

FALSE APPLICATIONS OF RELIABLE RELAYING PRINCIPLES

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FALSE APPLICATIONS OF RELIABLE RELAYING PRINCIPLES (Things We All Know To Be True – Which Are Not)

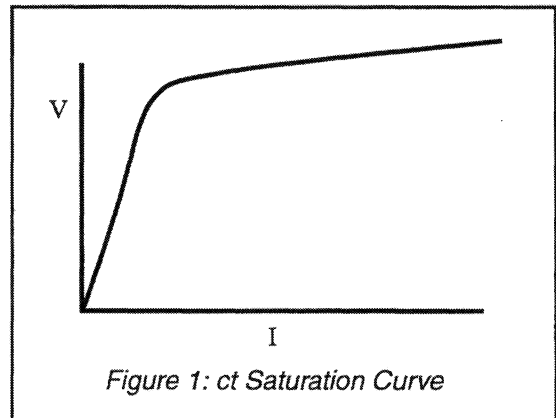
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Introduction

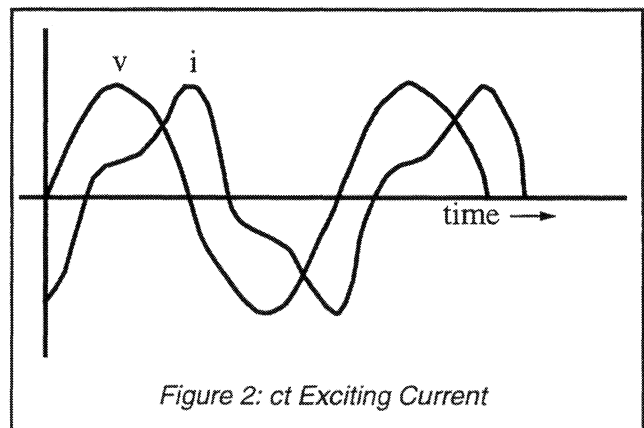
This paper describes a series of significant fundamental principles that are often misunderstood and used improperly. All of these concepts are related to protective relaying directly or indirectly. This paper was written in the interests of shedding light on these basic fundamentals. While the paper has no theme and is merely a group of one-line statements that contain mis-representations that are often encountered, an effort was made to collect them into somewhat related areas.

Current Transformers

1. The excitation curve supplied with current transformers relates instantaneous secondary voltage and exciting current. False. These curves, as in figure 1, are a plot of sinusoidal, clean, 60 hertz RMS voltage applied to the secondary terminals versus the reading of an RMS responsive ammeter, even though the secondary current which flows is replete with harmonics (See figure 2). It is incorrect to assume that this curve represents instantaneous voltage to instantaneous current or 60 hertz voltage to 60 hertz current relationship. Experience has shown though, that reasonable results can be achieved by using an RMS to RMS assumption. Indeed the ANSI Standards allow this approach. (Reference 1).



2. For a C class current transformer, the maximum error with no more than rated secondary burden is 10%. False. This applies for symmetrical currents (with no dc component) from 5 to 100 amperes secondary, but for only a ct having no residual flux. Figure 3 shows that the secondary voltage can be generated in a number of ways such as loop ab, cd or ef in figure 3, depending upon the starting point (Reference 2). Previous history of the magnetic circuit, caused by faults or load and point of deenergization establish this starting point. Each of these loops have a different peak exciting current, even though they are all based on the same secondary current and burden.



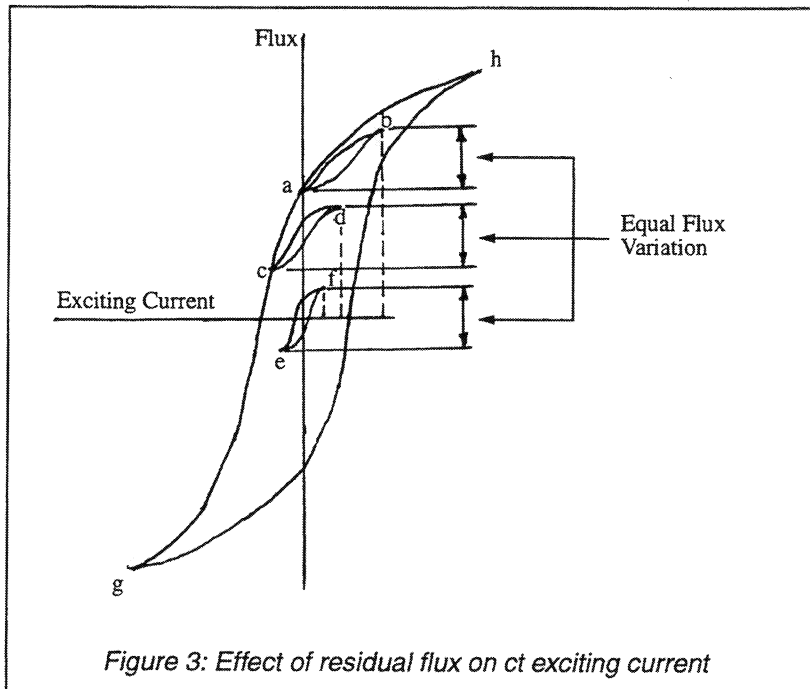


Figure 3: Effect of residual flux on ct exciting current

Loop ab cannot persist because of the dc component inherent in the non-symmetry about the vertical axis. This dc component in the secondary current (not matched by primary current) will cause the location to move to loop cd. This loop can remain forever, along with the excessive error associated with the difference between the peak currents associated with d and f. Changing conditions change the location of the loop. Only ef relates to the specified behavior of the ct for relaying or metering because the standard tests reduce the residual flux to zero by applying a secondary voltage to the ct high enough to produce loop gh and reducing it gradually to zero. This restores symmetry.

