UNIVERSIDAD NACIONAL DE INGENIERÍA
FACULTAD DE INGENIERÍA ELÉCTRICA Y ELECTRÓNICA

"DISEÑO AUTOMATIZADO DE LA PROTECCIÓN FRENTE A FALLAS A TIERRA EN SISTEMAS ELÉCTRICOS AISLADOS"

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PRESENTADO POR:

JOSE BENJAMIN RIVERA CABALLERO

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Sea mi agradecimiento eterno a Dios y a la memoria de mis Padres César y Otilia Maria, por su esfuerzo y abnegación. Un inmenso agradecimiento por su apoyo incondicional a mis tíos: Zelmira, Maurino (Q.E.P.D.) y Maurino (hijo), Saturnino e Inés; a mis Hermanos: Adolfo, Lucy, Benjamín, María Otilia, Martín, Eddy, Hector y Jenny, a mis suegros José y Rosa; y sobretodo a mi Esposa Marlene y a mis queridas Hijas Rosa María y Alejandra que son el estímulo para seguir superándome.

"DISEÑO AUTOMATIZADO DE LA PROTECCIÓN FRENTE A FALLAS A TIERRA EN SISTEMAS ELÉCTRICOS AISLADOS"

SUMARIO

Los sistemas eléctricos aislados o con neutro aislado, presentan la ventaja de que ante la puesta a tierra de una fase, la continuidad del servicio no se ve afectada; su contraparte es que, ante una caída de conductor a tierra, el mismo va a permanecer con tensión en tanto no dispongan de una protección que considere este tipo de fallas.

En este tipo de configuración aislado, las corrientes de falla monofásicas a tierra son muy pequeñas, debido a la carencia de un camino de retorno franco de las corrientes de falla y a la alta impedancia de contacto; siendo las únicas rutas que permiten su paso las capacitancias parásitas de los alimentadores.

Por consiguiente, se hace indispensable que los sistemas eléctricos con neutro aislado dispongan de una protección contra las fallas a tierra orientada a proteger a las personas de los choques eléctricos al romperse un conductor de una línea aérea.

En la actualidad existen tecnologías de alta sensibilidad que permiten detectar pequeñas corrientes y/o tensiones homopolares, ya sea

directamente, o mediante la creación de un neutro artificial conectando un transformador Zig-zag.

En el presente informe se hace la evaluación de distintas alternativas tecnológicas, tales como la inserción de transformador zig-zag, así como el uso de los relés multifunción de alta sensibilidad.

Asimismo se presenta una aplicación para un sistema eléctrico aislado, conformado por dos alimentadores aéreos, donde luego de evaluar las distintas alternativas se llega a la conclusión de que la opción del uso de relé de sobretensión homopolar, juntamente con la automatización de alimentadores en base a PLC para la discriminación del alimentador fallado, constituye la mejor alternativa técnico-económica para este caso en particular.

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PROLOGO

Un sistema eléctrico, una red adecuadamente diseñada y operada debe satisfacer entre otros, los siguientes requerimientos:

- Cuantitativamente, debe entregar las magnitudes de potencia y energía eléctrica, definidas mediante acuerdos o contratos celebrados con los usuarios, o con otros sistemas con los que eventualmente pueda esta interconectado.
- Cualitativamente, la energía eléctrica debe entregarse, por un lado, sujeta a limitaciones en cuanto a las variaciones de tensión y de frecuencia, aspectos que junto con las perturbaciones, se denomina CALIDAD DE PRODUCTO.
- Debe reunir las mayores exigencias de Seguridad tanto para con las instalaciones, como para con el personal operativo y con los usuarios.

Por lo general, el cumplimiento de los requerimientos cuantitativos depende de un adecuado y oportuno planeamiento y diseño de la red eléctrica, mientras que el de los requerimientos cualitativos, en cuanto a las fluctuaciones de tensión y frecuencia, de una adecuada operación de la misma. Los niveles de continuidad, en cambio, dependen de la topología que adopte la red, de los recursos operativos y de la filosofía de la protección destinada a dicho fin.

Por su parte, los requerimientos y exigencias de seguridad dependen, por un lado de un adecuado diseño de la red y, de otro lado, de una oportuna política de mantenimiento y de los criterios de protección de la misma.

Respecto a este último párrafo, conviene recordar que “En cualquier tipo de sistema de suministro, con neutro o sin neutro, deberá asegurarse en todo momento que el sistema de protección debe ser capaz de detectar y aislar fallas causadas por desprendimiento de conductores o fase a tierra, para evitar tensiones de contacto y de paso peligrosas”.

En el presente informe se describen las distintas alternativas tecnológicas de protección de fallas a tierra, que permiten detectar las corrientes pequeñas que se producen en los sistemas eléctricos aislados, siendo las principales las siguientes:

- Instalación de Relés multifunción Hompolar-direccional.
- Transformador Zig-zag existente como neutro artificial.
- Instalación de Relé de Sobretensión Homopolar y Sistema de Automatización con PLC

Como un caso especial para los sistemas eléctricos aislados, que tienen pocos alimentadores, se presenta una aplicación en la Subestación Ninatambo ubicado en la localidad de Tarma, que cuenta con dos alimentadores aéreos, luego de hacer una evaluación de distintas alternativas de protección, se llega a la conclusión de que la alternativa consistente en la instalación de un relé de sobretensión homopolar conjuntamente con un controlador lógico programable PLC, que permite discriminar el alimentador fallado, es la alternativa más ventajosa, tanto desde el punto de vista técnico como el económico.

CAPITULO I

PROTECCIÓN EN SISTEMAS ELÉCTRICOS AISLADOS

1.1 Introducción

En nuestro medio existen varios sistemas eléctricos aislados, en conexión delta o con el neutro aislado. Si bien es cierto este tipo de configuración dota al sistema de continuidad en su operación, aún cuando una de las fases hace contacto con tierra; sin embargo su contraparte es que, ante una caída de conductor a tierra, el conductor va a permanecer con tensión en tanto que no se disponga de una protección que considere este tipo de fallas.

En los sistemas eléctricos aislados, las corrientes de falla monofásicas a tierra son muy pequeñas, debido a la carencia de un camino de retorno franco de las corrientes de falla y a la alta impedancia de contacto; siendo las únicas rutas que permiten su paso, las capacitancias parásitas de los alimentadores.

Por consiguiente, se hace indispensable que los sistemas eléctricos con neutro aislado dispongan de una protección contra las fallas a tierra orientada a proteger a las personas de los choques eléctricos al romperse un conductor de una línea aérea.

En la actualidad existen tecnologías de alta sensibilidad que permiten detectar pequeñas corrientes y/o tensiones homopolares directamente o mediante la creación de un neutro artificial, conectando un transformador Zig-zag.

Dentro de las principales tecnologías para la protección frente a fallas a tierra en sistemas aislados tenemos los siguientes:

- Relés multifunción de sobrecorriente hompolar-direccional.
- Transformador Zig-zag como neutro artificial.
- Relés de sobretensión homopolar y Sistema de automatización con PLC

1.2 Relés Multifunción de Sobrecorriente Homopolar-Direccional

En la Figura N° 1.1 se muestra el comportamiento de las corrientes homopolares en un sistema eléctrico con neutro aislado, ante una falla a tierra. Como se puede apreciar, en el circuito con la falla a tierra existe una corriente desde la barra de la subestación hacia la falla. Debido a que la conexión en delta del transformador de potencia aísla al transformador del sistema de distribución, de acuerdo a la teoría de las componentes simétricas, según la ley de Kirchoff esta corriente tiene que regresar a la barra a través de los otros alimentadores y de sus capacidades homopolares teniendo una dirección contraria; es decir, ante una falla a tierra de un alimentador, en todos los alimentadores de la subestación circulan corrientes homopolares siendo la dirección de la corriente homopolar en el alimentador con falla en un sentido y en sentido contrario en todos los otros alimentadores.

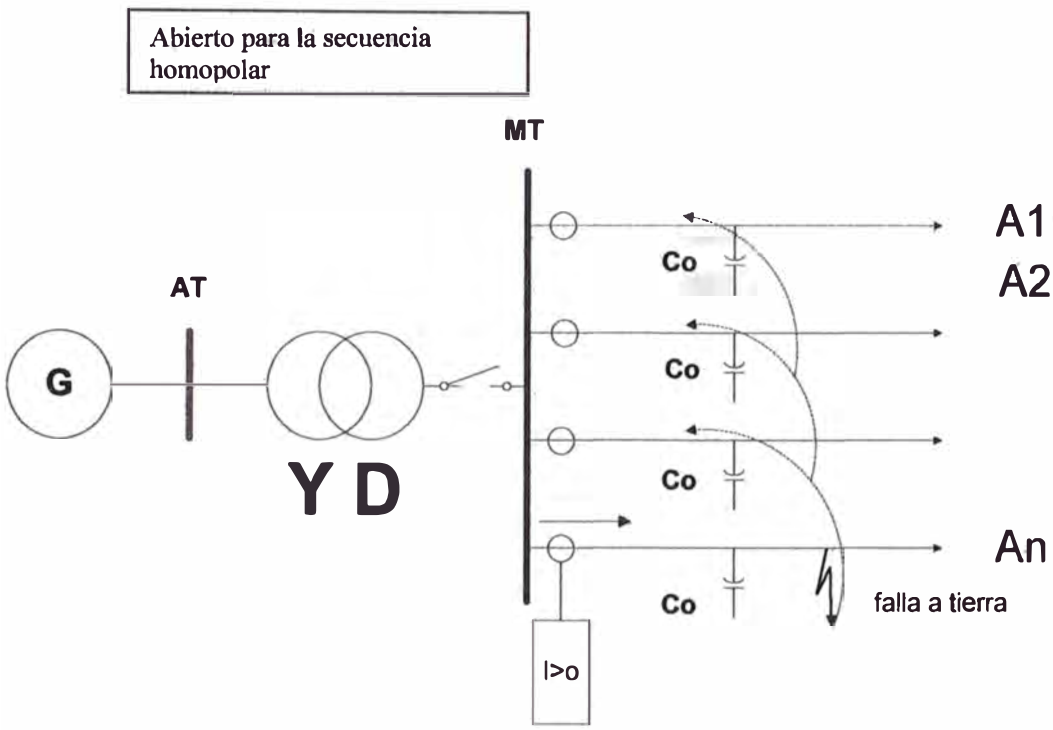


Figura N° 1.1: Comportamiento de las corrientes de falla a tierra

Por consiguiente, con la finalidad que la detección de la falla sea selectiva, se plantea como primera alternativa consistente en la implementación de relés de sobrecorriente homopolar direccional, cuya tecnología permite despejar fallas a tierra con alta impedancia y en la actualidad se cuentan con relés que tienen una sensibilidad de 10 mA en el lado secundario. Sin embargo, en la práctica no es recomendable calibrar a este valor, puesto que cualquier desbalance en el sistema podría sacar de servicio el alimentador. En estos casos un valor típico de calibración es de 2 Amperios en el lado primario.

Por otro lado, la actuación del relé multifunción homopolar direccional, en muchos casos está limitada cuando la falla ocurre en zonas alejadas donde la resistencia de contacto es elevada, presentándose corrientes muy bajas. Desde que estas corrientes de falla a tierra dependen de las capacitancias entre fases y a tierra de todos los alimentadores, se requiere la contribución de todos aquéllos, y para sistemas de distribución aéreos demandarían 4 o más alimentadores conectados a la barra, para lograr corrientes que puedan ser detectadas por los dispositivos de protección.

Por consiguiente, en circuitos de 2 alimentadores no es recomendable usar esta tecnología puesto que si uno de los alimentadores está fuera de servicio y se presenta una falla a tierra en el segundo alimentador, no habría contribución de corriente y por lo tanto no se daría la apertura del alimentador fallado.

1.3 Transformador Zig-Zag como Neutro Artificial

En circuitos con bajas corrientes de falla a tierra, una segunda alternativa es la creación de un neutro artificial, que puede ser a través de un transformador Zig-zag, con el cual se logra elevar las corrientes de falla a tierra. Es fundamental en esta alternativa que el transformador sea adecuadamente diseñado y, por lo tanto, debe ser capaz de soportar la corriente de falla a tierra durante el tiempo establecido, sin que sufran daños.

Para el diseño del transformador Zig-zag, debe tenerse en cuenta la corriente de cortocircuito monofásica en las barras donde será instalado, de modo que no debe exceder su capacidad que normalmente se dá en Amperios para un tiempo de 10 segundos.

Cuando la corriente de cortocircuito monofásica excede la capacidad del transformador Zig-zag, se hace necesario el uso de una resistencia RNGR a ser conectada entre el neutro del transformador Zig-zag y tierra tal como puede apreciarse en la Figura N° 1.2. Los valores típicos de la resistencia RNGR son del orden de 10 a 100 Ohmios.

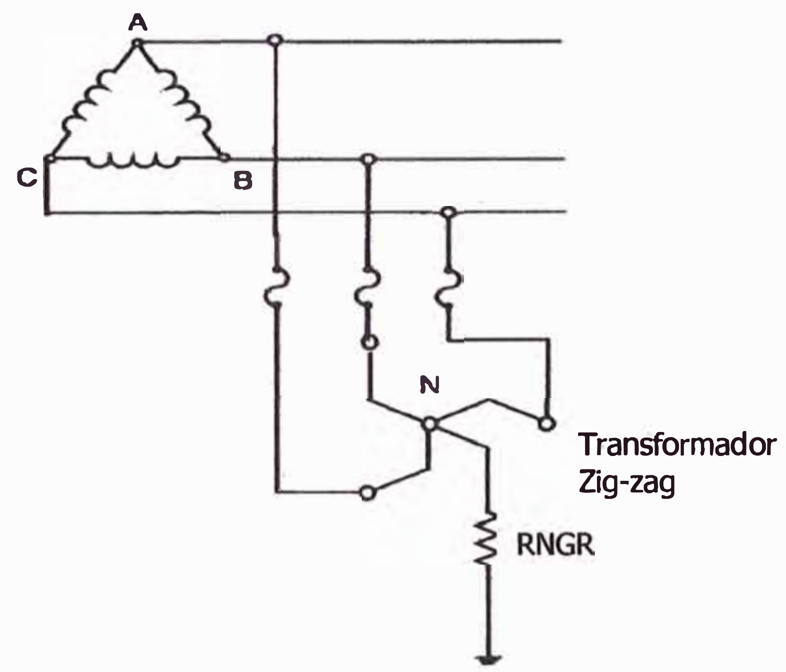


Figura N° 1.2: Transformador Zig-zag con resistencia RNGR

Para los circuitos con bajas corrientes de falla a tierra, esta alternativa pierde su ventaja en los casos donde la falla se presente en el extremo del alimentador y en zonas donde la resistencia de contacto sea elevada, es decir del orden de 1 500 a 2 000 Ohmios (casos de arenales y veredas secas), en los cuales los valores de corrientes mínimas que se obtendrán serán muy bajas, tal como podrá apreciarse en los resultados de los cálculos efectuados en la aplicación del Capítulo IV.

Con valores de corriente pequeñas, no es posible garantizar que un relé actúe adecuadamente para despejar la falla, es decir, habría un margen de incertidumbre en la actuación del equipo para estas contingencias.

1.4 Instalación de Relé de Sobretensión Homopolar y Sistema de Automatización con PLC

En un sistema aislado, cuando uno de los conductores hace contacto con tierra, en las otras fases se presenta una sobretensión respecto a tierra la misma que puede alcanzar los niveles de tensión de línea - línea. Es decir, se presenta una tensión homopolar resultante, en toda la barra y el sistema, que será la magnitud de actuación para un relé de sobretensión homopolar.

Una disposición típica para la medición de la tensión homopolar, es la que se muestra en la Figura N° 1.3, donde se puede notar que el primario del transformador de tensión se conecta en estrella y el secundario se dispone en delta abierto, de modo que se pueda obtener el valor de 3Vo.

Donde:

$$Vo = (V_R + V_S + V_T)/3 \qquad ------(1.1)$$

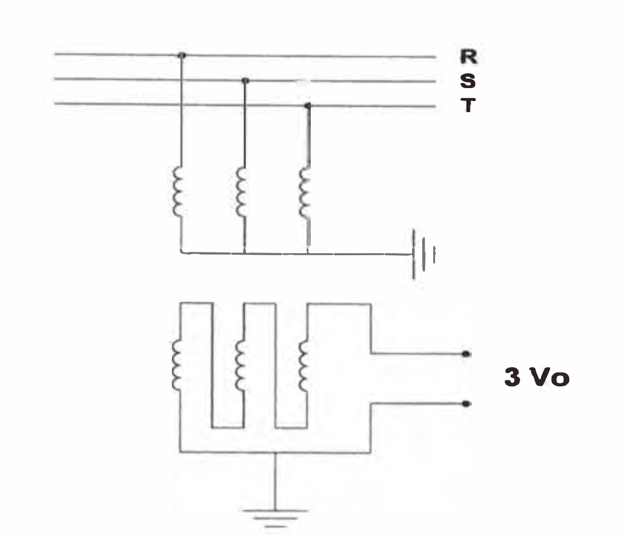


Figura N° 1.3: Conexión para la Medición de la Tensión

La actuación de este esquema de protección es más confiable comparado con los casos anteriores, puesto que la tensión homopolar se presenta en barras y en todo el sistema, independientemente de donde se produzca la falla; a diferencia de la magnitud de la corriente homopolar que tiene un amplio rango de valores, dependiendo donde se produzca la falla y del valor de resistencia de contacto que se presente en el punto de falla.

Sin embargo, desde que la protección por sobretensión homopolar no puede determinar por sí sola dónde se origina la falla, no puede ser efectivamente aplicado en sistemas con varios alimentadores; sin embargo para los casos de sistemas eléctricos con 2 o 3 alimentadores, esta alternativa es aplicable adicionándosele un sistema de automatización de alimentadores basado en un controlador lógico programable-PLC, con una lógica de prueba-falla, que permitirá discriminar el alimentador fallado y sólo éste quedará desenergizado.

CAPITULO II

METODOLOGIA PARA LA AUTOMATIZACIÓN DE LA PROTECCIÓN EN SISTEMAS ELÉCTRICOS AISLADOS

2.1 Introducción

Las fallas monofásicas en sistemas eléctricos aislados no producen corrientes considerables como para diseñar un sistema de protección selectivo, dado a que una variación de la carga podrla ocasionar el mismo efecto. La variación de la tensión fase-tierra, tiene la limitación del punto de referencia, ya que éste puede movilizarse como consecuencia de variación de carga desbalanceada.

Ante una falla a tierra aparecen sobretensiones homopolares, las cuales por medio de un relé de sobretensión homopolar, una vez que se supere el respectivo ajuste, podría enviar la señal de disparo a los interruptores correspondientes y por lo tanto la falla sería despejada. Sin embargo esta acción del relé de sobretensión no es posible, porque existe la limitación de que no se tiene la forma de determinar la ubicación de la falla, por lo tanto es necesario buscar la manera de que haya selectividad de la protección.

Para este propósito se ha planteado un sistema de automatización en base a un Controlador Lógico Programable-PLC, que de acuerdo a una rutina determina el alimentador fallado y ordena la apertura del interruptor correspondiente, manteniendo la continuidad de servicio en los otros alimentadores.

2.2 Metodología

El relé de sobretensión homopolar generalmente se emplea como protección secundaria o de respaldo, en este caso dicho relé trabaja como una protección principal, respaldada por un sistema de automatización en base a un controlador lógico programable-PLC.

Cuando se produce una falla a tierra, se genera una tensión homopolar que es sensada por el relé de sobretensión homopolar a través de tres transformadores de tensión cuyos secundarios se encuentran en conexión delta abierto, para medir la tensión homopolar (3Vo) tal como se ha indicado en la Figura N° 1.3 del acápite 1.4.

Cuando se origina una sobretensión homopolar, el **Relé de Sobretensión homopolar**, una vez que ha superado el respectivo ajuste, manda alarma y a la vez hace actuar el sistema de automatización en base a PLC, para discriminar el alimentador en el cual se ha presentado la falla monofásica.

Luego que el PLC ejecuta la secuencia de maniobras de los interruptores, el alimentador con falla quedará fuera de servicio.

En la Figura N° 2.1 se muestra un esquema donde se puede apreciar como interactúa el relé de sobretensión homopolar sobre el PLC y éste a su vez interactúa con los interruptores de cada uno de los alimentadores.

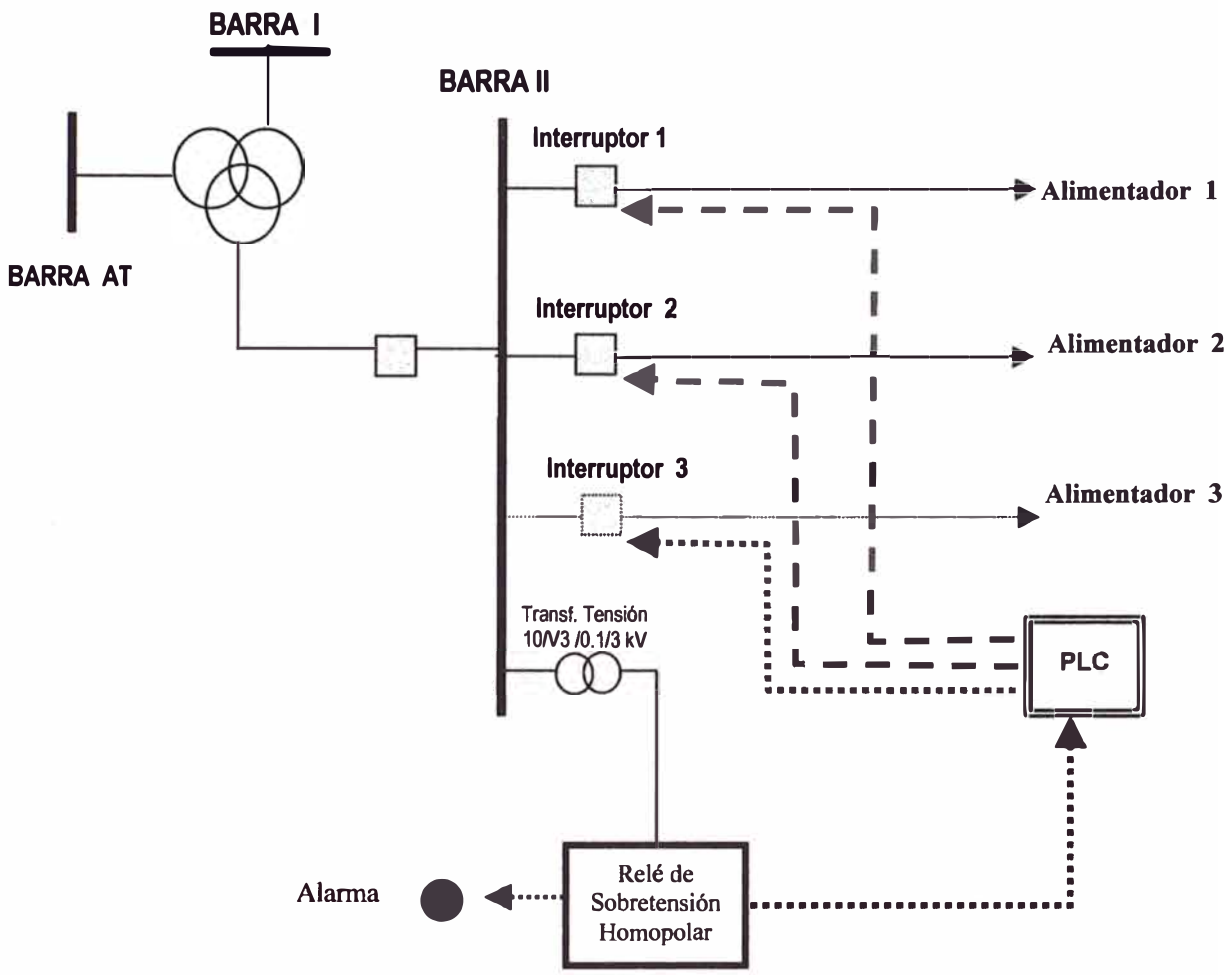


Figura N° 2.1: Esquema de Operación de la Automatización

Al aperturar el alimentador o circuito en el cual se ha presentado la falla, ésta quedará despejada y por lo tanto el relé de sobretensión homopolar dejará de percibir tal señal, de modo que el circuito con falla quede en posición de apertura.

2.3 Descripción de la Operación

Una vez que el PLC recibe la señal del relé de sobretensión homopolar, empieza a correr su lógica de apertura y cierre de los interruptores de cada alimentador, probando uno a uno a fin de determinar en cual de los alimentadores a ocurrido la falla.

En la Figura N° 2.2 vemos que el PLC recibe como señal de entrada principal, la señal del relé de sobretensión homopolar y como señales de entrada adicionales, la posición de cada uno de los interruptores.

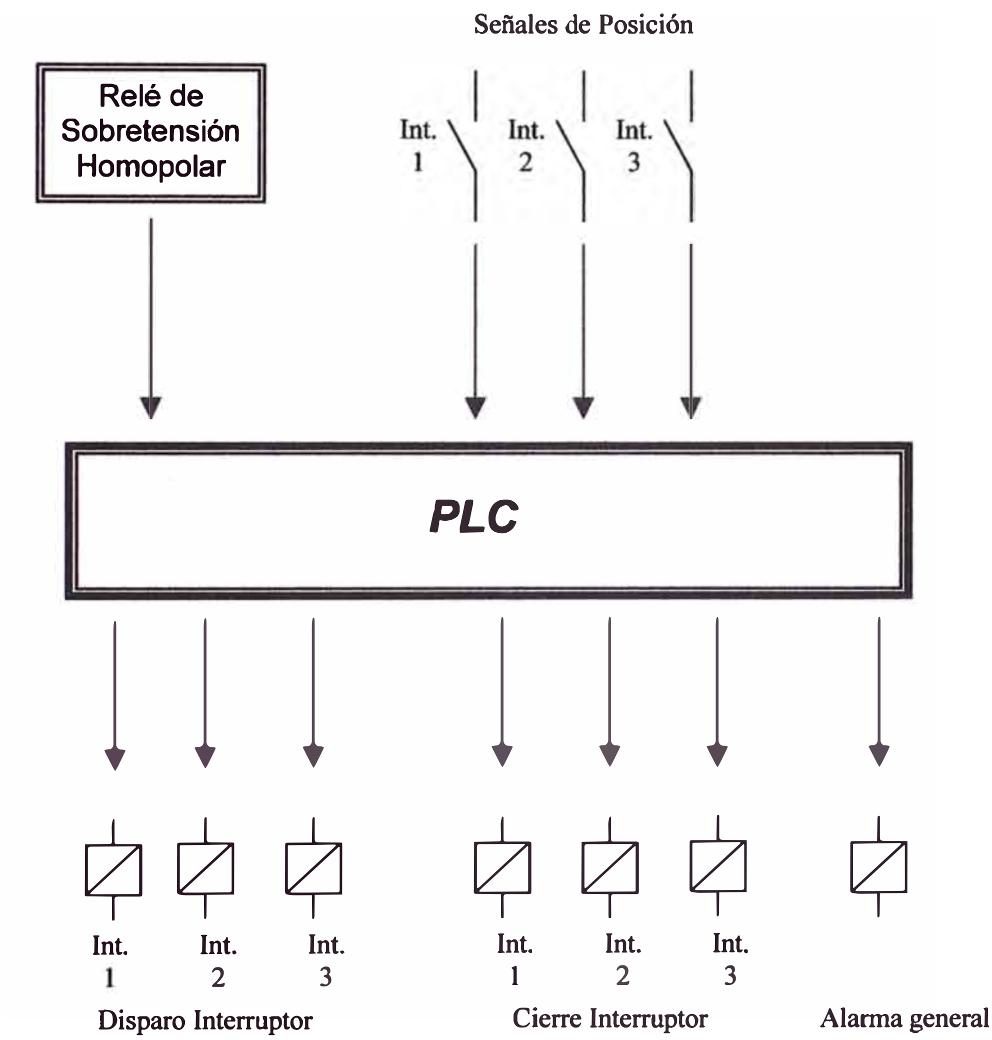


Figura N° 2.2: Esquema de Operación del PLC

Luego que el PLC ejecuta su lógica, envía las señales de salida; cuando se requiere la apertura de un interruptor la señal de salida del PLC será dirigida hacia la bobina de disparo del interruptor que se desea aperturar. Y cuando se requiere el cierre de un interruptor, la señal de salida del PLC será dirigida hacia las bobinas de cierre del interruptor que se desee cerrar.

En la lógica de la secuencia de operaciones se han tomado en cuenta los tiempos de apertura y cierre de los interruptores.

2.4 Secuencia de Operación

A continuación se explica la lógica de la secuencia de operación una vez que el relé de sobretensión detecta la falla y ordena al PLC para que inicie el sistema de automatización.

2.4.1 Falla en el Alimentador 1:

Si la falla se produce en el Alimentador 1, el PLC es alertado por el relé de sobretensión homopolar y empieza la secuencia de la Figura 2.3:

- El PLC manda la aperturar el Interruptor 1 en un tiempo T1.
- Como la falla es en el alimentador 1, el relé de sobretensión homopolar ya no recibe señal de tensión homopolar puesto que con la apertura del interruptor la falla ha quedado despejada, quedando dicho alimentador fuera de servicio.

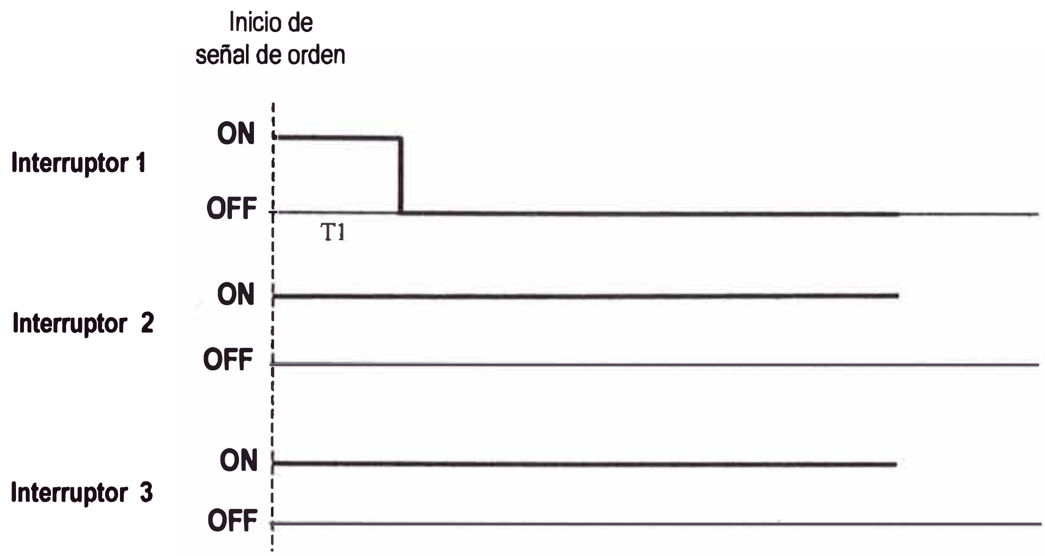


Figura N° 2.3: Secuencia de Operación con falla en el Alimentador 1

2.4.2 Falla en el Alimentador 2:

Si la falla se produce en el Alimentador 2, el PLC inicia la secuencia que se muestra en la Figura 2.4:

- El PLC manda la apertura del Interruptor 1 en un tiempo T1.
- Como la falla es en el alimentador 2, el relé de sobretensión homopolar seguirá señalando falla, entonces el PLC luego de un tiempo T2 ordena el cierre del Interruptor 1 y a la vez la apertura del Interruptor 2.
- Al aperturar el Interruptor 2, la falla queda despejada, quedando el Alimentador 2 fuera de servicio.

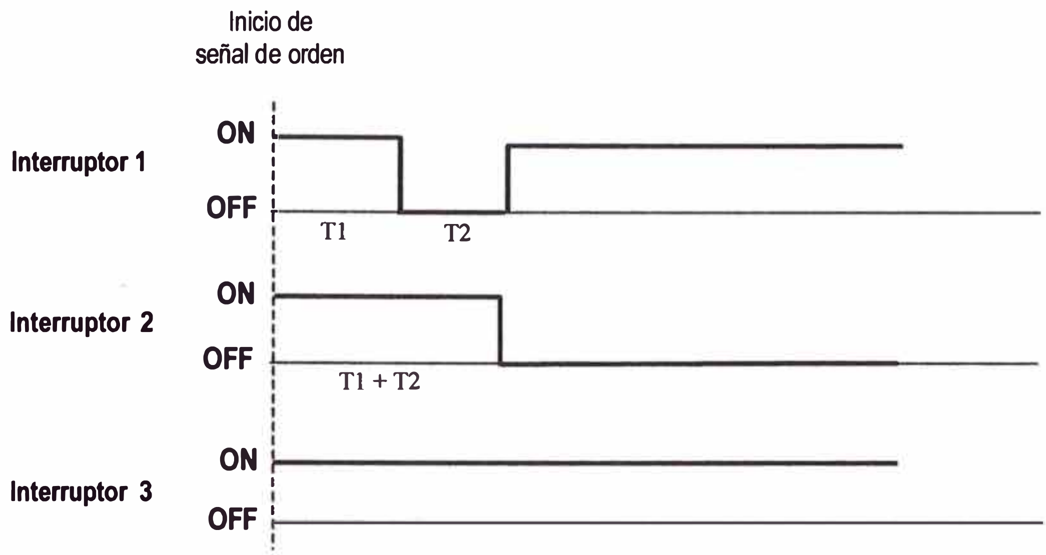


Figura N° 2.4: Secuencia de Operación con falla en el Alimentador 2

2.4.3 Falla en el Alimentador 3:

Si la falla se produce en el Alimentador 3, una vez que el PLC recibe la orden del relé de sobretensión homopolar, se inicia la secuencia que se muestra en la Figura 2.5:

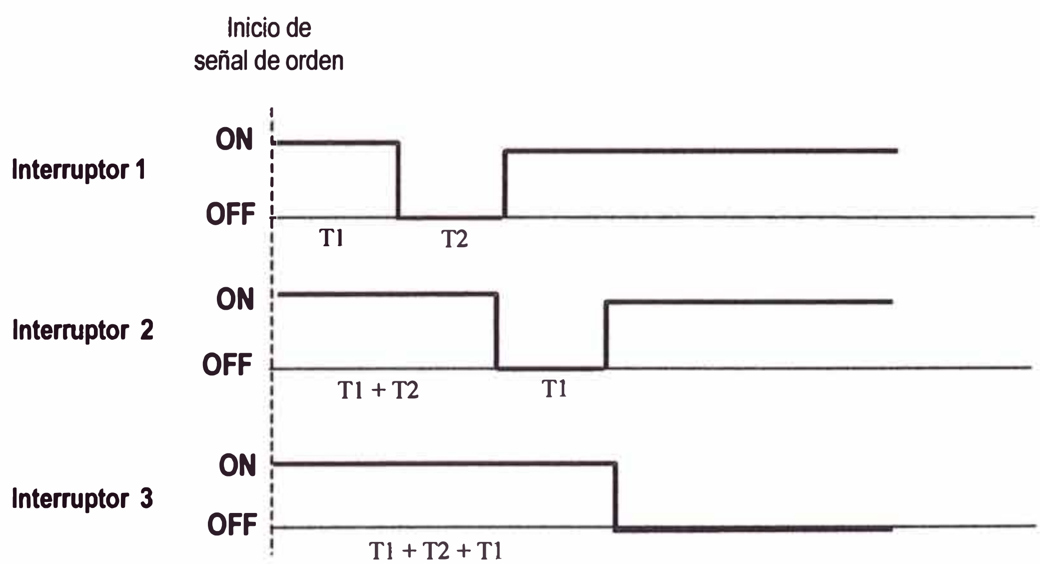


Figura N° 2.5: Secuencia de Operación con falla en el Alimentador 3

- El PLC manda la apertura del Interruptor 1 en un tiempo T1.
- Como la falla es en el alimentador 3, el relé de sobretensión homopolar seguirá señalando falla, entonces al lapso de un tiempo T2 el PLC ordena el cierre del Interruptor 1 y a la vez la apertura del Interruptor 2.
- Al cerrar el Interruptor 2 la falla persiste y el relé de sobretensión homopolar seguirá señalando falla, entonces al lapso de un tiempo adicional T1 el PLC ordena la apertura del interruptor 3
- Al aperturar el Interruptor 3, la falla queda despejada, quedando el Alimentador 3 fuera de servicio.

CAPITULO III

CALCULO DE FALLAS A TIERRA

EN SISTEMAS ELECTRICOS AISLADOS

3.1 Componentes Simétricas

Para el cálculo de cortocircuitos no trifásicos, se emplea el método de componentes simétricas, que se basa en un sistema de 3 fasores que pueden ser descompuestos en 3 subsistemas fasoriales:

- Sistema de Secuencia Positiva o Directa.
- Sistema de Secuencia Negativa o Indirecta.
- Sistema de Secuencia Homopolar o Nula.

3.1.1 Subsistema de Secuencia Positiva:

Es un sistema trifásico equilibrado que se compone de 3 vectores con igual módulo y desfasados en 120º y se encuentran presentes en cualquier estado o condición del sistema eléctrico.

$$A_1 + B_1 + C_1 = 0 \qquad --------(3.1)$$

3.1.2 Subsistema de Secuencia Negativa:

Es un sistema trifásico equilibrado similar al de secuencia positiva, cuya secuencia es contraria. Se produce ante cualquier desequilibrio del sistema eléctrico.

$$A2 + B2 + C_2 = 0 \qquad --------(3.2)$$

3.1.3 Subsistema de Secuencia Cero u Homopolar

Es un sistema desequilibrado compuesto por 3 vectores de igual módulo e igual argumento, se da el subsistema de secuencia homopolar cuanto el sistema es desequilibrado (la suma vectorial tiene resultante distinto de cero), es decir cuando se da falla monofásica o bifásica a tierra.

$$A0 + B0 + C_0 = 0 \qquad -------(3.3)$$

Por lo tanto tres vectores R, S y T pueden descomponerse en sus tres subsitemas:

$$\begin{aligned} R &= R_1 + R_2 + R_0 \\ S &= S_1 + S_2 + S_0 \qquad --------(3.4) \\ T &= T_1 + T_2 + T_0 \end{aligned}$$

Para calcular cada uno de los componentes del subsistema, se hace necesario el uso de los siguientes operadores vectoriales:

$$a = 1\angle 120^{\circ} \rightarrow a^2 = 1\angle 240^{\circ} \qquad ------(3.5)$$

Considerando:

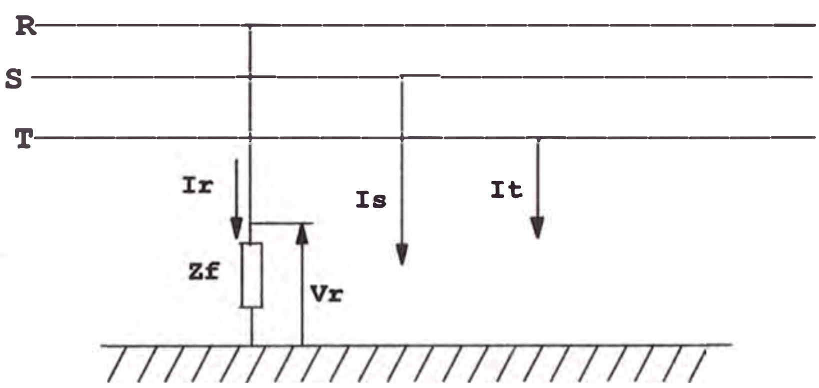
$$\overline{S}_1 = a^2 \overline{R}_1 \rightarrow \overline{T}_1 = a\overline{R}_1 \qquad \text{--------}(3.6)$$
$$\overline{S}_2 = a\overline{R}_2 \rightarrow \overline{T}_2 = a^2 \overline{R}_2$$

Entonces los componentes del subsistema serían los siguientes:

$$\overline{R}_0 = \overline{S}_0 = \overline{T}_0 = (\overline{R} + \overline{S} + \overline{T})/3$$
$$\overline{R}_1 = (\overline{R} + a\overline{S} + a^2\overline{T})/3 \qquad \text{--------}(3.7)$$
$$\overline{R}_2 = (\overline{R} + a^2\overline{S} + a\overline{T})/3$$

3.2 Cálculo de Falla Monofásica a Tierra

Cuando una de las fases de un circuito aislado hace contacto con tierra, el análisis de las corrientes se muestra en la Figura N° 3.1:



Ir = Ifalla   Is = It = 0

Vr = Zf x Ir

Figura N° 3.1: Corrientes de Falla a Tierra

Puesto que solamente existe corriente de falla hacia tierra por la fase R, y en las otras no existen corrientes hacia tierra, se plantea la ecuación (3.8) para las corrientes de secuencia de la fase R.

$$\begin{bmatrix} Ir_0 \\ Ir_1 \\ Ir_2 \end{bmatrix} = 1/3 \begin{bmatrix} 1 & 1 & 1 \\ 1 & a & a^2 \\ 1 & a^2 & a \end{bmatrix} \begin{bmatrix} Ir \\ 0 \\ 0 \end{bmatrix} \quad \text{--------} (3.8)$$

De la ecuación (3.8) se desprende:

$$Ir_0 = Ir_1 = Ir_2 = 1/3\, Ir \quad \text{--------} (3.9)$$

Asimismo tenemos que las tensiones de fase: ***Vr**, **Vs**, y **Vt*** *están dadas por la ecuación (3.10).*

$$\begin{bmatrix} Zf\,.Ir \\ Vs \\ Vt \end{bmatrix} = 1/3 \begin{bmatrix} 1 & 1 & 1 \\ 1 & a^2 & a \\ 1 & a & a^2 \end{bmatrix} \begin{bmatrix} Vr_0 \\ Vr_1 \\ Vr_2 \end{bmatrix} \quad \text{-------} (3.10)$$

De la ecuación (3.10) se desprende:

$$Vr = Vr_0 + Vr_1 + Vr_2 = 3(Zf\,.Ir) \quad \text{------} (3.11)$$

Por consiguiente, para el caso de fallas de fase a tierra el circuito que corresponde a la ecuación (3.11) se muestra en la Figura N° 3.2:

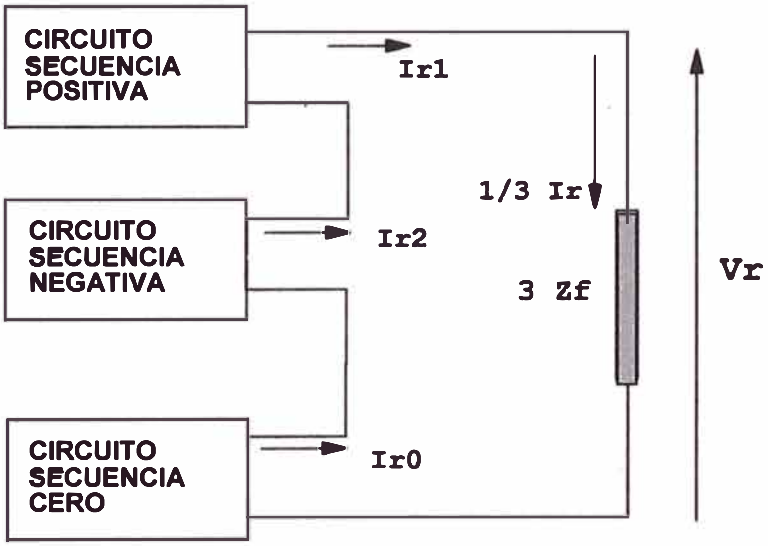


Figura N° 3.2: Circuito para Falla Monofásica a Tierra

3.3 Circuito Equivalente para Fallas a Tierra

Para determinar el circuito equivalente, tenemos la siguiente representación en la Figura N° 3.3, con falla en el punto "P":

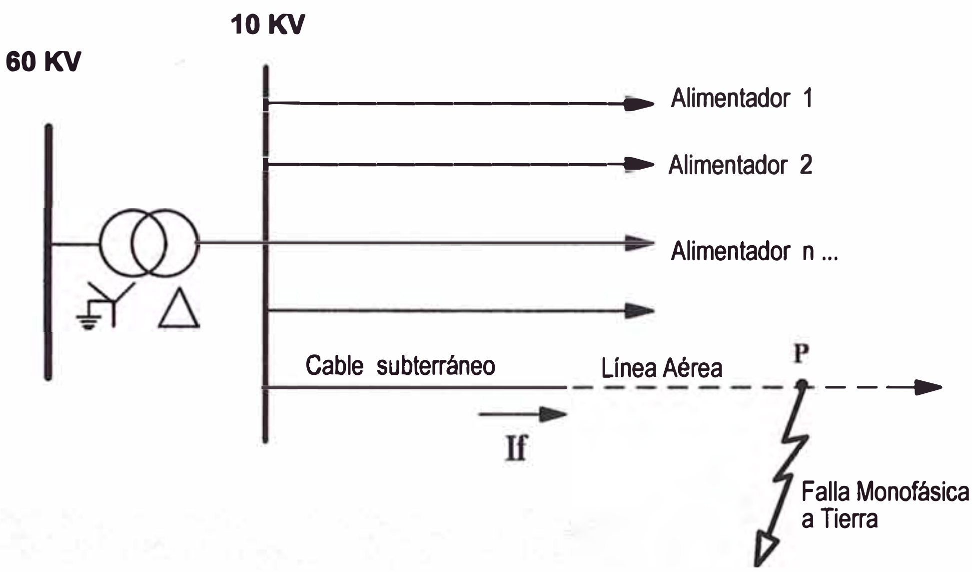


Figura N° 3.3: Circuito con Falla Monofásica a Tierra en el punto P

Para el cálculo de la corriente monofásica de falla a tierra, los circuitos de secuencia van conectados en serie, tal como se ve en la Figura N° 3.4.

