Surge Protection & Grounding Recommendations for Rain Bird Golf Control Systems

November 2024

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Introduction

Rain Bird recommends the installation of a grounding system, including surge devices, to protect irrigation equipment from lightning strikes and subsequent surge damage. To be effective, surge devices must be connected to a suitable ground electrode. They are designed to transfer surge energy to ground via this connection before it travels through protected equipment.

Factors influencing performance of a grounding system

Grounding system performance is measured as the resistance of a grounding electrode to the surrounding earth. For any given voltage, the higher the resistance of the path to ground, the lower the current flow will be on that path. This means the lower the resistance a ground electrode has to earth, the better it will dissipate electrical energy in a surge event.

Typically, a grounding rod or plate is used to make the electrical connection to the earth ground. The soil itself is the surge dissipation reservoir, meaning soil resistance is a critical factor in the design of an effective grounding system.

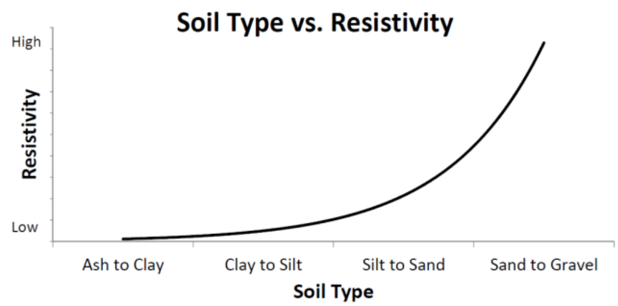
Soil resistance varies widely. There are 4 factors that affect the resistance of a given soil:

1. Soil Type
2. Soil Moisture Content
3. Soil Temperature
4. Mineral Content

Understanding the impact from each of these factors will help determine grounding equipment selection, location, and the strategies used for effective grounding. Certain factors may also serve to alert the designer to tougher grounding conditions such as dry, rocky or sandy soil conditions. As an example, in a sandy soil profile where the water table is encountered at 8’ (2.4 m), a 10’ (3 m) grounding rod may offer better performance than a grounding plate installed at a 30” (0.8 m) depth. In a similar sandy profile where the water table is too deep to engage, even with coupled rods, installing a copper plate under an irrigated area may offer better performance than can be achieved with a rod.

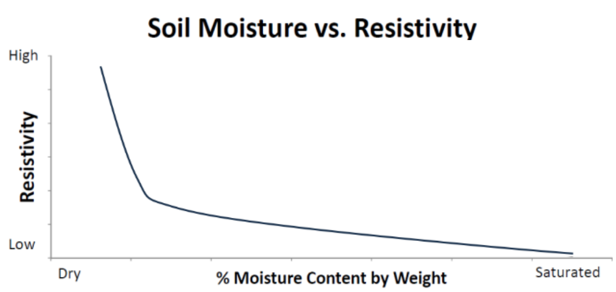
1. Soil Type

As soil particle size increases, soil resistance increases. Smaller soil particles have more contact area between particles per linear unit than larger particles and are better able to conduct charge. For example, less equipment and effort will be required to achieve a given ground resistance in clayey soils than in sandy soils. The resistivity of various soil types is provided in the chart below that demonstrates how resistance increases as soil particle size increases.



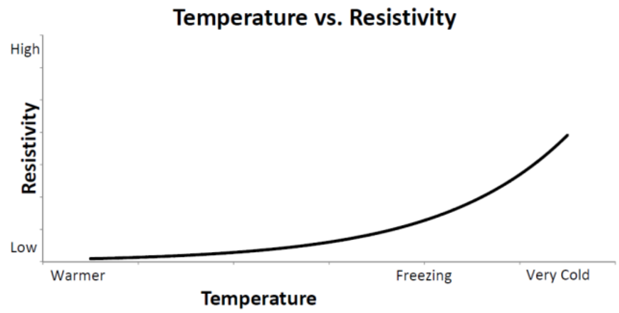
2. Moisture Content

As soil moisture decreases, soil resistance increases. Dry soil has higher resistance than wet soil and is less effective in grounding. The increase in resistance grows exponentially when soil moisture content by weight drops below 20%. For moisture content between 20% and saturation point, the decrease in soil resistance is more linear.



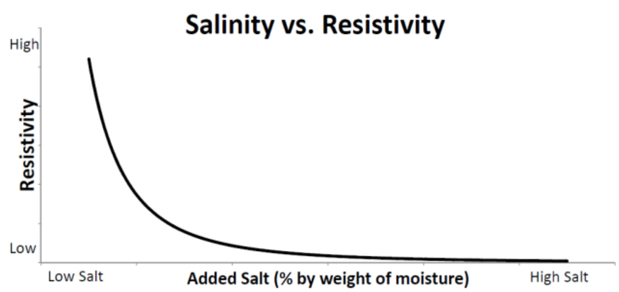
3. Temperature

As soil temperature decreases, soil resistance increases. This means that grounding will not perform as well in colder weather as it does in warmer weather. Soil temperature is typically not an important factor when designing a grounding system to protect irrigation equipment. Since lightning activity is prevalent during warmer periods, higher soil temperatures do not adversely affect the performance of a grounding system.



4. Mineral Content

As soil salinity decreases, soil resistance increases. Higher salinity improves grounding performance. The salinity of a soil plays an important role in determining its electrical conductivity. Where high resistance soils are encountered, chemical treatment of grounding installations is often employed to improve the electrical conductivity of the soil.



Grounding Types Definitions

For this manual, we will be discussing mainly three types of grounding points. Each type is identified by a color for ease of identification throughout the document. The three types discussed are:

- **Utility Ground:** Main grounding point of a building, normally located just outside the utility room where the electrical entrance is located.
- **Auxiliary Grounds:** Grounding points that are not required by the electrical code. They are permitted to be connected to the equipment grounding conductors. Since they serve no purpose

related to the electrical safety addressed by the electrical code, they have no requirements defined by the electrical code but may have requirements defined by the manufacturer.

Auxiliary grounds **are not to be confused with** supplemental electrodes, which are used to lower the ground resistance of the utility ground. Please refer to section 250.54 of the NEC for more information on auxiliary grounds.

- **Isolated Grounds:** Grounding points that are not bonded to an auxiliary or utility ground. For our purpose, these are always associated with low voltage wiring (less than 30 VAC).

Conducting a Pre-Installation Grounding Survey

Where moderate or high soil resistance conditions are suspected or known, it is highly recommended that a grounding survey be conducted well in advance of system installation. This practice will identify the most cost-efficient method of achieving target ground resistance. Doing this before installation begins will ensure the right equipment is selected for installation and help avoid costly changes or delays at the end of the project.

