Hotliner Application Note

HARMONIC SUPPRESSION REACTOR (HSR)

Printed in USA 4/98

Introduction

These instructions are intended for telephone and power company personnel who plan to conduct tests to determine the need for an SNC Harmonic Suppression Reactor (HSR). The instructions explain how to find the proper location for an HSR, and how to test that location to determine the amount of inductance needed from the permanent HSR. All testing and installation procedures are explained in detail. SNC recommends that you read the entire set of instructions before you begin field testing.

A Message on Safety

SNC Manufacturing Co. is concerned about your safety. Read these instructions carefully. Pay strict attention to all DANGER, WARNING and CAUTION statements. When you see these statements, take heed - your personal safety, the safety of your co-workers, and the safety of your equipment may be at risk.

DANGER: Possibility of personal injury.
CAUTION: Possibility of service interruption.
WARNING: Possibility of equipment damage.

This safety alert symbol is used throughout these instructions to alert you to hazardous situations. When you see this symbol pay strict attention to all safety instructions that follow!

Form No. T0142
Printed 4/98

Contents

1. SYMPTOMS

- Entire telecommunication cable route is noisy.
- Noise starts and stops on cable route at specific times.
- One induced harmonic of 50/60 Hz is substantially higher than either adjacent significant harmonic.
- Shunt capacitors are failing on a distribution power line.
- Excessive or unexplained fuse cut-outs or circuit breaker operation on a distribution power line.

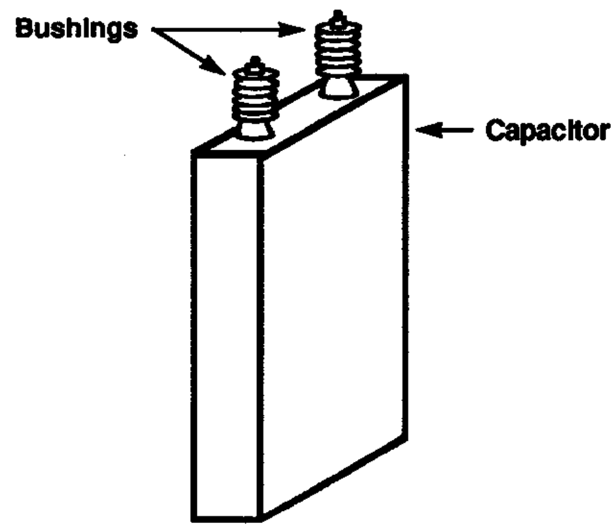


Figure 1: Capacitor Bank (Shunt Capacitor)

2. TEST PROCEDURES (FINDING THE SOURCE OF THE PROBLEM)

A. Spectrum Analyzer and Exploring Coil

2.01 If you are experiencing any of the above symptoms on a telephone line;

(a) Check to see if the power line parallelling the telco facilities contains any shunt capacitors.

(b) If it does, use a Spectrum Analyzer (such as a Wilcom T132B or 132EZ) and obtain access to a pair in the noisy telephone route. This pair should be clear of shorts or grounds, and have greater than 10 megohms insulation resistance tip (T) to ring (R) or T or R to ground (G). (Some parts of the world may refer to T and R as "a" and "b".)

(c) Short and ground the pair at the near end, which is usually the serving central office.

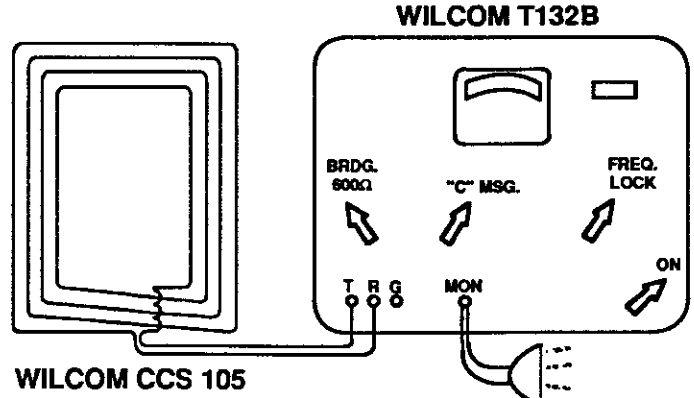
(d) At the far end, measure the Power Influence (PI) or noise-to-ground (Ng) (PI=Ng + 40 dB) on the pair. Use the worksheet in the Appendix to record the measurements.

(e) Measure the PI of the fundamental power frequency (50/60 Hz) and the significant harmonic frequencies using a "C" message weighting network. Also perform 3 KHz flat weighted measurements, particularly to note the magnitude of low order harmonics (3rd, 5th, 7th). A dedicated data circuit or electronic equipment may be sensitive to those harmonics.

(f) If harmonic resonance is the problem, locate the problem capacitor bank before involving the power company line crew. This can usually be done by asking the power company for the location of their banks in the area covered by the noisy telephone line. (See "Additional Information" concerning underground power lines.)

Note: The capacitor bank is usually not the <u>cause</u> of harmonics. It is the location at which harmonic current generated on the power system conducts to ground. Harmonic resonance results when power system inductive reactance and shunt capacitor reactance are equal in magnitude at a given harmonic frequency. The reactances cancel each other out, allowing the harmonic frequency voltage to induce a potentially large current to flow to ground or neutral through the capacitor bank.

WILCOM T132B



WILCOM CCS 105
OR >200' WIRE COIL

Figure 2: CCS 105 or >200 Foot Wire Coil with Wilcom 132B or 132EZ

2.02 It is unusual for a capacitor bank to have a resonant condition above the 21st harmonic. However, it is a good idea to check the entire voice band, since other interference sources may produce symptoms that can be detected by this test. Any harmonic frequency measuring substantially higher than the next significant harmonic may indicate a resonant condition on the power line. (Harmonic resonance most often occurs at the 9th harmonic, 540 Hz on 60 Hz power lines and 450 Hz on 50 Hz power lines.)

Note: Many capacitor banks are switchable and may not be connected to the power line at all times. If symptoms come and go, run the tests when the symptoms are present.

2.03 The capacitor(s) to which the harmonic current is conducted may be some distance from the affected area. There have been cases where a capacitor bank was the harmonic drainage point for a noise problem in an adjacent exchange.

Continuing Test Procedure

(g) Connect the exploring coil to the T & R terminals of the spectrum analyzer and set the spectrum analyzer for a 600 ohm bridged reading. The wire loop exploring coil may be a Wilcom CCS105 or a 200 foot or greater coil of wire, connected so that a single wire forms the loop across the T & R. (See Figure 2)

(h) Set the scale of the spectrum analyzer to the desired frequency that provides an on-scale reading. Don't worry about the actual value - the change in level is what is important. It is also a good idea to listen with the monitor jack, as the ear may provide diagnostic insight that the meter readings won't yield..

