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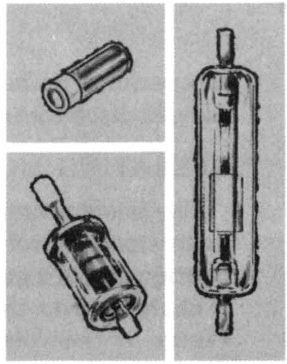


Vol. 11, No. 3

Signalite, 1933 Heck Avenue, Neptune, N. J. 07753

GAS DISCHARGE DEVICES FOR USE IN TRANSIENT VOLTAGE PROTECTION

By: Albert V. Bazarian
Manager of Development Engineering
Signalite

This is the second of a two-part series by Mr. Bazarian, detailing the most recent information available on Gas Discharge Devices and their application in Transient Voltage Protection. The first part which covered the sources of transients and compared different types of protectors appeared in Vol. 11, No. 1.

In our previous installment we compared gas discharge transient protectors, such as the Signalite Uni-Imp® and Comm. Gap, with other types of protectors, specifically varistors, thyrites and zeners. As was indicated several new and significant advances have brought gas discharge devices again into focus as an important family of devices for wide-range transient protection.

Although the gas discharge type device has been around for a long time, its original applications were somewhat limited, particularly in view of their present potential. The ultimate extent of this potential can perhaps be better appreciated through an understanding of how the gas discharge device is constructed and how it works.

OPERATING MODE OF GAS DISCHARGE DEVICES

The basic operation of the gas discharge transient protector is best understood by referring to the schematic form of the voltage-current relationship of a gas discharge device. If the current through the device is changed over the range of values of 10^{-18} to 10^{2} amps, as shown in Figure 1, the voltage across the device will also vary. When a gas discharge device is operated as a transient protector, the modes of operation are in regions A, F, and G.

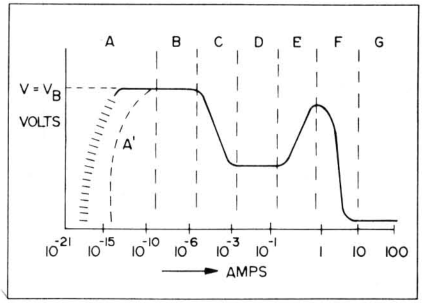


Figure 1 Schematic form of V-i relationship of a gas discharge device
Regions shown are: A-current subject to statistical fluctuation; A'-higher current due to supplementary sources of electrons; B-discharge self-sustained in this region (this is the breakdown voltage of the device); C-transition region; D-glow region; E-abnormal glow region; F-transition region; and G-arc region.

The applied voltage normally is less than V_B at which time the current through the device is in the A region. The charged carriers of electric current in this mode originate from the cathode by photon emission and, within the fill gas, by collisions of gas particles with cosmic ray or radioactive decay particles if an isotope is used in the protector design.

As soon as the applied voltage across the protector exceeds V_B (breakdown), the current through the protector increases rapidly to values of several amps or greater. The current level reached is limited by the resistance which is in series with the device. The voltage across the device at this time is very low, with typical values of 20 to 30 volts.

VOLTAGE/CURRENT CHARACTERISTICS OF TRANSIENT PROTECTORS IN AC AND DC CIRCUITS

The voltage and current characteristics of a transient protector in AC and DC circuits may readily be understood from the theory of operation of gas discharge.

The voltage appearing across a transient protector in an AC circuit is shown in the waveform of Figure 2. In this waveform breakdown

