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Electrical Safety in the farm: Case Study Research at Michigan USA 2010

Fathurrahman
Pendidikan Teknik ELektro, Fakultas Tarbiyah dan Keguruan,
UIN Ar-Raniry Banda Aceh
e-mail: fathur.rusli@gmail.com

Abstract

Electrical safety concern has been rise from early utilization of electricity. This report is about electrical accident that took place in one agricultural farm in Michigan, USA in summer 2010. A bilingual Latino farm worker (28) was electrocuted in a 6000-acre potato farm when he touched one of tower of self-propelled central pivot irrigators, which is irrigating the farm at that time. The delta corner-grounded system is used at the farm. The multicultural environment is also escalated the risk.

***Keywords**: Electrical safety, electrical accident, delta corner-grounded and self-propelled central pivot irrigators*

Abstrak

Kekhawatiran keamanan listrik telah meningkat dari pemanfaatan awal listrik. Laporan ini adalah tentang kecelakaan listrik yang terjadi di salah satu pertanian pertanian di Michigan, AS pada musim panas 2010. Seorang pekerja pertanian latino bilingual (28) tersengat listrik di sebuah peternakan kentang 6000-acre ketika dia menyentuh salah satu menara pivot pusat yang digerakkan sendiri irrigators, yang mengairi pertanian pada waktu itu. Sistem delta-grounded delta digunakan di pertanian. Lingkungan multikultural juga meningkatkan risiko.

***Kata kunci:** Keselamatan kelistrikan, kecelakaan listrik, delta sudut-sudut dan self-propelled irrigator pivot pusat*

1. Introduction

Electricity is just like a double-edge sword. On one hand it is the heart of human activity and on the other hand it can be harmful to the human and environment, if not handle properly. The electrical safety concern has been rise from early utilization of electricity. The first record of electrical accident was back to 1849, where the accident killed one lighting worker at operatic stage in Paris. The record was collected and published by Jex-Blake in 1913 (Handbook of electrical hazards and accidents, 1995). The past record, report, investigation and case study about various electrical accidents are an important and valuable data to record, share and study in order to effectively avoid potential electrical accidents and hazards in the near future.

This report developed based on actual electrical accident investigation report from Michigan Fatality Assessment and Control Evaluation (MIFACE, 2012). MIFACE investigation was merely conducted for educational purpose only. There are aspects from the investigation that was not

revealed to the public such as, whom responsible for the accident and what kind sanctions and penalties applied. The exact place, names, farm's name and date are also kept anonymous based on the Michigan Occupational Safety and Health Administration (MIOSHA) policy and agreement with the farm owner. Therefore, this report will summarizes the incident and try to reveal as much as possible the things that 'hidden' from MIFACE investigation on this particular accident.

The accident it self took place in one agricultural farm in Michigan, USA in summer 2010. A bilingual Latino farm worker (28) was electrocuted in a 6000-acre potato farm when he touched one of tower of self-propelled central pivot irrigators, which is irrigating the farm at that time. The victim was standing right in puddle of water "while pulling free growing corn" (MIFACE, 2012). The worker was affirmed dead at the scene of the accident. There are three main issues that rise from this report. Firstly, agricultural firm is supply by three-phase delta grounded corner, which is not recommended to use nowadays due to it safety issue (Schneider, 2012, Bolin and Kubin,1988). Secondly, the agricultural farms are also susceptible to the lightning strike during the storm, which multifold the safety issues. Lastly, most of the workers are Latino who has different primary language and cultural background. This condition creates multicultural work place, it has been reported that in this kind of working environment the safety risks are escalated (Ringeisen, 2007; Mooresville, 2014).

1.1. Time and date of occurrence

The accident occurred around 02:45 p.m. EDT, summer 2010 during weekdays. This time also known as, growing season to the most potato farms in Michigan. The exact day and date are remained anonymous.

1.2. Incident location

The incident took place in one of potato farms in Michigan USA. Michigan known as the city of potato farm industry. There are more than 50 big potato farms located in Michigan (Cyclosoft, 2013). For the sake of anonymity the firm name substitute with 'farm A'. Farm A has two circular farms that located next to each other. These two farms are irrigated by two-centre pivot self-propelled electrogator irrigation system. The typical potato farm irrigated with self-propelled centre pivot can be seen in figure 1.

