STOPPING OILFIELD LIGHTNING DAMAGE

Thomas R. Brinner, PM&D Engineering, Inc.
Joseph A. Lanzoni, Lightning Eliminators & Consultants, Inc.

ABSTRACT

With a significant oil-price drop drilling programs are stopped and marginal wells are abandoned. Production must be continued with minimum down-time if an oil company is to stay profitable. One low-cost way to do this is to stop lightning damage.

Tank battery protection is the highest priority. Fiber glass tanks and explosive gases have made this a major challenge. Lightning collection has never been truly successful. Charge transfer systems (CTS) have prevented lightning strikes with nearly 100% elimination of damage. The particulars of CTS are discussed.

Electrical equipment must be protected from transient voltage surges carried in on the power wires. A listing from most important to least would be disposal facilities, electric submersible pumps (ESPs), ESP variable speed drives and pumping units. Transient voltage surge suppressor (TVSS) design and proper grounding are critically important if equipment is to be saved from lightning damage.

INTRODUCTION

Common oilfield thinking is, “You can’t stop lightning.” That is absolutely true. Lightning either goes from cloud to cloud or cloud to ground. However, you can stop the damage that lightning does. Although oilfields are a special case, other industries have much less lightning damage. An engineering approach can bring the same reliability to the oilfield.

Lightning protection has three, distinctly different aspects: grounding, surge suppression and direct strike attraction or avoidance. A good electrical connection into the earth, i.e. grounding, is important if the huge electrical charge of a lightning bolt is to be controlled to void equipment damage. Without good grounding surge suppression is ineffective and direct strike lightning can neither be attracted nor repelled safely.

Certainly oil production facilities are a special case because of their remoteness and the fact that they are often the highest objects on the horizon. When the presence of natural gas, electrically charge fluids and unprotected power systems are added in, the protection problem becomes more challenging. However with present day equipment technology and engineered installation, damage can be stopped. The benefits are less lost production, fewer lost man-hours, and lower equipment replacement and repair costs. All this means improved oilfield profitability.

Since it is not practical to change everything at once, priorities need to be established to protect the most critical and costly equipment first. At the top of the list is tank battery protection. When a tank battery is struck by lightning, parts of that battery may become heavily damaged, and the battery will not only become useless but will also become a liability. Production from the field will be severely reduced or possibly stopped. Production might be continued with the use of frac tanks and trucking water for disposal, but these are expensive options. Rebuilding the battery not only takes time, but it diverts expensive man-hours from other needed activities. If slightly radioactive fluid was being produced or the battery was in an urban area, liability concern will predominate.

A second priority is protection of disposal pumps motors and controls. When this equipment is damaged it is impossible to dispose of produced water quickly and reliably. This likewise reduces or stops production.

Loss of production from an individual well is normally far less significant than loss of either a tank battery or disposal pump. Still, it can take days or weeks to get back to the same production rate after a replacement ESP is installed. This, when added to the expense of a replacement pump, rig, rig crew and lost production during down time, makes an ESP failure very costly.

ESP's are particularly prone to lightning damage because they operate in a solidly grounded environment, the bottom of an oil well surrounded by salt water. Further, an ESP is subjected to extreme voltages when operated at the end of a distribution feeder, where a voltage transient (such as those caused by lightning) will double in size from reflection at the end of the line. Protection from these and other conditions is possible if:

- TVSS or SPD is properly designed, i.e. 4-wire
- The wellhead is used as the primary ground
- Lightning arresters and TVSS are on separate ground wires only connected together at the wellhead
- Transformer windings feeding the ESP are ungrounded except for the TVSS
- The TVSS is mounted on the junction box
- New electric distribution is four-wire with an overhead shield (neutral) wire.

Variable speed drives powering ESP's are quite expensive to repair. These drives typically are high horsepower and designed specifically for ESP operations. This is a fourth priority. If parts are available, downtime can be kept to a minimum. Unlike the ESP the drive is very accessible.

Finally, a last and fifth priority is pumping units. Motor rewinds and control failures can be greatly reduced with a TVSS. Many of the same grounding principles that work for ESP's are applicable for pumping units. Normally the pumping rate is low compared to an ESP, and lost production during downtime is minimal. Gas well dewatering may take a few days to recover.

TANK BATTERY PROTECTION

Lightning rods, Franklin rods and air terminals are three names for the same device. Historically, lightning rods have been the traditional equipment used to protect tank batteries. A typical lightning rod system consists of pointed rods, each about 12 inches tall, installed on all of the elevated structures within the battery. These lightning rods are then interconnected with copper conductors, and the conductors are grounded using simple ground rods. A simple extension of the lightning rod concept often used to protect multiple tanks is called a catenary system. In a catenary lightning protection system, a heavy gauge wire is suspended above the battery between two poles, with the ends of the wire being grounded to earth.

Since Benjamin Franklin invented the lightning rod over 250 years ago, the world has enjoyed a great reduction in lightning-initiated building fires, and for this alone he deserves the title of America's first great man-of-science. However, it has always been difficult to define exactly what is protected versus what isn't protected, when using a lightning rod or catenary lightning protection system. The National Fire Prevention Association (NFPA) publishes standard 780 to answer this question, and the Lightning Protection Institute publishes a document that is "intended as the installation guide for compliance with the NFPA 780 Standard and LPI Certification (1)." The calculation method in vogue today is called "Rolling Sphere." A sphere (ball) with a 150 foot radius is imagined to be rolling along the ground. If the rolling sphere touches a lightning rod before touching a structure, that structure is considered to be protected. The "Zone of Protection" is the volume beneath the sphere when the sphere is touching lightning rods.

However, oilfield tanks contain explosive fluids. According to the LPI "the use of a 100 ft. (30m) radius sphere model is required for structures housing explosives and hazardous materials to cover approximately 98% of recorded strikes (1)." So, 2% of the time lightning is still going to strike the battery with possible explosive and inflammable results, even with a small zone of protection? Is that acceptable?

A newer type lightning collector called "Early Streamer Emitter" (ESE) claims to expand the zone of protection. According to the sales literature, ESE's extend the upward streamer so that the downward lightning streamer is intercepted higher in the sky. Initially radioactive material was built into the tip of the collector, but more recent designs accomplish the same effect by designing a metallic sphere around a central rod. One manufacturer of this type of equipment only guarantees coverage of 91% of recorded strikes.

