7PG21 Solkor Rf

Feeder Protection

Document Release History

This document is issue 2010/02. The list of revisions up to and including this issue is:

Pre release

02/2010	Document reformat due to rebrand

Software Revision History

Contents

List of Tables

1 General

Solkor R & Rf are well established Pilot Wire Current Differential Protection for use with privately owned 2 core pilots with relatively high core resistance.

Solkor R/Rf protection benefits from the following main features:

- High transient stability
- High speed operation
- Low phase and earth fault settings
- Little or no variation of settings with pilot length
- In zone bleed off of up to 20% of rated load
- Easy to install, commission and maintain
- 15kV pilot isolation option
- Easily reconnected as either Solkor Rf or Solkor R
- Pilot Supervision schemes available
- Remote end injection intertripping via pilot cores available

2 Description

The Solkor Rf protection system (excluding current transformers) is shown below. The alternative basic Solkor R protection circuit is also shown.

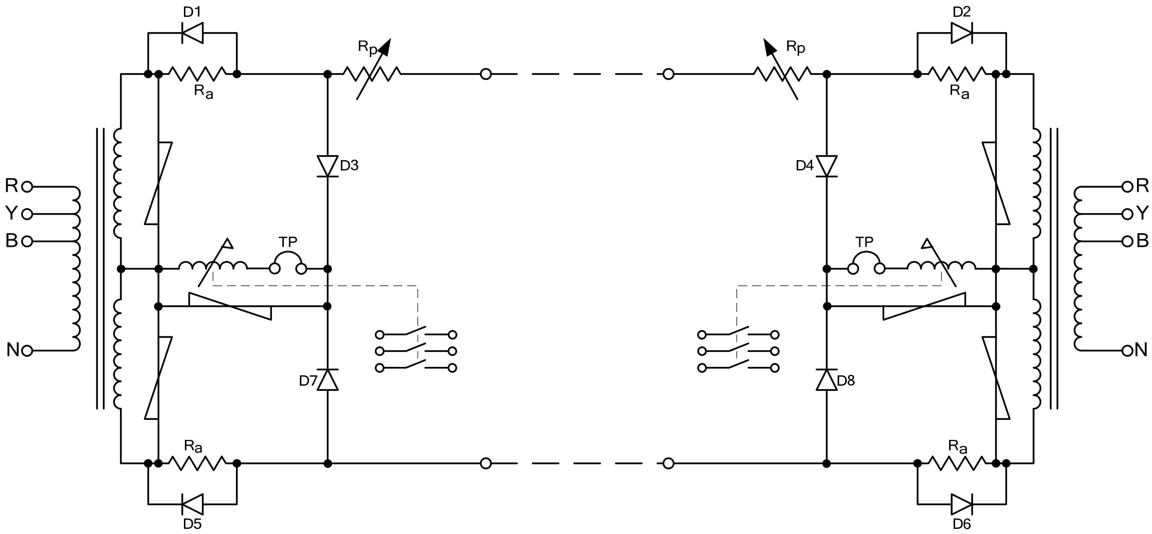


Figure 1 Solkor Rf schematic

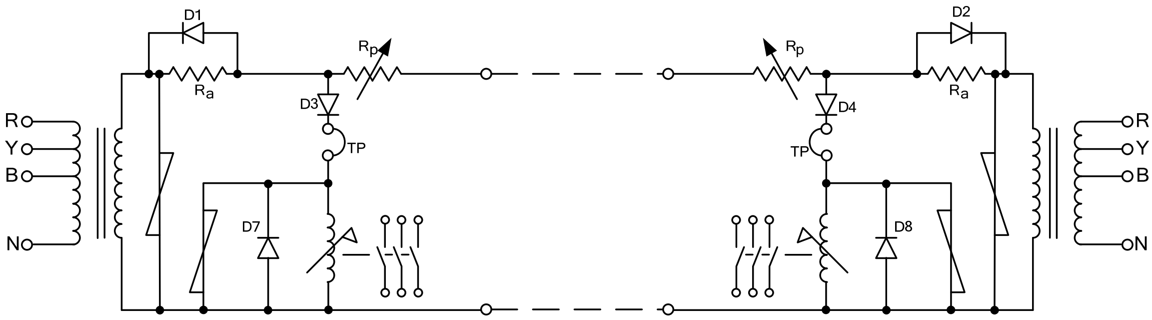


Figure 2 Solkor R schematic

Conversion of the Solkor Rf to Solkor R is arranged by wire links, internal to the relay.
The relay contains an 8-way internal terminal block. 4 wires marked 1-4 must be moved from 4 terminals marked 'Solkor Rf' to 4 adjacent terminals marked 'Solkor R'. Additionally a wire link must be fitted, externally to the relay on the rear terminal block to use the relay in Solkor R mode.

In addition to the basic components there are at each end, three non-linear resistors, a tapped 'pg' resistor and three diodes. The non-linear resistors are used to limit the voltage appearing across the pilots and the operating element. The purpose of the 'padding' resistors at each end is to bring the total pilot loop resistance up to a standard value. The protection is therefore always working under constant conditions and its performance is to a large extent of the resistance of the pilot cable' The 'padding' resistors comprise five series connected sections, each section having a short circuiting link. The values of the resistance on the sections are 35 ohms, 65 ohms, 130 ohms, 260 ohms and 500ohms.

For Solkor R the value chosen should be as near as possible to ½(1000-R_p) ohms, where R_p is the pilot resistance. The 500 ohm resistor should therefore be fitted for the Solkor R and the link will always be fitted for this mode.

