False Applications of Reliable Relaying Principles Revisited

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Original Paper

"False Applications of Reliable Relaying Principles " presented in 1997 by the late Walter A. Elmore.

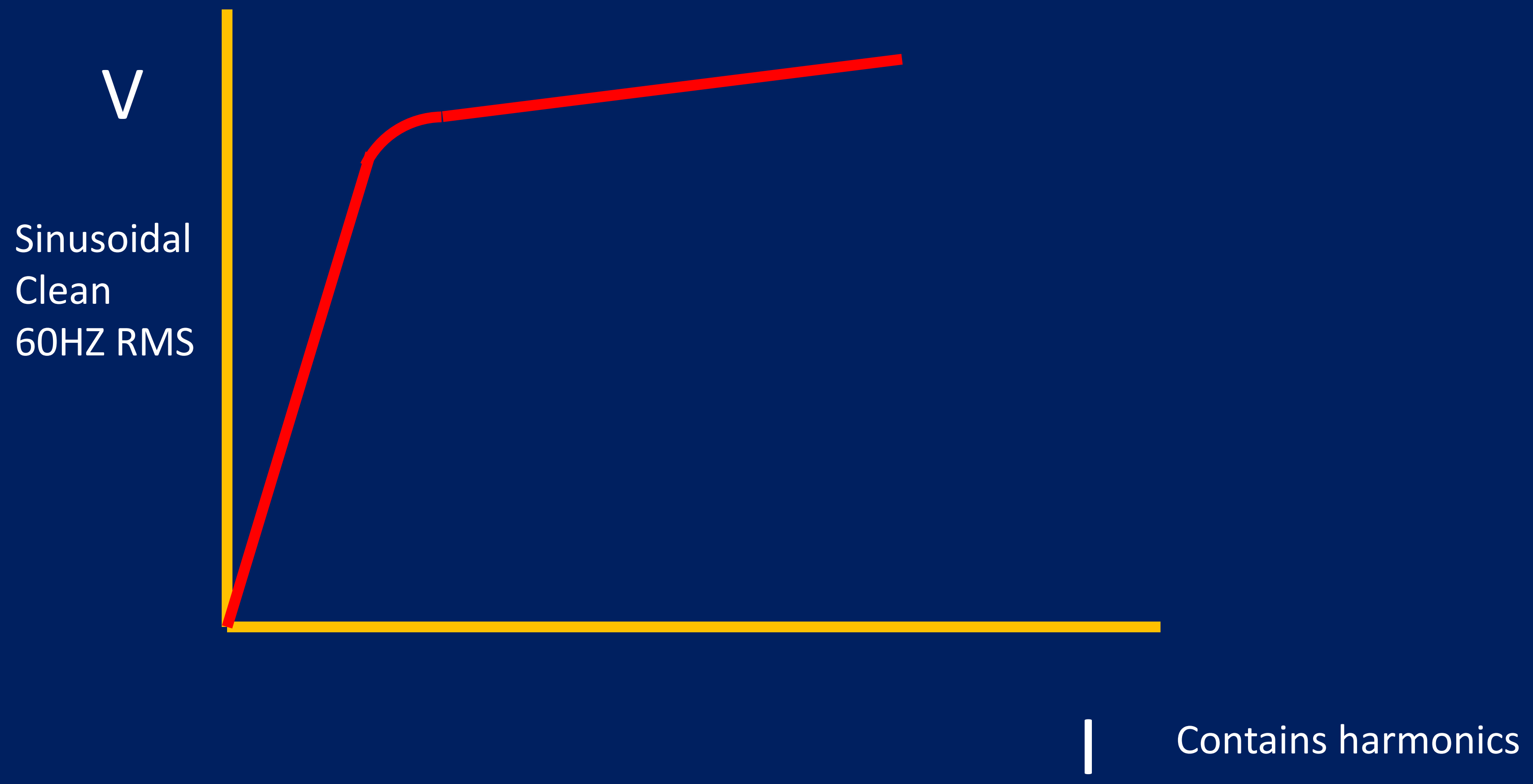
Good to review sound relaying principles

Is paper still valid for today's microprocessor relaying systems ?

THE FOLLOWING "TRUTHS" DEAL WITH EXCITATION CURRENT, ERROR CURRENTS, AND DC OFFSET

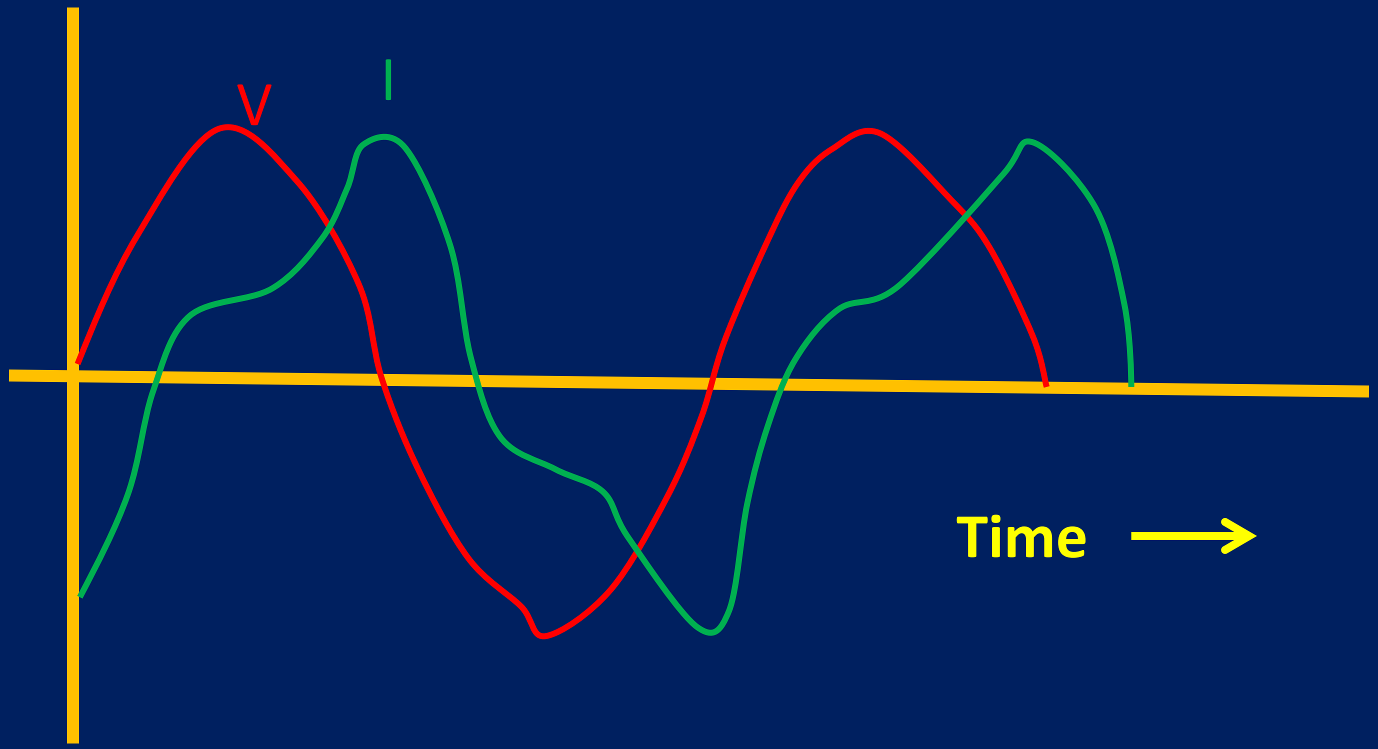
The Excitation Curve supplied with current transformers relates instantaneous secondary voltage and exciting current