(i) While riding along the power line, hold the exploring coil out the window in a position that provides the maximum reading (parallel to the power line exposure). A major change in the frequency level, up or down, can indicate the direction to, or presence of the faulty bank. If the change occurs at a power line branch or tee, it can usually be followed to its source.

(j) If the frequency level change occurs at a power apparatus, the apparatus or its wiring arrangement could be the problem. If it is a capacitor bank, visually inspect the bank for obvious problems, such as open fused cutouts, broken wires, or ruptured capacitors. If you don't see any problems, it is still likely that you have found the problem bank. Power company assistance is now necessary. See Paragraph 2.08.

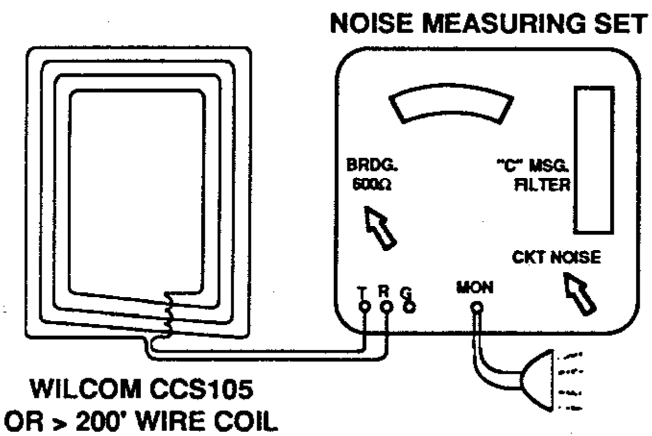


Figure 3: CCS 105 or >200 Foot Wire Coil with Noise Measuring Set

B. Noise Measuring Set and Exploring Coil

2.04 If a spectrum analyzer is not available, a telephone noise measuring set (NMS), such as a Western Electric 3C or Hewlett Packard HP3551A can be used. These are not as good as a spectrum analyzer because the noise level changes may not be as obvious.

(a) Check the power line for capacitor banks.

(b) If there are capacitors present, ride the route with an NMS and an exploring coil (600 ohm-bridge - circuit noise - "C" message settings) just as you would with a spectrum analyzer. (See step i under paragraph 2.03)

2.05 Any significant change in noise level, up or down, or when passing a capacitor bank or other power apparatus, could indicate the problem. If possible, listen to the noise also. Examine the bank or equipment for obvious problems. If nothing appears to be wrong, it is time to involve the power company.

2.06 If the NMS can't make bridged readings with an exploring coil, it may not be possible to locate the problem bank. An exploring coil connected across the T & R of the NMS with the selector set to measure noise metallic (or circuit noise) may not receive a strong enough signal to obtain a reading. In this case, power company help may be necessary before the bank is located. See Paragraph 2.08.

C. Measuring "Power Volts"

2.07 A more tedious method of finding a problem capacitor is to measure "Power Volts" with a Wilcom 132B or 132EZ.

(a) After the capacitor is located, access the power line at a nearby service outlet (Example: 120V, 60 Hz in USA).

(b) Measure and record the "Power Volts" of the significant harmonics in the voice frequency spectrum (50/60 Hz through 4K Hz). See the Wilcom T132B or 132EZ instruction manual for instructions on making "Power Volts" measurements.

(c) Make at least two sets of measurements near each capacitor location. One set near the bank on the power substation side and one set just beyond the bank. Record the measurements on the worksheet in the Appendix. Any harmonic frequency that is substantially higher than the next significant harmonic may indicate a resonant condition on the power line. Remember, harmonic resonance usually occurs at the 9th harmonic - 540 Hz on 60 Hz power lines and 450 Hz on 50 Hz power lines.

Note: If a power company is experiencing the symptoms listed in Section 1 of these instructions on a power line, any of the above procedures can be used to locate the problem bank(s).

(d) If a problem is found using the "Power Volts" method, the capacitor bank should be temporarily disconnected. Another set of "Power Volts" measurements should be made and recorded. If these measurements indicate a significant decrease in the noise level, that bank is a candidate for an HSR.

POWER COMPANY INVOLVEMENT

2.08 It is not unusual for the problem bank(s) to be some distance from where the symptoms are occurring. Therefore, testing the noise condition from the site of the capacitor bank may be difficult. To coordinate the tests, communication is needed between the capacitor bank and the test site. Two way radio is easiest. If a radio isn't available, a wire line "talk circuit" can be established over nearby telephone lines.

(a) Access a test pair, similar to the pair used in paragraph 2.01, in the telephone line. It should be shorted and grounded at the near end.

Note: A seldom used or temporarily connected POTS circuit may be substituted for this pair. If a POTS circuit is used, the dial-up "Balanced Termination" should be accessed and "held".

(b) Measure and record the noise to ground. If a spectrum analyzer is used it should be tuned to the offending frequency.

(c) The power company can now disconnect the suspected bank(s), one at a time, on all three phases at each site. Each time a bank is disconnected, the Ng on the telephone line should be recorded. If a spectrum analyzer is being used, it may help to measure and record the other harmonics and the overall Ng value in addition to the offending frequency. A significant drop in telephone line noise when a bank is removed means that bank is a candidate for an HSR.

3. SOLUTION PRINCIPLES

A. Shunt Capacitors

3.01 The series impedance of a distribution power line is inductive and the connected load is also normally inductive in nature. Power companies compensate for this by installing shunt capacitors to boost voltage and power factor on their lines. These capacitors, placed between the phase wires and the neutral of a wye-connected system, are normally used only on three phase lines. Occasionally one is placed near the end of a long single phase line. The amount of capacitance needed depends on the location of the bank and that particular line's load. Some banks are permanently connected, while others are switched on and off as needed. This need is determined by load, temperature, time of day, time of year, etc. The banks can be switched on and off manually, automatically or by remote control.

3.02 There are times when the capacitance (rated in KVAR [kilo-Volt Amperes reactive]) causes a resonant condition to occur with the source and line inductance. This usually occurs at the ninth harmonic (540 Hz on a 60 Hz line or 450 Hz on a 50 Hz line), but it can occur at any harmonic. When this condition occurs, unusually high amounts of AC current circulate through the line, the capacitor and the earth at that frequency. This current can couple into paralleling telephone lines, resulting in noisy circuits. It may also cause capacitors to fail and contribute to unexplained fuse or circuit breaker operation on that line.

3.03 The HSR is an iron core inductor wound with heavy #3 AWG square wire and is installed in the neutral circuit of the capacitor bank (See Figure 4). The possibility of HSR failure in an open neutral circuit condition is highly unlikely because the fusing time of an HSR-42 far exceeds the maximum clearing time of a 65K fuse link (typically the largest fuse link used on capacitor banks).

When added in series with the neutral or ground circuit of the capacitor bank, the HSR can shift the resonant frequency point of the power line and capacitors to a lower frequency region. This "detuning" reduces the high harmonic current, reducing the PI that causes telephone line noise, capacitor bank failure, or false breaker operation.

