ETM

ENGINEERING & TECHNOLOGY MANAGEMENT

Title: IINT: A Telephone Noise Troubleshooting Expert System (with Emphasis on Integrating the CONTEL Method Info System)

Course:
Year: 1990
Author(s): D. Ekmark

Report No: P90035

ETM OFFICE USE ONLY	
Report No.:	See Above
Type:	Student Project
Note:	This project is in the filing cabinet in the ETM department office.

Abstract:

INNT: A TELEPHONE NOISE TROUBLESHOOTING EXPERT SYSTEM

D. Ekmark

EMP - P9035

IINT: A TELEPHONE NOISE TROUBLESHOOTING EXPERT SYSTEM

(With Emphasis on Integrating the CONTEL Method into System)

13 MAR 91

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EXECUTIVE SUMMARY

The telephone industry, especially those that are publicly owned, have entered a new era of shrinking profit margins and reduction in construction funding. As a result, increasing emphasis is being placed on reducing labor costs and improving maintenance of the existing infrastructure. Fairbanks Municipal Utilities System (FMUS) is one such publicly owned utility company that is leading in the area of troubleshooting power induced noise, transmission and inductive interference problems (IINT) on telephone cable pairs.

Existing methods of identifying and correcting problems on telephone lines have been successful, the CONTEL method, but are wrought with inefficient utilization of manpower and resources. Management is attempting to reduce this inefficiency through "traditional" methods. Results have not been forthcoming.

Acting on the suggestion by a FMUS telephone technician, I have developed the underpinnings of an EXPERT system, the IINT, which when implemented, should show dramatic improvement in employee utilization and an increased efficiency in isolating and correcting power-induced noise problems.

Several non-EXPERT system problems must be overcome before implementation can be called successful. They are possible labor union contract discrepancies and natural environmental extremes in which this system must operate.

A knowledge base and inference methodology have been completed. All that remains is to prepare training documentation and to code, in a suitable Artificial Intelligence language, the collection of rules.

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SITUATION/BACKGROUND

This project entails designing and possibly implementing an EXPERT system that would assist telephone technicians and engineers, but preferably the technicians, in troubleshooting power-induced noise on telephone cable pairs. From research, and an interview with a Fairbanks Municipal Utilities System troubleshooting technician, it became apparent that a vast majority of the noise is due to odd harmonics of 60 hz power. Although noise is transmitted throughout the electromagnetic spectrum on telephone cable pairs, we will limit our study to the frequency range of 0 to 3000 hz. The actual range of hearing is approximately from 300 to 3000 hz, which dictated this decision. In addition, "voice grade" cable pair is designed to handle only the frequencies in this range. This system is intended for use when problems are unidentifiable and are NOT related to telephone circuit balance or shield continuity. This should not pose a problem, however, since these would be eliminated prior to the investigation for power induced noise.

Noise is one of the more troublesome problems in the telephone industry. Not only are noise problems difficult to solve, they are even more difficult to understand. However, nearly all of the noise present on a telephone cable pair has its origin in the electrical high-voltage transmission/distribution system. By continued co-location of power lines and telephone cables, this problem will not disappear. With present technology, it isn't economically feasible to completely separate the two systems. Therefore, it is imperative that power induced telephone noise be approached from the (locate, isolate, identify and correct) problem resolution methodology. The first three of the four will be the intended emphasis of this system.

The major anomaly, when dealing with 60 hz interference, is that it usually doesn't cause total catastrophic failures. It causes electronic equipment to operate poorly and, if strong enough, may cause audible noise on the cable pair. Electronic offices are susceptible to power induced noise as are electronic fire/burglar alarm systems and monitoring circuits. The C msg filter built into the telephone set makes the ordinary telephone somewhat immune to 60 hz interference but this isn't true of most electronic equipment.

It soon became apparent that the possible approaches to attacking this problem, by utilization of an expert system, could expand rapidly. Of the various noise-mitigating techniques identified, I selected the CONTEL Method for integration into the EXPERT system. The CONTEL method is a manual method of assigning weights to various possible power induced noise causes. Though quite long and convoluted, it lends itself readily to being transferred to an EXPERT system. It is also the system most often used by this new, but growing, branch of telephone preventative maintenance; a very important point to emphasize when we approach the implementation stage.