Is either the traditional lightning rod or the ESE suitable for oilfield use? To answer this question an examination of tank battery parameters and operation is necessary. First, it must be fully acknowledged that the tanks contain explosive fluids and fluid levels fluctuate continually. Pressure/vacuum (P/V) relief valves, either in-line or stack mounted, are used to minimize oxygen in the tanks so that explosions are less likely. The fuel, natural gas, is certainly present. The ignition source, lightning, is random and an ever present danger. Thus oxygen is the only component of the fire triangle that can be controlled. Obviously tank thief hatch must be sealed and only opened briefly for measurement purposes.

Steel tanks provide a barrier around the contained fuel. Lightning striking a steel or metallic tank will travel on the outside of the tank because like charges repel. Technically such a steel tank becomes a "Faraday Shield." Unfortunately produced well fluid is highly corrosive, and steel tanks are quickly eaten away and leak. Thus gun barrel tanks, where the produced fluid is separated into natural gas, crude oil and salt water, are now generally constructed of fiber glass rather than steel. This solves the corrosion problem but creates a second operating parameter, charged fluid.

A bound charge situation may occur where a fluid inside a tank may take on a charge from filling or an overhead thunderstorm. Direct or nearby lightning will collapse the cell between the cloud and ground and cause a massive amount of charge to flow in the direction of the strike termination. This movement of charge, including that charge bound inside the tank, could cause an ignition if the charge arcs across any incontinuity in the presence of flammable vapors.

Electric charge is inherent in produced fluid but can also be created during the tank filling process. If produced fluid is simply allowed to drop into a tank from the top, a "Kelvin Electrostatic Generator" is effectively created. Should the charge on this fluid be the opposite of lightning in the vicinity, the attractive force will easily puncture the fiber glass tank and ignite the flammable fluid.

Both the traditional lightning rod and the ESE collect lightning, a serious source of ignition. Bringing lightning down through a tank battery containing flammable fluid and electric charge is paramount to tempting disaster. The magnitude of the electric and magnetic fields produced by the lightning bolt commonly generates high voltages that arc between conductors creating further sources of ignition. For tank battery protection the attraction and collection of lightning has historically been a catastrophe – there have been numerous recorded cases of tank battery equipment being damaged or destroyed due to lightning.

One viable and attractive alternative to lightning strike collection is a "Charge Transfer System" (CTS) which prevents lightning from striking a tank battery, thereby providing far superior protection. A CTS consists of three parts: an ionizer, a ground current collector (grounding system) and wire to connect the two. The ionizer is constructed of multiple, sharp, wire points suspended above the facility to be protected. The ionizer points must be deployed in sufficient quantity and in the proper geometric orientation to maximize their ionization effect. When a thundercloud passes over the ionizer, voltage in the air causes electric charge in the ground or fiber glass tanks to form a corona off the wire points that transfers that charge into the atmosphere. This "Cold Corona" can not ignite any gas that may be present. The electric charge that is neutralized by the ionizer prevents it and the tank battery below from being a target for lightning. One type of dissipater is shown in Fig. 1.

Collection of ground current is a critical factor. Grounding systems containing ground rods, loops of ground rods and/or loops containing chemical grounds and conventional rods are necessary to extract charge from the soil beneath the tank battery. As explained above, charge inside fiber glass tanks is dangerous. Therefore a thief-hatch ground rod, Fig. 2, must be installed inside a fiber glass tank to remove charge from the contained fluid or alternatively, the carbon veil inside a fiber glass tank and any steel inlet or outlet pipes must also be grounded. It should be noted that the thief hatch has a ground wire. Once this is done and the collector is connected to the ionizer, the CTS is in place.

To date CTS has a nearly 100% protection coverage for recorded strikes. Failures have only occurred for tanks set outside the engineered zone of protection. CTS have been compared technically in a peer evaluated publication (2). Creating an electrical model of a CTS system is no small task, but modern day finite-element analysis has indeed verified that CTS is a technically correct and viable technology (3).

GROUNDING

Safety is the over-riding reason for grounding. The earth, particularly when wet, is a good conductor of electricity, and any metal object that has a voltage could cause electrocution. Grounding brings the voltage on such a metal object down to zero. This eliminates the electrocution hazard.

Effective grounding requires a good, low-resistance connection into the earth. Special ground resistance meters have been designed to measure ground resistance. For residential buildings ground resistance is supposed to be less than 25 ohms according to the National Electric Code (NEC). In most cases this can be accomplished with a single, copper-clad steel ground rod. When ground resistance is over 25 ohms, an additional rod needs to be installed. Optimum spacing of rods is 2.2 times the rod length. An actual grid of rods all welded together is built under every electric substation.

For tank batteries ground rods are normally driven into the ground outside the dike and connected together in a loop. Usually a liner is installed inside the dike to contain produced fluid in case of a leak. Because of possible leaks, driving a rod through the liner is generally prohibited. Placement of ground rods is also critical. Driving a rod into a buried flow line can have disastrous effects. Often the location of flow line is unknown or a calculated guess.

Chemical grounds provide an alternative to multiple rods, particularly in dry and/or rocky soil. These are copper tubes, 8 to 10 feet long, filled with salt and water and backfilled with a conductive ground enhancement material. Salts seeping out of the chemical ground rods make the surrounding soil more conductive while the conductive backfill material increases the actual contact area with the soil.

Without a doubt a wellhead is an exceptionally low resistance, good ground. For surge protection a connection to the wellhead is highly recommended. It is also a requirement of the NEC for electric power. However, it may not provide any real benefit for CTS. CTS are not trying to attract lightning but prevent it. The most important consideration here is making contact with the electric charge that is to be transferred so that the structure is not struck by lightning.

Removing the electric charge from the fluid inside a fiber glass tank is extremely important, and several ways of doing this are discussed above.

It must be emphasized that copper wire is not just a piece of long, cylindrical metal. Wire has resistance and inductance. Standard #6 AWG copper ground wire has just 0.4 ohms (Ω) resistance per 1000 ft. Thirty feet of ground wire down a pole has about .01 Ω of resistance. If this plus the ground resistance of a rod amounts to 1.0 Ω, then by Ohms law a 20,000 amp lightning bolt would produce 20,000 volts.