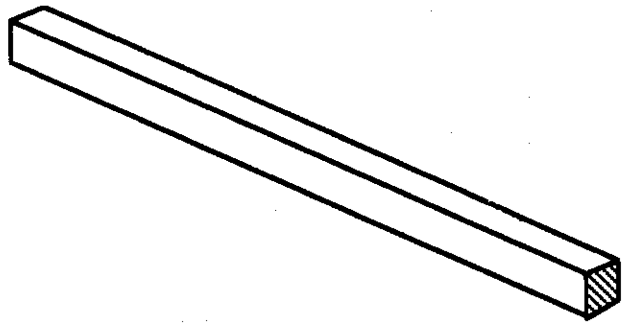


Figure 4: HSR #3 AWG Square Wire (Actual Size)

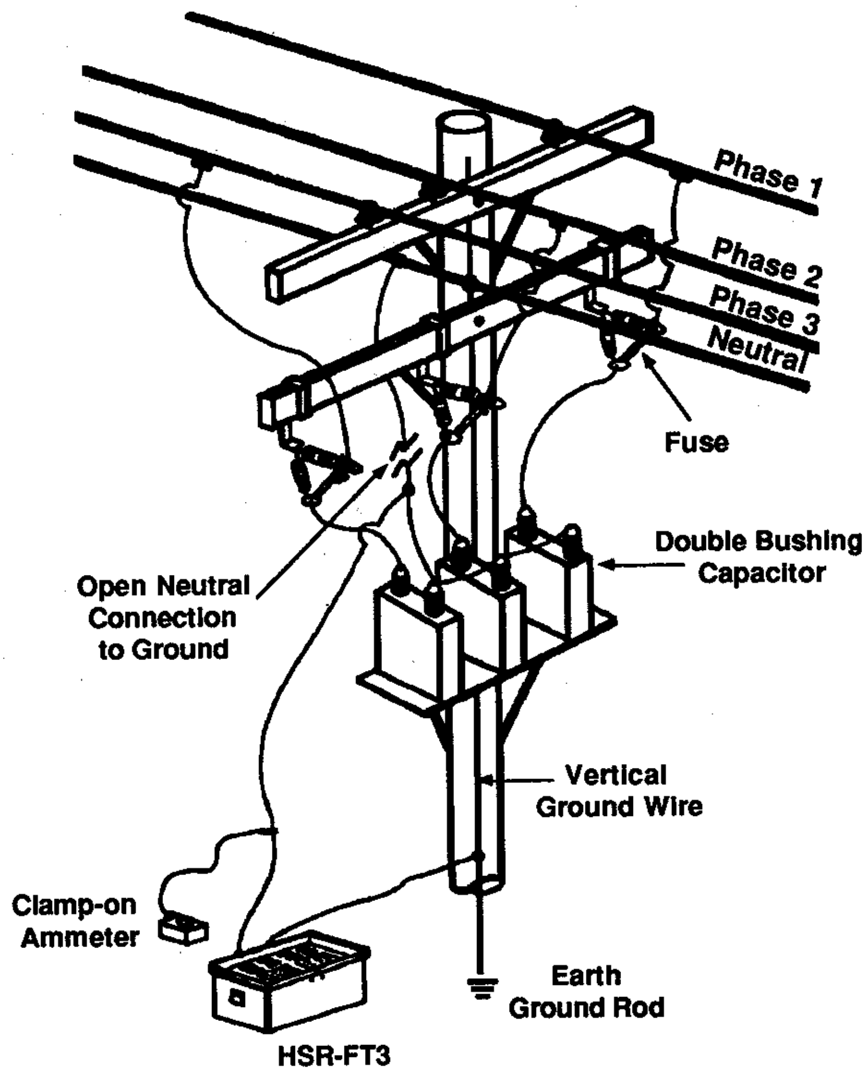


Figure 5: HSR-FT3 Test Connections

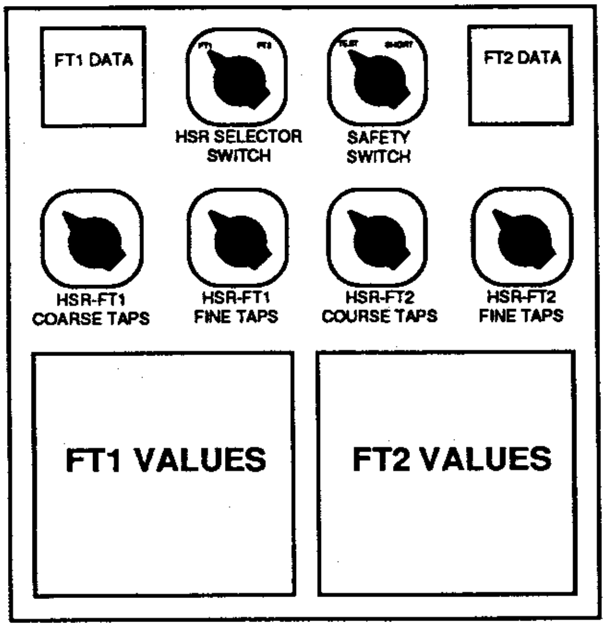


Figure 6: FT3 Control Panel

B. HSR-FT3 Field Test Procedure

3.04 If removing a capacitor bank(s) reduces the PI, an HSR field test should be conducted. SNC's HSR-FT-3 Field Test Reactor is designed to be temporarily placed in the ground circuit path of the capacitor bank (between the capacitor bank and the vertical ground wire). (See Figure 5)

3.05 The FT-3 has two reactors (FT-1 and FT-2) in one case, each with individual coarse and fine make-before-break switches. Two more two-position switches are used to connect; 1) one of the reactors to the external terminals, and; 2) provide reactor shorting or testing means positions. The tap changing switches are used to vary the amounts of inductance (3-85 millihenries) that can be inserted into the ground circuit of the capacitor bank.

3.06 The shorting/testing switch MUST be in the shorting position (fully clockwise) any time a change is made to the capacitor bank connections. This means; 1) when installing the FT-3 test reactor; 2) when opening or closing a capacitor bank phase while the FT-3 is installed; 3) switching from the FT-1 reactor to the FT-2, or vice versa; 4) when coarse and fine test values are changed.

DANGER: The shorting/testing switch on the FT-3 test reactor MUST be in the shorting position (fully clockwise) any time a change is made to the capacitor bank connections.

Note: When using SNC's discontinued line of individual FT-1 and FT-2 test reactors, the shorting requirement is also necessary. This can be done by placing an external metallic by-pass connection across the terminals of the test reactor.

(a) Make arrangements with the power company to place an HSR-FT-3. It should be placed in the neutral circuit path of the previously located offending capacitor bank.

DANGER: Whenever a test reactor or permanent HSR is installed, the power company must make all the connections.

(b) Before the FT-3 is connected, the power company should measure the current in the capacitor's neutral ground circuit with a clamp-on ammeter. Record this measurement on the work sheet in the Appendix. This value is usually only a few amperes (roughly 7 amperes or less). If the value is more than five, make sure the power company is satisfied that there are no evident abnormalities on the power system, such as a bad capacitor, before continuing.

