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Marine Leakage Current Detection
White Paper on a new approach

Company: Sieltec
Product: ElectroSentinel
Purpose: Marine DC Leakage Current Monitor

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Abstract

Leakage current corrosion on boats represents the most aggressive and hence the most damaging corrosion mechanism witnessed. It can be caused by many different types of electrical failure and because it has the power of the onboard battery banks as an energy source, the damage caused can be catastrophic and hence expensive.

This paper presents a new way to detect leakage currents and introduces a product developed to monitor leakage currents and alert the user to leakage currents that may cause fast and aggressive corrosion.

This paper does not address galvanic corrosion and does not attempt in any way to provide any remedy for galvanic corrosion.

Background

Leakage Current Corrosion can cause devastating damage to boat hardware below the waterline. It shows merciless indifference to the cost of the metal destroyed. It is a type of corrosion all knowledgeable boat owners fear and hope they never encounter. The results of leakage current corrosion need to be observed and acted upon quickly as often the damage is so great the impacted part needs to be replaced, irrespective of if it is a seacock or a stern drive leg. In extreme cases, metal boat hulls can be destroyed beyond economical repair as the hull integrity is so severely damaged.

Several types of corrosion exist, however two are prevalent, galvanic corrosion and leakage current corrosion, sometimes called electrolytic corrosion or sometimes even loosely referred to as electrolysis.

Galvanic corrosion is not the subject of this paper. The ElectroSentinel provides no monitoring or protection at all regarding galvanic corrosion. This white paper only addresses Leakage Current Corrosion and the detection of leakage currents that can cause corrosion to boats.

Leakage Current Corrosion typically occurs when some part of an electrical installation has a component failure or a wiring anomaly allowing current to flow in a path that was not the intention of the electrical designer. These unintentional “leakage currents” may be quite harmless to the integrity of the vessel or they may be catastrophic depending upon the exact scenario.

The purpose of the Sieltec ElectroSentinel is to detect those leakage currents and report the presence of the leakage currents to the owner. The owner can then

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investigate the nature of the leakage current and correct the problem ensuring that the electrical integrity of their boat is maintained. The device is to be permanently installed and continuously monitor the state of the leakage currents so if a component or DC wiring fails, the failure is immediately identified and the user alerted.

How are leakage currents detected?

Leakage currents are difficult to detect because the failure mode to develop leakage currents can be so varied. A connector in bilge water, a navigation light with a low resistance path to ground, a faulty water pump, a faulty bilge pump, a chaffed supply cable to a binnacle compass light. Any of these various scenarios can provide a potential problem that can be an aggressive catalyst for corrosion and may go unnoticed for some time. Vigilance in recognising and acting on any unusual physical characteristics of the boat hardware is vital in halting potential problems before too much damage is endured.

In the case of metal hulls, a common way to test for leakage current probability is to take periodic measurements that infer a problem may exist. A common design practice for metal hulls is to keep the hull floating with respect to positive and negative battery potentials. In this case one method is to periodically test the integrity of the floating hull to ensure no leakage to the hull exists. The electrical resistance can be tested and if anything but a very high resistance is measured, that “leakage” is investigated.

While this method to test for the possibility of leakage currents is perfectly valid, it does take a certain discipline by the owner. It is possible that after a few years of uneventful testing, the owner may lapse in complacency while leakage currents may occur.

In the case of a boat with effective bonding of underwater components, a leakage current path can blow the fuse feeding the circuit. This provides a positive means of identifying a problem as that circuit will no longer function. Some vessels do not have a bonding system however so a leakage path may have enough resistance to not blow the fuse but may still allow damaging corrosive currents.

Leakage currents may be difficult to detect and certainly difficult to monitor in real time.

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A new way

Let's consider one of a thousand possible Leakage Current Corrosion scenarios to simply illustrate the point on a relatively simple boat sitting in salt water.

On our example boat a bilge pump is connected to a small switch panel via a float switch. The float switch is installed using a connector that is unfortunately not quite waterproof. The connector over time slips down into the bilge water which is of course salty and conductive. The voltage on the float switch is now sitting in the salty bilge water. Also in the bilge water is a seacock connected to a thru hull. Figure 1 shows a diagram of this scenario.