The CONTEL method also emphasizes the analysis of 60 hz harmonics. By analyzing the harmonics making up the power influence and comparing those harmonics with known interference patterns, it is often possible to identify the offending source. To make use of this EXPERT system, and the CONTEL method, it is necessary to measure the individual harmonics on a "noisy" cable. The Power influence readings are taken in dbnrc. Through experience, it has been shown that roughly 95% of the noise problems can be directed to approximately 20 causes. The real troubleshooting problem lies in the common case where noise readings of the 48 harmonics indicate the possibility of multiple causes. This is more the rule than the exception. Your resultant is a tremendous amount of possible combinations which really detracts from manually using this method. Instead of taking and recording all readings of the noisy cable, the technician tries the "hit or miss" tactic in an attempt to limit the amount of calculations required to be performed by hand using the CONTEL method. On the surface, the "hit or miss" method appears to be a conservation of labor. In reality, it tends to be counterproductive since more than likely the technician will have to return to the cable pair to gather more information.

Since the problem is nothing more than associating meter readings with known causes, this lends to easy conversion to "IF-Then-Else" rules. I have developed approximately 100 "rules" based on the entire 0-3000 hz spectrum. This is where I have to deviate slightly from the avoidance of algorithms/mathematical formulas for this project. In order to produce the desired output, a ranked order listing, with associated probabilities of the problem, it was necessary to borrow CONTEL's weighting system and integrate it into the system. Since meter readings could indicate multiple problems, it would be advantageous for troubleshooting efficiency to include this weighting list. Thus, the troubleshooter could begin his/her trouble isolation with the most probable cause and work progressively down the list. He/she could also eliminate possible causes that could not occur in the current situation. I believe this slight deviation is necessary for successful implementation of this project. This weighting technique, or uncertainty factor, has been used in such famous AI systems as MYCIN.

"Backward-chaining" was investigated as a possible approach to this problem. Though this approach is plausible, "Forward-chaining" was selected as the most applicable in this situation. The IINT expert system operator is required to provide only a single page of data input. This data is both readily and easily obtained and must be gathered whether doing manual analysis or using the expert system. The root of the problem is the unwieldy computations that were required previously. In a clear-concise one page data entry, all possible causes of the power-influenced noise will be output with weighted probabilities attached. Also, due to the myriad of possible combinations of possible power induced problems, it became quite difficult and cumbersome to adapt "Backward-chaining". Though not impossible, I believe that it is not productive.

One of the main objectives of this project, was to develop a "technician" friendly system. The proposed clientele, the field technicians in the trenches, have indicated that they desire a system that they can "plug" their data into, hit return, and the resultant is an output list of possible causes. In addition, they also indicated that they preferred to have the input/output similar to what "we've always done". Answering multiple questions, on multiple screens, deviates from this purpose. This is exactly what backward-chaining would have entailed. In reality, the keystrokes necessary would probably be less with "Backward-chaining" but the perception of an increased workload would probably not be accepted well.

By the very nature of this problem, there is a lack of knowledge transfer across professional lines from the engineer, in the home office, to the field technicians. The converse is also true. A unique problem arises in this situation. While the analytic knowledge is possessed by the engineer, the technical knowledge rests with the technician. The ideal situation would be to have both "knowledges" in a single location. In this case, they are not.

"TYPICAL" TROUBLESHOOTING SCENARIO

A typical scenario in troubleshooting a noise problem is as follows. A trouble call will be received from a customer about erratic electronic equipment problems. A troubleshooting team will be dispatched to attempt to isolate the obvious, such as telephone circuit imbalance, broken continuity on a shield or even a shorted wire. If this fails, a common corrective action is to merely reroute the customer to a new cable pair and disable the offending pair. This will work as a stop-gap fix, but, as with the little boy with his finger in the dam, it will only work for a short time. Before long, the entire cable bundle will be rendered inoperative. This is obviously not an optimal solution approach. To remedy this, telephone companies have recently begun to utilize specialized troubleshooting teams (technicians) to attack this problem from a preventative and corrective posture. This is where the KBS will increase the efficiency and productivity of the telephone company.