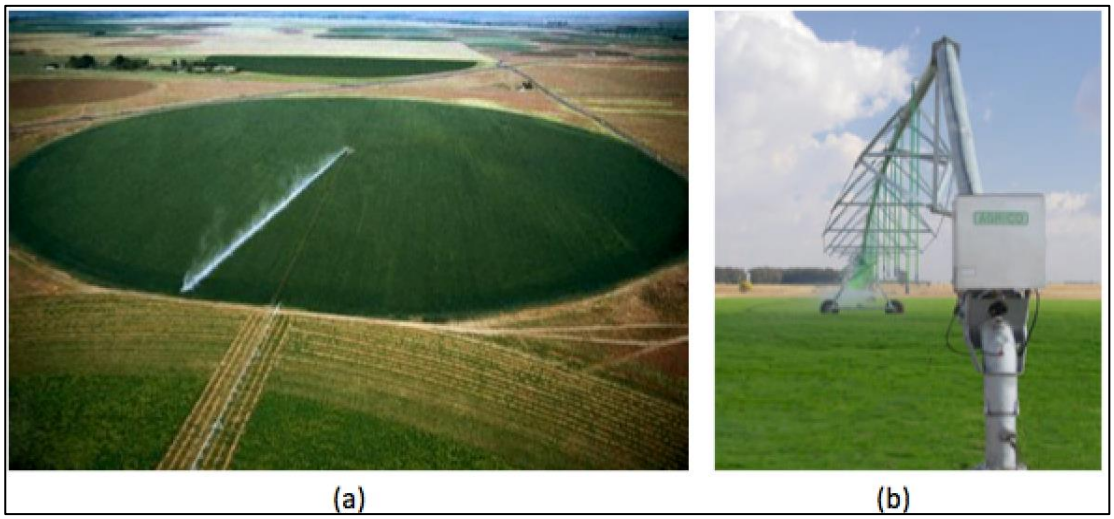

Figure 1. (a). Typical potato farm in Michigan, (b). Self Propelled centre pivot (Irridyne, 2014; Agrico, 2014).

1.3. Notification of incident

The incident ware first notified by two workers who work nearby the victim (separated by 6-7 metres). A couple minute after the incident they called the main office and told them the situation. Immediately the person in charge in main office called the owner of the farm. Afterwards the farm owner called 911 and drove his truck to the farm. The irrigator system was fully shutdown the minute after the farm owner arrives in the farm.

1.4. Investigation inspector

A team of engineers and police conducted the investigation. The engineers were comprised of engineer from the supply farm company who installed the irrigator system and local electrical consultant engineer from farm an insurance company. The initial investigation was started on the accident day and ended in a couple of days.

2. Summary of Events

2.1 Before the Incident

The farm has two circular farms located next to each other, irrigated with two different centre-pivot irrigators. The south circular farm is irrigated with Rainke irrigator and the north farm is irrigated with Valley irrigator. Valley unit has been working for 20 years and Reinke Unit has been installed for several years. Both of the pivot have disconnect switch in the centre pivot. The main distribution panel is located close to the Valley unit. The electrical power to the Valley unit is supply by underground cable from the main panel. The underground cables are continued from Valley unit to the Reinke unit. Both of this system is supply by the 3-phase 480 Volt delta corner-grounded system. The farm has 52 workers most of them are Latino. Figure 2 illustrated the overview of the potato farms and its centre pivot system.