For Solkor Rf without isolating transformers the value chosen should be as near as possible to ½(2000-R_p) ohms.

For Solkor Rf with isolating transformers the value chosen should be as near as possible to

½(SV-R_p)/T ohms.

where T = Isolating transformer tap.

& SV = Standard resistance value for tap on transformers,

1780Ω for tap1, 880Ω for tap 0.5 & 440Ω for tap 0.25

The operating element is of the attracted armature type with three contacts, each pair being brought out to separate terminals. The inherent advantages of such a relay are robustness and simplicity and since the contacts are suitable for direct operation of a circuit breaker trip coil, no repeat relay is necessary.

A 5kV insulation level is provided between the secondary winding of the summation transformer and its primary winding. The core and the relay coil is also insulated at 5kV.

Since the only external connections to the relay are those to the current transformers, the pilots and the tripping and alarm circuits, the installation and commissioning of the equipment is extremely simple. To check the current in the operating element, a test point is provided.

The 15kV arrangement is for applications where the voltage across the pilot insulation due to induction or a rise in station earth potential are excessive and where, consequently, the normal 5kV insulation level is not considered adequate. The complete protection scheme is shown in figure below.

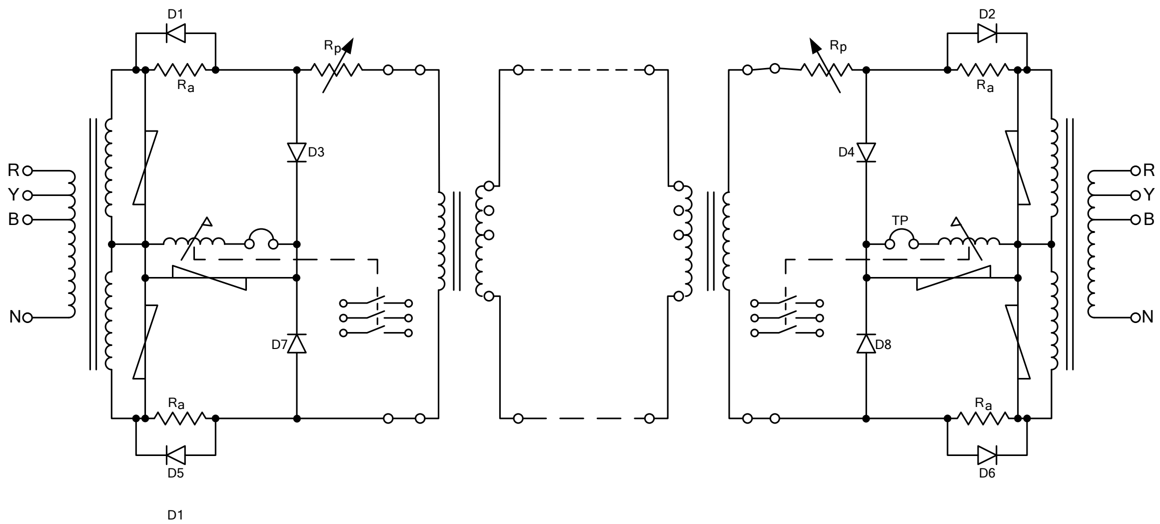


Figure 3 Solkor Rf 15kV schematic

The difference between this circuit and that shown previously is that the pilots are connected via interposing transformers which incorporate 15kV insulation barriers between windings to isolate the pilot circuit. The introduction of the isolating transformer does not modify the basic principle of operation of the protection but allows greater range of pilot coverage by the use of taps on the isolating transformer secondary windings.

3 Operation

Solkor R belongs to the circulating current class of differential protections which can be recognised by two main features. Firstly, the current-transformer secondaries are arranged to produce a current circulating around the pilot loop under external fault conditions. Secondly, the protective relay operating coils are connected in shunt with the pilots across points which have the same potential when the current circulates around the pilot loop. In this particular scheme equipotential relaying points during external fault conditions exist at one end during one half cycle of fault current, and at the other end during the next half cycle. During half cycles when the relay at either end is not at the electrical midpoint of the pilot system the voltage appearing across the relay is in the reverse direction to that required for operation.

At each end of the feeder the secondaries of the current transformers are connected to the primary of the summation transformer – see section 4 Theory of Summation Transformer. For various types of current distribution in the three current transformers, a single phase quantity appears in the summation transformer secondary winding and is applied to the pilot circuit. By this means a comparison between the currents at each end of a three phase line is effected over a single pair of pilot wires on an equivalent single phase basis. The tappings on the summation transformer primary have been selected to give an optimum balance between the demands of fault setting and stability.

The pilot is shown as a 'lumped' resistor R_P. The rest of the pilot loop is made up of four resistors R_a and four diodes D1, D2, D5 and D6. The operating elements, which are made unidirectional by diodes D3, D4, D7 and D8 are connected in shunt with the pilots.

During an external fault condition, an alternating current circulates around the pilot loop. Thus on successive half cycles one or other of the resistors R_a at the two ends of the pilot is short circuited by its associated diode D1 or D2. The total resistance in each leg of the pilot loop at any instant is therefore substantially constant and equal to R_a+R_p. The effective position of R_a however, alternates between ends, being dependent upon the direction of the current. The change in the effective position of R_a makes the voltage distribution between the pilot cores different for successive half-cycles of the pilot current.

In other words stability is achieved by current balance using the Solkor R principle of establishing the electrical centre point geographically within the end which has positive polarity so that the positively polarised measuring elements remain in the negative part of the circuit and are thus biased against operation.