Currently, the technician will locate the problem by using a noise-transmission meter such as the T-136 meter manufactured by Plantronics/Wilcom. The readings from these meters are then either hand carried or transmitted by radio to the home office engineering department. It is here that the engineer performs analytic "magic", in the technician's eyes, to identify the problem and then recommend possible corrective action to be implemented. There is a possibility that the corrective action did not work (was incorrectly diagnosed) or that the engineer needs additional readings caused by the technician's "hit and miss" technique. As a result, this whole procedure will have to be repeated.

BENEFITS

It should be evident from the above scenario that an incredible amount of inefficient manpower utilization exists in the current environment. By reducing, not eliminating, the technician/engineer interface, manpower utilization can be greatly improved. In order to accomplish this, it is necessary to bring the analytic knowledge into the field. This could be accomplished by bringing the engineer and his/her expertise into the field, but a more plausible and economic solution would be to package the analytic knowledge in a portable PC-based expert system, the IINT!!!

It is completely possible, and probably advantageous from a program updating standpoint, to also implement this system on a PC at the "home office" where the engineers usually reside. My only concern rests with the data transfer problem that has led to the development of this system in the first place. It is true that we could get results from the engineer much more rapidly than in the past, but the time wasted in data transfer would not change. The engineer could utilize the system to provide updated software as more interference cause-effect relationships are discovered and also to provide technical assistance if needed, nothing more. The real-time feedback presented to the technician-user will be more beneficial in the field, which is my recommendation. Undoubtably, this system will not be a replacement of the engineer in every situation. By the ill-defined, poorly understood nature of this problem, there will always be the need for the Engineer/Technician interface. My goal was to produce the framework of a system that minimizes this interface, is easy to use, will be readily accepted and is cost effective. I believe it was reached.

IMPLEMENTATION

Implementation of this system in the target company, the Fairbanks Municipal Utilities System, will provide both technical and managerial problems. Due to unionization, possible conflicts may arise between negotiated job descriptions and management's attempt to introduce this system. Since the idea originated at the technician level, I believe this problem will not be insurmountable.

Training of technicians/operators should be minimal. For the technicians, there may be a need to prepare and present a basic "How-To" class on PC operation to get them started. The actual use of IINT should be straight-forward and fool proof. I envision having the program either executed via a selection from a main menu or the autoexec.bat file.

Documentation should be included in the delivered package which includes step by step instructions on system usage, including PC operation procedures. Several completely explained examples should be included. The documentation should not be too long, however. Permission should be obtained to include the CONTEL methodology in the documentation.

The real hurdle to overcome will be environmental. It is not technically possible at this time to provide a system (computer/software) that will operate in temperature extremes to -70° F. Procedures will have to be implemented to keep the system within it's design temperature limits. This may dictate that the system be installed in the technician's vehicle during the winter months. This may slightly increase response time but not nearly approaching the previous data transfer problem between the field and the home office.

RULES

THESE RULES ARE DIRECTLY TRANSLATED FROM CONTEL'S C-MESSAGE COORDINATION ANALYSIS MATRIX CHART USED IN MANUAL CALCULATION OF POWER INDUCED NOISE PROBLEMS.

NOTE: There is a procedure that verifies that all significant harmonics have been tested that is similar to a relative weighted decision tree. By dictating that the operator input all dB values, I have eliminated this step. If after use, experience shows that the operators are returning to the "hit or miss" procedure, this procedure can be implemented. In this model, I believe that it isn't necessary.

C1...C20 = PROBABLE CAUSE #1..#20. THESE 20 CAUSES PRESENTLY CONSTITUTE 97% OF THE KNOWN CAUSES OF POWER INDUCED NOISE ON TELEPHONE CABLE PAIRS.

PRIMARY--ODD HARMONICS

FIRST HARMONIC (60 hz)

1. IF POWER INFLUENCE (PI) < 60 THEN 3, ELSE 2,
2. IF 60 ≤ PI , THEN C1,C17 = 1.

THIRD HARMONIC (180 hz)

3. IF PI < 69, THEN 6, ELSE 4,
4. IF 69 ≤ PI ≤ 80, THEN C4,C5,C6,C8,C11,C17 = .5, ELSE 5,
5. IF 80 < PI, THEN C4,C5,C6,C8,C11,C17 =1.0.