Since fault current interruption occurs at zero current, which is at zero ct secondary voltage with a resistive burden, which is near peak ct core flux, there is a good likelihood, that severe faults will leave near-peak flux entrapped.

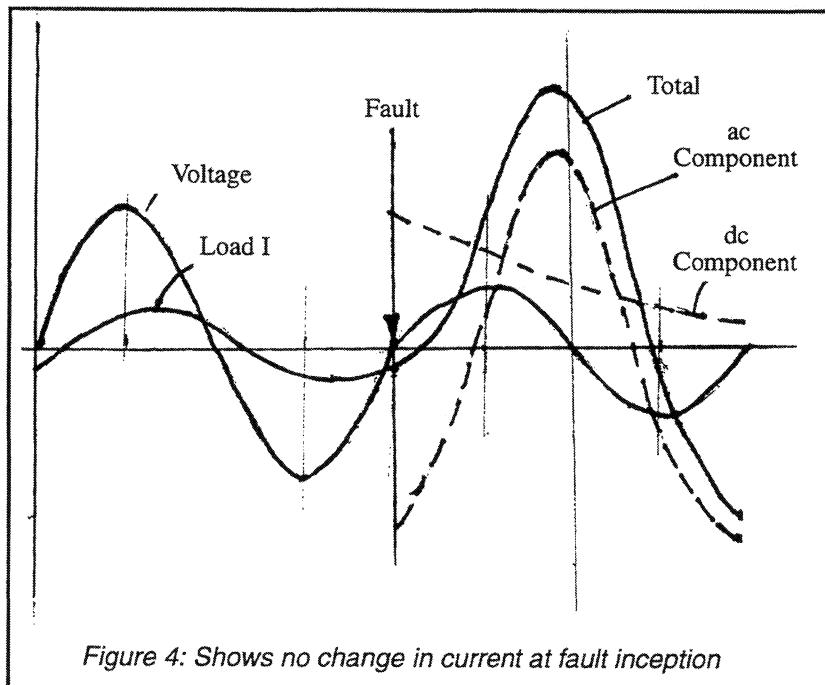


Figure 4: Shows no change in current at fault inception

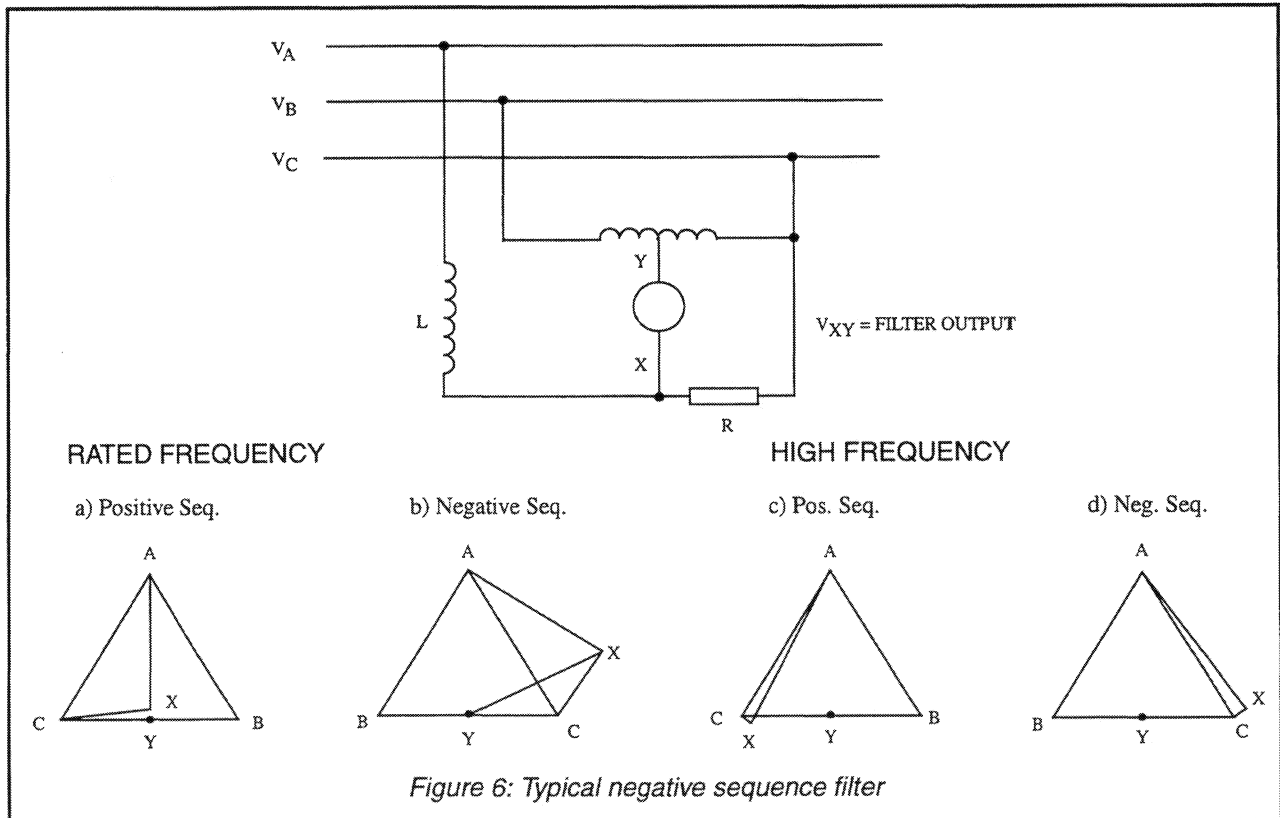
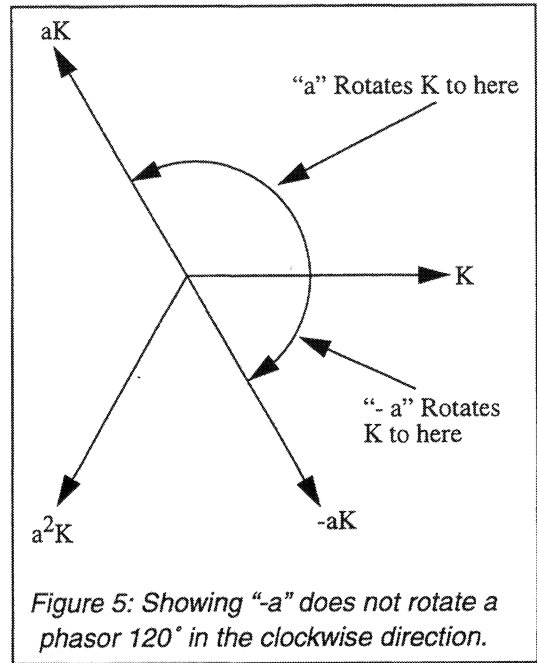
3. Fault current having dc offset is initially very high. False. Following the occurrence of a fault, the current immediately after the fault is exactly the same as the current immediately preceding the fault. Current cannot change instantaneously in an inductance. As figure 4 shows, the instantaneous magnitude of current does not change at fault inception. The high current usually associated with faults having dc offset is that of the first peak, which occurs a full half-cycle after the occurrence of the fault.