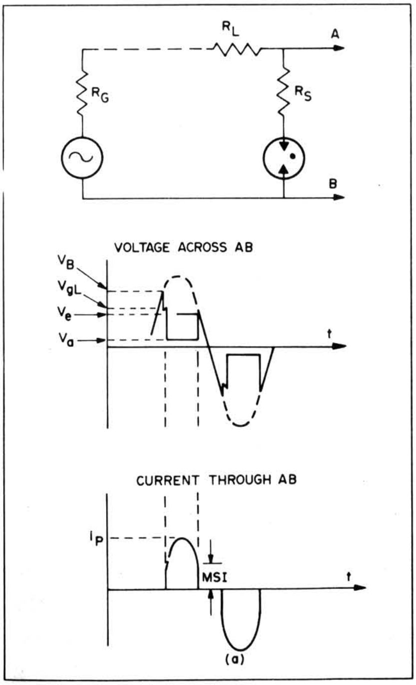


Figure 2 AC voltage-current variation across the transient protector
t = time; V_B = breakdown voltage; V_{gl} = glow voltage; V_a = arc voltage; V_e = extinguishing voltage; ip = peak current; MSI = minimum sustaining current.

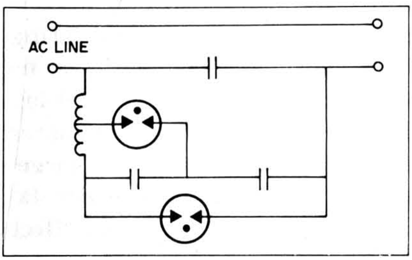


Figure 3 Phase Correcting Capacitors
Capacitors used on AC lines are protected against lightning and inductive transients by using a transient protector to discharge the stored energy in case of overload.

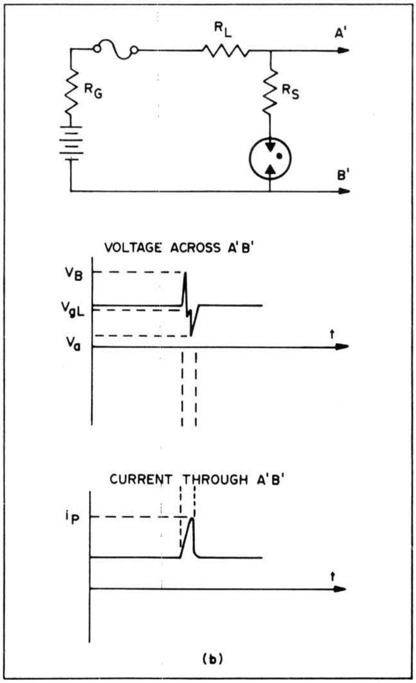


Figure 4 DC voltage-current variation across the transient protector
V_B = breakdown voltage; V_{gl} = glow voltage; V_a = arc voltage; ip = peak current; t = time.

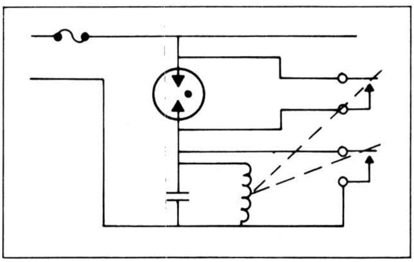


Figure 5 DC Circuits
When long discharge times or follow-on current can destroy the transient protector it is advisable to use grounding relays which are actuated by the discharge current and usually provided with some form of self-holding arrangement.

occurs on the leading edge of the first half cycle. The voltage is shown to drop sharply to the glow voltage, and then to the arc voltage as, simultaneously, the current rises rapidly as shown. The current wave then follows the supply voltage waveform, and the arc voltage across the gap remains at a constant low voltage level. When the current is reduced on the trailing edge of the first half cycle, a minimum sustaining current (MSI) is reached where the discharge can no longer be sustained in the arc mode. At the MSI the current drops to zero and voltage across the gap changes rapidly to the instantaneous supply voltage. The MSI values for most transient protectors range from 3 to 150 amps dependent mostly upon the gap design.

For DC circuits, when the voltage instantaneously exceeds the breakdown voltage—as may be caused by a voltage transient—the voltage across the gap will drop sharply to the glow voltage and then to the arc voltage level. (Figure 4) In this illustration it is assumed the resistor in series with the gap has limited the peak current to a value below the MSI.