Referring to the basic circuit of Solkor Rf as shown in Figure 1, the circulating current will flow from the summation transformer through the diode or the resistor depending on the polarity of the summation transformer output. Thus the circuit may be redrawn to suit the polarities of summation transformer output as shown in Figure 4 & Figure 5 below.

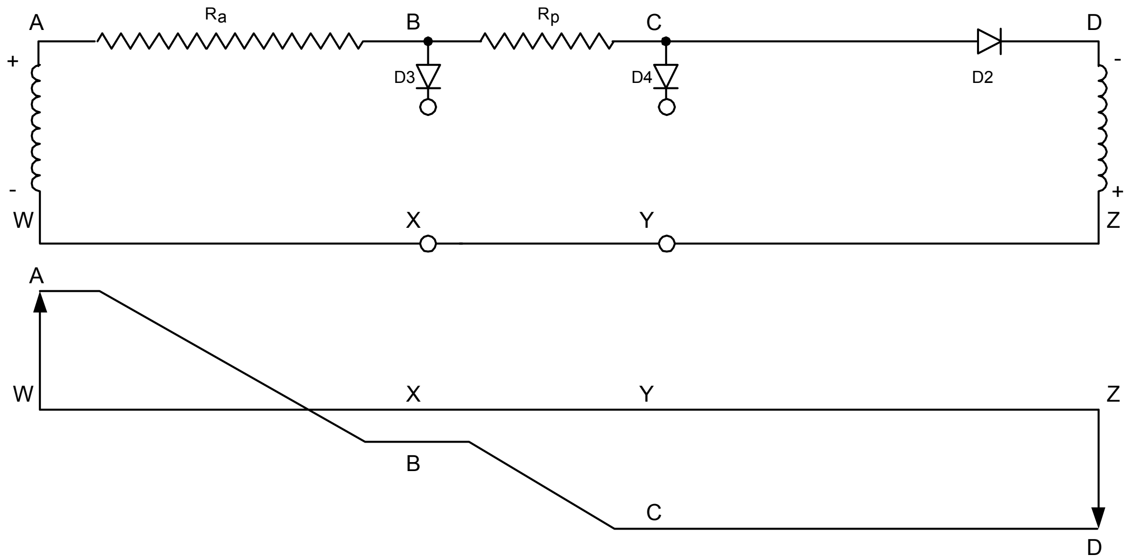


Figure 4 Through Fault, zero ohm pilots, Positive half cycle.

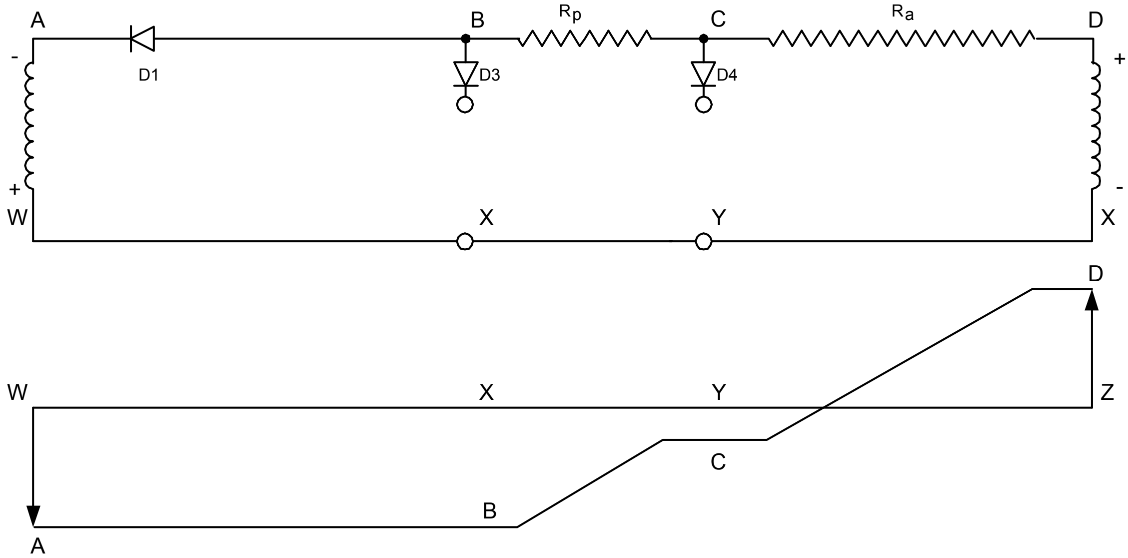


Figure 5 Through Fault, zero ohm pilots, Negative half cycle.

Figure 4 & Figure 5 above represents the operations of Solkor R protection with zero ohm pilots so that the loop resistance is represented entirely by the 500 ohm padding resistor in each relay and the 1000ohm sum in the pilot circuit is in one leg of the pilot circuit as shown, R_P.

Resistors R_a are of greater resistance than the pilot loop resistance R_p and this causes the point of zero potential to occur within the resistors R_a, as shown in Figure 5. The voltage across each relaying point (B-X and C-Y) throughout the cycle is now always negative. This voltage bias must be overcome before operation can take place; consequently the effect is to enhance the stability of the protection against through faults.