Excitation curve



RMS Secondary excitation voltage vs RMS excitation current

Excitation Current



HOW CAN WE USE THIS CURVE ?

Experience has shown that it’s reasonable to use the RMS - RMS assumption.

ANSI Standard C57.13 - 2008 allows this approach

FOR C CLASS CURRENT TRANSFORMERS, THE MAXIMUM ERROR WITH NO MORE THAN RATED SECONDARY BURDEN IS 10%.

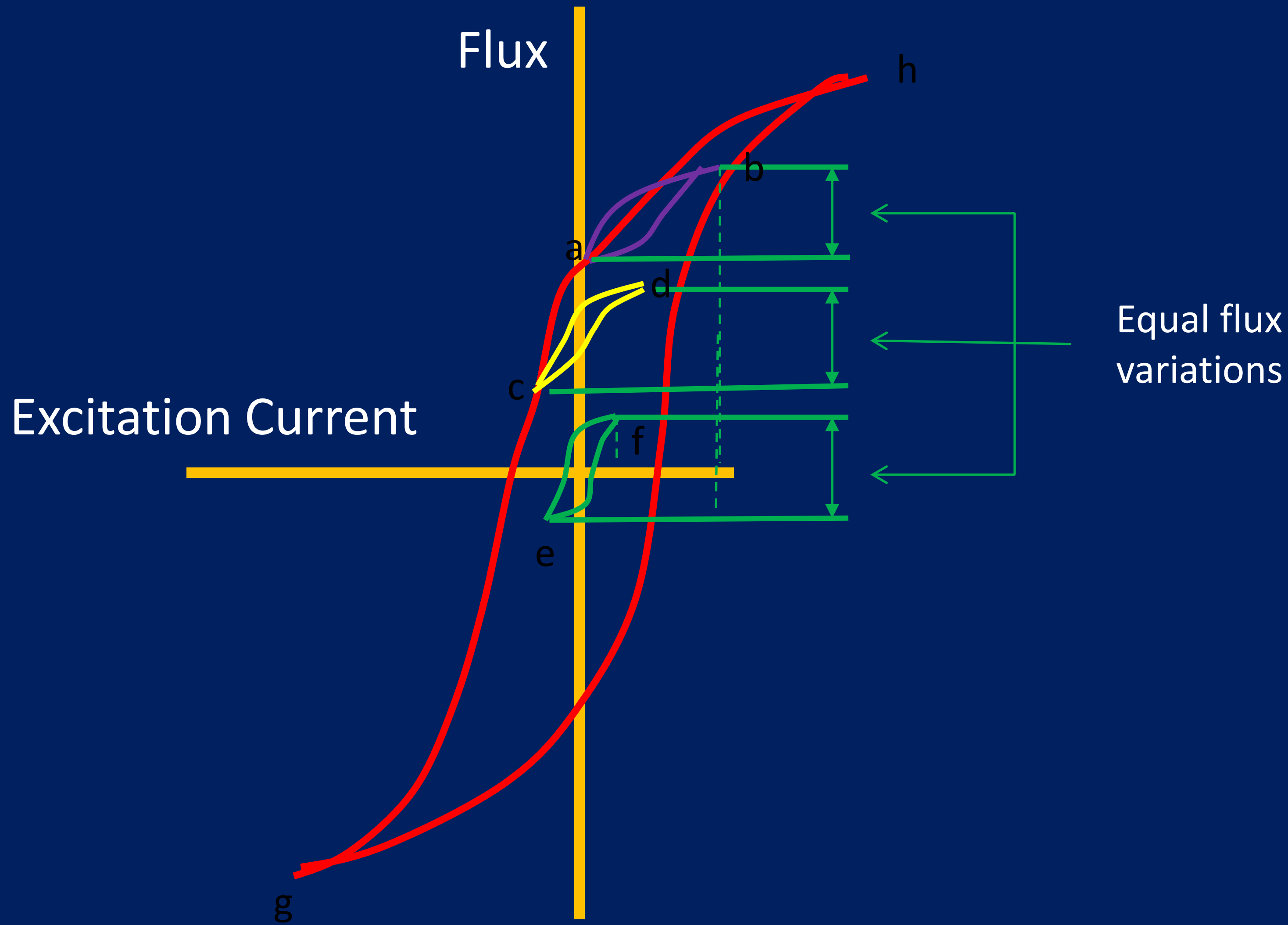
WHEN IS THIS TRUE ?