Grounding Survey Procedure:

1. Select a proposed grounding location that is representative of the soil type encountered on the site. If there is significant variability in soil types found at the site, at least one test should be conducted for each soil type encountered.
2. Install grounding equipment and test as follows:

    a. Begin by installing and then testing a 5/8”x10’ (1.6 cm x 3 m) copper clad ground rod. If the ground rod meets specification immediately, a single grounding rod at each proposed **isolated ground** location will usually suffice.

    b. If resistance of the rod is marginal, it may be appropriate to wait 2 weeks and test the location again, as resistance will typically decrease significantly in that timeframe and grounding will be improved.

    c. If resistance is higher than specification, adding a second grounding rod 20’ (6 m) away and bonding the rods together with a #6 AWG (16 mm^2) solid, bare copper wire will typically offer a 40% reduction in overall resistance. For example, if a single rod has a resistance of 100 ohms, and a second rod is added and bonded to the first rod, the combination should drop resistance to about 60 ohms.

d. If adding a second rod does not bring the ground resistance to what is specified, install and test a 4”x8’ (10 cm x 2.4 m) copper plate, bedded in ground enhancement material, a minimum of 20’ (6 m) from the grounding rod location. If the resistance of the plate alone meets specification, then plates may offer the best solution.

e. If the resistance of the plate does not meet specification but is lower than the resistance of the rod alone, bond the rod and plate together with a #6 AWG (16 mm^2) solid, bare copper wire and test this bonded assembly. At the same time, assuming soil conditions allow, couple a second rod on top of the first ground rod and drive to a depth of 20’ (6 m). Compare the reading to the single 10’ (3 m) rod. If the earth ground reading of the 20’ (6 m) rod is half that or lower than the 10’ (3 m) rod alone then a strategy of coupling rods is worthwhile.

3. Review the results of the grounding survey before system installation begins. Consider the cost of grounding equipment and installation labor and determine the most cost-efficient method that enables the ground resistance specification to be met or exceeded. If the desired results are not readily achieved using the aforementioned survey methods, consider the influences on soil resistivity and refine your strategy accordingly. It is entirely possible that different strategies will/should be employed in different areas of the site.

Testing Grounds

The suitability of a grounding point is determined by measuring the resistance of a grounding electrode or electrodes to the surrounding earth.

In testing, there are three types of grounding points encountered: the **utility ground**, **auxiliary grounds** and **isolated grounds**. The type of ground to be tested will determine the type of test equipment to be used. For the **utility ground** and at **auxiliary grounds**, such as at satellite locations, a ground clamp

meter may be used. Please note that these are specialized clamp meters and not the typical clamp meter used to measure current.

Example of a clamp-on ground resistance meter

For **isolated grounds**, such as at surge device locations in two wire control systems, a three-pole fall-of-potential method must be used. Note that a three-poll fall-of-potential method can be used to test any type of grounding locations.

Example of a three-poll fall-of-potential ground resistance test kit

Grounding resistance must be tested during installation of the irrigation system for all grounding points to confirm each of them will meet the desired specification and offer adequate system protection. Beyond that, grounding conditions will change over time and annual inspection of the grounding system is recommended. Ground resistance should be tested at least every other year to ensure grounds remain within specification. When doing this annual review, it is common to test 50% of the **isolated ground** sites across the property for one year and do the other 50% the following year. However, the **auxiliary grounding** location at the central control location should be tested every year. It is important to include these tasks in the irrigation system maintenance plan.

Newly installed grounding equipment will have a much higher resistance at installation than after a few weeks of aging. Voids around the grounding electrode take time to settle so that the soil can make good contact. As oxidation of the electrode begins, its electrical connection to the surrounding soil improves, decreasing resistance. For these reasons, it may be valuable to test grounds when they are installed and again 2 weeks after their installation to better understand the long-term performance that will be achieved.

WARNING: Under no circumstance should a **utility ground** be disconnected from an electrical service during testing or other service work. Doing so creates an extreme electrical hazard for personnel and equipment. Always follow local electrical codes. If in doubt, consult a licensed electrician before proceeding**.**

Grounding & Surge Protection Requirements for Rain Bird System Components

Central Computer & Field Interfaces (≤10 ohms)

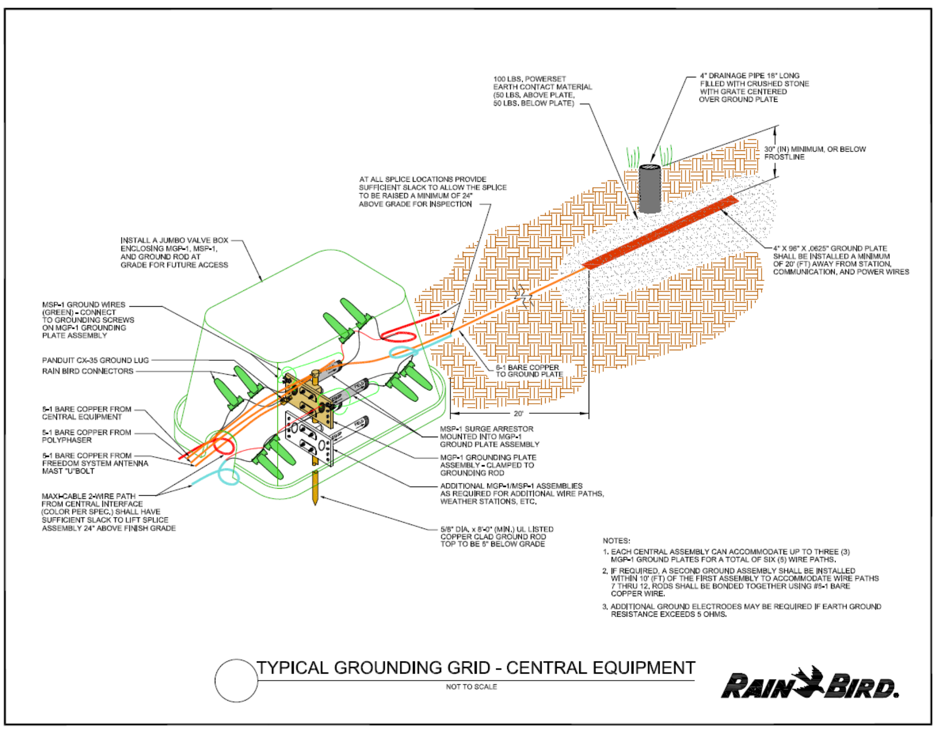
The central computer is the heart of the Rain Bird control system. All irrigation activity begins at the central computer. Field interfaces such as the Integrated Control Interface Plus (ICI+) and Large Decoder Interface (LDI) provide a live connection between the central computer and all field control devices. Even though some interfaces, such as the ICI+LINK, are not providing a live connection to the field controllers, it is critical to ground the surge protection (Polyphaser) on the antenna cable using either an **isolated ground** or to the **auxiliary ground** grid installed for the central. Because this equipment is critical to the irrigation system function, greater focus is placed on protecting this equipment from surge events.

The following are the minimum grounding and surge protection recommendations for the central computer and field interfaces:

1. A dedicated circuit is recommended from the breaker panel to the outlet(s) supplying power to the central computer and field interface (s). Because motor operated equipment such as air compressors, garage door openers, or air conditioners are known to cause interference, they should not be powered from the same circuit. Ideally, no other equipment should be connected to this circuit.