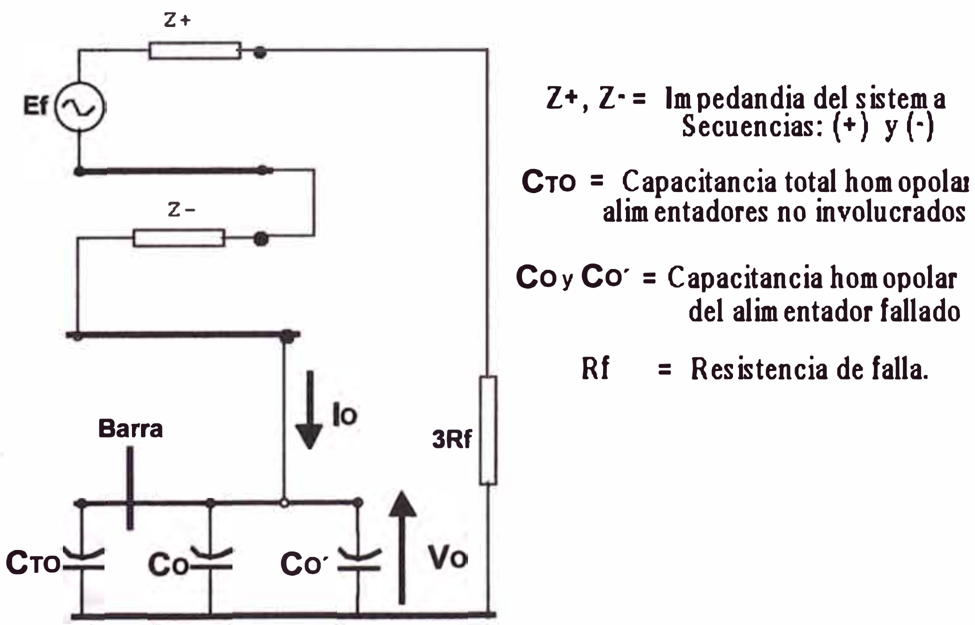


Figura N° 3.4: Circuito de Falla Monofásica a Tierra

Sin embargo en el circuito de secuencia negativa se considera la capacitancia total homopolar de todos los alimentadores no involucrados en la falla (C_{TO}), en paralelo con las capacitancias homopolares del alimentador fallado, antes y después del punto de falla (Co y Co´).

Puesto que las impedancias de secuencia negativa y positiva son pequeñas en comparación con las reactancias homopolares, el circuito puede quedar reducido tal como se muestra en la Figura N° 3.5:

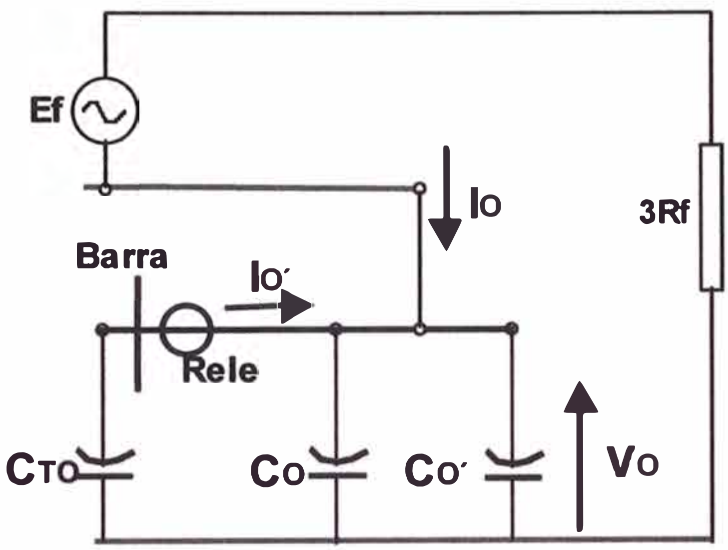


Figura N° 3.5: Circuito Equivalente de Falla Monofásica a Tierra

Del circuito equivalente se obtiene que:

$$Io = \frac{Ef}{\sqrt{(3Rf)^2 + \frac{1}{W^2(C_{TO} + C_O + C_{O'})^2}}} \qquad ---(3.12)$$

La corriente homopolar que circula por el Relé es:

$$Io' = Io\frac{C_{TO}}{C_{TO} + C_O + C_{O'}} \qquad ------(3.13)$$

Cuando se trata de un sistema con varios alimentadores donde la capacitancia total de los alimentadores no involucrados en la falla C_{TO} es mucho mayor las capacitancias del alimentador fallado Co y C´o, entonces la tensión homopolar Vo es :

$$Vo = \frac{I_O'}{WC_{TO}} \qquad --------(3.14)$$

3.4 Variaciones de la Tensión Durante las Fallas

En un sistema con neutro puesto a tierra, cuando se presente una falla a tierra, el punto neutro prácticamente no sufre desplazamiento, lo que no permite que se generen tensiones homopolares o que sean pequeñas.

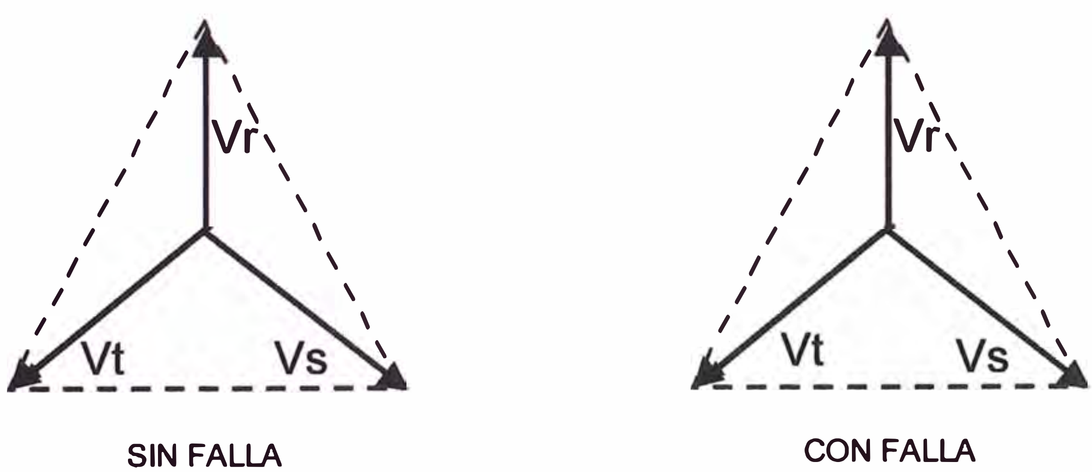


Figura N° 3.6: Fasores de Tensión en un sistema con neutro a tierra

En cambio en un sistema con neutro aislado, el punto de referencia de los fasores de tensión se desplaza. Es decir si un conductor cae al piso o hace tierra en alguna estructura, la tensión de fase de las otras fases no comprometidas se eleva de 5,8 kV (tensión de fase) hasta un valor cercano a los 10kV; generándose las tensiones homopolares.

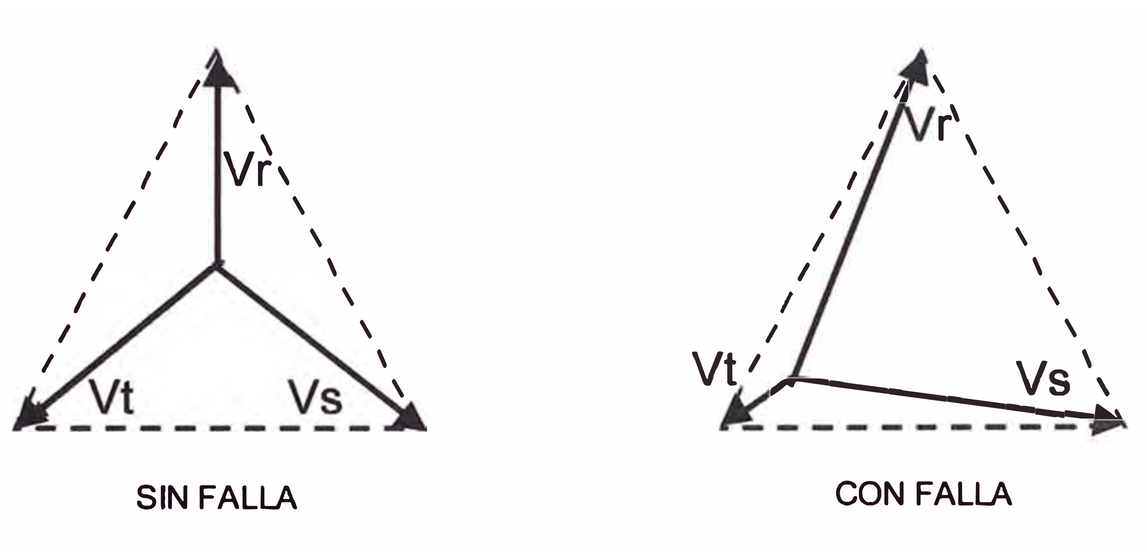


Figura N° 3.7: Fasores de Tensión en un sistema aislado

CAPITULO IV

APLICACIÓN

4.1 Ubicación

La Subestación Ninatambo se encuentra ubicada en al localidad de Tarma, capital de la provincia de Tarma en el departamento de Junín, localizada a 3.053 m de altitud, a orillas del río de igual nombre, situada a unos 50 kms. de La Oroya.

La Subestación Ninatambo recibe suministro energético desde la subestación Condorcocha en 44 kV, la que a su vez recibe suministro energético desde Caripa en 138 kV, subestación ésta última que se conecta a la red de ELECTROANDES S.A. La línea en 44 kV que viene desde la subestación Condorcocha (14,50 Kms), continúa hacia la subestación de Chanchamayo.

La Subestación Ninatambo cuenta con un transformador de potencia de tres devanados en 44/22,9/10 kV, de los cuales el que corresponde a 10 kV está en conexión delta, es decir es un sistema aislado; desde el cual se abastece el suministro de energía eléctrica a la localidad de Tarma a través de dos alimentadores aéreos, de los cuales el primero lleva suministro energético a la localidad de Huaricolpa y el segundo alimentador lleva suministro energético a la población urbana de Tarma.

4.2 Antecedentes

La configuración en delta dificulta la detección de las corrientes de fallas monofásicas a tierra, al presentarse corrientes muy pequeñas, debido a la carencia de un camino de retorno franco de las corrientes de falla y a la alta impedancia de contacto; siendo las únicas rutas que permiten su paso las capacitancias parásitas de los alimentadores.

En estos sistemas con neutro aislado, si bien es cierto presentan la ventaja de que ante la puesta a tierra de una fase, la continuidad del servicio no se ve afectada; sin embargo como contraparte se da que, ante una caída de conductor a tierra, el mismo va a permanecer con tensión en tanto no se disponga de una protección que considere este tipo de fallas.

Por consiguiente, se hace indispensable que los sistemas eléctricos con neutro aislado dispongan de una protección contra las fallas a tierra orientada a proteger a las personas de los choques eléctricos al romperse un conductor de una línea aérea.

La subestación Ninatambo contaba con un relé de sobretensión homopolar electromecánico marca BBC instalado en las barras de 10 kV que al producirse una falla fase a tierra, activaba una alarma pero no es posible interrumpir el suministro porque no se podía determinar en que circuito se producía la falla. En conclusión no se contaba con un sistema de protección efectiva que pudiera despejar este tipo de fallas.

Por otro lado en la Subestación Ninatambo se cuenta con un transformador Zig-zag, que se había previsto para ser instalado como neutro artificial, pero que nunca se puso en operación.

Ante esta situación la empresa ELECTROCENTRO que es propietaria de las instalaciones, ha visto por conveniente dotar de un sistema de protección efectivo, el cual es materia del presente informe, en el que se hace la evaluación de la operatividad y la conveniencia o no de la inserción del transformador zig-zag existente, en la barra de 10 kV. Asimismo, se han evaluado otras alternativas tecnológicas de solución para el despeje de las fallas monofásicas a tierra; buscando la alternativa técnico-económica más adecuada.

4.3 Características de los Equipos e Instalaciones Existentes

4.3.1 Transformador de Potencia

En la subestación Ninatambo existe un transformador de potencia de tres devanados cuyo primer devanado tiene posibilidades de conectarse a 44 o 60 kV, el secundario del transformador a 22,9 kV y el terciario a 10 kV. Tanto el primario como el secundario están conectados en estrella con neutro aterrado y el terciario en delta. El devanado terciario alimenta a una red de 2 troncales en 10 kV, para suministrar energía a la localidad de Tarma.

Los datos de placa del transformador de potencia se indican en el Cuadro N° 4.1 siguiente:

Marca Año de Fabricación Norma de Fabricación Altitud de operación (m.s.n.m.) Enfriamiento	BBICT 1 985 ITINTEC 370-002 3 100 ONAN
Tensión Nominal (kV) - AT - MT - BT	 44 / 60 ± 10x1,36/1% kV 22,9 kV - 10 kV
Tensión de prueba al impulso con 44kV en el Primario - Entre fases (kV) - Fase - Neutro (kV)	 325 / 125 / 75 95 / 95
Clase de aislamiento Grupo de Conexión Potencia Nominal Regulación de Tensión Número de posiciones de taps	Clase A Ynyn0 / YNd5 10 / 5 / 5 MVA Bajo carga 21
Tensión de cortocircuito (%)	AT/MT 3,3 / 3,1 % AT/BT 5,0 / 4,9 % MT/BT 1,5 /1,5 %
Calentamiento Peso total	60 /65 °C 29 550 kg

Cuadro N° 4.1: Datos de placa del transformador de potencia

Las impedancias de cortocircuito del transformador de potencia de tres devanados son dadas en el Cuadro N° 4.2 siguiente:

Devanados	Vcc (p.u.)	MVA
Primario-Secundario	0.033	10
Primario-Terciario	0.050	5
Secundario-Terciario	0.015	5

Cuadro N° 4.2: Impedancias de corto circuito del Transformador de Potencia

4.3.2 Transformador Zig-Zag Existente

En la subestación Ninatambo existe un transformador zigzag de 10 kV, de una capacidad de 57,4 KVA, con una impedancia homopolar de 96,4 Ohms y que puede soportar una corriente de 10 Amperios por el neutro, durante 10 segundos. Los datos de placa se dan en el Cuadro N° 4.3.

Marca	BBC
Año de Fabricación	1987
Serie Nro.	L 17774
Tipo	ND10N
Potencia Nominal	57,74 - Trifásico
Frecuencia	60 Hz
Grupo de Conexión	Zno
Norma	C.E.I.
Ais. Fase/neutro BIL kV	38 / 38
Altitud	4,000 msnm
Zo	96,4
Enfriamiento	OA
Primario Bornes	U-V-W Tension 10000 V
Neutro Bornes	O
Tensión Bornes	OU-OV-OW Tensión 57,74 V
Peso total del transformador	370 Kg
Peso del aceite	110 Kg
Servicio Contínuo	
KVA	No se tiene
Tensión	10000
Servicio Corta Duración	
KVA :	57.4
Tiempo (Segundos)	10
Amperios en el neutro	10

Cuadro N° 4.3: Datos de placa del transformador Zig-zag

En el acápite 4.4 del presente informe se hace un análisis de la posibilidad de conectar el transformador Zig-zag existente a la red de 10 kV y se plantea como una alternativa de solución.

4.3.3 Alimentadores de Media Tensión en 10 kV

A partir del lado de 10 kV del transformador de potencia de la Subestación Ninatambo salen dos alimentadores aéreos, de los cuales el primer alimentador lleva la energía a la localidad de Huaricolpa y el segundo alimentador a la parte urbana de la localidad de Tarma.

El primer alimentador Radial A4701 tiene una longitud total de 9,7 Kms con una carga instalada de 3 867 kW y el segundo alimentador Radial A4702 tiene una longitud de 4,2 Kms con una carga instalada de 3 615 kW. La demanda máxima proyectada es de 1,52 MVA para cada uno de los alimentadores.

Las redes son de aluminio en diversas secciones, siendo la de mayor sección 70 mm2. Las potencias de los transformadores son también variados, de modo que en la Salida 1 la mayor potencia es 250KVA y en la Salida 2 la mayor potencia es de 400 KVA.

4.4 Cálculos Justificativos y Analisis para la Instalación del Transformador Zig-Zag Existente

4.4.1 Cálculo de la Corriente Homopolar

Para la obtención de la impedancia capacitiva de los alimentadores, se han utilizado las siguientes ecuaciones:

$$Xc = \frac{10^6}{2\pi f Co} \, Omhios \;\; / \; fase \qquad ------(4.1)$$

$$Co = \frac{10^6}{2\pi f Xc} \, microF \;\; (\mu F)/ \; fase \qquad ----(4.2)$$

$$3Ico = \frac{2\sqrt{3}\,\pi f Co E}{10^6} \, Amperios \qquad --------(4.3)$$

Donde:

f = Frecuencia en Hz.

Co = Capacitancia a tierra en microF

E = Tensión de línea del sistema en Voltios

Una aproximación que puede ser usada para la capacitancia de las redes aéreas en función de su longitud y de los transformadores, son las siguientes:

Para transformadores : Co = 0.01 – 0.001 microF

Líneas aéreas : Co = 0.01 microF/milla = 0.0062 microF/km

Si consideramos que en el futuro la localidad de Tarma llega a tener 5 alimentadores (actualmente se tienen 2), asumiendo 5 kilómetros por cada alimentador, se tendría un total de 25 kilómetros de línea. Asimismo, considerando 5 transformadores por cada alimentador, en total se tendría 25 transformadores. Luego la capacitancia total de los 5 alimentadores con 25 transformadores por alimentador sería:

$$Co = 25km \times 0.0062\ microF/km + 25 \times 0.01\ microF = 1{,}405\ microF \quad \text{----(4.4)}$$

De esta forma obtenemos los valores de Xco e I_{CO}:

$$X_{Co} = \quad 6\ 549{,}6\ ohm/fase$$

$$3I_{Co} = \quad 2{,}64\ A.$$

Para un valor típico de resistencia de falla de 1000 Ohmios en terreno pedregoso o terreno arenoso, con esta corriente se tiene una tensión homopolar del orden de:

$$3V_o = \quad 2\ 640\ Votios$$

Como se puede apreciar, la corriente de falla a tierra en este tipo de redes aéreas, son muy bajas y se hace mucho menor cuando la resistencia de contacto a tierra es muy grande.

4.4.2 Cálculo de las Impedancias de Secuencia

Para el análisis de cortocircuito se han tomado los resultados del estudio de coordinación de la protección del Subsistema 138/44/35/22.9/10 kV Caripa - Condorcocha - Ninatambo - Chanchamayo, realizado por ELECTROCENTRO S.A. De este informe obtenemos las potencias de cortocircuito trifásicas y monofásicas en 44 kV en Ninatambo con la finalidad de obtener las impedancias equivalentes.

Para el cálculo se han tomado las siguientes bases indicadas en el Cuadro N° 4.4:

KV Base	MVA base	Z base (Ohms)	I base (A)
44.00	10.00	193.6	131.2160
10.00	10.00	10	577.3503

Cuadro N° 4.4: Bases para el cálculo en p.u.

a) Impedancias de Secuencia del Sistema

Los niveles de cortocircuito en la subestación Ninatambo en las barras de 44 kV son las que se muestran en el Cuadro N° 4.5:

Fases	Potencia MVA	Corriente KA	Tensión KV
Trifásica	116.60	1.53	44
Monofásica	155.47	2.04	44

Cuadro N° 4.5: Niveles de cortocircuito en Barras de 44 kV

Con estos valores se obtiene las impedancias equivalentes de secuencia, del sistema aguas arriba de las barras de 44 kV, las que a continuación se indican en el Cuadro N° 4.6:

Impedancia	Ohm	p.u.
Secuencia positiva	16.6035	0.0858
Secuencia negativa	16.6035	0.0858
Secuencia cero	4.1509	0.0214

Cuadro N° 4.6: Impedancias de secuencia equivalentes del Sistema

b) Impedancias de Secuencia del Transformador de Potencia

Las impedancias del transformador de potencia de la subestación Ninatambo, llevados a la base de 10MVA, son las indicadas en el Cuadro N° 4.7 siguiente:

Devanados	Vcc %	MVA	Vcc (pu) nueva
Primario - Secundario	3.1	5	0.062
Primario - Terciario	4.9	5	0.098
Secundario - Terciario	1.5	5	0.030

Cuadro N° 4.7: Impedancias de secuencia del Transformador de Potencia

Para el cálculo de la corriente de cortocircuito monofásica se ha tenido en cuenta la impedancia entre los devanados primario y terciario, es decir el lado de 44 kV y el de 10 kV.

c) Impedancia Homopolar de Transformador Zig-zag

Finalmente, la impedancia homopolar del transformador zig-zag en la base de 10 MVA es de 96,4 Ohmios (9,64 p.u.)

4.4.3 Inserción del Transformador Zig-Zag

a) Máxima Corriente de Cortocircuito.Monofásica

Con los valores de impedancias en p.u., uniformizados en una misma base, se han calculado las máximas corrientes de cortocircuito monofásica que se pueden presentar en las barras de 10 kV.

Considerando que en el neutro se puede colocar una resistencia para limitar la corriente por el mismo, de modo que no sobrepase la corriente máxima que puede soportar el transformador zig-zag, para distintos valores de resistencia del neutro, se han efectuado los cálculos obteniéndose los resultados mostrados en el Cuadro N° 4.8:

Resistencia Neutro RNGR	kV	Io (pu)	Io (A)	Ifalla = 3Io Máxima (A)
0	10	0.0987	57.01	171.03
100	10	0.0316	18.23	54.70
200	10	0.0164	9.49	28.46
300	10	0.0110	6.37	19.12
400	10	0.0083	4.79	14.38
500	10	0.0067	3.84	11.52
577.35	10	0.0058	3.33	9.98
600	10	0.0055	3.20	9.61

Cuadro N° 4.8: Corrientes de Falla Monofásica Máximas

b) Mínima Corriente de Cortocircuito.Monofásica

Para los casos en que la falla se presentara en el extremo del alimentador, se considera la impedancia del alimentador, la resistencia de contacto y la resistencia del terreno; con ello se obtienen las corrientes mínimas mostradas en el Cuadro N° 4.9 siguiente:

Resistencia Neutro RNGR	KV	Resistencia de Falla (Ohm)	Io Mínima (A)	Ifalla=3Io Mínima (A)
600	10	100.00	2.75	8.24
600	10	500.00	1.75	5.25
600	10	1000.00	1.20	3.61
600	10	1500.00	0.92	2.75

Cuadro N° 4.9: Corrientes de Falla Monofásica Mínimas

4.4.4 Análisis de los Resultados

La impedancia capacitiva de la red, asumiendo el máximo de valor de capacitancia a tierra para los transformadores, así como considerando 5 alimentadores de 5 km cada uno, llegaría como máximo a 6 549,6 ohm/fase, y la contribución por parte de ésta sería de 2,64 A, tal como se ha visto en el acápite 4.4.1. Valor muy bajo con el que no se podría garantizar la actuación efectiva de un relé multifunción de alta sensibilidad.

De los resultados de cortocircuito monofásico visto en el acápite 4.4.3, se puede observar que el neutro del transformador Zig-zag no puede ir conectado directamente a tierra (sin resistencia conectada a neutro) dado que se origina una corriente de cortocircuito máxima de 171 A, tal como puede apreciarse en el Cuadro N° 4.8 cuando la resistencia RNGR es cero. Este valor está muy por encima de la capacidad del transformador Zig-zag que es de 10 Amperios durante 10 segundos.

Para que esta alternativa sea considerada, es necesario que el neutro del transformador Zig-zag se conecte a tierra a través de una resistencia cuyo valor sería alrededor 600 Ohmios, que de acuerdo a los resultados de cortocircuito monofásico obtenidos, la corriente de falla sería 9.61 A (ver Cuadro N° 4.8), valor que no sobrepasa los 10 A que tiene como capacidad el transformador zig-zag.

La configuración del circuito tiene se muestra en la Figura N° 4.1:

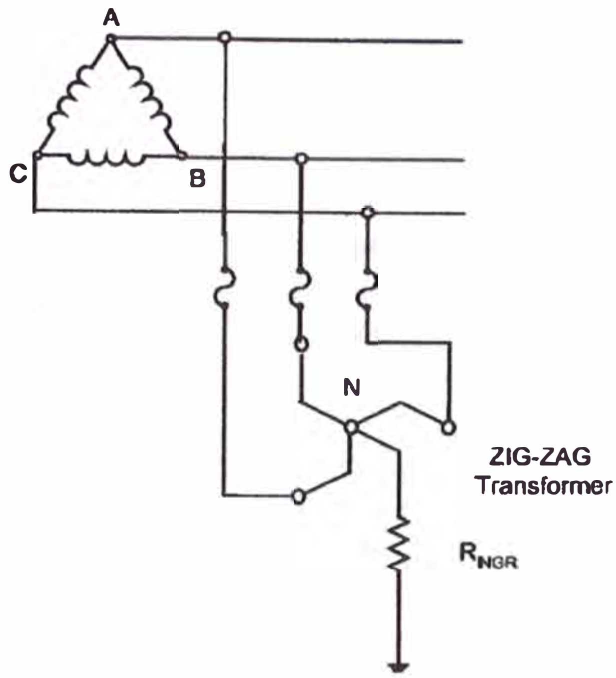


Figura N° 4.1: Transformador Zig-zag con resistencia RNGR

Las restricciones de diseño para la resistencia de neutro son las siguientes:

$$R_{NGR} = \frac{E}{\sqrt{3}\, I_G} \quad Ohmios \quad --------(4.5)$$

$$R_{NGR} \leq \frac{Xco}{2\pi f Xc} \quad Ohmios \quad --------(4.6)$$

$$I_G \geq 3\, Ico \quad Amperios \quad ------(4.7)$$

$$W_{NGR} = I_G^2\, R_{NGR} \quad Watts \quad --------(4.8)$$

De las ecuaciones (4.5) al (4.8), la resistencia que va conectado al neutro debería ser 10kV/(√3x 10 A) = 577.35 ohm. Luego, introduciendo esta resistencia en los cálculos de cortocircuito obtenemos una corriente de falla monofásica de 9.98 A. Asimismo la potencia de consumo sería de 57,74 kW. Tenemos además dos restricciones adicionales: la impedancia homopolar capacitiva a tierra de los alimentadores (XCo) y la contribución por parte de ellas (3ICo).

Como se puede apreciar en la ecuación (4.6) el valor de RNGR debe ser menor o igual que XCo/3, asimismo en la ecuación (4.7) la corriente I_G debe ser mayor o igual que $3I_{co}$; con los resultados obtenidos se cumplen ambas condiciones, concluyéndose que es posible conectar el transformador zig-zag, en la barra de 10 kV.

Sin embargo, aún cuando se conectaría el transformador Zig-zag, debido a la alta resistencia de contacto y a la resistencia R_{NGR} las corrientes de falla monofásicas mínimas, en los extremos del alimentador y con resistencia de falla de 1 000 Ohmios, son del orden de 3.61 A; con lo cual se tiene incertidumbre en la operación del sistema de protección.

4.5 Evaluación de Alternativas

La evaluación se ha efectuado para todas las alternativas posibles de aplicar en la subestación Ninatambo, siendo estas las siguientes:

- Instalación de relé multifunción Hompolar-direccional.
- Transformador Zig-zag existente como neutro artificial.
- Instalación de un nuevo Transformador Zig-zag, de mayor potencia que el existente.
- Instalación de Relé de Sobretensión Homopolar y Sistema de Automatización con PLC

4.5.1 Alternativa 1:

Instalación de Relé Multifunción Homopolar-Direccional

Tal como se vió en el acápite 1.2, con la finalidad que la detección de la falla sea selectiva, se plantea como primera alternativa la implementación de relés direccionales de sobrecorriente homopolar, cuya tecnología permite despejar fallas a tierra con alta impedancia y en la actualidad se cuentan con relés que tienen una sensibilidad de 10 mA en el lado secundario; sin embargo, como ya se dijo en la práctica no es aconsejable calibrar a este valor, puesto que cualquier desbalance en el sistema podría sacar fuera de servicio el alimentador. Es recomendable un valor típico de calibración de 2 Amperios en el lado primario.

Por otro lado, la actuación del relé multifunción homopolar direccional, en muchos casos está limitada cuando la falla ocurre en zonas alejadas donde la resistencia de contacto es elevada, presentándose corrientes muy bajas; tal como se ha calculado en el acápite 4.4.1, donde la corriente es de 2,64 Amperios.

Esta corriente es pequeña, con la cual no se garantiza la operación efectiva del relé de sobrecorriente homopolar direccional, puesto que este valor puede disminuir cuando el conductor cae en una zona donde se presenta una alta resistencia de contacto.

Por otro lado, en circuitos con 2 alimentadores no es recomendable usar esta tecnología puesto que si uno de los alimentadores está fuera de servicio y se presenta una falla a tierra en el segundo alimentador, no habría contribución de corriente y por lo tanto no se daría la apertura del alimentador fallado.

Se concluye que, debido a que solamente se tienen dos alimentadores de 10 kV en la Subestación Ninatambo, se presenta poca contribución de corriente por parte de las capacitancias parásitas, motivo por el cual en el presente proyecto se descarta técnicamente el uso de esta primera alternativa.

4.5.2 Alternativa 2:

Transformador Zig-zag Existente como Neutro Artificial

Para crear un neutro artificial se puede hacer uso de un transformador Zig-zag, con el cual se logra elevar las corrientes de falla a tierra, para esto el transformador debe ser adecuadamente diseñado.

En el acápite 4.4.3 se han efectuado el análisis considerando la inserción del transformador Zig-zag, de donde se desprende que se origina una corriente de cortocircuito que es del orden de 171 A, muy por encima de la capacidad del transformador Zig-zag existente en la subestación Ninatambo (10 A durante 10 Segundos), por lo que se hace necesario el uso de una resistencia RNGR a ser conectada entre el neutro del transformador Zig-zag y tierra tal como puede apreciarse en la Figura N° 4.2. El valor debe ser del orden de los 600 Ohmios, de acuerdo a los resultados de cortocircuito monofásico (9.61 A). Dicha resistencia RNGR resulta un valor inusualmente elevado, puesto que los valores típicos son del orden de 10 a 100 Ohmios.

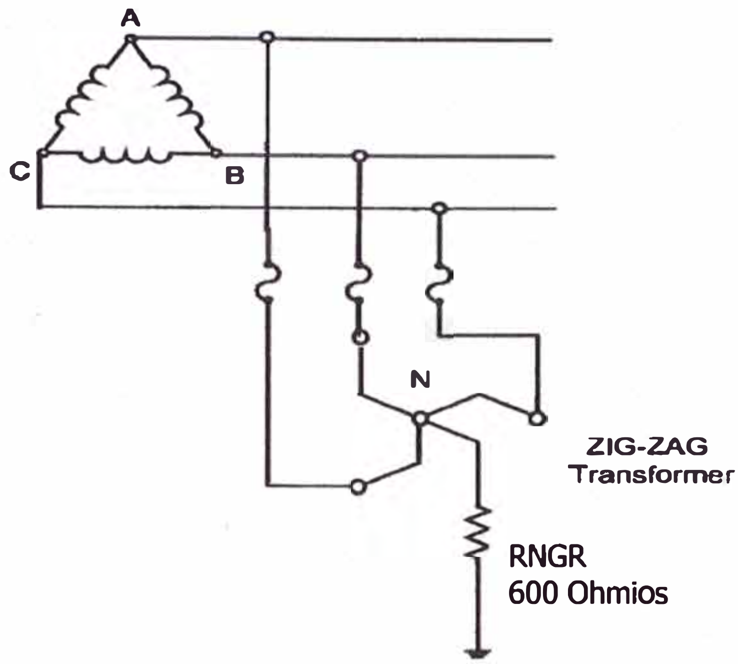


Figura N° 4.2: Comportamiento de las corrientes de falla a tierra

Esta segunda alternativa se torna preocupante en los casos donde la falla se presente en el extremo del alimentador y en zonas donde la resistencia de contacto sea del orden de 1 500 a 2 000 Ohmios (casos de arenales y veredas secas), en los cuales los valores de corrientes mínimas que se obtendrán serán muy bajos, según se desprende de los resultados de los cálculos indicados en el Cuadro N°4.9 del acápite 4.4.3.

Por lo tanto con estos valores de corriente que son muy pequeños, tampoco sería posible garantizar que un relé actúe adecuadamente para despejar la falla, es decir, habría un margen de incertidumbre en la actuación del equipo para estas contingencias.

4.5.3 Alternativa 3:

Instalación de un Nuevo Transformador Zig-zag

Puesto que el Transformador Zig-zag existente en la Subestación Ninatambo no tiene la capacidad adecuada y requiere una alta resistencia R_{NGR} para limitar la corriente, se plantea una tercera alternativa consistente en el suministro e instalación adicional de un nuevo transformador Zig-zag provisto de una capacidad de transporte de corriente en el neutro de 171 Amperios.

Sin embargo, análogamente a lo indicado en la alternativa anterior para los casos de fallas en los extremos del alimentador o en zonas donde la resistencia de contacto sea del orden de 1 500 Ohmios (casos de arenales y veredas secas), se generan corrientes de falla muy bajas, y sea que se instalen relés con alta sensibilidad, de todas maneras como en los casos anteriores, la operación del relé no estaría garantizada en la totalidad de los casos.

4.5.4 Alternativa 4:

Relé de Sobretensión Homopolar y Sistema de Automatización con PLC

Como ya se mencionó en el acápite 1.4 en un sistema aislado, cuando uno de los conductores hace contacto con tierra, en las otras fases se presenta una sobretensión respecto a tierra la misma que puede alcanzar los niveles de tensión de línea-línea. Es decir, se presenta una tensión homopolar resultante, en toda la barra y el sistema, que será la magnitud de actuación para un relé de sobretensión homopolar.

Como también ya se mencionó en el acápite 1.4 este tipo de protección es más confiable comparado con los casos anteriores, puesto que la tensión homopolar se presenta en barras y en todo el sistema, independientemente de donde se produzca la falla. Por lo demás, en nuestro país se tiene una vasta experiencia de instalación de estos esquemas.

Puesto que la protección por sobretensión homopolar no puede determinar por sí solo dónde se origina la falla; para este caso en particular de un sistema de distribución con 2 o 3 alimentadores, es aplicable la adición de una automatización con PLC, que basándose en una lógica de prueba-falla, permite discriminar el alimentador fallado y quedar desenergizado.

Esta alternativa es aplicable puesto que los interruptores instalados en las celdas de salida de la Subestación Ninatambo, poseen bobinas de apertura y cierre.

Asimismo se ha previsto el reemplazo de los relés electromecánicos de sobrecorriente BBC-ICM 22KP, existentes en cada alimentador y del cable de comunicación de 10kV.

4.5.5 Alternativa Optima

Luego de evaluar todas las alternativas posibles de aplicar en este caso particular para la Subestación Ninatambo, se llega a la conclusión que debido a la poca cantidad de alimentadores, su contribución para la generación de corrientes homopolares es mínima, generándose pequeñas corrientes que no garantizarían la operación del sistema de protección de sobrecorriente homopolar direccional.

Tampoco es posible la puesta en servicio del transformador Zig-zag existente, puesto que no soportaría la corriente de falla a tierra máxima que se produce en barras. Por otro lado con la inserción de una alta resistencia R_{GNR} y en los casos de caída de conductor en zonas con alta resistencia de contacto, las corrientes de falla a tierra en los extremos de los alimentadores son muy pequeñas, con lo cual tampoco se garantiza la efectiva operación de un relé de sobrecorriente homopolar direccional, aún cuando este último sea de alta sensibilidad.

Por la tanto, de la evaluación efectuada en este caso particular para el sistema de 10kV de la Subestación Ninatambo, se desprende que la Cuarta Alternativa cumple técnicamente con el propósito de despejar las fallas a tierra en este caso especial de dos o tres alimentadores.

4.6 Especificaciones de los Relés de Protección y del Sistema de Automatización

4.6.1 Relé de Sobretension

Relé de sobretensión homopolar con medición de componentes simétricas, marca SEG, modelo MRU – 21 DM, será instalado en barras de 10 kV.

Características Técnicas:

Alimentación	Multirango (16 a 360 Vdc / 16 a270 Vac)
Funciones	59N, 27, 59 47
Medición	Tensiones de fase y componentes simétricas de tensión.
Protocolo	Modbus RTU

Con capacidad de registro de fallas y oscilografías.

Características adicionales del relé de sobretensión homopolar son dadas en el ANEXO B,

4.6.2 Relé de Protección Contra Sobrecorrientes

a) Protección de Alimentadores

Relés de protección contra fallas a tierra entre fases y fase a tierra direccional, para sistemas en delta, serán instalados a la salida de los alimentadores de 10 kV, están preparados con la función de sobrecorriente homopolar direccional para que en el futuro puedan operar cuando se incrementen el número de alimentadores.

Características Técnicas:

Marca y Modelo	:	SEG MRI3
Funciones de protección	:	50 /51 y 67N
Alimentación Auxiliar	:	16 a 360 Vdc, 16 a 270 Vac
In fases / In neutro	:	5 A / 1 A
Protocolo	:	Modbus RTU

Registro de Fallas y oscilografías, con autosupervisión.

b) Protección del Cable de Comunicación a Barras 10 kV

Relé de protección de fallas entre fases y fase a tierra, no direccional, para la protección desde la salida del transformador hasta la llegada a las barras de 10 kV, también es un respaldo de la protección de los alimentadores.

Características Técnicas:

Marca y Modelo	:	SEG MRI3
Funciones de protección	:	50 /51 y 50N / 51 N
Alimentación Auxiliar	:	16 a 360 Vdc, 16 a 270 Vac
In fases / In neutro	:	5 A / 5 A
Protocolo	:	Modbus RTU

Registro de Fallas y oscilografías, con autosupervisión.

Características adicionales del relé de sobrecorriente son dadas en el ANEXO C,

4.6.3 Sistema de Automatización

Para la elaboración del sistema de automatización se ha tenido en cuenta la metodología explicada en el Capítulo II. Cuando se origina una sobretensión homopolar, el **Relé de Sobretensión homopolar**, una vez que ha superado el respectivo ajuste, manda alarma y a la vez ordena al PLC el inicio de la automatización de los alimentadores; cuya lógica de operación se muestran en los Cuadros N° 4.3, N° 4.4 y N° 4.5 siguientes:

Falla en el Alimentador 1:

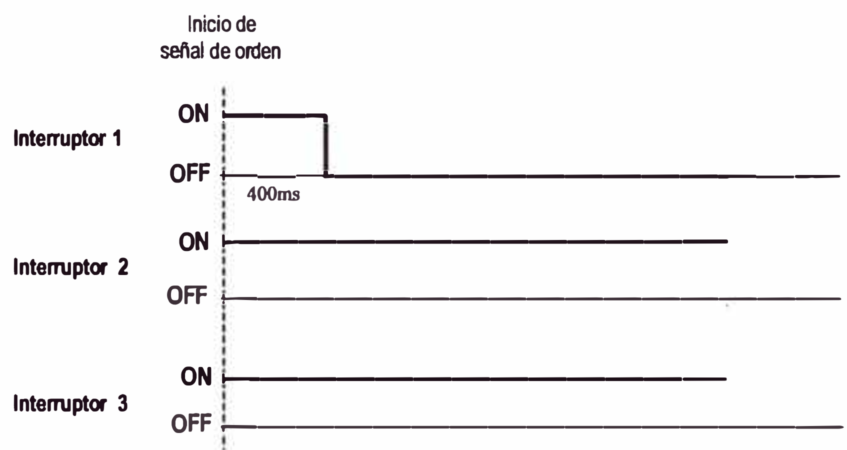


Figura N° 4.3: Secuencia de Operación con falla en el Alimentador 1

Falla en el Alimentador 2:

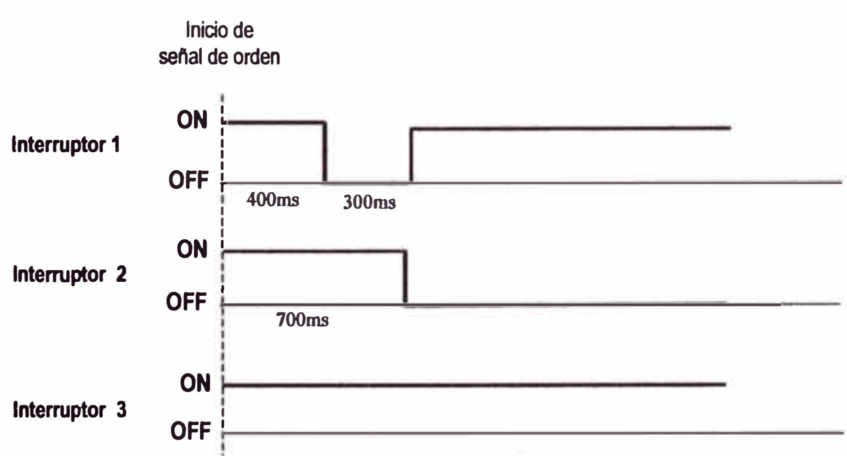


Figura N° 4.4: Secuencia de Operación con falla en el Alimentador 2

Falla en el Alimentador 3:

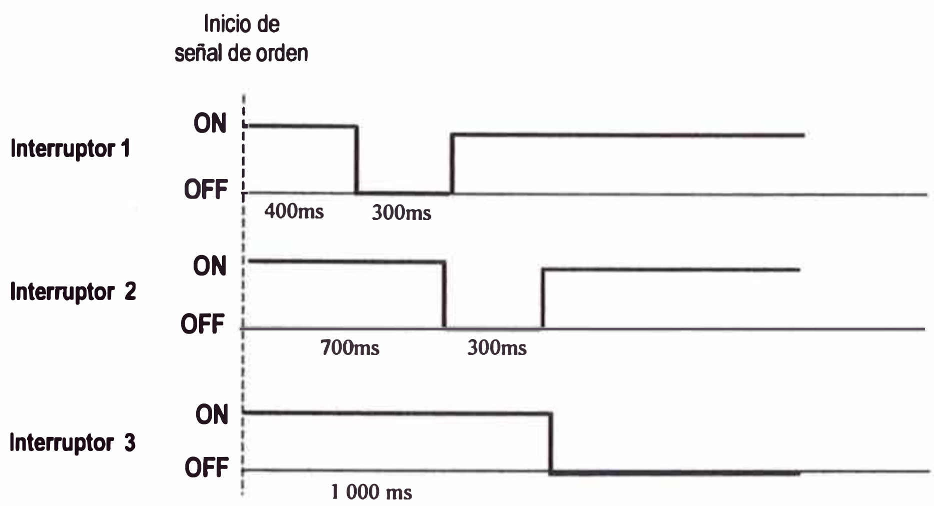


Figura N° 4.5: Secuencia de Operación con falla en el Alimentador 3

Condiciones de Operación

En la subestación se dispone de fuente auxiliar en 220 V corriente contínua (Vcc), sin embargo para los requerimientos del PLC, se ha considerado una fuente para su alimentación en 24 Vcc.