Symmetrical currents

No DC components

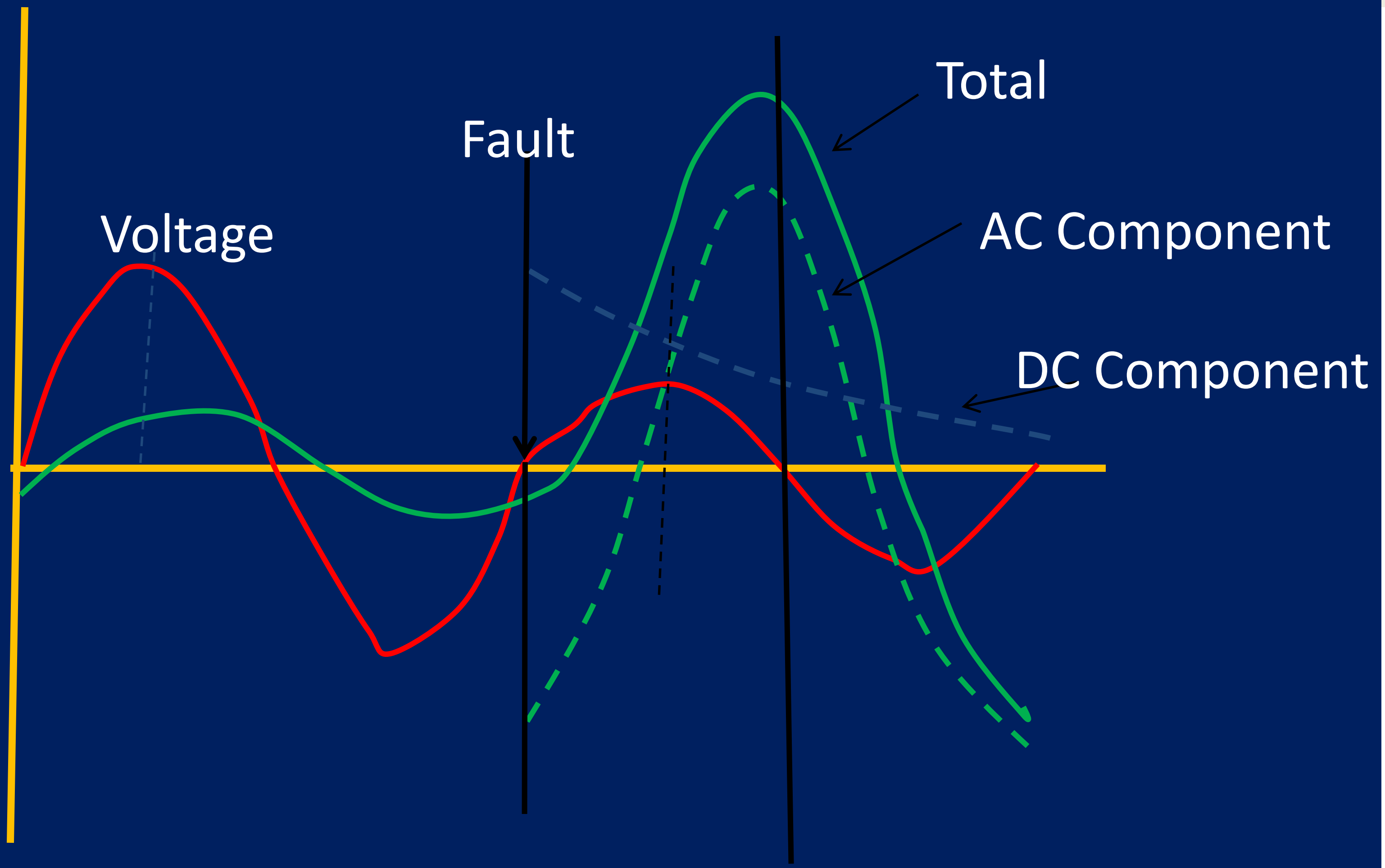
From 5 – 100 amps secondary

For a CT having no residual flux



Effects of residual flux on ct excitation current

Fault current having a dc offset is initially very high



No change in current at fault inception

Third harmonic is always zero sequence in character

Third Harmonic is always zero sequence in character ?

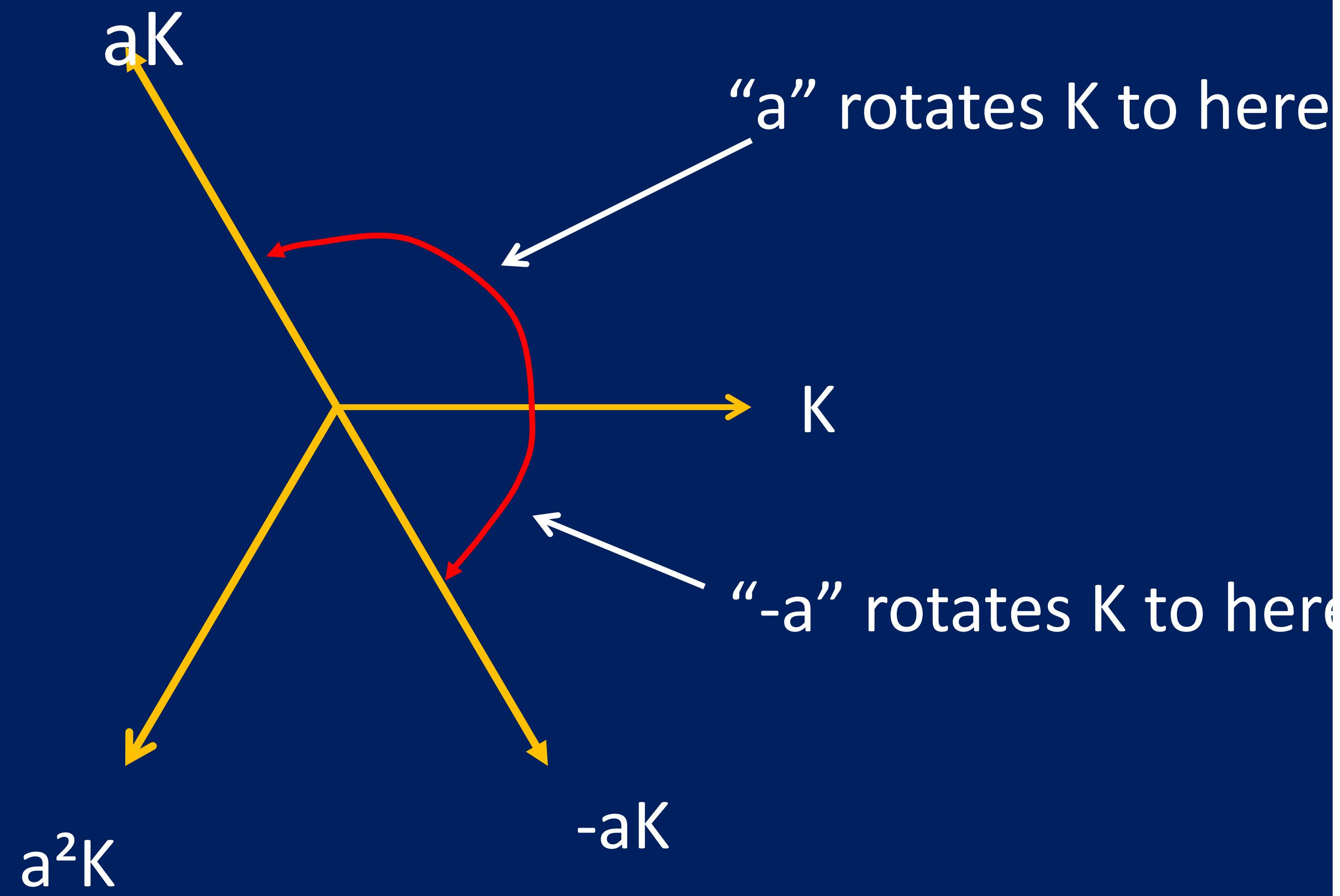
- True only if same level of third harmonic current is generated in each phase

