HomeShield™ – A Look Under The Hood

The HomeShield™ System

HomeShield™ is comprised of two basic components. The AC arrestor circuit and the ground status diagnostic interface circuit share the main housing. This housing is wired into the home's main electrical service entrance through the watt-hour meter and mounted under the meter housing, or into the homes load center. The ground status monitoring circuit is housed in a separate enclosure (Sensor Head) and is connected to the main unit via a pigtail connector. The sensor is installed onto the ground conductor and mounted inside the meter housing or load center. The sensor contains an 18 AWG cable that connects to an external metal probe which is used for voltage reference.

Diagnostic Circuit

Existing products in the marketplace, such as hand held Clamp-On Ground Resistance Testers and meggers, are readily available for the purpose of measuring the earth ground resistance and for the measurement of leakage current going to ground. While providing exact and highly accurate readings, these devises can be cost prohibitive and do not have the capability of detecting voltage. **HomeShield™** features the revolutionary patented S.M.A.R.T (System Monitoring and Recognition Technology) design. This S.M.A.R.T. design performs a complete system test at a rate of 132 times per second, allowing **HomeShield's™** ground status sensor to monitor three basic conditions with fixed parameters.

Ground Resistance

The earth ground resistance is measured by inducing a small fixed voltage pulse onto the ground wire and monitoring the corresponding current flowing through the wire from the ground resistance. The voltage is induced on the wire, using a transformer technique. The ground wire acts as a single turn secondary. The corresponding ground wire current is measured with a second transformer. The ground wire forms a single turn primary and the secondary winding picks up the signal. Both the voltage injection and the current monitoring transformers use toroidal cores.

The induced ground voltage pulse is generated by a timer circuit. The circuit generates a string of low voltage pulses with a narrow 25 microsecond pulse width. A two-transistor circuit forms a buffer circuit that provides the drive current. The low voltage pulse is connected to an inductor/capacitor series resonant circuit. The resonant circuit turns the single 25 microsecond voltage pulse into a classic "ring" signal. This ring signal is used to measure the ground resistance. Since short pulses are used, the circuit requires low average power from the +12 volt supply.

The induced ground wire current, which flows through the ground resistance, is measured with a current transformer. The circuit forms a parallel resonant circuit, tuned to the ground ring signal. This technique insures that only the ring signal is monitored. The ring signal from the current transformer is routed through both a high-pass and a low-pass filter network. The networks eliminate most noise signals that may also be collected by the current transformer. The filtered ring signal is then connected to a peak detector, which produces a DC voltage equal to the ring signal peaks. Additional circuits insure a clean voltage proportional to the induced ground wire current.

The average ground wire ring current signal is then connected to two voltage comparators. One comparator is used to monitor if the ring signal corresponds to a resistance of 25 ohms or less, while the other comparator monitors for a signal of 300 ohms or more of ground resistance. Additional logic circuits control the resistance green/amber status LEDs. If the measured resistance is 25 ohms or less, the green LED is turned on. If the resistance is between 26 ohms and 300 ohms, the amber LED is turned on. If the resistance is greater than 300 ohms, the amber LED is flashed on and off.

Ground Voltage

The voltage is measured between the earth ground conductor and the sensor probe. Under normal operation, little or no voltage exists between the earth ground conductor and the sensor probe. To maintain isolation between the power line and the monitoring circuit, an optically isolated circuit is used. The isolator consists of a light emitting diode (LED) and a light sensitive transistor, packaged inside a small integrated circuit. If a voltage of 5 or more volts AC exists between the ground conductor and the sensor probe, sufficient light is produced by the LED to toggle the light sensitive transistor. A resistor in series with the LED calibrates the circuit for the needed 5 volts AC. Additional logic circuits control the red/green LED ground voltage indicator light. The LED switches from green to red and the audible alarm is activated when the voltage exceeds 5 volts.

Ground Current

Under normal operation, little or no current flows through the earth ground conductor. The same current transformer used for measuring resistance is used to measure AC ground current. The voltage signal produced by the current transformer is proportional to current. A typical scale factor is roughly 1 volt peak to peak with an AC current of 1 amp. The 60Hz ground current signal is fed to a low pass filter circuit. This filter removes unwanted higher frequencies. The filtered ground current signal is connected to a voltage comparator circuit. When the ground current exceeds 1 amp the comparator changes state. Some additional logic circuits control the red/green LED ground current indicator light. The LED switches from green to red and the audible alarm is activated when the current exceeds 1 amp.