FIFTH HARMONIC (300HZ)

6. IF PI < 68, THEN 9, ELSE 7,

7. IF 68 ≤ PI ≤ 80, THEN C3,C5,C6,C9,C10,C11,C12 = .5, ELSE 8,

8. IF 80 ≤ PI, THEN C3,C5,C6,C9,C10,C11,C12 =1.0.

SEVENTH HARMONIC (420 HZ)

9. IF PI < 69, THEN 12, ELSE 10,

10. IF 69 ≤ PI ≤ 79, THEN C2,C3,C5,C6,C9,C10,C11,C12 =.5, ELSE 11,

11. IF 79 < PI, THEN C2,C3,C5,C6,C9,C10,C11,C12 =1.0.

NINTH HARMONIC (540HZ)

12. IF PI < 71, THEN 15, ELSE 13,

13. IF 71 ≤ PI ≤80, THEN C2,C4,C5,C6,C8,C11 =.5, ELSE 14,

14. IF 80 < PI, THEN C2,C4,C5,C6,C8,C11 =1.0.

11TH HARMONIC (660HZ)

15. IF PI < 61, THEN 18, ELSE 16,

16. IF 61 ≤ PI ≤ 71, THEN C2,C3,C5,C6,C7,C9,C10,C11,C12,C14 =.5, ELSE 17,

17. IF 71< PI, THEN C2,C3,C5,C6,C7,C9,C10,C11,C12,C14 =1.0.

13TH HARMONIC (780HZ)

18. IF PI < 56, THEN 21, ELSE 19,

19. IF 56 ≤ PI ≤ 67, THEN C2,C5,C6,C7,C9,C10,C11,C12,C14 = .5, ELSE 20,

20. IF 67 < PI, THEN C2,C5,C6,C7,C9,C10,C11,C12,C14 =1.0.

15TH HARMONIC (900HZ)

21. IF PI < 55, THEN 24, ELSE 22,

22. IF 55 ≤ PI ≤ 66, THEN C2,C4,C6,C8,C11 =.5, ELSE 23,

23. IF 66 < PI, THEN C2,C4,C6,C8,C11 =1.0.

17TH HARMONIC (1020HZ)

24. IF PI < 49, THEN 27, ELSE 25,

25. IF 49 ≤ PI ≤ 61, THEN C2,C7,C9,C10,C11,C12 = .5, ELSE 26,

26. IF 61 < PI, THEN C2,C7,C9,C10,C11,C12 =1.0.

19TH HARMONIC (1140HZ)

27. IF PI < 45, THEN 30, ELSE 28,

28. IF 45 ≤ PI ≤ 53, THEN C2,C7,C9,C10,C11,C12 = .5, ELSE 29,

29. IF 53 < PI, THEN C2,C7,C9,C10,C11,C12 =1.0.

21ST HARMONIC (1260HZ)

30. IF PI < 44, THEN 33, ELSE 31,

31. IF 44 ≤ PI 51, THEN C2,C8,C11=.5, ELSE 32,

32. IF 51 < PI, THEN C2,C8,C11=1.0.

23RD HARMONIC (1380HZ)

33. IF PI < 43, THEN 36, ELSE 34,

34. IF 43 ≤ PI ≤ 51, THEN C2,C7,C9,C11,C12,C14,C16=.5, ELSE 35,

35. IF 51 < PI, THEN C2,C7,C9,C11,C12,C14,C16=1.0.

25TH HARMONIC (1500HZ)

36. IF PI < 42, THEN 39, ELSE 37,

37. IF 42 ≤ PI ≤ 50.5, THEN C2,C7,C9,C11,C12,C14,C16=.5, ELSE 38,

38. IF 50.5 < PI, THEN C2,C7,C9,C11,C12,C14,C16=1.0.

27TH HARMONIC (1620HZ)

39. IF PI < 40, THEN 42, ELSE 40,

40. IF 40 ≤ PI ≤ 49, THEN C2,C8,C11=.5, ELSE 41,

41. IF 49 < PI, THEN C2,C8,C11 = 1.0.

29TH HARMONIC (1740HZ)

42. IF PI < 40, THEN 45, ELSE 43,

43. IF 40 ≤ PI ≤ 49, THEN C2,C11,C12,C16 =.5, ELSE 44,

44. IF 49 < PI, THEN C2,C11,C12,C16 =1.0.

31ST HARMONIC (1860HZ)