(c) Power company personnel should connect the external FT-3 terminals into the neutral circuit after the bank is disconnected. The FT-3 shorting/test switch must be in the shorting position. The ammeter will indicate changes in the neutral current as inductance is added. It should be used only after all capacitor phases are closed.

(d) After the FT-3 is connected, tests can be made without the power company making any changes until the FT-3 is removed.

3.07 Once the capacitor has been reconnected and the short removed from the test reactor, the current should not exceed 21 amperes if using the FT-1, or 11 amperes if using the FT-2 (except for a very short time to obtain a reading).

Note: A failed capacitor or open phase could cause a large 50/60Hz current to flow equal to the capacitor rated load current.

(e) The two tap changing switches should be turned completely counter-clockwise to position 1.

DANGER: Wear rubber lineman's gloves and stand on a rubber blanket when making any changes to the HSR test reactor tap settings.

DANGER: If using an older FT-1 or FT-2 that has a metal case, the case should be connected to the local vertical ground wire. The newer FT-3 case is made of an insulating material and need not be grounded.

3.08 Each HSR test unit has a serial number and data sheet that translates the dial switch positions into the amount of inductance the positions insert. If the data sheet becomes lost or misplaced, a replacement copy can be obtained from SNC.

(f) Once you have determined the amount of inductance needed, remove the capacitor bank from line and discharge it. Then remove the FT-3 test unit, reconnect the capacitor bank's neutral connections to ground, and order a permanent HSR.

3.09 When FT-3 reactor inductance is added it lowers the resonant frequency at the test capacitor bank. If the capacitor bank is resonating near 540 Hz (9th harmonic), adding inductance will lower the initial point of resonance. A value below 180 Hz (3rd harmonic) should be reached. By observing a 60 Hz harmonic frequency (using a spectrum analyzer), you will see the resonance decrease as inductance is added. A clamp-on ammeter may not reveal the decrease because it will respond to any 60 Hz unbalance current and most low-order harmonic currents.

Note: The graph in the appendix (App-4) illustrates how the resonant point of a capacitor bank and power system inductance change when FT-3 inductance is added.

WARNING: When adding inductance, do not leave the FT-3 at a setting that will allow the resonance to peak at a low order 60 Hz harmonic frequency. This is particularly important for 180 Hz, which is usually the largest of all harmonic voltages.

Note: A formula on page 9 (paragraph E, 4.0) permits easy calculation of approximate values of HSR inductance that could cause resonance at 180 Hz. That setting (value) should be avoided when a permanent HSR is installed.

C. MONITORING FT-3 INDUCTANCE

3.10 There are several methods for monitoring the effects of adding inductance with the HSR-FT-3. In all cases it is best to use a spectrum analyzer.

Current Probe and Spectrum Analyzer

3.11 The use of a current probe and spectrum analyzer is the best way to determine the inductance needed for a permanent HSR. A spectrum analyzer with a cathoderay tube output that performs rapid harmonic analysis and display (such as an HP 3561) is best. A tunable spectrum analyzer with a current probe, such as a Wilcom 132B or 132EZ, can also be used.

Measuring at a Pedestal

3.12 Noise measurements can be made on a pair at a nearby pedestal. Flat weighted noise to ground will show the changing levels of all harmonics on a spectrum analyzer. Some means of communication will have to be established between the capacitor bank site and the pedestal location.

Wire Loop Exploring Coil and Spectrum Analyzer

3.13 Another way to monitor the HSR tests is to use a wire loop exploring coil and a spectrum analyzer or NMS (one capable of making "bridged" readings). This can be done near the capacitor bank, eliminating the communication problem.

(a) Place the wire loop exploring coil and the NMS (or spectrum analyzer) under the power line, on the side of the capacitor with the harmonic resonance.

(b) Connect the coil to the T and R of the NMS (600 ohm - bridge - circuit noise - "C" message settings). The coil should be in a fixed, stable position, perpendicular to the earth and parallel to the power line. (This usually provides the greatest signal strength to the NMS.) Once the coil is positioned it should not be moved.

(c) Measure and record the overall circuit noise. If using a spectrum analyzer, measure and record the significant harmonics. Experience will help determine the need and number of measurements required. SNC recommends that a set of measurements be made without the HSR, and another set made with each tap setting of the HSR.

100 Foot Probe Wire and Spectrum Analyzer

3.14 Another method is to use a 100 foot probe wire and a spectrum analyzer or NMS set (one capable of making "bridged" readings). This test can also be done near the capacitor bank, eliminating the communication problem.

3.15 Tools needed for this procedure are:

- 100 foot single insulated wire
- two "ground" probes
- 2 to 4 foot jumper wire
- Noise Measuring Set or Spectrum Analyzer

3.16 The jumper wire connects one of the ground probes to the NMS. The ground probes are "T" shaped metallic rods, about 18 to 24 inches long, which are pushed into the ground to make electrical contact with the earth. Any bare metallic rod can be used as a probe.

(a) Place the 100 foot wire on the ground, parallel to and relatively close to the power line, on the side of the capacitor bank with the harmonic resonance. If possible, the probe wire should be placed in an area clear of metallic wires, fences, railroad rails, water main pipes, etc.

(b) Connect a ground probe to one end of the 100 foot wire and insert the probe into the earth.

(c) Connect the other end of the wire to either the T or R terminal of the NMS.

(d) Connect the other terminal (T or R) of the NMS to the short jumper wire.

(e) Connect the jumper wire to the second ground probe, which is inserted into the ground near the NMS.

(f) Set the NMS to measure "noise metallic, 600 ohm bridged, `C' message weighting" and adjust for an on-scale reading.

(g) Measure and record the readings as FT-3 inductance is changed. Once again, look for a minimum noise influence reading - actual values are not important.

(h) Once the minimum is found, make one test on the original test pair to make sure the best overall noise improvement has been obtained.

Note: For any of the above methods, the chance of selecting a final inductance value close to or on 180 Hz increases if a spectrum analyzer is not used. 180 Hz is weighted down roughly 30dB on "C" Message weighted noise set measurements. Therefore, it does not display as prominently on a standard NMS as it does on a spectrum analyzer.

3.17 Any excessive harmonic currents in the capacitor neutral are undesirable for either the telephone or power systems. The formula on page 9 (paragraph E, 4.0) describes how to calculate the value of HSR inductance so that large resonant currents can be avoided.

4. ELECTRICAL CHARACTERISTICS

4.01 The HSR-FT-3 contains two test reactor coils, the FT-1 and the FT-2. Inductance is changed by turning the tap switches. See Table A for electrical characteristics of the HSR-FT-3.

4.02 Although the field test reactors are similar to a permanent HSR, they are light duty and should never be left in a power line unattended. The HSR-42 is built for permanent installation. See Table B for electrical characteristics of the HSR-42.