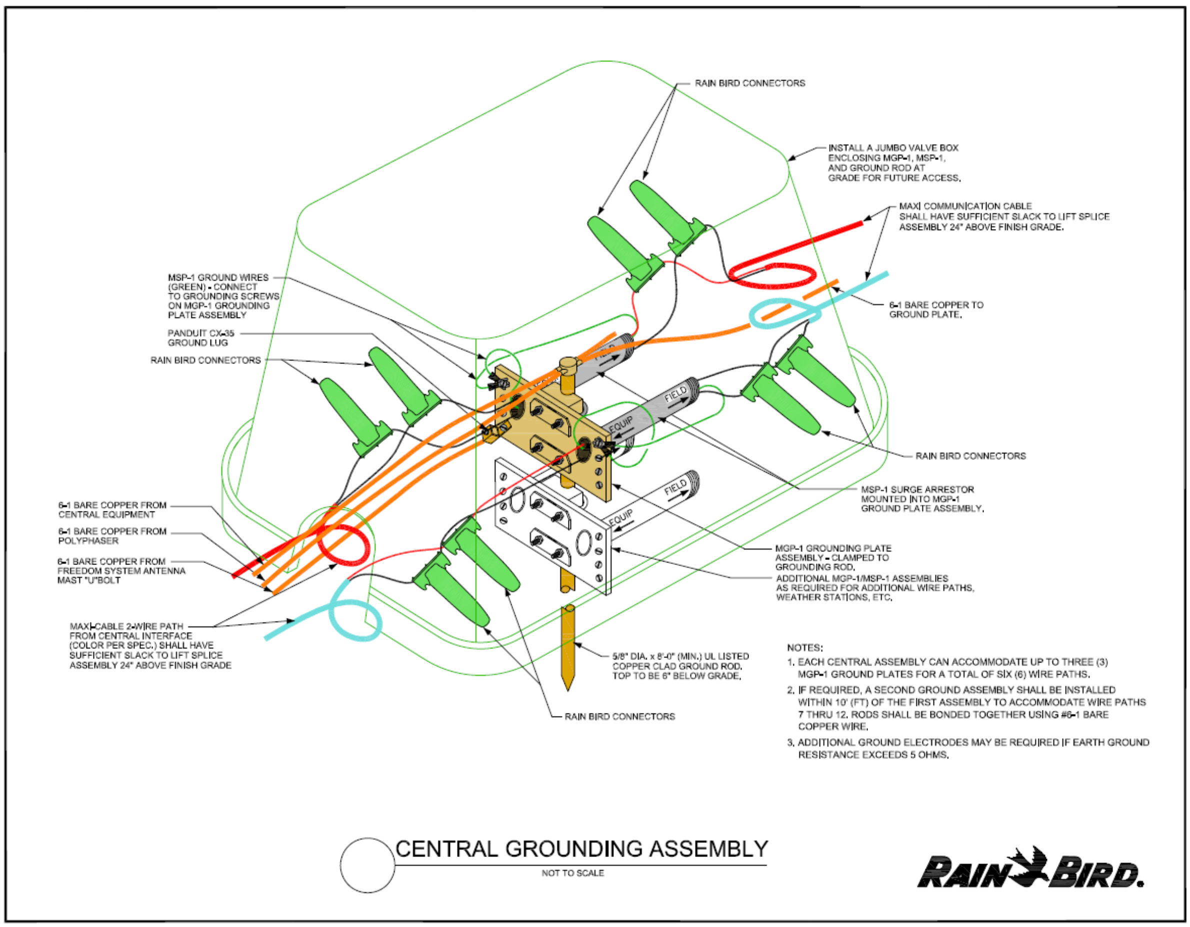
2. A nVent ERICO SES40P Service Entrance Suppressor or equivalent surge arrestor shall be installed in the breaker panel for the dedicated circuit supplying power to the central computer and field interface(s).

3. An **auxiliary ground** grid shall be installed outside the building where the central control is located. This **auxiliary ground** grid must be tested to 10 ohms resistance or less (<5 ohms is highly preferred). At a minimum, this grounding assembly shall consist of a 5/8”x8’ (1.6 cm x 2.4 m) copper clad ground rod, bonded via a #6 AWG (16 mm²) solid copper conductor to a 4”x96”x.0625” (10 cm x 2.4m x 1.6 mm) copper plate bedded in ground enhancement material that is installed 20’ (6 m) from the rod location. The grounding lug of each field interface shall be bonded to this **auxiliary ground** using a #8 AWG (10 mm²) or larger solid copper conductor.



4. An MSP-1 surge protection device shall be installed at the **auxiliary ground** rod servicing the MAXI wire paths and central control. The MAXI wire will be wired through this device. One MSP1 is required for each Wire path. Each MSP-1 shall be connected to the grounding rod using an MGP-1. Up to two MSP-1s may be installed on an MGP-1. No more than three MGP-1s may be installed on a single grounding rod. If more than 1 grounding rod is required, a #6 AWG (16 mm^2) bare copper wire shall be used to bond the rods together and the second rod shall be located at least 20 feet (6 m) from the first.

NOTE: MSP-1 devices must be installed in the correct orientation for equipment to be protected.



5. A #8 AWG (10 mm²) bond wire shall be installed between the computer chassis and ground lug of the nearest interface. The maximum distance for such a bond wire is 16’ (5 m), which is the maximum distance an ICI+ can be located from the central when directly connected via a 16’ (5 m) USB cable.

6. An Uninterruptable Power Supply (UPS) battery backup shall be provided for the central computer and field interface(s).

   a. The selected UPS shall have 1500 VA or greater capacity.

   b. A UPS unit is required for the ICI+ in an IC System™. A pure sine wave output is necessary for the proper function of the ICI+. Rain Bird has extensively tested the APC Smart UPS series with the ICI+ with very good results.

   c. If more than one field interface is connected to the same UPS, increasing the capacity of the UPS by 750 VA per additional field interface is recommended.

   d. Only the computer (CPU tower) and interface(s) should be connected to the battery protected side of the UPS. All other components (monitor, printer, FREEDOM, etc.) should be connected to the “non-battery” side of the UPS.

   e. NOTE:

      i. For IC System and Decoder installations: Rotor and valve operation will continue via power from the UPS during a short duration power outage. If the power outage also affects the pump station, the irrigation system may become depressurized, and air could enter the system. To prevent this in an IC System™, an IC-IN may be added to the pump station to monitor power, or with a pressure switch to monitor pressure, and pause irrigation during a power outage. In a Decoder system, an SD-212 may be used similarly.

      ii. For Satellite installations: rotor and valve operation should stop as the satellites should also be out of power.

Remote Field Interfaces (≤10 ohms)

Where a field interface is installed in a remote location that is separate from the central computer, the requirements for grounding and surge protection remain the same, except for the following:

1. A UPS of at least 1500 VA, with a pure sine wave output is required. The radio or data modem must also be connected to the battery-protected side of the UPS.

2. Where a field interface is located in an enclosure that is not associated with a building, an Intermatic AG-2401 or equivalent line surge protection device may be used instead of a nVent

ERICO SES40P Service Entrance Suppressor and shall be installed in the junction box of the primary power circuit for the field interface. An **auxiliary ground** grid shall be installed near the remotely located interface. The specification for this **auxiliary ground** grid is the same as described at item 3 of the "Central Computer and Field Interface" section above.