45. IF PI < 39, THEN 48, ELSE 46,

46. IF 39 ≤ PI ≤ 48, THEN C2,C11,C12,C16 =.5, ELSE 47,

47. IF 48 < PI, THEN C2,C11,C12,C16 =1.0.

33RD HARMONIC (1980HZ)

48. IF PI < 38, THEN 51, ELSE 49,

49. IF 38 ≤ PI ≤ 47, THEN C11 =.5, ELSE 50,

50. IF 47 < PI, THEN C11 =1.0.

35TH HARMONIC (2100HZ)

51. IF PI < 37, THEN 54, ELSE 52,

52. IF 37 ≤ PI ≤ 47.5, THEN C11,C12,C14,C16=.5, ELSE 53,

53. IF 47.5 < PI, THEN C11,C12,C14,C16=1.0.

37TH HARMONIC (2220HZ)

54. IF PI < 37, THEN 57, ELSE 55,

55. IF 37 ≤ PI ≤ 47.5, THEN C11,C12,C14,C16=.5, ELSE 56,

56. IF 47.5 < PI, THEN C11,C12,C14,C16=1.0.

39TH HARMONIC (2340HZ)

57. IF PI < 36.5, THEN 60, ELSE 58,

58. IF 36.5 ≤ PI ≤ 48, THEN C11 = .5, ELSE 59,

59. IF 48 < PI, THEN C11=1.0.

41ST HARMONICS (2460HZ)

60. IF PI < 36, THEN 63, ELSE 61,

61. IF 36 ≤ PI ≤ 48, THEN C11,C12,C16 =.5, ELSE 62,

62. IF 48 < PI, THEN C11,C12,C16 =1.0.

43RD HARMONIC (2580HZ)

63. IF PI < 36.5, THEN 66, ELSE 64,

64. IF 36.5 ≤ PI ≤ 48, THEN C11,C12,C16 =.5, ELSE 65,

65. IF 48 < PI, THEN C11,C12,C16 =1.0.

45TH HARMONIC (2700HZ)

66. IF PI < 36.5, THEN 69, ELSE 67,

67. IF 36.5 ≤ PI ≤ 45, THEN C11 =.5, ELSE 68,

68. IF 45 < PI, THEN C11 =1.0.

47TH HARMONIC (2820HZ)

69. IF PI < 34, THEN 72, ELSE 70,

70. IF 34 ≤ PI ≤ 43, THEN C11,C12,C14,C16 =.5, ELSE 71,

71. IF 43 < PI, THEN C11,C12,C14,C16 =1.0.

SIGNIFICANT INFLUENCING EVEN HARMONICS

SIXTH HARMONIC (360HZ)

72. IF PI < 68, THEN 75, ELSE 73,

73. IF 68 ≤ PI ≤ 79, THEN C13 =.5, ELSE 74,

74. IF 79 < PI, THEN C13 =1.0.

12TH HARMONIC (720HZ)

75. IF PI < 60, THEN 78, ELSE 76,

76. IF 60 ≤ PI ≤ 66, THEN C13,C15 =.5, ELSE 77,

77. IF 66 < PI, THEN C13,C15 =1.0.

18TH HARMONIC (1080HZ)

78. IF PI < 48, THEN 81, ELSE 79,

79. IF 48 ≤ PI ≤ 57, THEN C13 =.5, ELSE 80,

80. IF 57 < PI, THEN C13 =1.0.

24TH HARMONIC (1440HZ)

81. IF PI < 43, THEN 84, ELSE 82,

82. IF 43 ≤ PI ≤ 51, THEN C13,C15 =.5, ELSE 83,

83. IF 83 < PI, THEN C13,C15 =1.0.

30TH HARMONIC (1800HZ)

84. IF PI < 39, THEN 87, ELSE 85,

85. IF 39 ≤ PI ≤ 49, THEN C13 =.5, ELSE 86,

86. IF 49 < PI, THEN C13 =1.0.

36TH HARMONIC (2160HZ)

87. IF PI < 37, THEN 90, ELSE 88,

88. IF 37 ≤ PI ≤ 48, THEN C13,C15 =.5, ELSE 89,

89. IF 48 < PI, THEN C13,C15 =1.0.

42ND HARMONIC (2520HZ)