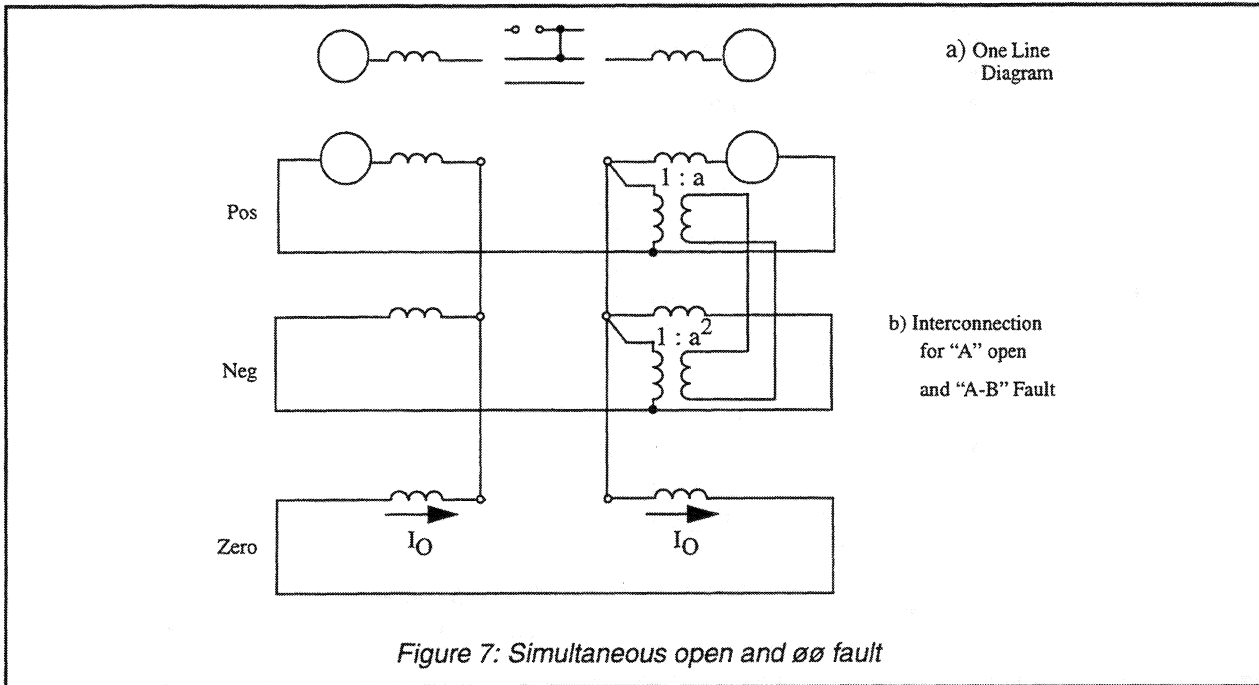
Symmetrical Components

1. Third harmonic is always zero-sequence in character. False. This statement is true

only if the same level of third harmonic is generated in each of the three phases. A non-linear load in a single phase circuit generates third harmonic voltage, but it contains positive, negative and zero-sequence characteristics in the same way that a phase-to-ground fault does.

- Since the operator "a" rotates a phasor 120° in the counter-clockwise direction, operator "-a" rotates a phasor 120° in the clockwise direction. False. Figure 5 shows that "-a" rotates phasor K only 60 degrees in the clockwise direction.
- Positive-sequence phasors rotate in a counter-clockwise direction and negative-sequence phasors rotate in a clockwise direction. False. All phasors rotate in the CCW direction. Negative-sequence phasors peak in the opposite sequence to that of positive-sequence phasors. (ACB for example as opposed to the normal ABC).
- Seventh harmonic is positive-sequence in character and therefore will have no effect on a negative-sequence voltage relay. False. Virtually all "negative-sequence filters" are designed for 60 hertz. They produce a single-phase output voltage proportional to the negative-sequence content of the input voltages or currents. Figure 6 shows, for a typical negative-sequence filter, that at high frequency the filter output voltage is nearly the same whether the character of the high frequency voltage is positive or negative-sequence. Triple harmonics (third, ninth, fifteenth etc.) are automatically screened-out through the use of phase-to-phase voltage rather than phase-to-ground for the relay input. Note that a filter, designed for 60 hertz negative-sequence sensing, will produce an output for a high frequency input, even though the fundamental is purely positive-sequence, which has essentially the same magnitude as if the fundamental were not present. Of course, some such filters are equipped with provision to desensitize the relay to high frequency influence.

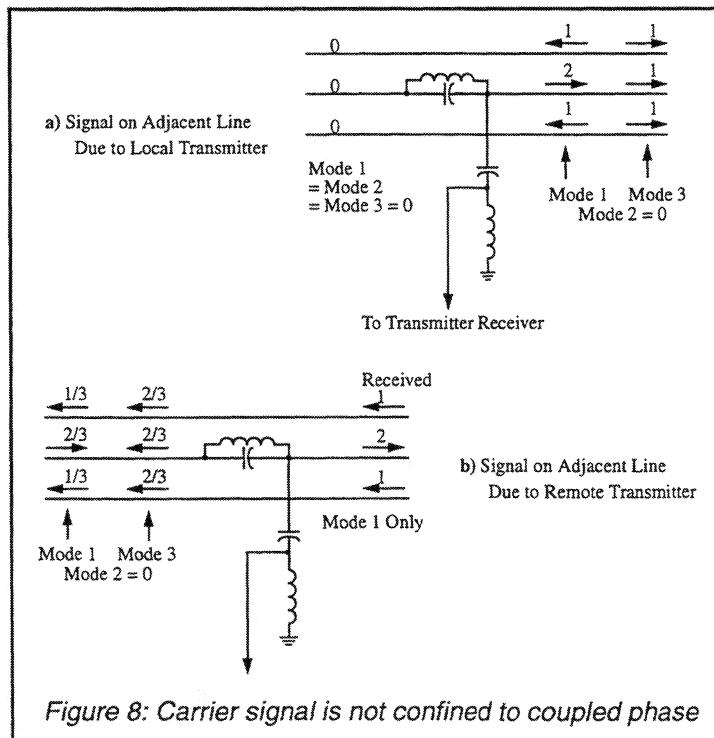




5. Faults which do not involve ground produce no zero-sequence current. False. Figure 7 shows the interconnection of the networks for a "simultaneous" open and phase-to-phase fault, from this, it is apparent that zero-sequence current will flow provided there is a zero-sequence path [so called source] on each side of the open. Care should be exercised with relays that have weighted zero-sequence response. This case could appear as an external fault, even though it is an internal phase-to-phase fault.

Power Line Carrier

1. With center-phase-to-ground coupling and center phase trapping, the carrier signal is confined to the coupled phase. False. With this type coupling mode 1 and mode 3 are coupled with magnitudes as shown in figure 8a and mode 2 is zero. Mode 3 attenuation is roughly 20 to 40 times (in db) that of mode 1, and so the received signal with any significant distance of transmission is purely mode 1. Since, the nature of mode 1 is essentially one unit in each of the two outer phases returning in the center phase, a substantial signal level can be expected at the receiving terminal on the two uncoupled phases in addition to the signal on the phase to which the carrier is coupled. Indeed, power line carrier systems have been operated for years unintentionally coupled to different phases at the two ends of the transmission line without ever experiencing difficulty.