3. Where a remotely located field interface is located in an existing building, there should still be an **auxiliary ground** grid installed outside the building. The specifications shall be the same as section 3 of the "Central Computer & Field Interface" section above. This **auxiliary grounding** gird can be bonded to the **utility ground** of that building using a #6 bare copper wire.

The FREEDOM System™ (≤10 ohms)

A Polyphaser shall be installed inline with the antenna cable, ideally within 5'-10' (1.5 m-3 m) of the FREEDOM repeater. The Polyphaser must be connected to the same **auxiliary ground** as the central computer and interfaces via a #8 AWG (10 mm^2) solid copper conductor.

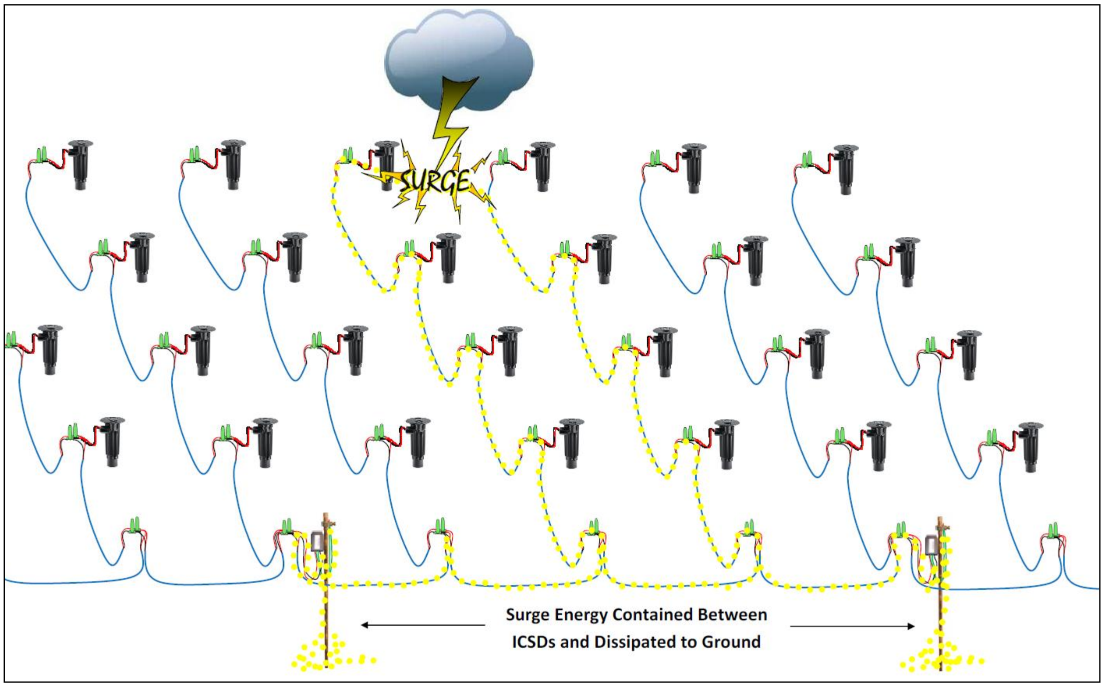
Weather Station (N/A)

The Rain Bird WatchDog 3552 weather stations do not require any grounding.

The Integrated Control System™

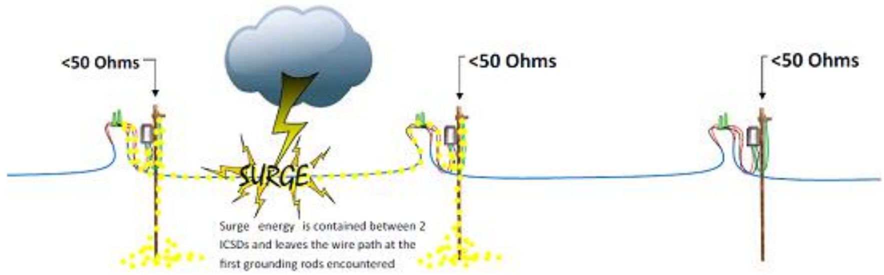
Integrated Control Surge Device (ICSD) on Wire Path (≤50 ohms)

Isolated grounding points and surge protection devices must be installed at certain intervals along the wire path to allow transient surge to exit to ground. For the IC System, the Integrated Control Surge Device™ (ICSD) is installed between the wire path and the **isolated grounding** equipment for this purpose. The ICSD is normally open, but will close in the presence of transient surge energy, shunting the surge to ground. ICSDs are located to offer "containment" of surge during an event so that damage caused by the event will be limited by ICSDs on either side of the event. The key for successful containment is proper installation of ground rods or plates so that the desired resistance level is achieved. The following requirements must be adhered to for proper grounding of the IC System:

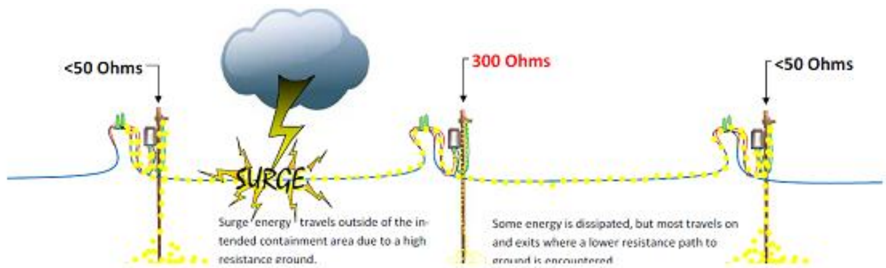


ICSD Placement Example

1. Each ICSD shall be connected to an **isolated ground** of 50 ohms or less resistance to earth.
   a. Where a grounding rod alone is effective at achieving 50 ohms or less, a single grounding rod is preferred. Where soil conditions prevent the installation of rods, grounding plates are recommended. If a grounding rod or plate alone does not meet 50 ohms or less, additional measures will be required. Since site conditions influence the effectiveness of grounding equipment, a grounding survey is recommended prior to system installation.
   b. If a shielding wire is used, the **isolated ground** rods or plates must be tested independently, prior to connecting the shielding wire to the rods or plates. It is important that the shield wire does not contact the ground rod during testing. A measurement with the shield wire connected does not give a true reading of the individual **isolated ground** location at the ICSD and will result in a reading that is considerably lower than the actual resistance at that location.
   c. The ICSD provides excellent containment and effective drainage of surge events when connected to an **isolated ground** of 50 ohms or less resistance to earth. Where an ICSD is connected to a higher resistance grounding point, some surge energy will be dissipated through the **isolated ground**, but the balance of the surge energy will continue along the wire path until it finds another exit point, exposing more equipment to potentially damaging surge energy.