PULSE BREAKDOWN

A brief description of gas discharge theory of time lag is necessary to understand the significance of a unit impulse characteristic. It is generally known that in gas discharge devices when a field sufficiently large to cause breakdown is applied, there are two reasons why breakdown does not occur immediately: 1) time is required for an initiating electron to appear in a favorable position in the gap to lead to the necessary avalanche, and 2) the development of the avalanche requires time because of the finite mobilities of the charged particles. Thus, there is a time delay before the breakdown which is the sum of these two periods—the first called the "statistical" time lag, and the second, the "formative" time lag.

Use of a radioactive isotope greatly enhances the source of initiating electrons for device breakdown. The "statistical" time lag can be sufficiently reduced so that the principal contribution to the total lag comes from the "formative" part. In the Uni-Imp family an insulator element is interposed and pressed between the electrodes. A discharge-initiating junction is established and spaced from the gap which facilitates the production of the main discharge across the gap. In effect the statistical time lag is completely eliminated, and the formative time is greatly reduced. The mechanism by which the formative time lag is reduced is the same as in "keep-alive" gaps. That is, a sufficient supply of electrons is provided so that the voltage and time required for the exponential increase in electron concentration to reach breakdown conditions are decreased. The mechanism of the supply of initiating electrons is a conductor-solid dielectric junction that is designed to "emit" charged particles when the electric field exceeds a minimum level.

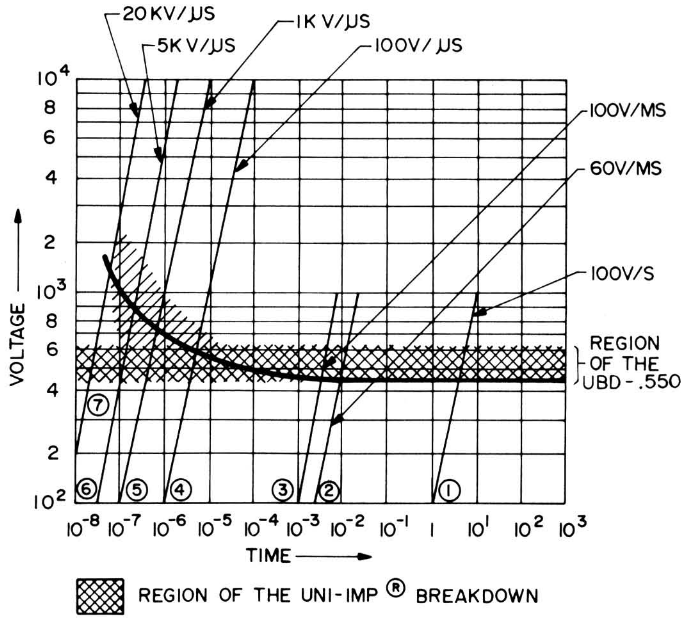


Figure 6 Pulse breakdown voltage for various ramp speeds as a function of time
Curves 1 to 3 represent slow ramp speeds. Curves 4 to 7 represent transient phenomena (lightning)

The effect of the statistical time lag in a gas discharge device is illustrated in the plot of Figure 6. Also shown is the region of breakdown of a device with unity impulse indicating an impulse ratio of one for all rates of rise of transient voltage. The various slopes depict different rates of rise of a ramp voltage. Curve 1 corresponds to a DC breakdown, and curves 2 and 3, to 60 and 400 cycle rates of application of voltages. Curves 4 through 7, however, represent much faster rates of rise. Note that for rates faster than curve 3 the breakdown for ordinary gas discharge devices increases, whereas that for the unity impulse device remains unchanged from its DC breakdown level.

FOLLOW-ON CURRENT

Follow-on current is that which flows due to the normal operating voltage after the transient protector has been discharged, and which continues to flow until the protector extinguishes.

Whether or not current will continue to flow through a transient protector from the main power source after the transient has passed will depend upon several factors. In an AC circuit at the end of each half cycle there is a period in which the current approaches and crosses through zero. In this period there is a very rapid deionization process taking place within the gap. As the voltage reverses a considerably larger voltage will be required to re-establish the same conductivity that existed before the zero current. Within the gap a deionization process takes place at the surface of the electrodes and insulating surfaces. The electrons and ions do not recombine within the gas but instead collide with a third body such as the electrode to allow recombination to take place.

