Type MDF
Microprocessor
Frequency Relay

F. Time delay setting for underfrequency or overfrequency trip, 0.01 to 0.99 seconds.

G. Alarm for:
1. underfrequency (or overfrequency) setting out of range
2. reclose enable setting out of range
3. reclose enable setting below an underfrequency trip setting
4. low internal voltage
5. unsatisfactory self-check

This relay is intended to sense hazardous underfrequency (or overfrequency) conditions and initiate selective load shedding to preserve service continuity to other loads. It is also applied to turbine-generators to trip the machine through external timers (minutes are required) to avoid possible turbine damage.

For the underfrequency application the reclose enable function allows load to be re-energized following system frequency restoration. Restoration should be accomplished with long time delay and/or in small blocks to avoid pumping. If this relay is used for overfrequency detection, the reclosing enable setting is functionally equivalent to the normal overfrequency setting, i.e. its contact closes if the frequency is above the setting.

2. CONSTRUCTION
The MDF relay is microprocessor-based under or over-frequency relay. It measures the line frequency by counting the pulses from a crystal oscillator and compares the period measurement to setpoint.
values. The relay consists of four modules, power supply (P/S), fuse, filter and processor. The relay has up to four frequency settings. Each frequency setting has its own indicator (LED), telephone relay contact output and a target seal-in unit (ICS). Two telephone relays and indicators (LED) are for alarm and restore functions.

The MDF relay is mounted in the semi-flush FT-32 Flexitest case. The internal schematics are shown in Figures 11 and 12 for dc and ac relay respectively.

2.1 Power Supply (P/S) Board

2.1.1 Dc MDF Relay

There are two transformers on the power supply board. Transformer TR2 and its associated components are used as a dc/dc converter to step down from a dc input voltage to a 5 volt power supply. Transformer TR1 is for monitoring ac line ac line frequency. The voltage on the secondary of TR1 is connected to the MDF board. Several transistors (Q4 to Q9) are used for driving the telephone relay. There are up to six telephone relays for the functions of alarm, reclose enable and trips. Two rows of capacitors on top and bottom of the circuit board are connected between every relay terminal and the relay chassis (ground) for the noise and surge suppression.

2.1.2 Ac MDF Relay

A conventional ac to dc converter is used for this application. A stepdown transformer TR2 supplies current to the logic circuits through a 5-volt voltage regulator and also directly supplies current to all the telephone relays. The other components, such as transformer TR1, transistors Q2 to Q8, etc., provide the same functions as described in the dc MDF power supply section.

2.2 MDF Board

The MDF board consists of a microprocessor (3870), timer (Intel 8253), crystal oscillator, under voltage detector, signal conditioning, power supply ready, program recovering circuit and several sets of BCD switches for frequency, reclose enable and time delay settings. A link (jumper) is provided for the selection of a system, 50 or 60 cycle. Up to six LEDs indicates the status of alarm, reclose enable and trips. For detail of the MDF board refer to the operation section.

2.3 Fuse Module

The fuse module contains two fuses, a varistor, a capacitor and a resistor where required. This module is used for dc power supplies only.

2.4 Filter Module

This module is used on all MDF versions. It is mounted behind the shield plate of the processor module. Contained within is a +5 to -5 Vdc converter IC, an op amp and several discrete resistors and capacitors.

2.5 Indicating Contactor Switch (ICS)

The indicating contactor switch is a small dc operated clapper type device. A magnetic armature, to which leaf-spring mounted contacts are attached, is attracted to the magnetic core upon energization of the switch. When the switch closes the moving contacts bridge two stationary contacts, completing the trip circuit. Also during this operation, two fingers on the armature deflect a spring located on the front of the switch which allows the target to drop. The target is reset from the outside of the case by a push rod located at the bottom of the cover.

3. OPERATION

The MDF relay's simplified internal schematics for single to four frequency settings (dc and ac) are shown in Figures 2 through 9. The relays block diagram and two internal schematic (dc and ac) are shown in Figures 10, 11, and 12 respectively.

