A NEW STATIC RELAY FOR TRANSMISSION LINE PROTECTION

by
Joseph G. Andrichak
William A. Massey
Ronald C. Patterson

General Electric Company
Power Systems Management Business Department
Philadelphia, Pennsylvania

Presented to
WESTERN PROTECTIVE RELAY CONFERENCE
October 27–29, 1981
Spokane, Washington

ABSTRACT

This paper describes the performance characteristics and typical applications for a new three-phase instantaneous ac voltage relay. A discussion is included on the special design approaches used to achieve a 99 percent dropout to pickup ratio and immunity to harmonics.

A New Static Relay for Transmission Line Protection

INTRODUCTION

There are numerous areas in the protection and control of a utility power system where an accurate instantaneous measurement of ac potential is required to detect abnormal system conditions. In many instances a very small difference between operate and reset levels is required to assure the recognition of a return to normal conditions after a disturbance. The harmonics and waveform distortion associated with abnormal conditions such as transmission system overvoltage or capacitor bank switching may tend to interfere with correct measurement of fundamental system voltage.

A new static ac voltage relay has been developed to meet the requirements of these critical applications. This Static Line Voltage (SLV) relay consists of three independently adjustable detectors, each of which can be operated in the undervoltage or overvoltage mode. Each detector has a dropout to pickup ratio of 99 percent, and a high degree of immunity to harmonics (less than 3 percent variation in operating point with a voltage waveform containing 50 percent third harmonic). The outputs of the individual detectors are user programmable in the type SLV relay to provide AND, OR, or other logical combinations of output contact wiring to the external control circuits.

APPLICATIONS

Transmission overvoltage conditions may be encountered as a result of the capacitive charging current in a line with one terminal open, malfunction of steam turbine generator voltage and speed controls, load rejection near hydro generation, or other emergency system operating conditions. Excessive voltage on the transmission system can overstress insulation, compromise proper switching operation, or cause thermal damage in connected equipment. Excessive voltage at normal frequency results in transformer overexcitation and core saturation which can cause insulation damage due to eddy current heating in structural members. *Figure 1* shows a typical overexcitation limit curve for a large power transformer. *(Refer to Reference 1.)*

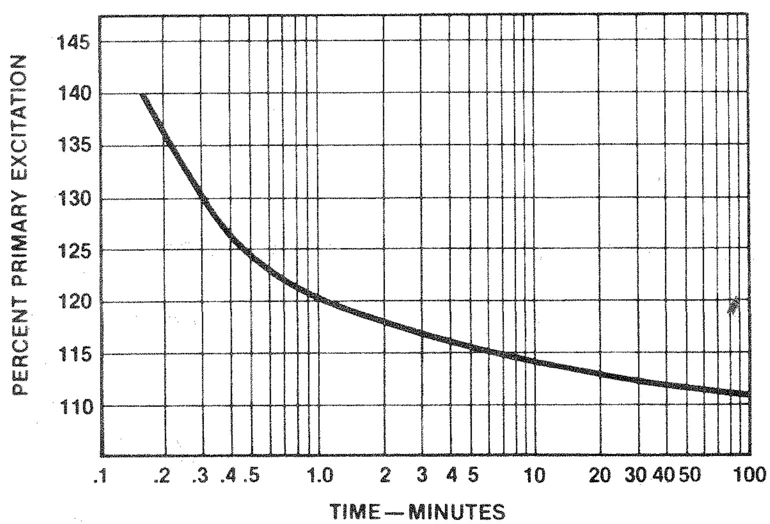

Figure 1.
Typical Power Transformer
Short-Time Overexcitation Limits

Prompt detection and corrective action during excessive voltage conditions is an important part of the overall protection and control of a transmission system. Overexcitation protection (volts per hertz relays) will usually be applied on individual large steam turbine generators and transformers specifically to avoid heating damage for sustained overvoltages. Overvoltage protection on a long high voltage transmission line would typically include two levels of overvoltage detection which would be coordinated with the permissible overexcitation limits on any individual equipments.

