the DC voltage across the rectifier shunt. See figure 7-6.
- Set the voltmeter to millivolts DC.
- Connect one lead of the voltmeter to one side of the shunt. Connect the other lead of the voltmeter to other side of the shunt.
- Make the connections to the measurement screws or tabs, not the mounting bolts.
- Use insulated clips or probes to avoid skin contact with the shunt.

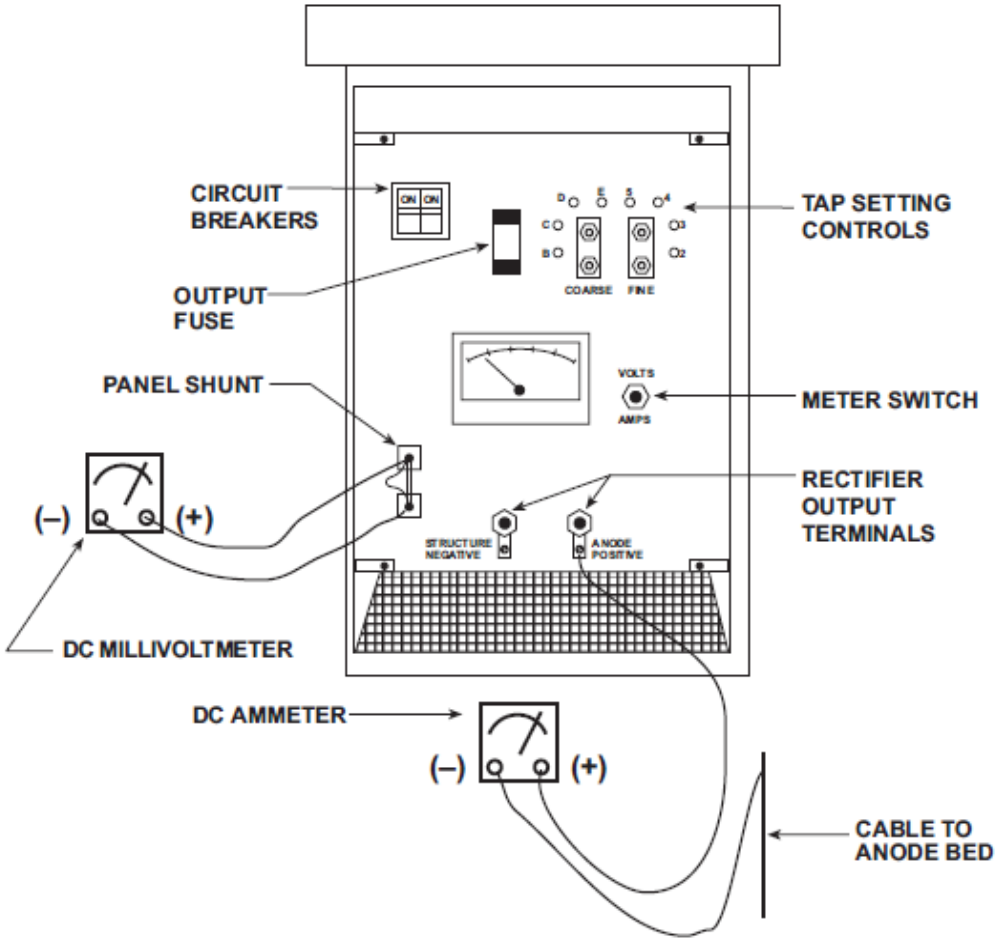
Measuring Rectifier Current

- Calculate the current output by multiplying the measured millivolts by the shunt factor as we learned in Chapter 6.
- The rectifier current output can also be measured by inserting an ammeter in either the DC positive or negative cable. However, this requires that the rectifier be shut off, one of the cables disconnected, and the ammeter inserted in the circuit.
- The rectifier current output can also be measured by using a clamp-on ammeter.
- Using the rectifier shunt is the simplest and most accurate way to measure the current output of a rectifier.

TWO METHODS:

1. **DC AMMETER IN SERIES WITH ONE OF THE DC LEGS. CURRENT READ DIRECT IN AMPERES.**

2. **DC MILLIVOLTMETER IN PARALLEL WITH PANEL SHUNT. RATING OF SHUNT WILL USUALLY BE STAMPED INTO THE SHUNT.**



MEASURING RECTIFIER CURRENT
FIGURE 7-6

Preventive Maintenance

When inspecting a rectifier, if qualified, you should also:

- Remove insect and rodent nests and plug any holes through which insects or rodents can enter the rectifier.
- Clean all ventilating screens in air-cooled units so that airflow will be completely unobstructed.
- Remove excessive dirt and dust accumulations.
- For oil cooled rectifiers, check the oil level and condition. The oil should be clear and nearly colorless. Failing oil is usually characterized by a murky or cloudy appearance with loss of transparency and should be replaced.

Preventive Maintenance

- Inspect all components, including lightning arresters, for signs of lightning damage – arc traces across insulators or panels; or discolored parts. If their appearance has been altered or if damage is suspected, the component should be replaced.
- Replace all wires on which the insulation has been damaged.

Basic Troubleshooting

- If a rectifier is found to be off, check to see if the cause is a blown fuse or a tripped circuit breaker. These are the two most common causes of rectifier malfunctions. If this is the case, resetting the breaker or replacing the fuse may be all that is required to restore the rectifier to operation.
- If you cannot restore the rectifier to operation by resetting breakers or replacing fuses, notify appropriate personnel so that additional troubleshooting can be performed.

Interrupting a Rectifier

- When measuring structure-to-electrolyte voltages on an impressed current cathodic protection system it is common practice to cycle the rectifier on and off. This is commonly referred to as interrupting the rectifier and is done by installing a current interrupter in the rectifier.
- A current interrupter is an automated switch that opens and closes a circuit in the rectifier so that the DC current output is alternately on and off.
- Different on and off cycles are used so they can be distinguished from each other.