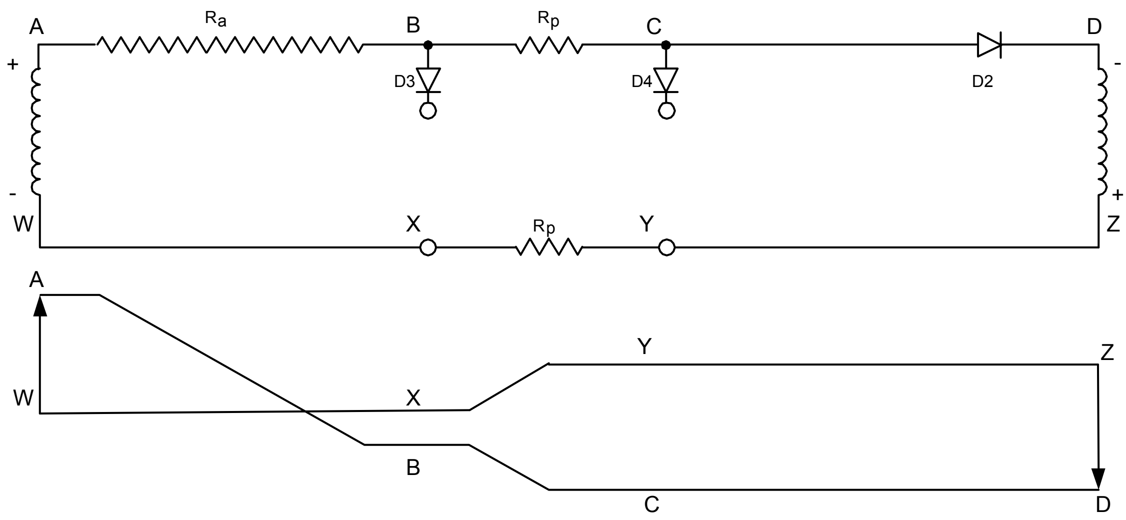


Figure 6 Through Fault, 1000 ohm pilots, Positive half cycle.

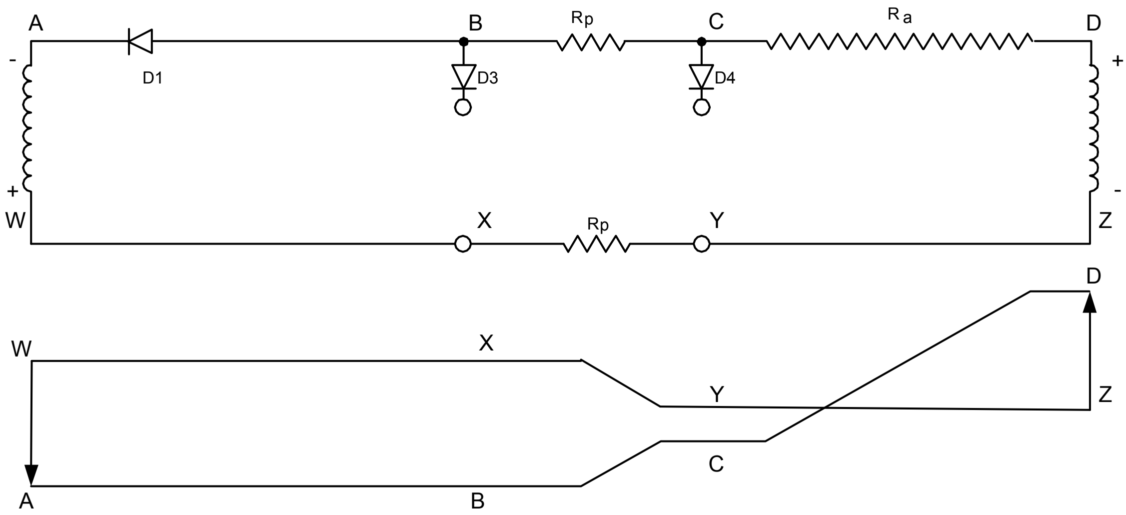


Figure 7 Through Fault, 1000 ohm pilots, Positive half cycle.

At the other limiting condition the pilot resistance is a 1000 ohms loop and the circuit will be as shown in Figure 6 & Figure 7. with 500 ohms in each leg of the pilot circuit and zero padding resistors. As shown in Figure 6 & Figure 7 the resultant voltage distribution of this maximum pilot arrangement gives identical voltages across the relay points B-X and C-Y.

