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## **GROUND FAULT PROTECTION ON NEON**

### **SECONDARIES**

**by**

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## 1 INTRODUCTION

Electricity is energy. It is a form of energy that has become an absolute necessity in modern society. The reason why electricity has seen such wide usage is because it has the unique properties, as a form of energy, of easy transportation (transmission and distribution) and easy conversion and control. Unlike any other forms of energy electricity can be transmitted over two pairs of metallic conductors in the quantities of micro-microjoules to megajoules, one Joule being the energy that equals one Watt-second. Conversion and control of the energy of electricity is also simple. Electrical Engineers and scientists have developed methods that can convert and control minute as well as large amounts of electricity from one frequency to another or from dc to ac and visa versa. Our communication systems make use of the property of electricity that makes it easy to convert and control. The state of development of computer technology would not have been possible were it not for the properties of electricity that we discussed. In the neon sign lighting industry we make use of the easy conversion and control properties of electricity to light luminous tubing.

As a form of energy electricity when used as intended can do all the things that we are accustomed in our modern world in addition to lighting our neon signs safely and economically. However, when an electrical accident, generally called a fault, happens electrical energy can be expended in ways that can cause loss or damage to equipment and property and possibly loss of life. Electrical faults occur as a consequence of natural events, physical accidents, equipment failures or human error.

## 2. TYPES OF FAULTS

The factors listed above can cause a variety of faults on electrical power systems or equipment. Short circuit, overload, over-voltage, under-voltage, reverse power flow, ground fault and others are some of these. Discussions of all the possible faults that can occur in electrical systems or equipment are beyond the scope of this article. Those interested in the study of this subject in more depth should review some of the reference material. In this article we will discuss three types of electrical faults that are most common and of most interest to us. These are short circuit, overload and ground fault. We will discuss briefly the nature of short circuit and overload and how we protect electrical equipment and systems. In the remaining article we will focus on ground fault, the evolution of ground fault protection and its importance to the protection of personnel and equipment, and the various applicable standards. We will look at methods of ground fault sensing and the application of ground fault protection in neon transformers and neon signs.

### 3.- SHORT CIRCUIT AND OVERLOAD

A short circuit takes place when two conductors of opposite polarity or that are at different voltages with respect to one another touch intentionally or accidentally. In an electrical equipment, for example, this fault can occur at the supply connections. A short circuit at the supply leads will cause a short circuit current which is only limited by the conduct resistance of the short circuit and the supply resistance and inductance i.e. the source impedance.