Arrestor Circuit

What is a Hybrid Circuit?

A 'Hybrid Circuit' is a circuit that employs components of differing technologies in such a way as to take advantage of the best each has to offer while removing their individual weaknesses. In the **HomeShield™**, a TMOV (Thermally Fused Metal Oxide Varistor) and a GDT (Gas Discharge Tube) are implemented to take advantage of differing technologies, which has resulted in a very durable and safe product and has raised the bar for reliability and performance. The disadvantages of either of these two technologies used on their own are now of no consequence. The failure mode of the TMOV during a voltage swell has been removed, and the possibility of a self-extinguishing problem with the GDT has also been removed.

The TMOV Based Circuit

The TMOV is a very durable device capable of dissipating a lot of energy during a surge. A surge happens in microseconds and is short lived, but what about an overvoltage fault. During a voltage swell, the voltage can abruptly rise 20 to 80%, and in a loss of neutral or full-phase fault mode, the voltage will increase 100%. These various over voltage faults will cause the TMOV to conduct, and in just a few cycles - fail catastrophically, which can result in the TMOV turning into a torch. The overvoltage fault mode is the challenge for circuit designers – to have both a high surge rating and a safe operation during overvoltage faults. The TMOV also has capacitance, in the case of a 25mm, 180Vac, 18kAmps TMOV, the capacitance would be 2600pF. The number of TMOVs placed in parallel multiplies the capacitance value. Therefore, if tied to ground, leakage currents must be kept in mind.

The Gas Discharge Tube

The Gas Discharge Tube or GDT is a very robust device – so where is the joule rating? The GDT crowbars (short circuits the load) instead of producing a clamping effect; thus, the voltage across it is much lower, typically 10 to 35V over a wide current range, making the joule rating irrelevant. This means that the GDT can operate at a high current level without dissipating/creating a lot of heat. In addition, a GDT, unlike the MOV, does not turn into a torch when it fails making it much easier to contain.

A TMOV of a similar surge current rating would clamp at a high voltage dissipating a lot of energy and heat, and the higher the current the higher the clamping voltage, causing an exponential growth in energy/heat dissipation. Because of the TMOV, the joule rating has become an item of interest to those who want to compare one product to another, but this only applies to products that clamp versus crowbar (TMOV versus GDT).

The GDT is referred to as a switching device because it operates like a switch, unlike the TMOV, which has a variable resistance. During a surge, the transition through the turn on point is unimportant, but with overvoltages – this transition is very important. This is where the GDT shines and the TMOV's soft turn on can be a problem.

The biggest disadvantage of the GDT is the problem that it may not self-extinguish (turn off) after the surge event. The GDT should extinguish itself when the waveform crosses zero by dropping the holding current to zero, but the heated gases can keep it in conduction mode causing a short circuit.

Gas Discharge Tube Meets TMOV – The Hybrid is born

Inserting a TMOV in series with the GDT ensures that the GDT turns off. When the voltage drops low enough to turn off the TMOV then the GDT is forced to turn off; in effect, the TMOV provides a hysteresis in the turn off curve. In turn, the GDT offers its switching characteristic to the TMOV removing the soft turn on problem. The TMOV cannot turn on until the GDT turns on, so the operating window is tightened up.

Enhanced Performance – Safer Operation

An additional improvement is in the operating window; it is tightened up with the hybrid combination. It is possible to hold off or not to turn on at an overvoltage up to 200%, but to still accomplish the desired clamping level by utilizing the sharper turn-on knee (switching action) of the GDT. The clamping level will be a combination of both the voltage across the TMOV and the little voltage that exists across the Gas Discharge Tube. Thus, the level of turn-on is increased while the clamping level is maintained.

Failure MODE of the Hybrid

The hybrid also provides for a safer failure mode during an overvoltage by removing much of the pre-heat condition of a TMOV only circuit. In a TMOV-only circuit, a voltage swell will cause the TMOV to begin to conduct at the rate of the overvoltage time frame, which can be in milliseconds – a lifetime in an electron's viewpoint. In a hybrid, the GDT will ride through most of the overvoltage conditions, and if the voltage did rise high enough to trigger the GDT, the GDT would crowbar - suddenly impressing the overvoltage on the TMOV. This causes the TMOV to conduct instantly, passing through the variable resistance range in short order, which brings the TMOV in a low resistant state quickly. This gives the fuse a chance to operate and go off line before a lot of heat – or catastrophic failure in the TMOV occurs. When a TMOV does fail in a hybrid, it looks more like a failure from a surge than it does an overvoltage.

