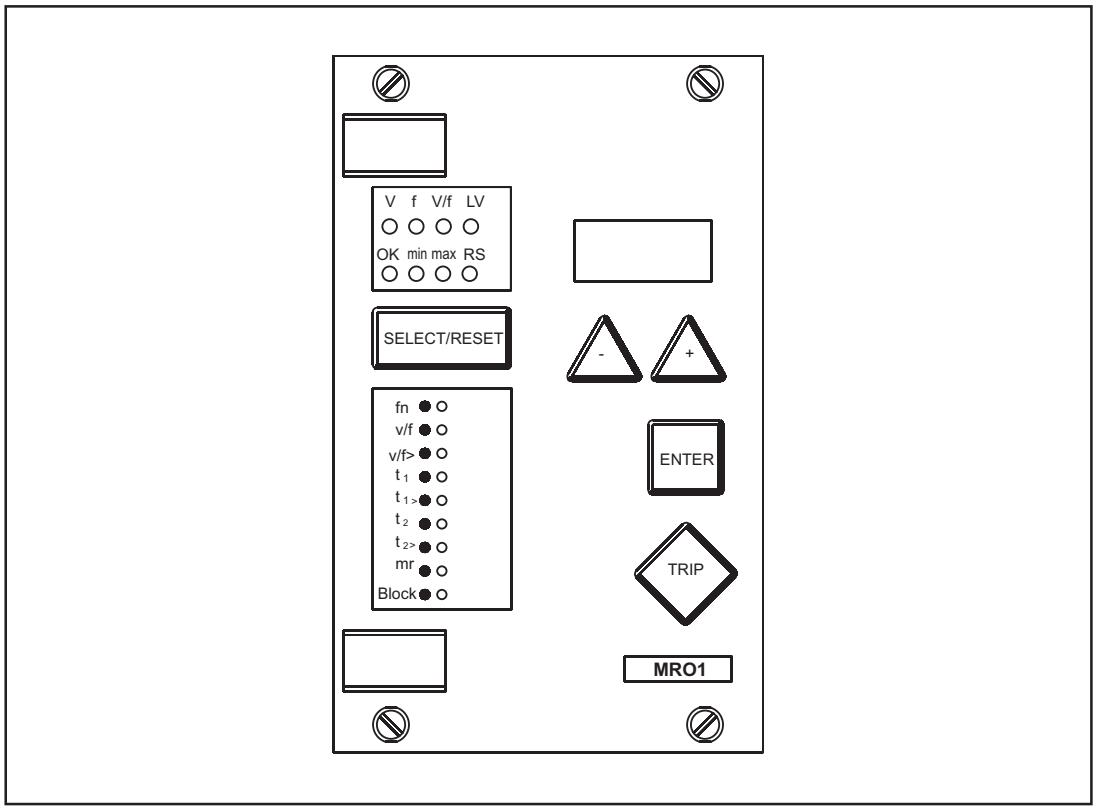
High-Tech Range

MRO1- Overfluxing Relay



Controls & Switchgear Group

C&S Protection & Control Ltd.

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1. Introduction and Application

The ***MRO1*** is a digital overfluxing relay designed to protect transformer against high flux density, called Overfluxing condition. A high flux density in the iron core of the transformer can cause saturation and hence large iron losses in the core. Consequently, severe damage can occur to the winding insulation and core laminations.

The ***MRO1*** relay simultaneously measures voltage and frequency and therefrom computes the voltage-to-frequency ratio continuously. This principle, called V/f or volts/hertz enables an accurate measurement of the flux density in the transformer core even when the frequency is varying. Hence the **MRO1** is totally dependable for protecting a transformer against overfluxing that is likely to occur when the generator speed is increasing towards synchronous speed or decreasing from synchronous speed. The condition can be more severe when the circuit breaker of the generator-transformer unit is open.

The relay produces an alarm signal as soon as the flux density exceeds a preselected value. If the condition persists for a short (adjustable) time, the relay generates another signal which can be used for reducing the generator excitation via the exciter control system. If the correction fails to remove the Overfluxing condition within a present time delay, the relay sends a trip signal.