The system has up to four settings used as either over or underfrequency outputs, indicated on the drawings as UF/OF 1 through UF/OF 4. These four settings are completely independent and are allowed, by the system, to be between 55.00 and 60.05 and 60.10 and 65.00 on a 60 Hz system or between 45.00 and 50.05 and 50.10 and 55.00 on a 50 Hz system. The base of the system, 50 or 60 cycle, is given by a link (jumper) position which is connected to pin 22 of the 3870 microprocessor. Settings in the lower portion of the allowable range are considered underfrequency settings, and an output is issued with line frequency at or below the value. Settings in upper position of the range are considered overfrequency settings with an output issued for line frequency at or above its set point. Each output has its own telephone relay, seal-in unit (ICS) and LED indicator.

The Reclose-Enable setting is for the restore function and is allowed to be between 55.00 and 65.00 Hz on
a 60 Hz system and between 45.00 and 55.00 Hz on a 50 Hz system. The recloseable telephone relay contacts are closed for frequencies 0.1 or above and are open for frequencies below 45.00 Hz. The oscillator circuit IC4 is used as an oscillator which is the time base for the system.

The power line frequency signal is taken through an input transformer (on P/S board) and an interface comparator IC1 (1) and then divided by two, by a flip flop IC2 (3). The waveform at TP1 having half period segment represents a whole line cycle serves as the base for subsequent timing and evaluation.

The integrated circuit IC1 (14) detects low voltage conditions, e.g., the cutoff voltage. If the relative line voltage at T7 falls below the set threshold voltage at pin 8 of IC(14), then the voltage at TP3 drops to zero, resets the microprocessor, clears all outputs except alarm, and disables the relay until line voltage is restored to an acceptable value. The alarm is activated by this condition.

The circuit of IC1 (13) and Q4 is known as a deadman configuration. Normally, a positive pulse in every cycle will be applied to the base of Q4 discharging the capacitor C11, and maintaining a low voltage on C11, e.g., the voltage at TP3 maintains a "high" level. If the processor or oscillator would stop or if the processor or oscillator would become "lost," the capacitor C11 would charge up according to the time constant R23x C11 and eventually pull the reset line (TP3) down to activate the alarm. The reset line is subsequently allowed to go back to its high state, due to the capacitor C11's discharge through R23, to give the processor the opportunity to restart.

The integrated circuit IC1 (2), transistors Q1, Q2 and Q3 are used for power-on ready circuit. It prevents erroneous output before the +5 volt supply reaches an acceptable level.

The frequency, reclose enable and time delay setting are given by the switches shown on the right side of the schematic. This system uses binary coded decimal (BCD) switches. The diodes shown for each switch bit are for isolation to allow the bussing of information to the processor.

Figures 14 to 17 show the component locations of the MDF boards for single frequency setting and up to four frequency settings.
3.2 Power Supply (P/S) Board

3.2.1 Dc MDF Relay

The dc input power supply from relay terminals 6 and 7 is applied to two switching transistors Q1 and Q2. The transformer TR2 gives a positive feedback to start and maintain the switching action between Q1 and Q2, and is also used as a voltage stepdown transformation. After a rectifier (DP1) and dc voltage regulator (VR), a 5 volt dc output is obtained for supplying the whole logic circuit's power. The integrated circuit IC1 is a pulse generator whose pulses synchronize the switching time and force the switchover action of the transistors Q1 and Q2.

The transformer TR1 is used as a stepdown isolation which provides an ac voltage of 48 volts on secondary. Its output is connected to the input of the MDF board for voltage and frequency evaluation.

Transistors from Q4 to Q9 are telephone relay and LED drivers. The LED indicates the status of the telephone relay, e.g., if the LED turns on, the relay is energized in all cases except the alarm relay. The alarm relay is normally picked up; its normally closed contact is open and its LED is off. For underfrequency application, the setting of Reclose Enable is lower than the normal line frequency. When the MDF relay is energized, the reclose enable telephone relay and its LED are both turned on.

Figures 18 to 21 show the component location of the dc relay P/S board.