In general it is found that reignition voltage decreases as the arc current increases*. Furthermore, increasing the rate of rise of the reapplied voltage will result in a lower reignition voltage for a given current level. Therefore, for applications in which a transient protector is used across an AC power line the current flow must be limited by a series resistor to the maximum value specified. In the circuit in Figure 2 the current is shown to be limited by the sum total of $R_S + R_L + R_G$.

In DC applications it is essential to insure that the protector will be extinguished after the transient has passed in order to be able to protect against recurring transients. For low impedance voltage sources, the minimum sustaining voltage (MSV) at which level the gap will continue to conduct after having been discharged by a transient ranges from approximately 50 to >160 volts. The MSV is related to gap design and is greatest for the unity impulses type of device.

A configuration in which deionization is enhanced by the internal geometry results in high levels of MSV. To insure uniformity of the product and that the MSV is preserved during life, processing of parts against impurity, particularly low work function materials such as sodium or potassium, must be maintained constantly. Materials which result in high emission levels cause adverse effects on desired levels of MSV. If the line voltage is greater than the MSV other methods must be provided to insure the turn-off of the gap. These methods include fuses, circuit breakers, and relays.

CONSTRUCTION MATERIALS

The transient protector design commonly employs glass-to-metal or ceramic-to-metal enclosures. Ceramic-to-metal units may now be obtained at very low cost. These offer high uniformity of product along with extreme levels of shock, vibration, and temperature capability. The ceramic used is alumina, ranging from 94% to 98% Al_2O_3. The seals are prepared by the moly-manganese metallizing process with nickel plating, and the final seal is made with a copper-silver eutectic. Electrode materials used are selected for specific applications. Refractory metals, such as tantalum and tungsten, are used when extremely high current is required. Alloys of tungsten and silver or copper are used for long duration discharges.

Cobine, J.D., "Gaseous Conductors", McGraw Hill Book Co., Inc., New York 1941, pp. 352-362

SUMMARY

The commonly accepted practice in electronic circuit design is to place increased dependence on a new generation of gas discharge transient voltage protectors. These protectors are now available in the voltage range from 75 to 30,000 volts with standardized designs allowing off-the-shelf delivery for many voltage levels. The protection offered against transients now allows the voltage ratings of circuit components to be based upon normal design requirements, rather than voltage ratings equal to high transient levels.

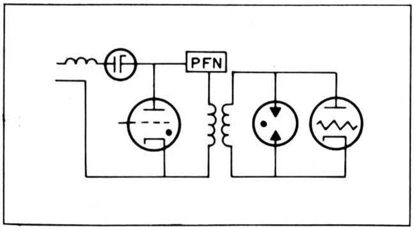


Figure 7 Pulse Modulator
The secondary of the pulse transformer in a pulse modulator circuit is normally protected against a "miss-fire" (missing pulse) of the magnetron. The charging choke, charging diode and PFN are also frequently protected against high surge voltages by using a gas discharge device across each component.

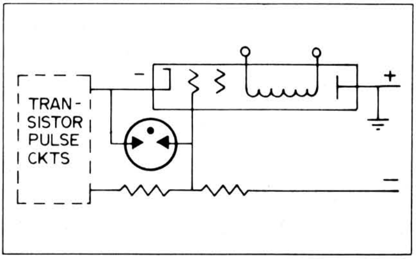


Figure 8 TWT Protection
Transient protectors are used to protect solid state components in TWT grid-cathode circuits where high potential arcs can wipe out entire circuits of rectifiers, zeners, etc.

Earlier practices, including increased insulation of components and higher levels of voltage and heat dissipation capability, no longer are necessary. Use of the new transient protectors has in most cases insured reliable circuit operation which otherwise would not have been possible. The established use of these protectors in all types of electrical systems has allowed economies in design with simultaneous increase in reliability that previously was not achievable.