4.03 If inductance values greater than 40 mhy are needed, two HSR-42's can be installed in series in the capacitor neutral circuit (See Schematic Drawings in App-7).

4.04 Each HSR-42 comes with a 3KV class surge arrester. This arrester connects between the capacitor side connection of the HSR and the neutral connection. It protects the HSR winding from lightning and switching transients. The main terminals of the HSR-42 are connected through power-industry-rated 5Kv bushings. The HSR-42 also has lifting brackets and standard pole-type mounting brackets.

Table A
HSR-FT3 Electrical Characteristics

Inductor	Inductance Range	DC Resistance at 20° C	Continuous Current Thermal Rating
HSR-FT1 Inductor	3 to 20 mHy (ea. tap approx. 0.3 mHy)	0.144Ω	21 amps 60 Hz RMS
HSR-FT2 Inductor	13 to 85 mHy (ea. tap approx. 1.5 mHy)	0.512Ω	11 amps 60 Hz RMS
HSR-FT3 Overall	3-85 mHy	(Contains FT1 and FT2 within one fiberglass case)	

Table B
HSR-42 Electrical Characteristics

Nominal Inductance Connected	DC Resistance at 20° C	Continuous Current Thermal Rating
3.0 mHy to 42.0 mHy	0.014 Ω to .04 Ω	50 amps 60Hz RMS

5. ADDITIONAL INFORMATION

A. Saturation Levels

5.01 Because the HSR is an iron core inductor, it is subject to magnetic saturation when current levels exceed the linear flux density region of the core. In a permanent HSR, this value develops roughly between 15-20 amperes, 60 Hz RMS. However, the HSR will continuously carry 50 amperes RMS 60 Hz if a single phasing situation occurs on a 3-phase capacitor bank (such as a blown fused cutout). For this reason the HSR should be applied only up to selected sizes of capacitor banks (3 phase KVAR rating) dependent on the distribution feeder voltage rating.

5.02 The table in App-5 shows the maximum KVAR ratings recommended for the HSR at various ANSI C84.1 Standard System distribution voltages. For example, a 900 KVAR, 3-phase capacitor bank is the largest recommended installation for the HSR when the feeder voltage is 7200/12470 Y volts.

B. Single and Double Bushing Capacitors

5.03 Shunt capacitors are available with either single or double bushings. **Double bushing capacitors** have each plate of the capacitor internally connected to an insulated bushing. One bushing is connected to the neutral, and the other to a fuse or oil switch and then to the phase wire. The steel case is insulated from each bushing terminal and is normally separately grounded to the neutral and/or pole ground wire.

Single bushing capacitors have one plate of the capacitor connected to a bushing and the other to the external steel case. The external case is used as the neutral connection with the bushing side connected to the fuse or oil switch and then to the phase wire.

DANGER: DO NOT install HSR on single bushing capacitors. Serious injury could result!

5.04 While double bushing capacitors are usually used in pole top applications, there are occasions when single bushing capacitors are used in pole top applications. **DO NOT** install HSR's on single bushing capacitor installations. This would require "floating" the capacitor case and mounting frame from pole ground to install the HSR in the grounding path of the capacitor. This is an unsafe condition, especially if it is a switched capacitor bank with an oil switch control box extended to the bottom of the power pole.

5.05 When a single bushing capacitor bank needs an HSR, the telephone company should ask the power company to change to double bushing capacitors before conducting tests with the FT-3 test reactor and before installing a permanent HSR.

C. Underground Power Lines

5.06 Underground power lines have much higher capacitance to ground than aerial lines. Therefore, an underground power line may have similar electrical characteristics to an aerial power line that has a capacitor bank, and a harmonic resonant condition could exist. In one case the power company was able to add a capacitor bank at the power cable riser pole and place an HSR on the new bank. This allowed them to shift the resonant frequency away from typical power line harmonics and solve the telephone company's problem.

D. 180 Hz And Core Losses

5.07 The graph in App-4 shows the results of detuning a resonant condition at 540 Hz on a 300 KVAR capacitor bank. Notice that the 540 Hz neutral current was the highest of all frequencies before HSR FT-3 inductance was added. Adding inductance reduced the 540 Hz current, while the other harmonics peaked on a new resonant point before declining as FT-3 inductance increased. Adding inductance significantly reduced the harmonic noise.

WARNING: Make sure the capacitor bank is "tuned" with enough inductance so that it does not resonate at 180 Hz.

5.08 The last frequency to peak is the 180 Hz current between 45 and 50 mHy of FT-3 inductance. It is important to shift the HSR inductance away from 180 Hz resonance because 180 Hz draws unnecessarily large currents through the capacitors and the HSR, even though the 180

Hz harmonic has 30 dB of "C" message weighted attenuation. The 180 Hz current causes undesirable core losses in the HSR and excessive shunt capacitor current.

5.09 Adding inductance to reduce the resonant frequency below 180 Hz reduces telephone line noise and decreases the chances of the capacitor bank resonating with any power system inductive changes in the future.

E. Odd Triple Harmonics

5.10 Odd triple harmonic (3, 9, 15, 21 ...) currents are usually most prominent in the power system capacitor neutral circuit. This is because they are generated from power system transformer excitation currents and are in-phase for each conductor and cannot be cancelled phase to phase, unlike the 120° displacement of other harmonic currents. When a capacitor is causing noise on a telephone line the 540 Hz harmonic is usually predominant. **If the capacitor is at or near resonance at 540 Hz** with the inherent power system inductance, and if the capacitor KVA and voltage are known, you can roughly determine the system inductance. For example, consider a 300 KVAR, three phase bank installed on a 7200/12470 Y volt power distribution line:

1.0 Capacitor Impedance is:

$$Z = \frac{KV^2(10)^3}{KVAR}$$

Where KV is line-to-line voltage and KVAR is the 3-phase value (sum of all phases).

2.0 Capacitance in micro-farad based on 60 Hz rated data is :

$$C = \frac{10^6}{2\Pi 60Z} = \frac{10^3\ KVAR}{2\Pi(60)KV^2}$$

3.0 System inductance in milli-Henrys at the capacitor bank for 540 Hz resonance is:

$$L = \frac{10^6\ (60)\ KV^2}{2\Pi\ (540)^2\ KVAR}$$

Where $X_L = X_C$, and X_C is determined using 2.0 above.

4.0 Inductance of an HSR in the capacitor neutral to create resonance at or near 180 Hz is:

$$L = \frac{8(10^6)(60)KV^2}{2\Pi(3)(540)^2\ KVAR}$$

or Roughly

$$(87.3) \cdot \frac{KV2}{KVAR}$$

Derived from 1/3 of the resultant of system 180 Hz resonant inductance minus system inductance found in 3.0 above.