Interrupting a Rectifier

- When testing a protected structure, the on cycle should be at least 3 times longer than the off cycle so as not to lose polarization.
- Some remote monitoring systems (RMUs) include a current interrupter circuit that can be activated remotely.
- If there are multiple rectifiers protecting a single structure, multiple synchronized interrupters are used so that they are all on and off simultaneously. The interrupters can be synchronized by GPS. All RMU interrupters and some portable interrupters can be synchronized by GPS.

Installing an Interrupter in a Rectifier

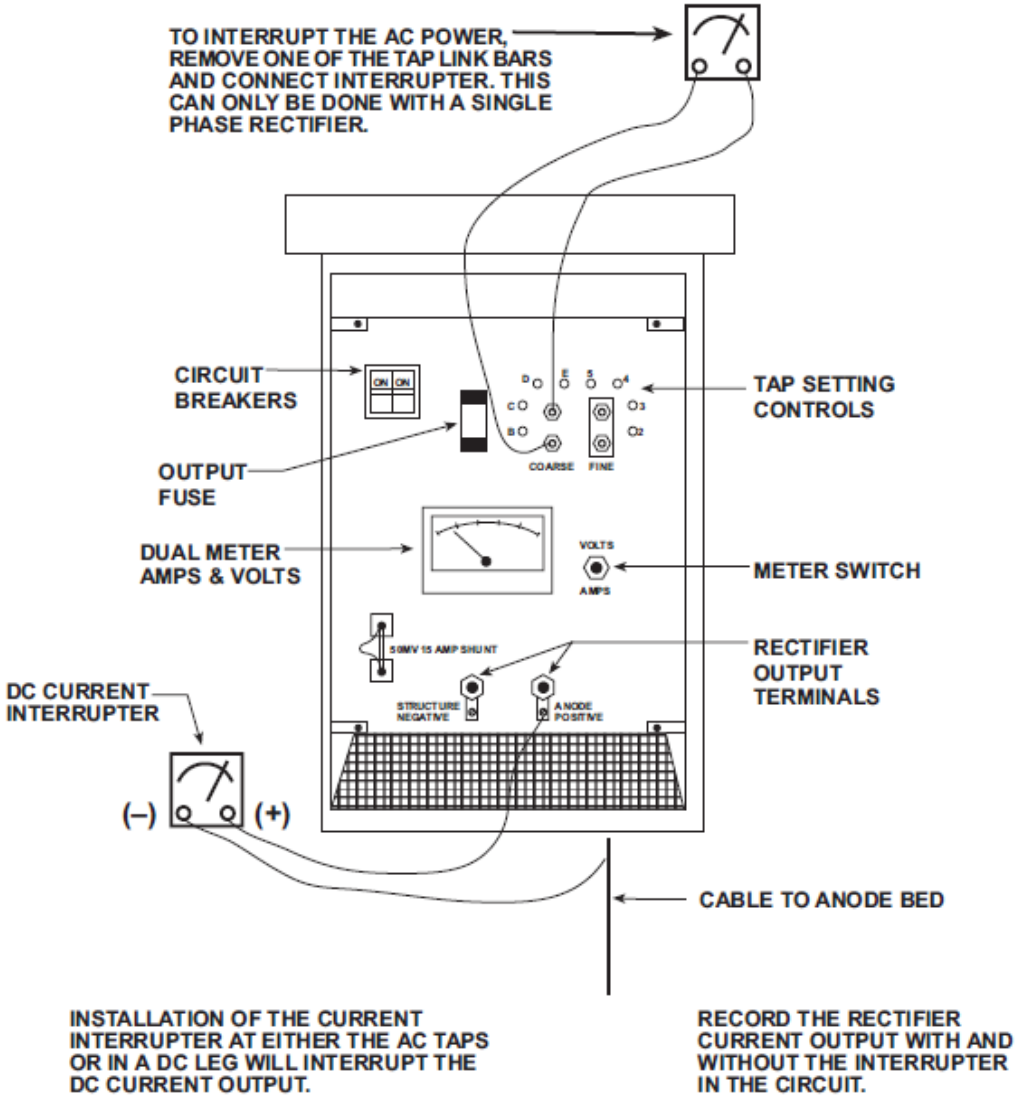
A current interrupter can be installed in:

- The positive DC output cable
- The negative DC output cable
- A transformer tap
- The AC input (see cautionary note to follow)

Installing an Interrupter in a DC Output Cable

To install a current interrupter in the positive or negative DC output cable:

- Shut the rectifier off.
- Remove the desired cable from the rectifier terminal.
- Connect one side of the interrupter to rectifier terminal.
- Connect the other side of the interrupter to the cable.
- Turn the rectifier back on.
- See Figure 7-7.



INTERRUPTING A RECTIFIER
FIGURE 7-7

Installing an Interrupter in a Transformer Tap

To install a current interrupter in transformer tap:

- Shut the rectifier off.
- Remove a tap connection by removing a tap bar or disconnecting a screwed tap connection. Either the coarse or fine tap can be used.
- Connect the 2 sides of the interrupter across the open tap connection.
- Turn the rectifier back on.

Installing an Interrupter in a Transformer Tap

- Note: if the structure has induced AC on it the DC output may not go to zero when interrupting a transformer tap.
- See Figure 7-7.

Installing an Interrupter in the AC Input

In order to install a current interrupter in the AC input:

- Installing an interrupter in the AC input should only be done by qualified personnel.
- Installing an interrupter in the AC input is typically only done with RMUs that have current interrupting capabilities, not with portable interrupters.