- Non linear single phase load generates third harmonic voltage but also contains positive, negative, and zero sequence characteristics in the same way phase to ground fault does.

SymmetricaL Components

Since operator “a” rotates a phasor 120° in the counter clockwise direction, operator “-a” rotates a phasor 120° in the clockwise direction.

Effects of “a” on rotation



Seventh harmonic is positive sequence in character and therefore will have no effect on a negative Sequence voltage relay.

FALSE FOR E/M RELAYS

- Nearly all negative sequence filters were designed for 60Hz
- At high frequencies, the filter output voltage was nearly the same whether the character of the high frequency is positive or negative sequence
- A filter designed for 60Hz will produce an output for a high frequency even though the fundamental is purely positive sequence

NumericaL Design

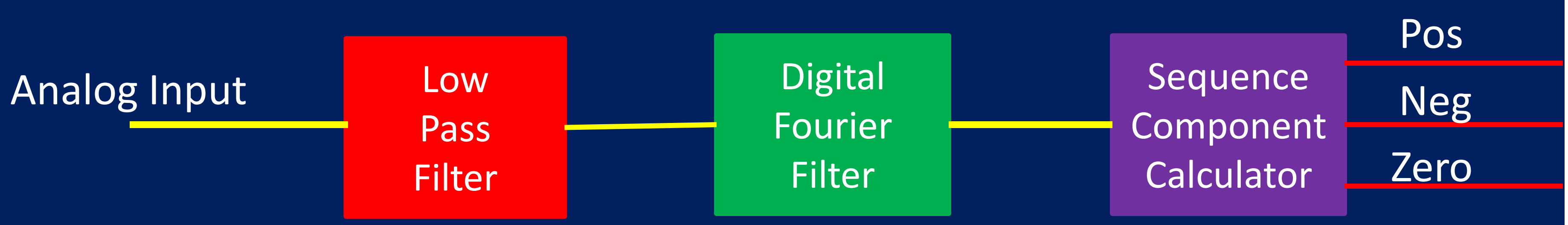
Analog input goes through low pass filter with a cutoff frequency of around 600Hz.

Individual phasors for the three phases are calculated using full cycle digital Fourier filter

Positive, Negative, and zero sequence phasors using classical matrix formulas

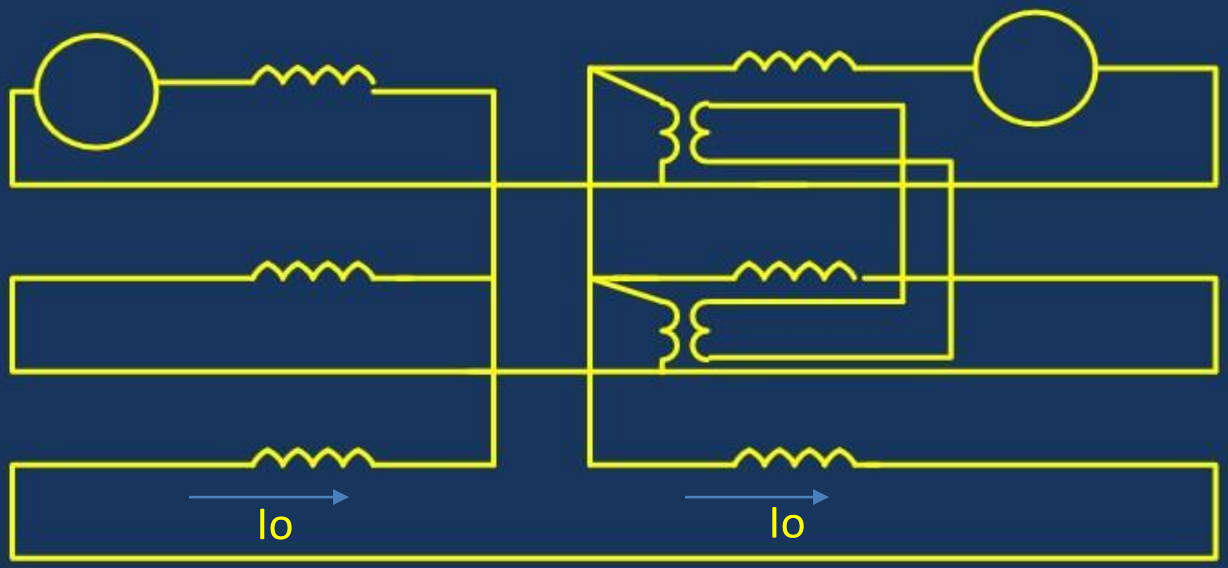
7th Harmonic will have negligible influence on sequence components calculated

Numerical Sequence Component calculator



Faults that do not involve ground produce no zero sequence current.