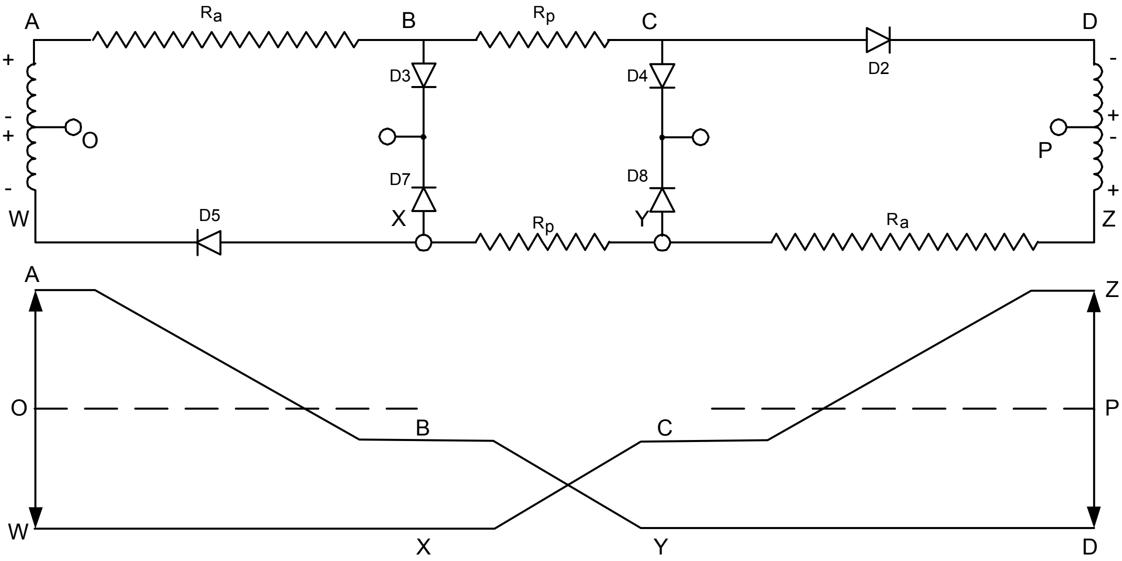


Figure 8 Through fault Rf mode, positive half cycle

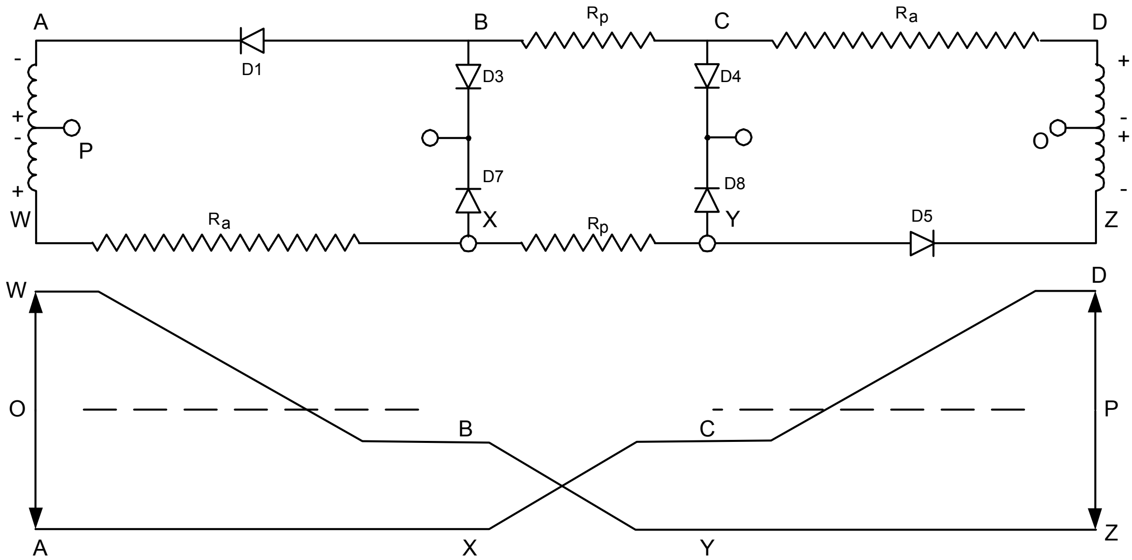


Figure 9 Through fault Rf mode, negative half cycle

Considering now the equivalent Solkor Rf circuit with 1000 ohms in each leg of the pilots as shown in Figure 8. the voltage distribution shows that the bias voltage across the polarising diodes (D3, D4, D7 and D8) with this arrangement are effectively identical with the minimum values obtained in the Solkor R arrangement. In other words, the balance of the full wave comparison gives the same value of bias for each polarity of half-cycle.