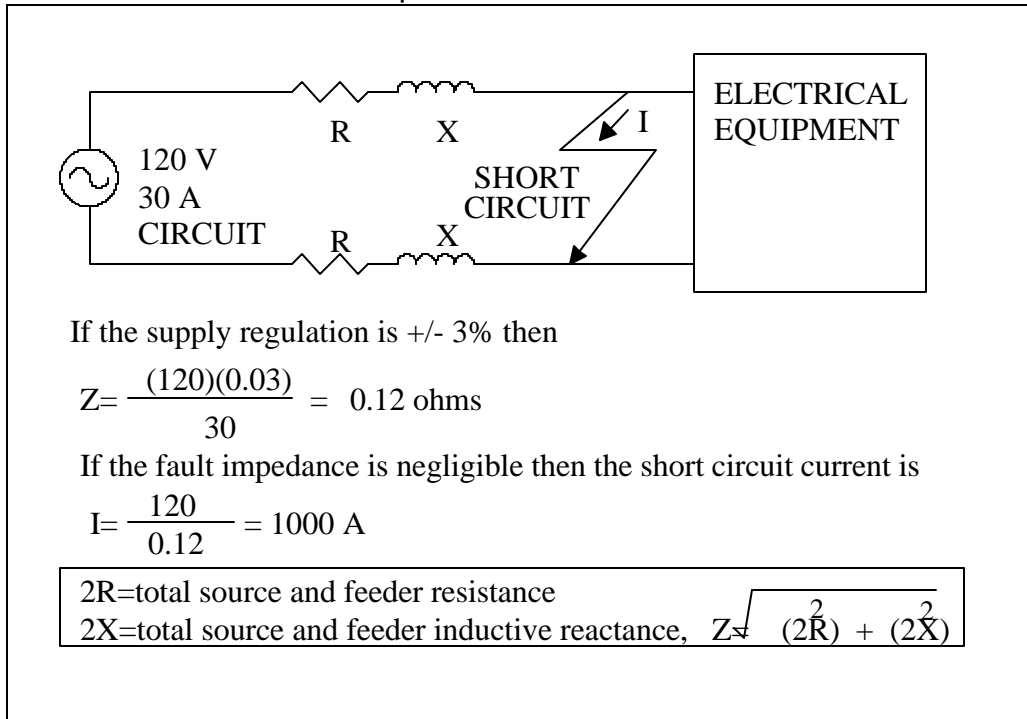


Figure 1. Short circuit at the supply connections

The short circuit in figure 1 has reduced the resistance of the load to zero. The amount of electrical energy that the source has to deliver under this condition is very high since the current the conductors will carry is 33.33 times rated. If this fault condition is allowed to persist the large amount of energy released will destroy the conductors and possibly the source (supply transformer).

Overloads on the other hand are less moderate electrical faults that can also cause damage or destroy the supply conductors, the supply and the equipment if allowed to persist. An example of overload is the increase of current above rated in a motor circuit if the motor's bearings fail. Another example of an overload is the increase in current in a transformer circuit due to a partial short in the windings of the transformer.

Failures of electrical equipment such as the ones discussed are not planned but they happen. It is the responsibility of the installer to ensure that when such faults happen provisions are made to mitigate damage to equipment and property as well as to ensure safety of personnel. Short circuits and overloads are the most common type of faults that occur in low voltage electrical systems and equipment. This is the reason that the NEC Article 240 requires that electrical equipment be protected in case of such faults with overcurrent devices. The overcurrent device can be a fuse, a circuit breaker or an elaborate system comprising a current transformer an electromechanical or solid state relay and a shunt trip circuit breaker. The function of the overcurrent protection device is to continuously monitor the current in the circuit it protects, sense any excess of current above rated and act to disconnect the faulty equipment before unsafe conditions develop. The art, science and skill of electrical protection, provided by simple fuses, simple circuit breakers or elaborate current transformer-relay-circuit breaker combinations, is to provide protection under all short circuit and overload conditions, but to avoid operation (tripping) under all permissible or tolerable conditions such as start up of equipment, normal supply voltage fluctuations, transient surges and electromagnetic interference that may be caused by other electrical or electronic equipment in the vicinity.

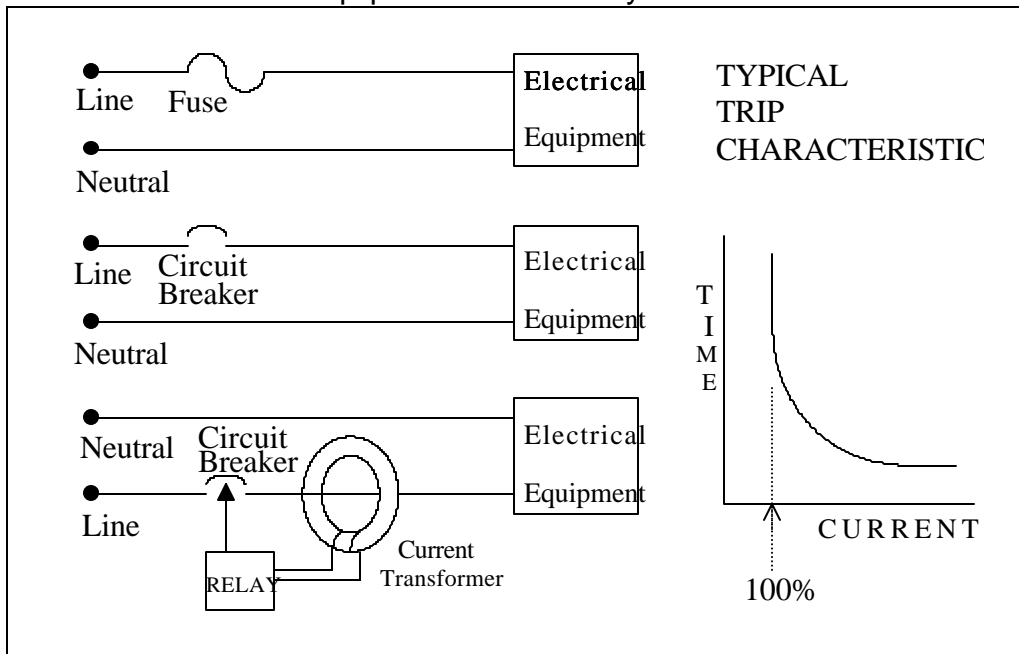


Figure 2. Forms of Overcurrent Protection and Operating Characteristic.