3.2.2 Ac MDF Relay

The ac line voltage from terminals 4 & 5 supplies the relay's power through a transformer TR2 and supplies a frequency signal source through TR1. Diodes D1 and D2 are used as a rectifier which drives the indicators (LED) telephone relays and supplies power to the solid-state circuits. The transistor Q1 and its associated components gives a relatively stable voltage at TP1. The voltage regulator VR supplies a constant 5-volt dc voltage source for logic and microprocessor circuits.

The reset components such as transformer TR1 and transistors Q2 to Q8, etc., are used to perform the same functions as described in the previous section.

3.3 Filter Module

The Filter Module is a fourth order butterworth low pass filter designed to suppress unwanted harmonics. IC1 is a dc voltage inverter to provide -5V dc to the op amp.

4. CHARACTERISTICS

See Table I on page 5.

5. SETTINGS

5.1 Frequency Setting

Load shedding should be accomplished in an integrated, orderly pattern throughout an interconnected power system area. This will usually involve several levels of underfrequency relay settings at many different locations in the system.

The highest level of underfrequency setting should be below the level from which recovery is reliably accomplished such as 59.5 hertz (all references are to 60 hertz systems, 50 hertz settings being proportional. Spacing of frequencies for dropping load should be established by, first estimating maximum frequency decay rate (approximately P/2H per unit, where P is maximum generation deficiency and H is system inertia constant each based on remaining MVA). From the maximum decay rate for each step and acknowledge of the time required after the frequency crosses the setting level until load dropping takes place, an estimate of the minimum frequency following each step can be obtained. The next shedding level should be below this point. Large blocks of load 8 to 15% of total connected load) are usually shed at the top frequency setting. The larger the block, the more abrupt the arresting of the frequency decline, but also the greater the amount of overshedding for smaller overloads. Many utilities use four or more shedding levels.

Coordination must be considered between a load shedding pattern and a generator dropping underfrequency relaying scheme. Generator dropping should not be allowed until load shedding has been accomplished.

5.2 Trip Time Delay Setting

The single time delay setting affects all of the frequency set points and outputs together.

The total trip time, from the time the frequency of the ac input crosses the setting threshold to contact closure, is as follows:
### TABLE I
**CHARACTERISTICS**

<table>
<thead>
<tr>
<th>Temperature Range:</th>
<th>-20 deg. to +60 deg. C ambient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency Range Base Frequency:</td>
<td>50 or 60 Hz</td>
</tr>
<tr>
<td>Under/overfrequency:</td>
<td>UF 45.00 to 50.05 Hz on 50 Hz system</td>
</tr>
<tr>
<td></td>
<td>OF 50.10 to 55.00 Hz on 50 Hz system</td>
</tr>
<tr>
<td></td>
<td>UF 55.00 to 60.05 Hz on 60 Hz system</td>
</tr>
<tr>
<td></td>
<td>OF 60.10 to 65.00 Hz on 60 Hz system</td>
</tr>
<tr>
<td>Setting Resolution:</td>
<td>0.01 Hz</td>
</tr>
<tr>
<td>Accuracy:</td>
<td>+0.005 Hz</td>
</tr>
<tr>
<td>Trip Time Delay:</td>
<td>65 ms to 990 ±10 ms</td>
</tr>
<tr>
<td>Alarm Output for:</td>
<td>1. Invalid settings</td>
</tr>
<tr>
<td></td>
<td>2. Low line voltage (undervoltage)</td>
</tr>
<tr>
<td></td>
<td>3. Dead or &quot;lost&quot; processor</td>
</tr>
<tr>
<td>Outputs:</td>
<td>1. Up to four under/overfrequency settings, one reclose enable setting and one alarm output.</td>
</tr>
<tr>
<td></td>
<td>2. Indicating LEDs for alarm, reclose enable and trips.</td>
</tr>
<tr>
<td></td>
<td>3. Telephone relay contact output for alarm, reclose enable and trips.</td>
</tr>
<tr>
<td></td>
<td>4. Indicating contactor switch (target) for each under or overfrequency trip.</td>
</tr>
<tr>
<td>Indicating Contactor Switch:</td>
<td>0.2/2 amperes</td>
</tr>
<tr>
<td>Contact Rating:</td>
<td>1. Trip contacts with ICS-30 amperes at 250 volts dc for 2 seconds.</td>
</tr>
<tr>
<td></td>
<td>2. Telephone relay contacts -3 amperes at 125 volts.</td>
</tr>
<tr>
<td>Sensing Voltage:</td>
<td>Adjustable cutoff voltage between 20% and 90% of normal ac line voltage for dc relay and between 60% and 90% of normal ac line voltage for ac relay.</td>
</tr>
<tr>
<td>Power Supply:</td>
<td>dc - 24, 48, 125, 250 volts (+15% and -25%)</td>
</tr>
<tr>
<td></td>
<td>ac - 110/220 v (50 Hz), 120/240 v (60 Hz)</td>
</tr>
<tr>
<td>Drain (dc):</td>
<td>dc Voltage of 48, 125 and 250 volts - 6 watts (max.) for logic circuit and 4 W per function such as alarm, reclose enable and each frequency settings. dc voltage of 24 volts-15 watts (max).</td>
</tr>
<tr>
<td>Burden (ac):</td>
<td>ac relay - 20 watts (max)</td>
</tr>
<tr>
<td></td>
<td>dc relay - less than 1 watt</td>
</tr>
</tbody>
</table>
a. For switch setting between .00 and .03 seconds. Actual trip time (sec) = 0.075 ±0.01 sec.
b. For switch setting between .03 and .99 seconds. Actual trip time (sec) = Digital Setting +0.047 sec. ±0.01 sec.