Ground wires permit even higher voltages due to inductance. This is similar to behavior of fluid in a pipeline when a pressure impulse occurs. The pressure instantaneously goes to a very high level until the fluid starts to move, because fluid has inertia. Likewise the voltage along a ground wire can reach a very high level until charge begins to flow. Charge flow is current.

Ground wire inductance is generally figured at 0.5-µH/ft. Thirty feet of ground wire would have an inductance of 15-µH. A lightning bolt increasing at the rate of 10,000-A/µs would produce a voltage in that wire of 15x10,000 or 150,000 volts. Obviously short ground wires and low ground resistances are better.

For surge protection purposes the order in which ground wires are connected is important. Simply connecting all ground wires together (bonding) is not acceptable. This is explained later.

TRANSIENT VOLTAGE SURGE PROTECTION

Oil production is plagued by a number of generally accepted but misused and misunderstood terms. A "Power Bump" can mean a brief interruption in power caused by operation of a recloser that extinguishes an arc struck by lightning and otherwise sustained by generated power. Or, it can mean any interruption in power such as a switching surge. Or, it can mean an increase in the AC voltage following a voltage sag. Or, it can mean lightning.

A surge in an oilfield normally means an increase in pipeline pressure or some oscillation in that pressure. Therefore a "Surge Protection Device or SPD" could be construed as something that regulates pipeline pressure. Because of this confusion the term "Transient Voltage Surge" is preferred when discussing protection against lightning and switching surges. These events are indeed transients because they last only a few microseconds.

Lightning striking power wires causes the most damage. Lightning is a massive injection of electrical energy into the power system. When a power company switches its lines, the energy stored in transformers and motors causes transient voltages. These can also be damaging. A TVSS keeps such voltages from reaching the high levels that cause electrical equipment damage.

The best explanation of a TVSS comes from comparison with a pressure relief valve as depicted in Fig. 3. Metal oxide varistors or MOVs are the basic devices in all TVSS and lightning arresters. A MOV symbol is presented at the left. Volts are analogous to pressure across the valve, from inside a tank or pipe to the atmosphere and current is similar to flow through the valve. At voltages or pressures below point X, neither device does anything. They can essentially be ignored. However, above point X current starts to flow through the MOV and fluid starts to flow out of the valve discharge. This action keeps pressure or voltage below a set limit that is far below either the maximum allowable working pressure or the insulation puncture voltage. In other words, pressure and voltage are prevented from reaching equipment damaging levels.

Protection against negative voltage transients is also possible with a MOV. The curve is simply flipped around and any voltage less than –X will be limited. Current is also reversed. Electricity can be either positive or negative. Negative voltage operation of a MOV or TVSS is an extremely important consideration. As shown later failure to design for this "Backward Conduction" can result in a TVSS actually causing equipment damage rather than preventing it.

Pressure can not be negative. The lowest pressure is a vacuum. Thus a complete comparison with a pressure relief valve is impossible.

A TVSS is a collection of MOVs, as illustrated in Fig. 4. Modes define how many MOVs are used in a TVSS. For protection of equipment operating on three-phase electric power how the phases (A, B & C) and ground (G) are connected is critical. The three-mode, delta TVSS has no ground terminal. It was only three wires. Therefore it can not possibly limit transient voltages between any phase and ground, where insulation thickness is the least. Any thought that phase-to-ground voltages can be limited by injection into the phases not struck is scientifically impossible. In the above discussion of inductance it was noted that voltage can be very high depending on the speed that current changes, A/µs. Both the transformer and the power lines have inductance which prevents any reasonable connection to ground. Operating a TVSS without a ground wire is like installing a pressure relief valve with a bull plug over the discharge.

All the other TVSS designs in Fig. 4 are 4-wire with a ground terminal. The three-mode Y and four-mode designs use the least number of MOVs. A six-mode TVSS is really a combination of the two, three-mode designs. Because more MOVs with higher voltage rating are needed, the six-mode can dissipate more energy. Further, there is redundancy should a single MOV fail.

Any inductance or resistance in series with a MOV means that fast voltage transients can not be completely limited. By analogy the pressure relief valve in Fig. 5 can not limit peak pressure impulses if the small diameter, long discharge tube is filled with fluid. Fluid can not instantly move because of inertia, and friction in the tube creates additional pressure. Consequently pressure at the valve discharge can initially be very high. Inertia is like inductance, and friction is similar to resistance.

ESP PROTECTION

Although disposal pump motors and controls have a higher priority, the problems involved with ESP protection highlight many additional design concerns that are germane to protection in general. These were mentioned in the introduction, and it seems reasonable to consider them first.

A 3-wire TVSS or SPD with no MOVs connected between the power phases and ground can not protect the thinnest and most vulnerable electrical insulation, that from phase-to-ground. This was mentioned in an above paragraph. A 4-wire TVSS is absolutely essential for lightning protection.

Grounding to the wellhead has been a common practice for over 80 years. A well is a ground rod thousands of feet deep, and it can not be damaged by lightning (4). Ground resistance is less than one ohm, which means that even the massive current of a lightning bolt will not raise the voltage appreciably. Even more important than this is the fact that an ESP is electrically connected to the wellhead by the tubing string and the salt water surrounding it. A TVSS in close proximity can effectively limit phase-to-ground voltage transients. In recent years wellhead grounding has been an NEC requirement, section 250.112(M).

Making a good electrical connection to a wellhead is imperative. Traditionally this has been attempted with ground clamps installed around pipes screwed into the wellhead. It is questionable just how well the pipes make contact with the wellhead and how well the clamp contacts the pipe and the ground wire. Over time clamps work loose around a pipe and wires work loose in the clamp. Workover crews are seldom trained as to the importance of ground clamps. Consequently they are often not reinstalled or inadvertently lost.

Exothermal Welding is the process of choice in the electric power industry. This process indeed welds copper wire to copper-clad steel ground rods. Grids of rods so connected are installed under every substation. However, exothermal welding has several drawbacks. Metallurgists say it can possibly weaken a well casing. If buried corrosion is a problem. Because the ground wire can not be removed, it is not possible to check the continuity of that wire.