The first two types of overcurrent protection in figure 2 should be familiar to all. It is the protection found in our fuse box or circuit breaker panel at home or office. The

third form of protection shown in figure 2 may be found in a more complex electrical system such as in a large building or factory.

#### **4.- GROUND FAULTS**

Before we begin to look at the subject of the title of this article first we need to have a look at the purpose of grounding and dispel some myths that have been propagating through the industry about ungrounded transformers and power supplies. The IEEE (Institute of Electrical and Electronic Engineers) standard 142-1982 states the following about ungrounded systems "Though called ungrounded, this type of system is in reality coupled to ground through its distributed capacitance of its phase windings and conductors....." Further on, the same standard states, "experience has shown [10], in a number of systems, that greater service continuity may be obtained with grounded-neutral systems than with ungrounded neutral systems." This experience is shared with our experience at our plant at Allanson. In 1988 we modernized our 600 volts distribution system by changing it from a delta secondary to wye (Y) grounded. Down time in our plant equipment has reduced dramatically since that time.

Grounding and bonding of all non-current carrying metal parts of equipment is important to the safety of people as well as property. Not every part of an electrical apparatus can be made out of insulating materials. For structural, economic, performance and other reasons metal parts have to be used in conjunction with electrical equipment. If these metal parts come in contact with ungrounded live conductors or become charged through capacitive coupling they will present a hazard if not bonded to ground. Article 250 of the NEC and section 10 of the Canadian Electrical Code (CEC) cover the requirements for grounding and bonding of electrical equipment and systems. In Article 250 and Section 10 of these codes, under 250-1 Scope and 10-002 Object you will find many good reasons why grounding and bonding are extremely important.

When electricity takes an unintended path to ground from a live conductor or a part of the electrical equipment such as a winding, a terminal etc. electrical energy is expended. This constitutes a ground fault. If the resistance of the path to ground is low such as in a "bolted" fault the current will increase to a level that will activate the overcurrent protection. If however the resistance of the path to ground is high as in figure 3, the increase in current will be marginal and will not activate the overcurrent protection. The energy that is expended in the fault shown in this example, if allowed to persist, will result in the damage of the motor. If the fault happens to be of the arcing type an enormous amount of energy is released in a small area which can result in complete destruction of the equipment such as this motor.

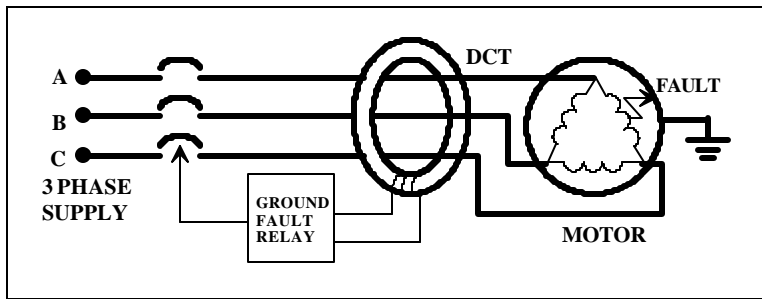


Figure 3. Faulted 3 phase motor equipped with ground fault protection.

The ground fault protection in figure 3 utilizes a very sensitive differential current transformer (DCT), a relay and a shunt trip circuit breaker. The DCT measures the current going to the load and the current returning. If the two are equal the output to the relay is zero. If a difference is detected, as in the example shown, the DCT supplies an output to the relay which will act in the same fashion as the overcurrent protection to trip the circuit breaker. Ground fault protection of equipment is a requirement of the NEC under Article 230 if the service exceeds 150 volts to ground, is solidly grounded wye (Y) and the service disconnect is rated over 1000 Amperes.

During the sixties the ability of DCT's to detect minute differences between current going to the load through one conductor and current returning to the source through the return conductor(s) was exploited by electrical engineers to develop ground fault protection for personnel. This work led to the development of the Ground Fault Circuit Interrupter (GFCI). Figure 4 illustrates the principle of GFCI.