A single center phase trap blocks mode 1 and mode 3 as generated by center-phase-to-ground coupling from the local transmitter. However, the received mode 1 from the remote transmitter is severely attenuated by the presence of the trap and mode 3 is generated on the side of the trap away from the protected line as figure 8b shows. A carrier signal is distinctly present at this location on the two outer phases in spite of the presence of this single trap. Three phase trapping will confine the carrier to the coupled phase.

The principal purpose of the trap, of course, in relaying is to assure that an external fault will not block the transmission of carrier to the remote terminal.

- Transmission line transpositions produce a concentrated 6 db carrier loss. False. At a transposition, there is no carrier power loss. There is however, a transformation of carrier mode, see figure 9a. A low-loss mode 1 signal arriving at a transposition is attenuated and partially converted to mode 2. The mode 1 voltage content is half of that of the arriving signal (down 6 db). Mode 2 voltage is generated by the transposition to a level of 3/4 of the original mode 1.

Mode 2 attenuates at roughly 4 times (in db) the rate of mode 1, but any mode 2 that remains at the next transposition is attenuated (to half value) and partially converted back to mode 1, as figure 9b indicates.

The worst possible attenuation expected from a transposition is 6 db, but may well be less than that. This description takes liberties with the method described accurately in reference 3, but the concept may be more clearly understood with this approach.

Transformers

- Phase-sequence is important in connecting the differential relays for a power transformer. False. As the example transformer of figure 10 demonstrates, phase-sequence does not control the connection of the current transformers nor the relays. The phase relationships are chosen for the ct's to match the transformer connection.