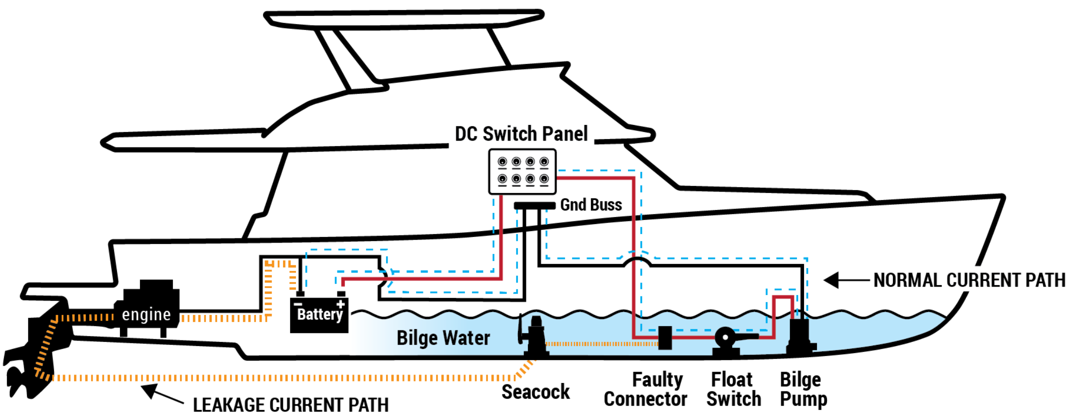

Figure 1. Basic example of possible Leakage Current path

The voltage from the "electrically leaky" connector induces a small but constant current through the seacock, through the seawater back to the sterndrive leg which is connected to the negative terminal of the battery via the engine block.

The amount of current flowing in this unintended circuit depends upon the resistivity of the bilge water and the seawater but full battery voltage is presented to the bilge so the resulting current can be considerable. In this case the current flowing in the wire to the bilge pump is slightly higher than the current flowing back in the return wire from the bilge pump to the negative bus. As a consequence of the leakage current, the two currents are no longer balanced. In fact, they are unbalanced by the exact amount of the leakage current.

What if we could measure the balance between the current flowing to the bilge pump and the current flowing from the bilge pump? If we see an unbalanced state, that denotes a leakage current must be flowing somewhere else in the system. If no leakage exists, the currents to and from the bilge pump are equal and opposite, cancelling one another out. If leakage current exists, the currents to and from the bilge pump are unbalanced and we can now measure that unbalance. We have only considered a bilge pump so far but this principle extends to all devices powered from that switch panel.

The Sieltec ElectroSentinel measures the current to and from the switch panel and constantly tests for an unbalanced supply current. If an unbalanced state is detected, the level of the unbalanced state is shown on the digital readout. If the level of the current difference is higher than a preset threshold, the LED changes from green to red and if the optional remote panel is installed, a buzzer sounds to alert the user.

With this system we can switch devices on and off on the boat's switch panel and be quite sure no leakage current exists because we are constantly monitoring the state of current balance into the switch panel.

The device provides instant feedback regarding leakage currents in all DC loads connected to the switch panel of the boat.