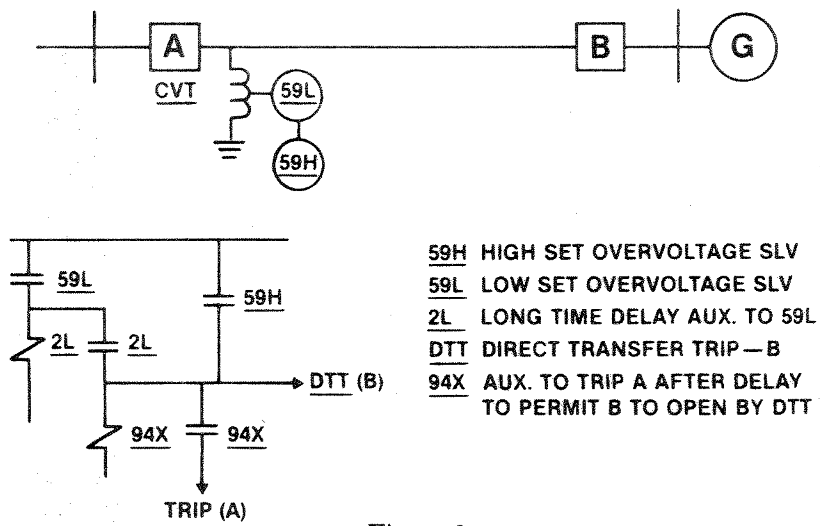

Figure 2.
Transmission Overvoltage Application

Figure 2 shows an arrangement where the remote terminal source is direct transfer tripped before a local trip is initiated. Because of its stability, high dropout, and immunity to overexcitation harmonics, the type SLV relay is particularly appropriate for this type of application. These same characteristics make the type SLV relay well suited for voltage control applications with the switching of shunt capacitor banks.

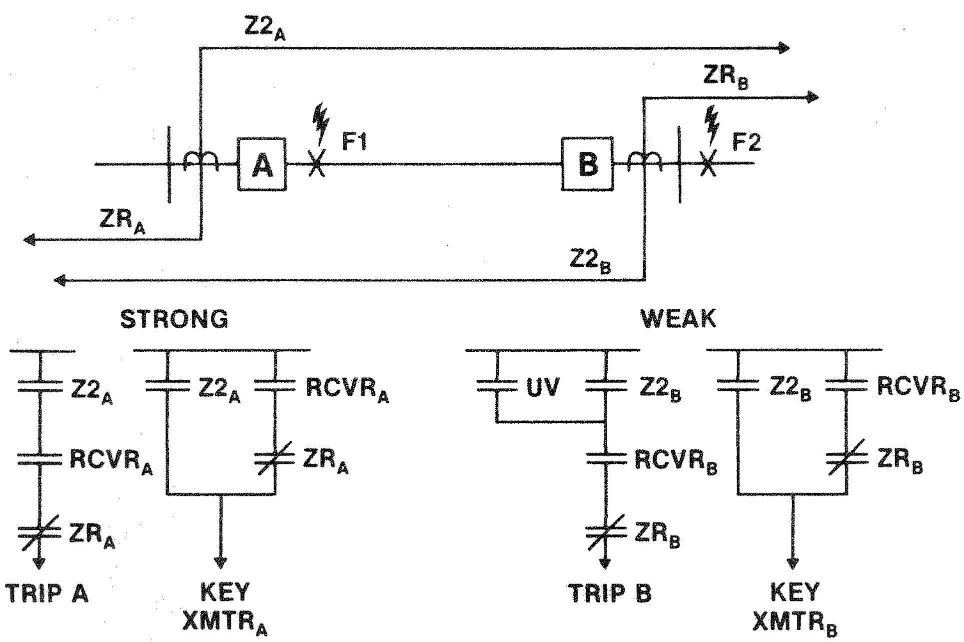

Figure 3.
Hybrid Directional Comparison Scheme With Undervoltage (UV) Supervision Of Weak Infeed Tripping

A typical undervoltage application is shown in *Figure 3.* Here the type SLV relay provides an accurate, stable, instantaneous undervoltage fault detector function to supervise the tripping of a weak infeed terminal in a hybrid directional comparison scheme for transmission line protection. The type SLV relay can similarly be used to provide both the undervoltage tripping and remote carrier start functions when blocking directional comparison schemes are applied with tapped lines or weak infeed terminals. These applications are described in detail in Reference 2.

Other typical undervoltage applications include phase selection for single pole trip and reclose schemes for line protection, and voltage supervision for high-speed sequential reclosing schemes.

PERFORMANCE OPTIMIZATION

Several novel approaches were utilized in the design of the type SLV11A relay to achieve the required stability and high dropout to pickup ratio, with the optimum combination of operating time, harmonic rejection and application flexibility. These design approaches are discussed below for four of the more significant performance characteristics of the type SLV relay.