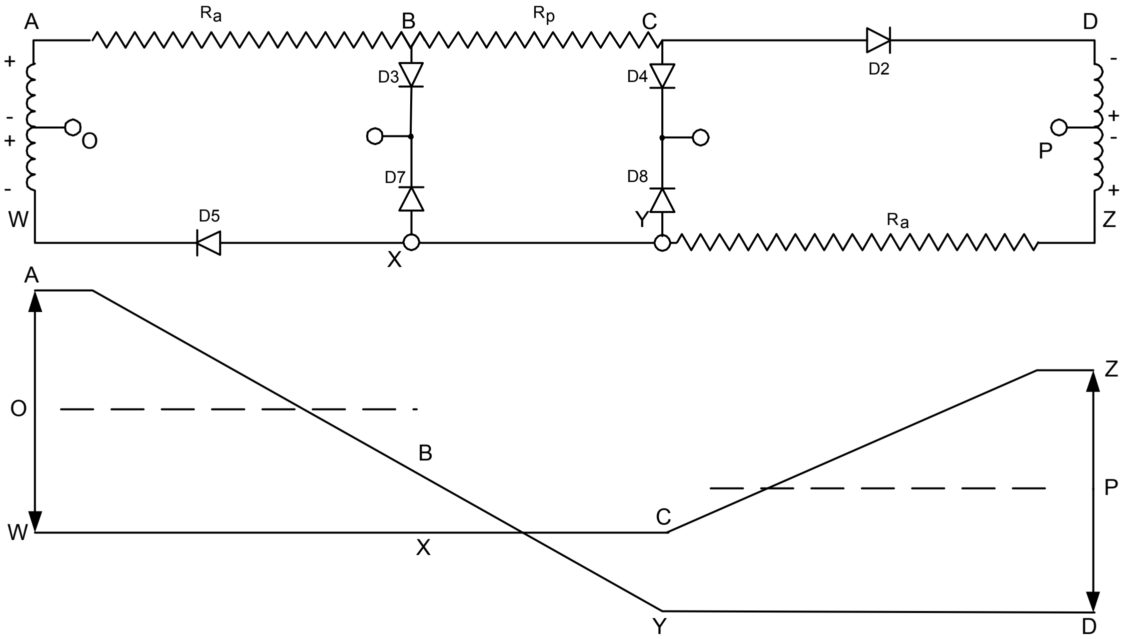


Figure 10 Through fault Rf mode, positive half cycle

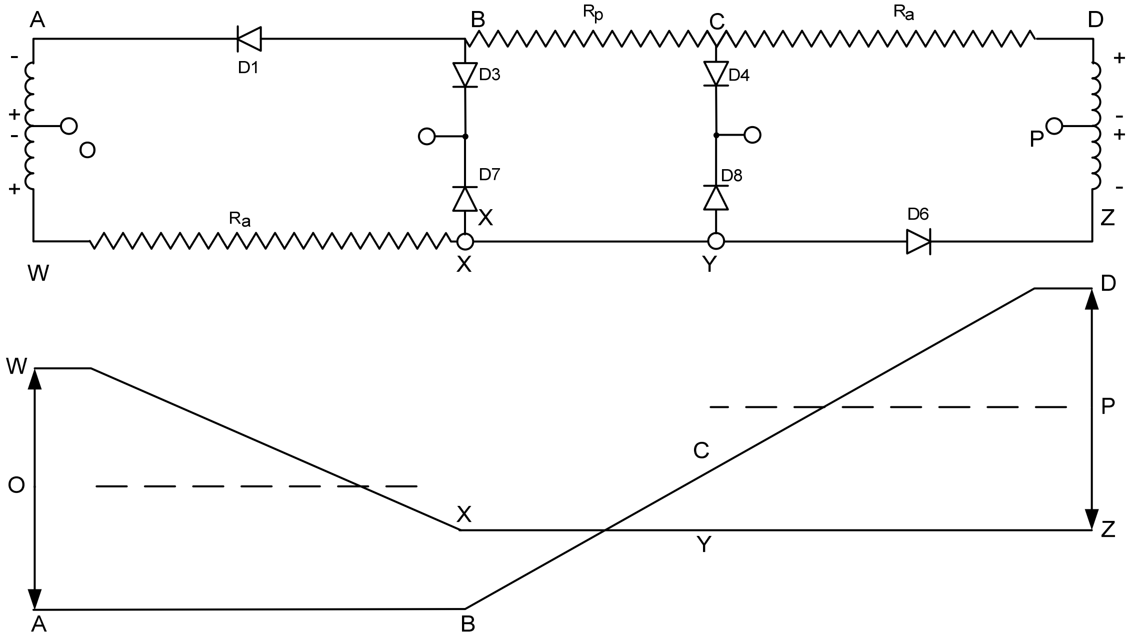


Figure 11 Through fault Rf mode, positive half cycle

If the condition of zero pilots is then considered for Solkor Rf (i.e. with 1000 ohms padding in each relay), the circuit and voltage distribution are as shown in Figure 10 & Figure 11. This shows that the same bias voltages are as obtained in Figure 8 & Figure 9.