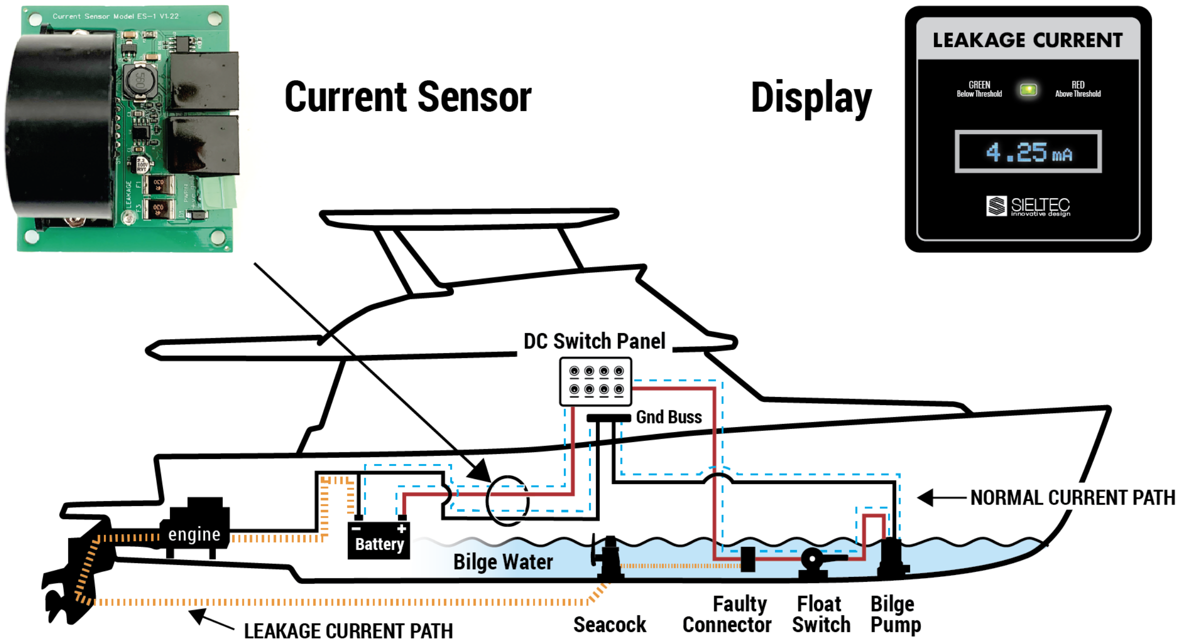

Figure 2. Location of Current Sensor Unit

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What precision can be expected?

A valid question would be relating to the amount of leakage current that is acceptable. An easy answer would be none. The specifications of the sensor do put a limit on the lowest measurable state of current imbalance that we can detect and report upon. The sensor has to be able to maintain stability through a range of temperature variations and a range of magnetic influence that can cause a zero offset, so a lower limit is set that dictates the lowest reliable valid reading.

We need a system that is reliable and able to detect very small levels of current imbalance in the cables to and from the switch panel. The Sieltec Electrosentinel can detect differential current levels as low as 1mA. That is one, one thousandth of an Ampere. If less than 1mA is detected, our readout reads 0.00mA. That is a function of the sensor so less than 1mA of leakage cannot be detected.

Also, the accuracy of the sensor is specified as +/- 0.4mA. In practice we observe no more than +/- 0.25mA variation but the specifications are slightly wider than our lab observations show.

We show the reading of leakage current to 2 decimal places. It may seem the precision of the readout is too ambitious for the accuracy of the sensor, however our lab tests show the accuracy is observed as an offset accuracy, not a random variable. In other words, that 0.25mA variation between sensors is an offset that tends to stay with the reading throughout its linear range. In that case we can use the full 2 decimal places of precision to validly show comparisons when various circuits are switched on and off.

We can set the threshold for the green to red light transition and audio alarm during the setup of the device to any level between 1mA and 10mA to a precision of 1 decimal place.

Any Caveats?

Simply put, Yes.

Wiring Discipline

The use of the ElectroSentinel requires a certain discipline in the wiring of devices to the switch panel. All supply cables must be matched to a return cable to the negative bus at the switch panel. That may be regarded as simply good design practice but it is very easy to install equipment and provide a supply cable from the switch panel and simply route the ground return to a local ground point. If that is done using the ElectroSentinel, when that circuit is activated, the system will alarm. Unfortunately as the sensor is measuring current imbalance any return path that does not pass through the sensor core will cause the system to alarm.

The cable gauge running through the core of the current sensor providing the supply and return current to the switch panel should be identical so the current through the core cancels perfectly.

Sensor Sensitivity.

The sensor used is extremely sensitive. It is optimised to provide a very linear response to currents from 1-15mA. Our tests have revealed a linear response from 1-35mA. Above that the unit is no longer linear and tends to compress the reading with respect to the actual current flow. That is simply a function of using such a sensitive sensor. The digital readout on the unit provides a real time readout of current imbalance up to 35mA and above that the readout is programmed to simply show “Leakage Current too High!”.

Although the sensor is extremely sensitive, it can measure a very low level of imbalance with quite a high current level through the sensor core providing they are balanced. Laboratory tests have revealed the ES-1 board maintains good differential current cancelling up to 400 Amps of current flow through the core. This level of current would normally never occur in practice so it is good to know the level of current flowing has no impact on the ability of the sensor to perform its task of measuring the differential current levels between two conductors.

Supply cable size

The cable for supply and return to the switch panel must pass through a core of 21mm diameter. Any cables smaller than that can pass through the core without too much regard for their location in the core. The sensor is remarkably tolerant of random positioning within the core.

Supply and return must pass through the core.

It may seem obvious but worth mentioning that the state of balance can only be detected if the current passes through the core of the sensor. If a DC load is not connected through the monitored switch panel, that circuit is not being monitored.

For instance if a bilge pump is being powered directly from a battery and not through the switch panel, it cannot be monitored by the switch panel monitoring sensor.

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Another sensor can be employed to monitor that circuit or several circuits to handle that situation but it must be recognised as a separate circuit and treated separately.

It is possible that several circuits may be monitored by passing the supply and return cables through the core. For instance, the cables to a yacht mast could all pass through the sensor core and that sensor would monitor the balance of all mast circuits. Several single sensor systems could handle that scenario but it would be more effective to employ the multisensor model if that was the requirement.