2. Features

- Employs digital technology.
- Uses a fast and powerful microcontroller.
- Effective low-pass filter for suppressing harmonics in the analog input signal.
- High sampling rate to avoid aliasing.
- Fast-Fourier Transform extracts the fundamental frequency component and hence eliminates errors due to harmonics and noise.
- Alphanumeric display of settings and actual measured values.
- Storage and display of fault data for the last five trippings.
- LED indication of relay operation/selected parameter.
- Self-supervision through a watchdog timer.
- Serial interface with RS-485 and Modbus protocols.
- High dropout to pickup ratio.
- Measurement repetition avoids unwanted operations.
- Self check on hardware and software simplifies the maintenance.
- Monitors and indicates low-voltage/P.T. fuse failure condition.
- V/f or volts/hertz principle leads to accurate flux measurement on all conditions.
- Three operating elements: an alarm element with instantaneous operation, and control & trip elements with independently adjustable delays.
- Auto/manual/remote reset options.
- Compliance with VDE0435, part 303, IEC 255 and IS: 8686.

3. Design

3.1 Connections

The external connections for the **MRO** relay, including the input and auxiliary voltage wiring, are shown in figure 3.1. It may be noted that the phase voltages can be directly connected to A3/A4 in case the nominal line voltage matches with the rated voltage of the relay.

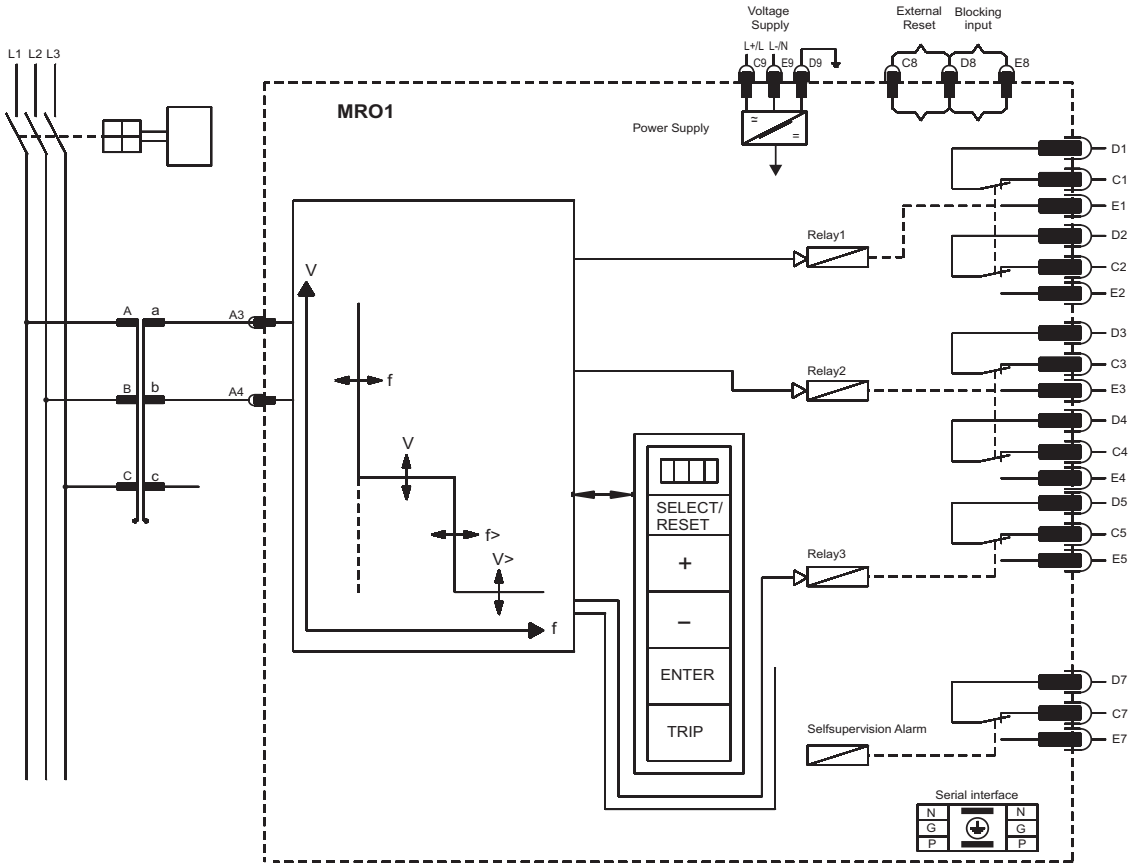

Fig. 3.1: Connection diagram MRO1

3.1.1 Analog input

The analog input voltage is galvanically isolated via an input transformer inside the relay. The output of this transformer is passed through a low-pass filter. It is also converted into square wave using a precision comparator.