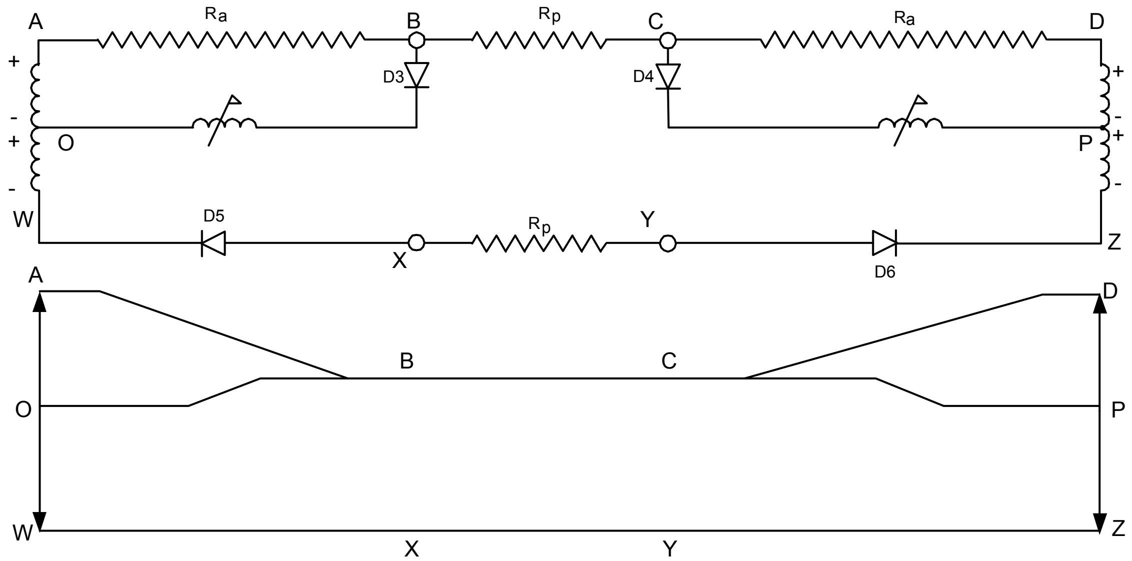


Figure 12 Internal fault Rf mode, positive half cycle

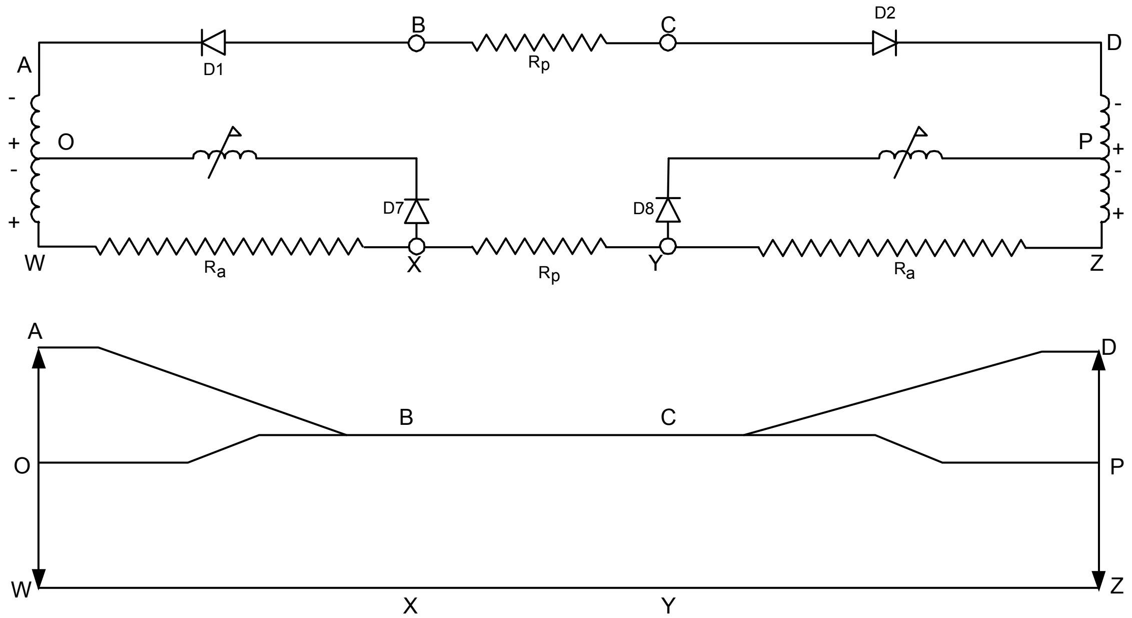


Figure 13 Internal fault Rf mode, positive half cycle

The application of pilot wire protection is generally in interconnected power systems so that it is reasonable to consider double end fed faults. For simplicity in explaining the basic principles, it may be assumed that the infeeds at both ends have the same magnitude and relative phase angle. The Solkor Rf circuit is then effectively as shown in Figure 12 & Figure 13 because the diodes in series with the pilots on the positive leg of the circuit will be out of circuit and the measuring element polarising diodes on this leg will be conducting. The voltage distribution fore this arrangement shows how, with the assumed balanced infeeds, no current flows in the pilots and each measuring element is energised via the resistor R_a.

The single end fed internal fault operates both measuring elements from the one end so that the setting level is twice that of the double end fed arrangement. However, both ends operate at this level (which is the normal setting claim) so that the intertripping is not required for internal faults even those which may be fed from one end or have low infeed at one end.