Two methods for successfully connecting to the lower flange of a wellhead are the welded bolt head and the service post. A ground lug can be easily installed on a welded bolt head with just a washer and nut, as shown in Fig. 6a. Since welding around a wellhead can be extremely dangerous, a "Hot Work" permit is strongly recommended.

The service post is typically bronze with a standard bolt on one end and a split bolt on the other. A hole is drilled and tapped in the lower wellhead flange between flange bolts. The bolt is screwed into this hole and ground wires are installed in the opposite split bolt end, as depicted in Fig. 6b. Service post grounding is preferred because the post does not corrode and it can be easily removed before a workover or replaced if broken off. If broken the bolt can be removed with an easy-out or the soft bronze material can be drilled out and the hole re-tapped.

One occasionally expressed objection to using the wellhead as the primary ground for surge protection is the possible conflict with cathodic protection. It is felt that ground rods and pole butt-wraps might divert DC currents in the earth away from the wellhead, lessening corrosion protection. A number of solutions have been used in the past. Some companies have been successful with positioning the anode bed on the far side of the wellhead from the power system and increasing the DC current. A cathodic protection evaluation tool, CPET, is available to actually measure the effectiveness of cathodic protection. Finally, there are products which can separate low-voltage DC from high-voltage transient surges. Coexistence of cathodic and surge protection is very important, because neither casing repair nor ESP failures are inexpensive.

If lightning arresters and TVSS are connected together on a single ground wire, they can interact and actually cause ESP failures instead of preventing them. This simple fact accounts for the questionable improvement in ESP reliability when TVSS and lightning arrester ground wires are not separated. Separation is not unsafe because the two ground wires are connected together, i.e. bonded, at the wellhead. In the NEC where ground wires are bonded is never addressed, just that they are bonded.

Calculations of ground wire voltages for the typical ESP installation involves an electrical model, Fig. 7, and an equivalent circuit, Fig. 8. It was demonstrated that impulse voltages on the ground wire at the switchboard can be almost as large as the lightning voltage itself (5). This is especially true in arid regions where the resistance of ground rods and butt wraps is very high.

"Backward Conduction" through a MOV (TVSS) was discussed above. This is illustrated in Fig. 9. A large portion of the lightning voltage passes straight through the TVSS directly onto the phase wires that feed the ESP. It is this phenomenon that has prevented switchboard mounted TVSS from unquestionably stopping ESP lightning damage. Lightning arresters, connected on the secondary or ESP side of step-down transformers, are equally as bad or worse. Removal of all secondary arresters is highly recommended.

A simple solution to this problem is to have lightning arresters and transformers on one ground wire that goes straight to the wellhead (Power System) and a second ground wire (ESP System) that connects the switchboard and TVSS to the wellhead. This is shown in Fig. 10. Stranded copper #2 AWG ground wire with green insulation is preferred. #2 is mechanically stronger than the minimum NEC requirement of #6 and green is the appropriate color for a ground wire. Insulation limits H_2S corrosion of copper. Coding the wires with different color tapes helps to identify which wire goes where. The big challenge is ensuring that the grounds are separated at the power pole.

Sometimes it is easier to just isolate the TVSS by using a fiber glass junction box and running a ground wire between the TVSS and the wellhead. This arrangement is depicted in Fig. 11.

Eighty years of experience has confirmed that ungrounded transformer windings are best for ESP operation. If windings are grounded, the first electrical fault in the cable or motor causes huge currents that melt copper and burn insulation. This ensures that the ESP has to be pulled for repair. If windings are ungrounded, the first fault produces a minimal current with no appreciable damage. Production is not interrupted because the ESP continues to run.

Another problem with grounded windings is increased lightning damage. The grounding point is at the top of the power pole where all three lightning arrester grounds are connected together. When lightning strikes, this point goes to a very high voltage, and that voltage is injected directly onto the transformer windings and cable, frequently causing equipment damage.

Occasionally it is argued that ungrounded windings are unsafe. This is not true. Equipment grounds, anything metal that an untrained person could possibly touch, must indeed be grounded and bonded. However, system grounds relate to how power wires are connected, and untrained personnel should never have access to the transformer winding connections up on the pole.

The down side of ungrounded windings is an unusual phenomenon called an "arcing fault." Such a condition produces transient voltages within the ESP and cable insulation that often lead to a high DC voltage on the windings. However, a TVSS permanently attached to the ESP phase wires prevents this from happening.

Junction box mounting of the TVSS has several advantages. The ground wire to the wellhead is the shortest and therefore has the least inductance. As demonstrated above, this provides the best lightning protection. Second, the TVSS is permanently connected to the ESP power. Lastly, should the TVSS start to fail and draw high amps, the over-current protection in the switchboard or drive will sense this condition and cut the power.

It might seem that mounting a TVSS on the junction box would leave switchboard components unprotected. This is not the case. It is well known in West Texas that a slack span pole set 200 feet beyond a previous end-of-line pole and equipped with grounded lightning arresters will greatly reduce lightning damage at the former end pole. The slack span reflects back a negative electric wave that subtract from the incoming wave or impulse, thereby reducing the voltage. This is exactly what happens with a junction box mounted TVSS.

Since transient voltage surges come into a wellsite on the power distribution lines, a review of distribution construction related to lightning protection is justified. Power companies normally transmit power with four wires, three for the phases and a fourth for a shield or overhead neutral (OHN). The shield wire is above the other wires and is intended to protect or shield the phase wires from direct strike lightning. This shield/OHN wire connects to the protection ground wire run down every pole. Thus lightning has multiple paths to ground.

Power distribution, at lower voltages than transmission, is understandably more cost sensitive. Shorter poles cost less. Wires, however, must be above a minimum height for safety. Power can be delivered with just three wires, but the phase wires are then very susceptible to direct strikes. Stringing a neutral wire beneath the phase wires, an underbuilt neutral or UBN, is common practice, but then again additional banks of lightning arresters are necessary to transfer lightning from the phase wire to the UBN and to ground. Failed lightning arresters used in such service need to be conscientiously replaced to avoid a lapse in protection.

For new oilfields construction with a shield wire is seriously recommended. The additional cost for taller poles is usually paid back in a year or two by the reduction in replacement equipment cost and reductions in lost production. One detail is extremely important. Because the shield wire is the intended target for lightning, at a power drop pole it should be brought straight to ground without connection to the lightning arresters or transformers. A second ground wire should be run up the pole to make these connections. If this is not done Backward Conduction through the lightning arresters could damage equipment.