Se ha requerido una señal de posición de cada interruptor (3 entradas). Esto para realizar un salto en la secuencia de disparo en el caso que ocurriese una falla en uno de los alimentadores y uno de ellos esté por alguna razón fuera de servicio.

Se ha requerido una señal adicional de entrada al PLC, este corresponde al relé de sobretensión homopolar. Esta señal es muy importante ya que inicia la secuencia en el PLC.

De acuerdo a la secuencia, el PLC enviará una señal de disparo a cada uno de los interruptores, para la apertura de los interruptores; o enviará señal de cierre a cada uno de los interruptores según sea el caso. Siempre se ha tenido en cuenta el criterio de que para los circuitos de disparo, se necesitará un contactor auxiliar 220 Vcc por cada interruptor, luego el PLC deberá contar con una salida tipo relé por cada interruptor para alimentar dicho contactor.

4.7 Evaluación Económica

De la evaluación efectuada en los acápites anteriores, para el caso particular de sistemas eléctricos aislados con dos o tres alimentadores la Cuarta Alternativa cumple técnicamente con el propósito de despejar las fallas a tierra.

Y de acuerdo al Cuadro N° 4.10 donde se indican los costos por el suministro y mano de obra de cada una de las alternativas, se concluye que la Cuarta Alternativa: Instalación de un relé de sobretensión homopolar con sistema de Automatización de Alimentadores en base a PLC, es la alternativa técnico-económicamente más adecuada para este caso especial.

Cuadro N° 4.10

EVALUACIÓN ECONÓMICA DE ALTERNATIVAS

Item	Descripción	Cant.	Unidad	Alternativa 1 (*) Relé Homopolar		Alternativa 2 Zig Zag con R		Alternativa 3 Nuevo Zig Zag		Alternativa 4 Relé y PLC	
				PU US$	PT US$	PU US$	PT US$	PU US$	PT US$	PU US$	PT US$
1	Relé Multifunción 50/51P, 50/51N, 67N (alta sensibilidad y oscilografía) Marca SEL	2	Unid	4,200	8,400						
2	Relé de Sobrecorriente Marca SEG (Cable comunicación)	1	Unid	2,980	2,980	2,980	2,980	2,980	2,980	2,980	2,980
3	Relé Multifunción 50/51P, 50/51N Marca SEG - Alimentadores	2	Unid			2,850	5,700	2,850	5,700	2,850	5,700
4	Relé de sobretensión marca SEG (Alemania)	1	Unid							2,500	2,500
5	Controlador Lógico Programable-Automatización	1	Glob							2,750	2,750
6	Transformador de Corriente Tipo Toroidal	2	Unid	570	1,140						
7	Anunciador de Alarmas	1	Unid	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200
8	Transformador Zig Zag nuevo	1	Unid					8,500	8,500		
9	Resistencia limitadora de corriente	1	Unid			6,000	6,000				
10	Gabinete para resistencia	1	Unid			1,000	1,000				
11	Materiales consumibles, borneras, cable GPT 2.5 mm2, Terminales, Cintillos, Numeradores, Cable NYY 4 mm2, etc.	1	Glob	100	100	100	100	100	100	100	100
12	Ferretería para la instalación del transformador ZIGZAG (Terminales, Cable, Conectores, Base Transformador)	1	Glob			1,000	1,000	1,500	1,500		
13	Suministro, transporte y montaje del equipamiento del transformador zigzag (Seccionador de potencia, fusibles limitadores, pletinas, etc.)	1	Glob			2,000	2,000	2,000	2,000		
14	Mano de obra para la instalación	1	Glob	5,400	5,400	5,800	5,800	6,200	6,200	4,200	4,200
	VALOR DE VENTA DE SUMINISTROS Y MANO DE OBRA			**US$**	**19,220**	**US$**	**25,780**	**US$**	**28,180**	**US$**	**19,430**
							133%		145%		100%

(*) Alternativa de referencia pero no es evaluable por su no aplicabilidad.

CONCLUSIONES Y RECOMENDACIONES

1. En la actualidad se cuentan con relés de sobrecorriente homopolar direccional de alta sensibilidad, de 10 mA e incluso 5 mA. Estos equipos funcionan de una manera efectiva en circuitos con muchos alimentadores y sobretodo en aquellos circuitos con redes subterráneas. Es decir en aquellos circuitos donde las fallas de fase a tierra, generan corrientes homopolares por encima de 3 ó 5 Amperios.

2. Los relés de sobrecorriente homopolar direccional de alta sensibilidad, aún cuando sean de 5 mA, en los casos de circuitos con pocos alimentadores que generan corrientes homopolares pequeñas, no garantizan una operación efectiva para despejar las fallas a tierra. Más aún no es recomendable ajustar la corriente homopolar por debajo de los 20 mA, puesto que cualquier desequilibrio o desbalance del sistema eléctrico, el relé dispararía ordenando la apertura del interruptor en cualquier momento, aún sin condición de falla.

3. Para los casos en los cuales se cuenta solamente con dos alimentadores, cuando uno de los alimentadores está fuera de servicio

(por mantenimiento), la situación empeora, puesto que un alimentador solo no tendría la capacidad de generar las corrientes necesarias para poder usar relés multifunción de sobrecorriente homopolar direccional. En este caso no es recomendable usar la protección con relé multifunción de sobrecorriente homopolar direccional.

4. El transformador Zig-zag existente en la subestación Ninatambo, no tiene la capacidad suficiente para soportar las corrientes de falla a tierra que alcanza su valor máximo de 171 A en las barras de 10 kV.

5. La instalación de un nuevo transformador Zig-zag de mayor potencia, en la subestación Ninatambo, tampoco es de mucha ayuda puesto que las corrientes de falla en los extremos de los alimentadores son muy bajas, no siendo posible la protección teniendo en cuenta las corrientes homopolares.

6. Por lo tanto, en el caso particular de dos alimentadores aéreos en 10 kV de la Subestación Ninatambo, se recomienda usar un relé de sobretensión homopolar con un sistema de automatización en base a PLC, para discriminar el alimentador con falla a tierra y sacarlo de servicio; puesto que satisface las condiciones técnicas y .es la alternativa más conveniente económicamente.

ANEXO A:

ESTUDIO DE COORDINACIÓN

DE LA PROTECCIÓN DE ALIMENTADORES DE 10 KV

ANEXO A

ESTUDIO DE COORDINACION DE LA PROTECCIÓN DE LOS ALIMENTADORES DE 10 KV DE LA SUBESTACIÓN NINATAMBO

INTRODUCCION

La Subestación Ninatambo tiene un transformador reductor de 3 devanados 44/22.9/10 kV de potencias 10/5/5 MVA. El lado de 10 kV alimenta la población de Tarma a través de dos alimentadores, donde el primer alimentador lleva suministro energético a la localidad de Huaricolpa, el segundo alimentador lleva suministro energético a la población urbana de Tarma.

Los transformadores de distribución a lo largo del primer alimentador, tienen una carga instalada de 3 867 kW. Asimismo en el otro alimentador la carga instalada es de 3 615 kW. Sin embargo en el "Estudio de coordinación de la protección del Subsistema 138/44/35/22.9/10 kV Caripa-Condorcocha-Ninatambo-Chanchamayo" de ELECTROCENTRO, se indica una máxima demanda para los próximos años de 1.52 MVA, en cada alimentador.

La subestación Ninatambo contaba con los siguientes relés de protección en lo que respecta a sobrecorrientes entre fases:

N°	kV	TC	Marca	Tipo	Observaciones
1	44	150/5	BBC	ICM 22kp	Transformador, lado alta
2	44	100/5	IORI	AS1	Salida a Chanchamayo
3	22.9	200/5	BBC	ICM 22kp	Principal, lado del transformador
4	22.9	100/5	BBC	ICM 22kp	Salida 1
5	22.9	100/5	BBC	ICM 22kp	Salida 2
6	10	400/5	BBC	ICM 22kp	Principal, lado del transformador
7	10	150/5	BBC	ICM 22kp	Salida 1
8	10	150/5	BBC	ICM 22kp	Salida 2

Cuadro N° A.1: Relés de protección de sobrecorriente entre fase

Los relés R6, R7 y R8 indicados en el Cuadro N° A.1, que protegen los circuitos de 10 kV, son reemplazados por relés nuevos de última generación, con la finalidad de darle mayor precisión, rapidez y sensibilidad ante fallas entre fases. Los relés R6, R7 y R8, electromecánicos protegen por fase, se utilizan dos unidades para proteger el circuito, en las fases R y T; ahorrándose la unidad que protege la fase S, esto es válido para un sistema aislado. Los nuevos equipos de protección son unidades trifásicas para cada circuito.

CRITERIOS Y METODOLOGÍAS

Los criterios y metodología usados para el estudio de Coordinación de la Protección son los siguientes:

➢ Los equipos de protección (relés de sobrecorriente) siempre deben dar seguridad de operación cuando se le requiera, sensibilidad a los valores de entrada de los Transformadores de corriente (CTs), rapidez de operación frente a fallas severas y otras características adicionales como fácil mantenimiento. Estos equipos por lo general no trabajan continuamente, en algunas ocasiones no trabajan por largos periodos, pero cuando existe una falla es importante su operación en ese momento.

- El análisis de cortocircuito toma como base un equivalente en la red de 44 kV en la Subestación de Ninatambo, este equivalente es calculado para la condición de máxima demanda. A partir de esta consideración se han calculado los niveles de cortocircuito trifásico en la barra de 10 kV y en los alimentadores a una longitud equivalente de 5 km, con la finalidad de verificar la sensibilidad de los equipos de protección. Los datos de la potencia de cortocircuito monofásico y trifásico en la barra de 44 kV para la determinación de los equivalentes, se han tomado del estudio de coordinación de la protección realizado por ELECTROCENTRO S.A.

- Los relés de protección responden a fallas a lo largo del alimentador, y si es posible de forma instantánea. Para fallas al otro lado del transformador de distribución ubicadas a lo largo de los alimentadores, el relé de protección no debe aperturar de forma instantánea, debe permitir un tiempo para que su protección local despeje la falla.

- Para la coordinación de la protección se ha considerado un umbral de tiempo de 300 ms de modo de asegurar la selectividad de la protección.

- Los ajustes de los relés de protección de sobrecorriente toman en consideración un 25% adicional de la máxima demanda proyectada para el alimentador respectivo.

- La referencia para la coordinación de la protección es el relé de sobrecorriente ubicado en el lado de 44 kV del transformador en Ninatambo. Los ajustes serán tomados del estudio de coordinación de la protección realizada por ELECTROCENTRO S.A. los cuales no son modificados.

- La protección de sobrecorriente ubicada en la barra principal funciona como respaldo de los alimentadores, esto quiere decir que la función instantánea, su ajuste, esta rezagada por encima de la máxima corriente de falla en la barra de 10 kV. De otra manera no se podría garantizar la selectividad y por consiguiente la coordinación de la protección.

DATOS CONSIDERADOS

Los datos considerados para la realización del estudio fueron recogidos del estudio de Coordinación de la Protección del Sub-sistema 138/44/35/22.9/10 kV Caripa- Condorcocha- Ninatambo – Chanchamayo, realizado por ELECTROCENTRO S.A.

1. Para el cálculo de los equivalentes se utilizó la potencia de cortocircuito en la condición de máxima demanda, estos son mostrados en el Cuadro N° A.2:

BARRA	**Tensión Nominal**	**Falla Trifásica**	**Falla Trifásica**	**Falla Bifásica**	**Falla Monofásica**
	kV	**MVA**	**KA**	**kA**	**KA**
Ninatambo 44kV	44	116.45	1.53	1.95	2.04

Cuadro N° A.2: Relés de protección de sobrecorriente entre fase

2. Luego considerando una Potencia base de 10 MVA, se obtienen los parámetros equivalentes dados en el Cuadro N° A.3:

Impedancia	Ohm	p.u.
Secuencia positiva	16.625	0.0859
Secuencia negativa	16.625	0.0859
Secuencia cero	4.107	0.0212

Cuadro N° A.3: Parámetros equivalentes

3. Los datos del transformador son los siguientes:

Lados	Vcc (p.u.)	MVA
Primario-Secundario	0.033	10
Primario-Terciario	0.05	5
Secundario-Terciario	0.015	5

Cuadro N° A.4: Datos del Transformador de Potencia

4. En cuanto a los datos de los alimentadores, se tiene el siguiente: Salida 1 – Radial A4701 y Salida 2 – Radial A4702

Salida 1: Radial A4701

Calibre	Material	Longitud Red (m)
2x16	Aluminio	692
2x25	Aluminio	50
3x10	Aluminio	910
3x120	Aluminio	440
3x16	Aluminio	405
3x25	Aluminio	4,479
3x35	Aluminio	738
3x70	Aluminio	1,969
	Total :	**9,684**

Salida 2: Radial A4702

Calibre	Material	Longitud Red (m)
2x10	Aluminio	854
2x16	Aluminio	377
2x25	Aluminio	33
3x120	Aluminio	161
3x16	Aluminio	203
3x25	Aluminio	160
3x35	Aluminio	658
3x50	Aluminio	151
3x70	Aluminio	1,570
	Total :	**4,167**

Cuadro N° A.5: Longitudes de Conductor de los Alimentadores

5. Los transformadores de distribución a lo largo de los alimentadores son muy variados, para el análisis se ha considerado el más grande por cada uno de los circuitos. De esta forma para la Salida 1 el transformador de 250 kVA es el más grande cuya impedancia de cortocircuito a considerada fue de 4%. Asimismo para la Salida 2 el transformador de 400 kVA es el más grande cuya impedancia de cortocircuito considerada es 4%. Ambos con relación 10/0.23 kV

6. La máxima demanda proyectada para cada alimentador es de 1.52 MVA y en conjunto se tiene alrededor de 3.04MVA, el consumo de servicios auxiliares es mínimo, teniendo instalado 25 kVA. Luego, se ha considerado una demanda proyectada de 3.07 MVA para el lado de 10 kV del Transformador de Ninatambo. Estos valores son importantes ya que estos fijarán el ajuste respectivo.

Circuito	**Tensión (kV)**	**Carga**		
		P (MW)	**Q (MVAR)**	**S (MVA)**
Lado del transformador	10	2.30	2.00	3.07
Alimentador 1	10	1.15	1.00	1.52
Alimentador 2	10	1.15	1.00	1.52

Cuadro N° A.6: Potencias Proyectadas

7. Los demás datos se han colocado en el respectivo diagrama unifilar, en donde se puede apreciar la relación de transformación de los

transformadores de corriente, de potencial, como también el consumo y su clase de precisión. Ver Figura N° A.1.

8. En la Figura A.2 se muestra el diagrama unifilar de protección, donde se indican los relés de sobrecorriente. Los relés de sobrecorriente ubicados en el lado de 10 kV son nuevos, los relés del lado de 44 kV y 22.9 kV son existentes (electromecánicos), siendo importante para el presente estudio el del lado de 44 kV ya que es la referencia para la coordinación de la protección. El ajuste de este relé es el siguiente:

Relé	Marca/ Modelo	Tensión (kV)	T.C.	I op (A)	Curva	Ajuste Temporizado		Instan-táneo
						TAP	DIAL	TAP
R1	BBC ICM 2kp	44	150/5	90	Very Inverse	3 Amp.	35%	Infinito

Cuadro N° A.7: Ajustes del Relé R1

9. El relé a utilizarse en el lado de 10 kV del sistema eléctrico de Ninatambo (R2, R21 y R22) son de la marca SEG-Alemania, cuyo modelo es MRI3, que es un relé digital multifunción para protección de sobrecorriente. En el presente análisis se usa la unidad de sobrecorriente entre fases temporizada e instantánea (50/51).

10. Con los datos mostrados arriba se ha efectuado el estudio de coordinación de la protección en el lado de 10 kV del Sistema Eléctrico de Ninatambo.

ANALISIS DE RESULTADOS

Uno de los resultados inmediatos es la simulación de cortocircuito para fallas entre fases, este resultado se puede visualizar en los reportes gráficos de contribución (Figuras N^{os} A.3, A.4, A.5, A.6 y A.7). Aquí se muestra el resumen de estos resultados:

Ubicación	Tensión (kV)	Falla Trifásica (kA)
Barra 10 kV – Ninatambo	10	3.05
Long. Equiv. (5km) – Salida 1	10	1.31
Long. Equiv. (5km) – Salida 2	10	1.31
Trafo Distribución – Salida 1	0.23	13.99
Trafo Distribución – Salida 2	0.23	21.03

Cuadro N° A.8: Corrientes de cortocircuito

De las simulaciones de cortocircuito, las cuales se pueden apreciar en las Figuras: A.3, A.4, A.5, A.6 y A.7; existe un gran margen entre las fallas para una longitud equivalente y una posible falla en un transformador de distribución de uno de los transformadores. Así, en el Alimentador 1 se tiene una contribución de 1,31 kA para una falla trifásica a una distancia de 5 km. Mientras que para una falla en el lado de 0,23kV del transformador de distribución ubicado bastante cerca de la barra de 10 kV (200 m de Ninatambo), se tiene una contribución por el Alimentador 1 de 0,32 kA. Para el caso del segundo alimentador solo varía en el caso de la falla trifásica en el transformador de distribución, siendo la contribución de 0,48 kA. Luego podemos garantizar un ajuste instantáneo en un 80% del nivel de cortocircuito al final de la línea equivalente en cada alimentador.

Una falla entre fases cercana a la barra de 10 kV (3 050 A) en cualquiera de las salidas, permitirá que pase por el respectivo transformador de corriente (150/5 A) un poco mas de 20 veces su capacidad nominal. Se ha recomendado verificar que dicho transformador de corriente tenga una clase de precisión que soporte por lo menos 20 veces su valor nominal, en todo caso se ha previsto el cambio.

Con este resultado de cortocircuito se ha verificado la coordinación de la protección de sobrecorriente en el lado de 10 kV. El ajuste de los relés R2, R21 y R22 de acuerdo a los criterios considerados tienen los siguientes valores:

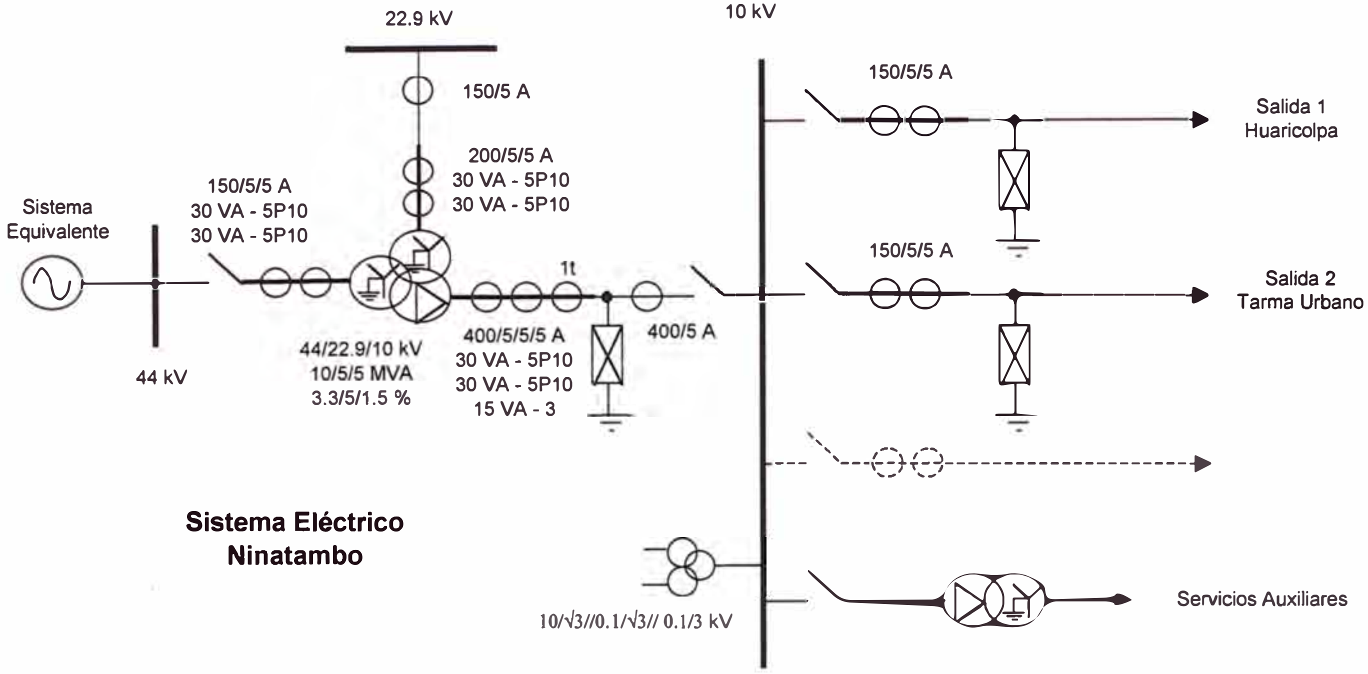
Relé	Tensión (kV)	Máx. Demanda (MVA)	Iprim. (A)	CT	Isec. (A)	1.25Isec (A)	Iajuste (Is)
R2	10	3.07	177.25	400/5	2.22	2.78	0.56xIn
R21	10	1.52	87.76	150/5	2.93	3.66	0.73xIn
R22	10	1.52	87.76	150/5	2.93	3.66	0.73xIn

Cuadro N° A.9: Ajustes de los Relés R2, R21 y R22

El ajuste de Dial para la coordinación respectiva, se ha tomado de acuerdo a los criterios mencionados arriba y del resultado de la Gráfica de la curva de coordinación. De este modo se ha obtenido el ajuste completo de los relés R2, R21 y R22:

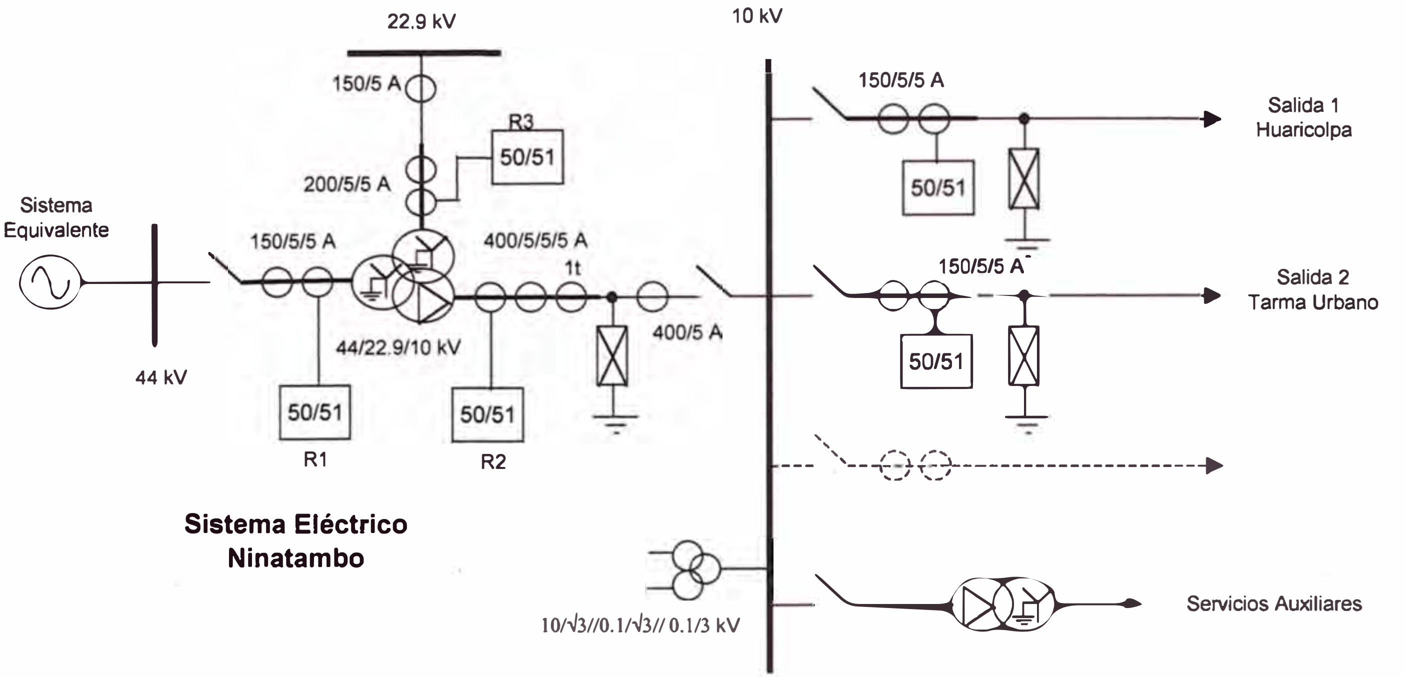
Relé	Tensión (kV)	CT	Marca	Tipo	Ajuste			Observaciones
					TAP	DIAL	INS	
R2	10	400/5	SEG	MRI3	0.56xIn	0.33	Infinito	Salida Trafo
R21	10	150/5	SEG	MRI3	0.73xIn	0.20	6.7xIn	Salida 1
R22	10	150/5	SEG	MRI3	0.73xIn	0.20	6.7xIn	Salida 2

Cuadro N° A10: Ajuste Completo de los Relés R2, R21 y R22



LEYENDA	
CODIGO	DESCRIPCIÓN
	Transformador de Potencia de tres devanados
	Transformador de dos devanados Servicios Auxiliares
	Transformador de medida de potencial de tres devanados
	Transformador de medida de corriente de dos nucleos
1t	Transformador de medida de corriente en la fase t
	Pararrayos
	Sistema Equivalente en 44 kV
	Interruptor de Potencia
-------	Circuito Proyectado

Figura N° A.1 : Diagrama Unifilar Sistema Eléctrico Ninatambo



LEYENDA	
CODIGO	DESCRIPCIÓN
	Transformador de Potencia de tres devanados
	Transformador de dos devanados Servicios Auxiliares
	Transformador de medida de potencial de tres devanados
	Transformador de medida de corriente de tres devanado
	Transformador de medida de corriente en la fase t
	Pararrayos
	Sistema Equivalente en 44 kV
	Interruptor de Potencia
	Circuito Proyectado
50/51	Relé de sobrecorriente entre fases con unidad temporizada e instantánea

Figura N° A.2 : Diagrama Unifilar de Protección (sobrecorriente) Sistema Eléctrico Ninatambo

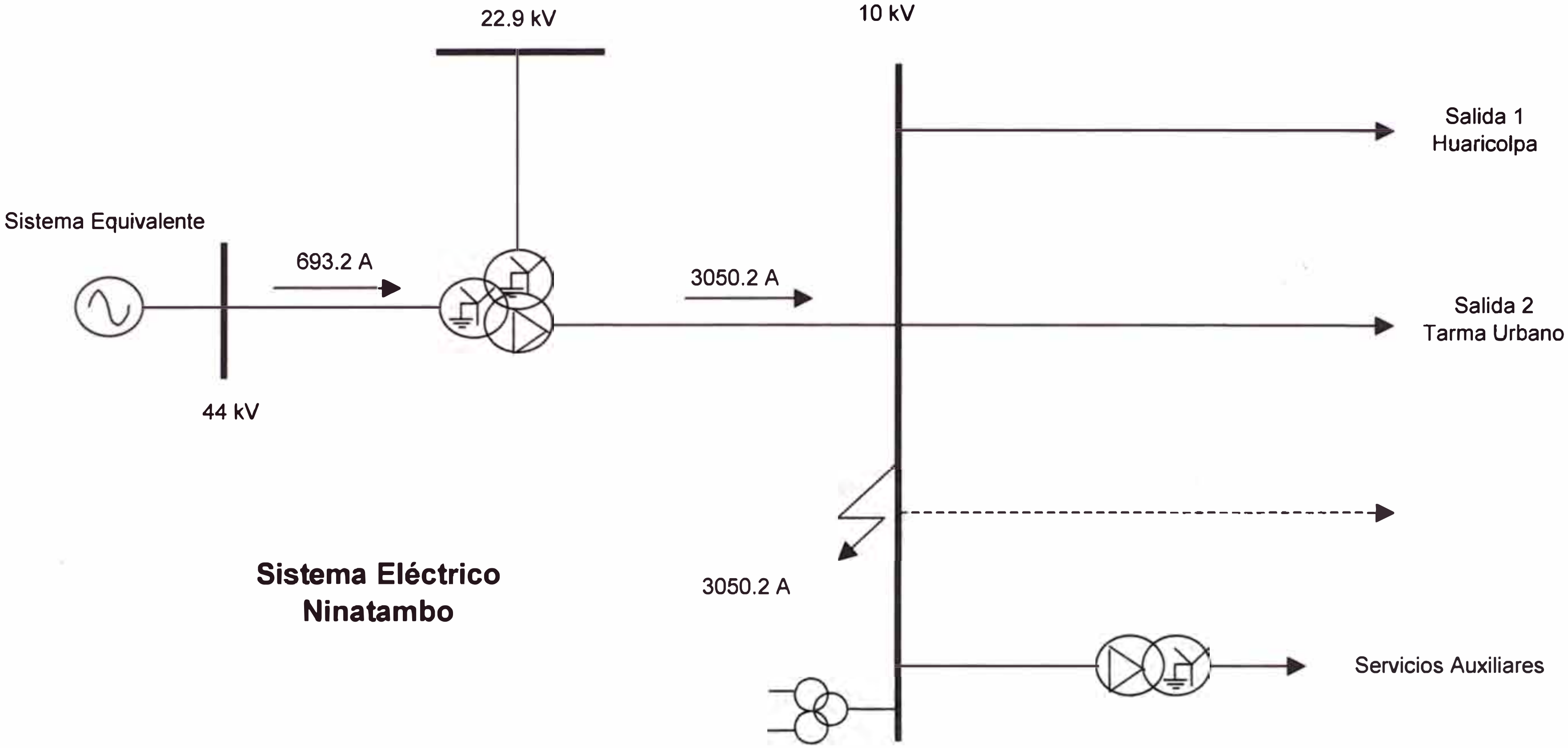


Figura N° A.3: Contribucion de corriente de cortocircuito falla entre fases Barra 10 kV Subestación Ninatambo

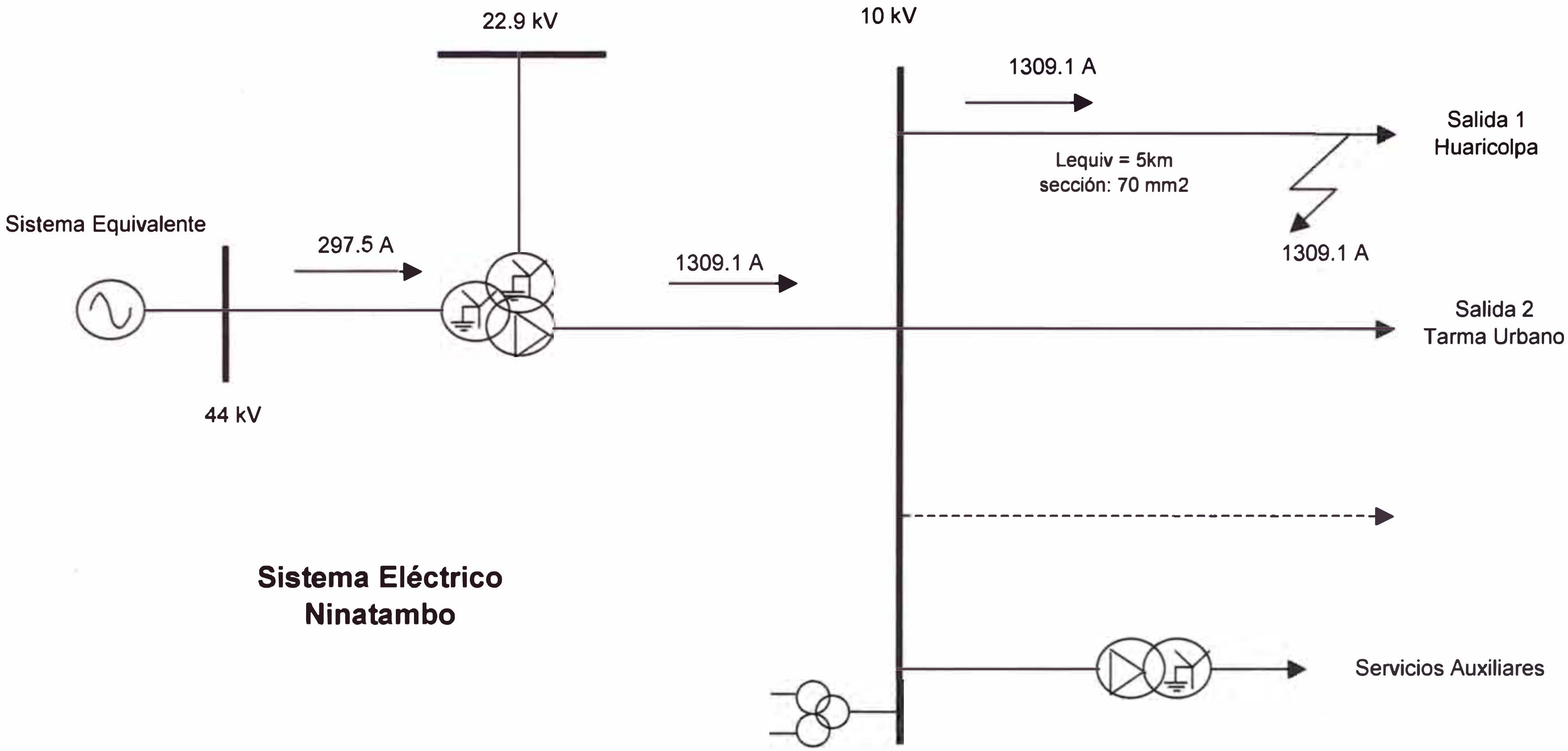


Figura N° A.4 : **Contribucion de corriente de cortocircuito falla entre fases Longitud equivalente 5 km, salida 1**

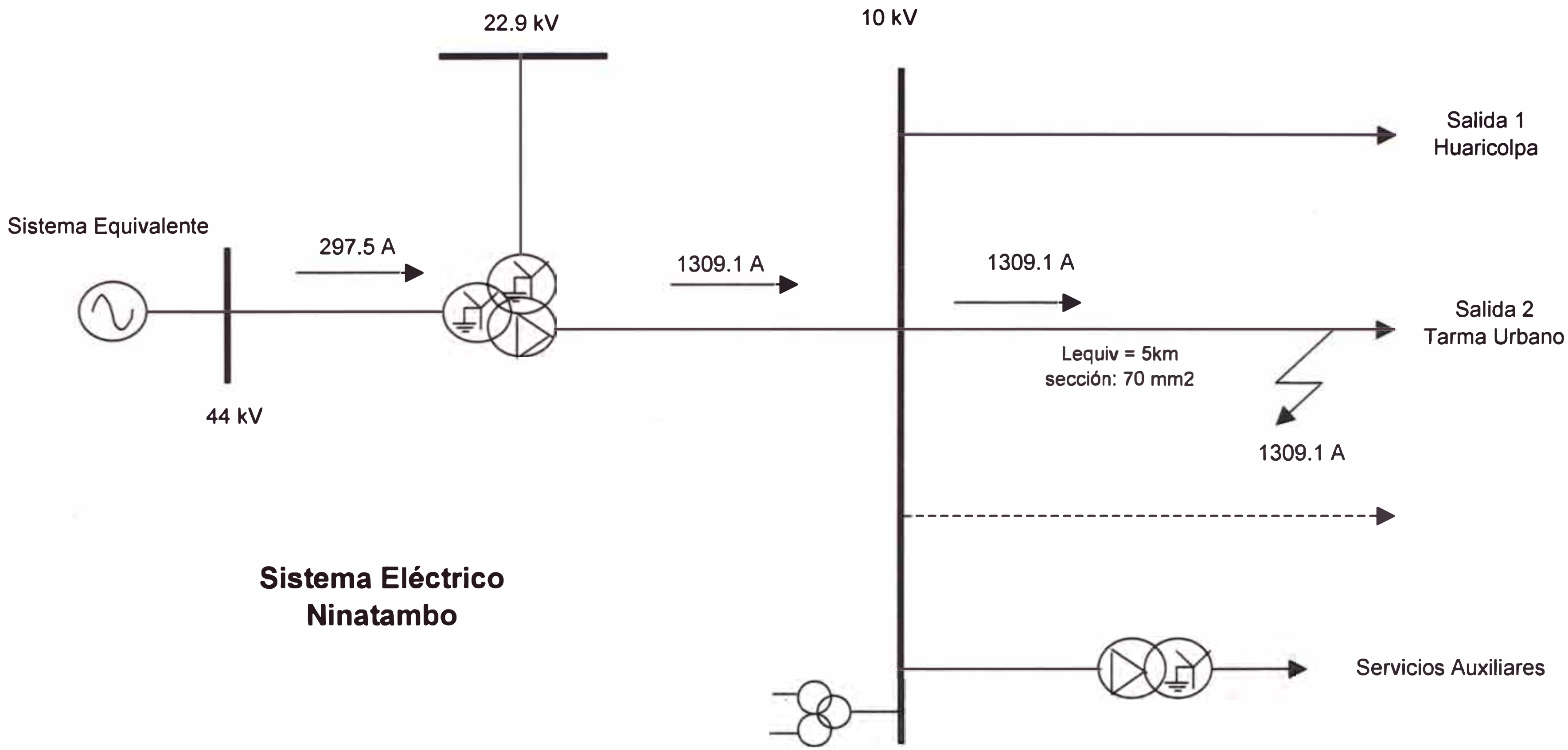


Figura N° A.5 : **Contribucion de corriente de cortocircuito falla entre fases Longitud equivalente 5 km, salida 2**

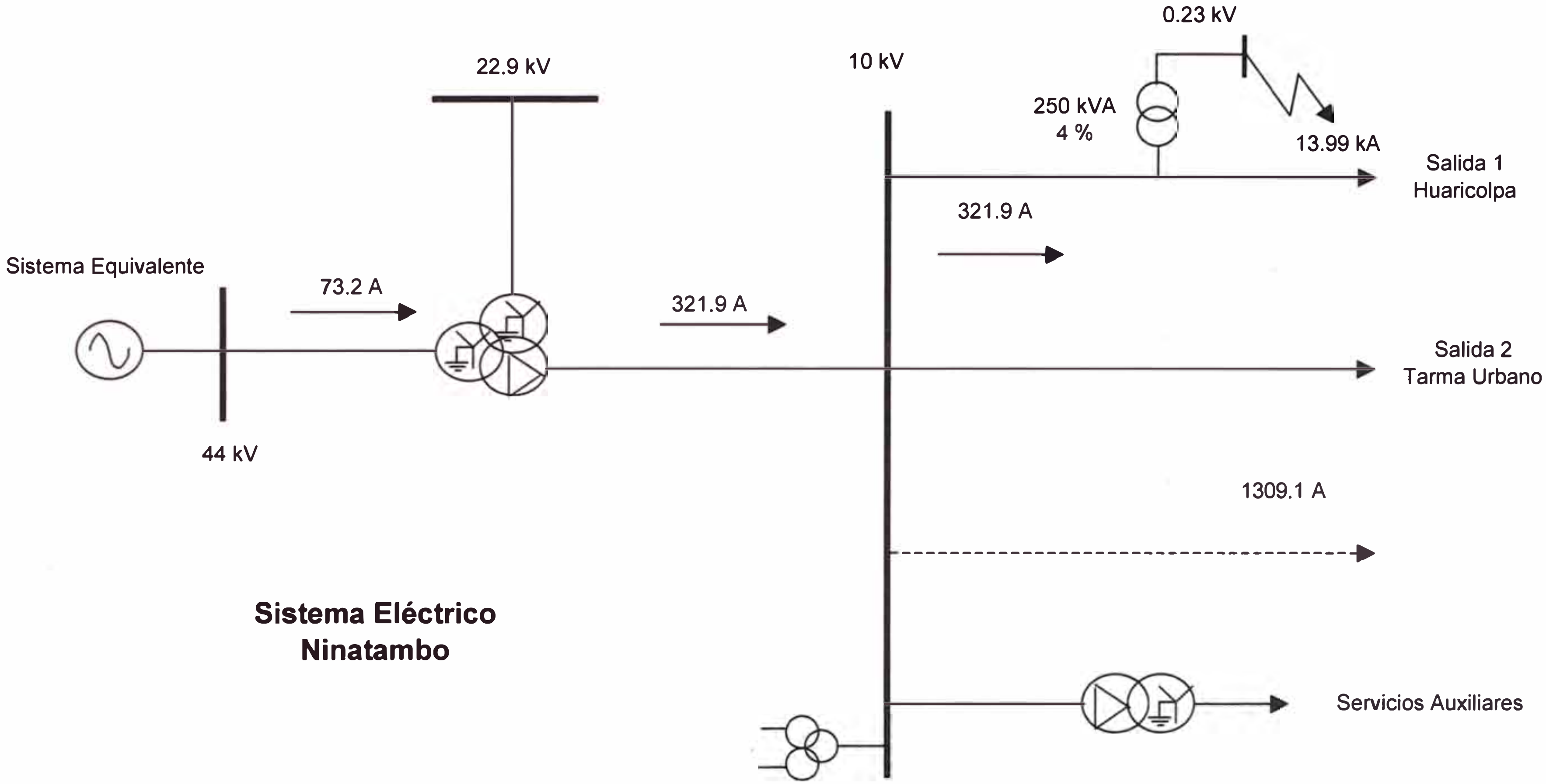


Figura N° A.6 : **Contribucion de corriente de cortocircuito falla entre fases Trafo de distribución 230 V - salida 1**