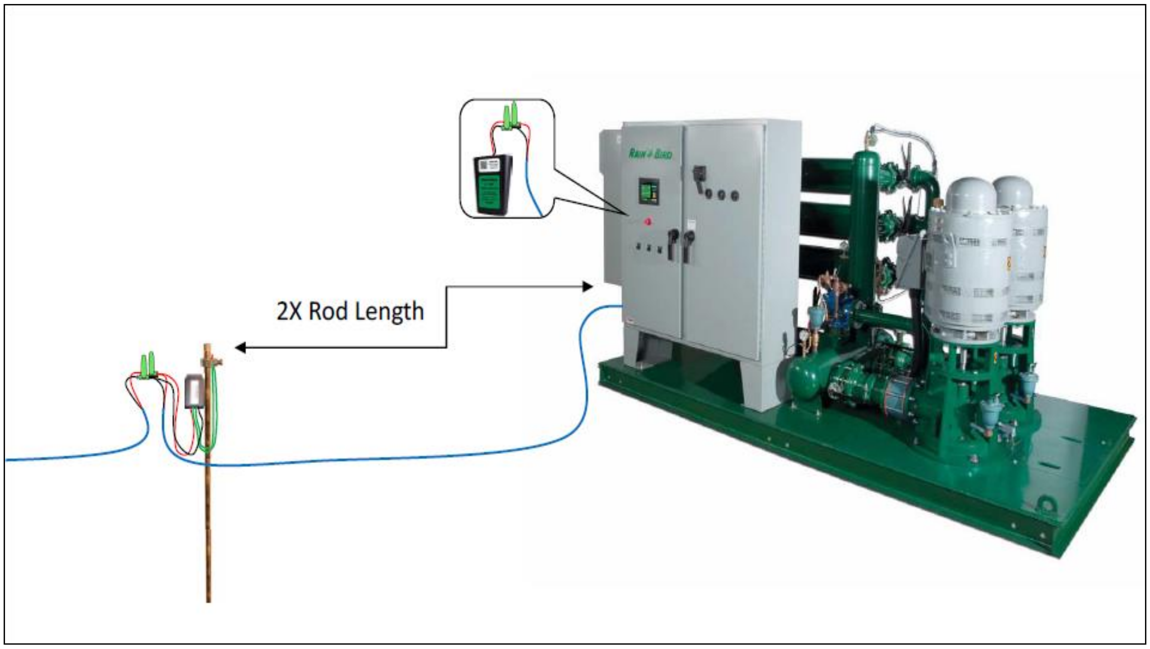
Example of a Well Contained Surge



Example of a Poorly Contained Surge

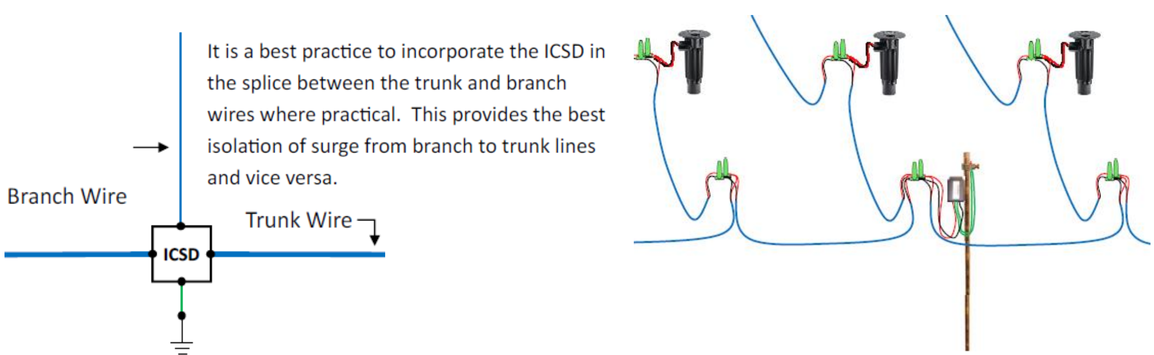
2. An ICSD shall be located every 15 ICMs or every 500 feet (150 m), whichever condition is reached first.
    a. This is a design guideline and should be adhered to as closely as practical. However, in the example of a herringbone system with 4 stations per pipe lateral, an ICSD could be installed every fourth lateral (therefore every 16th station) as a normal design practice.
    b. During long runs of wire where there are no ICMs, an ICSD is not required every 500 feet (150 meters). For example, if there is a wire run of 2,000 feet (609 meters) between ICMs, an ISCD should be installed immediately after the last ICM and just prior to the next ICM.
    c. At the ICI+, for a long run (greater than 500 feet or 150 meters) at the beginning of the wire path, the MSP should be installed at the interface and an ICSD installed just prior to the first ICM on the wire path.
3. ICSDs should be located at dead ends on long wire runs (approaching 500 feet or 150 m) to provide a discharge point and prevent reflection. Short wire runs do not require ICSDs at the dead ends. In particular, herringbone pipe layouts do not require ICSDs at the end of each herringbone lateral.
4. Where IC Connect™ devices are installed in critical equipment (e.g. pump control panels), an ICSD should be connected to an **isolated ground** point as close to the point where the MAXI™ wire enters the equipment as practical, while maintaining sufficient distance from the equipment for dissipation of surge energy. For example, if an IC Connect device is installed in a pump panel and an ICSD is installed with an 10’ (3 m) rod, the rod should be located at least a

distance equal to the depth of the rod, or 10’ (3 m) from the equipment panel or the building ground.