DISPOSAL PUMPS, DRIVES AND ROD PUMPS

Disposal pump motors and controls are a high priority for protection. In general no ground as good as a wellhead is available. Still, this equipment is usually located at a tank battery, and if tank battery protection includes a good, low resistance ground, the TVSS and equipment grounds should be connected to it. Again, the TVSS should be a 4-wire design to ensure phase-to-ground protection.

ESP variable speed drive (VSD) repairs can get expensive. A major cause of VSD damage is lightning. Protecting the VSD and ESP requires two TVSS units in addition to the lightning arresters. As before, it is important to keep each of these on separate ground wires only connected together at the wellhead. Such an arrangement is displayed in Fig. 12. The biggest concern is separation of grounds between the transformers and the VSD, since this 480V power is often run inside conduit or sealtite. Isolation inserts are available for sealtite. Step-up transformer windings feeding the ESP are nearly always ungrounded, and the ground isolation method in Fig. 11 is easily adapted.

Quite often a VSD is trailer mounted and used primarily for evaluation of well inflow performance. Once performance has been determined the VSD and ESP are removed. An ESP operating on 60-Hz electric power is sized for that performance and operated on a switchboard. The changes required from Fig. 12 are different pole transformers, grounding the switchboard with the red wire and possibly resizing the TVSS.

Rod pump protection is illustrated in Fig. 13. Frequently one bank of transformers reduces the common 12,470 V distribution down to 480 V to power multiple units. Except for the pump nearest the transformers, 480V power is run to all pumping units via power poles and overhead wires. The same general principle applies. The lightning arresters need to be on a separate ground wire that goes directly to the nearest wellhead. Pumping unit, motor and controls are on a separate ground wire connected to the wellhead.

SUMMARY

For tank battery protection CTS eliminates the problems associated with bringing a lightning bolt down to earth through the battery. It provides nearly 100% protection compared to 91% or less protection with lightning rods, ESE or catenaries. Thief hatch and P/V valves should form a nearly sealed system. Grounding must make contact with the charge beneath the tanks and the charged fluid inside fiber glass tanks.

The best protection for ESP units and the VSDs powering them involves:

- 4-wire TVSS
- Wellhead grounding
- Separate but bonded ground wires
- Ungrounded transformer windings
- Junction box TVSS mounting
- A shield wire over new distribution

Protection of controls and motors for disposal and rod pumps is most effective with a 4-wire TVSS. The rod pump equipment can still be grounded to the wellhead; however, disposal pump equipment is most readily grounded to the loop surrounding the tank battery.

Application of these principles and diligent attention to proper grounding and installation can significantly improve the profitability of any oil company.

REFERENCES

1. Lightning Protections Institute, Standard of Practice for the DESIGN – INSTALLATION – INSPECTION of Lightning Protection Systems, LPI-175, Maryville, MO, 2004.

2. Donald W. Zipse, Lightning Protection Methods: An Update and a Discredited System Vindicated, IEEE paper ICPS-00-19, New York, IEEE, 2000.

3. Lee, Joon-Ho; Chung, Young-Ki and Park, Il-Han, Local Electric Field Analysis for Evaluation of Charge Transfer Systems Using Sequential Sub-window Technique, Saratoga Springs, NY, Compumag, July 2003.

4. Brinner, T. R. and Atkins, J. D., Electric Submersible Pump Grounding, New York, IEEE Trans on Industry Applications, Vol. 40, No. 5, Sept/Oct 2004.

5. Brinner, T. R. and Durham, R. A., Transient Voltage Aspects of Grounding, Cincinnati, OH, IEEE/IAS Petroleum and Chemical Industry Conference, Sept 2008.