Tested for Safety

We test our products to UL's requirements, but the most difficult test to survive is our own test developed by Square D. That would be the SCCR test – which applies full phase voltage with 500Amps available current. UL's SCCR test is performed at a much higher current level which is an easier test to pass because the fault current fuse takes the TMOVs off line before any real damage can occur. UL also will test at low current levels (5Amps), but this current is low enough that the thermal fuse has time to react. The more realistic value of available fault current is this intermediate current level of 500Amps. At this amperage level, the current is high enough to break the MOVs down too fast for the thermal fuse, but not fast enough to open the fault current fuse before the TMOVs have gone thermal (catastrophic failure).
The **HomeShield™** is designed not to fail during a full phase fault (loss of neutral), so the circuitry has to be defeated to conduct for this test (proof of the increased reliability of this circuit).

The TMOV has to be pre-failed and a lower voltage Gas Discharge Tube has to be installed so that the **HomeShield™** will conduct during this test. When both components are defeated, then the device will conduct until the fuse/s opens. There is no breach of containment as a result of the test. The module is not even hot to the touch only moments after the test. EFI actually tests both modes individually to make certain that the containment is not breached.

HomeShield™ – Under the Hood

In the **HomeShield™**, we went the extra mile for performance, safety and reliability. In each mode, we have two TMOVs that are each individually fused for safety and redundancy, and then stacked in series with a GDT. The TMOVs and the GDTs are both rated to withstand the line voltage independently of the other in the event that either the GDT or MOV should fail short. The TMOVs are thermally protected with their own built in thermal fuse for an extra level of safety and redundancy - even though they should never experience a thermal event because of the switching action provided by the GDT.

Real-Life Examples

Numerous examples of **HomeShield's™** diagnostic capabilities have been demonstrated thus far at consumer homes throughout the country. One such example occurred in New Hampshire, where upon activation of the **HomeShield™,** the alarm and corresponding flashing LED indicated current and/or voltage was present on the ground conductor. The source was a shorted hot water tank element. There have been several reports of well pumps and HVAC units as sources for alarm activation.

No one knows how long these conditions were present but the problems were easily identified and quickly corrected thus eliminating potentially dangerous situations.

The most common occurrence is a high resistance ground or "no ground". On at least two occasions **HomeShield™** immediately identified ground rods that had been altered in length to less than three feet due to rocky conditions. In another location it was discovered that the developer's crew routinely failed to properly clamp the ground conductor to the rod. The clamp was in place however it was never tightened. These problems were easily identified and quickly corrected.

Mobile or manufactured homes represent unique issues which are well documented. One of the least noticeable and yet most dangerous is a frame of a manufactured home that is energized. All mobile homes should have the frame grounded per the NEC prior to electricity being turned on to the home. This should prevent current passing through the frame by tripping a breaker at the time of the short. However, over time, changes to the electrical wiring, installation of appliances, damage or non-certified changes can cause the frame to become 'hot' electrically. The frame in this case becomes a bus-bar and is extremely dangerous. This situation is not noticeable to the eye but will be encountered in the worst possible situation with hands or knees on the ground.

There are deaths every year where service personnel, homeowners and children come in contact with a 'hot' frame and are electrocuted. Once again, these problems were easily identified and quickly corrected.

Unplanned Outages

HomeShield™ will prove its value during mass power outages, such as those caused by hurricanes, tornados or ice storms. Whenever the power is restored after an outage **HomeShield™** goes through its initial comprehensive service entrance ground system test. By simply observing the **HomeShield™** diagnostics, a lineman will know immediately if a potentially hazardous neutral problem still exists on the line.

Summary

In the case of **HomeShield™**, every step has been taken to provide a real level of performance in regard to both surge protection and safety - without one subtracting from the other. **There is nothing more important than safeguarding a family from potentially dangerous electrical shock and destructive fire hazards. HomeShield™** provides ***Peace of Mind*** by alerting the homeowner of a potentially hazardous condition and allows for corrective action to be taken before it is too late. **HomeShield™** is the smartest, safest and most comprehensive residential power quality package ever offered. ***"An ounce of prevention can save lives."***