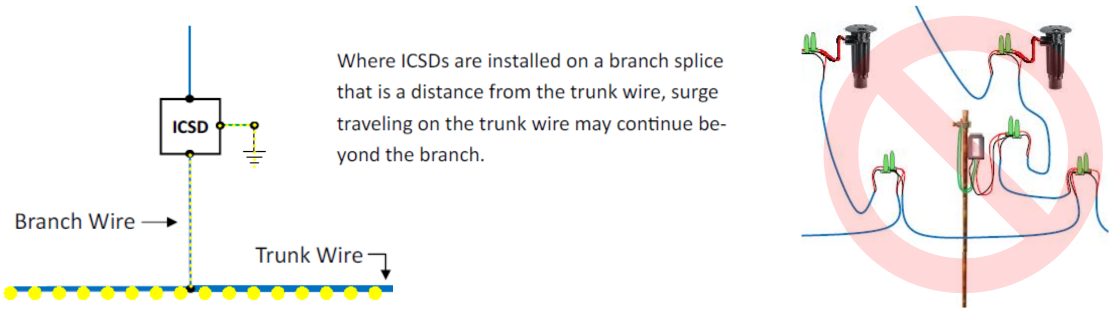


ICSD Placement for IC Connect Applications

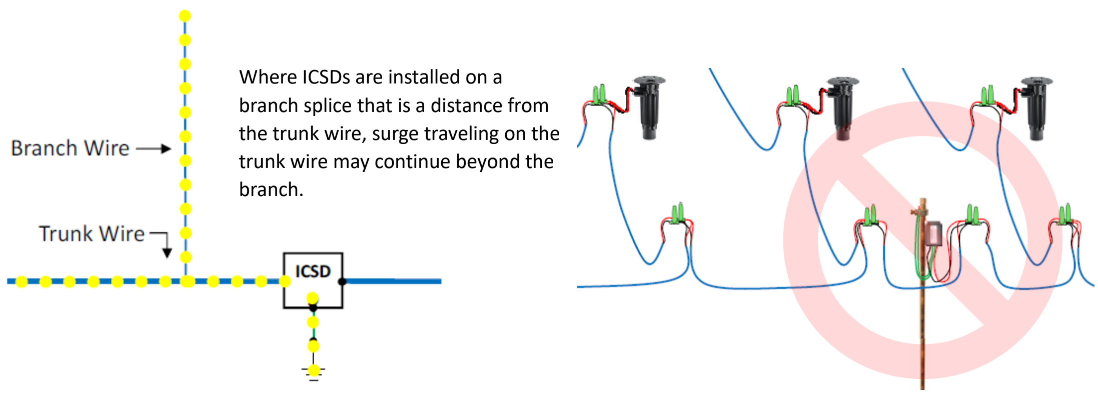
5. ICSDs, the MAXI wire they are spliced to and their connection to the **isolated ground** rod or plate should be installed so that they are easily serviceable. Installing ICSDs in an appropriately sized valve box is ideal.
6. The intersection between mainline and lateral lines is often a very practical location for an ICSD. In this case, the ICSD should be incorporated into the splice between the trunk wire and lateral wire. ICSDs located a distance away from this splice point may allow surge to flow in an undesirable direction.



Example of Ideal Surge Device Placement

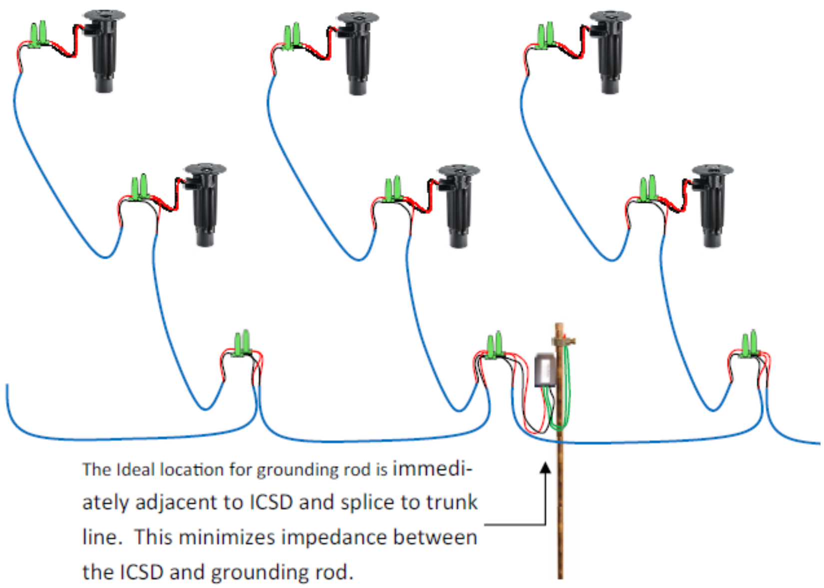


Example #1 of Poor Surge Device Placement

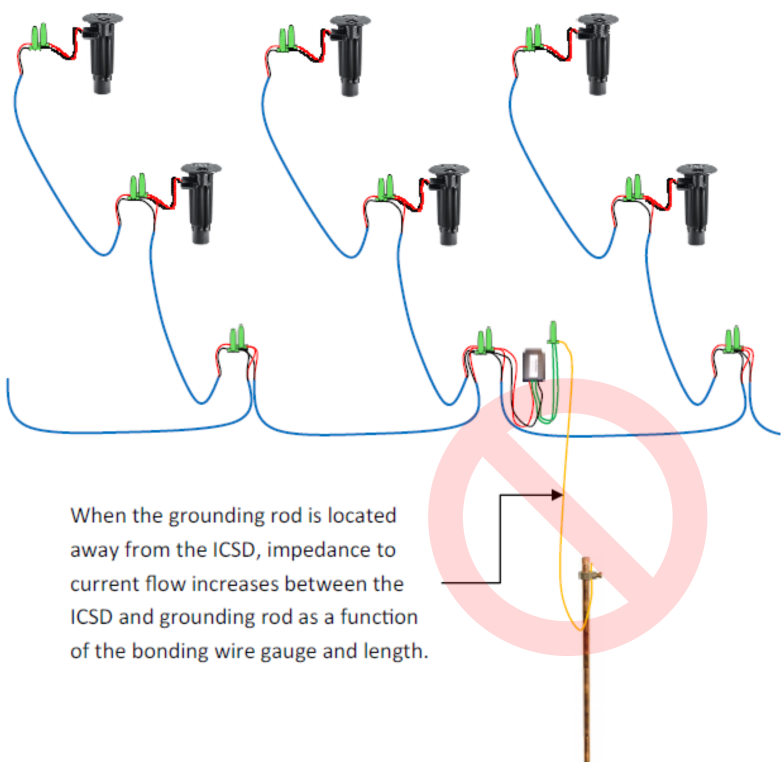


Example #2 of Poor Surge Device Placement

7. The ICSD should be located as close to the grounding rod or plate lead wire as practical. When additional wire is used between the ICSD and rod or plate, there is greater opposition to current flow reducing the effectiveness of the ground.