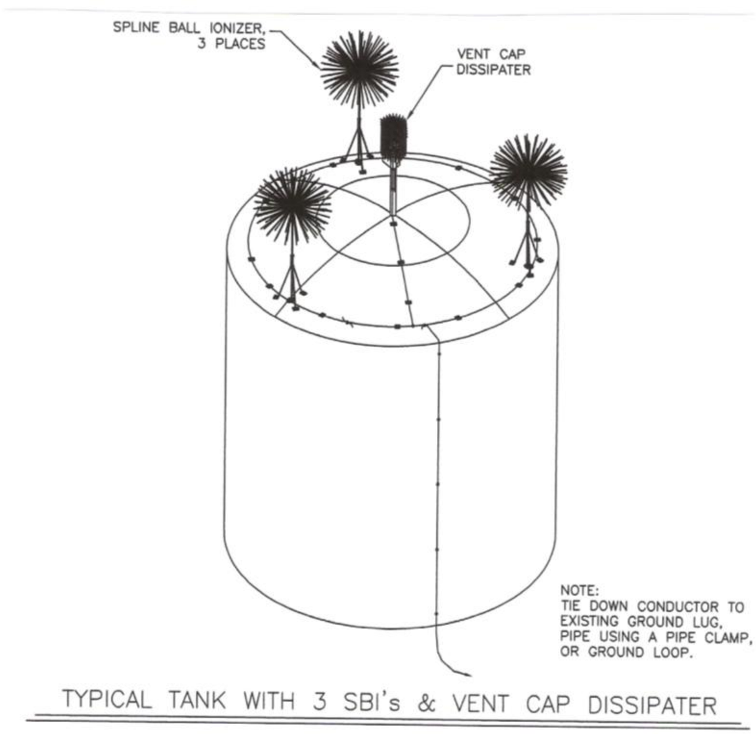


Figure 1 – Ionizer over a Tank

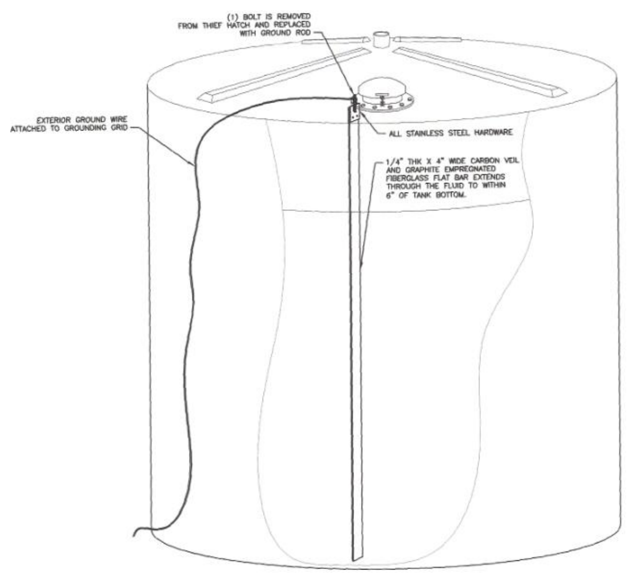


Figure 2 – A Thief Hatch Ground Rod, note ground wire

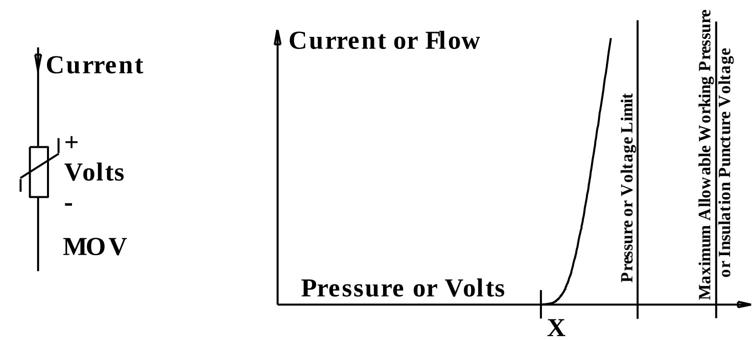


Figure 3 – MOV and Pressure Relief Valve Operation

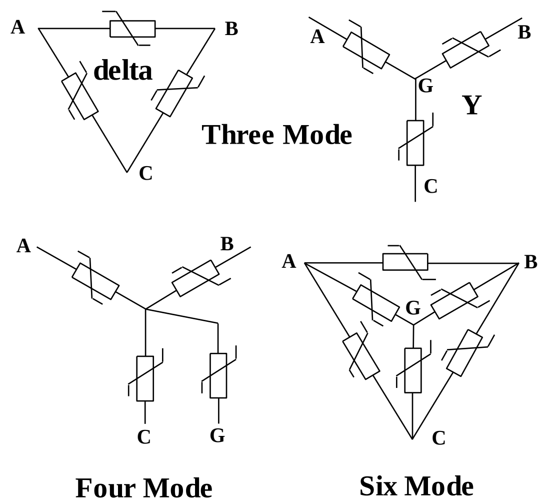


Figure 4 – TVSS Modes and Wires

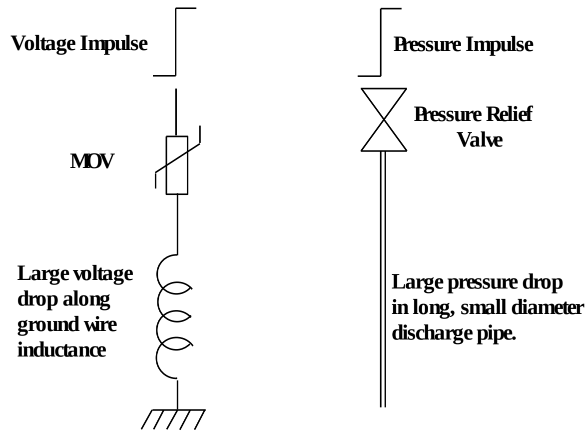
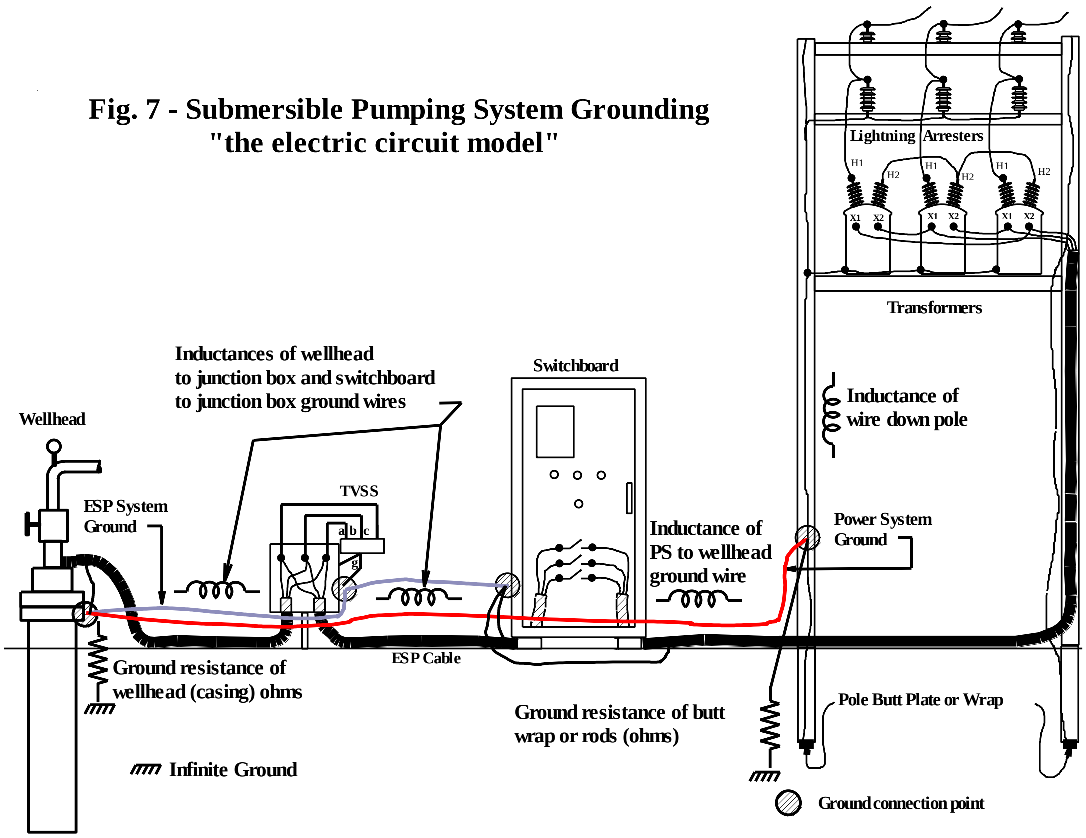