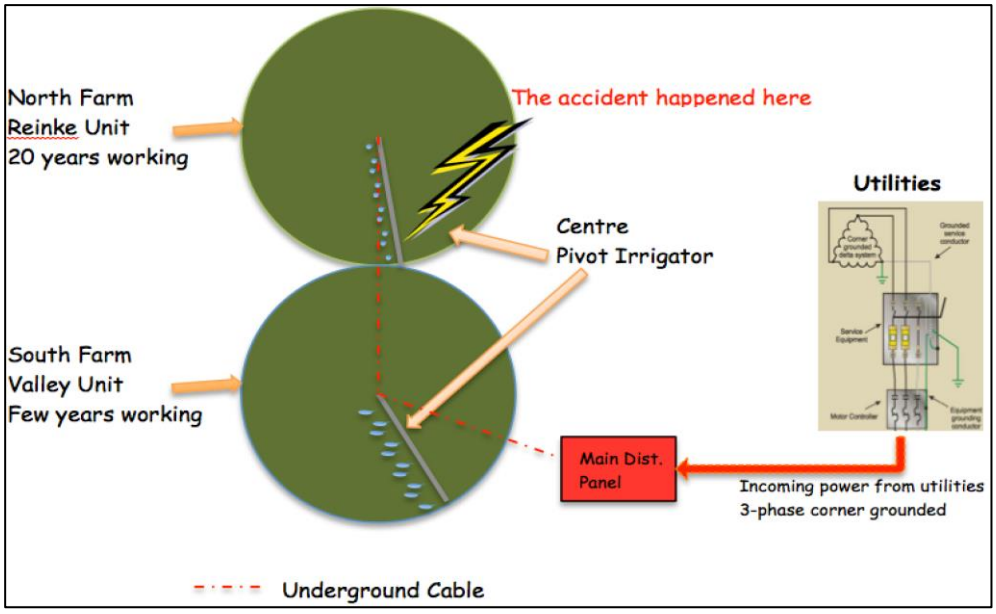

Figure 2. Overview of potato farms where the accident is happened. (Recreated based on investigation report narrative.)

The victim is a bilingual (Spanish and English) 28-year-old male Latino worker. He has been working in the farm for one year. He got the training from another senior farm worker in Spanish due that time Spanish was the only language he could speak. He and his other two friends were in charge to pull unwanted corn plantation in potato field. On the incident day he started working with other two Latino workers from 08.30 a.m. They had a break around 12.00 a.m. for about 20 minutes, then afterwards they were continues to work. They were working in the north farm, clearing 80 row of potato farm and they were moving toward the south. At 01.30 p.m. the Reinke centre-pivot is turned on remotely from the farm main office and began irrigating the farm. According to the report it was a very clear sunny day, and there were no lightning-storm presented within 80 km from the field.

2.2 During Incident

At around 02.43 a.m. the three farm workers were approaching active overhead irrigator. The victims tell the other two workers to get hurry and pass by the irrigator system (Reinke unit, north farm). However, the victim was behind the other two workers. The other two worker had already pass by the overhear irrigator system and ahead of the victims by several meters, and they were all soaked by the irrigator system. At approximately 02.45 a.m. the victims were standing in the puddle of water right below the irrigator system and beside one of its self-propelled tower. According of his two friends, he was unintentionally touched the brace-arm of the tower while pulling the corn plantation. The minute he touched the tower, he yelled at loud and then suddenly leaning against the tower bar.

The two workers thought he might just sick and just resting in the bar tower. The two workers then began to think that the victim might have the heart attack and started walk toward the victim. When they were close enough to the victim (2-3 metres) one of the worker warned his friend that maybe the victim was electrocuted, and they stopped walking and notified other worker in main office about the accident. Figure 3 shown the tower where the victim got electrocuted.

Figure 3. The tower where the accident happened (MIFAHE and MSU, 2012).

2.3. Post incident

After getting the notification from the two workers from the scene, the person in the main office rather than called ambulance and shutting down the irrigator system first, he called the owner of the farm. Then afterward the owner of the farm got hurry to the farm with his truck and called the ambulance. The ambulance and the owner of the farm arrived in the farm at the same time. The irrigator system was fully shutdown when the owner of the farm arrived. It has been found that the overhead tower, which associated with the accident, was stopped at more than 6 metres from the victim. Lucky enough somehow the victim leaning position was not in the self- propelled tower's track; otherwise the victim could easily crushed by the tower tires and the accident could be more brutal.

2.4. Accident Investigation

Electrical System in the farm

The farm is supplied with 3-phase delta corner grounded (B phase grounded) 480 V from the utilities. In delta corner grounded, the B phase is grounded, which make the voltage from phase B to the ground is zero, phase A to phase B, phase A to phase C, and phase B to phase C are 480 V. The schematic diagram of delta corner grounded wiring can be seen in figure 4. All metallic part of the tower also bounded to the ground, which comply with NEC section 250.24 (McPartland & Brian, 2011) as shown in figure in appendix 1. Each tower is equipped with one motor to drive the two tower's wheels.

The first action

The first action that the investigation did is restoring the power to the pivots system, to measure if there is any voltage presented in the tower to the ground. When the investigator was attempting to restore the power, the fuse in main disconnect is blown. Later it was found that the fuses were oversize. However, the fuse at each pivot disconnect were in proper size. The team then asked the farm owner to check and dig the underground cable, which supply the centre-pivot system. The team believe the problem came from underground cable.