For example, if a digital number of .06 is set, the actual trip time will be 0.095 seconds with an error of ±0.01 seconds.

Security is achieved through the multiple-cycle counting procedure, and the shortest delay settings can be used.

For virtually all normal load-shedding applications, extra time delay is undesirable. It reduces the ability of the load-shedding scheme to arrest rapid frequency decline, and makes coordination of generation dropping more difficult. The shortest trip time of .075 s is recommended; set the MDF delay timer function to less than .035 to obtain this.

For generator dropping, time delay is generally required. Set in accordance with turbine manufacturer's time-underfrequency limits and recommendations.

6. ADJUSTMENTS AND MAINTENANCE

The proper adjustments to insure correct operation of the relay have been made at the factory and should not be disturbed after receipt by the customer.

6.1 Acceptance Tests

The following check is recommended to ensure that the relay is in proper working order. Refer to the internal schematic and apply the rated dc voltage to terminals 7 (+) and 6 (-). Connect a variable ac voltage and frequency source to terminals 4 and 5. For those customers who want a quick check of the relay and do not have a variable frequency source, refer to step #8 for the relay's acceptance tests.

For 60 Hz line voltage system (typical), set the digital switches as follows:

<table>
<thead>
<tr>
<th>Delay Time</th>
<th>Reclose Enable</th>
<th>Frequency #1</th>
<th>Frequency #2 (Optional)</th>
<th>Frequency #3 (Optional)</th>
<th>Frequency #4 (Optional)</th>
</tr>
</thead>
<tbody>
<tr>
<td>.00</td>
<td>61.00</td>
<td>57.50</td>
<td>57.50</td>
<td>57.50</td>
<td>57.50</td>
</tr>
</tbody>
</table>

For 50 Hz line voltage system, set the digital switches 10 Hz below the above values and comparable input test frequency should be used. Before any test make sure that the voltage Vc on MDF board is between 4.75 and 5.25 volts.

6.1.1 Alarm Check

To verify alarm function perform the following tests:

a. Turn the dc power on and ac input off. The alarm LED should be on and the alarm telephone relay should drop out.
b. Apply the rated ac input frequency and voltage to the relay. The alarm relay picks up and its LED turns off.
c. Reduce the ac input voltage below 80% of the rated voltage. The alarm relay drops out and its LED turns on. Return the ac input voltage to the rated voltage.