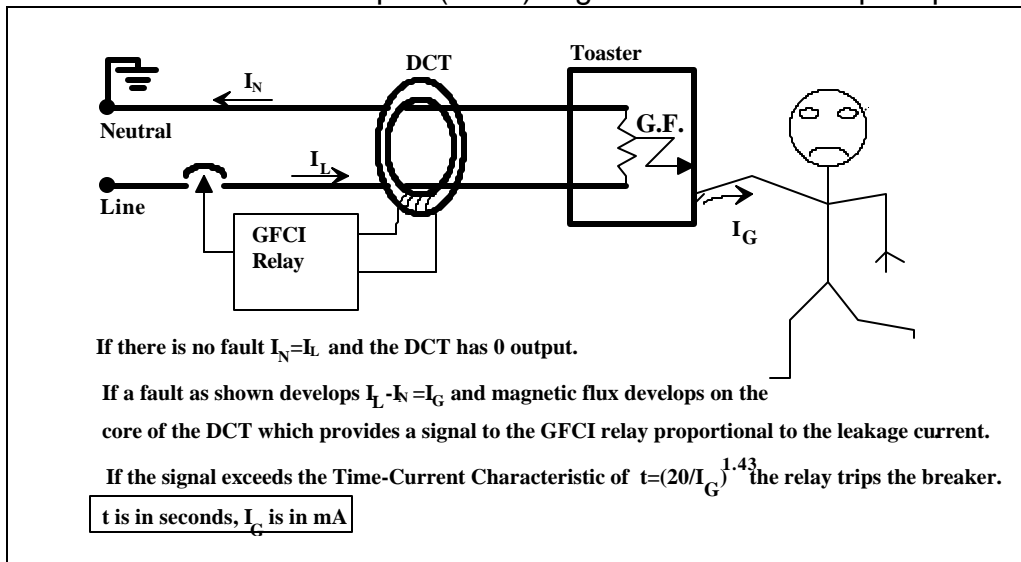


Figure 4. Principle of GFCI used in personnel protection.

The DCT is a very sensitive device. Its core is usually made of Nickel-Iron which has very high permeability at low flux levels. The secondary is toroidally wound with many turns of fine magnet wire. Accurate and consistent detection of differential leakage current in the range of a few mA is therefore possible. For the GFCI to work reliably and protect against shock hazards, grounding of the neutral on the load side of the breaker is not permitted because the ground fault current can go through a person to ground and back to the neutral via the second grounding point, defeating the DCT detector. To prevent this from happening commercial GFCI's use a second DCT not shown in the example of figure 4 that monitors for grounding of the neutral on the load side and if found the breaker trips. Because of its potential for averting electrocutions both the NEC and the CEC mandate the use of GFCI in outdoor, bathroom and kitchen outlets. GFCI's are evaluated in USA to UL943. In Canada their evaluation is to C22.2 No. 144. The evaluation of ground fault devices for equipment protection is to UL 1053.

## **5.- SECONDARY GROUND FAULT PROTECTION FOR NEON SIGNS**

A neon sign is powered by either a high voltage transformer or a high voltage power supply that according to the existing applicable standards, UL506 and CSA C22.2 No. 13 must be able to operate under any condition ranging from open circuit to short circuit. Further more the load of a neon transformer or power supply is an arc contained in glass tubing. Because of these characteristics protection of the secondary of a neon sign against abnormal conditions such as arcing to ground or line to line arcing is not an easy task. This is because an arc line to line or line to ground on the high voltage circuit of a sign does not affect the easily measured primary current appreciably to enable reliable detection of abnormal conditions. Thus even though all signs have overcurrent protection supplied locally or via the panelboard this protection is of no value in clearing faults on the high voltage side of a sign.

Up to the middle of the eighties the only reported work on the subject of secondary fault protection for neon signs, that this author is aware of, is a form of open circuit protection for cold cathode lighting advocated by Samuel Miller, [2]. During the eighties the subject received a lot of attention due to developments in electronic power supplies for neon signs. A number of power supplies that became commercially available were marketed with a feature called *secondary ground fault and open circuit protection*. This feature was provided to protect these power supplies from self-destruction under shorts to ground and open circuit conditions due to inadequate high voltage winding insulation and not to provide traditional circuit protection. It should be noted that this protection feature was not evaluated by either UL or CSA.

Secondary ground fault protection for neon signs is a beneficial protection feature that can prevent arcing from the secondary wiring of a sign to grounded metal parts. Such arcing will not be detected by conventional overcurrent devices as stated above. Once it starts it will continue arcing creating a potential fire hazard. Allanson in 1989 developed a secondary ground fault protection device that utilized the differential current transformer principle discussed earlier. This device is used in production testing for the safety of personnel. In 1990 Allanson saw a need for a ground fault protection device similar to the above that could be used in signs to mitigate the effects of arcing ground faults in the high voltage circuits of neon signs. A device was developed that uses the principle outlined in figure 5. The device can be used with all signs that use balanced mid point grounded transformers.