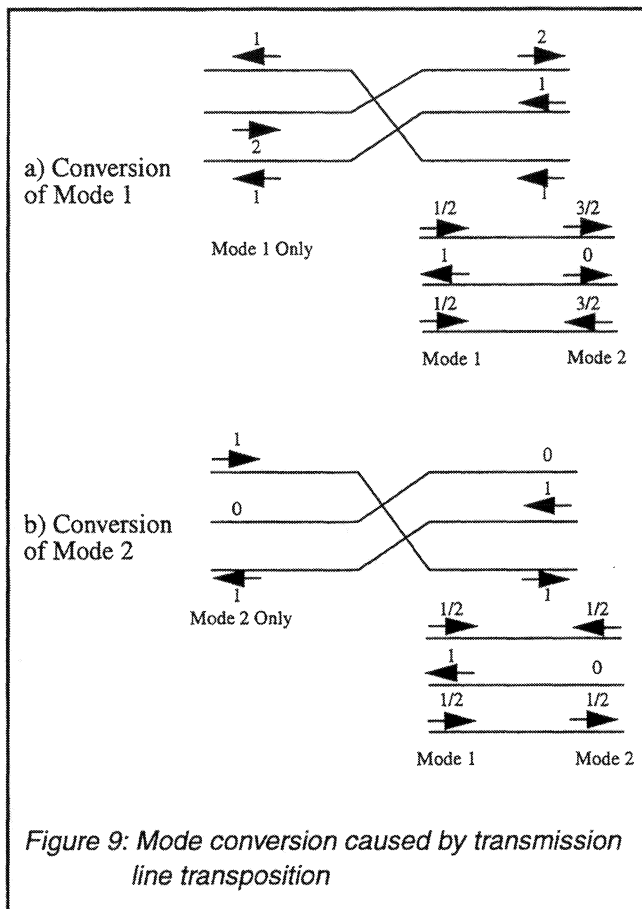


Figure 9: Mode conversion caused by transmission line transposition

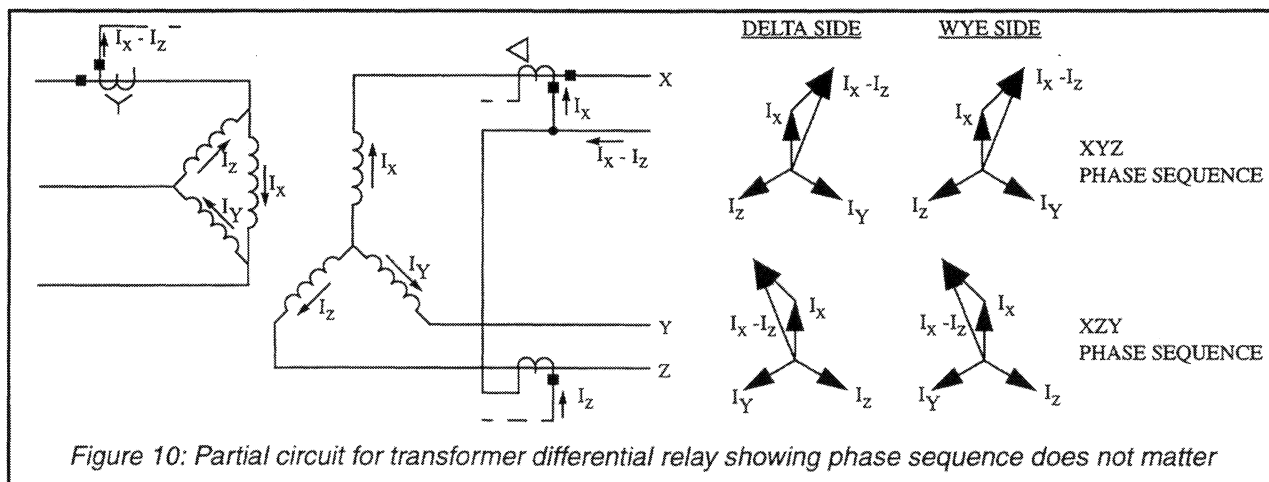
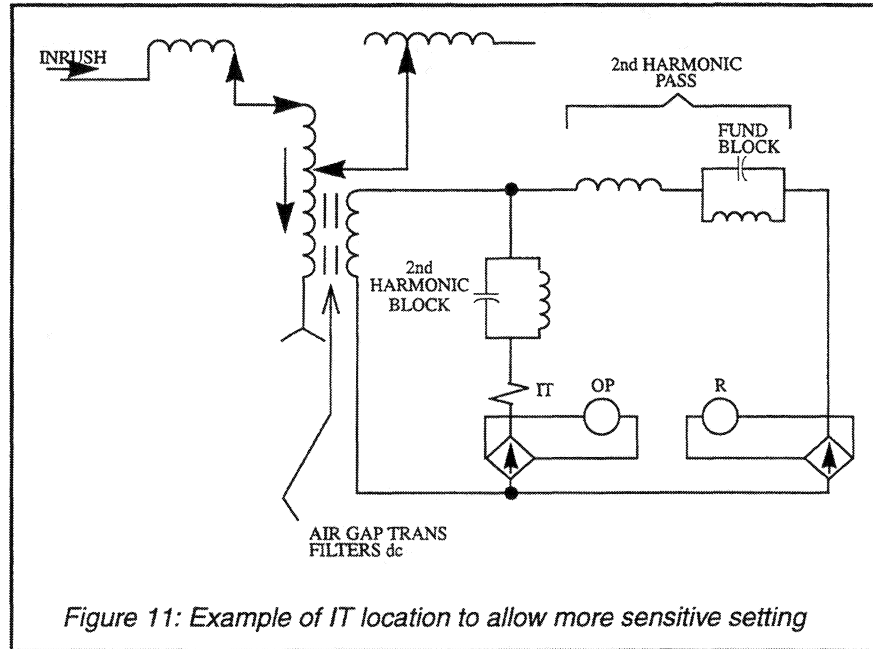
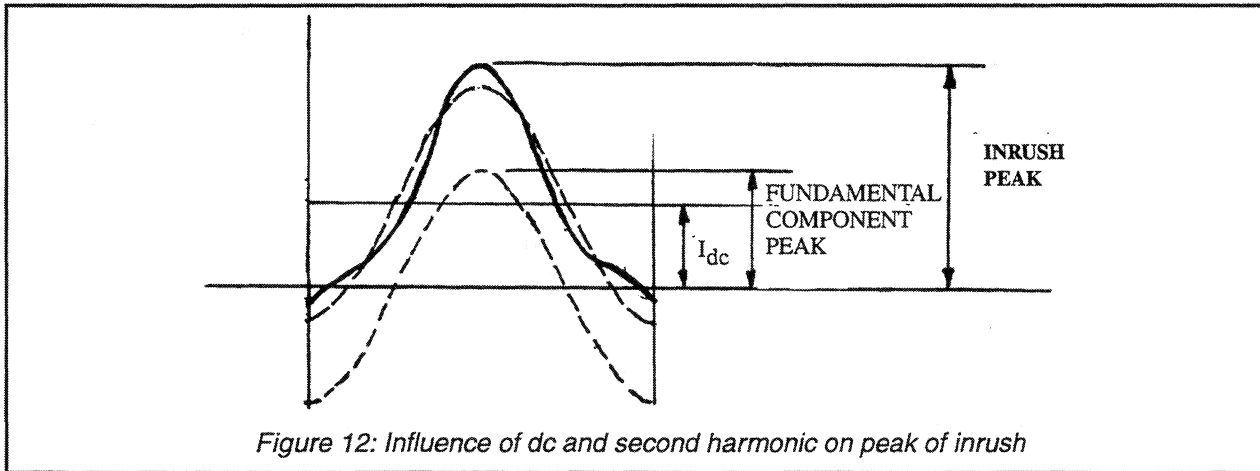


Figure 10: Partial circuit for transformer differential relay showing phase sequence does not matter

2. The instantaneous trip protecting a transformer must always be set above inrush current. False. Some transformer differential relays, such as that of figure 11, have the instantaneous trip located in such a position that it is not responsive to either dc current or second harmonic, both of which are significant components of inrush current. Considering a fundamental value of 100% peak, a dc component of 70% and a second harmonic of 20% peak for the inrush current, an instantaneous setting that is roughly 40% lower than that which would otherwise be required may be used, and still be secure. Figure 12 shows this.



Also consider the fact that the harmonics can be segregated in microprocessor relays and utilized in any way desired. The instantaneous trip, then, can be made responsive to the fundamental only, and thereby be settable to a lower level.