Note: The cutoff voltage is set at 80% of the rated line voltage when the relay is shipped from the factory.

d. Invalid settings for Frequency #1 (F1). The alarm LED should be turned on for any one of the following settings:
   - Set the F1 switches to 54.99
   - Set the F1 switches to 60.06
   - Set the F1 switches to 65.01

Return the F1 switches to 57.50.

e. Repeat step (d) for F2, F3, F4 (optional) if they are supplied with the relay.

f. Invalid or improper settings for Reclose Enable (optional). The alarm LED should be turned on, if the Reclose Enable (R) is set at any one of the following numbers:
   - Set the R switches to 57.49
   - Set the R switches to 54.99
   - Set the R switches to 65.01

6.1.2 Reclose Enable

To verify the Reclose Enable function, perform the following tests:

a. Set the Reclose Enable switches to 59.90.
b. With a rated ac voltage and 60 Hz input, the reclose enable telephone relay should be picked up and its LED should be turned on.
c. Reduce the ac input frequency to 59.80 Hz. The reclose enable telephone relay drops out and its LED turns off.
d. Change the input frequency to 57.55 Hz and set the reclose enable switches on 57.45. The alarm LED should be turned on.

6.1.3 Trip Condition and Accuracy

a. Set the Reclose Enable switches to 59.50 and Frequency #1 switches to 59.00.

b. With a rated ac input voltage, gradually lower the input frequency from 60 Hz. The Reclose Enable LED should be turned off at 59.49 Hz. The Frequency #1 LED turns on at 58.99 Hz and its telephone relay picks up. Return the Frequency #1 setting to 57.50.

c. Repeat step (a) and (b) for Frequency #2, #3 and #4 (if supplied).

6.1.4 Cut-Off Voltage Setting (Trimpot P1)

The relay has been set at 80% ±2% of the line voltage. The procedures for checking and changing the setting are shown as follows:

a. A scope probe to TP3 on MDF board and scope common to COM.

b. A rated ac input voltage and frequency, the voltage at TP3 should be “1” (approximately 5v).

c. The ac input voltage below 80% of the line voltage. The voltage at TP3 should be “0” (below 0.5v).

d. Set the ac input voltage to the desired cutoff voltage. Adjust the trimpot P1 to obtain the Voltage at TP3 which jumps from “1” to “0”.

6.1.5 Cut-off Voltage Dropout Ratio

Normally, the dropout ratio is between 92% and 97% for a 60 Hertz system, and between 94% and 99% for a 50 Hertz system. However, the dropout ratio can be changed by replacing the resistor R11 on the MDF module. By increasing or decreasing the value of R11, the relay will have higher or lower dropout ratio respectively. If the R11 is changed, be sure that the voltage at TP3 is a solid voltage, high or low, near the cut-off voltage setting. No pulse type waveform should appear.

6.1.6 Time Delay

Use a voltage controlled oscillator (VCO) and DPDT switch for this section test. One set of the DPDT switch contacts is for the frequency change from 60 Hz to 55 Hz by the sudden change of the biasing voltage of the VCO and another set of the contacts is for timer start. At normal condition, the ac input is set at 60 Hz.

a. Set the time delay BCD switches to 00.

b. Use a digital timer to measure the time delay. Connect the timer start to one set of the DPDT switch contacts and connect the timer stop to the Frequency #1’s telephone relay contact, e.g., the relay terminals 2 and 3.

c. Suddenly switch the ac input switch (DPDT) from 60 Hz to 55 Hz. The delay time should be between 55 and 75 milliseconds.

d. Repeat step (c) for the following time delay settings:

<table>
<thead>
<tr>
<th>Delay Time Settings (sec)</th>
<th>Min &amp; Max. Reading (ms)</th>
</tr>
</thead>
<tbody>
<tr>
<td>.00</td>
<td>65 - 85</td>
</tr>
<tr>
<td>.10</td>
<td>137 - 162</td>
</tr>
<tr>
<td>.55</td>
<td>587 - 612</td>
</tr>
<tr>
<td>.90</td>
<td>937 - 962</td>
</tr>
</tbody>
</table>

† NOTE: This tolerance is based on the input frequency of 55 Hz.