Example of Ideal Grounding Rod Location

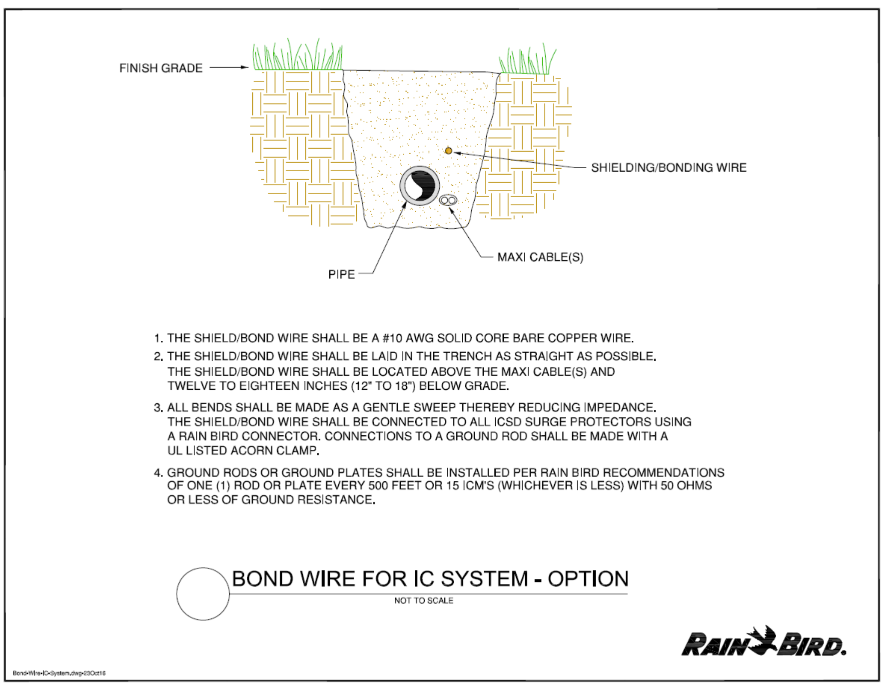


Example of Poor Grounding Rod Location

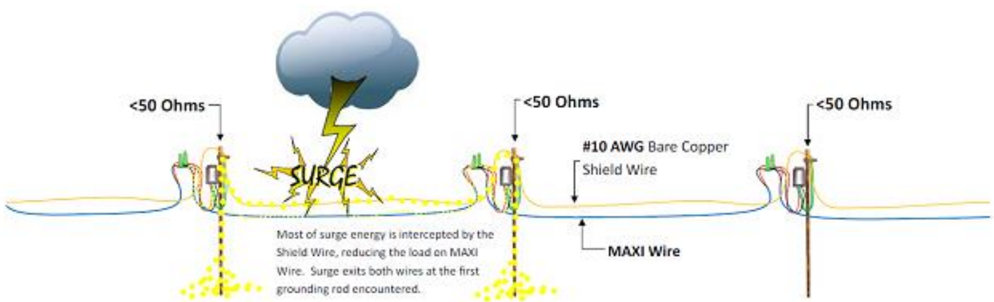
Shielding Wire

Rain Bird **DOES NOT** require installation of a shielding wire for an IC System™. In areas where lightning is prevalent, adding a shielding wire may help reduce wear on surge devices from repetitive surge events. When properly designed and installed, a shielding wire will intercept surge and reduce the load on the wire path, ICMs and ICSDs. If a shielding wire is to be specified on a Rain Bird control system as a perceived enhancement, then that enhancement should be considered a requirement for any other control system under consideration, regardless of manufacturer. In such case, the shielding wire should be connected to all ICSD grounding locations and to the **auxiliary grounding** grid at the central computer and/or remotely located ICI+.

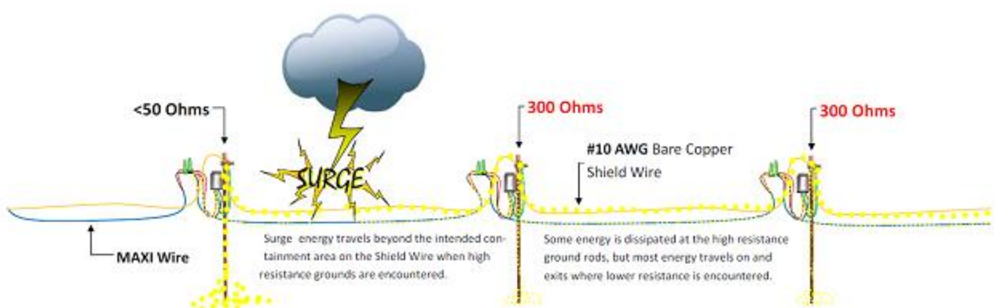
The purpose of a shielding wire is to intercept the surge energy from a lightning strike before it reaches the wire path and conduct that energy to the nearest grounding location where it can dissipate harmlessly. Adding a shielding wire may minimize the surge energy experienced by the wire path and surge devices. A shielding wire consists of a continuous run of 10 AWG (6 mm²) solid bare copper wire installed 4-6" (10-15 cm) above the MAXI Cable and connected to each grounding rod or plate in the grounding system.



While the shielding wire effectively bonds all of the **isolated grounds** in a system, its purpose is not to distribute surge energy, but rather to shunt the surge to the nearest ground before it enters the components of the irrigation control system. The addition of a shielding wire is not a solution for high resistance encountered at individual ground locations. Individual grounding locations must still have a resistance of 50 ohms or less. If surge traveling on a shielding wire encounters a high resistance ground, a portion of the energy may continue along the shielding wire to the next ground. The higher the resistance of the ground, the greater the probability that surge energy will continue past a grounding location.



Well Contained Surge Event with Shield Wire



Poorly Contained Surge Event with Shield Wire

The installation of a shielding wire does not alter or reduce the requirement for surge devices at the recommended intervals along the wire path. While a shielding wire may prevent much of the surge energy from entering the wire path, surge devices are still required to contain a surge event and drain excess energy from the wire path.

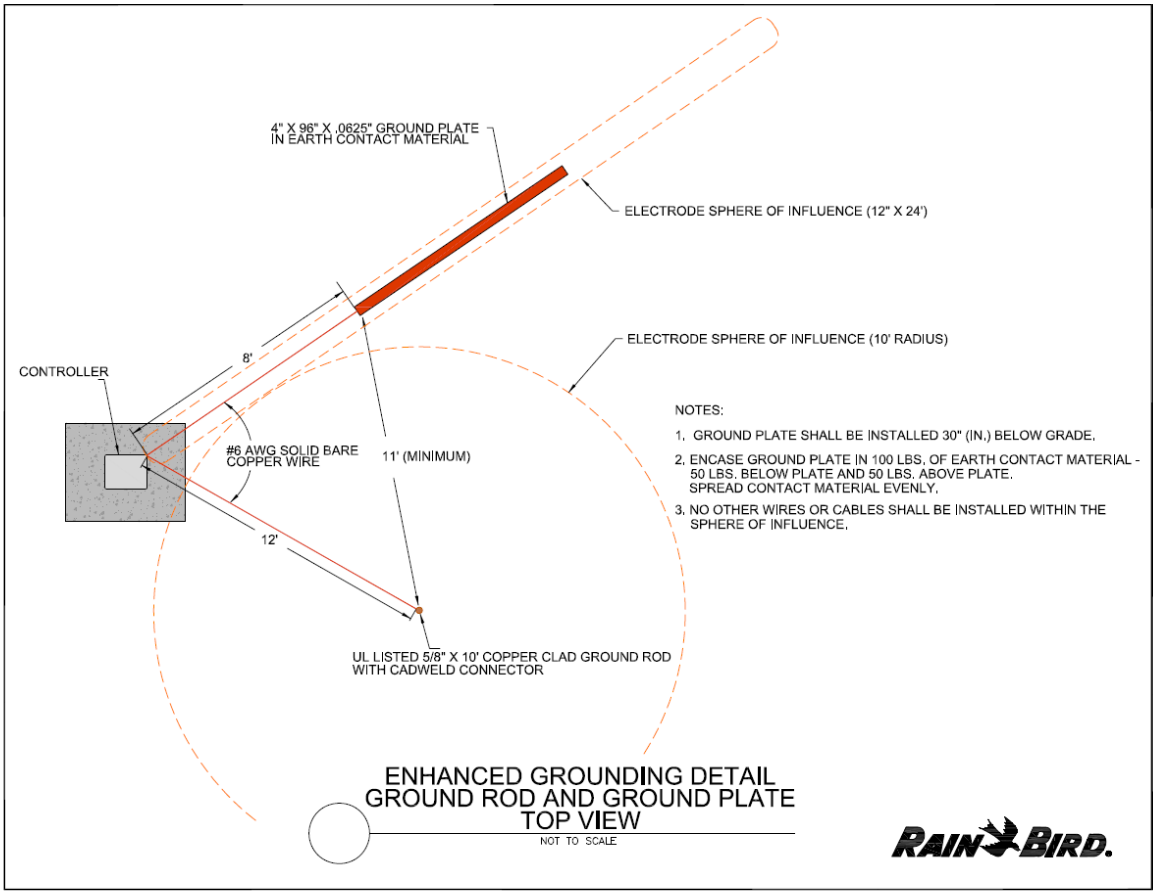
When a shielding wire is specified, special considerations must be made when testing grounding locations. In all cases, the shielding wire MUST NOT BE CONNECTED TO OR CONTACTING the grounding rod or plate under test. Doing so will result in an artificially low resistance value. Where permanent welded connections (such as Cadweld) are made between the shielding wire and grounding location, grounds must be tested BEFORE the weld is made.