So for the 300 KVAR capacitor bank the HSR inductance that would tend to cause resonance at 180 Hz would be approximately:

$$(87.3) \cdot \frac{(12.47)^2}{300} = 45.3$$

5.11 Therefore, while detuning 540 Hz noise with the FT-3, adding inductance will reduce the noise. However, as you approach roughly 45.3 mHy the 180 Hz currents may significantly increase. For this reason it is very important to add enough additional inductance to keep resonance effects below 180 Hz, while still decreasing the higher order harmonic frequency levels. See graph in App-4.

5.12 Resonant or near resonant conditions are most common at the 9th harmonic because the 9th harmonic is zero sequence in nature; it is in-phase on all three conductors. Other harmonics, such as the 7th or 5th, are displaced 120° from each other on the three conductors of the power line. These harmonics normally cancel and do not flow in the capacitor neutral, unless power line load unbalance conditions exist.

F. Multiple Capacitor Banks

5.13 There is often more than one capacitor bank installed on a power line feeder route. In these situations it is necessary to determine which banks are causing telephone line noise. It may be necessary to remove each capacitor bank and check its effect on the telephone line as it is reconnected to the power line. More than one HSR may be needed to eliminate noise in this situation.

CO ______________________ Test Location ______________________

Date ______________ Time ________ Power Company ______________________

Power Employees & Phone Numbers: ______________________________________

____

FT-1 Mhy	C	F	I	dBrn3k/f I 180Hz	PI
*	**1**	1			
	1	2			
	1	3			
	1	4			
	1	5			
	1	6			
*	**2**	1			
	2	2			
	2	3			
	2	4			
	2	5			
	2	6			
*	**3**	1			
	3	2			
	3	3			
	3	4			
	3	5			
	3	6			
*	**4**	1			
	4	2			
	4	3			
	4	4			
	4	5			
	4	6			
*	**5**	1			
	5	2			
	5	3			
	5	4			
	5	5			
	5	6			
*	**6**	1			
	6	2			
	6	3			
	6	4			
	6	5			
	6	6			

FT-2 Mhy	C	F	I	dBrn3k/f I 180Hz	PI
	2	5			
	2	6			
*	**3**	1			
	3	2			
	3	3			
	3	4			
	3	5			
	3	6			
*	**4**	1			
	4	2			
	4	3			
	4	4			
	4	5			
	4	6			
*	**5**	1			
	5	2			
	5	3			
	5	4			
	5	5			
	5	6			
*	**6**	1			
	6	2			
	6	3			
	6	4			
	6	5			
	6	6			

C = Coarse
F = Fine
I = Current
I 180Hz = Current at 180Hz on telephone cable or with CCS105 Coil.
PI = Power Influence on telephone cable or with CCS105 Coil. (Indicate whether PI was taken on cable or with coil.)
*** = Changes in course settings.**

How to use this sheet: Transfer the FT-1 and FT-2 values from the sheet attached to your HSR FT-3 test unit into the FT-1 and FT-2 columns above. Record your test measurements in the appropriate columns.

50 Hz Spectrum Analyzer Work Sheet

50 Hertz Harmonic	Frequency in Hertz	"C" Message Weighted"				Unweighted 3 KHz Flat			
		Noise Metallic dBrnc		Noise to Ground dB(NG) "C"		Noise Metallic dBrn		Noise to Ground dB(NG)	
		Before	After	Before	After	Before	After	Before	After
1	50								
2	100								
3	150								
4	200								
5	250								
6	300								
7	350								
8	400								
9	450								
10	500								
11	550								
12	600								
13	650								
14	700								
15	750								
16	800								
17	850								
18	900								
19	950								
20	1000								
23	1150								
25	1250								
27	1350								
29	1450								
31	1550								
35	1750								
39	1950								
43	2150								
47	2350								
51	2550								
55	2750								
59	2950								
63	3150								
67	3350								
71	3550								
75	3750								
79	3950								
81	4150								
Noise Measuring Set									
HSR AC Current									

Location

Test No.

Test Condition

Time

60 Hz Spectrum Analyzer Work Sheet

60 Hertz Harmonic	Frequency in Hertz	"C" Message Weighted"				Unweighted 3 KHz Flat			
		Noise Metallic dBrnc		Noise to Ground dB(NG) "C"		Noise Metallic dBrn		Noise to Ground dB(NG)	
		Before	After	Before	After	Before	After	Before	After
1	60								
2	120								
3	180								
4	240								
5	300								
6	360								
7	420								
8	480								
9	540								
10	600								
11	660								
12	720								
13	780								
14	840								
15	900								
16	960								
17	1020								
18	1080								
19	1140								
20	1200								
21	1260								
23	1380								
25	1500								
27	1620								
29	1740								
31	1860								
33	1980								
35	2100								
37	2220								
39	2340								
41	2460								
45	2700								
49	2940								
53	3180								
57	3420								
61	3660								
65	3900								
69	4140								
Noise Measuring Set									
HSR AC Current									