Motor driver system and ground voltage check

While waiting for the underground completely dig up, investigators continued to check motor and cable junction to on each tower, it showed normal result. All grounding wires were perfectly connected. The tower also well bounded to the ground. The investigators concluded that there is no way the tower energized due the faulty cable that supplies the motor or the faulty motor itself. The investigator also found some minor thing that could potentially create safety risk issues; such as plugs cords and receptacle were not in good condition due to ageing.

The investigators then supplied the power to the Reinke centre-pivot system (where the accident happened) from the portable generator and bypass underground cable. With portable generator supplied the system there was no voltage reading appeared from all tower or motor casing to the ground.

Lightning Protector and Damaged Underground Cable

The investigators found the lightning arrester were damaged by lightning and need to be replace, and no one know since when the lightning arrester were damaged. The damaged lightning arrester made the underground cable even more exposed and susceptible to the lightning strike and it escalate the safety risks. Both of pivot system also did not have the lightning arrester installed. This condition violated with NEC standard. Based on the NEC standard, centre-pivot system must have an adequate lightning arrester as mentioned in (Bolin & Kubin 1988; Chamberlain and Hallman, 1914). The Recommended centre pivot system with its lightning arrester installed is shown in the figure in appendix 1. After the workers completely finish digging up the underground found several part of cable insulation were struck by lightning as shown in figure 5. It is believed that the underground cable system has never been getting inspected since the first time it was installed.

The Main Cause of the accident.

After examined the underground cable system, it was concluded that at the time of accident the victim was providing a conduction path from the ground (faulty cable either phase A or C) to the tower (ground) which has 480 V potential different. It is usual for the underground cable that struck by lightning to work for a while even though in the fault condition, therefore the protection system sid not react. The worker was exposed to the amount of the current, which caused ventricular fibrillation for long period (more than three minute). That condition is enough to kill one the victims on the spot. The other contributing cause of the accident is presented below.

Non-Standard Electrical Insulation

It also has been found that the fuses were installed in the intentionally grounded phase (phase B) in the main distribution panel, which violated with the NEC standard section 230.90B. Although it was not the main contributing factor of the accident, it still potentially create safety problem. Related to the fuse installation in the delta grounded system, it mentioned in the NEC 230.90B (Schneider, 2012; Bolin & Kubin 1988; EATON, 2013) that no overcurrent device is permitted in

the intentionally grounded phase except the circuit breaker, which can open the circuit instantaneously.

Based on the report investigation there are a few electrical installation which violate with the NEC standard:

1. No lightning arrester on the overhead centre-pivot system,
2. Oversize fuse in the main disconnect,
3. Few cords, plugs and receptacle that associated with the pivot system were not in good shape,
4. There were fuse installed on the grounded phase (phase B) from the main disconnect that supplied the pivot system,
5. The underground were buried directly without the enclosure protection such us pipe or surrounded by special filling trench.

Other contributing factors

According to the report, it's known that there was no adequate maintenance to the farm electrical system. A few electrical devices were in non-proper condition. There were no electrical routine inspections and test, which make the underground cable deterioration exacerbate every time the lightning strike. The cable also has been operated for long time since the first time the centre-pivot unit installed.

There was no adequate safety training to the worker. It is proved by how the person in charge in the main office reacted when he got the notification about the accident. In my humble opinion, in ideal case he should have turned off the centre-pivot irrigator system first, called the ambulance, then notified the farm owner about the accident. The workers should have also do the first aid CPR to the victim after the safety thread is clear. This safety procedure must be well written communicated and trained and to all workers. The safety drill also must be done periodically. Especially, in multicultural working environment, known to have high safety risk accident (Ringeisen, 2007; Mooresville, 2014). As stated in (Lavy et al., 2010) that language barrier and cultural background difference are the main reason for high mortality rate Latino immigrant worker in USA.

3. Who Is Responsible For The Incident?

The investigation report did not include the part about who responsible to the accident and what were the sanctions and penalties applied. In fact there was no further investigation about who ass responsible to the accident. Based on the report narrative, facts and founding, it is strongly believed that the main responsibility of this accident is in the burden the owner of the farm. The owner of the farm was conducting non-standard operation of the farms, which causes the loss of life one worker. The owner also did not consider giving the safety training to the worker hence, the victim get electrocuted and other the workers reacted in very wrong procedure prior to the accident.