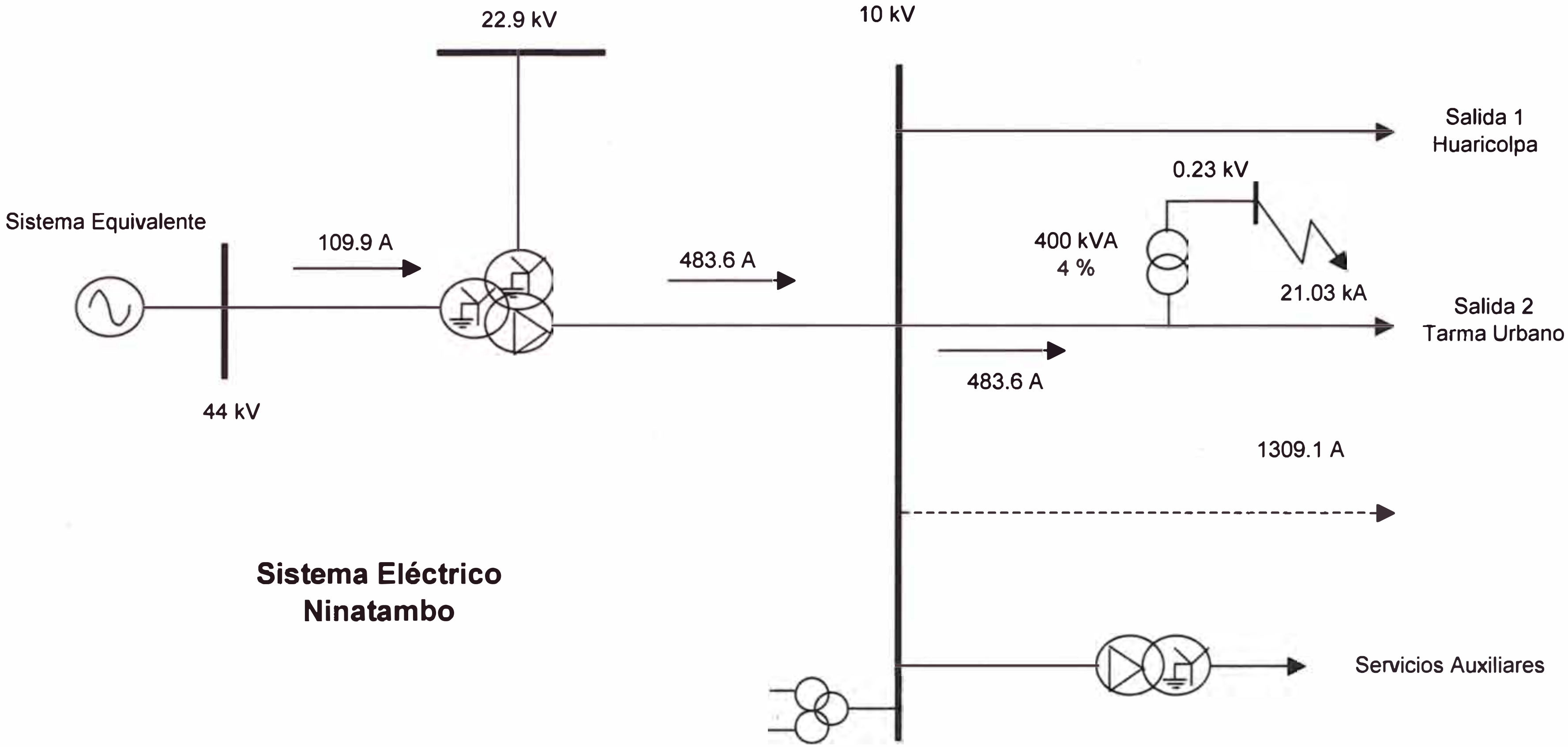
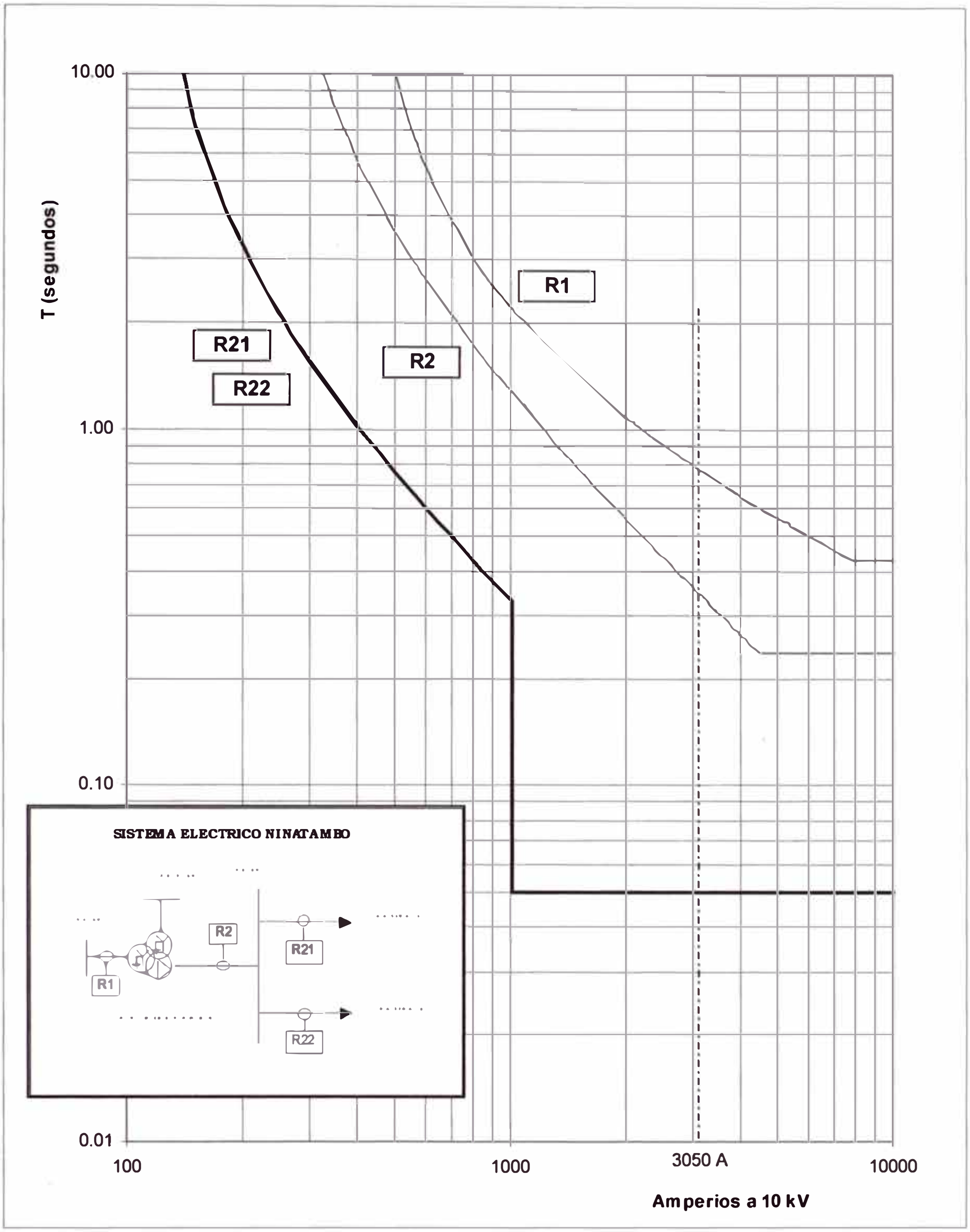


Figura N° A.7 : **Contribucion de corriente de cortocircuito falla entre fases**
Trafo de distribución 230 V - salida 2

COORDINACION DE PROTECCION NIVEL 10 kV
S.E. NINATAMBO 44/22.9/10 kV
SOBRECORRIENTE FASE - FASE



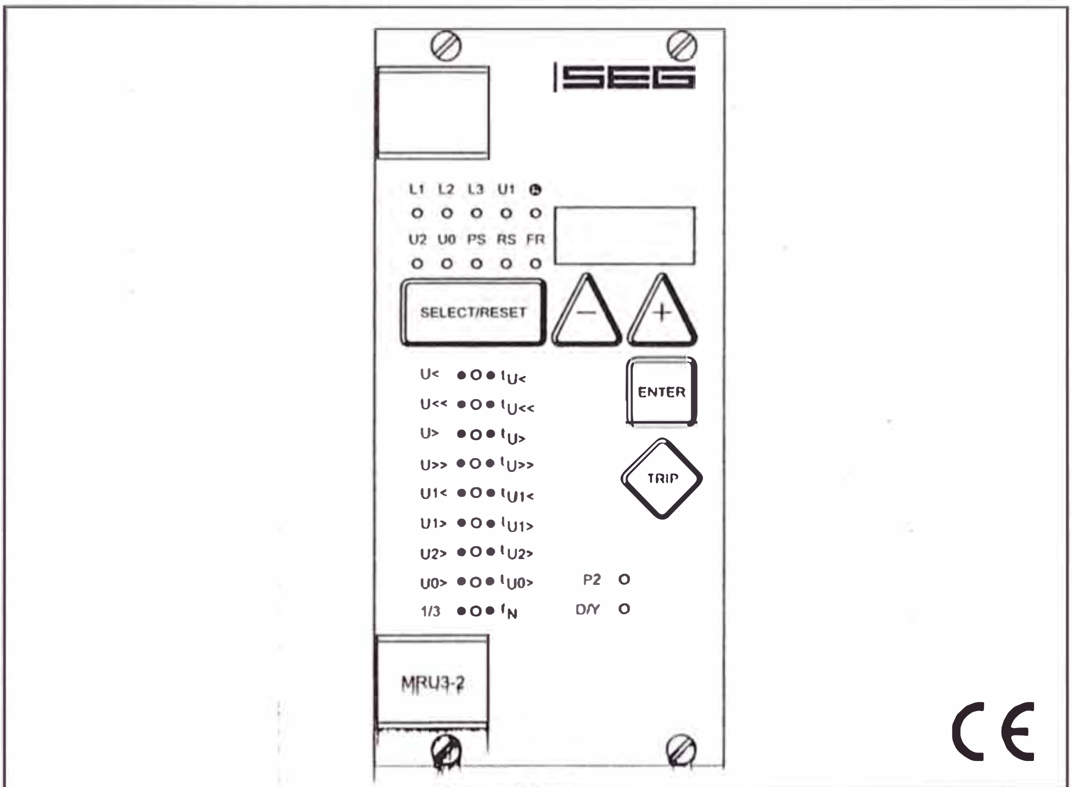
N°	MARCA	MODELO	TENSION (kV)	C.T.	Ioperación (A)	Curva	Ajuste Temporizado		Instantáneo
							TAP	DIAL	TAP
R1	BBC	ICM 2kp	44	150/5	90	Very inverse	3 Amp.	35%	Infinito
R2	SEG	MRI3	10	400/5	224	Very inverse	0.56xIn	0.33 s	Infinito
R21	SEG	MRI3	10	150/5	109.5	Very inverse	0.73xIn	0.2 s	6.7xIn
R22	SEG	MRI3	10	150/5	109.5	Very inverse	0.73xIn	0.2 s	6.7xIn

ANEXO B:

ESPECIFICACIONES TÉCNICAS DEL RELÉ DE SOBRETENSIÓN

HIGH TECH LINE

MRU3-2 - Voltage relay with evaluation of symmetrical components



Contents

1 Introduction and application

The *MRU3-2* is a relay for voltage supervision with universal application, it protects the three-phase network against voltage unbalance or earthfaults in isolated networks. Beside the pure rms value measurement of the line voltage the *MRU3-2* evaluates the symmetrical components (positive-, negative- and zero sequence system). By evaluating these components relay *MRU3-2* can detect the phase sequence, voltage unbalance and earthfaults.

Important:
For additional common data of all *MR*-relays please refer to technical description "*MR* - Digital Multifunctional Relays".

2 Features and characteristics

- Microprocessor technology with watchdog,
- digital filtering of the measured values by using discrete Fourier analysis to suppress higher harmonics and d.c. components induced by faults or system operations,
- analog low pass filter,
- two parameter sets,
- voltage supervision each with two step under-/ and overvoltage detection,
- Voltage supervision for each phase separately
- Completely independent time settings for voltage supervision
- separate tripping elements for over- and undervoltage and positive sequence system
- overvoltage detection in negative- and zero sequence system,
- display of measuring values of the line voltages and system voltages U0, U1 and U2 as rms values (zero-, positive- and negative sequence system)
- alternatively connection and measurement of the phase-to-neutral or phase-to-phase voltage
- display of the phase sequence,
- display of all measuring values and setting parameters for normal operation as well as tripping via a alphanumerical display and LEDs,
- display of measuring values as primary quantities,
- tripping memory for all line voltages and the voltages of the symmetrical components,
- storage and display of tripping values in a fault memory (voltage-failure safe),
- recording of up to eight fault occurences with time stamp
- for blocking the individual functions by the external blocking input, parameters can be set according to requirement,
- suppression of indication after an activation (LED flash),
- free assignment for output relays,
- display of date and time,
- in complience with VDE 0435, part 303 and IEC 255,
- mains frequency is adjustable to 50 Hz or 60 Hz or variable from 40 - 70 Hz,
- RS485 interface for communication with master systems
- serial data exchange via RS485 interface possible; alternatively with SEG RS485 Pro-Open Data Protocol or Modbus Protocol.

3 Design

3.1 Connections

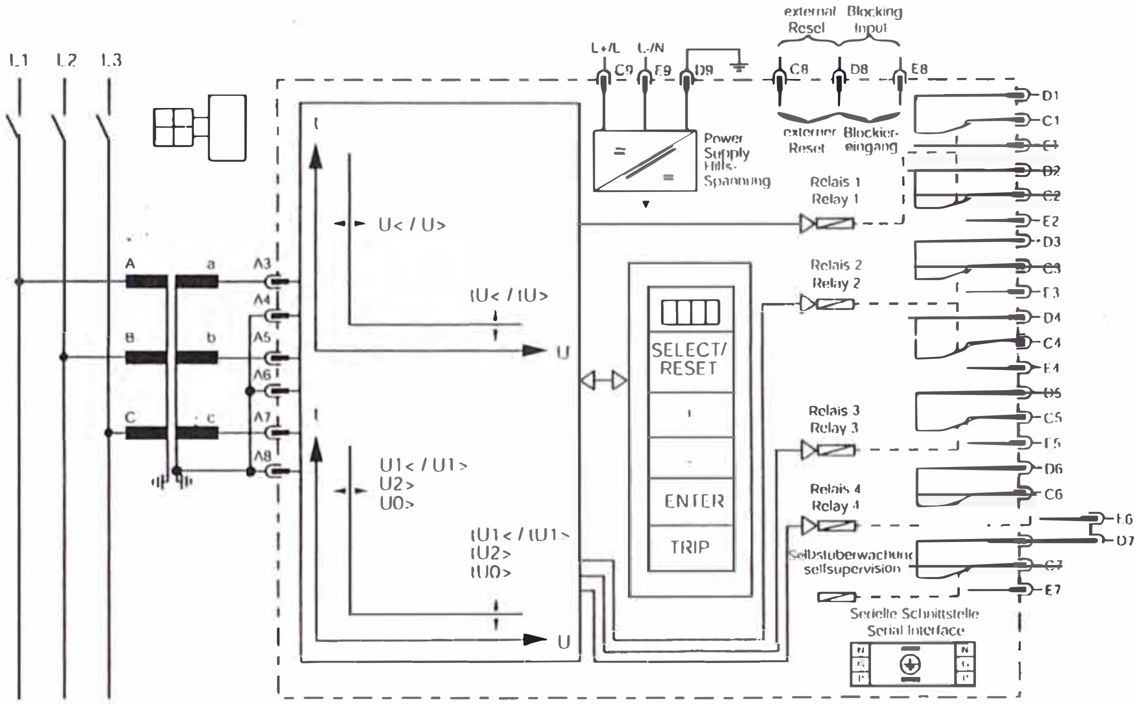


Figure 3.1: Star connection of the voltage transformers

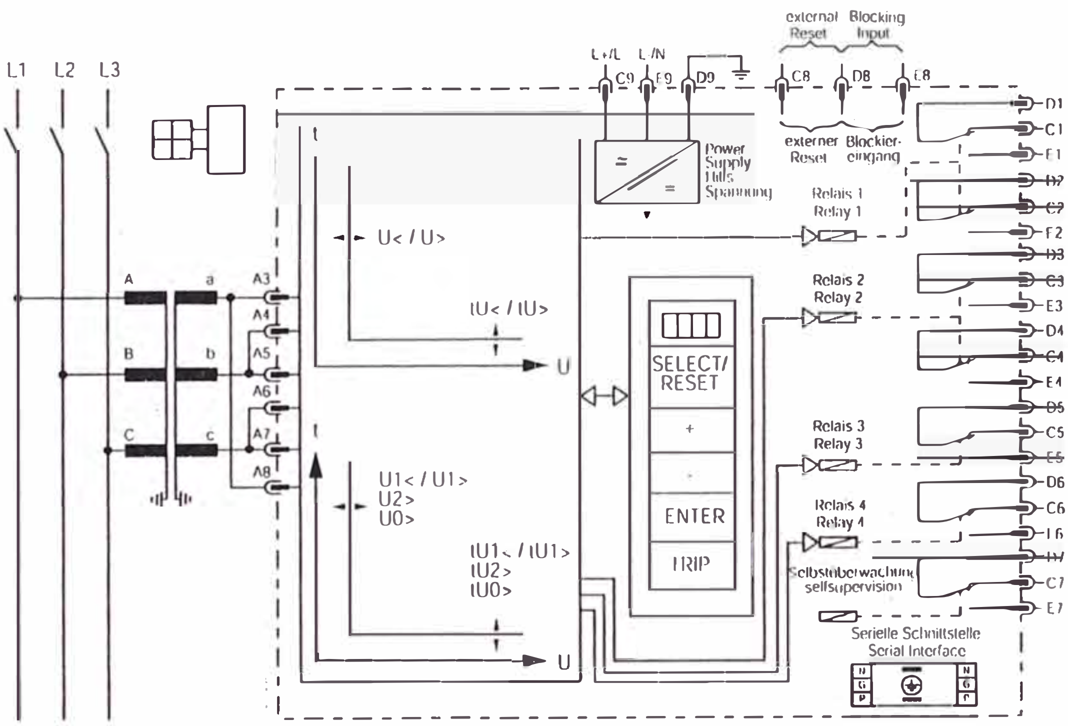


Figure 3.2: Delta connection of the voltage transformers

Attention !
If the input transformers are connected in delta circuit no detection of zero phase sequence (U_0) is possible.

3.1.1 Analog input circuits

The analog input voltages are galvanically decoupled by the input transformers of the device, then filtered and finally fed to the analog digital converter. Depending upon the demands the *MRU3-2* can be connected directly to the mains or via external voltage transformers in star- or delta connection. The priority should be given to the star connection, because of the ability to detect a sero sequence system.

3.1.2 Blocking input

When the voltage, which must be in the admissible range of the auxiliary voltage, is connected to terminals D8/E8, the following tripping functions are blocked undelayed:

- undervoltage U</U<<
- overvoltage U>/U>>
- positive sequence system undervoltage U1<
- positive sequence system overvoltage U1>
- negative sequence system overvoltage U2>
- zero sequence system overvoltage U0>

Blocking can be freely selected via the allocation mode. (refer to chapter 5.9).

Input D8 is the ground (L- or N) for blocking and the external reset. The blocked functions are again released undelayed when the auxiliary voltage is disconnected from the terminals D8/E8.

The above mentioned functions remain blocked for 2 s after the supply voltage had been applied.

3.1.3 External reset input

Refer to chapter 5.9.2

3.1.4 Output relays

The *MRU3-2* is equipped with 5 output relays.

- Relay 1; C1, D1, E1 and C2, D2, E2
- Relay 2; C3, D3, E3 and C4, D4, E4
- Relay 3; C5, D5, E5
- Relay 4; C6, D6, E6
- Relay 5; Signal self-supervision (internal failure of the unit) C7, D7, E7

All trip and alarm relays are working current relays, the relay for self supervision is an idle current relay.

3.1.5 Fault recorder

The *MRU3-2* has a fault value recorder which records the measured analog values as instantaneous values. The instantaneous values

U_{L1}; U_{L2}; U_{L3} for star connection
or U_{12}; U_{23}; U_{31} for delta connection

are scanned at a raster of 1.25 ms (at 50 Hz) and 1.041 ms (at 60 Hz) and saved in a cyclic buffer.

Storage division

Independent of the recording time, the entire storage capacity can be divided into several cases of disturbance with a shorter recording time each. In addition, the deletion behaviour of the fault recorder can be influenced.

No writing over

If 2, 4 or 8 recordings are chosen, the complete memory is divided into the relevant number of partial segments. If this max. number of fault event has been exceeded, the fault recorder block any further recordings in order to prevent that the stored data are written over. After the data have been read and deleted, the recorder to ready again for further action.

Writing over

If 1, 3 or 7 recordings are chosen, the relevant number of partial segments is reserved in the complete memory. If the memory is full, a new recording will always write over the oldest one.

The memory part of the fault recorder is designed as circulating storage. In this example 7 fault records can be stored (written over).

Memory space 6 to 4 is occupied.
Memory space 5 is currently being written in

Figure 3.3: Division of the memory into 8 segments, for example

Since memory spaces 6, 7 and 8 are occupied, this example shows that the memory has been assigned more than eight recordings. This means that No. 6 is the oldest fault recording and No. 4 the most recent one.

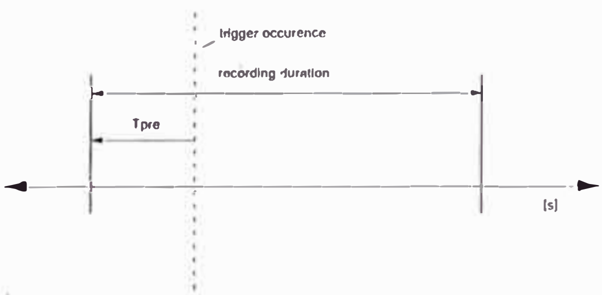


Figure 3.4: Basic set-up of the fault recorder

Each memory segment has a specified storage time which permits setting of a time prior to the trigger event.

3.1.6 Parameter settings

System parameters

Uprim/Usek	Primary/secondary measured value display of the voltage transformers
D/Y	Selection of switching groups
f_N	Rated frequency
LED-Flash	Suppression of LED flashing after activation
P2/FR	Parameter switch/external trigger for the fault recorder

Protection parameters

1/3	1-phase or 3-phase U</U> tripping
U<	Pickup value for undervoltage
$t_{U<}$	Trip value for undervoltage low set element
U<<	Pickup value for undervoltage
$t_{U<<}$	Trip value for undervoltage high set element
U>	Pickup value for overvoltage
$t_{U>}$	Trip value for overvoltage low set element
U>>	Pickup value for overvoltage
$t_{U>>}$	Trip value for overvoltage high set element
U1<	Pick-up value for undervoltage in positive-phase sequence system
$t_{U1<}$	Trip value for undervoltage in positive-phase sequence system
U1>	Pick-up value for overvoltage in positive-phase sequence system
$t_{U1>}$	Trip value for overvoltage in positive-phase sequence system
U2>	Pick-up value for overvoltage in negative-phase sequence system
$t_{U2>}$	Trip value for overvoltage in negative-phase sequence system
U0>	Pick-up value for overvoltage in zero-phase sequence system
$t_{U0>}$	Trip value for overvoltage in zero-phase sequence system

Parameters for the fault recorder

FR	Number of disturbance events
FR	Trigger events
FR	Pre-trigger time T_{vor}

Date and time

Year	Y = 00
Month	M = 04
Day	D = 18
Hour	h = 07
Minute	m = 59
Second	s = 23

Additional functions

Blocking function
Relay configuration
Fault memory

3.2 Display

The display is used for indicating all setting- and measuring values. The actual measuring values as also the fault values can be indicated. In faultless operation the indicated value of the normal operation can be called by pressing the <SELECT> and <ENTER> pushbuttons.

After tripping the display changes into the tripping mode from where fault data can be called.

3.3 LEDs

LEDs L1, L2, L3, U1 and U2 left from the display are two-colored and indicate the measured quantities; green for measuring values and red for fault indication.

LED U0 lights yellow which normally indicates (relay not tripped) that the measuring value of the zero sequence system and in case of tripping the tripping value of the zero sequence system is shown in the display.

The LED marked with the letters RS lights up during setting of the slave address for the serial interface (RS 485) of the unit.

The LED marked with "FR" lights up during parameter setting at the fault recorder. When LED ⏱ lights up, date and time are displayed. LED "PS" indicates the phase sequence.

The 9 LEDs below the <SELECT/RESET> pushbutton signalize the parameter of the individual tripping elements. In case of tripping they indicate, together with the upper LEDs, the respective kind of fault.
A permanent red light indicates tripping. When the tripping delay has not elapsed the LEDs of the corresponding combination (at pickup) are flashing.
If one of the limit values is exceeded for only a short time before the set tripping delay is not expired, the corresponding LED combination flashes. This flashing is shorter than for warning. This pickup warning signal can be switched off with a reset. This activation signal can be shut-down with the "Reset" key (refer to chapter 5.9.2) or suppressed by the FLASH/NO_FLASH function. The active parameter set is indicated by LED "P2". LED D/Y lights up during parameter setting for the interlinking of the input voltage CTs.

3.4 Front plate

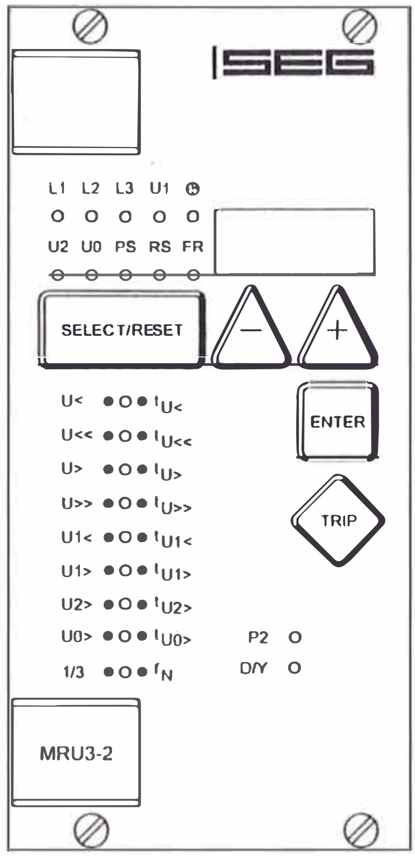


Figure 3.5: Front plate MRU3-2

4 Working principle

4.1 Analog circuits

The input voltages are galvanically insulated by the input transformers. The noise signols caused by inductive and capacitive coupling are supressed by an analog R-C filter circuit.

The analog voltage signals are fed to the A/D-converter of the microprocessor and transformed to digital signals through Sample- and Hold- circuits. The analog signals are sampled with a sampling frequency of 16 x f_N, namely, a sampling rate of 1.25 ms for every measuring quantity, at 50 Hz.

4.2 Digital circuits

The essential part of the *MRU3-2* relay is a powerful microcontroller. All of the operations, from the analog digital conversion to the relay trip decision, are carried out by the microcontroller digitally. The relay program is located in an EPROM (Electrically-Programmable-Read-Only-Memory). With this program the CPU of the microcontroller calculates the three phase voltage in order to detect a possible fault situation in the protected object.

For the calculation of the voltage value an efficient digital filter based on the Fourier Transformation (DFFT - Discrete Fast Fourier Transformation) is applied to suppress high frequency harmonics and d.c. components caused by fault-induced transients or other system disturbances. The microprocessor continuously compares the measured values with the preset thresholds stored in the parameter memory (EEPROM). If a fault occures an alarm is given and after the set tripping delay has elapsed, the corresponding trip relay is activated.

The relay setting values for all parameters are stored in a parameter memory (EEPROM - Electrically Erasable Programmable Read Only Memory), so that the actual relay settings cannot be lost, even if the power supply is interrupted.
The microprocessor is supervised by a built-in "watchdog" timer. In case of a failure the watchdog timer resets the microprocessor and gives an alarm signal via the output relay "self supervision".

4.3 Selection of star or delta connection

All six connections of the input voltage transformers are led to screw terminals. The nominal voltage of the device is equal to the nominal voltage of the input transformers. Dependent on the application the input transformers can be connected in either delta or star. The connection for the phase-to-phase voltage is the delta connection. In star connection the measuring voltage is reduced by $1/\sqrt{3}$. During parameter setting the connection configuration either Y or Δ has to be adjusted.

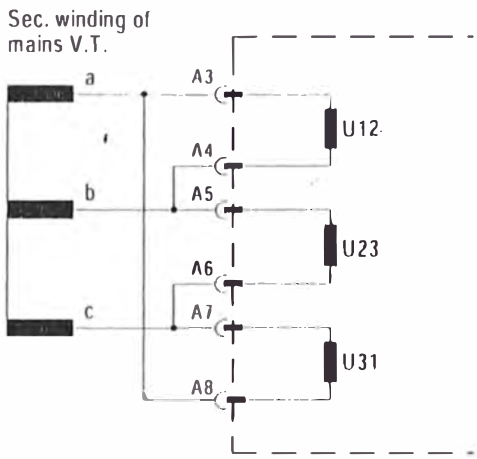


Figure 4.1: Input v.t.s in delta connection (D)

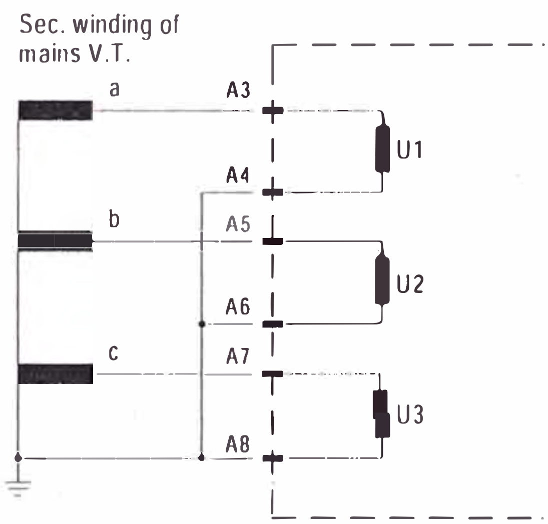


Figure 4.2: Input v.t.s in star connection (Y)

4.4 Voltage supervision

4.4.1 1-phase/3-phase supervision

The voltage relay *MRU3-2* protects electrical generation systems, consumers and appliances in general against over- and/or undervoltage. The relay is equipped with an independent, 2-step over- (U>, U>>) and undervoltage supervision (U<, U<<) with separately adjustable tripping values and delay times. Voltage measuring is 3-phase. In this process there is a continuous comparison of the line conductor voltages in case of a delta connection and of the phase voltages in case of a star connection with the pre-set limit values.

With the *MRU3-2* the highest voltage is always evaluated for overvoltage supervision and the lowest voltage for undervoltage supervision.

A distinction is made between 1-phase and 3-phase tripping. (1/3 – Parameter)

With 1-phase tripping the voltages are evaluated as follows:

U</U<</U</U>>: Activation cum tripping takes place if at least one phase has fallen short of the tripping value.

With 3-phase tripping the voltages are evaluated as follows:

U<: Activation cum tripping takes place if all three phases have fallen short of the tripping value.
U<<: Activation cum tripping takes place if one phase has fallen short of the tripping value.
U>: Activation cum tripping takes place if all three phases have exceeded the tripping value.
U>> Activation cum tripping takes place if one phase has exceeded the tripping value.

4.4.2 Principle of the voltage unbalance protection

The principle of this procedure is to detect faults which effect an asymmetry of the voltage vector.

A single-phase line interruption can for instance cause voltage unbalance in the mains which does not guarantee that the voltage will be zero in the faulty phase. Especially in higher impedance networks the missing phase can partly be rebuilt through running engines or transformers. A pure undervoltage protection cannot detect this condition, however, the rebuilt phase does not coincide with its old position in amount and phase. So an asymmetrical voltage vector system is formed.

In a compensated or isolated grid a single-phase earthfault will hardly cause a significant earth current. Because, however, the faulty phase takes on the earth potential the entire voltage vector system is shifted by the amount of the faulty phase and does not rotate anymore around the initial star point (earth). The relative position of the voltage vectors between each other is hereby not changed. Also this vector system is not symmetrical anymore in relation to the earth potential.

The *MRU3-2* can detect such asymmetry.

4.4.3 Measuring principle

Any rotating three-phase system (original system) can be replaced by three symmetrical systems acc. to the method of the "symmetrical components", a positive sequence system, a negative sequence system and a zero sequence system.

Positive sequence system U1:
The rms value of the positive sequence system represents the component of the original system which is symmetrical and rotates in the positive direction acc. to its definition. A pure symmetrical voltage vector system consists only of its positive sequence system.

The residual voltage in the positive sequence system is calculated by:

$$U1 = \frac{1}{3} \left| \left(\underline{U}_1 + \underline{a}^1 \underline{U}_2 + \underline{a}^2 \underline{U}_3 \right) \right|$$

Negative sequence system U2:
The rms value of the negative sequence system describes the component of the vector system which rotates in negative direction. The rotating field, which rotates in the mathematical sense in the negative direction (so-called "left rotating field"), consists only of a negative sequence system. A measure for the size of the asymmetry of the original system represents the residual voltage in the negative sequence system.

The residual voltage in the negative sequence system is calculated as follows:

$$U2 = \frac{1}{3} \left| \left(\underline{U}_1 + \underline{a}^2 \underline{U}_2 + \underline{a}^1 \underline{U}_3 \right) \right|$$

Zero sequence system U0:
The zero sequence system describes the displacement of the vector star point from the reference star point. This reference star point is generally the earth potential.

The residual voltage in the zero sequence system is calculated as:

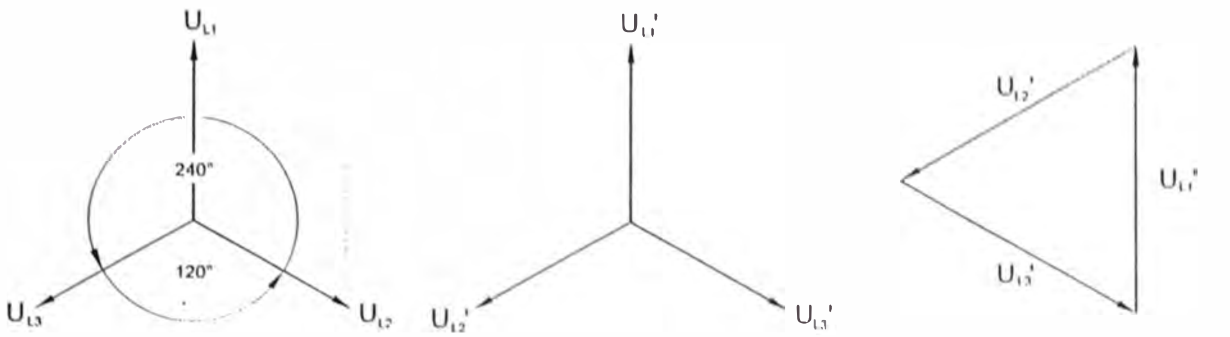
$$U0 = \frac{1}{3} \left| \left(\underline{U}_1 + \underline{U}_2 + \underline{U}_3 \right) \right|$$

Used variables:
(complex vectors are underlined)

$\underline{U}_1$	rms value vector of phase voltage L_1
$\underline{U}_2$	rms value vector of phase voltage L_2
$\underline{U}_3$	rms value vector of phase voltage L_3
U0	rms value of the zero sequence system
U1	rms value of the negative sequence system
U2	rms value of the positive sequence system
$\underline{a}^1$	$= e^{j120°}$ rotation operator for 120°
$\underline{a}^2$	$= e^{j240°}$ rotation operator for 240°

Explanation:
$\underline{a}^2 \underline{U}_2$ means:
Rotate the voltage vector $\underline{U}_2$ by 240° in positive direction (to the left).

4.4.4 Negative sequence system of a symmetrical voltage system



Symmetrical voltage system

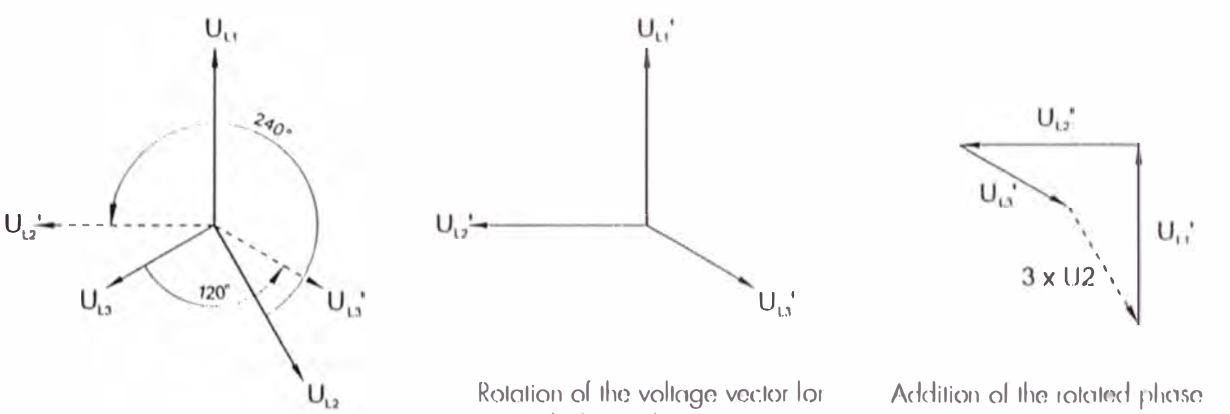
Rotation of the voltage vectors for calculation of the negative phase-sequence system

Addition of the rotated phase vectors to the negative phase-sequence system voltage (U2 = 0)

Figure 4.3: Graphical determination of the negative sequence system in a symmetrical system

Figure 4.3 shows a symmetrical vector system. As indicated in the calculation the *MRU3-2* forms the negative sequence system. For this it rotates per software both voltage vectors U_2 by 240° and U_3 by 120° and adds them. Acc. to definition the result of the vector must be multiplied by 1/3. In this example the sum equals zero. Conclusion: the source system is symmetrical.

4.4.5 System with voltage unbalance



Asymmetrical voltage vector system

Rotation of the voltage vector for calculating the negative phase-sequence system

Addition of the rotated phase vectors to the negative phase-sequence system voltage (U2 > 0)

Figure 4.4: Graphical determination of the negative sequence system in an asymmetrical system

Figure 4.4 shows the voltage vectors of an asymmetrical grid. A residual negative sequence system voltage, which is not zero, is calculated in this example. Should this residual voltage exceed the set treshold, which is indicated as rms value, the relay trips after the preselected time delay.
For the exact rotation of the current vectors by 120° or 240° the system frequency has to be pricisely adjusted.

4.4.6 Zero sequence system

To decide whether a vector system is symmetrically, the point, the symmetry has to refer to, is always to be mentioned. Usually this point is the earth potential.

When an earthfault occurs in an isolated or compensated grid, it does not influence the relative position of the three voltage vectors to each other, mains operation can be maintained. The vector peak of the missing phase is forced on the earth potential. For an observer who takes the earth potential as reference, the star point shifts by the amount of the missing phase. For him the voltage vector system is not anymore symmetrical. The exact measure of the shifting results from replacing this system in symmetrical components in the developed zero sequence system.

Note:

Shall the relay evaluate the zero sequence system it is absolutely necessary that the voltage transformers and the *MRU3-2* are wired in star connection. The star points must be earthed, furthermore the *MRU2-2* must be set to Y-connection. In delta connection no zero sequence system evaluation is possible and thus no earthfault detection.
When only the phase-to-phase voltages are measured, the vector star point is not known, thus also the position of the star point in regard to the earth potential cannot be defined.

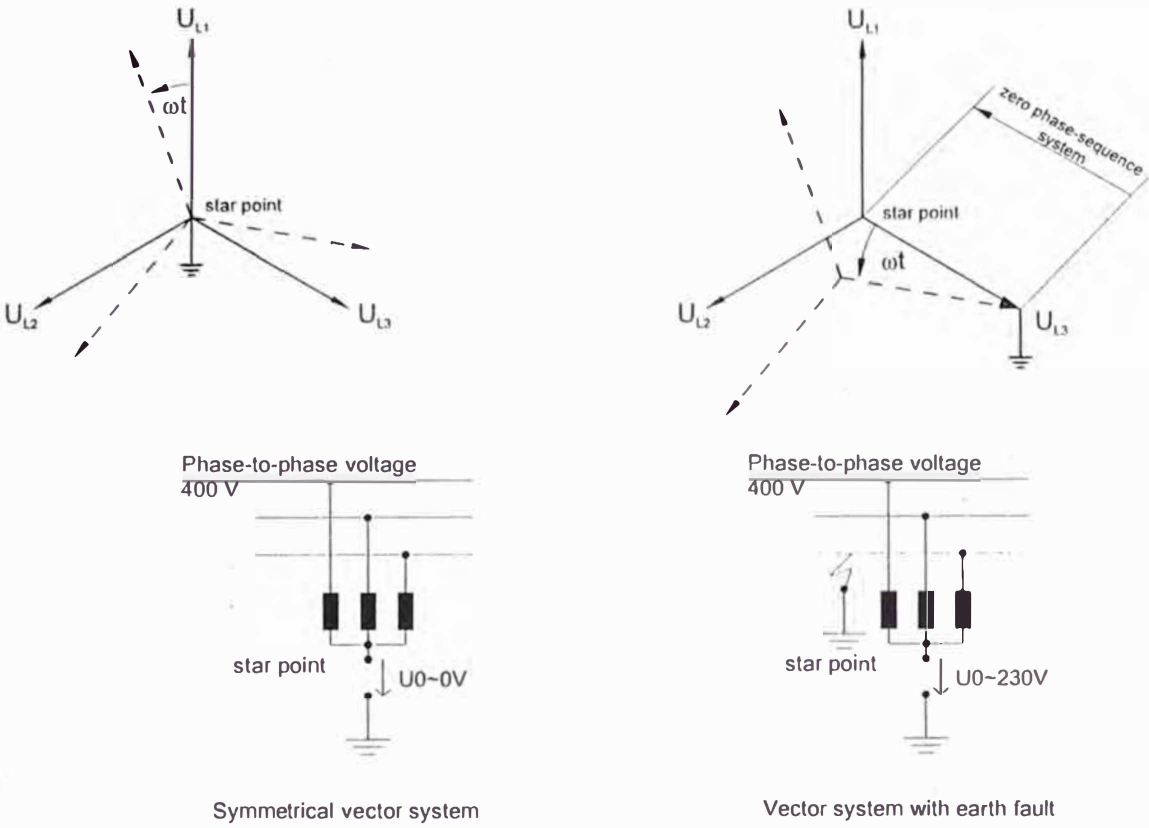


Figure 4.5: Zero point shifting after earthfault in the isolated grid

5 Operations and settings

5.1 Display

Function	Display shows	Pressed pushbutton	Corresponding LED
Normal operation	ISEG		
Measured operating values	Actual measured value	<SELECT/RESET> one time for each value	L1, L2, L3, U1, U2, U0
Phasenfolge	123; 321		PS
Transformer ratio of the CT's	(SEK) 1.01-6500=prim	<SELECT/RESET><+><->	L1, L2, L3
Setting values Star/delta connection	Y/DELT	<SELECT/RESET><+><->	D/Y
Mains frequency	f = 50 Hz, f = 60 Hz v = 50 Hz, v = 60 Hz	<SELECT/RESET><+><->	f_N
Parameter switch/external trigger for the fault recorder	SET1, SET2, B_S2, R_S2, B_FR, R_FR, S2_FR	<SELECT/RESET><+><->	P2
Switch-over LED flash No LED flash	FLSH NOFL	<SELECT/RESET><+><->	
U</U> 1-phase/3-phase tripping	U<>1/U<>3	<SELECT/RESET><+><->	1/3
undervoltage (low set) tripping delay of low set element	Setting value in volt Setting value in seconds	<SELECT/RESET><+><-> one time for each value	U< $t_{U<}$
undervoltage (high set) tripping delay of high set element	Setting value in volt Setting value in seconds	<SELECT/RESET><+><-> one time for each value	U<< $t_{U<<}$
overvoltage (low set) tripping delay of low set element	Setting value in volt Setting value in seconds	<SELECT/RESET><+><-> one time for each value	U> $t_{U>}$
overvoltage (high set) tripping delay of high set element	Setting value in volt Setting value in seconds	<SELECT/RESET><+><-> one time for each value	U>> $t_{U>>}$
positive-phase sequence system undervoltage U1<; trip delay $t_{U1<}$	Setting value in volt Setting value in seconds	<SELECT/RESET><+><-> one time for each value	U1< $t_{U1<}$
positive-phase sequence system overvoltage U1>; trip delay $t_{U1>}$	Setting value in volt Setting value in seconds	<SELECT/RESET><+><-> one time for each value	U1> $t_{U1>}$
negative-phase sequence system overvoltage U2>; trip delay $t_{U2>}$	Setting value in volt Setting value in seconds	<SELECT/RESET><+><-> one time for each value	U2> $t_{U2>}$
zero-phase sequence system U0> trip delay $t_{U0>}$	Setting value in volt Setting value in seconds	<SELECT/RESET><+><-> one time for each value	U0> $t_{U0>}$
Function blocking	EXIT	<+> until max. setting <-> until min. setting	LED of blocked parameter
Slave adresse of serial interface	1 - 32	<SELECT/RESET><+><->	RS
Baud-Rate [1]	1200-9600	<SELECT/RESET><+><->	RS
Parity-Check [1]	even odd no	<SELECT/RESET><+><->	RS
Recorded fault data: Star-connection: L1, L2, L3 Symmetrical components: U1, U2, U0	Tripping values in volt	<SELECT/RESET><+><-> one time for each phase	L1, L2, L3; U1, U2, U0, U<, U<<, U>, U>>, U1<, U1>, U2>, U0>
Delta-connection: L1/L2, L2/L3, L3/L1 symmetrical components: U1, U2	Tripping values in volt	<SELECT/RESET><+><-> one time for each phase	L1, L2, L3, U1, U2, U<, U<<, U>, U>>, U1<, U1>, U2>
Save parameter?	SAV?	<ENTER>	
Save parameter!	SAV!	<ENTER> for about 3 s	
Delete failure memory	wait	<-> <SELECT/RESET>	
Enquiry failure memory	FLT1 ; FLT2.....	<-><+>	L1, L2, L3 U<, U<<, U>, U>>
Trigger signal for the fault recorder	TEST, P_UP, A_PI, TRIP	<SELECT/RESET> <+><->	FR

[1] only Modbus

Function	Display shows	Pressed pushbutton	Corresponding LED
Number of fault occurences	S = 2, S = 4, S = 8	<SELECT/RESET> <+><->	FR
Display of date and time	Y = 99, M = 10, D = 1, h = 12, m = 2, s = 12	<SELECT/RESET> <+><->	◷
Software version	First part (e. g. D02-) Second part (e. g. 6.01)	<TRIP> one time for each part	
Manual trip	TRI?	<TRIP> three times	
Inquire password	PSW?	<SELECT/RESET>/ <+>/<->/<ENTER>	
Relay tripped	TRIP	<TRIP> or fault tripping	
Secret password input	XXXX	<SELECT/RESET>/ <+>/<->/<ENTER>	
System reset	ISEG	<SELECT/RESET> for about 3 s	

Table 5.1: Possible indication messages on the display

5.2 Setting procedure

In this paragraph the settings for all relay parameters are described in detail. For parameter setting a password has to be entered first (please refer to 4.4 of description "*MR*-Digital Multifunctional Relays").