3.1.2 Output relays

The **MRO** has four output relays with changeover contacts. Their functions and contact terminals are given in table 3.1. It may be noted that the self supervision relay (output relay 4) is normally in on state and turned off in the event of an internal fault in **MRO.**

Relay number	Function	Confi-guration	Output contacts
Output relay 1	Control element	Normally off	C1,D1,E1 and C2,D2,E2
Output relay 2	Trip element	Normally off	C3,D3,E3, and C4,D4,E4
Output relay 3	Alarm element	Normally off	C5,D5,E5
Output relay 4	self supervision element	Normally on	C7,D7,E7

Table 3.1 Particulars of the output relays.

3.1.3 Blocking input

When it is required to inhibit the protective function of the relay, the auxiliary voltage has to be connected to the terminals D8/E8.

3.1.4 External reset input

For external (electrical) resetting of the relay, the auxiliary voltages has to be connected to the terminals C8/D8. For various reset modes, please refer to section 5.4.

3.2 Display

A four-character 5x7 dot matrix LED display unit displays the relay status or parameter name or parameter value, as the case may be. The display under various situations is as shown in table 3.2

Display

Function/Condition	Display	Required push button operation	LED indication/ Relay operation	LED colour
Normal operation	CSPC	None	Ok, Input	green, green
Low voltage	No change	None	Input	red
Display measured values (in this sequence)	Value of voltage (in volts)	<SELECT/RESET> one time for each value	V	green
	Minimum value of voltage after the last reset		V,min.	green, yellow
	Maximum value of voltage after the last reset		V,max.	green, yellow
	Value of frequency (in Hz)	<SELECT/RESET> One time for each	F	green
	Minimum value of frequency after the last reset		f,max	green, yellow
	Value of v/f ratio (normalised)	<SELECT/RESET> one time for each value	V/f	green
	Minimum value of v/f ratio after the last reset		V/f, min.	green, yellow
	Maximum value of v/f ratio after the last reset		V/f, max.	green, yellow
Display stored fault values (in this sequence)	Values of voltage (in volts)	<SELECT/RESET> one time for each value	V	green
	Value of frequency (in Hz)		F	green
	Value of v/f ratio (normalized)		v/f	green
	FLT1,.....,FLT5		-	-
Display stored fault values for next/previous fault (FLT1 is the latest fault)	FLT1,.....,FLT5	<SELECT/RESET>,<+>	-	-
	FLT5,.....,FLT1	<->	-	-
Display/set parameters (in this sequence)	Nominal frequency (in Hz)	<SELECT/RESET><+><->	fn	green
	Pick-up value of v/f ratio(normalised)	<SELECT/RESET><+><->	v/f	green
	Time-delay of control element (in seconds)	<SELECT/RESET><->	t1	green
	Time-delay of trip element (in seconds)	<SELECT/RESET><->	t2	green
	Measuring Repetitions	<SELECT/RESET><+><->	m r	green
	Slave address of serial interface (1-32)	<SELECT/RESET><+><->	RS	yellow
Function blocked	EXIT	<+> press until maximum setting value	LED of blocked parameter	green
Save parameter?	SAV?	<ENTER>	-	-
Save parameter!	SAV!	<ENTER>for about 3 second	-	-
Software version	Part 1 or 2 of software version	<TRIP> one time for each part	-	-
Manual tripping?	TRI?	<TRIP> three times	-	-
Trip (manually)!	TRIP	Password combination of keys, press trip after correct password	All LED's light up in sequence for is each. Then output relays operate and self supervision relay reset at is intervals.	-
Reset output relays after manual trip	CSPC	<SELECT/RESET>	Output relays reset and self-supervision relay operates.	-
Set password?	PSW?	Any push button along with J1	-	-
Inquire password	PSW?	Any push botton except <TRIP>	-	-
Feed password	****	A four-key sequence of <SELECT/RESET> <+x-> <ENTER>	-	-
Manual reset	CSPC	<SELECT/RESET> for about 3 seconds	Alarm, Control and Trip LED's go off	-
External reset	CSPC	None	Alarm, Control and Trip LED's go off	-
Blocking input	CSPC	None	Block	red

Table 3.2 Display, LED indications and relay outputs under various situations.