The information presented in these two parts was excerpted from Signalite's Technical Manual TPTM-2-73, "Gas Discharge Devices for use in Transient Voltage Protection and Electrical Energy Transfer." Copies of the Technical Manual may be obtained free of charge by writing the Sales Department at Signalite.

YOUR GLOW LAMP APPLICATION FORUM

It is Signalite's policy to publish letters based on their intrinsic interest only. We do not necessarily agree with all comments and suggested uses and will upon occasion wait for your reaction before taking editorial space for ours.

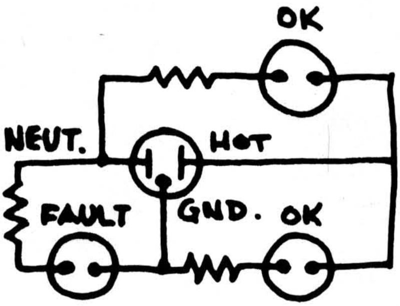
COMMENTS ON: Vol. 10, No. 1

MODIFYING HOUSEHOLD AC RECEPTACLE TESTER

Gentlemen:

Since you are in the business of selling neon glow lamps, why not sell 3 lamps instead of 2 and at the same time indicate that a wiring error has been made.

In the following circuit both OK lamps will light if the wiring is correct.



Should the common and hot wires be reversed the FAULT light and one OK light will light.

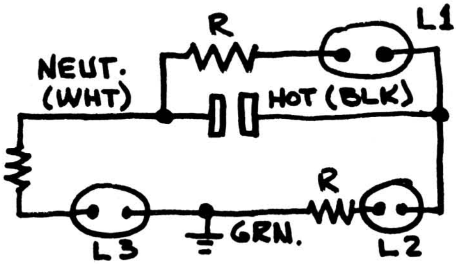
R. E. Lammers
The Babcock & Wilcox Company

Gentlemen:

A modification can be made to the circuit to further identify problems. The modified circuit is as follows:

L1	L2	L3	Circuit Conditions
X	X	-	Circuit Ok.
X	-	X	Neutral and Hot reversed.
X	-	-	Neutral and Hot reversed, ground open.
X	-	-	Ground open.
-	-	-	Hot Open.
-	X	-	Neutral open.
-	X	X	Hot and Ground reversed.
-	X	-	Hot and Ground reversed, neutral open.

X - *Indicates lamps on.*



Very truly yours,

R. E. Colquitt
Westinghouse Engineer

Gentlemen:

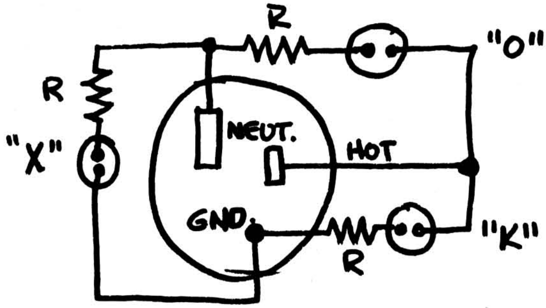
Note that the circuit can be built as shown in attached diagram to provide an additional test for Reversed Polarity.

This is accomplished by connecting a third lamp and resistor between Neutral and Ground: and by labeling the three lamps as follows:

Lamp between Hot and Neutral is labeled . . . . . . "O"
Lamp between Hot and Ground is labeled . . . . . . "K"
Lamp between Neutral and Ground is labeled . . . "X"

In use the three lamps indicate as follows:

Lights On	**Indication**
O and K	Circuit is OK!
O and X	Circuit has Reversed Polarity.
O only	Open Ground.