Figure 5 – Effect of Long Ground Wire

Figure 6a – Welded Bolt Head and Ground Lug

Figure 6b – Service Post Ground

Fig. 7 - Submersible Pumping System Grounding "the electric circuit model"



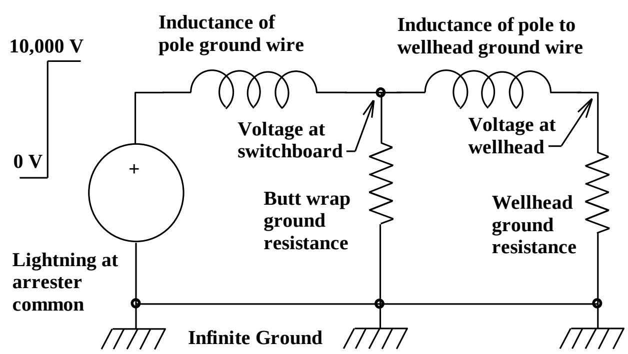


Figure 8 – Ground Equivalent Circuit

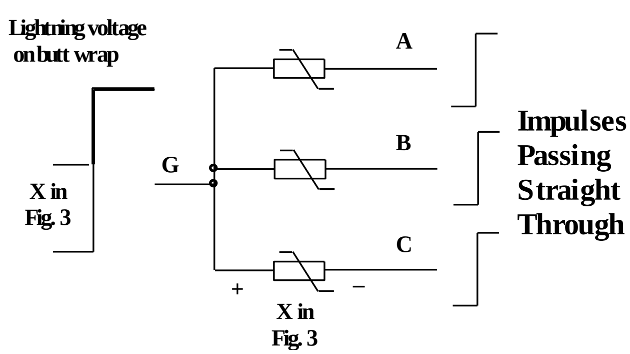


Figure 9 – Backward Conduction of Transients through a TVSS or Lightning Arresters