One line Diagram

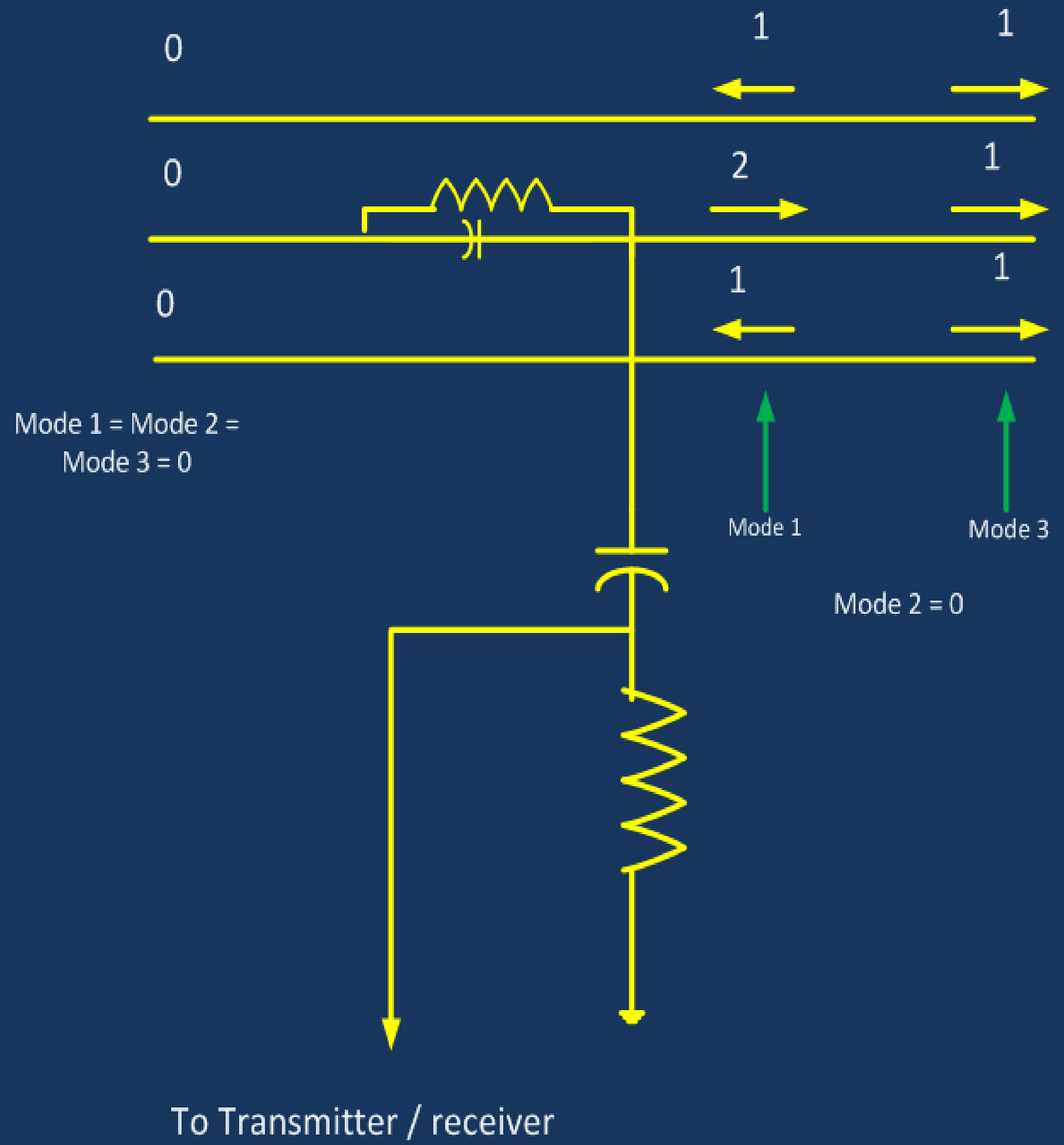


Interconnection for “A” Open

and simultaneous phase to phase fault

Relays that have a weighted zero sequence response could interpret this as an External fault.

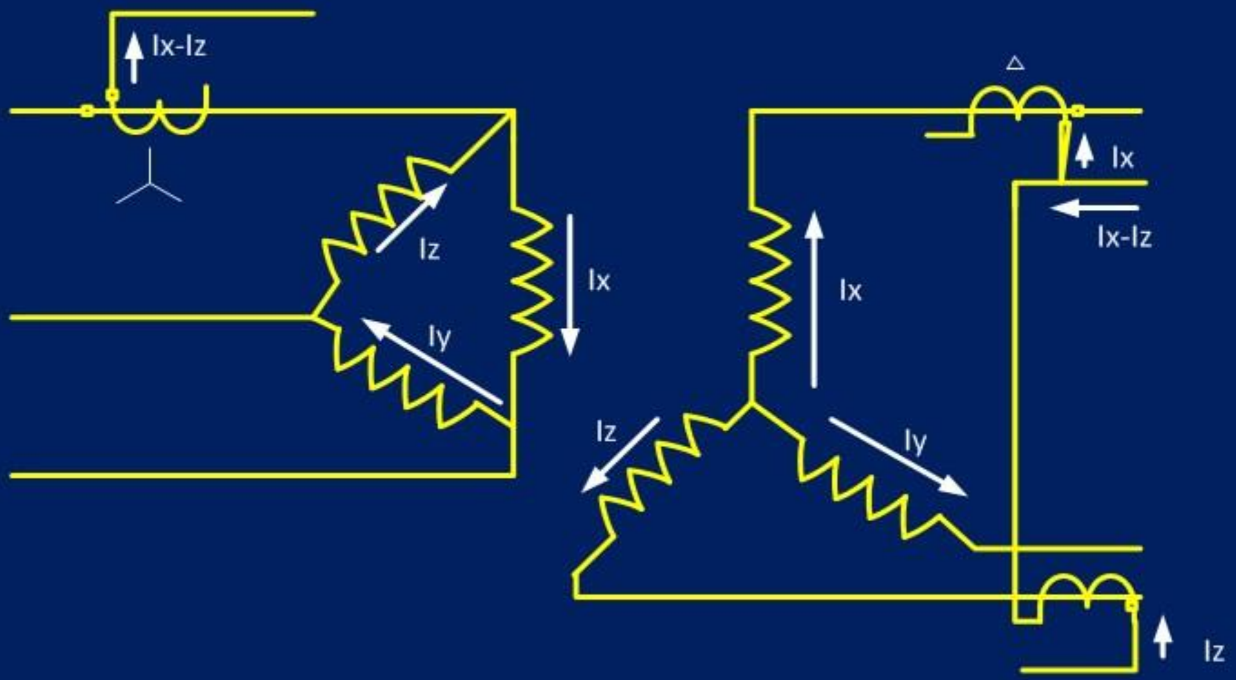
With center phase coupling and center phase trapping, the carrier signal is Confined to the coupled phase.