5.3 System parameter

5.3.1 Display of residual voltage U_E as primary quantity (U_{prim}/U_{sec})

The residual voltage can be shown as primary measuring value. For this parameter the transformation ratio of the VT has to be set accordingly. If the parameter is set to "sec", the measuring value is shown as rated secondary voltage.

Example:
The voltage transformer used is of 10 kV/100 V. The transformation ratio is 100 and this value has to be set accordingly. If still the rated secondary voltage should be shown, the parameter is to be set to 1.

5.3.2 D/Y – Switch - over

Depending on the mains voltage conditions, the input voltage transformers can be operated in delta or Y connection. Change-overs are effected via the <+> and the <-> keys and stored with <ENTER>.

5.3.3 Setting of nominal voltage

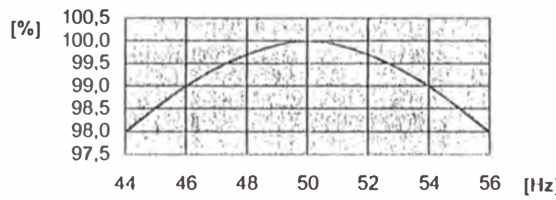
For proper functioning it is necessary to first adjust the rated frequency (50 oder 60 Hz).

It can be selected between „f = 50 Hz", „f = 60 Hz" or „v = 50 Hz", "v = 60 Hz".

The difference lies in the method of voltage measuring. With the setting "v = 50 Hz" or "v = 60 Hz" voltage measuring is independent of the existing frequency. This means, the voltage value can be correctly measured between 40 Hz and 70 Hz without adverse effects from the frequency.

With the setting "f" = 50/60 Hz the measured voltage value is influenced by the frequency. (see Table 5.2)

Declination of measuring value at 50Hz



Declination of measuring value at 60Hz

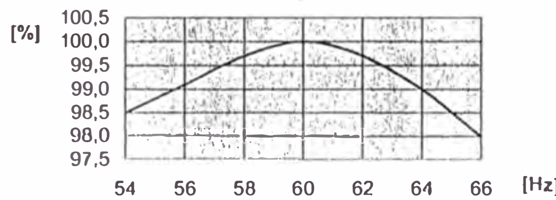


Table 5.2: Impairment of voltage measuring

This difference in settings is required for the fault recorder. If the fault recorder is to be used, the setting must be f = 50 Hz or f = 60 Hz.
At 50 Hz or 60 Hz the fault recorder determines 16 measured values per period. With the setting "v = 50 Hz" or "v = 60 Hz" 16 measured values of the presently measured frequency would always be determined. The disturbance recorder would not indicate any frequency changes and thus render incorrect measuring results.

Setting	v = 50	f = 50	v = 60	f = 60
Rated frequency	50 Hz	50 Hz	60 Hz	60 Hz
Influence on voltage measurement	none	0,5..1%/Hz (refer to table 5.1)	none	0,5..1%/Hz (refer to table 5.1)
Fault recorder	Recording distorted**	Recording correct**	Recording distorted**	Recording correct**
Influence on all other functions	none	none	none	none

Table 5.3: Deviation of measured value at 50 Hz or 60 Hz

* Setting is important for correct recording of fault recorder
** Sample rate is variably adjusted to the momentarily measured frequency. 16 samples are always measured in one period.
*** Sample rate setting is fixed to 50 Hz or 60 Hz. 16 samples per 20 ms or 16.67 ms are always measured.

5.3.4 Display of the activation storage

If after an activation the existing current drops again below the pickup value, e.g. U<, without a trip has been initiated, LED U< signals that an activation has occured by flashing fast. The LED keeps flashing until it is reset again (push button <RESET>). Flashing can be suppressed when the parameter is set to NOFL.

5.3.5 Parameter set change-over switch/external trigger for the fault recorder

By means of the parameter-change-over switches it is possible to activate two different parameter sets. Switching over of the parameter sets can either be done by means of software or via the external inputs RESET or blocking input. Alternatively, the external inputs can be used for Reset or blocking of the triggering of the fault recorder.

Software-parameter	Blocking input used as	RESET input used as
SET1	Blocking input	RESET input
SET2	Blocking input	RESET input
B_S2	Parameter switch	RESET input
R_S2	Blocking input	Parameter switch
B_FR	Externe Triggerung des Störschreibers	Reset input
R_FR	Blocking input	External triggering for the fault recorder
S2_FR	Parameter switch	External triggering for the fault recorder

With the settings SET1 or SET2 the parameter set is activated by software. Terminals C8/D8 and D8/E8 are then available as external reset input or blocking input.

With the setting B_S2 the blocking input (D8, E8) is used as parameter-set change-over switch. With the setting R_S2 the reset input (D8, E8) is used as parameter-set change-over switch. With the setting B_FR the fault recorder is activated immediately by using the blocking input. On the front plate the LED FR will then light up for the duration of the recording. With the setting R_FR the fault recorder is activated via the reset input.

With the setting S2_FR parameter set 2 can be activated via the blocking input and/or the fault recorder via the reset input.
The relevant function is then activated by applying the auxiliary voltage to one of the external inputs.

Important note:
When functioning as parameter change over facility, the external input RESET is not available for resetting. When using the external input BLOCKING the protection functions must be deactivated by software blocking separately (refer to chapter 5.9.1).

5.4 Protection parameters

5.4.1 1-phase or 3-phase U</U>-tripping

Switching-over of the parameter permits selection between 1-phase and 3-phase tripping of the U</U> steps.
Keys <+> or <-> are used to change the value and <ENTER> to store it.

Note
When the *MRU3-2* is to be used for measuring the residual voltage in systems with isolated or compensated neutral or as generator earth fault protection, the measuring voltage has to be applied to terminals A3-A4. Undervoltage functions U< and U<< have to be set to "EXIT" and overvoltage functions U> and U>> have to be adjusted to the required pickup values. The frequency must be set to 50 or 60 Hz. The parameter 1-phase or 3-phase tripping mut be set to U<>1 (1-phase tripping).

5.4.2 Parameter setting of over- and undervoltage supervision

The setting procedure is guided by two coloured LEDs. During setting of the voltage thresholds the LEDs U<, U<<, U> and U>> are lit green. During setting of the trip delays $t_{U>}$, $t_{U>>}$, $t_{U<}$ and $t_{U<<}$ the according LEDs light up red.

Thresholds of the voltage supervision

During setting of the threshold U>, U>>, U< and U<< the displays shows the voltages directly in volt. The thresholds can be changed by the <+> <-> push buttons and stored with <ENTER>.

The undervoltage supervision (U< and U<<) as well as the overvoltage supervision (U> and U>>) can be deactivated by setting the threshold to "EXIT".

Tripping delay of voltage supervision

During setting of the tripping delays $t_{U<}$, $t_{U<<}$, $t_{U>}$ and $t_{U>>}$ the display shows the value directly in seconds. The tripping delay is changed via the push button <+> and <-> in the range of 0,04 s to 50 s and can be stored with the push button <ENTER>.
When setting the tripping delay to "EXIT" the value is infinit meaning only warning, no tripping.

5.4.3 Positive sequence system voltage (U1<, U1>)

Rms values and tripping delays can be set in the similar manner as described for the normal under-/over voltage settings. Both elements can be blocked or set as alarm stages.

5.4.4 Negative sequence system overvoltage (U2>)

This parameter determines the treshold for the rms value of the negative sequence system. As described in 5.4.2, the entire stage can be blocked or set as alarm element.

5.4.5 Zero sequence system overvoltage (U0>)

The treshold for the rms value of the zero sequence system can be set with this parameter. Also here it is possible, as described in chapter 5.4.2, to block the entire element or to set it only as alarm element.

5.4.6 Adjustment of the slave address

By pressing push buttons <+> and <-> the slave address can be set in the range of 1 - 32. During this adjustment the LED RS lights up.

5.4.7 Setting of Baud-rate (applies for Modbus-Protocol only)

Different transmission rates (Baud rate) can be set for data transmission via Modbus Protocol.
The rate can be changed by push buttons <+> and <-> and saved by pressing <ENTER>.

5.4.8 Setting of parity (applies for Modbus-Protocol only)

The following three parity settings are possible :

- "even" = even
- "odd" = odd
- "no" = no parity check

The setting can be changed by push buttons <+> and <-> and saved by pressing <ENTER>.

5.5 Parameter for the fault recorder

5.5.1 Adjustment of the fault recorder

The *MRU3-2* is equipped with a fault recorder (refer to chapter 3.1.5). Three parameters can be determined.

5.5.2 Number of the fault recordings

The max. recording time is 16 s at 50 Hz or 13.33 s at 60 Hz.
The number of max. recordings requested has to be determined in advance. There is a choice of (1)* 2, (3)* 4 or (7)* 8 recordings and dependent on this the duration of the individual fault recordings is defined, i.e.

(1)* 2 recordings for a duration of 8 s (with 50 Hz) (6.66 s with 60 Hz)
(3)* 4 recordings for a duration of 4 s (with 50 Hz) (3.33 s with 60 Hz)
(7)* 8 recordings for a duration of 2 s (with 50 Hz) (1.66 s with 60 Hz)
* is written over when a new trigger signal arrives

Caution:
If the fault recorder is used, the frequency should be set to f = 50 Hz or f = 60 Hz (refer to chapter 5.3.3).

5.5.3 Adjustment of trigger occurences

There is a choice between four different occurences:

P_UP (PickUP)	Storage is initiated after recognition of a general activation.
TRIP	Storage is initiated after a trip has occured.
A_PI (After Pickup)	Storage is initiated after the last activation threshold was fallen short of.
TEST	Storing is activated by simultaneous actuation of the keys <+> and <->. During the recording time the display shows "Test".

5.5.4 Pre-trigger time (Tvor)

By the time T_{pre} it is determined which period of time prior to the trigger occurence should be stored as well. It is possible to adjust a time between 0.05s and the max. recording interval (2, 4 and 8s at 50 Hz and 1.33; 3.33 and 6.66 s at 60 Hz). With keys <+> and <-> the values can be changed and with <ENTER> be saved.

5.6 Date and time

5.6.1 Adjustment of the clock

When adjusting the date and time, LED ⏲ lights up. The adjustment method is as follows:

Date :	Year	Y=00
	Month	M=01
	Day	D=01
Time :	Hour	h=00
	Minute	m=00
	Second	s=00

The clock starts with the set date and time as soon as the supply voltage is switched on. The time is safe-guarded against short-term voltage failures (min. 6 minutes).

Note:
The window for parameter setting is located behind the measured value display. The parameter window can be accessed via the <SELECT/RESET> key.

5.7 Indication of measuring values

5.7.1 Measuring indication

In normal operation the following measuring values can be displayed.

- Voltages (LED L1, L2, L3 green)
- In star connection all phase-to-neutral voltages
- In delta connection all phase-to-phase voltages
- Phase sequence (LED PS yellow)

5.7.2 Unit of the measuring values displayed

The measuring values can optionally be shown in the display as a multiple of the "sek" rated value (x In) or as primary current (A). According to this the units of the display change as follows:

Indication as	Range	Unit
Sec. voltage	000V - 999V	V
Primary voltage	.00V – 999V 1k00 – 9k99 10k0 – 99k0 100k – 999k 1M00 – 3M00	V kV kV kV MV

Table 5.4: Units of the display

5.7.3 Indication in faultless condition

In normal operation the display always shows |SEG. After pressing the pushbutton <SELECT/RESET> the display switches cyclically to the next value. After the measuring values had been indicated the setting parameters are displayed. Hereby the LEDs in the upper section signalize which measured value is indicated, the LEDs in the lower section signalize which setting parameter is indicated on the display. Longer actuating the pushbutton resets the relay and the display changes into normal operation (|SEG).

5.7.4 Indication after pickup / tripping

In tripped condition "TRIP" appears on the display and the LEDs of the operating measuring data light up red together with the LEDs of the tripping parameter (U0: yellow). All operating data, which were measured at the moment of tripping, can now be called one after another by pressing pushbutton <SELECT/RESET>. (refer to chapter 5.8). By pressing the <-> key, the fault memory can be retrieved. If in this condition setting parameters are to be indicated, pushbutton <ENTER> has to be pressed.

The graphic below shows again the difference between the different display modes.

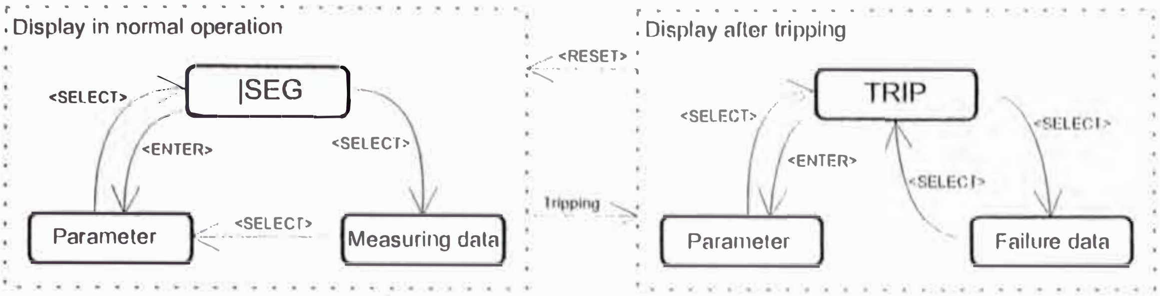


Figure 1.1: Switching over of the display in dependence of the operating mode.

5.7.5 Indication of the phase sequence

The indication refers to the designation of the voltage input terminals. The sequence can be "123" or "321". Which phase sequence is the correct one depends upon the given case of application. But in any case the assignment has to be met which phase sequence shall correspond to the positive sequence system.

Display "123" means that the connected rotating field has the positive sequence system of unit *MRU3-2* and thus is considered as correct. If these voltages are additionally symmetrical, there will be no negative sequence system and the positive sequence system has the same rms value as the phase voltages.

If the phase sequence "321" is indicated the assignment could be wrong. This has to be checked whether the applied voltages show a wrong phase sequence or whether there is a fault in the connection. When "???" is indicated the unit signalizes that no clear measurement of the phase sequence is possible.

5.8 Fault memory

When the relay is energized or is energized or trips, all fault data and times are stored in a non-volatile memory manner. The *MRU3-2* is provided with a fault value recorder for max. five fault occurrences. In the event of additional trippings always the oldest data set is written over.

For fault indication not only the trip values are recorded but also the status of LEDs. Fault values are indicated when push buttons <-> or <+> are pressed during normal measuring value indication.

- Normal measuring values are selected by pressing the <SELECT/RESET> button.
- When then the <-> button is pressed, the latest fault data set is shown. By repeated pressing the <-> button the last but one fault data set is shown etc. For indication of fault data sets abbreviations FLT1, FLT2, FLT3, ... are displayed (FLT1 means the latest fault data set recorded). At the same time the parameter set active at the occurence is shown.
- By pressing <SELECT/RESET> the fault measuring values can be scrolled.
- By pressing <+> it can be scrolled back to a more recent fault data set. At first FLT8, FLT7, ... are always displayed.When fault recording is indicated (FLT1 etc), the LEDs flash in compliance with the stored trip information, i.e. those LEDs which showed a continuous light when the fault occured are now blinking blinking to indicate that it is not a current fault. LEDs which were blinking blinking during trip conditions, (element had picked up) just briefly flash.
- If the relay is still in trip condition and not yet reset (TRIP is still displayed), no measuring values can be shown.
- To delete the trip store, the push button combination <SELECT/RESET> and <->, has to be pressed for about 3s. The display shows "wait".

Recorded fault data:

Measuring	Displayed values	Correspon-ding LED
Voltage	L1; L2; L3; star L1/L2; L2/L3; L3/L1: delta	L1; L2; L3
Time stamp Date:	Y = 99 M = 03 D = 10	◷ ◷ ◷
Time:	h = 17 m = 21 s = 14	◷ ◷ ◷
Symmetrical components	Voltage: positive-phase sequence ; negative-phase sequence; zero-phase sequence	U1; U2; U0
Phase sequence	123: positive sequence; 132: negative sequence	PS

5.9 Additional functions

5.9.1 Setting procedure for blocking the protection functions

The blocking function of the *MRU3-2* can be set according to requirement. By applying the aux. voltage to D8/E8, the functions chosen by the user are blocked. Setting of the parameter should be done as follows:

- When pressing push buttons <ENTER> and <TRIP> at the same time, message "BLOC" is displayed (i.e. the respective function is blocked) or "NO_B" (i.e. the respective function is not blocked). The LED allocated to the first protection function U< lights red.
- By pressing push buttons <+> <-> the value displayed can be changed.
- The changed value is stored by pressing <ENTER> and entering the password.
- By pressing the <SELECT/RESET> push button, any further protection function which can be blocked is displayed.
- Thereafter the menu is left by pressing <SELECT/RESET> again.
- If the <SELECT/RESET> key is actuated again, the blocking menu is left and the assignment mode is accessed^.

Function	Description	Display	LED
U<	Undervoltage step 1	BLOC	green
U<<	Undervoltage step 2	BLOC	green
U>	Overvoltage step 1	NO_B	green
U>>	Overvoltage step 2	NO_B	green
U1<	Undervoltage step in positive-phase sequence system	BLOC	green
U1>	Overvoltage step in positive-phase sequence system	BLOC	green
U2>	Overvoltage step in negative-phase sequence system	BLOC	green
U0>	Overvoltage step in zero-phase sequence system	BLOC	green

Table 5.5: Blocking function for two parameter sets

Assignment of the output relays:

Unit *MRU3-2* has five output relays. The fifth output relay is provided as permanent alarm relay for self supervision is normally on. Output relays 1 - 4 are normally off and can be assigned as alarm or tripping relays to the voltage functions which can either be done by using the push buttons on the front plate or via serial interface RS485.

The assignment of the output relays is similar to the setting of parameters, however, only in the assignment mode. The assignment mode can be reached only via the blocking mode.
By pressing push button <SELECT/RESET> in blocking mode again, the assignment mode is selected.
The relays are assigned as follows: LEDs U<, U<<, U>, U>>, U1>, U1<, U2> and U0>are two-coloured and light up green when the output relays are assigned as alarm relays and $t_{U<}$, $t_{U<<}$, $t_{U>}$, $t_{U>>}$, $t_{U1<}$, $t_{U1>}$, $t_{U2>}$, and $t_{U0>}$ red as tripping relays.

Definition:
Alarm relays are activated at pickup.
Tripping relays are only activated after elapse of the tripping delay.

After the assignment mode has been activated, first LED U< lights up green. Now one or several of the four output relays can be assigned to under voltage element U< as alarm relays. At the same time the selected alarm relays for under voltage element 1 are indicated on the display. Indication "1_ _ _" means that output relay 1 is assigned to this under voltage element. When the display shows "_ _ _ _", no alarm relay is assigned to this under voltage element. The assignment of output relays 1 - 4 to the current elements can be changed by pressing <+> and <-> push buttons. The selected assignment can be stored by pressing push button <ENTER> and subsequent input of the password. By pressing push button <SELECT/RESET>, LED U< lights up red. The output relays can now be assigned to this voltage element as tripping relays.

Relays 1 - 4 are selected in the same way as described before. By repeatedly pressing of the <SELECT/RESET> push button and assignment of the relays all elements can be assigned separately to the relays. The assignment mode can be terminated at any time by pressing the <SELECT/RESET> push button for some time (abt. 3 s).

Note:

- The function of jumper J2 described in general description "MR Digital Multifunctional Relays" does not apply for *MRU3-2*. For relays without assignment mode this jumper is used for parameter setting of alarm relays (activation at pickup or tripping).

A form is attached to this description where the setting requested by the customer can be filled-in. This form is prepared for telefax transmission and can be used for your own reference as well as for telephone queries.

5.9.2 Reset

All relays have the following three possibilities to reset the display of the unit as well as the output relay at jumper position J3=ON.

Manual Reset
- Pressing the push button <SELECT/RESET> for some time (about 3 s)

Electrical Reset
- Through applying auxiliary voltage to C8/D8

Software Reset
- The software reset has the same effect as the <SELECT/RESET> push button (see also communication protocol of RS485 interface)

The display can only be reset when the pickup is not present anymore (otherwise "TRIP" remains in display).

During resetting of the display the parameters are not affected.

5.9.3 Erasure of fault storage

To delete the trip store, the push button combination <SELECT/RESET> and <->, has to be pressed for about 3s. The display shows "wait".

Relay function		Output relays				Display- Indication	Corres- ponding LED
		1	2	3	4		
U< tU<	Alarm Tripping	X				_ _ _ _ 1 _ _ _	U<; green tU< red
U<< tU<<	Alarm Tripping	X				_ _ _ _ 1 _ _ _	U<< green tU<< red
U> tU>	Alarm Tripping	X				_ _ _ _ 1 _ _ _	U> green tU> red
U>> tU>>	Alarm Tripping	X				_ _ _ _ 1 _ _ _	U>> green tU>> red
U1< tU1<	Alarm Tripping		X			_ _ _ _ _ 2 _ _	U1< green tU1< red
U1> tU1>	Alarm Tripping		X			_ _ _ _ _ 2 _ _	U1> green tU1> red
U2> tU2>	Alarm Tripping			X		_ _ _ _ _ _ 3 _	U2> green tU2> red
U0> tU0>	Alarm Tripping				X	_ _ _ _ _ _ _ 4	U0> green tU0> red

Table 5.4: Example of assignment matrix of the output relay (defaults settings)

6 Relay testing and commissioning

The following test instructions should help to verify the protection relay performance before or during commissioning of the protection system. To avoid a relay damage and to ensure a correct relay operation, be sure that:

- The auxiliary power supply rating corresponds to the auxiliary voltage on site.
- The rated frequency and rated voltage of the relay correspond to the plant data on site.
- The voltage transformer circuits are connected to the relay correctly.
- All signal circuits and output relay circuits are connected correctly.

6.1 Power-On

NOTE!
Prior to switch on the auxiliary power supply, be sure that the auxiliary supply voltage corresponds to the rated data on the type plate.

Switch on the auxiliary power supply to the relay and check that the message "ISEG" appears on the display and the self supervision alarm relay (watchdog) is energized (Contact terminals D7 and E7 closed).
It may happen that the relay is tripped because of under- voltage condition after power-on. (The message "TRIP" on the display and LED L1, L2, L3 and U< light up red). An undervoltage condition has been detected after power-on, because no input voltages are applied to the relay. In this case:

- Press the push button <ENTER>, thus entering into the setting mode. Now set the parameters U< and U<< to "EXIT" to block the undervoltage functions. After that, press the <SELECT/RESET> for app. 3 s to reset the LEDs and "TRIP" message.
- The undervoltage tripping after power on can also be eliminated by applying three phase rated voltages after power-on and reset the LED and "TRIP" message.
- Apply auxiliary voltage to the external blocking input (Terminals E8/D8) to inhibit the undervoltage functions (refer to 6.5) and press the <SELECT/RESET> for app. 3 s to reset the LEDs and "TRIP" message.

Refer to chapter 5.9.1

6.2 Testing the output relays

NOTE!
Prior to commencing this test, interrupt the trip circuit to the circuit breaker if tripping is not desired.

By pressing the push button <TRIP> once, the display shows the first part of the software version of the relay (e.g. „D08-"). By pressing the push button <TRIP> twice, the display shows the second part of the software version of the relay (e.g. „4.01". The software version should be quoted in all correspondence. Pressing the <TRIP> button once more, the display shows "PSW?". Please enter the correct password to proceed with the test. The message "TRI?" will follow. Confirm this message by pressing the push button <TRIP> again. All output relays should then be activated and the self supervision alarm relay (watchdog) be deenergized one after another with a time interval of 1 second. Thereafter, reset all output relays back to their normal positions by pressing the push button <SELECT/RESET>.

6.3 Checking the set values

By repeatedly pressing the push button <SELECT>, all relay set values may be checked. Set value modification can be done with the push button <+><-> and <ENTER>. For detailed information about that, please refer to chapter 4.3 of the description "MR – Digital multifunctional relays".
As relay input energizing quantities, three phase voltages should be applied to *MRU3-2* relay input circuits. Depending on the system conditions and the voltage transformer used, three voltages can be connected to the relay input circuits with either star or delta connection. In case of a star connection the phase-to-neutral voltage will be applied to the voltage input circuits, while the phase-to-phase voltages will be connected to the voltage input circuits in case of a delta connection. The voltage input connection must be set as a parameter, and should correspond with the actual voltage input connection:

Star connection:	Phase-to-neutral voltages will be measured and evaluated.
Delta connection:	Phase-to-phase voltages will be measured and evaluated.

NOTE!
For *MRU3-2* relay used for earth fault protection be sure that the frequency set value (f=50/60) has been selected correctly according to your system frequency (50 or 60 Hz).
This also applies when using the disturbance recorder (refer to Chapter 5.3.3).

6.4 Secondary injection test

6.4.1 Test equipment

- Voltmeter with class 1 or better
- Auxiliary power supply with the voltage corresponding to the rated data on the type plate
- Three-phase voltage supply unit with frequency regulation (Voltage: adjustable from 0 to ≥ 2 x U_N)
- Timer to measure the operating time (Accuracy class ±10 ms)
- Switching device
- Test leads and tools

6.4.1 Example of the test circuit

For testing of the *MRU3-2* relay, a three phase voltage source is required. Figure 6.1 shows an example of a three-phase test circuit energizing the *MRU3-2* relay during test. The three phase voltages are applied to the relay in Y-connection.

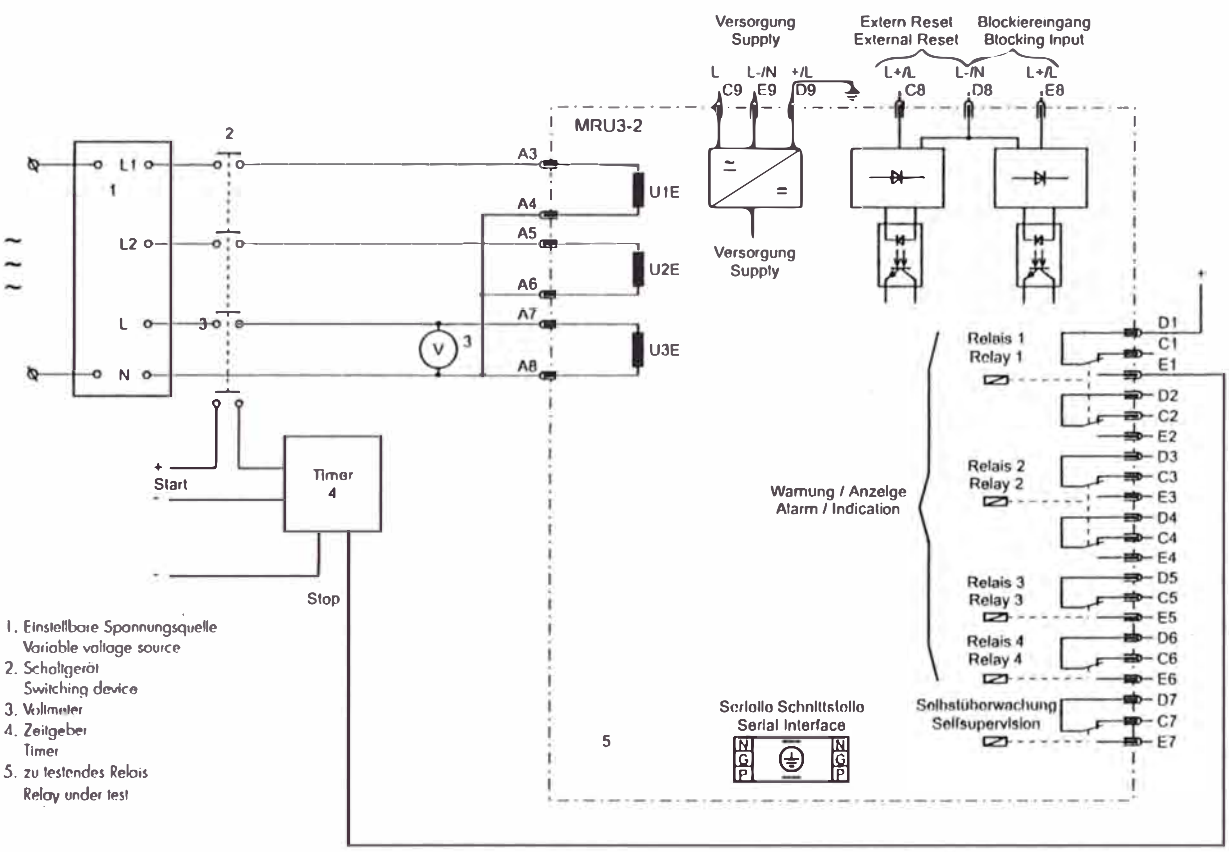


Figure 6.1: 3-phase test circuit

6.4.2 Checking the input circuits and measuring functions

Apply three voltages of rated value to the voltage input circuits (terminals A3 - A8) of the relay. Check the measured voltages, frequency and vector surge on the display by pressing the push button <SELECT/RESET> repeatedly.

The voltages are indicated on the display in volts, at Y-connection:
- Phase-to-neutral voltages: LED L1, L2, L3

Delta-connection:
- Phase-to-phase voltages: LED L1+L2, L2+L3, L3+L1

Change the voltages around the rated value and check the measured voltages on the display.

Compare the voltage displayed with the reading at voltmeter. The deviation for the voltage must not exceed 1%.

By using an RMS-metering instrument, a greater deviation may be observed if the test voltages contains harmonics. Because the *MRU1* relay measures only the fundamental component of the input signals, the harmonics will be rejected by the internal DFFT-digital filter. Whereas the RMS-metering instrument measures the RMS-value of the input signals.

6.4.3 Test of the symmetrical components values

The following tests describe basically the indicating values and voltages of the symmetrical components with which the measuring functions of the *MRU3-2* can be tested. If simultaneously the tripping function is to be tested, the corresponding parameter must be set between the rated voltage and the theoretical value accept to the table.

Symmetrical measuring voltage system
For this test the relay has to be correctly connected with all of the three phases and the star point. If the measuring voltage system is symmetrical, the unit should indicate the following measuring values:

measuring value	indication
L1, L2, L3	U_N
U1	$\approx U_N$
U2	≈ 0
U0	≈ 0

Table 6.1: Indication at normal rotating field (symmetrical)

The deviation must not exceed some Volts. Exact data cannot be given here because this depends upon the actual symmetry of the test voltage system. By an exactly symmetrical system the data must be precisely within the tolerance of the unit. Also a deviation of the mains frequency from the set frequency can lead to errors in the measurements. In this case it is better to set the system frequency to "v = 50 Hz" or "v = 60 Hz".

Wrong phase sequence
For this test two phases must be reversed to the *MRU3-2*. The third phase and the star point N are connected as usual. The theoretical indicating values are:

measuring value	indication
L1, L2, L3	U_N
U1	≈ 0
U2	$\approx U_N$
U0	≈ 0

Table 6.2: Indication during simulated left rotating field

Phase failure
The *MRU3-2* is now to be connected with the two phases L2 and L3 and with the neutral conductor. The two phases must be assigned correctly. The measuring input of phase L1 is connected with the star point of the relay in order to prevent interference voltages at the input. (This simulation is realistic because in a real case of failure other relays in parallel or the voltage transformer itself would cause this "pull down" effect).

The test can basically be carried out with any phase. The result of the measurement differs only in the indicating values for the phase voltages L1-L3.

Measuring value	indication
L1	0
L2, L3	U_N
U1	$\approx 2/3 \times U_N$
U2	$\approx 1/3 \times U_N$
U0	$\approx 1/3 \times U_N$

Table 6.3: Indication at phase failure

Earthfault

For this test all conductors L1-L3 have to be correctly connected. The star point N from the mains is not connected. Instead the star point of the *MRU3-2* is connected with phase L1. This type of connection simulates an earthfault of phase L1.

Measuring value	Indication
L1	0
L2, L3	$\sqrt{3} \times U_N$
U1	$\approx U_N$
U2	≈ 0
U0	$\approx U_N$

Table 6.4: Indication at earthfault

6.4.4 Checking the operating and resetting values of the over/undervoltage functions

Apply three voltages with the rated value and gradually increase (decrease) the voltages until the relay starts, i.e. at the moment when the LED U> (or U<) lights up or the voltage alarm output relay (contact terminals D4/E4) is activated. Read the operating voltage indicated by the voltmeter. The deviation must not exceed 1% of the set operating value.

Furthermore, gradually decrease (increase) the voltages until the relay resets, i.e. the voltage alarm output relay is disengaged. Check that the dropout to pickup ratio is greater than 0.97 (for overvoltage function) or smaller than 1.03 (for undervoltage).

6.4.5 Checking the relay operating time of the over/undervoltage functions

To check the relay's operating time, a timer must be connected to the trip outpnut relay contact (Contact terminals D1/E1).
It must be ensured that the respective output relay is assigned to the function to be tested. (refer to chapter 5.9.1).
The timer should be started simultaneously with the voltage change from sound condition to a faulty condition and stopped by the trip relay contact. The operating time measured by timer should have a deviation about 3% of the set value or < 20 ms.

6.4.6 Checking the external blocking and reset functions

The external blocking input blocks the selected voltage functions.

Care must be taken that these terminals are also assigned the blocking function (refer to chapter 5.9.1). The external blocking input inhibits undervoltage functions. To test the blocking function apply auxiliary supply voltage to the external blocking input of the relay (terminals E8/D8). Inject a test voltage which could cause tripping for the functions above mentioned. Observe that there is no trip and alarm.

Remove the auxiliary supply voltage from the blocking input. Apply test voltages to trip the relay (message „TRIP" on the display). Return the test voltages to the sound condition and apply auxiliary supply voltage to the external reset input of the relay (terminals C8/D8). The display and LED indications should be reset immediately.

6.5 Primary test

Generally, a primary injection test could be carried out in the similar manner as the secondary injection test described above. With the difference that the protected power system should be, in this case, connected to the installed relays under test „on line", and the test voltages should be injected to the relay through the voltage transformers with the primary side energized. Since the cost and potential hazards are very high for such a test, primary injection tests are usually limited to very important protective relays in the power system.

Because of its powerful combined indicating and measuring functions, the *MRU3* relay may be tested in the manner of a primary injection test without extra expenditure and time consumption.

In actual service, for example, the measured voltage values on the *MRU3-2* relay display may be compared phase by phase with the concerned indications of the instruments of the switchboard to verify that the relay works and measures correctly.

6.6 Maintenance

Maintenance testing is generally done on site at regular intervals. These intervals vary among users depending on many factors: e.g. the type of protective relays employed; the importance of the primary equipment being protected; the user's post experience with the relay, etc.

For electromechanical or static relays, maintenance testing will be performed at least once a year according to the experiences. For digital relays like *MRU3-2*, this interval can be substantially longer. This is because:

- the *MR*- relays are equipped with very wide self-supervision functions, so that many faults in the relay can be detected and signalised during service. Important: The self-supervision output relay must be connected to a central alarm panel!
- the combined measuring functions of *MR*-relays enable supervision the relay functions during service.
- the combined TRIP test function of the *MR*-relay allows to test the relay output circuits.

A testing interval of two years for maintenance will, therefore, be recommended.
During a maintenance test, the relay functions including the operating values and relay tripping times should be tested.

7 Technical Data

7.1 Measuring input circuits

Rated data:	Nominal voltage U_N	100 V, 230 V, 400 V
	Nominal frequency f_N	40 - 70 Hz
Power consumption in voltage circuit:	< 1 VA per phase at U_N	
Thermal withstand in voltage circuit:	continuously	$2 \times U_N$

7.2 Common data

Dropout to pickup ratio:	U>/U>> : >98%	U</U<< : < 102%
Dropout time:	40 ms	
Time lag error class index E:	±10 ms	
Minimum operating time:	40 ms	
Max. allowed interruption of the auxiliarxy supply without effecting the function of the device:	50 ms	
Weight:	approx. 1.5 kg	
Mounting position:	any	
Influences:		
Frequency influence on voltage measuring circuit:	$0.9\ f_N < f < 1.1\ f_N$, ≤ 2 % / Hz bei 50/60 Hz	
Voltage influence on frequency measuring circuit:	$0.5\ U_N < U < 1.5\ U_N$, no influence	
Temperature influence:	-20 °C ... 70 °C, < 1 %	
Auxiliary voltage influence:	no influence within the admissible range	
GL-Approbation:	98776-96l-lH	
Bureau Veritas Approbation:	2650 6807 A00 H	

7.3 Setting ranges and steps

Function	Parameter	Setting range	Step	Pickup tolerance
Transformer ratio	U_{prim}/U_{sek}	(sek) 1.01...6500	0.01; 0.02; 0.05; 0.1; 0.2; 0.5; 1.0; 2.0; 5.0; 10; 20; 50	
Switch group	D/Y	D = DELT/Y = Y		
Rated frequency	f_N	f = 50 / f = 60 / v = 50 / v = 60		
LED blinking at pick-up		FLSH/NOFL		
Parameter switch/ext. Triggering for the fault recorder	P2|2	SET1/SET2/B_S2/R_S2/B_FR/R_FR/S2FR		
1/3-phase tripping	1/3	U<>1; U<>3		
U<	U<; U<< U1< $t_{U<}$; $t_{U<<}$; $t_{U1<}$	U_N = 100 V: 2...200 V (EXIT) U_N = 230 V: 2...460 V (EXIT) U_N = 400 V: 4...800 V (EXIT) 0.04...50 s (EXIT)	 1 V 1 V 2 V 0.01; 0.02; 0.05; 0.1; 0.2; 0.5; 1.0; 2.0 s	 ±1% of set value or <0,3% U_N ±1% oder ±15 ms
U>	U>, U>>, U1>, $t_{U>}$, $t_{U>>}$, $t_{U1>}$	U_N = 100 V: 2...200 V (EXIT) U_N = 230 V: 2...460 V (EXIT) U_N = 400 V: 4...800 V (EXIT) 0,04...50 s (EXIT)	 1 V 1 V 2 V 0.01; 0.02; 0.05; 0.1; 0.2; 0.5; 1.0; 2.0 s	 ±1% of set value or <0.3% U_N ±1% or ±15 ms
U>	 $U_{2>}$, $U_{0>}$ $t_{U2>}$, $t_{U0>}$	U_N = 100 V: 2...100 V (EXIT) U_N = 230 V: 2...230 V (EXIT) U_N = 400 V: 4...400 V (EXIT) 0.04...50 s (EXIT)	 1 V 1 V 2 V 0.01; 0.02; 0.05; 0.1; 0.2; 0.5; 1.0; 2.0 s	 ±1% of set value or <0,3% U_N ±1% or ±15 ms

7.3.1 Interface parameter

Function	Parameter	Modbus-Protocol	RS485 Open Data Protocol
RS	Slave-Adresse	1 - 32	1 - 32
RS	Baud-Rate*	1200, 2400, 4800, 9600	9600 (fixed)
RS	Parity*	even, odd, no	„even Parity" (fixed)

* only Modbus Protocol

7.3.2 Parameter for the fault recorder

Function	Parameter	Adjustment example
FR	Number of recordings	(1)* 2 x 8 s; (3)* 4 x 4 s; (7)* 8 x 2 s (50 Hz) (1)* 2 x 6.66 s, (3)* 4 x 6.66 s, (7)* 8 x 1.66 s (60 Hz)
FR	Savings of the recording at the occurence	P_UP; TRIP; A_PI; TEST
FR	Pre-trigger-time	0.05 s – 8.00 s

* is written over when a new trigger signal arrives

7.4 Output relays

	Trip relays/change-over contacts	Alarm relaya/change-over contacts
MRU3	2/2	3/1

8 Order form

Mains decoupling relay	**MRU3-**				
Standard		**1**			
incl. measuring of the positive phase-sequence, negative phase-sequence and zero phase-sequence system component		**2**			
Rated voltage	100 V		**1**		
	230 V		**2**		
	400 V		**4**		
Housing (12TE)	19"- rack			**A**	
	Flash mounting			**D**	
RS 485	Alternatively with Modbus protocol				**-M**

Technical data subject to change without notice!

Setting list *MRU3-2*

Project: ______________________ SEG-Job.-No.: ______________________

Function group: =__________ Location: +__________ Relay code: -______________________

Relay functions: ______________________ Password: ______________________

Date: ______________________

All settings must be checked at site and should the occasion arise, adjusted to the object/item to be protected.