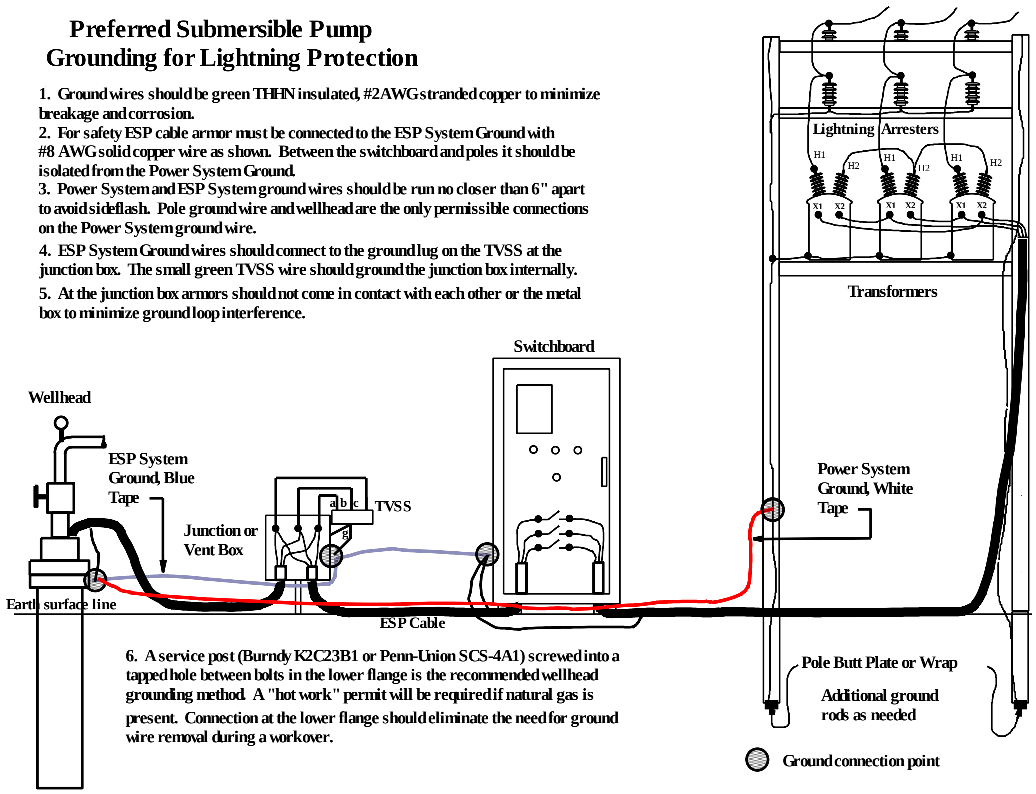


Figure 10 – Separate Lightning Arrester and TVSS Ground Wires

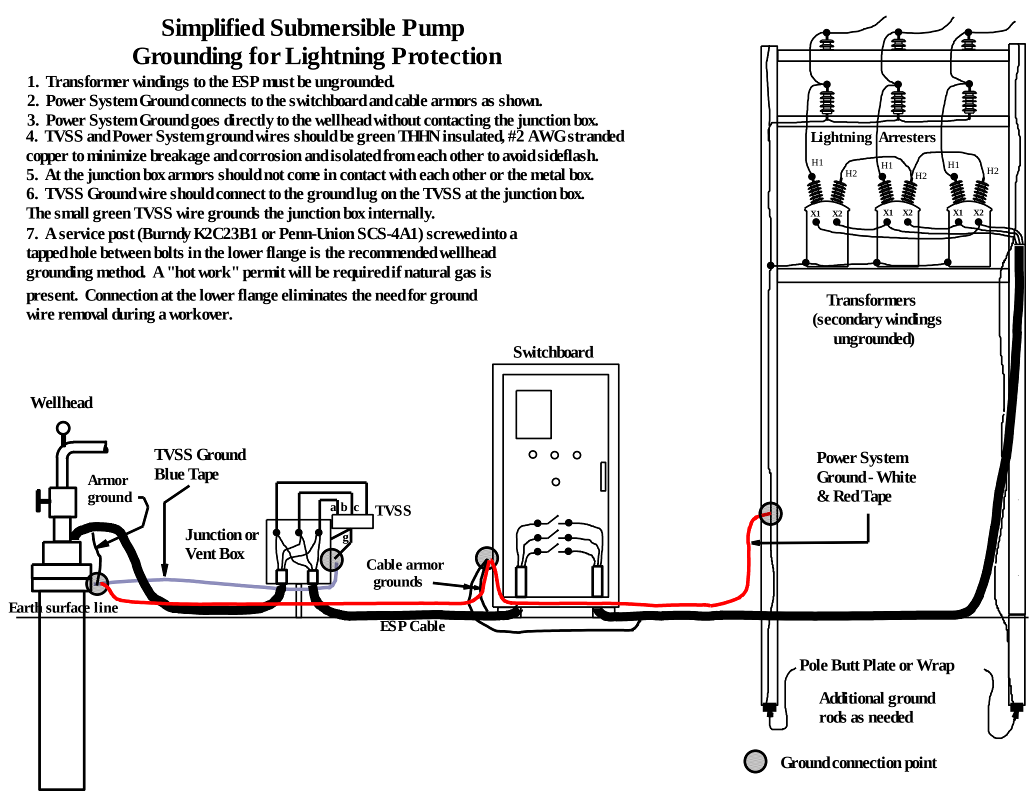


Figure 11 – Simplified Ground Wire Separation

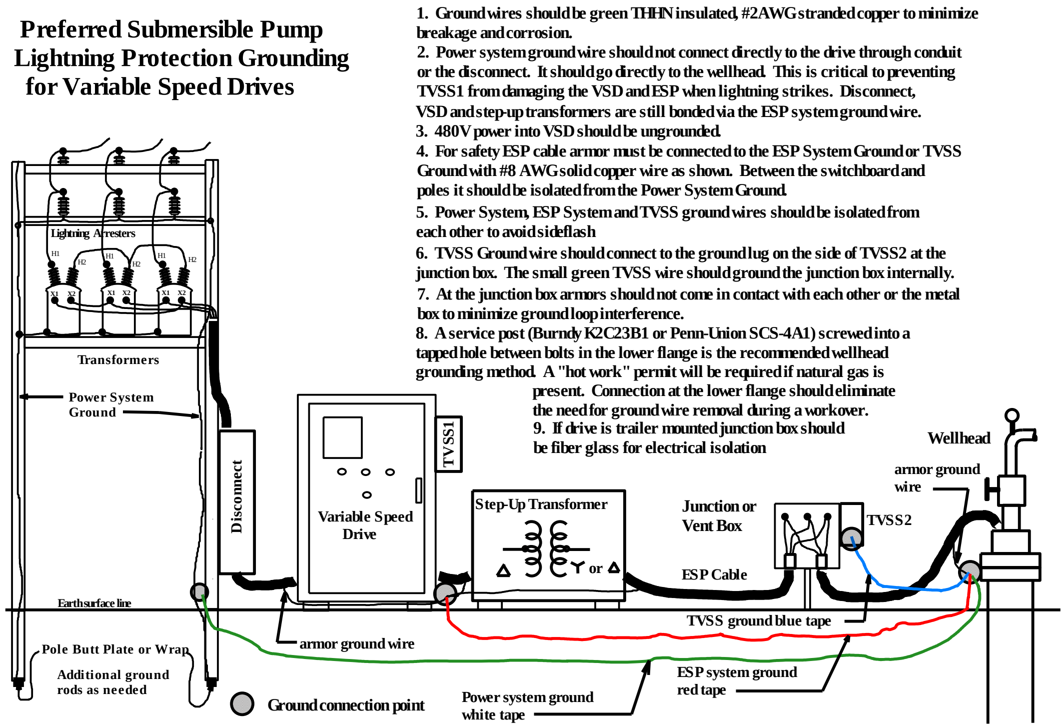


Figure 12 – VSD and ESP Protection

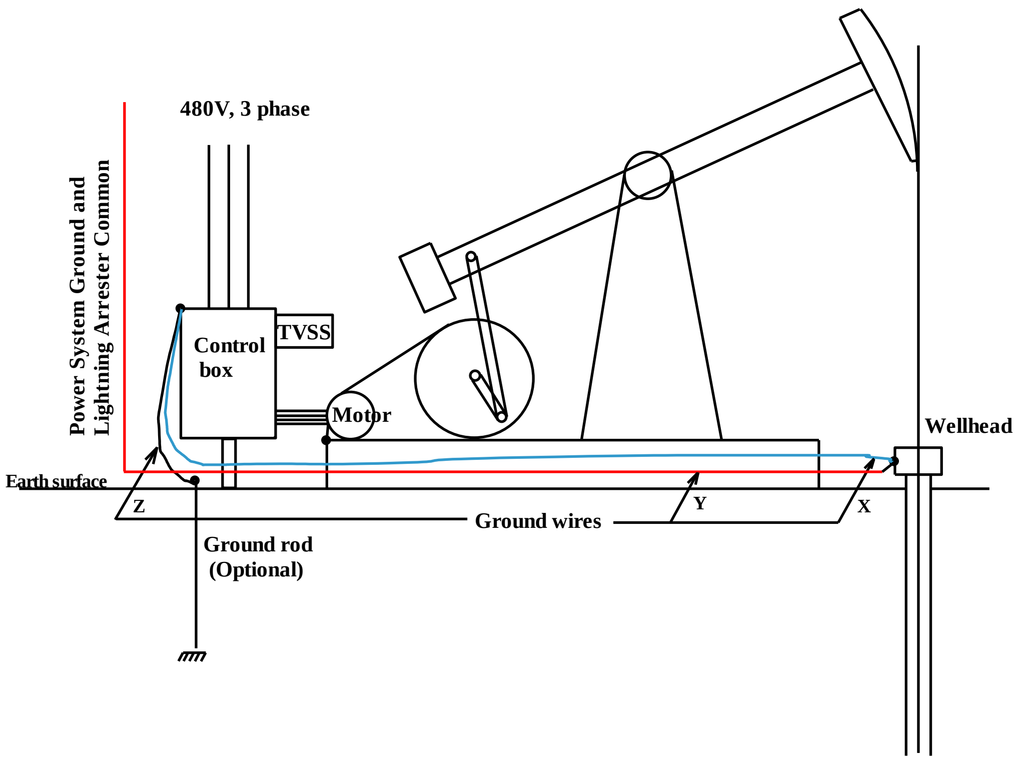


Figure 13 – Rod Pump TVSS Protection