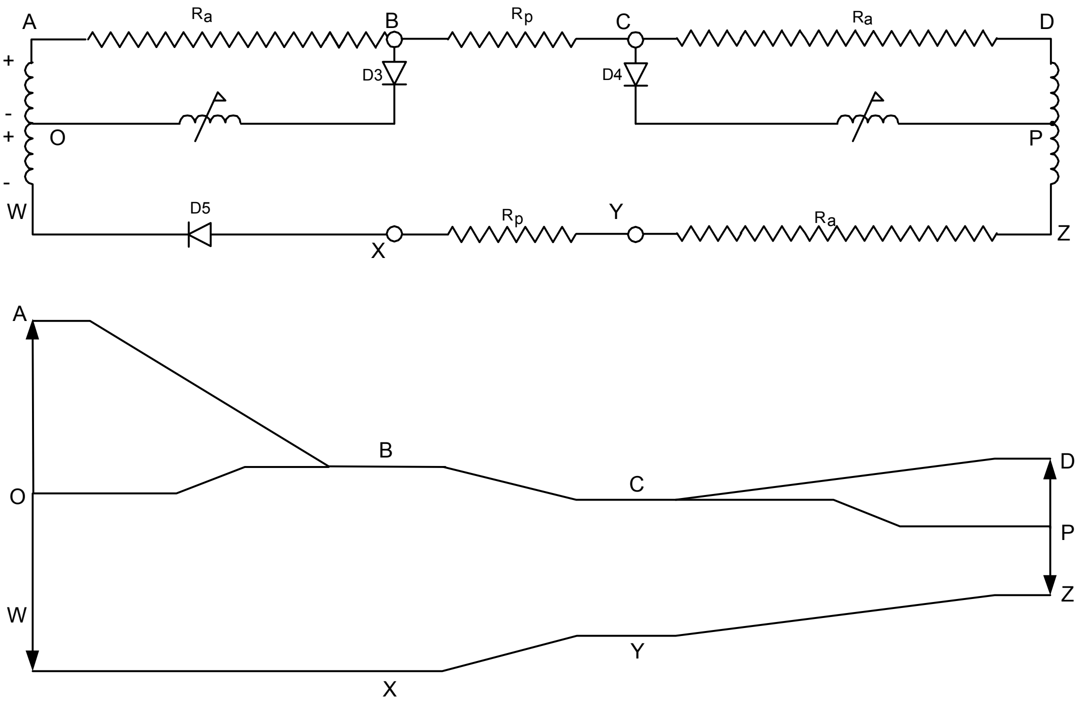


Figure 14 Single End Fed fault Rf mode, positive half cycle

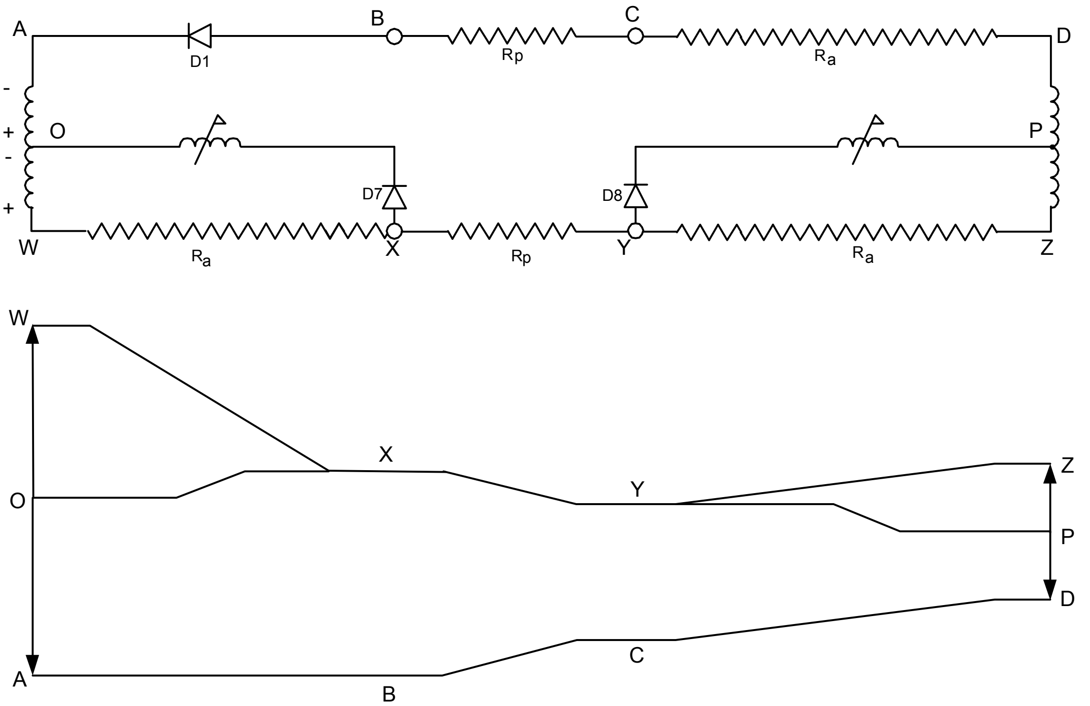


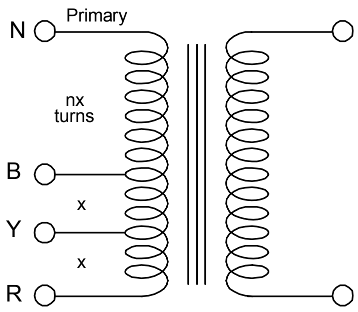
Figure 15 Single End Fed fault Rf mode, negative half cycle

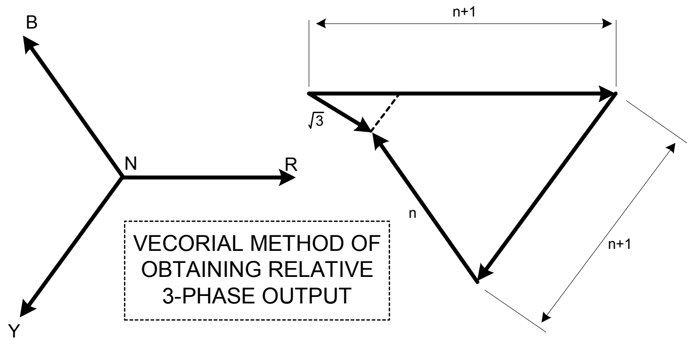
The single end fed internal fault conditions configure the circuit in a similar way to the double end fed internal fault but only one summation transformer has any output. Thus the other summation transformer acts only as an equalising transformer, re-circulating current through the measuring element as indicated in Figure 14 & Figure 15. The voltage distribution shows diagrammatically how, in each half cycle, the measuring elements are energised via R_a at the energised end and the action of the remote end summation transformer re-circulating current via the polarising diodes D4 on one half-cycle and D8 on the other half-cycle.

4 Theory of Summation Transformer

The main purpose of the summation transformer is to enable either balanced or unbalanced three phase currents to be re-produced as a single phase quantity. This makes it possible in a feeder protection to compare the various fault currents on a single phase basis over only two pilot cores. As this device is essentially a transformer it can also be used to reduce the burden imposed by the pilot circuit on the current transformers by changing the impedance levels. In addition, it provides isolation between the current transformers and the pilot circuit and makes it possible to have the current transformers earthed and the pilots unearthed.

SUMMATION TRANSFORMER





Fault Type	Effective Primary Ampere-turns	Relative Output
R-E	I(nx + x + x) = Ix. (n+2)	n+2
Y-E	I(nx + x) = Ix. (n+1)	n+1
B-E	I(nx) = Ix. (n)	n
R-Y	I(x) = Ix. (1)	1
Y-B	I(x) = Ix. (1)	1
B-R	I(2x) = Ix. (2)	2
3P	I(√3x) = Ix. (√3)	√3