3. An auto-transformer neutral is always a reliable source of zero-sequence polarizing current for ground relays. False. Reliability means that the current is always up the neutral when zero-sequence current is flowing to a ground fault, irrespective of fault location.

For two winding auto-transformers, the neutral is obviously inadequate because the current is always down the neutral for faults on the high voltage system and always up for faults on the low voltage system. It is therefore unsuitable for a polarizing source. As figure 13 shows, the relays on both the high voltage and low voltage systems would either trip for both fault locations or block for both fault locations.

For auto-transformers equipped with a tertiary, the neutral current may be a reliable polarizing source for

4. Wye-ground-broken-delta transformers always provide a reliable source of polarizing voltage. False. Figure 15 describes a connection that is sometimes proposed which will not work. The wye-ground-broken-delta transformer properly reproduces across the break, any zero-sequence voltage that is present. However, the open-delta open-delta connection used with it in this figure delivers no zero- sequence voltage to it. There is no zero-sequence content in phase- to-phase voltages. There will then be no output from the wye-ground-broken-delta transformer even though considerable zero- sequence voltage may be present on the power system.

Microprocessor Relays

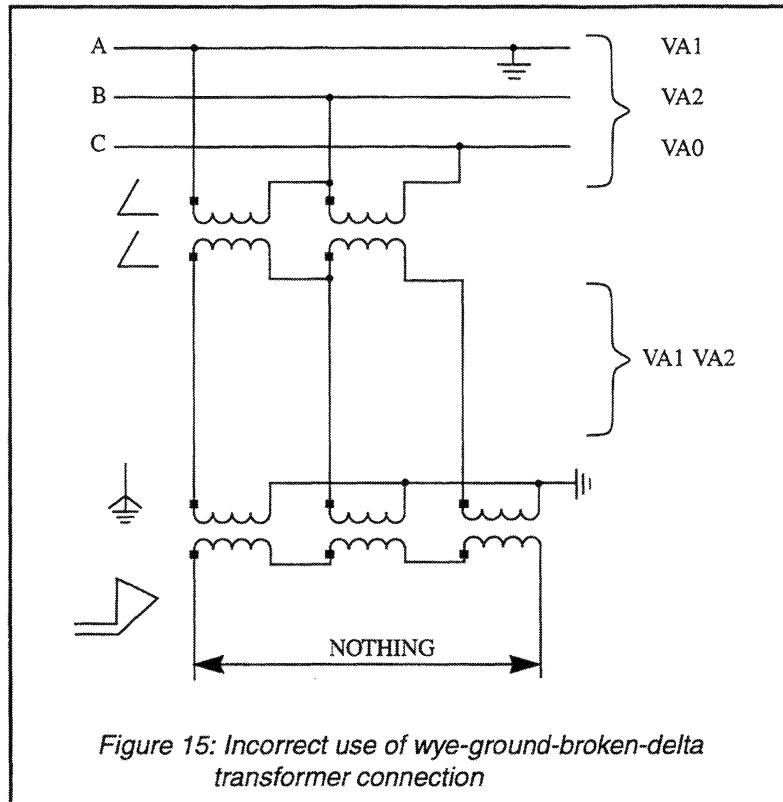
Anti-aliasing filters must be used on all microprocessor relays. False. In addition to the hardware cost savings, the real advantage of omitting a front-end low-pass filter is to allow the higher frequency components which influence the RMS value to remain in the wave-form. Using asynchronous sampling (for example, 8 uniformly spaced samples followed by a time delay and then 8 more etc.), the error associated with sampling at the same point in each cycle is removed. High frequency components are aliased into the appearance of having a lower frequency character, but the RMS value is not influenced appreciably over time because of the jump (the time delay). This is applicable only to time delayed relays because of the need of evaluating the samples over a period of several cycles.