3.3 LED indicators

The LED indicators provided in the *MRO* can be seen in the front-plate diagram shown in figure 3.2 and the various indications given by them under various situations are given in table 3.3.

Starting with the top left-hand LED indicator, the name, function and colour of each of them is given in table 3.3.

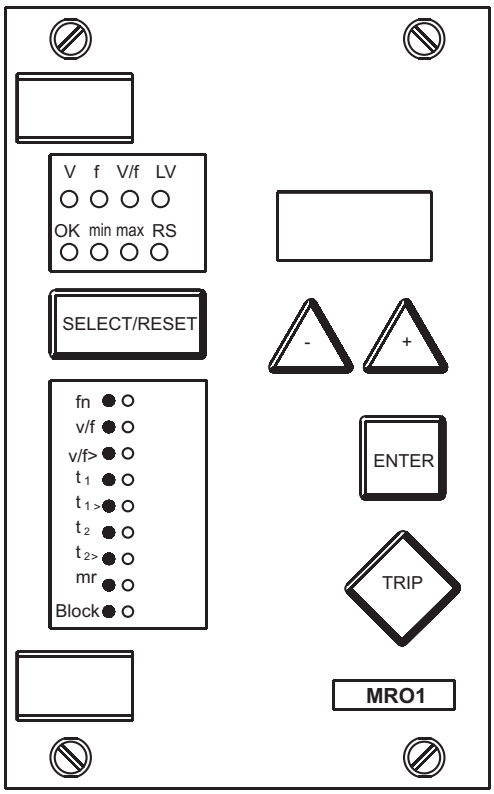

Fig. 3.2 : Front Plate MRO1

Name	Function	Colour	Indication
V	Voltage	green	Voltage value on display
f	Frequency	green	Frequency value on display
V/f	Voltage-to-frequency ratio	green	Voltage-to-frequency ratio (normalized) is on display
LV	Low-voltage input	green	Input voltage >10% of U_n
LV	low-voltage input	red	Input voltage <10% of U_n
ok	Self-check	green	Self-check on hardware and software passed
min	Minimum	yellow	Minimum value of parameter on display
max	Maximum	yellow	Minimum value of parameter on display
RS	Slave address for Rs 485	yellow	Slave address of the unit for serial interface (RS 485) on display
fn	Nominal frequency	green	Nominal frequency setting on display
V/f	V/f ratio setting	green	V/f setting (normalized) on display
V/f>	Alarm	red	Alarm element operated
t_1	Control	green	Time delay setting of element delay control element on display
t_1>	Control	red	Control element operated element operation
t_2	Trip element delay	green	Time delay setting of trip element on display
t_2>	Trip element operation	red	Trip element operated
mr	Measuring repetitions	green	Number of measuring repetitions on display
Block	External blocking of relay	red	Relay function is inhibited through external blocking

Table 3.3 LED indicators and their functions

4. Working principle

4.1 Digital section

The ***MRO1*** is a digital relay built around a high-speed high-performance microcontroller with a time-proven track record. The microcontroller has an on-chip 10-bit multi-channel analog-to-digital converter that ensures high immunity to noise in data conversion and fast data transfer to CPU. All measurements, comparisons and decisions are carried out by the microcontroller digitally. Since all the timer-counters, watchdog timer, analog and digital interface and scratchpad are on the chip, the data transfers are not only fast but also highly secured against external noise. For the same reason, the chip count is low and inter-component connections are fewer. Consequently the circuit reliability is very high.

The software of the relay is located on EPROM (erasable programmable read-only memory). Parameter setting and fault data are stored in an EEPROM (electrically erasable programmable read-only memory), so that this information is not lost on a power interruption.

4.2 Voltage measurement

The relay circuit is galvanically isolated from the input via an input voltage transformer located inside the relay. The secondary voltage of this transformer is passed through an active low-pass filter to limit the signal bandwidth and suppress harmonics in it. The low-pass filtering alongwith a high sampling rate used for data conversion ensures freedom from aliasing error in digitization.