90. If PI < 37 then 93, else 91,

91. If 37 ≤ PI ≤ 46, then C13, C17=.5, else 92,

92. If 46 < PI then C13, C17= 1.0.

ADDITIONAL RULES

93. IF Σ OF OUT OF LIMIT HARMONICS= 1 AND IS AT LEAST 6dB WORSE THAN NEXT HARMONIC, THEN C18=1.0, ELSE 94,

94. IF AUDIBLE FRYING NOISE HEARD ON HEADSET, THEN C19=1, ELSE 95,

95. IF MULTIPLE HARMONICS OF A NON-60HZ FUNDAMENTAL FREQUENCY, THEN C20=1, ELSE OUTPUT.

PROBABLE CAUSE LIST

C1. Poorly balanced 3 phase power system or too much exposure to single phase power circuits, or one or two capacitors of a 3 phase capacitor installation not working.

C2. Open cable shield.

C3. Malfunctioning capacitor bank.

C4. Circuit resonance, usually aggravated by presence of capacitor bank.

C5. Exciting currents of distribution transformers (silicon iron core). Possibly aggravated by circuit resonance resulting from presence of shunt capacitors.

C6. Overexcited power transformer.

C7. Defective power step-down transformer.

C8. Grounded 3 phase transformer or transformer equipped with no (or inadequate) tertiary or could be a grounded Y-autotransformer, often aggravated by grounded capacitors.

C9. Balanced harmonics from generator or synchronous motor or condenser.

C10. SCR control device.

C11. Defective and/or overexcited power transformer.

C12. AC side of 6 phase rectifier or SCR control devices.

C13. DC side of 6 phase rectifier.

C14. AC side of 12 phase rectifier.

C15. DC side of 12 phase rectifier.

C16. Other multi-phase rectifier (AC side).

C17. Saturable reactor devices in 1 phase rectifiers, vapor lamps, welders, frequency changers, power tools, induction heaters, etc.

C18. Resonance in balanced or residual circuit of power system (may be due to shunt capacitors).

C19. Ringer gas tubes firing (also related to cause 1-C1).

C20. Electronic frequency converters (cycloconvertors).

WEIGHTING SYSTEM

The weighting system is based on assigning a .5 to all possible causes corresponding to a particular Db reading that falls within the "marginal" zone of readings. A 1.0 corresponds to an "out of limits" reading. A 0 is automatically assigned to a normal reading.

The Ci characters correspond with various probable causes.

OUTPUT PROCESSING CALCULATION

$(\Sigma(Ci = .5) + \Sigma(Ci = 1.0))/Yi = P\{Ci\}$ of Ci i=1,2....17

Yi = (1,13,3,3,6,7,6,5,8,6,23,15,7,7,3,9,46)

For all P{Ci} > 0, Generate a statement...i.e. .76 C4:

You have a 76% chance your problem is caused by Circuit Resonance which is usually caused by the presence of capacitor banks.

(SAMPLE PROBLEM INPUT)

WELCOME TO IINT

PLEASE ANSWER THE FOLLOWING QUESTIONS and INPUT YOUR T-136 READINGS

NAME: Dale

DATE: MAR 8, 1991

LOCATION: Penrose Ln   CLOSEST JUNCTION BOX/PEDESTAL: Ivory Jack's

T-136 READINGS

FREQUENCY ODD HARMONICS	FREQUENCY EVEN HARMONICS
60: 30	360:
180: 60	720:
300: 62	1080:
420: 78	1440:
540: 90	1800:
660: 50	2160:
780: 53	2520:
900:50	
1020:20	
1080:32	
1140:41	
1260:39	
1380:90	
1500:86	
1620:36	
1740:32	
1860:39	
1980:37	
2100:36	
2220:32	
2340:11	
2460:20	
2580:22	
2700:39	
2820:60	

WOULD YOU LIKE TO ENTER EVEN HARMONIC VALUES? yes/no NO
WOULD YOU LIKE TO CHANGE ANY OF YOUR DATA? yes/no NO
IS FRYING NOISE AUDIBLE ON HEADSET? yes/no NO
DID YOU NOTICE NON 60HZ HARMONICS? yes/no NO
PLEASE PRESS RETURN FOR IINT'S ANALYSIS

IINT PROBABLE CAUSE ANALYSIS

Dale,
YOUR PROBABLE CAUSE(S) ARE LISTED BELOW IN DESCENDING PROBABILITY ORDER
(((Note))) Your probabilities are relative to the historic cause, therefore they will not add up 1.