Very truly yours,

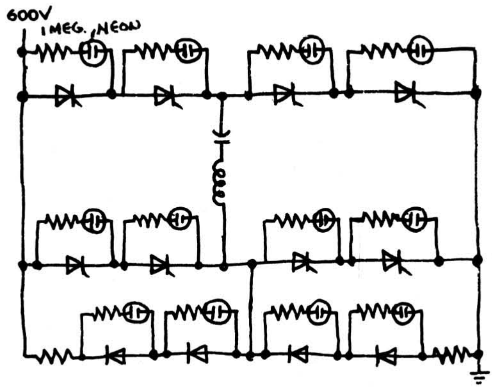
Stephen M. Meginiss II
Towson, Maryland

SCR 3-PHASE FAILURE CHECKER

Dear Sir:

We have two SCRs in series in our DC/AC three phase Inverter. Sometimes one of the SCRs would fail for one reason or another, and the other SCR would fail eventually because it has to support all, instead of half the voltage.

By placing a 1 meg resistor and a neon lamp across each SCR as an indicator, we can readily identify the problem before we lose another $200 SCR.



Sincerely yours,

Harvey C. Wong
General Electric

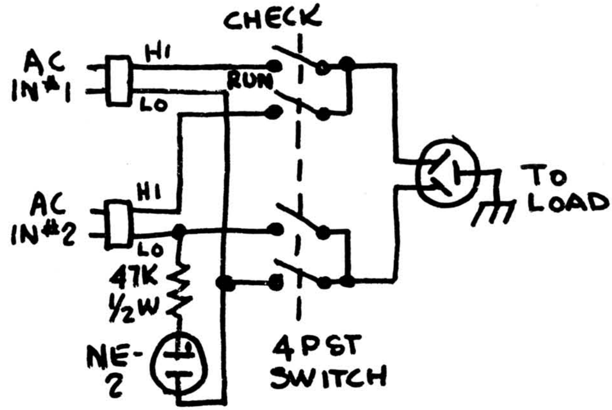
Ed. Note: Additionally, you could also monitor each neon lamp with a photocell. These cells might be connected to control circuitry such that the total SCR system is protected i.e., turned off when any one lamp lights.

GROUND PHASE CHECKER

Gentlemen:

An application arose recently in our plant where we had to power a 400 Hz motor generator from an area that could not handle the mot starting current. A solution was as below:

Main problem was that we had separate lines in the area, but some outlets were wired incorrectly, i.e., ground lines were reversed. So we made a box with 2 plugs and 1 outlet with switch and neon lamp. The lamp lights when phasing is reversed and switch is in check position.



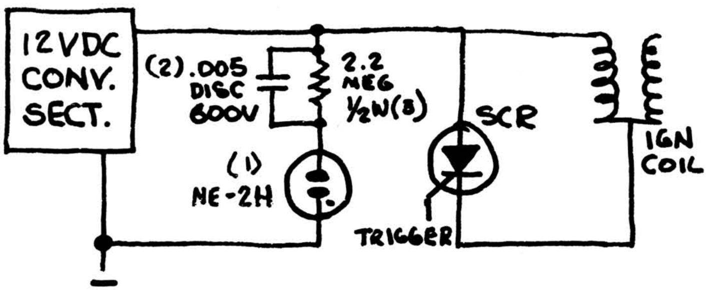
A simple device but it works.

R. A. Suddath
Block Engineering, Inc.

CAPACITOR DISCHARGE TROUBLE INDICATOR

Gentlemen:

This shows an application for a built-in test on the operation of a C.D. system. By the addition of only 3 low cost components (1. NE-2H neon lamp, 2. a .005 600v capacitor, 3. a 2.2 meg ½ w resistor) the following is evident immediately:



1. A steady glow of neon shows presence of high voltage DC.
2. When cranking a flashing neon shows SCR is firing.

Then it is apparent only things left are a faulty coil, or capacitor, or what happens most of the time are loose wires and bad grounds—which can be expected in such an environment as under the hood of a car.

Sincerely,

Roger W. Hamel
Bendix Research

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Applications which in the opinion of Signalite have significant interest will also be brought to the attention of the editors of leading technical publications for consideration as articles and featurettes. If you would like help in preparing your material for publication, just send us the facts and data; we will put it in the correct form for publication. Your by-line and company credit will be given with your permission.

For immediate technical application or circuit design assistance, you may contact Signalite directly at:

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