Signal on Adjacent line due to Local Transmitter

Phase sequence is important in connecting the differential relays for a power transformer

Phase sequence doesn't matter in this connection



Partial circuit for Transformer Differential

NUMERICAL DIFFERENTIAL RELAY

Current transformers usually are Wye connected

Phase compensation setting are used to compensate for phase shift across transformer

Phase sequence doesn't effect setting

The Instantaneous trip protecting a Transformer Must always be set above inrush current

Numerical relays

Inrush high in harmonic content

Harmonics and DC can be stripped out via Fourier Filtering

Result : Instantaneous only responsive to fundamental current

An autotransformer neutral is always a
Reliable source of zero sequence polarizing
Current for ground relays.

(Reliable means that the current is always
Up the neutral when zero sequence current
Is flowing to a ground fault, irrespective of
fault location.)

2 Winding transformer

Current always down the neutral for a fault on the high voltage system

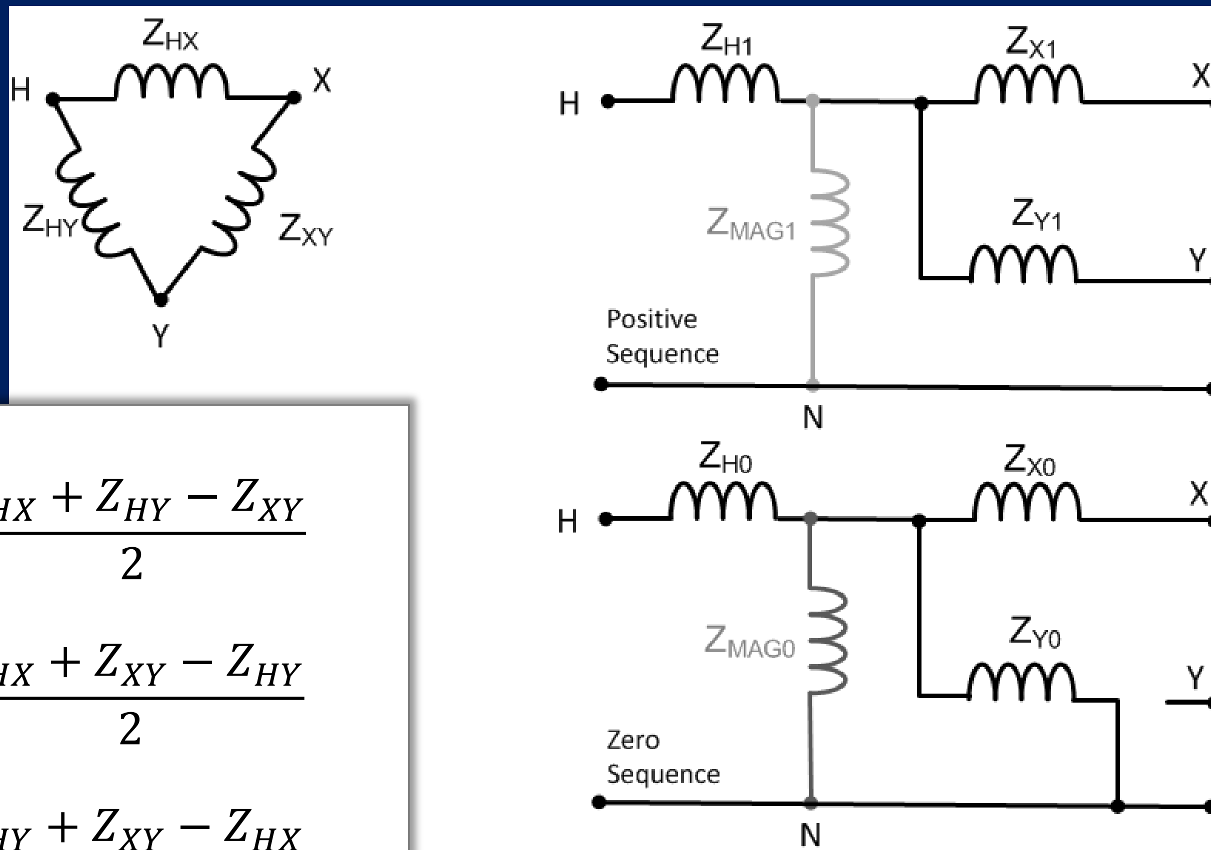
Current always up the neutral for faults on the low voltage system