The digitized output is used for voltage measurement inside the microcontroller. The fundamental frequency component of input is extracted by using FFT (Fast Fourier transform) algorithm, specially developed for on-line implementation. This ensures a correct voltage measurement in the presence of harmonics, sub-harmonics and noise. Furthermore, the effect of frequency variation on voltage measurement is avoided altogether by using synchronous sampling of the input signal, that is, exactly 16 samples per cycle of the signal.

4.3 Frequency measurement

The filtered analog signal is also converted into a square wave using a precision comparator. The square wave is used for measurement of the time period of the signal by counting high-frequency clock pulses. The count is subsequently used for computing the frequency of the input signal. Both voltage and frequency measurements are carried out simultaneously and continuously.

4.4 Detection of overfluxing condition

The ratio of winding voltage to frequency is directly proportional to the flux density in the transformer core. This relation being true even under varying frequency and voltage conditions, the voltage/frequency principle always gives a correct value of the flux density. The CPU of **MRO1** computes flux density every cycle from the product of the measured values of voltage and time period. When the calculated value of V/f ratio exceeds the threshold value (V/f setting), the alarm relay is activated.

4.5 Repetition of measurement

When the V/f ratio exceeds the pickup value the *MRO1* repeats the process of measurement (i.e. measurement of voltage, frequency and calculation of V/f ratio and comparison with threshold). If repeated measurements confirm that V/f ratio is higher than the threshold value, the alarm relay is activated. Similarly, after pickup, if the V/f ratio falls below the threshold value, the ***MRO*** repeats the process of measurement to confirm a reset condition. The number of measuring repetitions (mr) can be set by the user between 1 and 9. This feature avoids unwanted operation on transient conditions.

4.6 Control and trip outputs

The measurement of V and f and computation of V/f ratio continue even after giving the alarm signal. If the V/f ratio continues to be above the V/f setting for a preset time (t_1 setting), the control relay is activated. The contacts of this relay can be suitably wired to the control circuit of the generator exciter so as to immediately reduce the generator voltage.

In case the excitation controller fails to bring down the generator voltage to a level where Overfluxing condition is removed within another preset time (t_2 setting), the trip relay is activated. The contact of this relay can be wired to energize a trip/master relay, which in turn would trip the circuit breaker in the generator field.

4.7 Low-voltage detection

A precision comparator is used for converting the input signal (nearly sinusoidal waveform) into a square wave. It is designed to ensure correct frequency measurement even at extremely low input voltage. However, the MRO1 gives a visual indication of a low voltage condition by turning the LED marked as "LV" red, which is otherwise green. This detection is achieved by comparing the measured (digital) value of the input voltage with a threshold value, which is set to 10% of the nominal voltage.

This feature is very useful in indicating a possible failure of the generator exciter or blown off fuse of the voltage transformer feeding the ***MRO1***.

5. Measurements and settings

5.1 Measurements available

The ***MRO1*** measures the following quantities continuously, which are displayed on demand:

V	:	Input voltage in volts.
V_{min}/V_{max}	:	Minimum/maximum value of input voltage in volts after the last reset.
f	:	Input frequency in Hz.
f_{min}/f_{max}	:	Minimum/maximum value of system frequency in Hz after the last reset.
V/f	:	Value of voltage-to-frequency ratio (normalized).
$V/f_{min}/V/f_{max}$	:	Minimum/maximum value of voltage-to-frequency ratio (normalized) after the last reset.

5.2 Setting available

The following parameters can be set by the user:

f_n	:	nominal frequency
V/f	:	pickup value of voltage-to-frequency ratio
t_1	:	pickup delay for the control element
t_2	:	pickup delay for the tripping element
mr	:	number of measuring repetitions
RS	:	slave address of the **MRO1** unit for serial interface RS485

5.3 Setting procedure

The order in which the parameter setting can be displayed or changed is the one in which they are listed above (Article 5.2).

To display the nominal frequency setting, the user has to press the push button <ENTER> and then <SELECT/RESET>. Alternatively, the user can scroll though the display of the nine measured values (serial no.2 of table 3.2) and then press the push button <SELECT/RESET> once again. At this stage the LED marked fn lights up and the current fn setting is displayed. The setting can be changed by pressing the push button <+> or <-> to increase or decrease the value of fn, respectively. It can be set to either 50 Hz or 60 Hz.