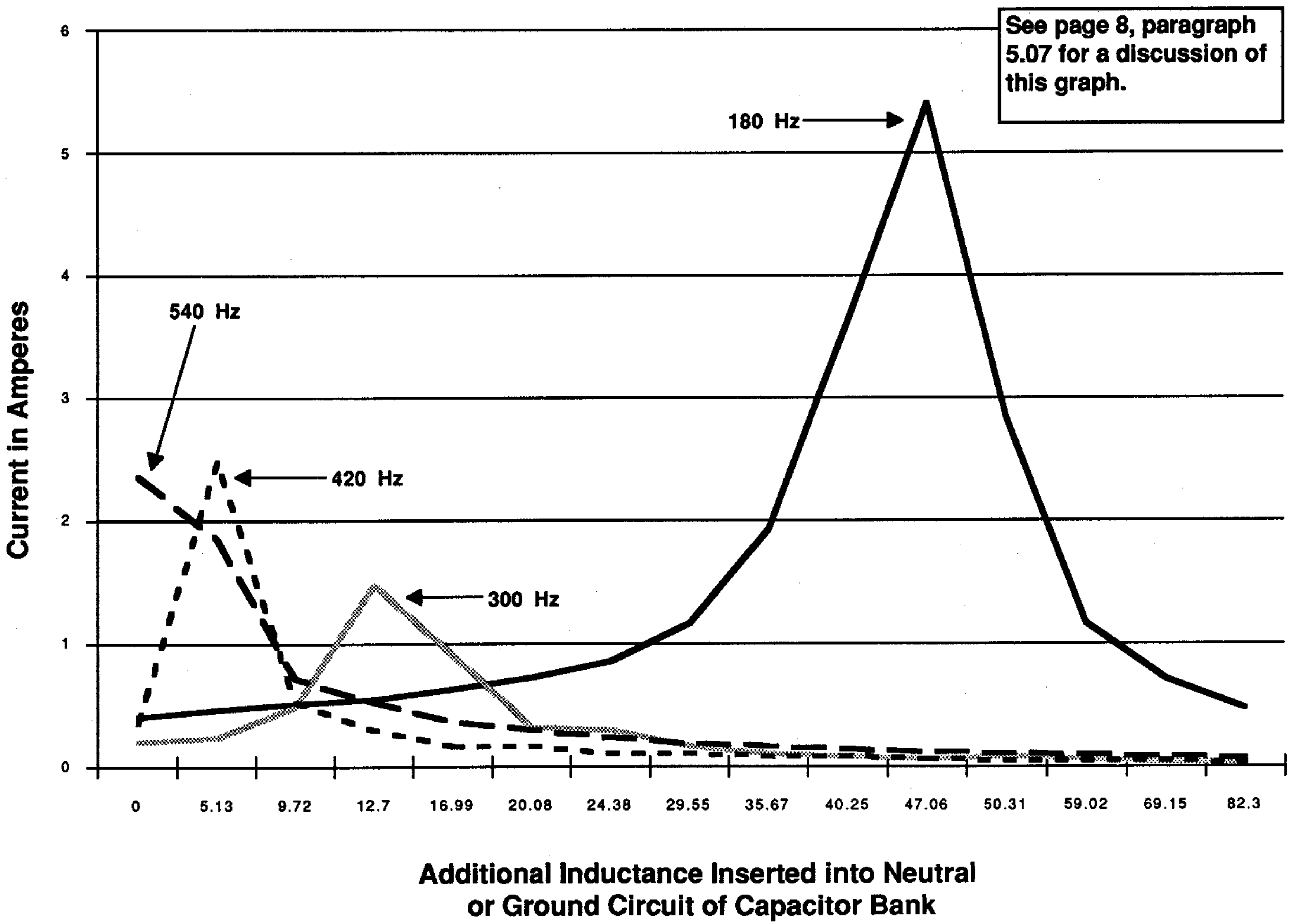
Location

Test No.

Test Condition

Time

Effect of Adding FT-3 Inductance
Newport, Oregon - Georgia Pacific
Cap. F101/35 300 KVAR



Maximum KVAR Ratings for HSR Installations at Various Standard System Voltages.

(Based on 50 amperes, 60Hz Continuous Current Rating of HSR-42)

ANSI C 84.1 Standard System Voltages

Amperes, 60Hz, RMS

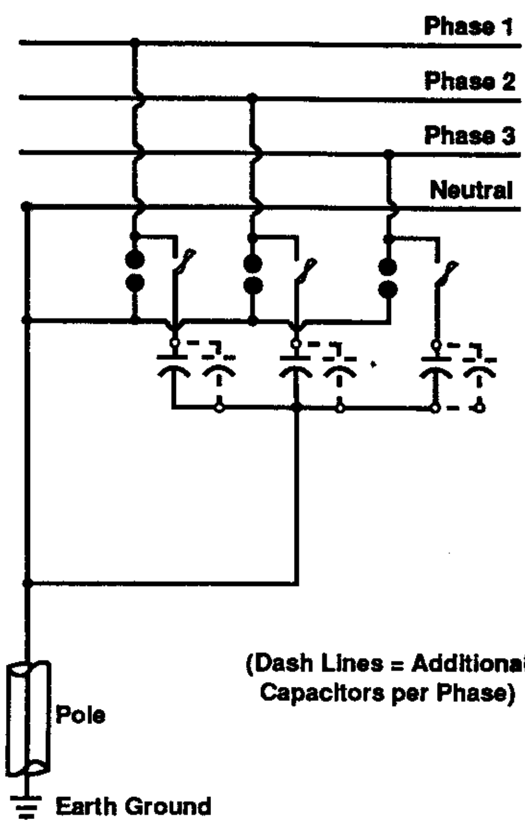
3-phase KVAR Capacitor Banks	2400 4160Y	4800 8320Y	6930 12000Y	7200 12470Y*	7620 13200Y*	7970 13800Y	12000 20780Y	13200 22860Y	14400 24940Y*	19920 34500Y*
150	20.8	10.4	7.2	6.9	6.6	6.3	4.2	3.8	3.5	2.5
300	41.6	20.8	14.4	13.9	13.1	12.6	8.3	7.6	6.9	5.0
450	**62.5**	31.2	21.7	20.8	19.7	18.8	12.5	11.4	10.4	7.5
600		41.6	28.9	27.8	26.2	25.1	16.7	15.2	13.9	10.0
750		**52.0**	36.1	34.7	32.8	31.4	20.8	18.9	17.4	12.6
900			43.3	41.7	39.4	37.7	25.0	22.7	20.8	15.1
1200			**57.7**	**55.6**	**52.5**	**50.2**	33.3	30.3	27.8	20.1
1500							41.7	37.9	34.7	25.1
1800							**50.0**	45.5	41.7	30.1
2100								**53.0**	48.6	35.1
2400									**55.6**	40.2
2700										45.2
3000										**50.2**

Example: A 900 KVAR, 3-phase capacitor bank is the largest recommended installation for an HSR when the feeder voltage is 7200/12470 Y volts.

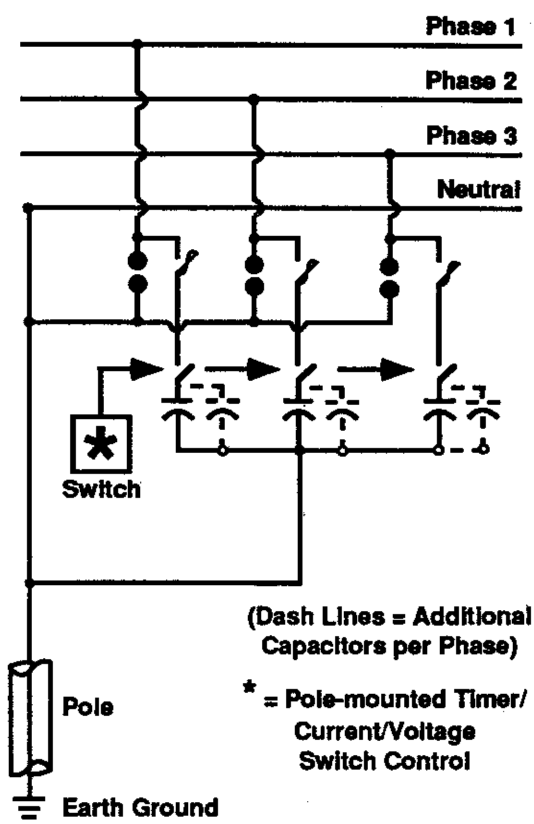
* Common System Voltages

Bold Numbers at bottom of columns exceed the continuous current rating of an HSR under worst case condition for that particular voltage.