Not suitable

Autotransformers with tertiary

Neutral current may be a reliable polarizing source

T BRANCH MODEL

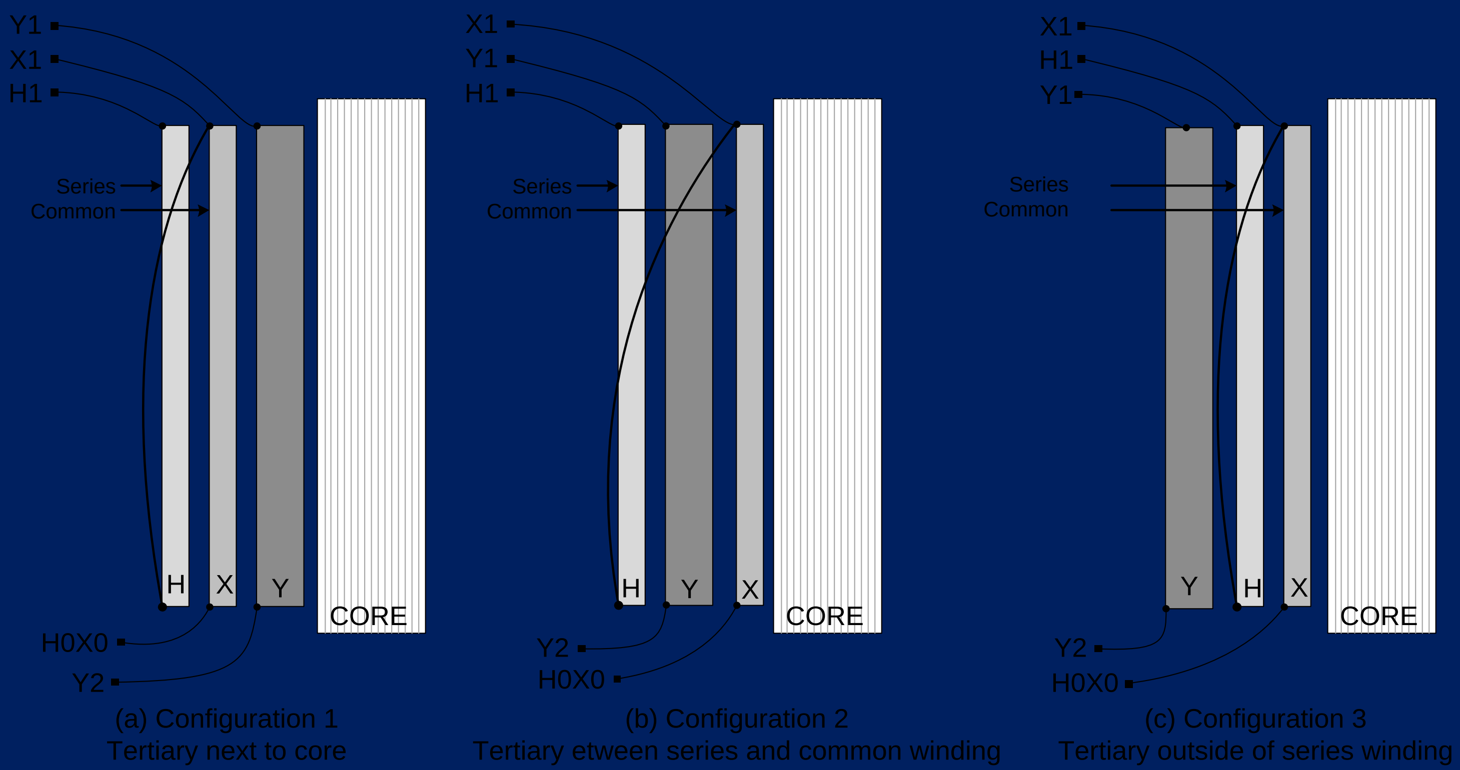


$$Z_H = \frac{Z_{HX} + Z_{HY} - Z_{XY}}{2}$$

$$Z_X = \frac{Z_{HX} + Z_{XY} - Z_{HY}}{2}$$

$$Z_Y = \frac{Z_{HY} + Z_{XY} - Z_{HX}}{2}$$

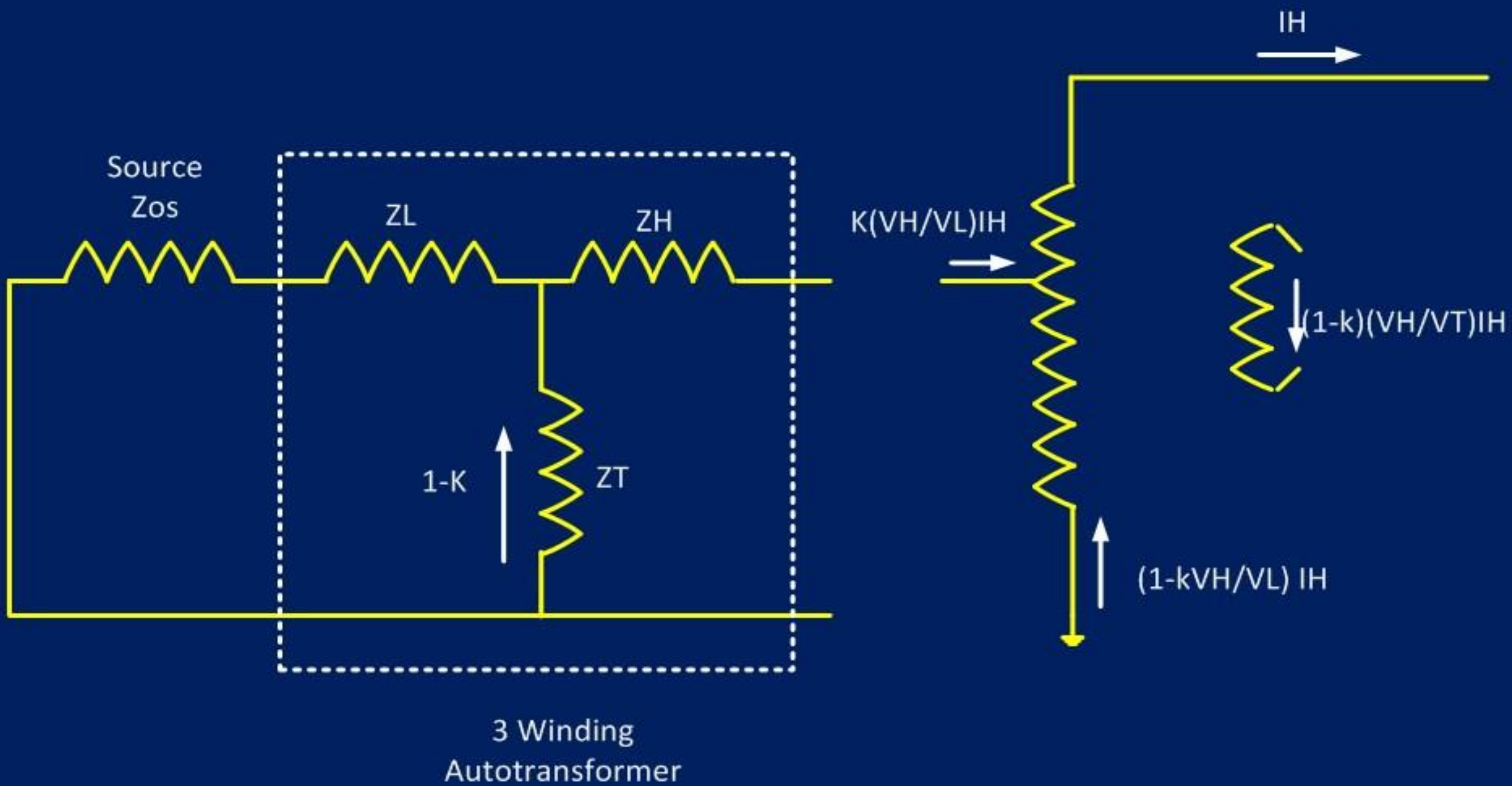
WINDING PLACEMENT AFFECTS ON LEAKAGE IMPEDANCE



IMPEDANCES FOR DIFFERENT WINDING ARRANGEMENTS

Winding Configuration		Positive Sequence Impedance			Positive Sequence Impedance		
		H - X	H - Y	X - Y	H	X	Y
1	Core-TV-LV-HV	10.6	29.0	14.4	12.6	-2.00	16.4
2	Core-LV-TV-HV	10.2	8.4	11.4	3.6	6.6	4.8
3	Core-LV-HV-TV	10.4	39.7	70.3	-10.1	20.5	49.8
All impedances are in % on 0.6*280 MVA base at rated winding voltage. Z_{Base} = kV^2/MVA, $Z_W = Z_{Base}$ x Z%/100, HVR - regulating winding							

280 MVA Autotransformer

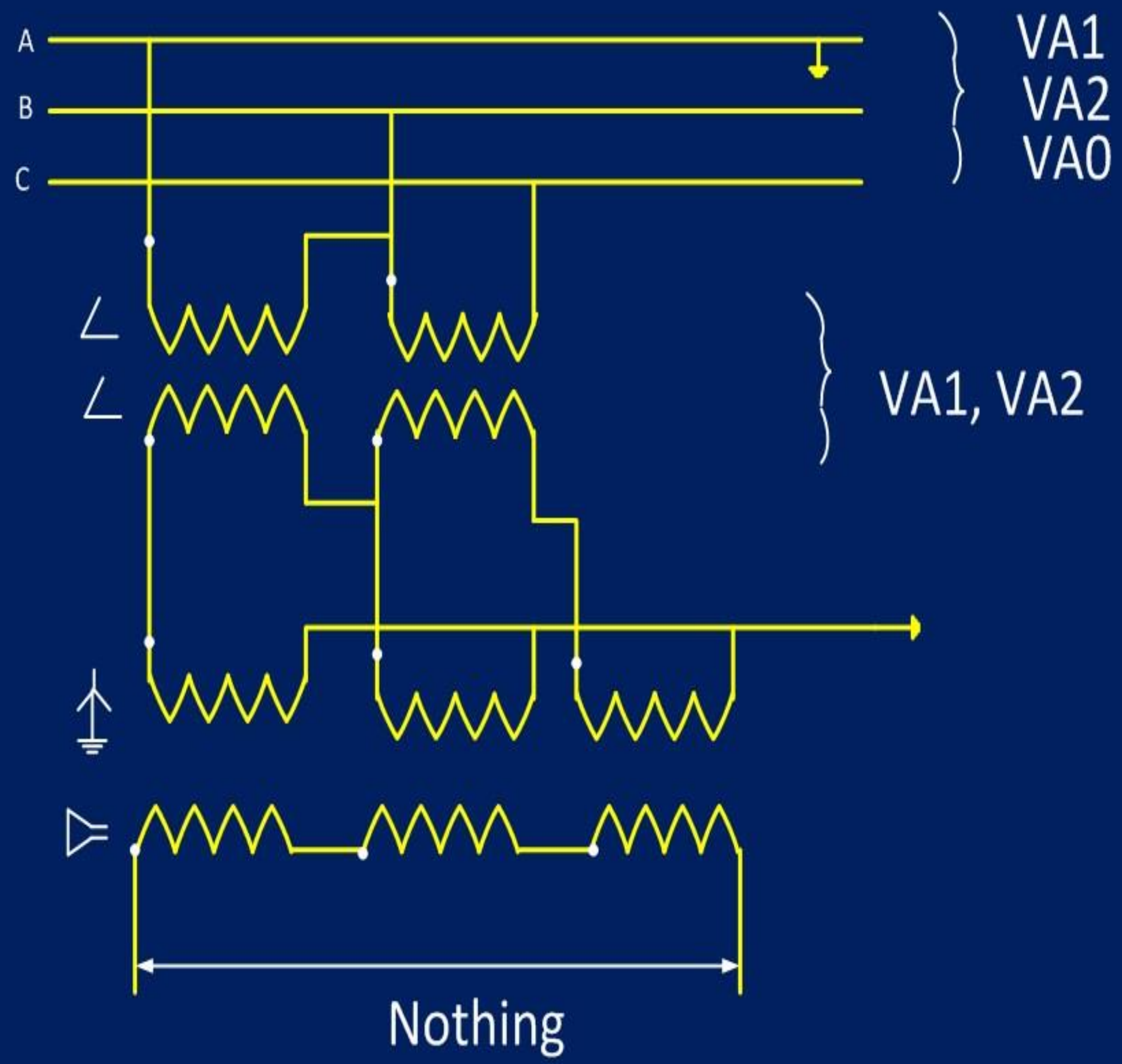


k is current distribution factor

Neutral is good polarizing source if : kVH/VL<1

Wye –ground – Broken Delta transformers Always provide a reliable source of Polarizing voltage

Open Delta – Open Delta Potential Transformer



Parallel line compensation is always Good for ground distance relays

Parallel Line Compensation

Eliminates error in ground distance relay caused by zero sequence mutual inductance

Parallel Line Compensation

Why a problem ?

Zero Sequence current in adjacent line increases the reach of the ground relay for faults on the protected line

Adjacent line I0 is limited only by source impedance for a 0% fault. Not line impedance

Compensation may be overpowering, causing relay to have false sense of direction to the fault

Conclusions

Original paper correct in nearly every case

- Current transformers still obey the laws of physics
- Fortescue's rules of Symmetrical components still apply
- Power line carrier modal analysis is the same
- Kirchoff's law still applies to differential relays
- Life's Beautiful !


Questions ?