To store the changed setting, press <ENTER>. The ***MRO1*** asks for confirmation by displaying "SAV?". Press <ENTER> again. There upon the **MRO1** enquires the password by displaying "PSW?" Feed the password by pressing the keys in appropriate sequence. If the password matches with the stored password, the ***MRO1*** asks for confirmation by displaying "SAV!". Press <ENTER> for 3 seconds to store the changed setting. The ***MRO1*** displays the setting it has finally stored.

The user can go to the next parameter by pressing <SELECT/RESET> push button. If a setting is saved within 2 minutes of the last saving operation, the MRO1 does not ask for the password again.

5.4 Reset

(i) With jumper J3 off, ***MRO1*** comes in Auto-Reset mode. In this mode, the output relays reset automatically as soon as pickup condition is removed. However, LED indicators can be reset only by pressing <SELECT/RESET> for about 3 seconds.

(ii) With jumper J3 on, there are three possible ways as follows to reset the LED indicators as well as the output relays. However, the resetting is possible only if the pickup condition has been removed.

(a) **Manual reset:** By pressing push button <SELECT/RESET> for about 3 seconds.

(b) **Electrical reset:** By applying auxiliary voltage to the terminals C8/D8.

(c) **Software reset:** Software reset has the same effect as the <SELECT/RESET> push button.

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 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 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 switching 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 "CSPC" appears on the display, "ok" LED glows in green colour and self-supervision alarm relay (watchdog) is energized (contact terminals D7 and E7 closed).

6.2 Testing the output relays

NOTE!

Prior to commencing this test, interrupt the tripping circuit of the circuit breaker if tripping is not wanted.

By pressing the push button <TRIP> once, the display shows the first part of the software version of the relay (e.g. DO1-). By pressing the push button <TRIP> again, the display shows the second part of the software (e.g. FO1-). The software version should be quoted in all the correspondence. Pressing the <TRIP> button once more, the display shows "PSW"?. Enter the correct password to proceed with the test. The message "TRI"? will follow. Confirm this message by pressing the push button <TRIP> again. The message "TRIP" is displayed. Thereafter, all bi-colour LEDs follow red-green-off light up sequence one at a time with a time delay of 1 second in sequence from top left corner. All single colour LEDs follow on-off sequence with a time delay of 1 second and one at a time. All output relays shall then be activated and the self-supervision alarm relay (watchdog) shall be deenergized one after another with a time interval of 1 second. Finally, the "ok" LED switched on in green colour. Thereafter, reset all output relays back to their normal positions by pressing the push button <SELECT/RESET>. The "LV" LED also lights up.

6.3 Checking the set values

By repeatedly pressing the push button <SELECT/RESET>, all set values (settings) may be checked. The setting can be modified as described in section 5.3.

6.4 Secondary injection test

6.4.1 Test equipment

- Voltmeter and frequency meter
- Auxiliary power supply with the voltage corresponding to the rated data on the type plate
- AC voltage supply with frequency regulation

  (Voltage: adjustable from 0 to 2xVn;

  Frequency: adjustable from 10 to 70 Hz)

- Timer to measure the operating time
- Switching device
- Test leads and tools

6.4.2 Test circuit

For testing ***MRO1,*** a voltage source with variable voltage and frequency is required. Figure 6.1 shows a simple example of test circuit.