Two versions of the ElectroSentinel

Single Sensor version. (ElectroSentinel Mini)

The single sensor version is designed for a relatively simple vessel with a single central distribution point for electrical services. The Current Sensor Unit (Model ES-1 or CSU) is mounted in a dry, reasonably protected location to pass the supply cables through the sensor core. Power is supplied from the vessel house battery. The remote readout (ES-2) is connected by a standard Cat 5 cable to the Current Sensor Unit. The remote readout is powered from the CSU.

The single sensor version can also have the simple remote with the green and red LED and an audio alarm (ES-3). The audio alarm can be enabled or disabled with a dip switch on the back of the panel in accordance with the user's wishes. The ES-3 readout and audio alarm is also connected to the Current Sensor Unit with a standard Cat 5 cable.

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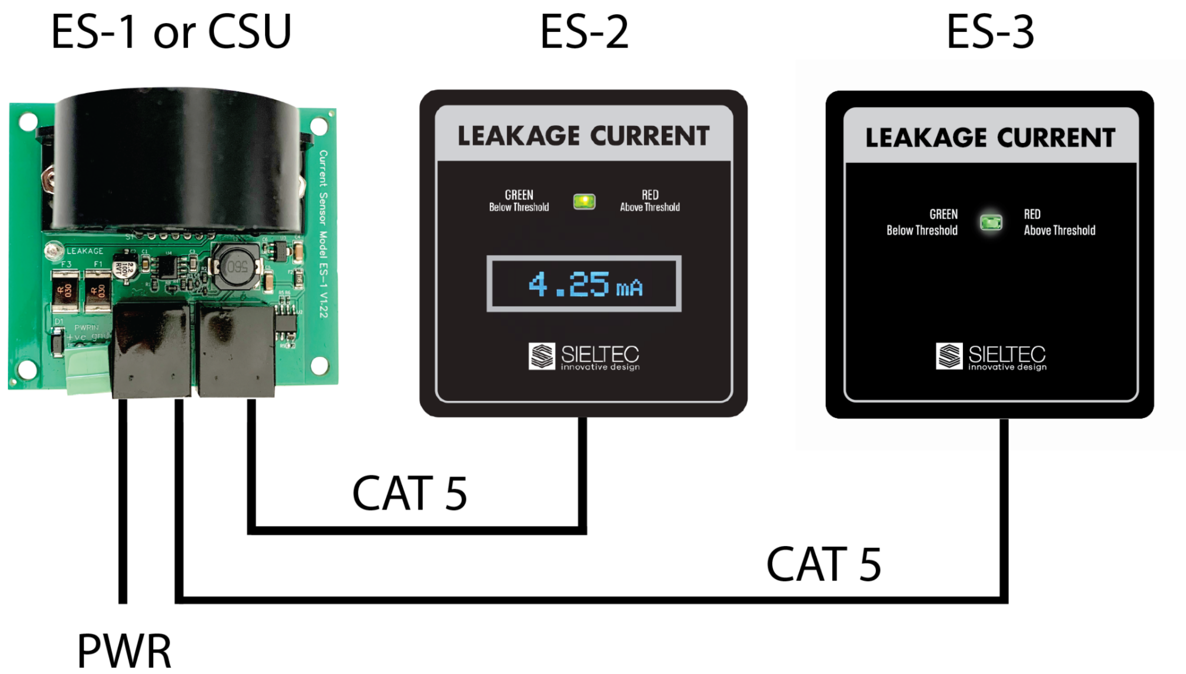

Figure 3. Basic configuration of single sensor system

Multiple sensor version (ElectroSentinel Maxi)

This configuration is suitable for larger vessels that have a more distributed power topology. The multiple sensor version allows for a maximum of 30 current sensors. The number of sensors in the system is programmed during the commissioning process. Each sensor daisy chains to the next sensor with standard Cat 5 cable so they are all on one RS485 data bus.   Power to each sensor comes from the Central Control Unit (CCU) and is carried through the daisy chain.   If however the power is more conveniently supplied from one of the Current Sensor Units that is also allowable. The supply can be any voltage from 8 - 60 volts.

The simple remote display (ES-3) with green and red LED and audio alarm can also be used for this configuration.   In fact, multiple ES-3 remote LED and audio alarms can be employed as required.   It is possible to have one of these units at each distribution switch panel to provide immediate feedback at each switch panel. This could be useful during fault finding as circuits could be energised with immediate feedback regarding leakage currents.