Setting of the parameters

System parameter

Function		Einheit	Default settings	Actual settings
U_{prim}/U_{sek}	Voltage transformer ratio		sek	
D/Y	Input voltage correction dependent on the connection of the input transformer		DELT	
f_N	Rated frequency	Hz	f = 50 Hz	
LED Flash	LED – Display of the activation storage		FLSH	
P2/FR	Parameter switch/ext. triggering for the fault recorder		SET1	

Protection parameter

Function		Unit	Default setting Set 1/Set 2	Actual setting Set 1/Set 2
1/3	1-phase/3-phase tripping		U<>1	
U<	Pickup value for undervoltage element	V	90/210/360*	
$t_{U<}$	Tripping delay for undervoltage element	s	0.04	
U<<	Pickup value for undervoltage element	V	80/190/320*	
t_U<<	Tripping delay for undervoltage element	s	0.04	
U>	Pickup value for overvoltage element	V	110/250/440*	
t_U>	Tripping delay for overvoltage element	s	0.04	
U>>	Pickup value for overvoltage element	V	120/270/480*	
$t_{U>>}$	Tripping delay for overvoltage element	s	0.04	
U1<	Pickup value for undervoltage in positive-phase sequence system	V	90/210/360*	
$t_{U1<}$	Trip value for undervoltage in positive-phase sequence system	s	0.04	
U1>	Pickup value for overvoltage in positive-phase sequence system	V	110/250/440*	
$t_{U1>}$	Trip value for overvoltage in positive-phase sequence system	s	0,04	
U2>	Pickup value for overvoltage in negative-phase sequence system	V	50/115/200*	
$t_{U2>}$	Trip value for overvoltage in negative-phase sequence system	s	0.04	
U0>	Pickup value for overvoltage in zero-phase sequence system	V	30/70/120*	
$t_{U0>}$	Trip value for overvoltage in zero.phase sequence system	s	0.04	
RS	Slave address of the serial interface		1	
RS**	Baud-Rate		9600	
RS**	Parity-Check		even	

* thresholds dependent on rated voltage 100 V / 230 V / 400 V **only Modbus

Fault recorder

Function		Unit	Default setting	Actual setting
FR	Number of recordings		4	
FR	Saving of the recording at the occurrence		TRIP	
FR	Time prior to trigger impulse	s	0,05	
Uhr	Year setting	year	Y=00	
Uhr	Month setting	month	M=01	
Uhr	Day setting	day	D=01	
Uhr	Setting of the hour	hour	h=00	
Uhr	Setting of the minute	minute	m=00	
Uhr	Setting of the second	second	s=00	

Blocking function

	Default setting				Actuala setting			
	Blocking		Not blocking		Blocking		Not blocking	
Parameter set	Set 1	Set 2	Set 1	Set 2	Set 1	Set 2	Set 1	Set 2
U<	X	X						
U<<	X	X						
U>			X	X				
U>>			X	X				
U1<	X	X						
U1>	X	X						
U2>	X	X						
U0>	X	X						

Assignment of the output relays

Funktion	Relay 1		Relay 2		Relay 3		Relay 4	
	Default settings	Actual settings	Default settings	Actual settings	Default settings	Actual settings	Default settings	Actual settings
U< alarm								
$t_{U<}$ tripping	X							
U<< alarm								
$t_{U<<}$ tripping	X							
U> alarm								
$t_{U>}$ tripping	X							
U>> alarm								
$t_{U>>}$ tripping	X							
U1< alarm								
$t_{U1<}$ tripping			X					
$U_{1>}$ alarm								
$t_{U1>}$ tripping			X					
$U_{2>}$ alarm								
$t_{U2>}$ tripping					X			
$U_{0>}$ alarm								
$t_{U0>}$ tripping							X	

Setting of code jumbers

Code jumper	J1		J2		J3	
	Default settings	Actual settings	Default settings	Actual settings	Default settings	Actual settings
Plugged						
Not plugged	X		No function		X	

Code jumper	Low/High-range for reset input		Low/High-range for blockage input	
	Default settings	Actual settings	Werkseinstellung	Eigene Einstellung
Low=plugged	X		X	
High=not plugged				

This technical manual is valid for
For software-Version number: D06-7.01 (*MRU3-1*)
D07-8.01 (*MRU3-2*)

Modbus-version number: D56-1.01 (*MRU3-1-M*)
D57-1.01 (*MRU3-2-M*)

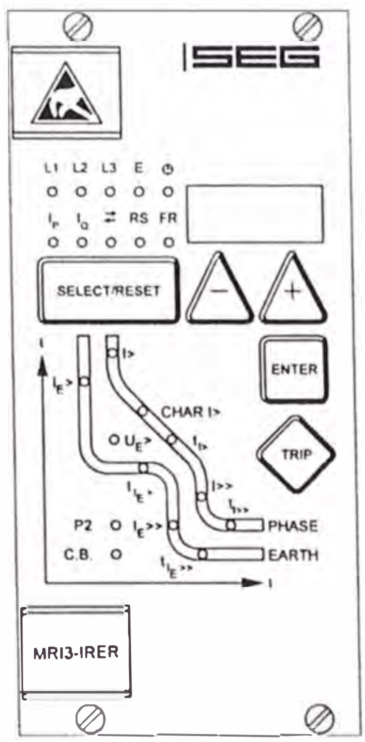
Schaltanlagen-Elektronik-Geräte GmbH & Co. KG
Abteilung Gerätevertrieb / Electronic Devices Sales Department
Krefelder Weg 47 · D - 47906 Kempen (Germany)
Postfach 10 07 55 (P.O.B.) · D - 47884 Kempen (Germany)
Tel.: +49 (0)21 52 1 45-1 · Fax.: +49 (0)21 52 1 45-3 54
e-mail: electronics@avkseg.com

ANEXO C:

ESPECIFICACIONES TÉCNICAS

DE LOS RELÉS DE SOBRECORRIENTE

MRI3 - Digital multifunctional relay for overcurrent protection



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Contents

1 Introduction and application

The *MRI3* digital multifunctional relay is a universal time overcurrent and earth fault protection device intended for use in medium-voltage systems, either with an isolated/compensated neutral point or for networks with a solidly earthed/resistance-earthed neutral point.

The protective functions of *MRI3* which are implemented in only one device are summarized as follows:

- Independent (Definite) time overcurrent relay,
- inverse time overcurrent relay with selectable characteristics,
- integrated determination of fault direction for application to doubly infeeded lines or meshed systems,
- two-element (low and high set) earth fault protection with definite or inverse time characteristics,
- integrated determinotion of earth fault direction for application to power system networks with isolated or arc suppressing coil (Peterson coil) neutral earthing. (ER/XR-relay type),
- integrated determination of earth short-circuit fault direction in systems with solidly-earthed neutrol point or in resistance-earthed systems (SR-relay type).

Furthermore, the relay *MRI3* can be employed as a back-up protection for distance and differential protective relays.

A similar, but simplified version of overcurrent relay *IRI1* with reduced functions without display and serial interface is also available.

Important:
For additional common data of all *MR*-relays please refer to manual "*MR* - Digital Multifunctional relays". On page 51 of this manual you can find the valid software versions.

2 Features and characteristics

- Digital filtering of the measured values by using discrete Fourier analysis to suppress the high frequence harmonics and DC components induced by faults or system operations,
- two parameter sets,
- selectable protective functions between:
  definite time overcurrent relay and
  inverse time overcurrent relay,
- selectable inverse time characteristics according to IEC 255-4:
  Normal Inverse (Type A)
  Very Inverse (Type B)
  Extremely Inverse (Type C)
  Special characteristics,
- reset setting for inverse time characteristics selectable,
- high set overcurrent unit with instantaneous or definite time function,
- two-element (low and high set) overcurrent relay both for phase and earth faults,
- directional feature for application to the doubly infeeded lines or meshed systems,
- earth fault directional feature selectable for either isoloted or compensated networks,
- sensitive earth fault current measuring with or without directional feature (X and XR-relay type),
- determinotion of earth short-circuit fault direction for systems with solidly-earthed or resistance-earthed neutral point,
- numerical display of setting values, actual mea-sured values and their active, reactive components, memorized foult data, etc.,
- display of measuring values as primary quantities,
- withdrawable modules with automatic short circuiters of C.T. inputs when modules are withdrawn,
- blocking e.g. of high set element (e.g. for selective fault detection through minor overcurrent protection units after unsuccessful AR),
- relay characteristic angle for phase current directionol feature selectable,
- circuit breaker foilure protection,
- storage of trip values and switching-off time (t_{CBFP}) of 5 fault occurences (fail-safe of voltage),
- recording of up to eight fault occurences with time stamp,
- free assignment of output relays
- serial data exchange via RS485 interface possible; alternatively with SEG RS485 Pro-Open Data Protocol or Modbus Protocol,
- suppression of indication after an activation (LED flash),
- display of date and time

Voltage measuring for the directional detection:

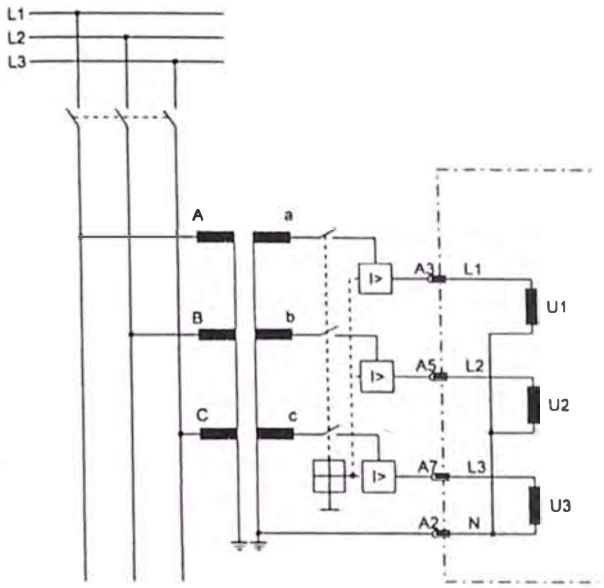


Figure 3.4: *Measuring of the phase voltages for the directional detection at overcurrent, short-circuit or earth-fault protection (I>, I>>, I_E, and $I_{E>>}$).*

For details on the connection of ER/XR-unit type c.t.s, see para 4.5.

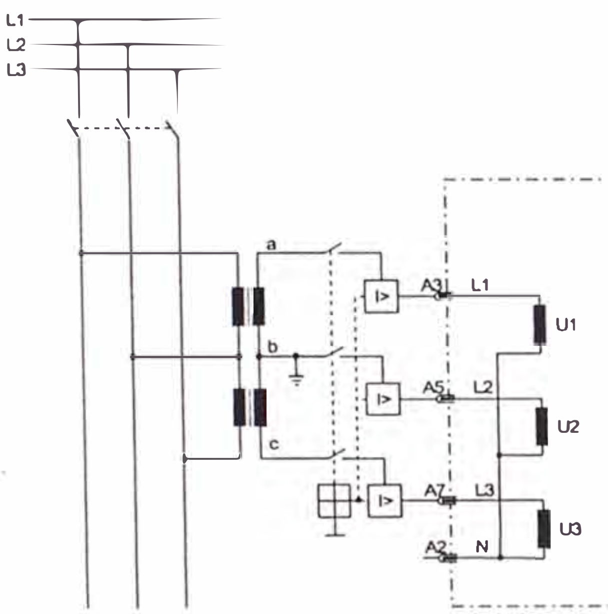


Figure 3.5: *Voltage transformer in V-connection for the directional detection at overcurrent and short-circuit protection.*

The V-connection can not be applied at earth fault directional feature.

3.1.1 Analog input circuits

The protection unit receives the analog input signals of the phase currents IL1 (B3-B4), IL2 (B5-B6), IL3 B7-B8) and the current IE (B1-B2), phase voltages U1 (A3), U2 (A5), U3 (A7) with A2 as star point, each via separate input transformers.

The constantly detected current measuring values are galvanically decoupled, filtered and finally fed to the analog/digital converter.
For the unit type with earthfault directional features (ER/XR-relay type) the residual voltage U_E in the secondary circuit of the voltage transformers is internally formed.
In case no directional feature for the phase current path is necessary the residual voltage from the open delta winding can directly be connected to A3 and A2.
See Chapter 4.5 for voltage transformer connections on isolated/compensated systems.

3.1.2 Output relays

The *MRI3* is equipped with 5 output relays. Apart from the relay for self-supervision, all protective functions can be optionally assigned:

- Relay 1: C1, D1, E1 and C2, D2, E2
- Relay 2: C3, D3, E3 and C4, D4, E4
- Relay 3: C5, D5, E5
- Relay 4: C6, D6, E6
- Relay 5: Self-supervision C7, D7, E7

All trip and alarm relays are working current relays, the relay for self supervision is an idle current relay.

3.1.3 Blocking input

The blocking functions adjusted before will be blocked if an auxiliary voltage is connected to (terminals) D8/E8. (See chapter 5.7.1)

3.1.4 External reset input

Please refer to chapter 5.10.

3.2 Relay output contacts

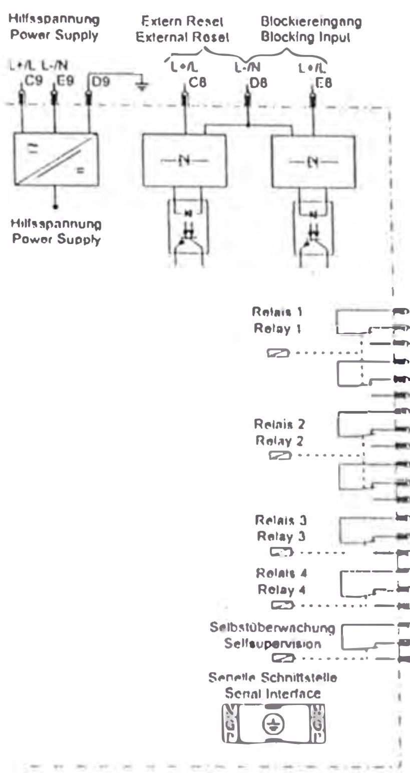


Figure 3.6

Contacts at *MRI3*:

To prevent that the C.B. trip coil circuit is interrupted by the *MRI3* first, i.e. before interruption by the C.B. auxiliary contact, a dwell time is fixed.
This setting ensures that the *MRI3* remains in self holding for 200ms after the fault current is interrupted.

3.2.1 Fault recorder

The *MRI3* is equipped with a disturbance value recorder which records the measured analogue values as momentary values. The momentary values

$$i_{L1}, i_{L2}, i_{L3}, i_E$$

are scanned within a grid 1.25 ms (with 50 Hz) or 1.041 ms (with 60 Hz) and filed in a circulating storage. The max. storage capacity amounts to 16 s (with 50 Hz) or 13.33 s (with 60 Hz).

Storage division

Independent of the recording time, the entire storage capacity can be divided into several cases of disturbance with a shorter recording time each. In addition, the deletion behaviour of the fault recorder can be influenced.

No writing over

If 2, 4 or 8 recordings are chosen, the complete memory is divided into the relevant number of partial segments. If this max. number of fault event has been exceeded, the fault recorder block any further recordings in order to prevent that the stored data are written over. After the data have been read and deleted, the recorder to ready again for further action.

Writing over

If 1, 3 or 7 recordings are chosen, the relevant number of partial segments is reserved in the complete memory. If the memory is full, a new recording will always write over the oldest one.

The memory part of the fault recorder is designed as circulating storage. In this example 7 fault records can be stored (written over).

Memory space 6 to 4 is occupied.
Memory space 5 is currently being written in

Figure 3.7: Division of the memory into 8 segments, for example

Since memory spaces 6, 7 and 8 are occupied, this example shows that the memory has been assigned more than eight recordings. This means that No. 6 is the oldest fault recording and No. 4 the most recent one.

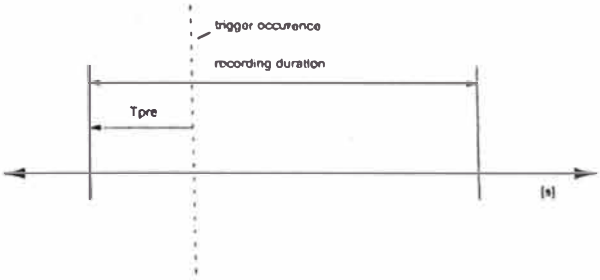


Figure 3.8: Recording scheme of the fault recorder with pre-trigger time

Each memory segment has a specified storage time which permits setting of a time prior to the trigger event.

Via the interface RS485 the data can be read and processed by means of a PC with HTL/PL-Soft4. The data is graphically edited and displayed. Binary tracks are recorded as well, e.g. activation and trip.

3.2.2 Parameter settings (see chapter 5)

System parameter

Relay type MRI3-	I	IE IX	IRE IRX	IR	IER IXR	IRER IRXR	ER XR	E X	ISR	IRSR	SR
Display of measuring values as primary quantities (I_{prim} phase)	X	X	X	X	X	X			X	X	
Display of earth current as primary quantities (I_{prim} earth)		X	X		X	X	X	X	X	X	X
Display of residual voltage U_r as primary quantity (U_{prim}/U_{s})					X	X	X				
3pha/e-n/1:1					X	X	X				
50/60 Hz	X	X	X	X	X	X	X	X	X	X	X
LED-Flash	X	X	X	X	X	X	X	X	X	X	X
RS 485/Slaveaddress	X	X	X	X	X	X	X	X	X	X	X
Baud-Rate [1]	X	X	X	X	X	X	X	X	X	X	X
Parity-Check [1]	X	X	X	X	X	X	X	X	X	X	X
Adjustment of the clock: Y = year; M = month; D = day; h = hour; m = minute; s = sec.	X	X	X	X	X	X	X	X	X	X	X

Table 3.1: System parameters of the different relay types

Protection parameter

Relay type MRI3-	I	IE IX	IRE IRX	IR	IER IXR	IRER IRXR	ER XR	E X	ISR	IRSR	SR
2 parameter sets	X	X	X	X	X	X	X	X	X	X	X
I>	X	X	X	X	X	X			X	X	
CHAR I>	X	X	X	X	X	X			X	X	
$t_{I>}$	X	X	X	X	X	X			X	X	
0 s/60 s [2]	X	X	X	X	X	X			X	X	
I>>	X	X	X	X	X	X			X	X	
$t_{I>>}$	X	X	X	X	X	X			X	X	
RCA			X	X		X				X	
U_E					X	X	X				
$I_{E>}$		X	X		X	X	X	X	X	X	X
warn/trip		X	X		X	X	X	X			
CHAR I_E		X	X					X	X	X	X
t_{E}		X	X		X	X	X	X	X	X	X
0s / 60 s [3]		X	X					X	X	X	X
$I_{E>>}$		X	X		X	X	X	X	X	X	X
$t_{IE>>}$		X	X		X	X	X	X	X	X	X
sin/cos					X	X	X				
soli/resi									X	X	X
tCBFP	X	X	X	X	X	X	X	X	X	X	X
Block/Trip	X	X	X	X	X	X	X	X	X	X	X

Table 3.2: Protection parameters of the different relay types.

[1] Only devices with Modbus-Protocol
[2] Reset setting for inverse time characteristics in phase current path
[3] Reset setting for inverse time characteristics in earth current path

Parameter for the fault recorder

Relay type MRI3-	I	IE IX	IRE IRX	IR	IER IXR	IRER IRXR	ER XR	E X	ISR	IRSR	SR
Number of fault events	X	X	X	X	X	X	X	X	X	X	X
Trigger events	X	X	X	X	X	X	X	X	X	X	X
Pre-trigger time (T_{pre})	X	X	X	X	X	X	X	X	X	X	X

Table 3.3: Parameters for the fault recorder of the different relay types

Additional parameters

Relay-type MRI3-	I	IE IX	IRE IRX	IR	IER IXR	IRER IRXR	ER XR	E X	ISR	IRSR	SR
Blocking mode [1)]	X	X	X	X	X	X	X	X	X	X	X
Relay parameterizing	X	X	X	X	X	X	X	X	X	X	X
Fault recorder	X	X	X	X				X	X	X	X

Table 3.4: Additional parameters of the different relay types

[1)] For 2 parameter sets (separately for each parameter set)

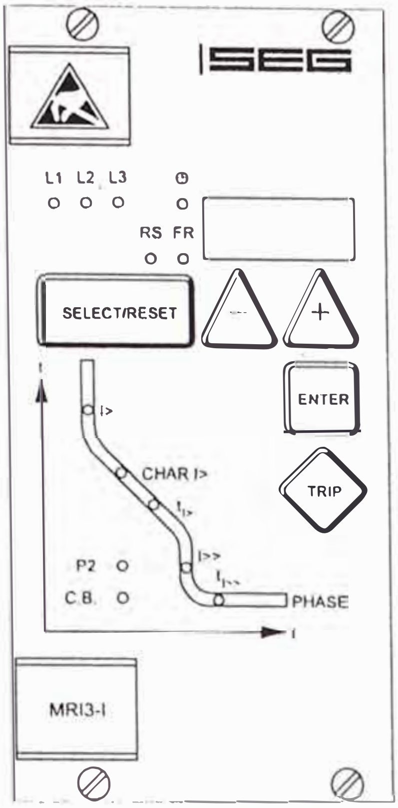


Figure 3.9: Front plate MRI3-I

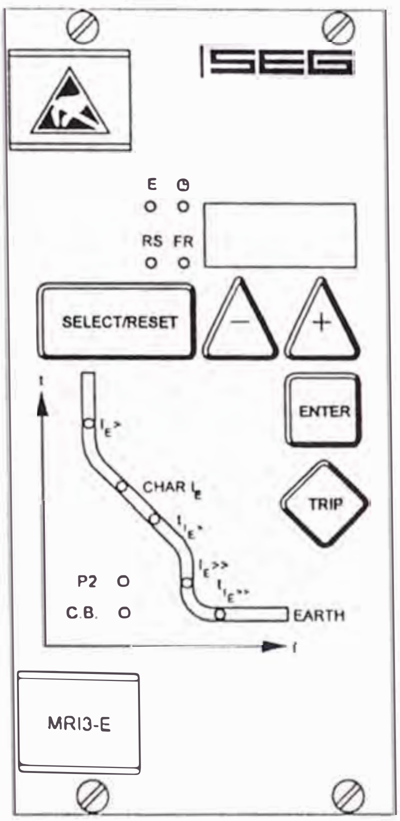


Figure 3.10: Front plate MRI3-E/X

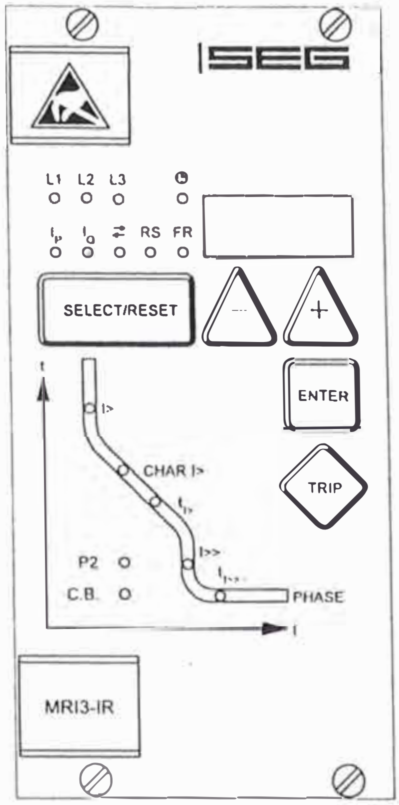


Figure 3.11: Front plate MRI3-IR

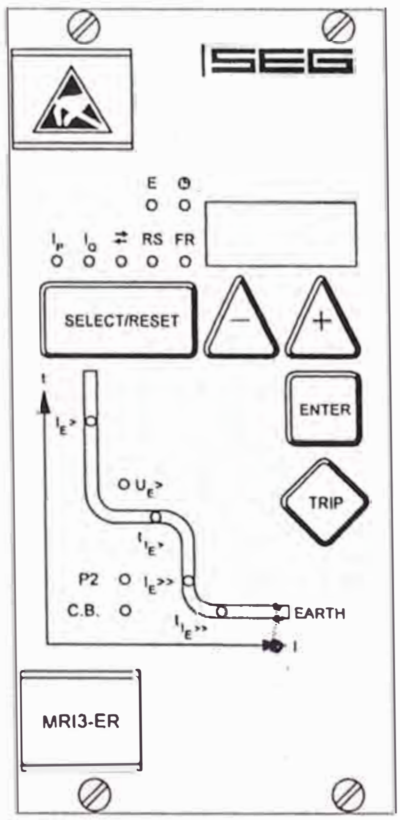


Figure 3.12: Front plate MRI3-ER/XR

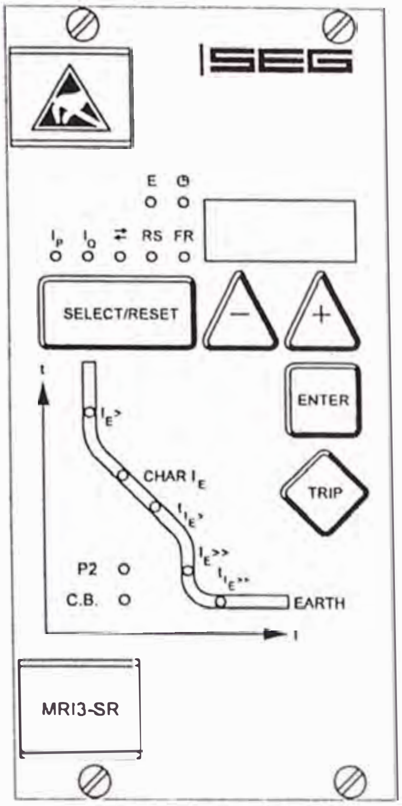


Figure 3.13: Front plate MRI3-SR

3.3 LEDs

The LEDs left from the display are partially bi-colored, the green indicating measuring, and the red fault indication.

MRI3 with directional feature have a LED (green- and red arrow) for the directional display. At pickup/trip and parameter setting the green LED lights up to indicate the forward direction, the red LED indicates the backward direction.

The LED marked with letters RS lights up during setting of the slave address of the device for serial data communication.

The LEDs arranged at the characteristic points on the setting curves support the comfortable setting menu selection. In accordance with the display 5 LEDs for phase fault overcurrent relay and 5 LEDs for earth-fault relay indicate the corresponding menu point selected.

The LED labelled with the letters LR is alight while the fault recorder is being adjusted.

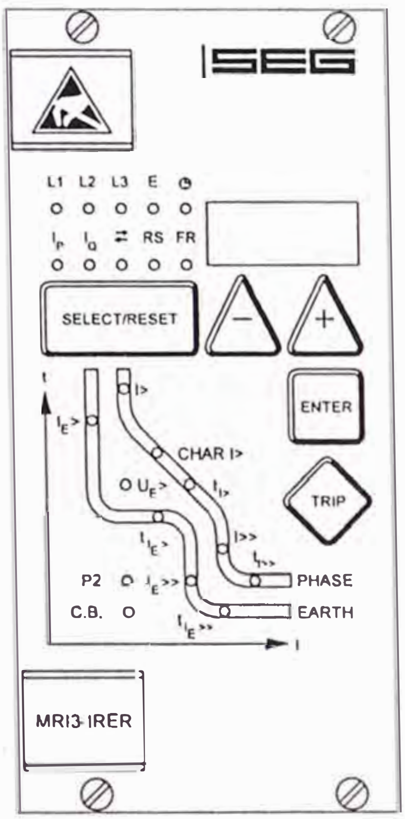


Figure 3.14: Front plate MRI3-IRER/IRXR and MRI3-IER/IXR

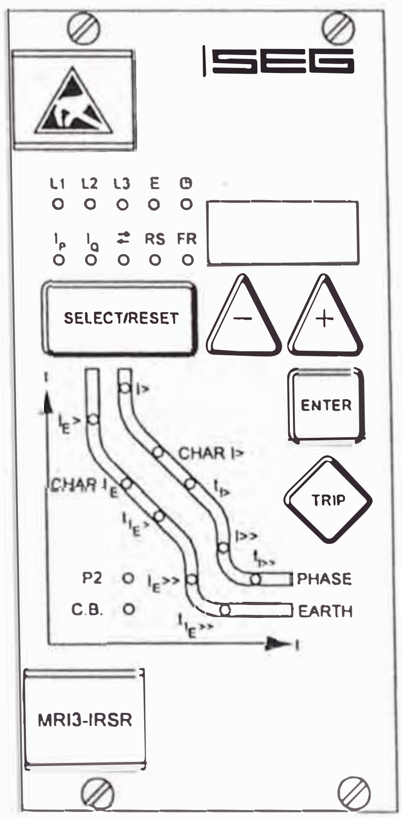


Figure 3.15: Front plate MRI3-IRSR; MRI3-IRE/IRX and MRI3-ISR

4 Working principle

4.1 Analog circuits

The incoming currents from the main current transformers on the protected object are converted to voltage signals in proportion to the currents via the input transformers and burden. The noise signals caused by inductive and capacitive coupling are supressed by an analog R-C filter circuit.
The analog voltage signals are fed to the A/D-converter of the microprocessor and transformed to digital signals through Sample- and Hold-circuits. The analog signals are sampled at 50 Hz (60 Hz) with a sampling frequency of 800 Hz (960 Hz), namely, a sampling rate of 1.25 ms (1.04 ms) for every measuring quantity. (16 scans per periode).

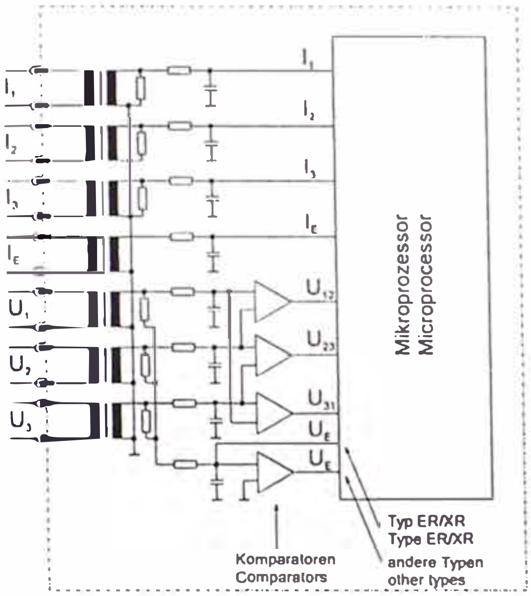


Figure 4.1: Block diagram

4.2 Digital circuits

The essential part of the *MRI3* relay is a powerful microcontroller. All of the operations, from the analog digital conversion to the relay trip decision, are carried out by the microcontroller digitally. The relay program is located in an EPROM (Electrically-Programmable-Read-Only-Memory). With this program the CPU of the microcontroller calculates the three phase currents and ground current in order to detect a possible fault situation in the protected object.
For the calculation of the current value an efficient digital filter based on the Fourier Transformation (DFFT - Discrete Fast Fourier Transformation) is applied to suppress high frequency harmonics and DC components caused by fault-induced transients or other system disturbances.

The calculated actual current values are compared with the relay settings. If a phase current exceeds the pickup value, an alarm is given and after the set trip delay has elapsed, the corresponding trip relay is activated.
The relay setting values for all parameters are stored in a parameter memory (EEPROM - Electrically Erasable Programmable Read-only Memory), so that the actual relay settings cannot be lost, even if the power supply is interrupted.
The microprocessor is supervised by a built-in "watchdog" timer. In case of a failure the watchdog timer resets the microprocessor and gives an alarm signal, via the output relay "self supervision".

4.3 Directional feature

A built-in directional element in *MRI3* is available for application to doubly infeeded lines or to ring networks.
The measuring principle for determining the direction is based on phase angle measurement and therefore also on coincidence time measurement between current and voltage. Since the necessary phase voltage for determining the direction is frequently not available in the event of a fault, whichever line-to-line voltage follows the faulty phase by 90° is used as the reference voltage for the phase current. The characteristic angle at which the greatest measuring sensitivity is achieved can be set to precede the reference voltage in the range from 15° to 83°.

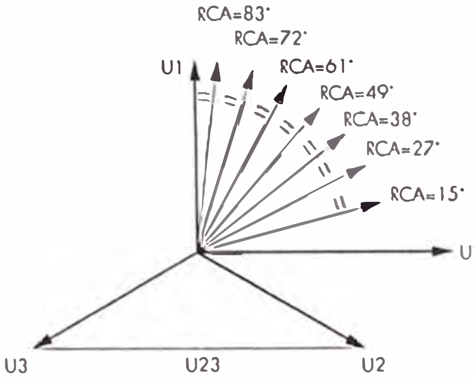


Figure 4.2: Relay characteristic angle

The TRIP region of the directional element is determined by rotating the phasor on the maximum sensitivity angle for ± 90°, so that a reliable direction decision can be achieved in all faulty cases.

4.3.1 Reversal in direction during the activation phase

Reversal of the current direction during the activation phase can lead to hyperfunctions. This mainly applies to installations where parallel connected lines are monitored by current relays with directional feature. For this reason the directional determination for the phase current is shown in a time window; this applies to all SR versions. In case of activation due to a fault, a timer is started and measures the time in the determined direction for max. 1 s. This timer runs backwards at half speed if, during the activation phase, a fault causes reversal of the direction. Only when the timer is at zero again, the *MRI3* recognizes the reversal in direction. The switch-over time is max. 2 s. The activation delays tI> and tI>> are not affected by the delayed recognition of direction.

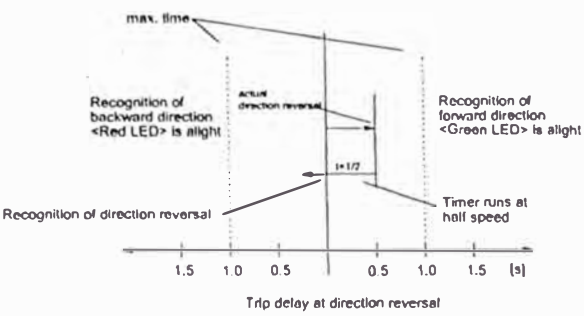


Figure 4.3: *Recording scheme of the fault recorder with lead time*

Example:
Figures 4.4 and 4.5 illustrate a possible fault situation with a reversal in direction in the fault-free line.
The current transformers used have a primary current of 250 A. The switch point for the I> stage is 0.25 kA and for the I>> stage 1 kA. All devices have the same setting and will, if set to "Forward", recognize the direction in relation to the forward direction of the line.
The critical point here is the *MRI3* No. 1. Using delay action in directional recognition, it is possible to prevent shut-down of the fault-free line.

The following relay setting applies:

I>	1.00 x In
CHAR I>	DEFT (inverse) ·trip delay
tI>(V)	10s Trip delay in forward direction
tI>(R)	EXIT (no trip) Delay in backward direction
I>>	4.00 x In
tI>>(V)	0.1 s
tI>>(R)	EXIT

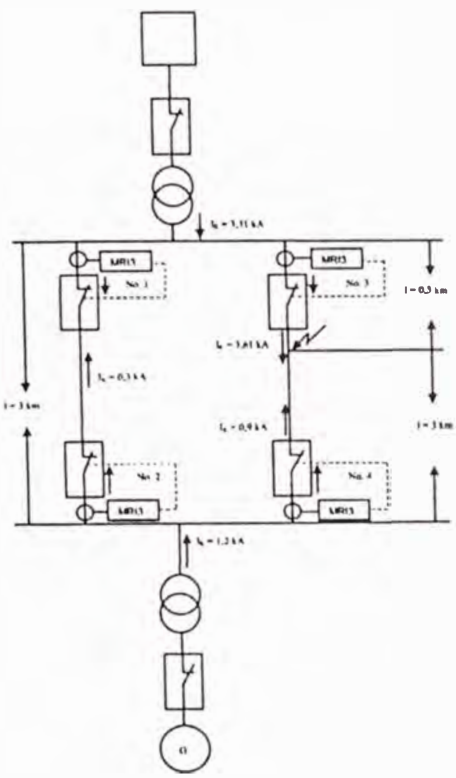


Figure 4.4

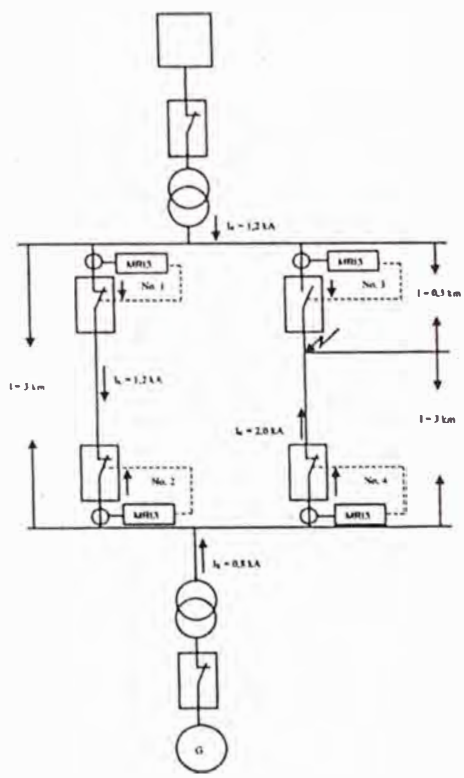
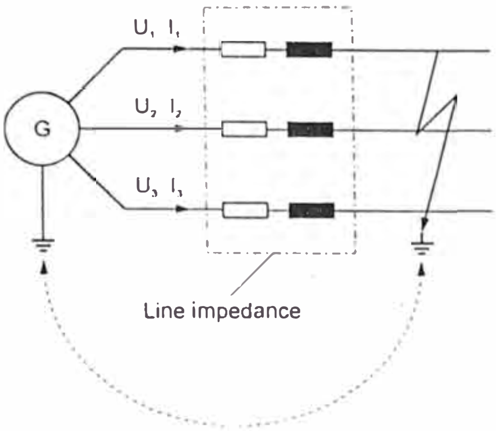
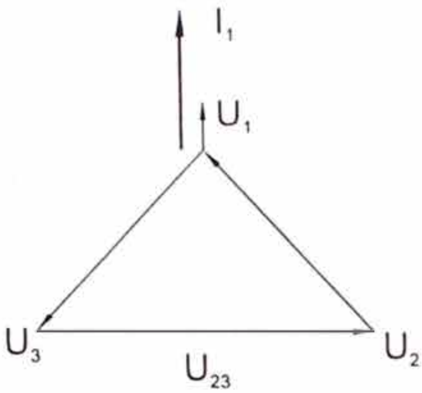


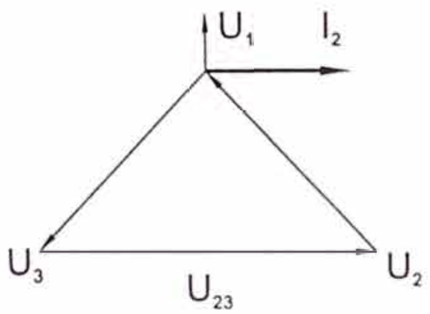
Figure 4.5



If line impedance and internal resistance of the generator is only ohmic:



If line impedance and internal resistance of the generator is only inductive:



The maximum sensitivity angle corresponds to the R/L component.

The TRIP region of the directional element is determined by rotating the phasor on the maximum sensitivity angle for ±90°, so that a reliable direction decision can be achieved in all faulty cases.

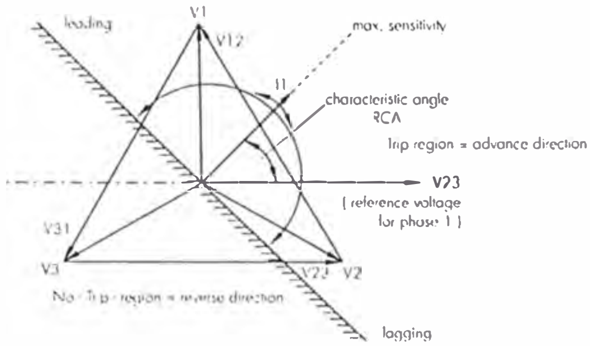


Figure 4.6: TRIP/NO TRIP region for directional element in MRI3. In this case the foreward direction is defined as TRIP region and the backward direction as NO-TRIP region.

By means of accurate hardware design and by using an efficient directional algorithm a high sensitivity for the voltage sensing circuit and a high accuracy for phase angle measurement are achieved so that a correct directional decision can be made even by close three-phase faults.

As an addition, to avoid maloperations due to disturbances, at least 2 periods (40 ms at 50 Hz) are evaluated.

For the *MRI3*-overcurrent relays with directional feature different time delays or time multipliers can be set for forward and backward faults (ref. to chapter 5.4.3).

If the trip delay for backward faults is set longer than the one for forward faults, the protective relay works as a "backup"-relay for the other lines on the same busbar. This means that the relay can clear a fault in the backward direction with a longer time delay in case of refusal of the relay or the circuit breaker on the faulted line.

If the trip delay for backward faults is set out of range (on the display "EXIT"), the relay will not trip in case of backward faults.

The assignment of the output relays can be used to select in which direction the failure is to be indicated (refer also to Chapter 5.7.1). It is possible to indicate the activation and/or the tripping for each tripping direction via the output relays.

4.4 Earth fault protection

4.4.1 Generator stator earth fault protection

With the generator neutral point earthed earthed as shown in Figure 4.7 the *MRI3* picks up only to phase earth faults between the generator and the location of the current transformers supplying the relay.
Earth faults beyond the current transformers, i.e. on the consumer or line side, will not be detected.

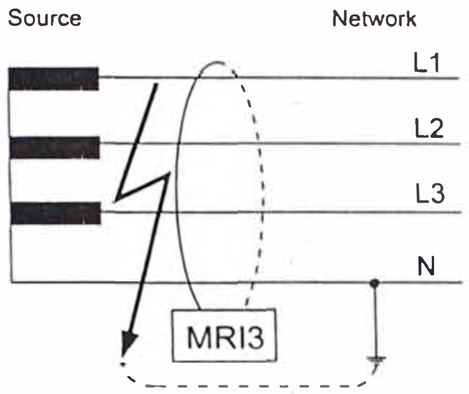


Figure 4.7: Generator stator earth fault protetion

4.4.2 System earth fault protection

With the generator neutral point earthed as shown in Figure 4.8, the *MRI3* picks up only to earth faults in the power system connected to the generator. It does not pick up to earth faults on the generator terminals or in generator stator.

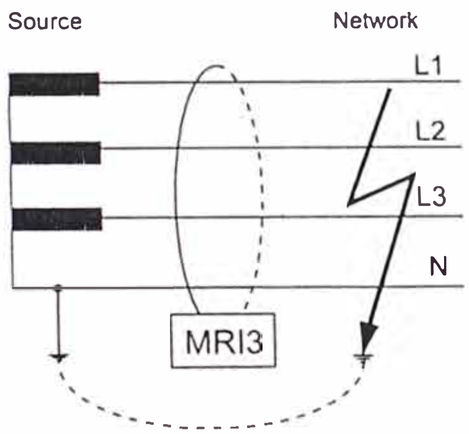


Figure 4.8: System earth fault protection

4.5 Earth-fault directional feature (ER/XR-relay type)

A built-in earth-fault directional element is available for applications to power networks with isolated or with arc suppressing coil compensated neutral point.
For earth-fault direction detection it is mainly the question to evaluate the power flow direction in zero sequence system. Both the residual voltage and neutral (residual) current on the protected line are evaluated to ensure a correct direction decision.
In isolated or compensated systems, measurement of reactive or active power is decisive for earth-fault detection. It is therefore necessary to set the ER/XR-relay type to measure according to sin φ or cos φ methods, depending on the neutral-point connection method.

The residual voltage U_E required for determining earth fault direction can be measured in three different ways, depending on the voltage transformer connections.
(refer toTable 4.1). Total current can be measured by connecting the unit either to a ring core C.T. or to current transformers in a Holmgreen circuit. However, maximum sensitivity is achieved if the MRI1 protective device is connected to a ring core C. T. (see Figure 3.2).

The pick-up values $I_{E>}$ and $I_{E>>}$ (active or reactive current component for cos φ or sin φ method) for ER-relay types can be adjusted from 0.01 to 0.45 x I_N. For relay type *MRI3-XR* these pick-up values can be adjusted from 0.1 to 4.5% I_N.

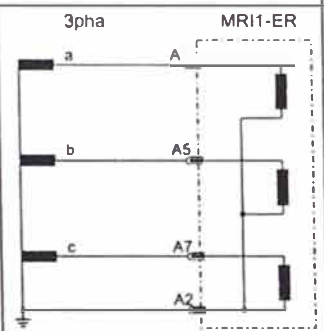
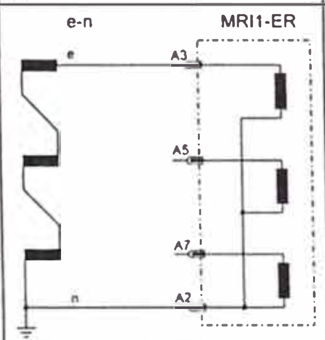
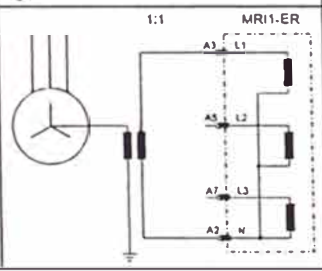
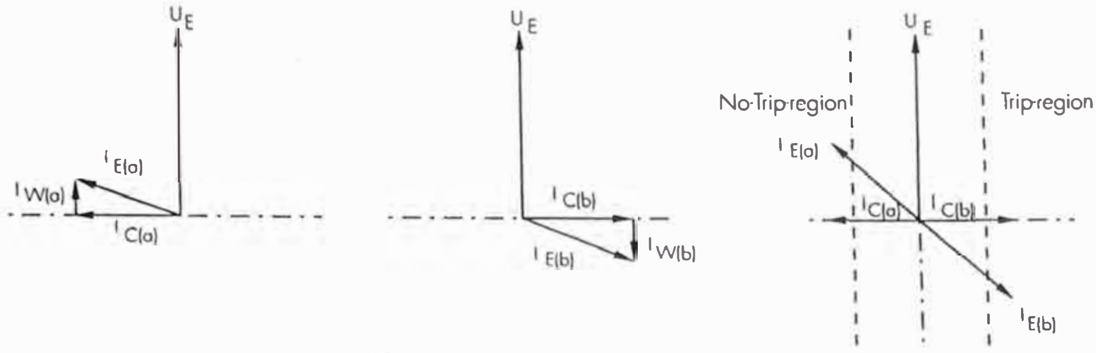
Adjustment possibility	Application	Voltage transformer connections	Measurd voltage at earth fault	Correction factor for residual voltage
"3pha"	3-phase voltage transformer connected to terminals A3, A5, A7, A2 (*MRI3-IRER; MRI3-IER; MRI3-ER/XR*)		$\sqrt{3} \times U_N = 3 \times U_{1N}$	K = 1 / 3
"e-n"	e-n winding connected to terminals A3, A2 (*MRI3-IER; MRI3-ER/XR*)		$U_N = \sqrt{3} \times U_{1N}$	K = 1 / √3
"1:1"	Neutrol-point voltage (= residual voltage) terminals A3, A2 (*MRI3-IER; MRI3-ER/XR*)		$U_{1N} = U_{NE}$	K = 1

Table 4.1: Connection of the voltage transformers

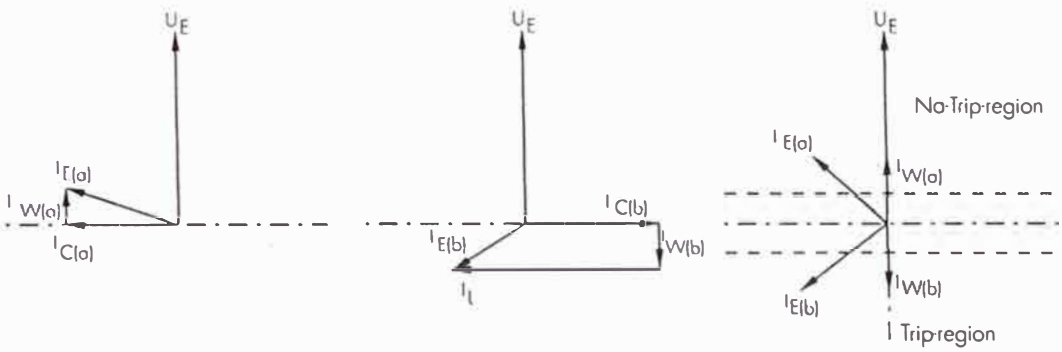


(a) non-faulted lines (b) faulted lines (c) Trip / No-Trip-region

Figure 4.9: Phase position between the residual voltage and zero sequence current for faulted and non-faulted lines in case of isolated systems (sin φ)

U_E - residual voltage
I_E - zero sequence current
I_C - capacitive component of zero sequence current
I_W - resistive component of zero sequence current

By calculating the reactive current component (sin φ adjustment) and then comparing the phase angle in relation to the residual voltage U_E, the ER/XR-relay type determines whether the line to be protected is earth-faulted.
On non-earth-faulted lines, the capacitive component Ic(a) of the total current precedes the residual voltage by an angle of 90°. In case of a faulty line the capacity current $I_{C(b)}$ lags behind the residual voltage at 90°.