The second one to blame was the government department who responsible to give the license to the farm owner to operate the farm. In this case Michigan Department of Licensing and Regulatory Affairs (LARA). Ideally, the government must put one agency to periodically or yearly check and ensure the farm operation is comply with the law and standard and periodically renew the licence. The government also must applied strict rule and give sufficient punishment to every stakeholder who found violated with the rule and standard. The government must also ensure that the victim

or his/her family get fair compensation prior to the accident, which in this accident was not applied. I also strongly believed that the immigrant workers were exploited and treated unfair and unjust both by owner of the farm and the government.

The third one to blame was the electrical consultant who approved non-standard installation of the electrical system in the farm such as underground cable installation, delta corner-grounded protection system, and lightning protection.

4. RECOMMENDATIONS

Based on the investigation report, there are a few recommendations that can be applied to avoid such of the accident in the future:

1. The owner of the farm should consider installing the new underground cable in the PVC conduit and filling the cable trench with special filling. This can protect the cable insulation from frost heaving, stones and shovel cut.
2. The lightning arrester must be installed in each centre-pivot system. Due to the pivot system is highly exposed to the lightning strike, the farm owner must consider to install the lightning arrester in each pivot system as mention in (Traxco, 2014; Schottman et al., 1993). Other lightning protector such as lightning rod and grounding system also must properly install.
3. The utility company should consider changing the electrical supply system to the farm. Many article, journal and report (Schneider, 2012; EATON 2013) stated that the delta corner-grounded system must be discontinue or highly not recommended for the new system, because it poses some safety thread. Here the direct quote about safety concern in delta corner grounded system according to one IEEE journal written in 1988 (Bolin, & Kubin, 1988):
    - Dangerous step and touch potentials can exist.
    - Non-automatic isolation and location of phase to ground shorts.
    - Ground currents objectional t o residents living in the area.

Ground potentials have been known to cause solid-state starters to start in the "off" position .

- Lightning arrestor application may be unsatisfactory.
- AC interference to communicate equipment.
- Higher dielectric stress on two phases.
- Higher magnitudes on transient over voltages.

Alternatively the utility could apply three-phase wye grounded system, which more common and safer compared to delta corner-grounded system (Schneider, 2012, Bolin & Kubin, 1988).

4. Perform regular inspection to the electrical and mechanical system.
   The owner of the farm must employ or assign at least one qualified personnel who do the regular check in the farm electrical, mechanical and safety system of the farm. This person will particularly check and conduct the non-destructive electrical test such as cable resistance test or known as ‘megged’ especially prior to the growing season. These personnel will also check every other cable; cable junction and motor drive system centre-pivot system of the farm. A special attention must be put to the lightning arrestor prior to the thunderstorm.

5. Safety training
   The farm stake holder must give adequate training to the farm worker which not only include the training of farm operation but also the safety training. Hence the workers know what to ‘do and don't’ regarding the safety. The training also must really emphasized that whenever getting

any notification about the accident in the farm field, the person in charge to operate the centre-pivot system must directly shutdown the system.

6. Do not perform any job under active overhead irrigation system. Unless the licenced professional who want to perform maintenance to the system.

7. The government must applied strict rule and sufficient punishment to every stakeholder who do not comply with the law and standard especially the law and standard that could potentially rise the safety issues.

5. CONCLUSION

1. The electrical accident could be happening any where even in the agricultural farms, which seem do not use intensive electrical appliances, hence the safety operation cannot be underestimated.
2. The delta corner-grounded system is not recommended due to it pose safety risks.
3. The agricultural farm, which uses centre-pivot system, must properly install the lightning protector such as surge arrester.
4. The electrical and mechanical system of the farm must be regularly inspect, check, test, and replace (if needed) by qualified personnel.
5. Safety training must done properly and safety drill must regularly perform.