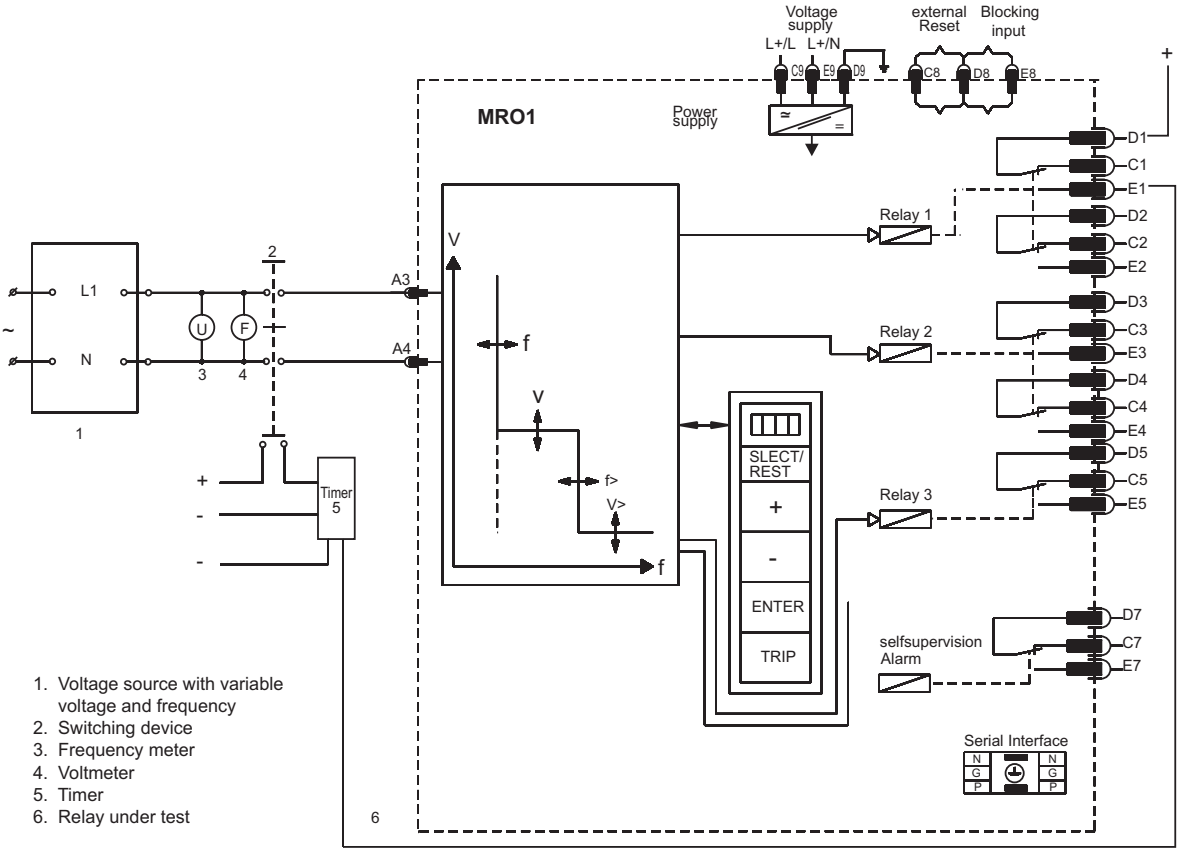

Fig. 6.1: Test circuit

6.4.3 Checking the input circuits and measured values

First the input voltage as high as the nominal voltage is to be connected to terminals A3 and A4. Then the actual measured values of the voltage, frequency and V/f ratio can be read by pressing push button <SELECT/ RESET>. The measured quantity is indicated on the display alongwith the simultaneous lighting up of the relevant LED.

6.4.4 Checking of operating and resetting values of V/f ratio

To check the operating value of V/f ratio, increase the magnitude of the input voltage gradually while keeping the frequency constant at the nominal value, until the relay picks up i.e. the alarm element operates and LED marked as "V/f" lights up. The V/f ratio display should match with the ratio calculated from voltmeter and frequency meter readings.

The check should be repeated by holding the voltage magnitude constant at nominal value and reducing the frequency gradually until the relay picks up.

The reset value of V/f ratio be checked one the relay has picked up by reducing the voltage magnitude or increasing the frequency gradually until the relay resets. The reset value of V/f ratio should be equal to or more than 0.97 times the pickup value at a given V/ f setting.

6.4.5 Checking the delays

For checking the delay t_1, the timer should be connected to the contact terminals of the control relay. The voltage of the input source is changed in step mode and the time delay is measured on the timer.

This should match with the t1 setting. Similarly, the delay t_2 can be checked by connecting the timer to the contact terminals of the trip relay.

6.4.6 Checking the external blocking and reset functions

At the beginning of the test, the auxiliary voltage is connected to the terminals D8/E8. "Block" LED should light up in red colour. Then the input voltage is raised sufficiently that would have normally lead to the operation of the **MRO1.** Because of the blocking signal present, none of the alarm, control and trip elements shall operate. Thereafter, remove the auxiliary voltage from the terminal D8/E8. "Block" LED shall turn off, the alarm element shall operate instantaneously and after delays t_1 and t_2 the control and trip elements, respectively, shall operate.