Harmonic Rejection

A high degree of harmonic rejection is incorporated in the type SLV relay to avoid errors in system voltage measurement due to waveform distortion resulting from transformer saturation or other nonlinear conditions. The specified performance requires less than 3 percent variation in operating point when the applied voltage waveform consists of a 3rd harmonic component equal to 50 percent of the fundamental. This corresponds to a harmonic rejection of about 24 db. Four identical cascaded active low pass filters are used to obtain the desired harmonic rejection and also provide a constant filter gain in the fundamental 50 to 60 Hertz (Hz) region. This is illustrated in *Figure 4* which shows an 85 Hz cutoff and 32 db attenuation at 150 Hz.

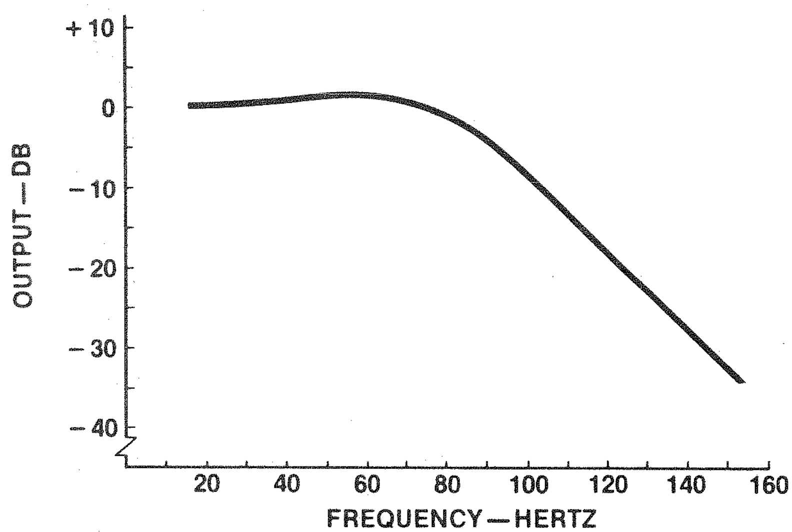

Figure 4.
Type SLV Relay Low Pass Filter Response

Operating Speed

A consistent operating time of 32 milliseconds (ms) is achieved in the design. At the same time, a stable and extremely high dropout to pickup ratio is required. The low pass harmonic filter contributes about 8 ms delay to the operate time. The output relay contributes another 6 ms. The optimum dependability and security are obtained in the remaining 16-18 ms of operating time by adopting the following approach.

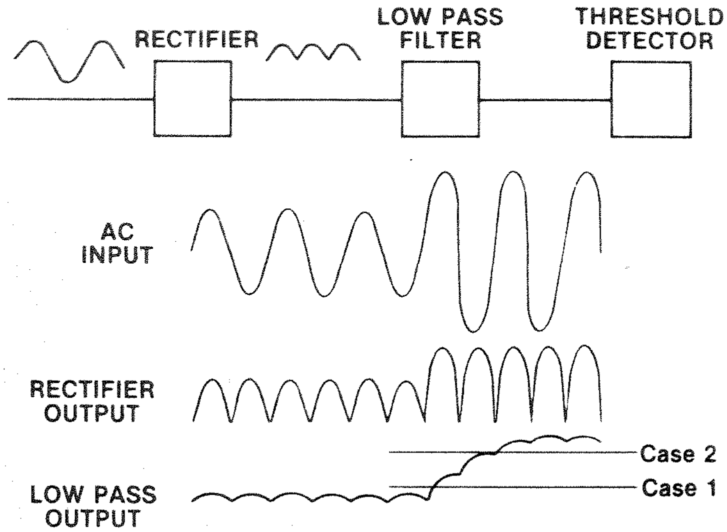

Figure 5.
Performance Of A Simple Filtered Level Detector

The harmonic filter provides good rejection of impulse noise so additional filtering in the remaining 16 ms could be used to improve security by requiring that two half cycles beyond the threshold are required for operation. A commonly used approach is shown in *Figure 5*, where the rectified output of a harmonic filter is applied to a level detector via a low pass filter. However, the operate time of this type of circuit would vary considerably with input level as illustrated.