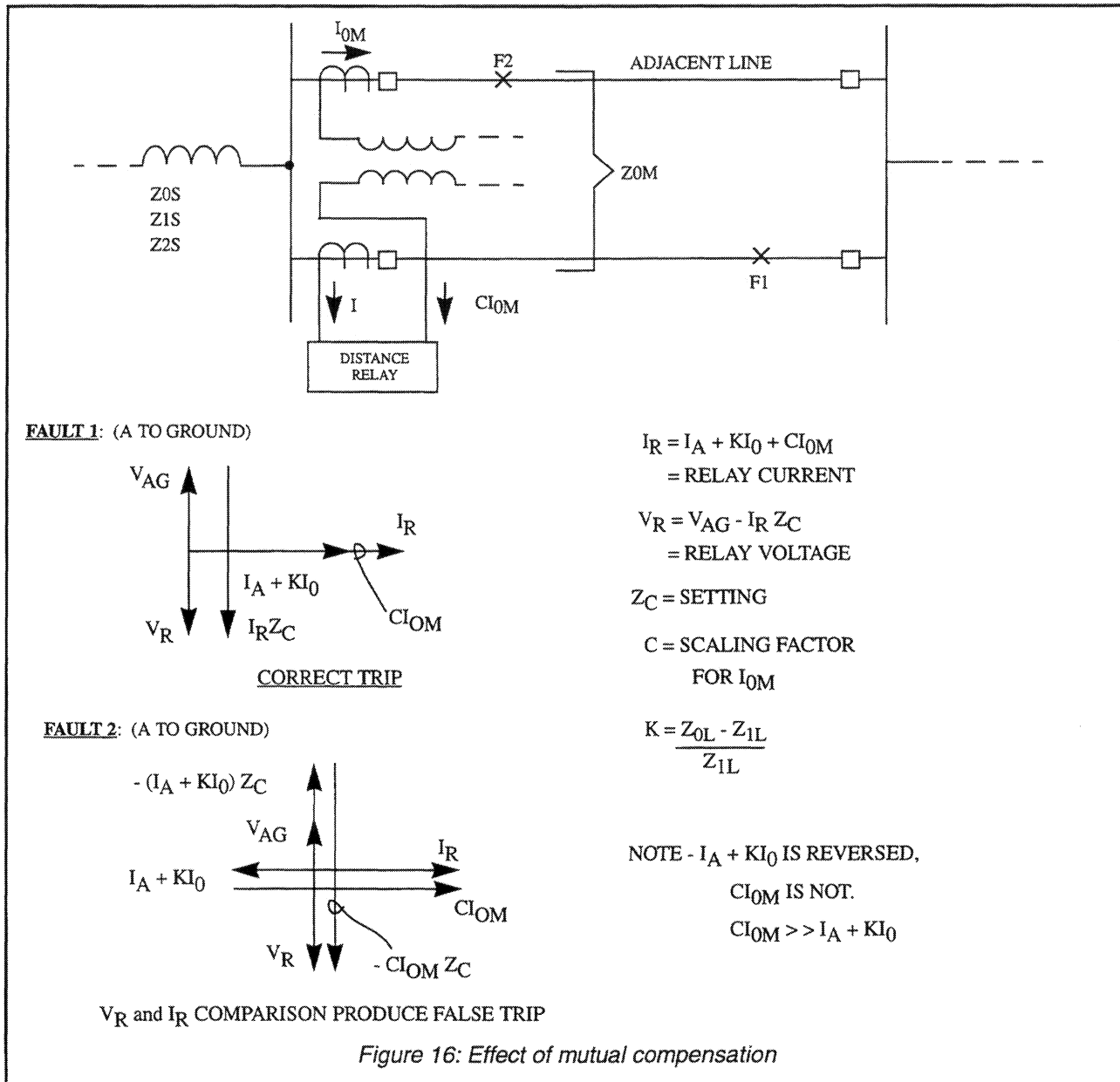
Transmission Line Relaying

Parallel line compensation is always good for ground distance relays. False. The introduction of adjacent line zero-sequence current into a relay is very appealing from the viewpoint of eliminating the error in a ground distance relay that is caused by zero-sequence mutual inductance. However, the nature of compensation is that the zero-sequence current in the adjacent line increases the reach of the ground relay for faults on the protected line, and this increase also occurs for faults on the adjacent line. Since adjacent line zero-sequence current for a zero percent fault on the adjacent line is limited almost exclusively by the source impedance (rather than the line impedance), the compensation may be overpowering, causing the relay to have a false sense of direction to the fault (see figure 16.) The addition of a zero-sequence directional unit solves this problem, as would decreasing or eliminating the adjacent line zero-sequence mutual compensation.

Conclusions

This paper has attempted to examine certain nuances of fundamental principles which are directly or indirectly related to protective relaying. If it has provided any help in minimizing the confusion that often surrounds these principles, it will have served its purpose.





References

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2. Instrument Transformers, ABB Technical Data 42-800 Low Voltage Instrument Transformers Pinetops, North Carolina.
3. M.C. Perz "Natural Modes of Power Line Carrier on Horizontal Three Phase Lines", IEEE Transactions on Power Apparatus and Systems, July 1964, pages 679 -686.

Biographical Sketch

Walter Elmore was born in Bartlett, Tennessee, and graduated from the University of Tennessee with a B.S.E.E., 1949. He was in Substation Design at Memphis Light Gas and Water Division until he joined Westinghouse Electric Corp. in 1951 as a District Engineer in Seattle, WA. He transferred to the Relay-Instrument Division in Newark, NJ in 1964 where he became manager of the Consulting Engineering Section. He held that position, following a 1989 merger with ABB, until 1992 in Coral Springs, FL. Since 1992, he held the position of Consulting Engineer for ABB Power T&D Company Inc. He is presently retired but continues as a consulting engineer for ABB.

He is past chairman of the IEEE/PES Technical Council, and past chairman of the IEEE/PES Power System Relaying Committee. He is a member of Eta Kappa Nu, Phi Kappa Phi and Tau Beta Pi. He is a registered Professional Engineer in the state of Florida. He is a Life Fellow of the IEEE and was presented the IEEE Gold Medal for Engineering Excellence in 1989.

He has presented 100 papers and is the Editor of the book "Protective Relaying Theory and Applications".