After this, reduce the input voltage so as to bring down the V/f ratio below the reset value. Now, if auxiliary voltage is applied to the terminals C8/D8, "V/f", "$t_1>$" and "$t_2>$" LEDs shall go off and the alarm, control and trip relays shall reset.

6.5 Primary injection test

Generally, a primary injection test could be carried out in a 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 voltage should be injected to the relay through the transformer 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 **MRO1** 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 and frequency values on the **MRO1** relay display may be compared with the concerned indications of the instruments on the switchboard to verify that the relay works and measures correctly.

6.6 Maintenance testing

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

For electromechanical or static relays, maintenance testing is generally performed at least once a year. For digital relay like **MRO1,** this internal can be substantially longer. This is because:

- The **MRO1** relay is equipped with very wide self supervision functions, so that many faults in the relay can be detected and signaled during service. Important: The self-supervision output relay must be connected to a central alarm panel!
- The combined measuring functions of ***MRO1*** relay enable supervision of the relay functioning during service.
- The combined TRIP test function of the ***MRO1*** relay allows testing of all LED indicators, the display unit and the output relays.

A testing interval of two years for maintenance will, therefore, be recommended.

During a maintenance test, the relay functioning including the operating times should be tested.

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7. Technical Data

7.1 Measuring input circuits

Rated data	:	Nominal voltage U_n : 110/230/400V
Nominal frequency fn:50/60 Hz Power consumption	:	<1 VA at U_n
Thermal rating	:	2x U_n (continuous)

7.2 Common data

Dropout to pickup ratio	:	97%
Dropout time	:	30 ms
Time lag error class index E	:	+- 10 ms
Minimum operating time	:	20-40 ms
Maximum allowed interruption of the auxiliary supply without influencing the function of the relay	:	50 ms

7.3 Default settings and setting ranges

Various default setting of the **MRO1** are shown in table 7.1. To enter them, pass the push buttons in the sequence <+>,<->, <ENTER>.

The setting ranges available on the **MRO1,** alongwith the step values and tolerances, are also shown in table 7.1.

Function	Parameter	Default setting	Setting range	Step	Tolerance
Nominal frequency	fn	50Hz	50Hz/60Hz	50Hz/60Hz	-
Pickup value of V/f ratio	V/f	1.20	1.00 to 1.40	0.01	0.005
Time delay of control element	t1	1.0 second	0.1 to 10 seconds 10 to 50 seconds EXIT	0.1 second 1 second	50 ms 50 ms
Time delay of trip element	t2	12 seconds	0.1 to 10 seconds 10 to 120 seconds EXIT	0.1 second 1 seconds	50 ms 50 ms
Measuring repetitions	MR	2	1-9	1	-
Slave address of serial interface	RS	1	1 to 32	1	-
Password	PSW	++++	-	-	-

Table 7.1 Various default settings and setting ranges

7.4 Order form

Overfluxing relay		***MRO1-***				
Rated voltage	110 V	**1**				
	230 V	**2**				
	400 V	**4**				
Auxiliary voltage :						
24 V (16 to 60 V AC/16 to 80 V DC)			**L**			
110 V (50 to 270 V AC/70 to 360 V DC)			**H**			
RS 485 Communication				**R**		
Housing (12 TE):	19″ rack				**A**	
	Flush mounting				**D**	

* Serial interface capability: Available December 2001

Technical data subjected to change without notice.

For further information, please contact :

CSPC

C&S Protection & Control Ltd.

44, Okhla Indl. Estate, New Delhi-110020, Ph.: 011-55602414, 26319465-66 Fax: 011-55602413 email: cspc@controlsindia.com

Marketing Office : **DELHI :** Ph.: 55602414, 26319465-66 Fax : 55602413 **CHANDIGARH :** Ph. 2776154, 2776151, 2726153 Fax: 2726154 **KOLKATA :** Ph. 24549607-08 Fax: 24549371 **MUMBAI :** Ph.: 24114727-28 Fax : 24126631 **PUNE :** Ph.: 5444822-824, Fax: 5410820, **AHMEDABAD :** Ph.: 65841425, 6589132 Fax : 6589132 **BANGALORE :** Ph.: 5586147, 5323582, 5594939 Fax: 5582796, ***CHENNAI :*** Ph.: 26426475, 26426572 Fax: 26411972 ***HYDERABAD :*** Ph.: 27813003, 55332304 Fax: 27812987

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