Schematic Drawings



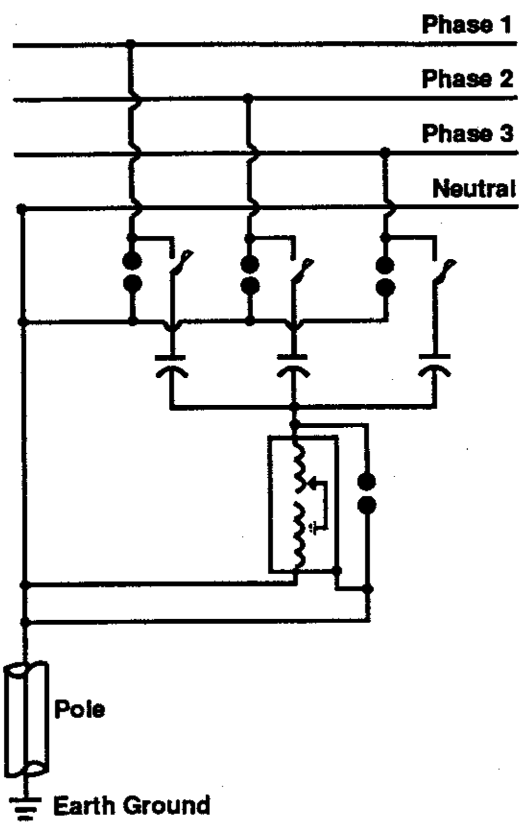
Basic Fixed Shunt Capacitor Bank



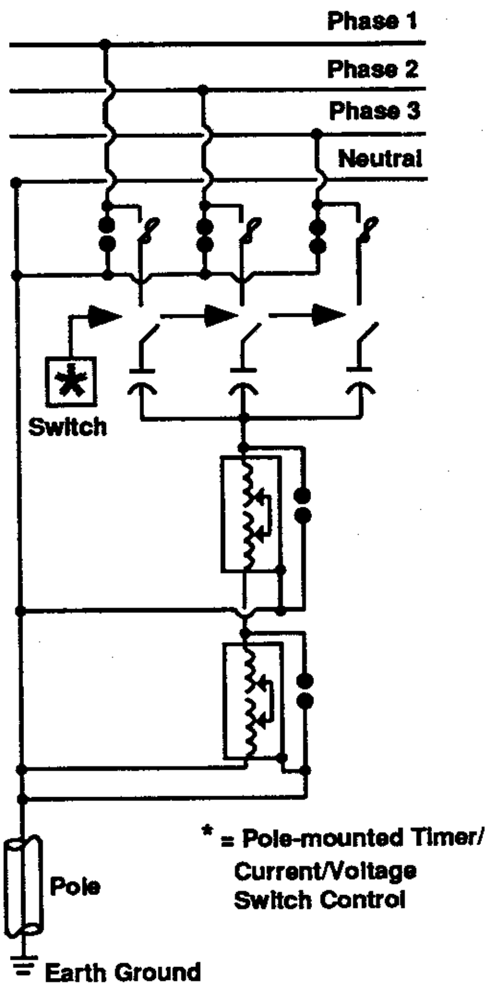
Basic Switched Shunt Capacitor Bank

Note: See App-8 for key to schematic drawings.

Schematic Drawings



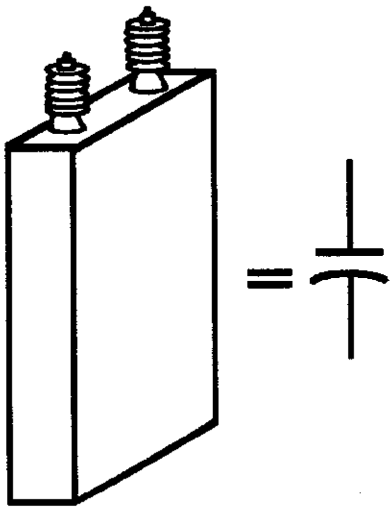
HSR Connected In Capacitor Neutral



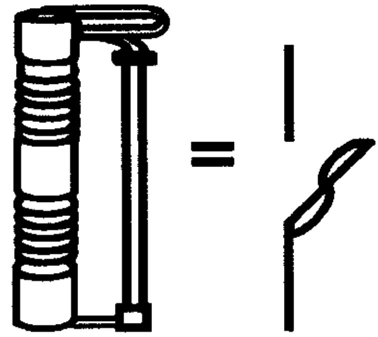
Tandem HSR's Connected In Capacitor Neutral

Note: See App-8 for key to schematic drawings.

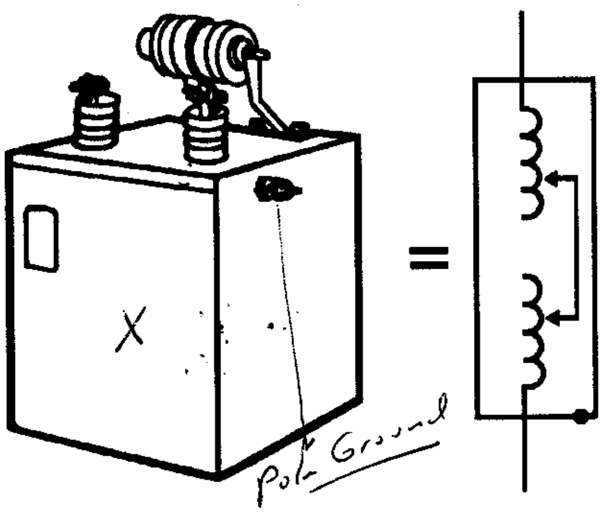
Schematic Symbols (Key)



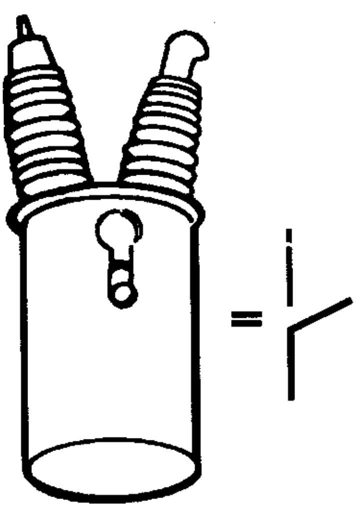
Capacitor
(Must have Two
Bushing Terminals for
HSR Installation)



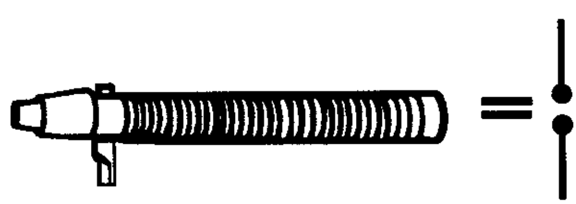
Open Fused
Cutout Switch



HSR-42
Reactor and Arrestor



Oil Switch



Lightning (Surge)
Arrestor

Contact SNC Manufacturing Co. for further information on these quality Noise Solution products:

- Induction Neutralizing Transformer (INT)
- Digital Induction Neutralizing Transformer (DINT)
- Single Noise Interference Xterminator (SNIX)
- Noise Chokes
- Transformer Exciting Network (TEN)
- Harmonic Drainage Reactor (HDR)
- Glitch Tamer
- Telecom Line Conditioner (TLC)
- Harmonic Suppression Reactor (HSR)
- HumZapper
- Li'l Zapper

For further information or for technical support call 800-558-3325 – or visit – www.sncmfg.com

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