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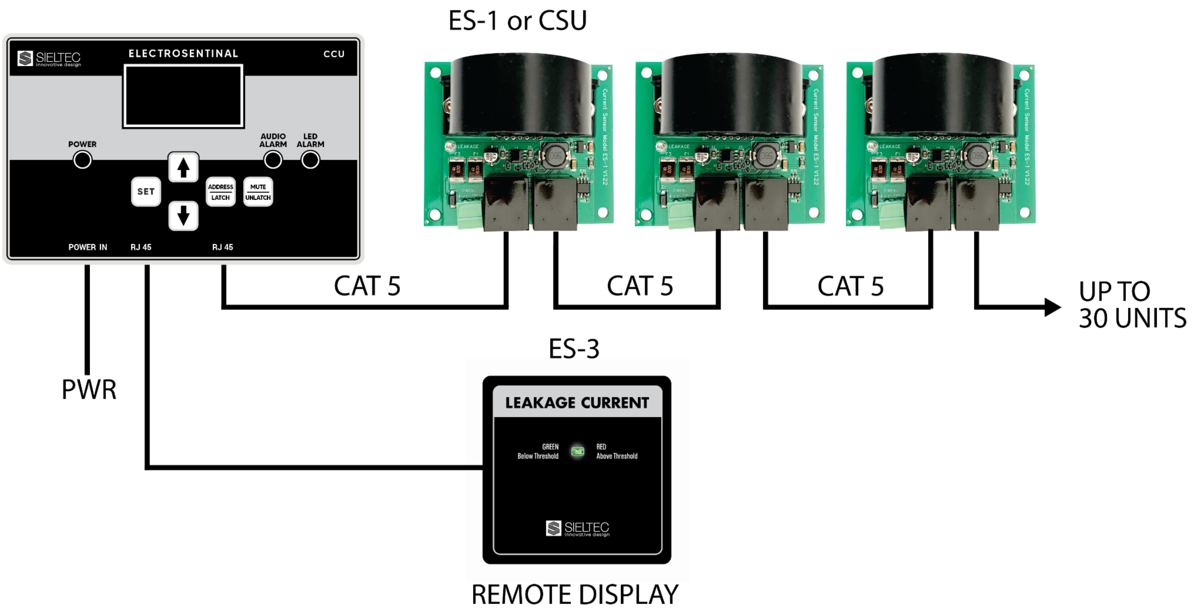

Figure 4. Basic configuration of multi current sensor system

Each Sensor is programmed during commissioning to have a unique address. That unique address allows the sensor to be interrogated by the CCU in turn with other sensors on the RS485 data bus.

The sequence of programming steps is

1. Number of Sensors
2. Threshold of sensor alarm
3. Address of each sensor
4. Audio alarm on or off
5. Latching alarm or only during that sensor readout

The addressing of each sensor is done one at a time. The single Current Sensor Unit is connected to the Central Control Unit. The address and threshold are programmed into that sensor. This takes less than a second. The address is confirmed as programmed by reading the response from the sensor and the new address is incremented ready for the next sensor to be programmed.

Each sensor is programmed in sequence and the system is cabled. Each sensor is then interrogated one at a time and the current recorded. If a current is reported that is over the preset threshold, that sensor is highlighted in the screen, the LED on the ES-3 display turns red and the audio alarm sounds.

When each sensor is interrogated, the response is checked and if an error is detected, that sensor is shown to have a communications fault. If a cable is disconnected or damaged, all sensors downstream of that sensor will show a communications fault. In this way the user can be assured that the readings they are seeing are genuine. If the network is broken at some physical connection, the fault can be simply found by noting the last sensor in the daisy chain to provide a valid readout.

The Multi Sensor system can provide an Open Collector output for signalling to a vessel management system to indicate an above threshold leakage has been detected. The characteristics of that signal regarding if it is latching or only active during the leakage current event is programmable during commissioning.

Conclusion

Boat owners must cope with many different destructive forces while trying to keep their vessel in great condition. No boat owner expects to suffer from Leakage Current Corrosion because it takes a failure within the electrical system to introduce this most aggressive form of corrosion. It is, however, devastating if it occurs. The Sieltec ElectroSentinel monitors for this particular type of scenario.

This monitoring of Leakage Currents provides assurance to the boat owner that for at least the circuits that are monitored, no leakage current exists. This provides some piece of mind by directly monitoring the leakage of those circuits. It is easily checked, provides an actual current measurement and allows the various circuits to be switched on and off and any differences observed. It takes the guesswork out of wondering if you have DC leakage current on your boat.

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