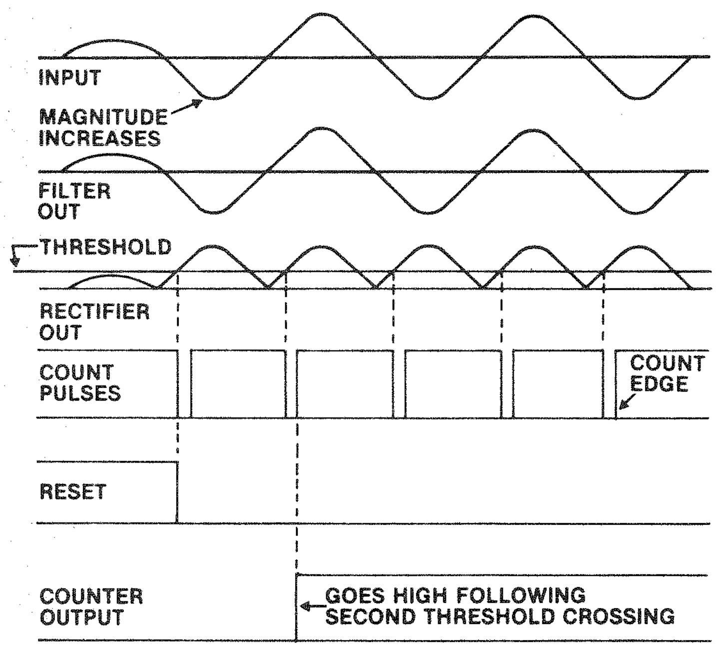

Figure 6.
Type SLV Relay Voltage Detector Counter Operation

To avoid this problem the SLV design utilizes a circuit which compares each rectified half cycle against the operate threshold level and counts successive half cycle threshold crossings as shown in *Figure 6.* Two crossings are required to operate in the normal mode to assure the required security. The number of crossings required to obtain an output is jumper selectable at 1, 2, 4, and 6, offering a range of operate delays from approximately 16 ms to 64 ms. The counter reset signal is disabled on the first threshold crossing and remains disabled for ¾ cycle after each crossing. The counter resets ¾ cycle after the last crossing. Since the harmonic filter bandwidth is relatively wide, its output follows the input rather closely with little "ring up" or "ring down" time for input voltage changes. Combining this with the comparison of each half cycle against the operate threshold yields an overvoltage relay whose operate speed is reasonably independent of the initial and final voltage levels.

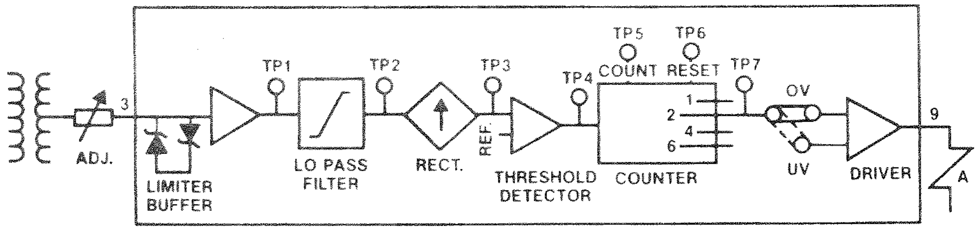

Figure 7.
Type SLV Relay Level Detector

High Dropout

When each half cycle is compared against the operate level threshold, there is no hysteresis inherent in the design. To provide a small amount of hysteresis the output from the half cycle counter is fed back to the threshold detector and this shifts the threshold slightly to give a 99 percent dropout to pickup ratio.

A simplified functional diagram of the type SLV voltage detector is shown in *Figure 7.* These design approaches result in good harmonic rejection, consistent operate time, and an extremely high dropout to pickup ratio.