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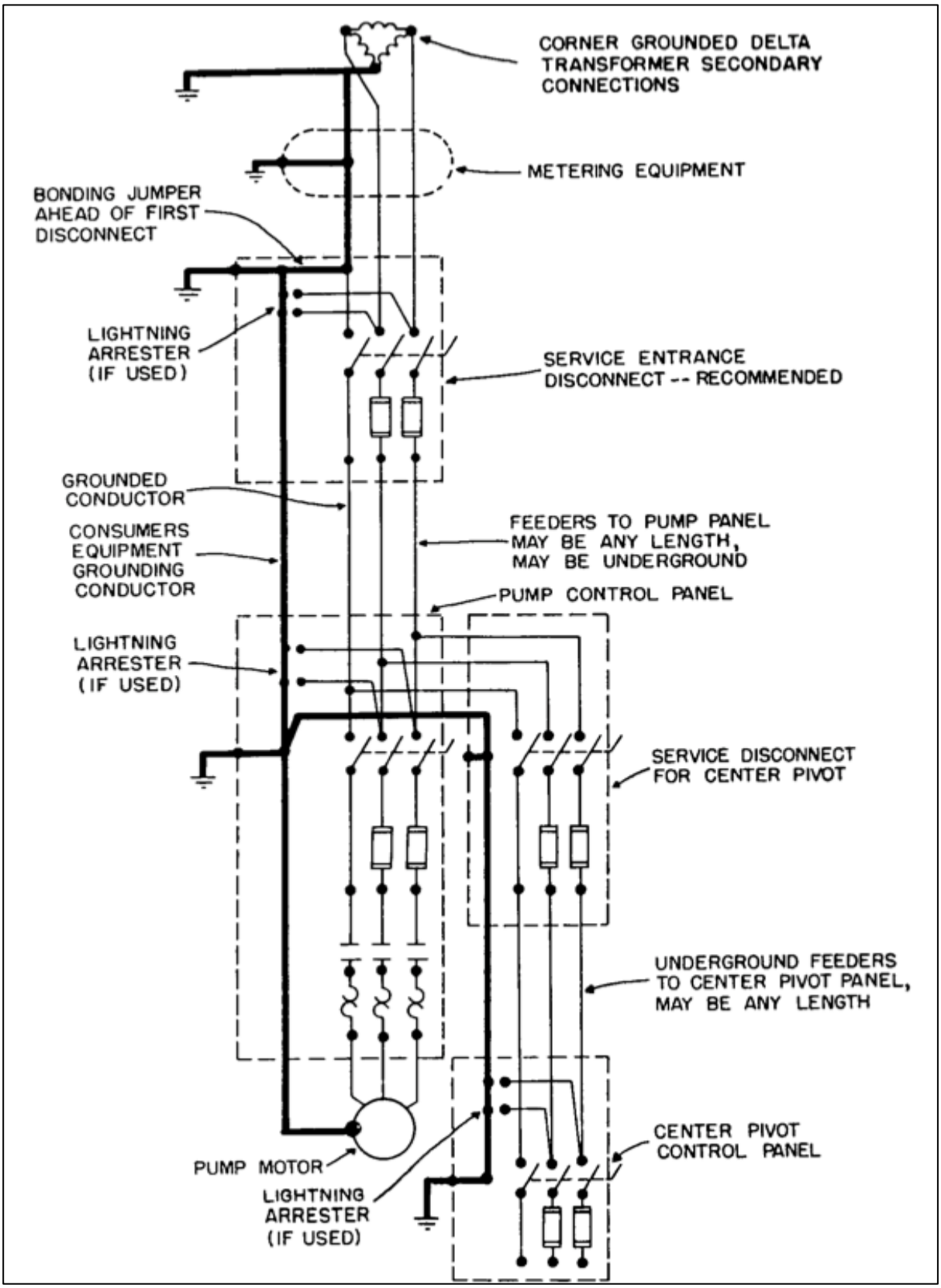
APPENDIX



NEC Standard installation of delta corner-grounded system from.

Figure from the investigation report.

Figure 1. Irrigation unit involved in incident.

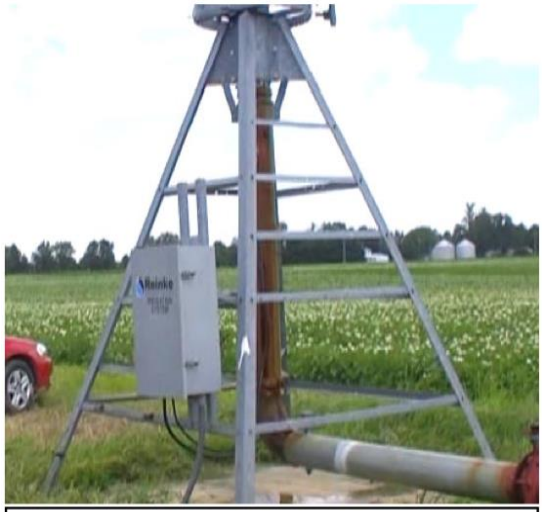


Figure 2. Center pivot involved in incident.

Figure 3. Power supply to Valley Pivot. Valley Pivot plugged into receptacle.

Figure 4. Machine ground of Reinke central pivot.

Figures 5-7. Path of Reinke ground wire.