(a) non - faulted lines (b) faulted lines (c) Trip / No-Trip-region

Figure 4.10: Phase position between the residual voltage and zero sequence current for faulted and non-faulted lines in case of compensated systems (cos φ)

U_E - residual voltage
I_E - zero sequence current
I_L - inductive component of zero sequence current (caused by Petersen coil)
I_C - capacitive component of zero sequencel current
I_W - resistive component of zero sequence current

In compensated mains the earthfault direction cannot be determined from the reactive current components because the reactive part of the earth current depends upon the compensation level of the mains. The ohmic component of the total current (calculated by cos φ adjustment) is used in order to determine the direction.

The resistive component in the non-faulted line is in phase with the residual voltage, while the resistive component in the faulted line is opposite in phase with the residual voltage.

By means of an efficient digital filter harmonics and fault transients in the fault current are suppressed. Thus, the uneven harmonics which, for instance, are caused on electric arc fault, do not impair the protective function.

4.6 Determining earth short-circuit fault direction

The SR-relay type is used in solidly-earthed or resistance-earthed systems for determining earth short-circuit fault direction. The measuring principle for determining the direction is based on phase angle measurement and therefore also on the coincidence-time measurement between earth current and zero sequence voltage.

The zero sequence voltage U_0 required for determining the earth short-circuit fault direction is generated internally in the secondary circuit of the voltage transformers.
With SR/ISR-relay types the zero sequence voltage U_0 can be measured directly at the open delta winding (e-n). Connection A3/A2.

4.6.1 Directly - earthed system

Most faults in a characteristic angle are predominantly inductive in character. The characteristic angle between current and voltage at which the greatest measuring sensitivity is achieved has therefore been selected to precede zero sequence voltage U_0 by 110°.

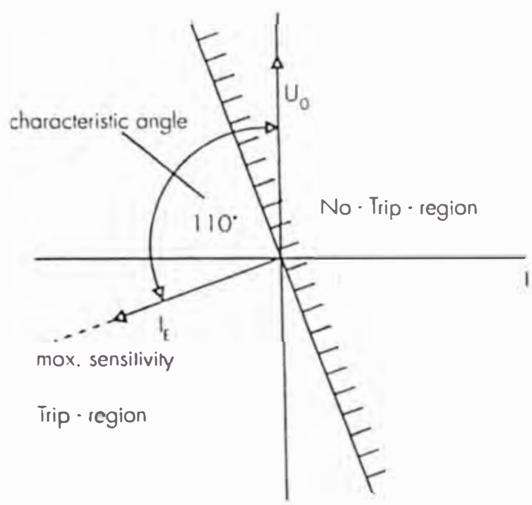


Figure 4.11: Characteristic angle in solidly earthed-systems (SOLI)

4.6.2 Resistance - earthed system

Most faults in a resistance-earthed system are predominantly ohmic in character, with a small inductive part. The characteristic angle for these types of system has therefore been set at +170° in relation to the zero sequence voltage U_0 (see Figure 4.12).

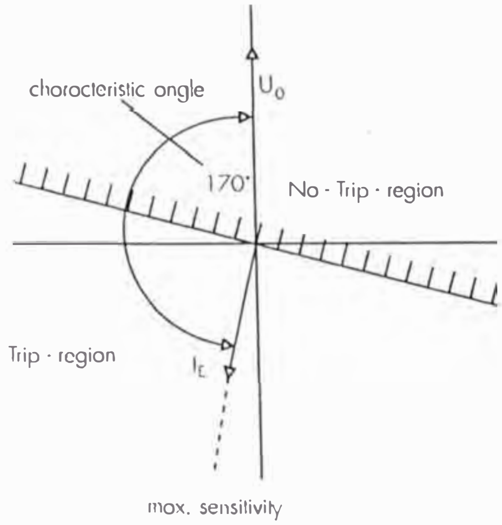


Figure 4.12: Characteristic angle in resistance-earthed systems (RESI)

The pickup range of the directional element is set by turning the current indicator at the characteristic angle through + 90°, to ensure reliable determination of the direction.

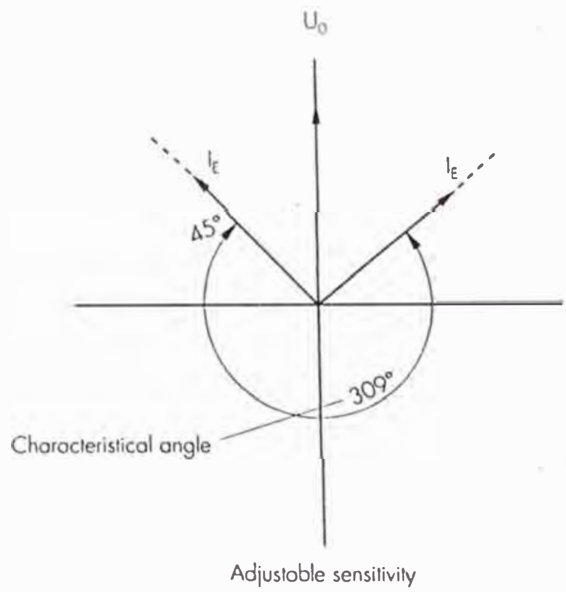


Figure 4.13: Adjustable characteristical angle of 45° to 309°

For all other applications the characteristical angle between 45° and 309° is free selectable

4.7 Demand imposed on the main current transformers

The current transformers have to be rated in such a way, that a saturation should not occur within the following operating current ranges:

Independent time overcurrent function:	K1 = 2
Inverse time overcurrent function:	K1 = 20
High-set function:	K1 = 1.2 - 1.5

K1 = Current factor related to set value

Moreover, the current transformers have to be rated according to the maximum expected short circuit current in the network or in the protected objects.

The low power consumption in the current circuit of *MRI3*, namely <0.2 VA, has a positive effect on the selection of current transformers. It implies that, if an electromechanical relay is replaced by *MRI3*, a high accuracy limit factor is automatically obtained by using the same current transformer.

- **Protective Relaying - Principles and Aplications**

  J. Lewis Blackburn

- **Fundamentos de Sistemas de Energía Eléctrica**

  Ing. Gilberto Enríquez Harper

- **Fundamentos de Protección de Sistemas Eléctricos**

  Ing. Gilberto Enríquez Harper

- **Protección en las Instalaciones Eléctricas**

  Dr. Paulino Montané Sangrá

- **Centros de Transformación - Criterios de Diseño**

  Manoel da Costa

BIBLIOGRAFIA

- **Protección de Fallas a Tierra en Sistemas de Distribución.**

  Ing. Carlos Arroyo Arana

- **Curto Circuito**

  Geraldo Kinderman

- **Análisis de Sistemas de Potencia**

  John J. Graiger y William D.Stevenson

- **Sistemas de Potencia**

  Pablo Hernán Corredor A.

- **Ground Fault Protection on Ungrounded an High Resistance Grounded Systems**

  Documento Técnico de Schneider Electric

- **Neutral Grounding Resistors**

  Documento Técnico de IPC RESISTORS INC.

Schaltanlagen-Elektronik-Geräte GmbH & Co. KG
Abteilung Gerätevertrieb / Electronic Devices Sales Department
Krefelder Weg 47 · D - 47906 Kempen (Germany)
Postfach 10 07 55 (P.O.B.) · D - 47884 Kempen (Germany)
Tel.: +49 (0)21 52 1 45-1 · Fax.: +49 (0)21 52 1 45-3 54
e-mail: electronics@avkseg.com

TB MRI3 12.00 E

Assignment of the blocking function:

	Default setting		Actual setting	
Parameter switch	Set 1	Set 2	Set 1	Set 2
Blocking the protection function PR_B Blocking the trip step TR_B	PR_B	PR_B		

	Default setting				Actual setting			
Function	Blocking		No blocking		Blocking		No blocking	
Parameter set	Set 1	Set 2	Set 1	Set 2	Set 1	Set 2	Set 1	Set 2
I>			X	X				
I>>	X	X						
$I_{E>}$			X	X				
$I_{E>>}$			X	X				
$I_{E>EFF}$			X	X				

This technical manual is valid for: software version	D01-9.03 (*MRI3-ER; -IER; -IRER*) D20-3.03 (*MRI3-XR; -IXR; -IRXR*) D24-2.03 (*MRI3-X; -IX; -IXR*) D00-9.04 (*MRI3; I; E; IE; IR; SR; -IRE; -ISR; -IRSR*)
Modbus-Version-number:	D51-2.12 (*MRI3-ER-M; -IER-M; -IRER-M*) D70-2.12 (*MRI3-XR-M; -IXR-M; -IRXR-M*) D74-2.12 (*MRI3-X-M; -IX-M; -IXR-M*) D50-2.12 (*MRI3-M; I-M; E-M; IE-M; -IR-M; SR-M; -IRE-M; -ISR-M; -IRSR-M*)

Fault recorder

Function		Unit	Default settings	Actual settings
FR	Number of recordings		2	
FR	Saving of the recording at the occurrence		TRIP	
FR	Time prior to trigger impulse	s	5	
🕓	Year settings	Year	Y=00	
🕓	Month settings	Month	M=00	
🕓	Day settings	Day	D=00	
🕓	Setting of the hours	Hours	h=00	
🕓	Setting of the minutes	Minutes	m=00	
🕓	Setting of the seconds	seconds	s=00	

Setting of code jumpers

Code jumper	J1		J2		J3	
	Default setting	Actual setting	Default setting	Actual setting	Default setting	Actual setting
Plugged						
Not plugged	X		no function		X	

Code jumper	Low/High-range for Reset input		Low/High-range for Blockage input	
	Default setting	Actual setting	Default setting	Actual setting
Low=plugged	X		X	
High=not plugged				

Assignment of the output relays:

Function	Relay 1		Relay 2		Relay 3		Relay 4	
	Default setting	Actual setting	Default setting	Actual setting	Default setting	Actual setting	Default setting	Actual setting
I> alarm (V)			X					
$t_{I>}$ tripping (V)	X							
I>> alarm (R)*			X		X			
$t_{I>>}$ tripping (R)*	X							
IE>> alarm (V)					X			
$t_{IE>>}$ tripping (V)	X							
IE>> alarm (R)*								
$t_{I>>}$ tripping (R)*	X							
$I_{E>}$ alarm (V)							X	
$t_{IE>}$ tripping (V)	X							
$I_{E>}$ alarm (R)*							X	
$t_{IE>}$ tripping (R)*	X							
$I_{E>>}$ alarm (V)							X	
$t_{E>>}$ tripping (V)	X							
IE>> alarm (R)*							X	
$t_{E>>}$ tripping (R)*	X							
t_{CNr} tripping								

* only relays with directional function

Setting list *MRI3*

Note !
All settings must be checked at site and should the occasion arise, adjusted to the object / item to be protected.

Project: ______________________________ SEG job.-no.: ________________

Function group: =__________ Location: +________ Relay code: -________________

Relay functions: ______________________________ Password: ________________

Date: ________________

Adjustment of the parameter

Systemparameter

Relay type MRI3-	I	IE IX	IRE IRX	IR	IER IXR	IRER IRXR	ER XR	E X	ISR	IRSR	SR	Default settings	Actual settings
I_{prim} (phase)	X	X	X	X	X	X			X	X		SEK	
I_{prim} (earth)		X	X		X	X	X	X	X	X	X	SEK	
U_{prim}/U_{1} (earth)					X	X	X					SEK	
1:1 / 3pha / e-n					X	X	X					3pha	
50 / 60 Hz	X	X	X	X	X	X	X	X	X	X	X	50Hz	
Indication Pickup	X	X	X	X	X	X	X	X	X	X	X	FLSH	
Parameter switch/external triggering for the fault recorder	X	X	X	X	X	X	X	X	X	X	X	SET1	

Protection parameter

Relay type MRI3-	I	IE IX	IRE IRX	IR	IER IXR	IRER IRXR	ER XR	E X	ISR	IRSR	SR	Default Settings	Actual Settings
2 parameter sets	X	X	X	X	X	X	X	X	X	X	X	set 1 / set 2	Set 1/Set 2
I>	X	X	X	X	X	X			X	X		0.2 xI_N	
CHAR I>	X	X	X	X	X	X			X	X		DEFT	
$t_{I>}$ / $k_{I>}$	X	X	X	X	X	X			X	X		0.03s	
0s / 60s (phase)	X	X	X	X	X	X			X	X		0s	
I>>	X	X	X	X	X	X			X	X		1.0 xI_N	
$t_{I>>}$ / $k_{I>>}$	X	X	X	X	X	X			X	X		0.03s	
RCA			X	X		X				X		49°	
$U_{E>}$					X	X	X					1V/2V/5V	
$I_{E>}$		X	X		X	X	X	X	X	X	X	0.01 xI_N (E) 0.1 % (X)	
trip / warn		X	X		X	X	X	X	X	X	X	Trip	
CHAR I_E		X	X					X	X	X	X	DEFT	
$t_{IE>}$ / $k_{IE>}$		X	X		X	X	X	X	X	X	X	0.05s (ER/XR) 0.04s others	
0s / 60s (Phase)		X	X					X	X	X	X	0s	
$I_{E>>}$		X	X		X	X	X	X	X	X	X	0.01 xI_N (E) 0.1 % (X)	
$t_{IE>>}$ / $k_{IE>>}$		X	X		X	X	X	X	X	X	X	0.05s (ER/XR) 0.04s others	
SIN / COS					X	X	X					SIN	
SOLI / RESI									X	X	X	SOLI	
Block/trip - time	X	X	X	X	X	X	X	X	X	X	X	EXIT	
I_{wr}	X	X	X	X	X	X	X	X	X	X	X	EXIT	
RS485 / Slave	X	X	X	X	X	X	X	X	X	X	X	1	
Baud-Rate*	X	X	X	X	X	X	X	X	X	X	X	9600	
Parity-Check*	X	X	X	X	X	X	X	X	X	X	X	even	

*only Modbus Protokoll

8 Order form

Time overcurrent- / Earth fault current relay		MRI3-
3-phase current I>, I>>[3]	none	•
Rated current	1 A	I1
	5 A	I5
Phase fault directional feature	none	•
Rated voltage[2]	100 V	R1
	230 V	R2
	400 V	R4
Earth current measuring[3]	none	•
Rated current standard	1 A	E1
	5 A	E5
sensitive	1 A	X1
	5 A	X5
[1]solid	1 A	S1
[1]grounded	5 A	S5
Directional feature in earth path	none	•
Rated voltage[2] in earth circuits	100 V	R1
	230 V	R2
	400 V	R4
Housing (12TE)	19"-rack	A
	Flush mounting	D
Communication protocol RS485 Pro Open Data; Modbus RTU		•
		-M

• leave box empty if option is not desired (no extra charge)

[1] Only in connection with directional detection in the earth current path

[2] Both rated voltages must be the same!

[3] At least one of these versions must be chosen

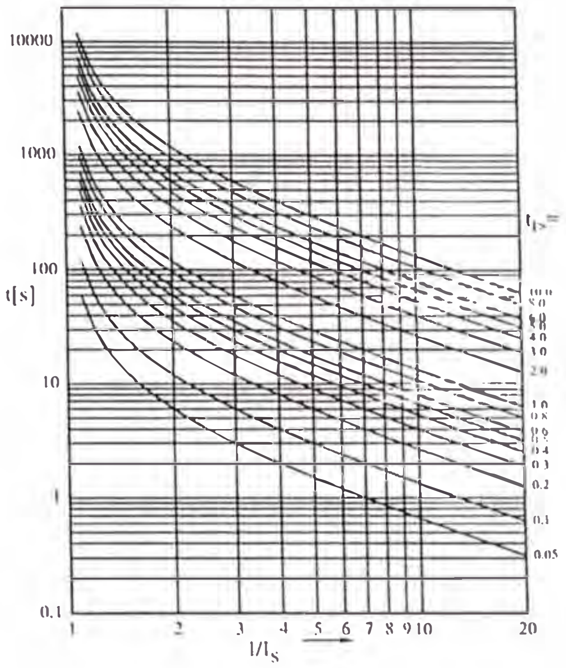


Figure 7.5: Long Time Inverse

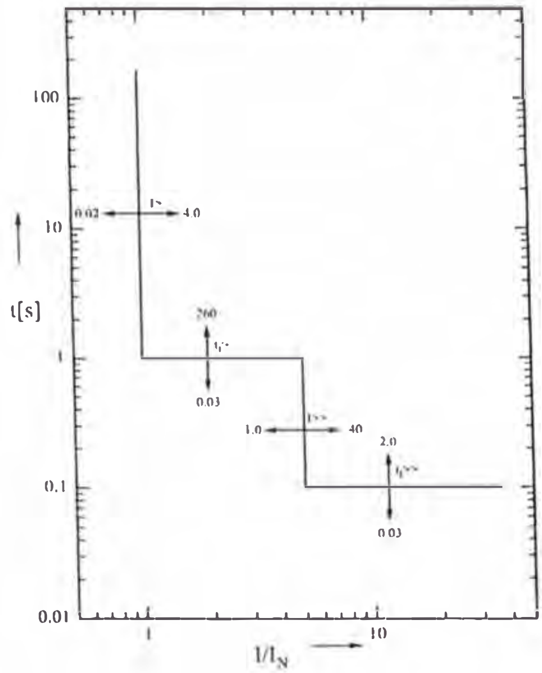


Figure 7.7: Definite time overcurrent relay

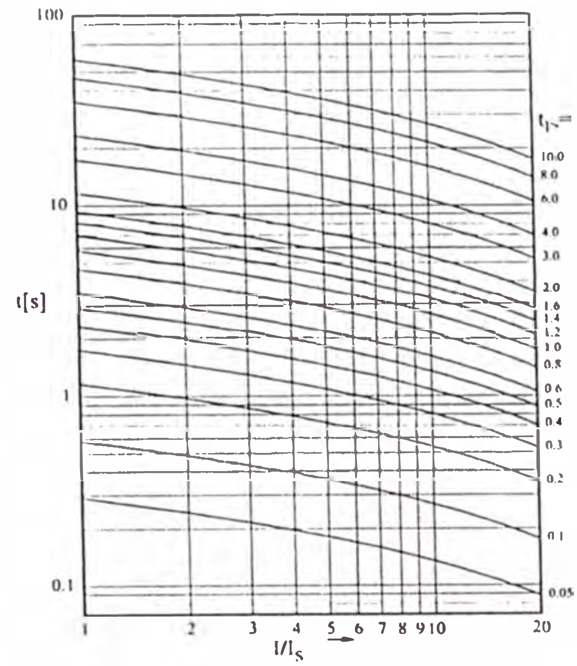


Figure 7.6: RXIDG-characteristic

7.5 Output contacts

Number of relays:	dependent on relay type
Contacts:	2 change-over contacts for trip relay
	1 change-over contact for alarm relays

Technical data subject to change without notice!

7.4 Inverse time characteristics

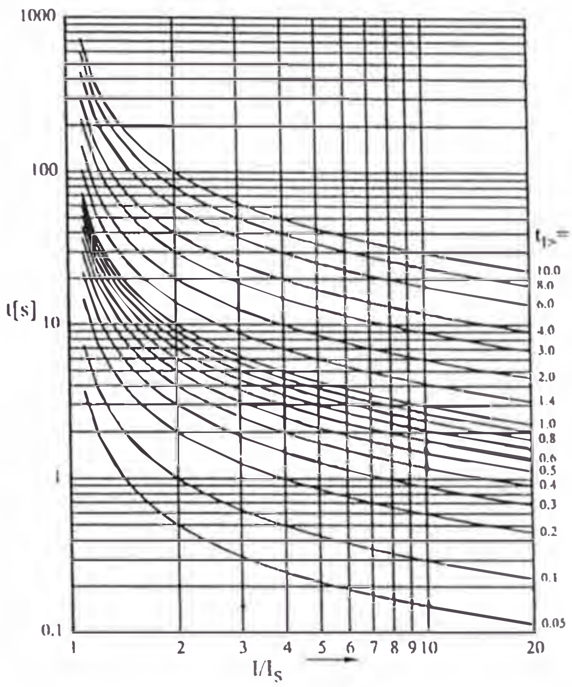


Figure 7.1 Normal Inverse (Type A)

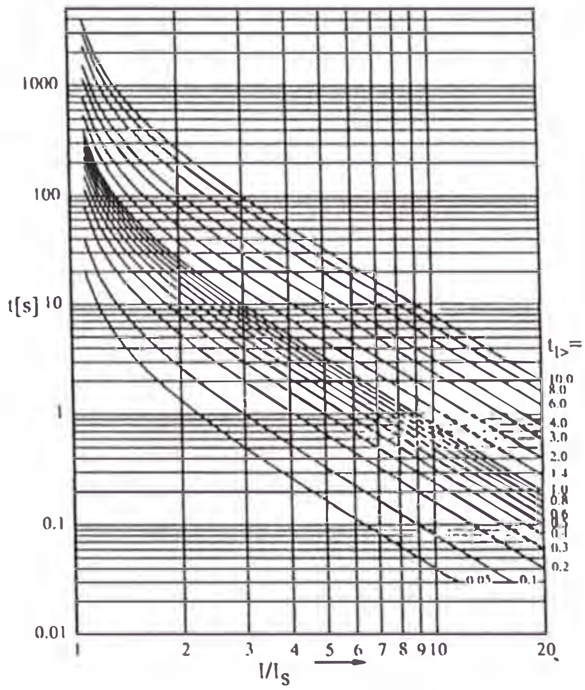


Figure 7.3: Extremely Inverse (Type C)

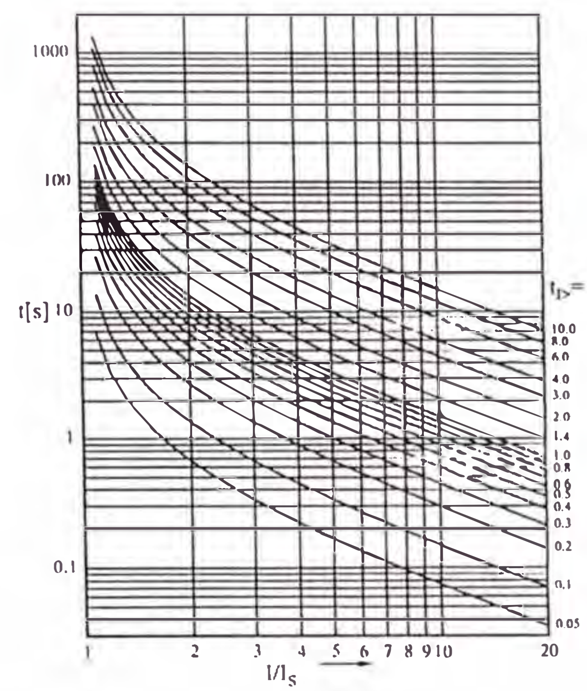


Figure 7.2: Very Inverse (Type B)

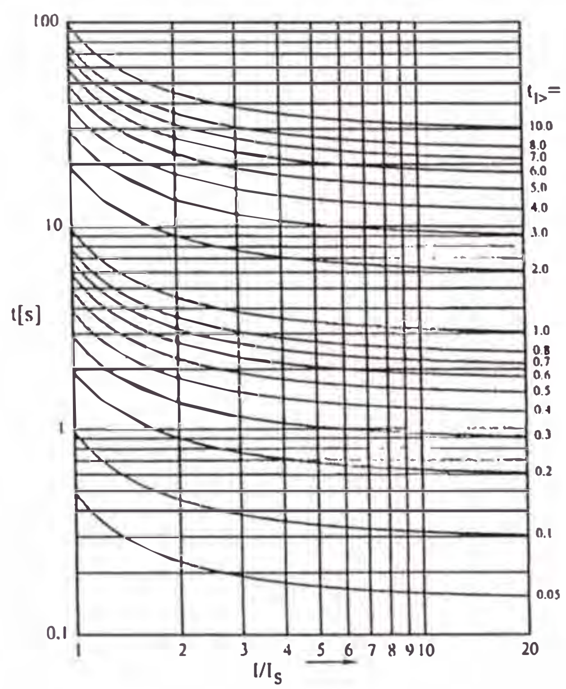


Figure 7.4: RI-Inverse

7.3.10 Direction unit for phase overcurrent relay

Directional sensitivity for voltage input circuit:	<0.025% U_N (phase-to-phase voltage) at $I = 1 \times I_N$
Connection angle:	90°
Characteristic angle:	15°, 27°, 38°, 49°, 61°, 72°, 83°
Effective angle:	±78° related to relay characteristic angle at U_N

7.3.11 Determination of earth fault direction (*MRI3-ER/XR*)

Measurement of active current component for compensated systems:	$I_E \times \cos\varphi$
Measurement of reactive current component for isolated systems:	$I_E \times \sin\varphi$
Angle measuring accuracy:	±3° at $I_E \times \cos\varphi$ or $I_E \times \sin\varphi$ >5% I_E

7.3.12 Determination of earth fault direction (*MRI3-SR*)

Characteristic angle:	"SOLI" setting - 110° "RESI" setting - 170°
Effective angle:	45° - 309° in 5.625° - steps ±70° related to relay characteristic angle at $U_N / \sqrt{3}$
Residual voltage sensitivity:	<0.2% U_N at $I = 0.1 \times I_N$

7.3.9 Inverse time overcurrent protection relay

According to IEC 255-4 or BS 142

Normal Inverse (Type A)

$$t = \frac{0{,}14}{\left(\frac{I}{Is}\right)^{0{,}02} - 1} t_I > [s]$$

Very Inverse (Type B)

$$t = \frac{13{,}5}{\left(\frac{I}{Is}\right) - 1} t_I > [s]$$

Extremely Inverse (Type C)

$$t = \frac{80}{\left(\frac{I}{Is}\right)^{2} - 1} t_I > [s]$$

Long Time Inverse

$$t = \frac{120}{\left(\frac{I}{Is}\right) - 1} t_I > [s]$$

RI-Inverse Time

$$t = \frac{1}{0.339 - \frac{0.236}{\left(\frac{I}{I_S}\right)}} t_I > [s]$$

*RXIDG – characteristic

$$t = 5.8 - 1.3 * \left[I_n \cdot \left(\frac{I}{I_S}\right)\right] \cdot t_I > [s]$$

Where:

t = tripping time
$t_I>$ = time multiplier
I = fault current
Is = Starting current
I_N = natural logarithm

*only for earth current

7.3.4 Earth fault protection (*ER/XR-Type*)

	Setting ronge	Step	Toleronce
$I_E>$ $t_{IE}>$	0.01...0.45 x I_N (EXIT) (ER) 0.1...4.5% I_N (EXIT) (XR) 0.05 - 260 s (definite time)	0.001; 0.002; 0.005; 0.01 x I_N 0.01%; 0.02%; 0.05%; 0.1% x I_N 0.01; 0.02; 0.05; 0.1; 0.2; 0.5; 1.0; 2.0; 5.0; 10; 20 s	±5% from set value or ±0.3% I_N (ER); ±0.03% I_N (XR) ±3% or ±15 ms
$I_E>>$ $t_{IE}>>$	0.01...0.45 x I_N (EXIT) (ER) 0.1...4.5% I_N (EXIT) (XR) 0.05...2.0 s	0.001; 0.002; 0.005; 0.01x I_N 0.01%; 0.02%; 0.05%; 0.1% x I_N 0.01 s; 0.02 s; 0.05 s	±5% from set value or ±0.3% I_N (ER); ±0.03% I_N (XR) ± 3% or ±15 ms
$U_E>$	U_N = 100 V: 3 PHA/e-n: 1 - 70 V 1:1: 1- 120 V U_N = 230 V: 3 PHA/e-n: 2 - 160 V 1:1: 2 - 300 V U_N = 400 V: 3 PHA/e-n: 5 - 300 V 1:1: 5 - 500 V	 1 V 1 V 2 V 2 V 5 V 5 V	±5% from set value or <0.5% U_N

7.3.5 Block/Trip – time

$t_{BLOCK/TRIP}$	0,1...2,0 s; EXIT	0,01; 0,02; 0,05; 0,1 s	±1% bzw. ±10 ms

7.3.6 Switch failure protection

t_{CBFP}	0,1...2,0 s; EXIT	0,01; 0,02; 0,05; 0,1 s	±1% bzw. ±10 ms

7.3.7 Interface parameter

Function	Porometer	Modbus-Protocol	RS485 Open Doto Protocol
RS	Slove-Address	1 - 32	1 - 32
RS	Baud-Rate*	1200, 2400, 4800, 9600	9600 (fixed)
RS	Parity*	even, odd, no	"even Parity" (fixed)

*only Modbus Protocol

7.3.8 Parameter for the fault recorder

Function	Parameter	Adjustment example
FR	Number of recordings	(1)* 2 x 8 s; (3)* 4 x 4 s; (7)* 8 x 2 s (with 50 Hz) (1)* 2 x 6.66 s, (3)* 4 x 3.33 s, (7)* 8 x 1.66 s
FR	Saving of the recording at the occurence	P_UP; TRIP; A_PI; TEST
FR	Pre-trigger-time	0.05 s – 8.00 s

* is written over at new trigger signal

7.3 Setting ranges and steps

System parameter

	Setting range	Step	Tolerance
I_{prim} IE_{prim}	(SEK) 0.001...50.0 kA	0.001; 0.002; 0.005; 0.01; 0.02; 0.05; 0.1; 0.2	
U_{prim} (U_{1prim}/ U_{Eprim})	(SEK) 1.01...6500	0.01; 0.02; 0.05; 0.1; 0.2; 0.5; 1; 2; 5; 10; 20; 50	

7.3.1 Time overcurrent protection (*I-Type*)

	Setting range	Step	Tolerance
I> tI>	0.2...4.0 x I_N 0.03 - 260 s (definite time) 0.05 - 10 (inverse time)	0.01; 0.02; 0.05; 0.1 x I_N 0.01; 0.02; 0.05; 0.1; 0.2; 0.5; 1.0; 2.0; 5.0; 10; 20 s 0.01; 0.02; 0.05; 0.1; 0.2	±3% from set value or min. ±2% In ±3% or ±10 ms ±5% for NINV and VINV ±7.5% for NINV and EINV
I>> $t_{I>>}$	0.5...40 x I_N 0.03...10 s	0.02; 0.05; 0.1; 0.2; 0.5; 1.0 x I_N 0.01 s; 0.02 s; 0.05 s; 0.1 s; 0.2 s	±3% from set value or min. ±2% In ±3% or ±10 ms

7.3.2 Earth fault protection (*SR-Type*)

	Setting range	Step	Tolerance
I_E> t_{IE}>	0.01...2.0 x I_N 0.03 - 260 s (definite time) 0.05 - 10 (inverse time)	0.001; 0.002; 0.005; 0.01; 0.02; 0.05 x I_N 0.01; 0.02; 0.05; 0.1; 0.2; 0.5; 1.0; 2.0; 5.0; 10; 20 s 0.01; 0.02; 0.05; 0.1; 0.2	±5% from set value or ±0.3% I_N ±3% or ±15 ms
I_E>> t_{IE}>>	0.01...15 x I_N 0.03...10 s	0.001; 0.002; 0.005; 0.01; 0.02; 0.05; 0.1; 0.2; 0.5 x I_N 0.01 s; 0.02 s; 0.05 s; 0.1 s; 0.2 s	±5% from set value ±3% or ±15 ms

7.3.3 Earth fault protection (*E/X-Type*)

	Setting range	Step	Tolerance
I_E> t_{IE}>	0.01...2.0 x I_N (EXIT) (E) 0.1...20% I_N (EXIT) (X) 0.03 - 260 s (definite time) 0.05 - 10 (inverse time)	0.001; 0.002; 0.005; 0.01; 0.02; 0.05 x I_N 0.01; 0.02; 0,05% I_N 0.01; 0.02; 0.05; 0.1; 0.2; 0.5; 1.0; 2.0; 5.0; 10; 20 s 0.01; 0.02; 0.05; 0.1; 0.2	±5% from set value or ±0.3% I_N(E); ±0.03% I_N(X) ±3% or ±15 ms
I_E>> t_{IE}>>	0.01...15.0 x I_N (E) 0.1...150% I_N (EXIT) (X) 0.03...10.0 s	0.001; 0.002; 0.005; 0.01; 0.02; 0.05 0.1; 0.2; 0.5 x I_N 0.01; 0.02; 0,05 % I_N 0.01 s; 0.02 s; 0.05 s	±5% from set value or ±0.3% I_N(E); ±0.03% I_N(X) ±3% or ±15 ms

7 Technical data

7.1 Measuring input circuits

Rated data:	Nominal current I_N	1 A or 5 A
	Nominal voltage U_N	100 V, 230 V, 400 V
	Nominal frequency f_N	50 Hz; 60 Hz adjustable
Power consumption in current circuit:	at I_N = 1 A	0.2 VA
	at I_N = 5 A	0.1 VA
Power consumption in voltage circuit:	<1 VA	
Thermal withstand capability in current circuit:	dynamic current withstand	
	(half-wave)	250 x I_N
	for 1 s	100 x I_N
	for 10 s	30 x I_N
	continuously	4 x I_N
Thermal withstand in voltage circuit:	continuously	1.5 x U_N
GL-Approbation:	98776-96HH	
Bureau Veritas Approbation:	2650 6807 A00 H	

7.2 Common data

Dropout to pickup ratio:	>97%
Dropout to pickup ratio for phase current in range 0.2 x I_N to 0.5 x I_N:	= 100 %
Returning time:	30 ms
Time lag error class index E:	±10 ms
Minimum operating time:	30 ms
Transient overreach at instantaneous operation:	≤5%
Influences on the current measurement	
Auxiliary voltage:	in the range of 0.8 <U_H / U_{HN} <1.2 no additional influences can be measured
Frequency:	in the range of 0.9 < f/f_N < 1.1; <0.2% / Hz
Harmonics:	up to 20% of the third harmonic; <0.08% per percent of the third harmonic up to 20% of the fifth harmonic; <0.07% per percent of the fifth harmonic
Influences on delay times:	no additional influences can be measured
GL-approbation:	98 775 - 96 HH

6.6 Maintenance

Maintenance testing is generally done on site at regular intervals. These intervals vary among users depending on many factors: e.g. the type of protective relays employed; the importance of the primary equipment being protected; the user's past experience with the relay, etc.
For electromechanical or static relays, maintenance testing will be performed at least once a year according to the experiences. For digital relays like *MRI3*, this interval can be substantially longer. This is because:

- The *MRI3* relays are equipped with very wide self-supervision functions, so that many faults in the relay can be detected and signalized during service. Important: The self-supervision output relay must be connected to a central alarm panel!
- The combined measuring functions of *MRI3* relays enable supervision the relay functions during service.
- The combined TRIP test function of the *MRI3* relay allows to test the relay output circuits.

A testing interval of two years for maintenance will, therefore, be recommended.
During a maintenance test, the relay functions including the operating values and relay tripping characteristics as well as the operating times should be tested.

6.4.9 Checking the external blocking and reset functions

By meons of the externol blocking input, it is possible to block oll protective functions. To give on example, the blocking function of the phase current high set element is described.
This can be tested by first setting the parameter for the phase current high set element to „BLOC" ond then connecting the auxiliary voltage to terminals E8/D8. The phase current low set element I> should be set to EXIT far this test. Inject a test current which cauld cause o high set (I>>) tripping. Observe thot there is no trip of any ossigned output relay af the high set or low set element.

Remove the auxiliary supply voltage from the blocking input. Inject a test current to trip the relay (message „TRIP" on the display). Interrupt the test current and apply ouxiliory supply voltoge to the externol reset input of the relay (terminals C8/D8). The display and LED indicatians should be reset immediotely.

6.4.10 Testing the external blocking with Block/Trip function

In arder to simplify things, the short-circuit stage is to be tested here as described in Chapter 5.7.1.
For this purpose, the porameter for the Block/Trip function must be set to "TR_B" (first value in the blocking menu of the protection functions Chapter 5.7.1. The oppertaining Block/Trip time should be longer than the set tripping time tI>> (see chapter 5.4.18). Here, too, a current is impressed which should make the short-circuit stage trip. After the Block/Trip time has expired, tripping will toke place. Tripping takes place when:

- the blocking input has been set
- o tripping stoge has been excited
- the appertaining tripping time has expired
- the Block/trip time has expired

If the Block/Trip time is set shorter than the tripping time, tripping will only toke place after the tripping time has expired.

6.4.11 Test of the CB failure protection

For testing the tripping time o test current of about 2 times the roted current to be injected. The timer is started upon tripping of the reloy of a protection function (I>, I>>, I_E>, I_E>>) and stopped os soon as the relay for the CB failure protection has picked up. Message "CBFP" is disployed. The tripping time ascertained by the timer should not deviate more than 1% or, at short trip delay, less thon ±10 ms from the set tripping time.
Alternatively, the timer can be started when the aux. voltage and the test current are injected simultaneously. The timer stops when the corresponding output relay for circuit breaker failure protection trips.
In this cose the previously meosured tripping delay has to be subtracted from the totol tripping time meosured.

6.5 Primary injection test

Generally, a primary injection test could be carried out in the similar manner as the secondary injection test described above. With the difference that the protected power system should be, in this cose, connected to the installed relays under test "on line", and the test currents and voltages should be injected to the relay through the current and voltage transformers with the primary side energized. Since the cast and potential hazards are very high for such a test, primary injection tests are usually limited to very important protective reloys in the power system.

Because of its powerful combined indicating and measuring functions, the *MRI3* relay may be tested in the manner of a primary injection test without extra expenditure and time consumption.
In actual service, for example, the measured current values on the *MRI3* relay display moy be compared phase by phase with the current indications of the ammeter of the switchboard to verify that the relay works ond measures correctly. In case of o *MRI3* relay with directional feature, the active and reactive parts of the measured currents may be checked and the actual power factor moy be calculated and compared it with the cosφ -meter indication on the switchboard to verify that the relay is connected to the power system with the correct polority.

6.4.8 Test circuit earth fault directional feature

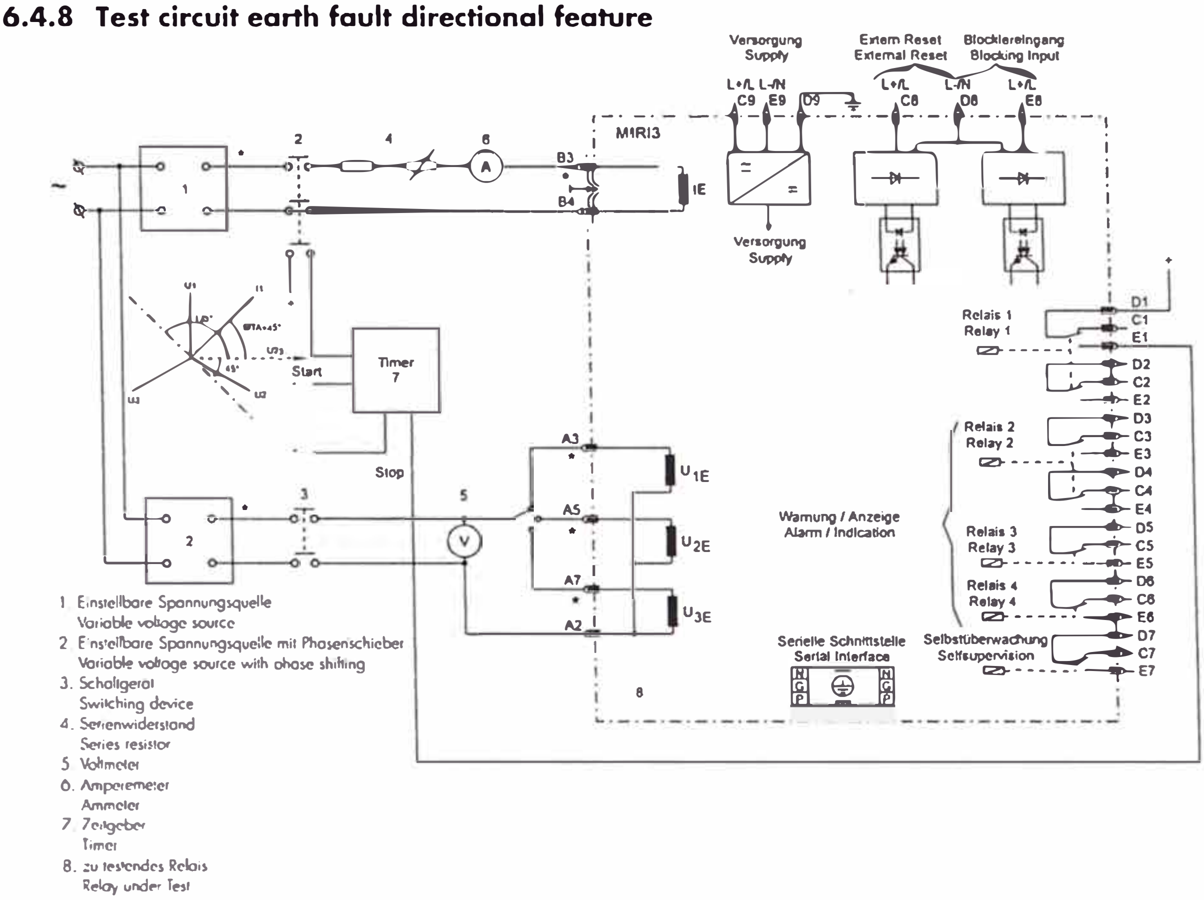


Figure 6.3: Test circuit

For testing relays with earth fault directional feature, current and voltage input signals with adjustable phase shifting are required. Figure 6.3 shows an example of a single phase test circuit with adjustable voltage and current energizing the *MRI3* relay under test.
For testing a relay with earth fault directional feature, one of the input energizing quantity (voltage) shall be applied to the relay with a constant value within its effective range. The other input energizing quantity (current) and phase angle shall be appropriately varied.

With the aid of phase angle indicated on the display the correct function of the relay can be checked (ER-relay type).

Parameters $I_{E>}$ and $I_{E>>}$should be set to EXIT.