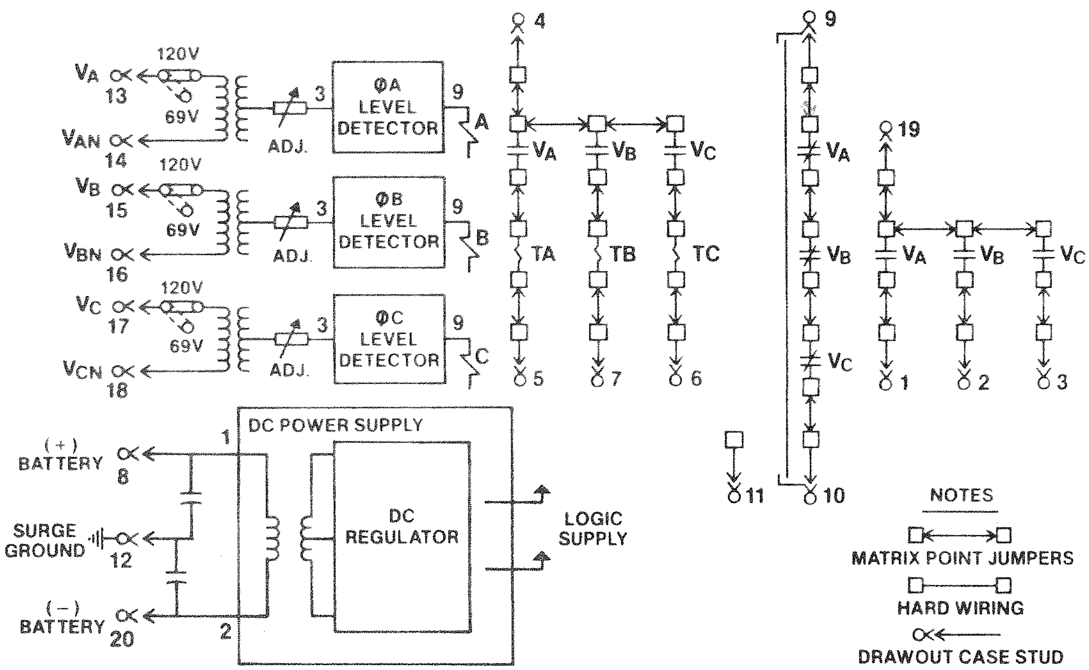

Figure 8.
Type SLV Relay Connection Diagram

Programmable Output Configuration

Since the type SLV relay consists of three independent voltage detectors, each adjustable from 55 to 180 volts for either undervoltage or overvoltage operation, there are a variety of possible applications. To permit the user to take advantage of this flexibility, the output relay contact interconnections are programmable. Programming is accomplished by means of two matrix point blocks utilizing gold plated taper pin connectors. *Figure 8* shows the individual voltage detector contacts, targets, and relay case stud connections to these matrix point jumpers. The standard OR mode connection is shown for the normally open contacts from the three voltage detectors.

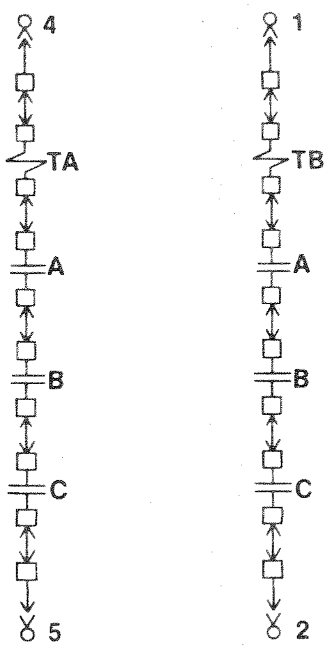

Figure 9.
Type SLV Relay Outputs
Programmed For The "AND" Mode

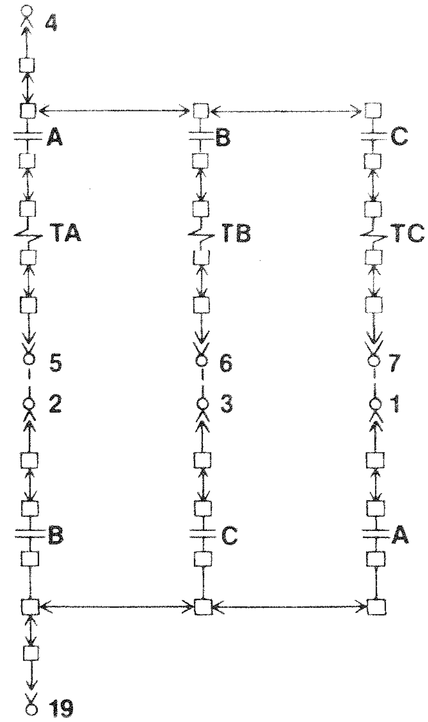

Figure 10.
Type SLV Relay Outputs
Programmed For A "Two Or More" Logic Mode

Figure 9 shows the normally open contacts reprogrammed at the internal matrix points to provide the AND mode. *Figure 10* shows a "two or more" connection program where at least two detectors must operate to get an output. A variety of other connections are possible depending on the requirements of the particular application.

SUMMARY

A new static ac voltage relay has been developed for instantaneous overvoltage or undervoltage applications requiring high accuracy and stability and a very high dropout to pickup ratio. The hardware utilizes high reliability hermetically sealed semi conductor components for long life, and is designed for maximum immunity to environmental effects. The SLV11A relay passes the IEEE SWC test, as well as the GE Co. "Fast Transient" and RFI tests, and has an operating temperature range of −20°C to +65°C.

The 99 percent dropout and immunity to overexcitation harmonics makes the SLV11A ideally suited for transmission overvoltage protection. Other typical applications include voltage detection in sequential reclosing schemes, fault detection for line terminals with weak fault current infeed, and voltage control with shunt capacitor banks.

References

1. "Overexcitation of Power Transformers" – GE Co. Publication GET-3364.

2. "Protection of Transmission Lines Having Weak Fault Current Infeeds" by W. C. New and R. C. Patterson – PEA paper dated February 19, 1981.