Satellite Controllers (≤10 ohms)

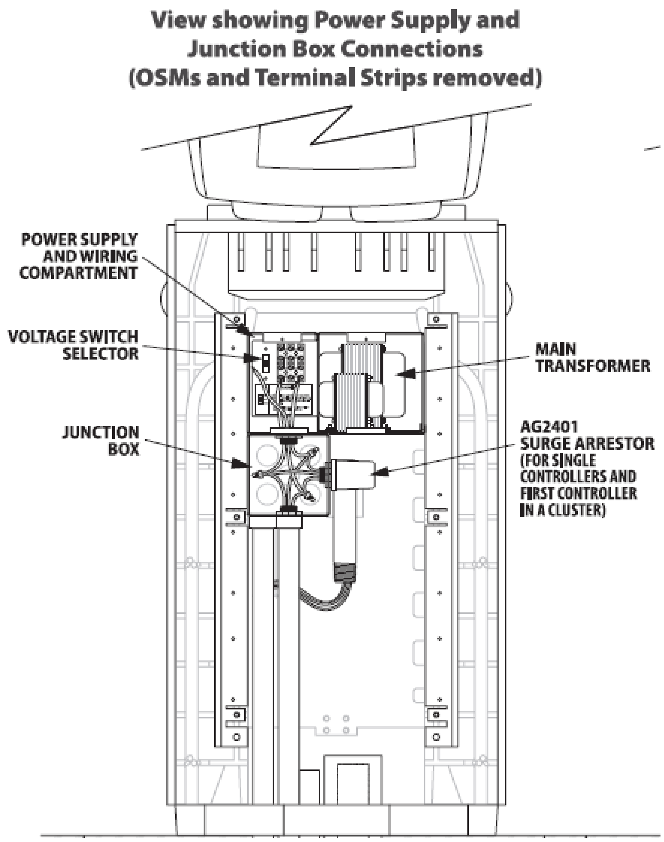
All Rain Bird Golf Field Controllers must be connected to an **auxiliary ground** of 10 ohms resistance or less using a 6 AWG (16 mm²) solid bare copper wire. A utility lug is provided in the base of PAR+ES and ESP-SAT controllers for this purpose. The connecting wire should be installed in as straight a line as possible. If the wire must turn or bend, it should do so in a sweeping curve with a minimum radius of 8" (20 cm) and a maximum included angle of 90°. To minimize resistance, the copper wire must be pre-welded to the grounding rods/plates or welded to the rods/plates using an exothermic welding process at the site. Make sure all welds are secure before burying the grounding rods. Rods and plates with welded joints do not need periodic visual inspection and can be fully buried (no valve box required). Measure the ground resistance of the **auxiliary ground** after installation, and once every year after that.

Where a grounding rod alone is effective at achieving 10 ohms or less, a single grounding rod is preferred. Where soil conditions prevent the installation of rods, grounding plates are recommended. If a grounding rod or plate alone does not provide a resistance of 10 ohms or less, additional electrodes will be required. Since site specific conditions influence the effectiveness of grounding equipment, a grounding survey is recommended prior to system installation.

Grounding rods and/or plates must be located where their sphere of influence is not in contact with the controller or field wiring. Unlike two wire control systems, Field Controllers have separate connections to primary power, communication cabling and solenoid wires. As surge energy enters from one connection and is dissipated by the **auxiliary ground**, the same surge energy may enter other field wiring that passes through the sphere of influence. An example with recommended separation based upon the sphere of influence for a rod and a plate is shown below.



An Intermatic AG2401 or equal surge arrestor shall be installed immediately prior to the main power connection for the controller. This provides protection against surge on the incoming power cable. This device is not supplied with the controller and requires a separate junction box for wire connection and device mounting as shown below:



Satellite Surge Arrestor Installation

For PAR+ES satellite controllers utilizing hardwired communication, an MSP-1 surge device is provided with the controller and mounted in the base of the pedestal. The MSP-1 is prewired to the controller's terminal strip from the factory. Since the HOT terminals and COM terminals are bussed, the MSP-1 only protects the controller that it is installed in. It does not protect controllers that are upstream or downstream on the wire path.

For PAR+ES LINK controllers utilizing radio for communication, most antennas are installed in the lid of the pedestal and do not require additional surge protection. Where radio conditions require an antenna to be remotely located 10' (3 m) or more from the radio, a Polyphaser or equal surge protector is recommended to protect the radio from incoming surge routing through the antenna or antenna cable. The Polyphaser must be bonded to the **auxiliary ground** of the controller. This may be accomplished by mounting the Polyphaser on the metal frame of the controller chassis, which is in turn bonded to the controller ground.

Where Field Controllers are clustered in groups of 2 or more, all controllers shall connect to the same **auxiliary ground**. A single AG2401 may be installed in the first controller and subsequent controllers in the same cluster may receive power downstream of the AG2401 connection. If power is distributed from a splice outside the controller cluster, then each controller will need an individual AG2401.

Decoder Systems

Lightning Surge Protection (LSP-1) device on Wire Path (≤50 ohms)

The guidelines for installing **isolated grounding** points for Decoder systems are governed by the same principles as for the ICSD for the IC System; except for the number of Decoders between LSP-1 devices. The grounding points and surge protection devices must be installed at every 500 feet (150 m) or 8 Decoders.

Summary Table

Item	Frequency of ground point(s)	Required Test Results
Interfaces (all)	One per	10 ohms or less
ICSD	Every 500’ (150 m) or 15 ICMs	50 ohms or less
IC-IN/IC-OUT	One per	50 ohms or less
LSP-1	Every 500’ (150 m) or 8 Decoders	50 ohms or less
SD-211	One per	50 ohms or less
PAR+ES	One per	10 ohms or less
Pump Stations	One per	10 ohms or less

Conclusion

For a surge protection system to perform optimally, it must be well grounded. It is important to understand the influences on ground resistance when selecting equipment type and placement for a grounding system. Conducting a grounding survey before the irrigation system is installed is the best practice to ensure the specified grounding equipment will meet the target for resistance. When well executed, a surge protection system will minimize exposure of the irrigation control system to harmful surge events and help avoid costly repairs and system downtime.

NOTE: The average lightning strike is about 300 million Volts and 30,000 Amps. Some strikes can be 1,000 more powerful than that. The practice of properly grounding an irrigation system is to minimize potential damage. However, please remember that it is not possible to protect a system 100% of the time against damage caused by lightning.