The following measured values are shown:

Measured value	LED
Earth current	E, $I_{E>}$
Active share	E, I_P
reactive share	E, I_Q
Earth voltage	E, $U_{E>}$
Angel	E, $I_{E>}$, $U_{E>}$

Table 6.4

Current input	Terminals	Reference voltage	Terminals	Display		
	S2/S1		L/N	Phase	I_P	I_Q
I1	B3/B4	U23	A5/A7	1.00 ±3%	±0.0 ±3% In	+1.0 ±3% In
I2	B5/B6	U31	A3/A7	1.00 ±3%	±0.0 ±3% In	+1.0 ±3% In
I3	B7/B8	U12	A3/A5	1.00 ±3%	±0.0 ±3% In	+1.0 ±3% In
E*	B1/B2	U1	A3/A2	1.00 ±5%	+1.0 ±5% In	±0.0 ±5% In

Table 6.1: Input currents and corresponding on the conductor voltages

* Only SR-Types

In order to check this, the following parameters should be set:

Parameter	Setting
I>	0,5 x In
tI> (V)	EXIT
tI> (R)	EXIT
IE>	0,5 x In
tIE> (V)	EXIT
tIE> (R)	EXIT

Table 6.2

for relay assignment:

Parameter	Relays
I> Alarm (V)	_2__
I> Alarm (R)	__3_
IE> Alarm (V)	_2__
IE> Alarm (R)	__3_

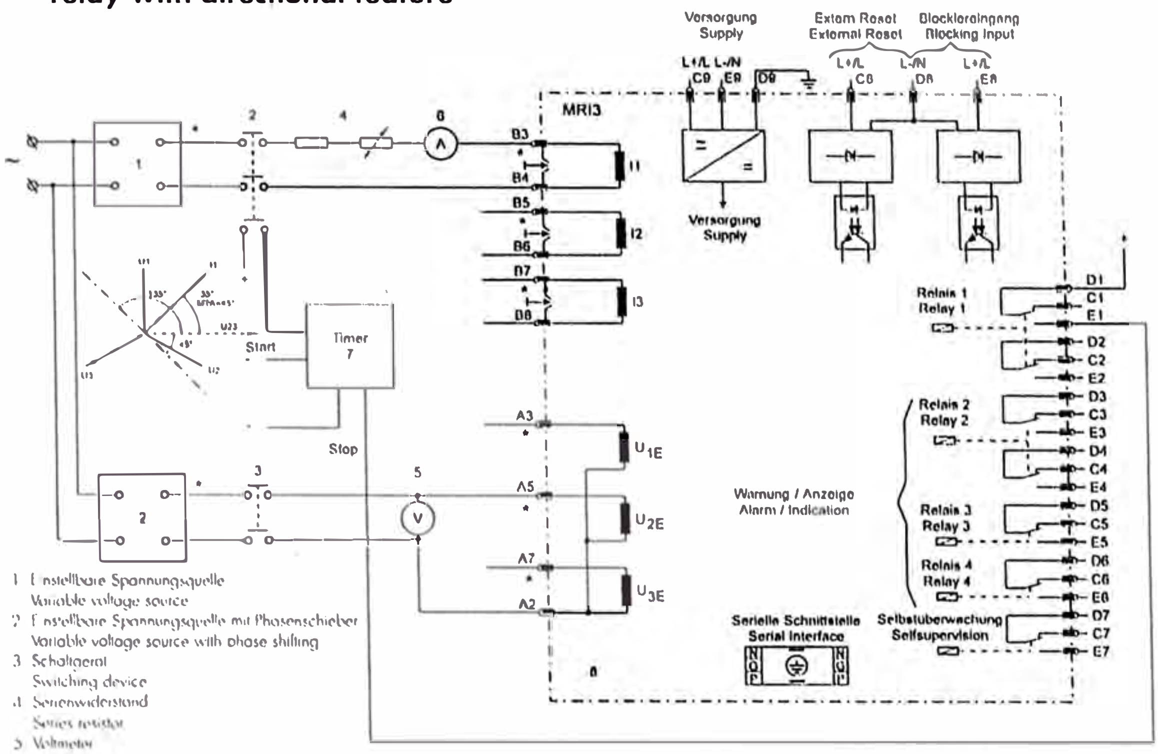
Table 6.3

A test current of 1 x In is impressed upon the current input I1. The voltage source is to be connected as provided for in Table 6.1. With an angle setting of 49° leading, relay 2 must respond and LED →← lights up green. If the angle is now changed beyond the marginal regions, the LED →← changes from green to red. Relay 2 drops and relay 3 responds. This test must be repeated for current inputs I2 and I3.

In order to determine the direction in the earth current circuit (SR version) refer to 4.11 with the characteristic angle in the rigid grid (SOLI) and to Fig. 4.12 with the characteristic angle in the grid with resistance earthing (RESI).

To check the trip delays for forward and backward direction they have to be set differently, because there's only one trip relay for both directions.
Great care must be taken to connect the test current and test voltage to the relay in correct polarity. In Figure 6.2 the relay and test source polarity are indicated by a * mark near the terminals. The markings indicate that the relay will trip in its maximum sensitive angle when the voltage drop from the marked end to the non-marked end in the voltage input circuit has 49° phase angle lagging the current flowing from the marked end to the non-marked in the current input circuit. Of course, regardless of polarity, the current level must be above the pickup value.

6.4.7 Example of a test circuit for *MRI3* relay with directional feature



1 Einstellbare Spannungsquelle
Variable voltage source
2 Einstellbare Spannungsquelle mit Phasenschieber
Variable voltage source with phase shifting
3 Schaltgerät
Switching device
4 Serienwiderstand
Series resistor
5 Voltmeter
6 Amperemeter
Ammeter
7 Zeitgeber
Timer
8 zu testendes Relais
Relay under Test

Figure 6.2: Test curcuit

For testing relays with directional feature, current and voltage input signals with adjustable phase shifting are required. Figure 6.2 shows an example of a single phase test circuit with adjustable voltage and current energizing the *MRI3* relay under test.
For testing a relay with directional feature, one of the input energizing quantity (voltage) shall be applied to the relay with a constant value within its effective range. The other input energizing quantity (current) and phase angle shall be appropriately varied.
MRI3 is a three phase directional time overcurrent relay with relay connection angle of 0°. The relay input currents and their corresponding reference voltages are shown in Table 6.1 (also refer to 4.3):

If the single phase test circuit as illustrated in Figure 6.2 is applied to test the directional feature of the relay and the current source is connected to phase 1 current input (B3/B4), then the voltage source should be connected to relay terminals A5/A7.

In order to test the directional feature, all thresholds should first be set to "EXIT". Then a test voltage equivalent to the rated voltage is connected to terminals A5/A7 and a current of 1 x In is impressed upon the current inputs B3/B4.
It is now possible to read and check all measured values in accordance with Table 6.1. If the phase position is changed, the values I_Q and I_P change. If the angle is changed by 90°, for example, the measured value for current input I1 must be 1.0 for I_P and ±0.0 for I_Q.

Determining the change in direction

The angle of greatest sensitivity for determining the phase direction is adjustable between 15° and 83°. Consequently, the greatest sensitivity is achieved with setting 49° if the input current leads the input voltage by 49°. This setting results in a tripping range in forward direction of 139° leading to 41° lagging if the marginal regions are neglected on account of lack in measuring precision.

6.4.5 Checking the relay operating time

To check the relay operating time, a timer must be connected to the trip output relay contact. The timer should be started simultaneously with the current injection in the current input circuit and stopped by the trip relay contact. Set the current to a value corresponding to twice the operating value and inject the current instantaneously. The operating time measured by the timer should have a deviation of less than 3% of the set value or ±10 ms (DEFT). Accuracy for inverse time characteristics refer to IEC 255-3.
Repeat the test on the other phases or with the inverse time characteristics in the similar manner.
In case of inverse time characteristics the injected current should be selected according to the characteristic curve, e.g. two times I_S. The tripping time may be red from the characteristic curve diagram or calculated with the equations given under "technical data".
Please obser e that during the secondary injection test the test current must be very stable, not deviating more than 1%. Otherwise the test results may be wrong.

6.4.6 Checking the high set element of the relay

Set a current above the set operating value of I>>. Inject the current instantaneously and check that the alarm output relay I>> operates. Check the tripping time of the high set element according chapter 6.4.5.
Check the accuracy of the operating current setting by gradually increasing the injected current until the I>> element picks up. Read the current value form the ammeter and compare with the desired setting.
Repeat the entire test on other phases and earth current input circuits in the same manner.

Note !
Where test currents >4 x I_N are used, the thermal withstand capability of the current paths has to be considered (see technical data, chapter 7.1).

6.4.2 Example of test circuit for *MRI3* relays without directional feature

For testing *MRI3* relays without directional feature, only current input signals are required. Figure 6.1 shows a simple example of a single phase test circuit with ad-justable current energizing the *MRI3* relay under test.

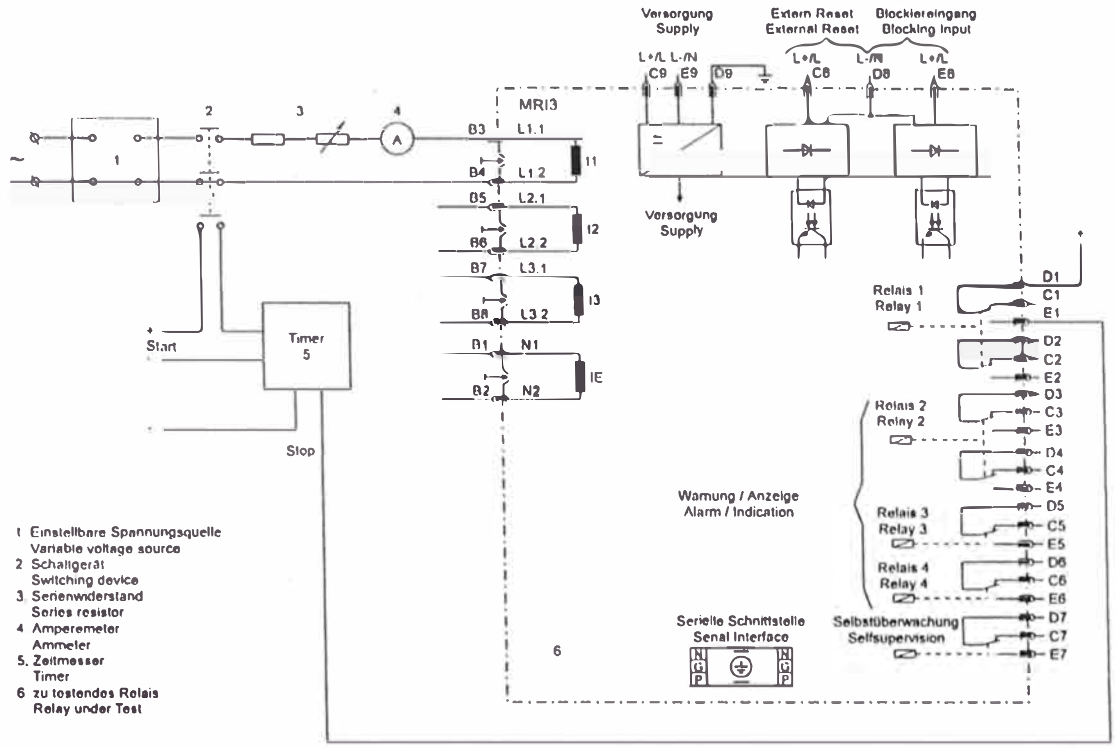


Figure 6.1: Test curcuit

6.4.3 Checking the input circuits and measured values

Inject a current, which is less than the relay pickupcurrent set values, in phase 1 (terminals B3-B4), and check the measured current on the display by pressing the push button <SELECT>. For a relay with rated current In = 5A, for example, a secondary current injection of 1A should be indicated on the display with about 0.2 (0.2 x In). When parameter Iprim = „SEK" is set, the indication is 0.2 x In and at „5" the indication is 1.00 [A]. The current can be also injected into the other current input circuits (Phase 2: terminals B5-B6, Phase 3: terminals B7-B8. Compare the displayed current value with the reading of the ammeter. The deviation must not exceed 3% or 1% In. By using an RMS-metering instrument, a greater deviation may be observed if the test current contains harmonics. Because the *MRI3* relay measures only the fundamental component of the input signals, the harmonics will be rejected by the internal DFFT-digital filter. Whereas the RMS-metering instrument measures the RMS-value of the input signals.

6.4.4 Checking the operating and resetting values of the relay

Inject a current which is less than the relay set values in phase 1 of the relay and gradually increase the current until the relay starts, i.e. at the moment when the LED I> and L1 light up or the alarm output relay I> is activated. Read the operating current indicated by the ammeter. The deviation must not exceed 3% of the set operating value or 1% In.
Furthermore, gradually decrease the current until the relay resets, i.e. the alarm output relay I> is disengaged. Check that the resetting current is smaller than 0.97 times the operating current.
Repeat the test on phase 2, phase 3 and earth current input circuits in the same manner.(Accuracy of earth current measuring ±3% of measuring value or 0.1% of In for E-type; 0.01% of In for X-type).

6 Relay testing and commissioning

The test instructions following below help to verify the protection relay performance before or during commissioning of the protection system. To avoid a relay damage and to ensure a correct relay operation, be sure that:

- The auxiliary power supply rating corresponds to the auxiliary voltage on site.
- The rated current and rated voltage of the relay correspond to the plant data on site.
- The current transformer circuits and voltage transformer circuits are connected to the relay correctly.
- All signal circuits and output relay circuits are connected correctly.

6.1 Power-On

NOTE!
Prior to switch on the auxiliary power supply, be sure that the auxiliary supply voltage corresponds with the rated data on the type plate.
Switch on the auxiliary power supply to the relay and check that the message "ISEG" appears on the display and the self supervision alarm relay (watchdog) is energized (Contact terminals D7 and E7 closed).

6.2 Testing the output relays and LEDs

NOTE!
Prior to commencing this test, interrupt the trip circuit to the circuit breaker if tripping is not desired.
By pressing the push button <TRIP> once, the display shows the first part of the software version of the relay (e.g. "D08-"). By pressing the push button <TRIP> twice, the display shows the second part of the software version of the relay (e.g. "4.01"). The software version should be quoted in all correspondence. Pressing the <TRIP> button once more, the display shows "PSW?". Please enter the correct password to proceed with the test. The message "TRI?" will follow. Confirm this message by pressing the push button <TRIP> again. All output relays should then be activated and the self supervision alarm relay (watchdog) be deactivated one after another with a time interval of 3 second and all LEDs with a delay of 0.5 seconds, with the self-supervision relay dropping. Thereafter, reset all output relays back to their normal positions by pressing the push button <SELECT/RESET> (about 3 s).

6.3 Checking the set values

By repeatedly pressing the push button <SELECT>, all relay set values may be checked. Set value modification can be done with the push button <+><-> and <ENTER>. For detailed information about that, please refer to chapter 5.
For a correct relay operation, be sure that the frequency set value (f=50/60) has been selected according to your system frequency (50 or 60 Hz).

6.4 Secondary injection test

6.4.1 Test equipment

- Voltmeter, Ammeter with class 1 or better,
- auxiliary power supply with the voltage corresponding to the rated data on the type plate,
- single-phase current supply unit (adjustable from 0 to ≥ 4 x In),
- single-phase voltage supply unit (adjustable from 0 to ≥ 1.2 x Un) (Only for relays with directional feature),
- timer to measure the operating time (Accuracy class ≤ ±10 ms),
- switching device and
- test leads and tools.

5.9.4 Fault memory

When the relay is energized or trips, all fault data and times are stored in a non-volatile memory manner. The *MRI3* is provided with a fault value recorder for max. five fault occurrences. In the event of additional trippings always the oldest data set is written over.

For fault indication not only the trip values are recorded but also the status of LEDs. Fault values are indicated when push buttons <-> or <+> are pressed during normal measuring value indication.

- Normal measuring values are selected by pressing the <SELECT/RESET> button.
- When then the <-> button is pressed, the latest fault data set is shown. By repeated pressing the <-> button the last but one fault data set is shown etc. For indication of fault data sets abbreviations FLT1, FLT2, FLT3, ... are displayed (FLT1 means the latest fault data set recorded). At the same time the parameter set active at the occurence is shown.
- By pressing <SELECT/RESET> the fault measuring values can be scrolled.
- By pressing <+> it can be scrolled back to a more recent fault data set. At first FLT8, FLT7, ... are always displayed. When fault recording is indicated (FLT1 etc), the LEDs flash in compliance with the stored trip information, i.e. those LEDs which showed a continuous light when the fault occured are now blinking blinking to indicate that it is not a current fault. LEDs which were blinking blinking during trip conditions, (element had picked up) just briefly flash.
- If the relay is still in trip condition and not yet reset (TRIP is still displayed), no measuring values can be shown.
- To delete the trip store, the push button combination <SELECT/RESET> and <-> has to be pressed for about 3s. The display shows "wait".

Recorded fault values:

Value displayed		Relevant LED
Phase currents L1, L2, L3 in I/In		L1, L2, L3
Earth current I_E in $I/I_E n$		E
C.B. switching time in s [1]		C.B.
Expired tripping time of I> in % of $t_{I>}$ [2]		I>
Expired tripping time of $I_{E>}$ in % of $t_{IE>}$ [2]		$I_{E>}$
Time stamp		
Date:	Y = 99	◷
	M = 04	◷
	D = 20	◷
time:	h = 11	◷
	m = 59	◷
	s = 13	◷

Table 5.3

[1] C.B. tripping time:
Time between energizing of the trip output relay and switching of the C.B. (current < 1 % I_N)).

[2] Expired tripping time:
Time between pickup and release of the low set element. This value is only displayed for I> and $I_{E>}$.

5.10 Reset

Unit *MRI3* has the following three possibilities to reset thedisplay of the unit as well as the output relay at jumper position J3=ON.

Manual Reset
- Pressing the push button <SELECT/RESET> for some time (about 3 s)

Electrical Reset
- Through applying auxiliary voltage to C8/D8

Software Reset
- The software reset has the same effect as the <SELECT/RESET> push button (see also communication protocol of RS485 interface).

The display can only be reset when the pickup is not present anymore (otherwise "TRIP" remains in display). During resetting of the display the parameters are not affected.

5.10.1 Erasure of fault storage

The fault storage is erased by pressing the key combination <SELECT/RESET> and <-> for about 3 s. At the display "Wait" appears.

5.9.2 Units of the measuring values displayed

The measuring values can optionally be shown in the display as a multiple of the "sec" rated value (xIn) or as primary current (A). According to this the units of the display change as follows:

Phase current:

Indication as	Range	Unit
Secondary current Active portion I_P Reactive portion I_Q	0.00 – 40.0 ±.00 – 40 ±.00 – 40.	x In x In x In
Primary current	.000 – 999. k000 – k999 1k00 – 9k99 10k0 – 99k0 100k – 999k 1M00 – 2M00	A kA* kA kA kA MA
active portion I_P	±.00 – ±999 ±k00 – ±k99 ±1k0 – ±9k9 ±10k – ±99k ±M10 – ±M99 ±1M0 – ±2M0	A kA* kA kA MA MA
Reactive portion I_Q	±.00 – ±999 ±k00 – ±k99 ±1k0 – ±9k9 ±10k – ±99k ±M10 – ±M99 ±1M0 – ±2M0	A kA* kA kA MA MA

*rated current transformer >2kA

Earth current (sensitive):

Indication as	Range	Unit
Secondary current Active portion I_P Reactive portion I_Q (X/XR types)	.000 – 15.0 ±.00 – 15 ±.00 – 15	x In x In x In
Primary earth current	00m0 – 99m9 100m – 999m .000 – 999. k000 – k999 1k00 – 9k99	mA* mA* A kA* kA
Active portion I_P	±00m - ±99m ±.10 – ±999 ±k00 – ±k99 ±1k0 – ±9k9	mA* A kA** kA
Reactive portion I_Q	±00m - ±99m ±.00 – ±999 ±k00 – ±k99 ±1k0 – ±9k9	mA* A kA** kA

* rated current transformer 0.019kA
** rated current transformer 20kA

Earth current (normal):

Indication as	Range	Unit
Secondary current Active portion I_P Reactive portion I_Q (E/SR/ER types)	.000 – 15.0 ±.00 – 15 ±.00 – 15.	x In x In x In
Primary earth current	.000 – 999. k000 – k999 1k00 – 9k99 10k0 – 99k0 100k – 999k 1M00 – 2M00	A kA* kA kA kA MA
Active portion I_P	±.00 – ±999 ±k00 – ±k99 ±1k0 – ±9k9 ±10k – ±99k ±M10 – ±M99 ±1M0 – ±2M0	A kA* kA kA MA MA
Reactive portion I_Q	±.00 – ±999 ±k00 – ±k99 ±1k0 – ±9k9 ±10k – ±99k ±M10 – ±M99 ±1M0 – ±2M0	A kA* kA kA MA MA

* rated current transformer >2kA

Earth voltage:

Indication as	Range	Unit
sec. Voltage	000V – 999V	V
primary voltage	.000 – 999V 1K00 – 9K99 10K0 – 99K9 100K – 999K 1M00 – 3M00	KV KV KV KV MV

5.9.3 Indication of fault data

All faults detected by the relay are indicated on the front plate optically. For this purpose, the four LEDs (L1, L2, L3, E) and the four function LEDs (I>, I>>, IE>, IE>> und →←) are equipped at *MRI3*. Not only fault messages are transmitted, the display also indicates the tripped protection function. If, for example an overcurrent occurs, first the corresponding LEDs will light up. LED I> lights up at the same time. After tripping the LEDs are lit permanently.

5.8 Setting value calculation

5.8.1 Definite time overcurrent element

Low set element (I>)
The pickup current setting is determined by the load capacity of the protected object and by the smallest fault current within the operating range. The pickup current is usually selected about 20% for power lines, about 50% for transformers and motors above the maximum expected load currents.

The delay of the trip signal is selected with consideration to the demand on the selectivity according to system time grading and overload capacity of the protected object.

High set element (I>>)
The high set element is normally set to act for near-by faults. A very good protective reach can be achieved if the impedance of the protected object results in a well-defined fault current. In case of a line-transformer combination the setting values of the high set element can even be set for the fault inside the transformer. The time delay for high set element is always independent to the fault current.

5.8.2 Inverse time overcurrent element

Beside the selection of the time current characteristic one set value each for the phase current path and earth current path is adjusted.

Low set element I>
The pickup current is determined according to the maximum expected load current. For example:
Current transformer ratio: 400/5 A
Maximum expected load current: 300 A
Overload coefficient: 1.2 (assumed)
Starting current setting:
$Is = (300/400) \times 1.2 = 0.9 \times I_N$

Time multiplier setting
The time multiplier setting for inverse time overcurrent is a scale factor for the selected characteristics. The characteristics for two adjacent relays should have a time interval of about 0.3 - 0.4 s.

High set element I>>
The high set current setting is set as a multiplier of the nominal current. The time delay tI>> is always independent to the fault current.

5.9 Indication of measuring and fault values

5.9.1 Indication of measuring values

The following measuring quantities can be indicated on the display during normal service:

- Apparent current in phase 1 (LED L1 green),
- active current in Phase 1 (LED L1 and I_P green),*
- reactive current in Phase 1 (LED L1 and I_Q green),*
- apparent current in phase 2 (LED L2 green),
- active current in Phase 2 (LED L2 and I_P green),*
- reactive current in Phase 2 (LED L2 and I_Q green),*
- apparent current in phase 3 (LED L3 green),
- active current in Phase 3 (LED L3 and I_P green),*
- reactive current in Phase 3 (LED L3 and I_Q green),*
- apparent earth current (LED E green),
- active earth current (LED E and I_P green),*
- reactive earth current (LED E and I_Q green),*
- residual voltage UR (LED U_E) only at ER/XR-relay type,
- angle between I_E and U_E (only ER/XR) (LED E green, LED $I_{E>}$ yellow and LED $U_{E>}$ yellow).

* only in case that the directional option is built in.

The indicated current measuring values refer to rated current. (For *MRI3-XR/X* relays the indicated measuring values refer to % of I_N)

After the assignment mode has been activated, first LED I> lights up green. Now one or several of the four output relays can be assigned to current element I> as alarm relays. At the same time the selected alarm relays for frequency element 1 are indicated on the display. Indication "1_ _ _" means that output relay 1 is assigned to this current element. When the display shows "_ _ _ _", no alarm relay is assigned to this current element. The assignment of output relays 1 - 4 to the current elements can be changed by pressing <+> and <-> push buttons. The selected assignment can be stored by pressing push button <ENTER> and subsequent input of the password. By pressing push button <SELECT/RESET>, LED I> lights up red. The output relays can now be assigned to this current element as tripping relays.

Relays 1 - 4 are selected in the same way as described before. By repeatedly pressing of the <SELECT/RESET> push button and assignment of the relays all elements can be assigned separately to the relays. The assignment mode can be terminated at any time by pressing the <SELECT/RESET> push button for some time (abt. 3 s).

Note:

- The function of jumper J2 described in general description "MR Digital Multifunctional Relays" has no function. For relays without assignment mode this jumper is used for parameter setting of alarm relays (activation at pickup or tripping).
- A form is attached to this description where the setting requested by the customer can be filled-in. This form is prepared for telefax transmission and can be used for your own reference as well as for telephone queries.

Relay function		Output relays				Display-indication	Lighted LED
			2	3	4		
I> (V)	alarm		X			_ 2 _ _	I>; →← green
tI> (V)	tripping	X				1 _ _ _	$I_{I>}$; →← green
I> (R)	alarm		X			_ 2 _ _	I>; →← red
tI> (R)	tripping	X				1 _ _ _	$I_{I>}$; →← red
I>> (V)	alarm			X		_ _ 3 _	$I_{>>}$; →← green
tI>> (V)	tripping	X				1 _ _ _	$I_{I>>}$; →← green
I>> (R)	alarm			X		_ _ 3 _	$I_{>>}$; →← red
tI>> (R)	tripping	X				1 _ _ _	$I_{I>>}$;→← red
IE> (V)	alarm				X	_ _ _ 4	$I_{E>}$; →← green
tIE> (V)	tripping	X				1 _ _ _	$I_{IE>}$; →← green
IE> (R)	alarm				X	_ _ _ 4	$I_{E>>}$; →← red
tIE> (R)	tripping	X				1 _ _ _	$I_{IE>>}$; →← red
IE>> (V)	alarm				X	_ _ _ 4	$I_{E>>}$; →← green
tIE>> (V)	tripping	X				1 _ _ _	$I_{IE>>}$; →← green
IE>> (R)	alarm				X	_ _ _ 4	$I_{E>>}$; →← red
tIE>> (R)	tripping	X				1 _ _ _	$I_{IE>>}$; →← red
tCBFP	tripping					_ _ _ _	C.B.; red

(V) = forward direction;
(R) = backward direction

This way, a tripping relay can be set for each activation and tripping direction.

Table 5.4: Example of assignment matrix of the output relays (default settings).

5.7 Additional functions

5.7.1 Blocking the protection functions and assignment of the output relays

Blocking of the protective functions:
The *MRI3-IHE* is equipped with a blocking function that can be parameterized arbitrary. Connecting supply voltage to terminals D8/E8 blocking of those functions which were selected by the user takes place.
It is possible to choose between two types of protective blocking:

1. Blocking of the individual protection stages. The excitation of the blocked protection stage is blocked..
2. Blocking of the individual tripping stages. The individual protection stages are excited and the set tripping time expires. Tripping only takes place when:

a) the voltage at the blocking input D8/E8 is reduced;
b) the voltage at the blocking input D8/E8 is applied, the tripping time and the blocking time have expired. (refer to Chapter 5.4.8)

Parameter setting is to be carried out as follows:

- After the <ENTER> and <TRIP> keys have been actuated simultaneously, the display shows the text "PR_B" (the protection stages are blocked) or "TR_B" (the tripping stages are blocked).
- The settings can be changed by actuating the keys <+> or <->. In this procedure, the LEDs I>; I>>; IE>; IE>> are simultaneously alight in case of protective blocking "PR_B" and LEDs tI>; tI>>; tIE>, tIE>> simultaneously emit light in case of trip blocking "TR_B".
- Actuation of the <ENTER> key with a one-time entry of the password will store the set function.
- After this actuate the <SELECT/RESET> key to call up the first blockable protection function.
- The display will show the text "BLOC" (the respective function is blocked) or "NO_B" (the respective function is not blocked.
- Actuation of the <ENTER> key will store the set function.
- By pressing the <SELECT/RESET> pushbutton, all further protective function that can be blocked are called one after the other.

After selection of the last blocking function renewed pressing of the <SELECT/RESET> pushbutton switches to the assignment mode of the output relays.

Function		Display	LED/Colour
Blocking of the protection stage		PR_B	I>; I>>; $I_{E>}$; $I_{E>>}$
Blocking of the trip function		TR_B	$t_{I>}$; $t_{I>>}$; $t_{IE>}$; $t_{IE>>}$
I>	Overcurrent	NO_B	I> red
I>>	Short circuit	BLOC	I>> red
$I_{E>}$	Earth current 1st element	NO_B	$I_{E>}$ red
$I_{E>>}$	Earth current 2nd element	NO_B	$I_{E>>}$ red
t_{CBFP}	Circuit breaker failure protection	NO_B	CB green

Table 5.2: Default settings of both parameter sets

Assignment of the output relays:
Unit *MRI3* has five output relays. The fifth output relay is provided as permanent alarm relay for self supervision is normally on. Output relays 1 - 4 are normally off and can be assigned as alarm or tripping relays to the current functions which can either be done by using the push buttons on the front plate or via serial interface RS485. The assignment of the output relays is similar to the setting of parameters, however, only in the assignment mode. The assignment mode can be reached only via the blocking mode.
By pressing push button <SELECT/RESET> in blocking mode again, the assignment mode is selected.

The relays are assigned as follows: LEDs I>, I>>, $I_{E>}$, $I_{E>>}$ are two-coloured and light up green when the output relays are assigned as alarm relays and red as tripping relays.
In addition, the LED →← also lights up with each adjustment. Green means forward and red backward direction.

Definition:
Alarm relays are activated at pickup.
Tripping relays are only activated after elapse of the tripping delay.

5.4.22 Setting of parity (applies for Modbus Protocol only)

The following three parity settings are possible

- "even" = even
- "odd" = odd
- "no" = no parity check

The setting can be changed by push buttons <+> and <-> and saved by pressing <ENTER>.

5.5 Fault recorder

5.5.1 Adjustment of the fault recorder

The *MRI3* is equipped with a fault recorder (see chapter 3.2.1). Three parameters can be determined.

5.5.2 Number of the fault recordings

The max. recording time is 16 s at 50 Hz or 13.33 s at 60 Hz.

The number of max. recordings requested has to be determined in advance. There is a choice of (1)* 2, (3)* 4 or (7)* 8 recordings and dependent on this the duration of the individual fault recordings is defined, i.e.

(1)* 2 recordings for a duration of 8 s (with 50 Hz) (6.66 s with 60 Hz)
(3)* 4 recordings for a duration of 4 s (with 50 Hz) (3.33 s with 60 Hz)
(7)* 8 recordings for a duration of 2 s (with 50 Hz) (1.66 s with 60 Hz)
* is written over at new trigger signal

5.5.3 Adjustment of trigger occurences

There is a choice between four different occurences:

P_UP (PickUP)	Storage is initiated after recognition of a general activation
TRIP	Storage is initiated after a trip has occured
A_PI (After Pickup)	Storage is initiated after the last activation threshold was fallen short of.
TEST	Storing is activated by simultaneous actuation of the keys <+> and <->. During the recording time the display shows "Test".

5.5.4 Pre-trigger time (T_{pre})

By the time T_{pre} it is determined which period of time prior to the trigger occurence should be stored as well. It is possible to adjust a time between 0.05s and 8s. With keys <+> and <-> the values can be changed and with <ENTER> be saved.

5.6 Adjustment of the clock

When adjusting the date and time, LED ⏲ lights up. The adjustment method is as follows:

Date :	Year	Y=00
	Month	M=00
	Day	D=00
Time :	Hour	h=00
	Minute	m=00
	Second	s=00

The clock starts with the set date and time as soon as the supply voltage is switched on. The time is safe-guarded against short-term voltage failures (min. 6 minutes).

Note:
The window for parameter setting of the clock is located behind the measured value display. The parameter window can be accessed via the <SELECT/RESET> key.

5.4.11 Time current characteristics for earth fault element (CHAR I_E) (not for ER/XR-relay type)

By setting this parameter, one of the following 7 messages appears on the display:

DEFT	Definite Time (independent overcurrent time protection)
NINV	Normal inverse (Type A)
VINV	Very inverse (Type B)
EINV	Extremely inverse (Type C)
RINV	RI-Inverse
LINV	Long Time Inverse
RXID	Special characteristic

Anyone of these four characteristics can be chosen by using <+> <->-pushbuttons, and can be stored by using <ENTER>-pushbutton.

5.4.12 Trip delay or time multiplier for earth fault element ($t_{IE>}$)

(Similar to chapter 5.4.3)

5.4.13 Reset mode for inverse time tripping in earth current path

(Similar to chapter 5.4.4)

5.4.14 Current setting for high set element of earth fault supervision ($I_{E>>}$)

(Similar to chapter 5.4.5)
The pickup value of X and XR-relay type relates to % I_N.

5.4.15 Trip delay for high set element of earth fault supervision ($t_{IE>>}$)

(Similar to chapter 5.4.6)

5.4.16 COS/SIN Measurement (ER/XR-relay type)

Depending on the neutral earthing connection of the protected system the directional element of the earth fault relay must be preset to cos φ or sin φ measurement.
By pressing <SELECT> the display shows "COS" resp. "SIN". The desired measuring principle can be selected by <+> or <-> and must be entered with password.

5.4.17 SOLI/RESI changeover (SR-relay type)

Depending on the method of neutral-point connection of the system to be protected, the directional element for the earth-current circuit must be set to "SOLI" (= solidly earthed) or "RESI" = (resistance earthed).

5.4.18 Block/Trip – time

The block/trip time serves for detection of a c.b. failure protection by rear interlocking. It is activated by setting the blocking input D8/E8 and by setting the parameter to TR_B. After the set block/trip time has expired, the relay can be tripped if the excitation of a protective function has been applied the delay time of which has expired and the blocking function is still active. If the parameter PR_B is set, the individual protection stages are blocked (refer to Chapter 5.7.1).

5.4.19 Circuit breaker failure protection t_{CBFP}

The CB failure protection is based on supervision of phase currents during tripping events. Only after tripping this protective function becomes active. The test criterion is whether all phase currents are dropped to <1% x I_N within t_{CBFP} (Circuit Breaker Failure Protection - adjustable between 0.1 - 2.0 s). If not all of the phase currents have dropped to <1%xI_N within this time, CB failure is detected and the related relay activated. The CB failure protection function is deactivated again as soon as the phase currents have dropped to <1% x I_N within t_{CBFP}

5.4.20 Adjustment of the slave address

Pressing push buttons <+> and <-> the slave address can be set in the range of 1-32.

5.4.21 Setting of Baud-rate (applies for Modbus Protocol only)

Different transmission rates (Baud rate) can be set for data transmission via Modbus protokol.
The rate can be changed by push buttons <+> and <-> and saved by pressing <ENTER>.

For the *MRI3*-version with directional feature, the different trip time delays or the time multipliers can be chosen for forward and backward faults.
By setting the trip delay, the actual set value for forward faults appears on the display first and the LED under the arrows is alight green. It can be changed with push button <+> <-> and then stored with push button <ENTER>. After that, the actual trip delay (or time factor) for backward faults appears on the display by pressing push button <SELECT> and the LED under the arrows is alight red.
Usually this set value should be set longer than the one for forward faults, so that the relay obtains its selectivity during forward faults. If the time delays are set equally for both forward and backward faults, the relay trips in both cases with the same time delay, namely without directional feature.

Note:
When selecting dependent tripping characteristics at relays with directional phase current detection, attention must be paid that a clear directional detection will be assured only after expiry of 40 ms.

5.4.4 Reset setting for all tripping characteristics in the phase current path

To ensure tripping, even with recurring fault pulses shorter than the set trip delay, the reset mode for inverse time tripping characteristics can be switched over. If the adjustment tRST is set at 60 s, the tripping time is only reset after 60 s faultless condition. This function is not available if tRST is set to 0. With fault current cease the trip delay is reset immediately and started again at recurring fault current.

5.4.5 Current setting for high set element (I>>)

The current setting value of this parameter appearing on the display is related to the rated current of the relay.
This means: I>> = displayed value x I_N.
When the current setting for high set element is set out of range (on display appears "EXIT"), the high set element of the overcurrent relay is blocked.
The high set element can be blocked via terminals E8/D8 if the corresponding blocking parameter is set to bloc (refer to chapter 5.7.1).

5.4.6 Trip delay for high set element ($t_{I>>}$)

Independent from the chosen tripping characteristic for I>, the high set element I>> has always a definite-time tripping characteristic. An indication value in seconds appears on the display.

The setting procedure for forward- or backward faults, described in chapter 5.4.3, is also valid for the tripping time of the high set element.

5.4.7 Relay characteristic angle RCA

The characteristic angle for directional feature in the phase current path can be set by parameter RCA to 15°, 27°, 38°, 49°, 61°, 72° or 83°, leading to the respective reference voltage (see chapter 4.3).

5.4.8 Pickup value for residual voltage U_E (ER/XR-relay type)

Regardless of the preset earth current, an earth fault is only identified if the residual voltage exceeds the set reference value. This value is indicated in volt.

5.4.9 Pickup current for earth fault element ($I_{E>}$)

(Similar to chapter 5.4.1)
The pickup value of X and XR-relay type relates to % I_N.

5.4.10 WARN/TRIP changeover (E/X and ER/XR-relay type)

A detected earth fault can be parameterized as follows. After delay time.
a) "warn" only the alarm relay trips
b) "trip" the trip relay trips and tripping values are stored.

5.3.7 Parameter switch/external triggering of the fault recorder

By means of the parameter-change-over switches it is possible to activate two different parameter sets. Switching over of the parameter sets can either be done by means of software or via the external inputs RESET or blocking input. Alternatively, the external inputs can be used for Reset or blocking of the triggering of the fault recorder.

Software-parameter	Blocking input used as	RESET Input use as
SET1	Blocking input	RESET Input
SET2	Blocking input	RESET Input
B_S2	Parameter switch	RESET Input
R_S2	Blocking input	Parameter switch
B_FR	Ext. triggering of the FR	Reset input
R_FR	Blocking input	Ext. Trigger for FR
S2_FR	Parameter switch	Ext. Trigger for FR

With the settings SET1 or SET2 the parameter set is activated by software. Terminals C8/D8 and D8/E8 are then available as external reset input or blocking input.

With the setting B_S2 the blocking input (D8, E8) is used as parameter-set change-over switch. With the setting R_S2 the reset input (D8, E8) is used as parameter-set change-over switch. With the setting B_FR the fault recorder is activated immediately by using the blocking input. On the front plate the LED FR will then light up for the duration of the recording. With the setting R_FR the fault recorder is activated via the reset input. With the setting S2_FR parameter set 2 can be activated via the blocking input and/or the fault recorder via the reset input.
The relevant function is then activated by applying the auxiliary voltage to one of the external inputs.

Important note:
When functioning as parameter change over facility, the external input RESET is not available for resetting. When using the external input BLOCKING the protection functions must be deactivated by software blocking separately (refer to chapter 5.7.1).

5.4 Parameter protection

5.4.1 Pickup current for phase overcurrent element (I>)

The setting value for this parameter that appears on the display is related to the nominal current (I_N) of the relay. This means: pickup current (Is) = displayed value x nominal current (I_N) e.g. displayed value = 1.25 then, Is = 1.25 x I_N.

5.4.2 Time current characteristics for phase overcurrent element (CHAR I>)

By setting this parameter, one of the following 6 messages appears on the display:
DEFT - Definite Time
NINV - Normal Inverse
VINV - Very Inverse
EINV - Extremely Inverse
RINV - RI-Inverse
LINV - Long Time Inverse
Anyone of these four characteristics can be changed by using <+> <->-push buttons, and can be stored by using <ENTER>-push button.

5.4.3 Trip delay or time factor for phase overcurrent element ($t_{I>}$)

Usually, after the characteristic is changed, the time delay or the time multiplier should be changed accordingly. In order to avoid an unsuitable arrangement of relay modes due to carelessness of the operator, the following precautions are taken:

If, through a new setting, another relay characteristic other than the old one has been chosen (e.g. from DEFT to NINV), but the time delay setting has not been changed despite the warning from the flashing LED, the relay will be set to the most sensitive time setting value of the selected characteristics after five minutes warning of flashing LED tI>. The most sensitive time setting value means the fastest tripping for the selected relay characteristic. If a definite time characteristic has been selected, the display shows the trip delay in seconds. When selecting an inverse time characteristic, the time multiplier appears on the display. Both settings can be charges by push-buttons <+><->. When the time delay or the time multiplier is set out of range (Text "EXIT" appears on the display), the low set element of the overcurrent relay is blocked. The "WARN"-relay will not be blocked.

5.2 Setting procedure

After push button <SELECT/RESET> has been pressed, always the next measuring value is indicated. Firstly the operating measuring values are indicated and then the setting parameters. By pressing the <ENTER> push button the setting values can directly be called up and changed. Before parameter setting can be started the relevant password must be entered (refer to chapter 4.4 of the "MR Digital Multifunctional Relay" description).

5.3 System parameter

5.3.1 Display of measuring values as primary quantities (I_{prim} phase)

With this parameter it is possible to show the indication as primary measuring value. For this purpose the parameter must be set to be equal with the rated primary CT current. If the parameter is set to "SEK", the measuring value is shown as a multiple of the rated secondary CT current.

Example:
The current transformer used is of 1500/5 A. The flowing current is 1380 A. The parameter is set to 1500 A and on the display "1380 A" are shown. If the parameter is set to "SEK", the value shown on the display is "0.92" x In.

Note:
The pick-up value is set to a multiple of the rated secondary CT current.

5.3.2 Display of earth current as primary quantity (I_{prim} earth)

The parameter of this function is to be set in the same way as that described under 5.3.1. If the parameter is not set to "SEK", to relay types *MRI3-X* and *MRI3-XR* it applies too, that the measuring value is shown as primary current in ampere. Apart from that the indication refers to % of I_N.

5.3.3 Display of residual voltage U_E as primary quantity (U_{prim}/U_{sec})

The residual voltage can be shown as primary measuring value. For this parameter the transformation ratio of the VT has to be set accordingly. If the parameter is set to "SEK", the measuring value is shown as rated secondary voltage.

Example:
The voltage transformer used is of 10 kV/100 V. The transformation ratio is 100 and this value has to be set accordingly. If still the rated secondary voltage should be shown, the parameter is to be set to 1.

5.3.4 Voltage transformer connection for residual voltage measuring (3pha/e-n/1:1)

Depending on the connection of the voltage transformer of ER/XR-relay types three possibilities of the residual voltage measurement can be chosen (see choper 4.5).

5.3.5 Nominal frequency

The adopted FFT-algorithm requires the nominal frequency as a parameter for correct digital sampling and filtering of the input currents.
By pressing <SELECT> the display shows "f=50" or "f=60". The desired nominal frequency can be adjusted by <+> or <-> and then stored with <ENTER>.

5.3.6 Display of the activation storage (FLSH/NOFL)

If after an activation the existing current drops again below the pickup value, e.g. I>, without a trip has been initiated, LED I> signals that an activation has occured by flashing fast. The LED keeps flashing until it is reset again (push button <RESET>). Flashing can be suppressed when the parameter is set to NOFL.

Function	Display shows	Pressed push button	Corresponding LED
Blocking of the protection function	BLOC, NO_B	<+> <-><SELECT/RESET>	I>, I>>, $I_{E>}$, $I_{E>>}$
Save parameter!	SAV!	<ENTER> for about 3 s	
Software version	First part (e.g. D01-) Sec. part (e.g. 8.00)	<TRIP> one time for each part	
Manual trip	TRI?	<TRIP> three times	
Inquire password	PSW?	<TRIP><ENTER>	
Relay tripped	TRIP	<TRIP> or after fault tripping	
Secret password input	XXXX	<SELECT/RESET> <+><-><ENTER>	
System reset	SEG	<SELECT/RESET> for about 3 s	

Table 5.1: possible indication messages on the display

[1] refer to 4.4

[2] only Modbus