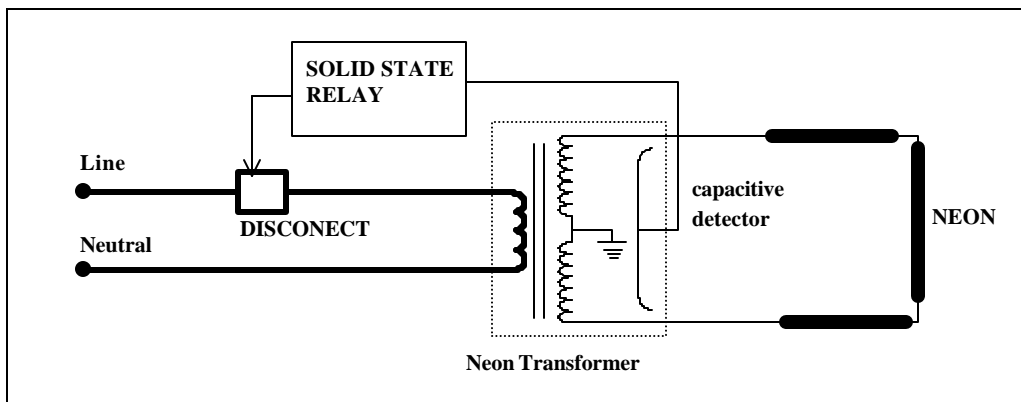


Figure 5. Principle of Operation of the Allanson Ground Fault Protector.

The operation of this device is as follows:

Under normal operation the two voltages on the secondary windings of the transformer are equal and opposite. The capacitive detector supplies zero volts to the solid-state relay. If one side shorts or arcs to ground its voltage becomes zero or reduces causing a net voltage to appear on the capacitive detector. The detector feeds this voltage to the solid-state relay and if its value exceeds the preset limit it de-energizes the primary of the neon transformer.

The above product, protected under the United States Patent #5,241,443 issued August 31 1993, was submitted to UL and to CSA for evaluation. It is listed under UL file number E39591 Vol. 1 Section 28, issued 12 August 1991. The CSA approval file is LR7442-149, issued 29 January 1991. This product is commercially offered under the trade name **UNITRAN PROTECTOR**. The Unitran™ Protector™ neon transformers meet fully the requirements of the applicable UL standard and the 1996 National Electrical Code requirements for secondary ground fault protection, see section 600-23 (a) and (b).

Application of secondary ground fault protection to neon signs, as mandated by the 1996 edition of NEC, has the potential of improving sign safety tremendously

and virtually eliminating neon sign fire hazards. Because of this potential and also because this field is still in its infancy the author urges others interested in neon sign safety to communicate ideas on the application and the improvement of secondary ground fault protection so that this *baby can grow up*.

The Europeans have been working now for several years as well for the development of secondary fault protection for neon signs. A final draft by CENELEC EN50107 "Signs and luminous-discharge-tube installations operating from a no-load output voltage exceeding 1000 V but not exceeding 10000 V" was published in April 1994 with section 10 defining the requirements for Earth-leakage and Open-Circuit protection.

In addition to the works reported above the author is aware of the following developments, currently in progress, towards the development of ground fault protection for neon secondaries:

- a) Sensing of the residual current at the grounded mid point or end point of the windings,
- b) Differential sensing of the currents in the two secondary windings and
- c) Sensing current differential by the use of integral auxiliary windings in the transformer or power supply.

With this product development activity as well as the activity in improving safety standards going on, it is expected that very soon SGFP for neon signs will reach the maturity now enjoyed by GFCI's.

## **6.- SIGN DESIGN AND SERVICING WITH SECONDARY FAULT PROTECTION**

Secondary Ground fault protection will affect the way we construct and service neon signs. Listed below are some of the of the author's experience with secondary ground fault protected signs.

- Excessive loading of transformers and power supplies will be less tolerable. This is because if a transformer is loaded with more tubing than its rating, capacitive leakage current will increase due to high frequency harmonics generated and this may cause the SGFP to trip.
- High voltage leads that are excessively long or unbalanced may cause the SGFP to trip.
- Moisture and dirt accumulation at the housing and high voltage connections will cause the SGFP to trip.
- Badly processed tubing that causes flicker may cause the SGFP to trip.
- Not bonding the transformer or power supply enclosure will cause the SGFP to trip.
- Excessive supply voltage fluctuation may cause the SGFP to trip.
- Servicing a sign will require more sophisticated equipment than those used presently (i.e. take the old tray out put a new one in).

- Service personnel will need to be trained on the operation of ground fault protective devices.

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