6.1.7 Indicating Contactor Switch (ICS)

Close the main relay contacts and pass sufficient dc current through the trip circuit to close the contacts of the ICS. This value of current should be greater than ICS’s rated current. The operation indicator target should drop freely.

The contact wipe should be approximately 0.016 inches. The bridging moving contact should touch both stationary contacts simultaneously.

6.1.8 Relay Check

This relay can be checked easily and quickly in the field by applying the line voltage and frequency to the relay terminals 4 and 5.

a. Use the step #1 for the Alarm condition check.

b. Use the step #2 for the Reclose Enable check by varying the RE switches near the rated line frequency. The RE’s LED and telephone relay should pick up or drop out if the setting is lower or higher than the line frequency respectively.

c. The accuracy can be checked by setting the RE switches at 61.00 Hz and F2, F3 and F4 switches at 60.04 Hz. By varying the setting of F1, the F1’s LED and telephone relay should pickup or drop
cut if the setting is higher or lower than the line frequency respectively. Repeat the same test for F2, F3 and F4.
d. Use the step #4 and #5 for the cut-off voltage setting.

6.2 Routine Maintenance
All relays should be checked and contacts should be cleaned at least once every year. A contact burnisher S#182A836H01 is recommended for cleaning.

6.2.1 Calibration
The relay's accuracy is mainly determined by an internal crystal oscillator. The only parts needed to be calibrated are as follows:
a. Cut-off Voltage Setting (Trimpot P1)
The procedures for setting the cut-off voltage is discussed in section 4 of the acceptance test. The relay is set at 80% of the line voltage. The cut-off voltage can be set between 20% and 90% of the line voltage for dc relay and between 60% and 90% for ac relay.

b. Indicating Contact Switch (ICS)
Initially adjust unit on the pedestal so that armature fingers do not touch the yoke in the reset position. This can be done by loosening the mounting screw in the mold pedestal and moving the ICS in the downward position.
Adjust the stationary contacts so that both stationary make with the moving contacts simultaneously and wipe 1/64" to 3/64" when the armature is against the core. Manually raise the moving contacts and check to see that the target drops at the same time as the contacts made or up to 1/16" ahead. The cover may be removed and the tab holding the target reformed slightly if necessary. However care should be exercised so that the target will drop with a slight jar.

7. RENEWAL PARTS
Repair work can be done most satisfactorily at the factory. However, interchangeable parts can be furnished to those customers who are equipped for doing repair work. When ordering parts, always give complete nameplate data.
Figure 6. Simplified Internal Schematic (ac) MDF-1

Sub 2
3530A13

Figure 7. Simplified Internal Schematic (ac) MDF-2

Sub 2
3530A14

Figure 8. Simplified Internal Schematic (ac) MDF-3

Sub 2
3530A15

Figure 9. Simplified Internal Schematic (ac) MDF-4

Sub 2
3530A16
Figure 10. Block Diagram for the MDF Relay
Figure 14. Component Location of MDF Board - One Frequency Setting

Figure 15. Component Location of MDF Board - Two Frequency Setting
Figure 16. Component Location of MDF Board - Three Frequency Settings

Figure 17. Component Location of MDF Board - Four Frequency Settings
Figure 18. Component Location of Power Supply Board (dc) - One Frequency Setting

Figure 19. Component Location of Supply Board (dc) - Two Frequency Settings
Figure 20. Component Location of Power Supply Board (dc) - Three Frequency Settings

Figure 21. Component Location of Supply Board (dc) - Four Frequency Settings
Figure 22. Component Location of Power Supply Board (ac) - One Frequency Setting

Figure 23. Component Location of Supply Board (ac) - Two Frequency Settings
Figure 24. Component Location of Power Supply Board (ac) - Three Frequency Settings

Figure 25. Component Location of Supply Board (ac) - Four Frequency Settings
Figure 26. Module Assembly MDF Filter Module

Figure 27. Module Assembly MDF Fuse Module

* Denotes Change
Figure 28. Outline & Drilling Plan for MDF Relay in FT-32 Case