33% CIRCUIT RESONANCE. USUALLY AGGRAVATED BY PRESENCE OF CAPACITOR BANK.
33% DEFECTIVE POWER STEP-DOWN TRANSFORMER.
31% BALANCED HARMONICS FROM GENERATOR OR SYNCHRONOUS MOTOR OR CONDENSER.
29% AC SIDE OF 12 PHASE RECTIFIER.
27% OPEN SHIELD CABLE
25% EXCITING CURRENTS OF DISTRIBUTION TRANSFORMERS (SILICON IRON CORE). POSSIBLY AGGRAVATED BY CIRCUIT RESONANCE RESULTING FROM PRESENCE OF SHUNT CAPACITORS.
22% DC SIDE OF 12 PHASE RECTIFIER.
21% OVEREXCITED POWER TRANSFORMER.
19% DEFECTIVE AND/OR OVEREXCITED POWER TRANSFORMER(S).
17% AC SIDE OF 6 PHASE RECTIFIER OR SCR CONTROL DEVICE.
16% MALFUNCTIONING CAPACITOR BANKS
8% SCR CONTROL DEVICES.

THANK YOU

REFERENCES

Bodas, Gerald D., Fairbanks Municipal Utilities System, Fairbanks, Alaska.

CONTEL Corp, C-MESSAGE INDUCTIVE COORDINATION-NOISE ANALYSIS CHART.

Tokarz, Roger F., The Handbook of Noise, Transmission, Inductive Interference, Spokane, WA, TAD Consulting.

C-MESSAGE INDUCTIVE COORDINATION-NOISE ANALYSIS CHART

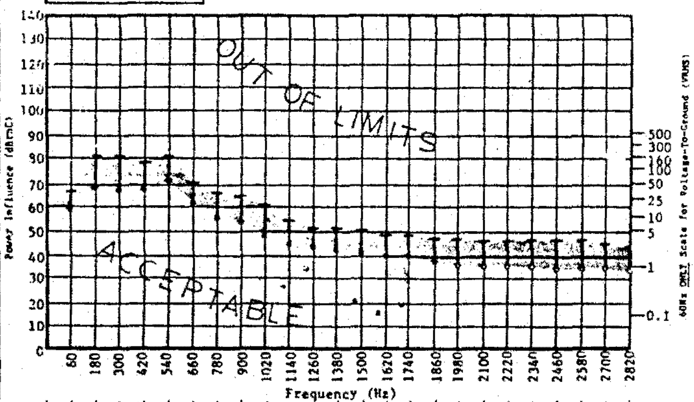
(for Problems Not Related to Telephone Circuit Balance or Shield Continuity)

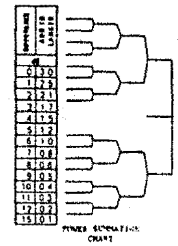
LEGEND:
- □ Marginal
- • Mean (μ)
- μ + σ
- Estimated σ & μ
- × First Test
- ● Second Test
- Third Test

Exchange ______
Location ______ Pair No. ______

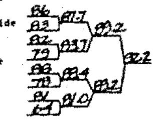
	1st Test	2nd Test	3rd Test
Date(s)			
Time(s)			
By			

I.





- To verify that all predominant harmonics have been observed:
  1. Identify from the Noise Analysis Chart each harmonic level within 15 dB of the highest.
  2. Post each of these levels, including the highest, on the series of lines at the left side of the power summation chart.
  3. Combine each pair of levels using the "difference/add" values. Continue working to the right until one combined value is obtained.
  4. This combined value should be within 1 or 2 dB of the measured power influence of the circuit under test. If not, one or more harmonics have been overlooked, or there has been a change in influence level.
- The Noise Analysis Chart allows the analyst to determine which harmonic(s), by order of significance, are affecting the circuit most.
- If the Noise Analysis Chart indicates more than one probable cause, the one(s) related to the most offensive harmonic(s) should be investigated first.

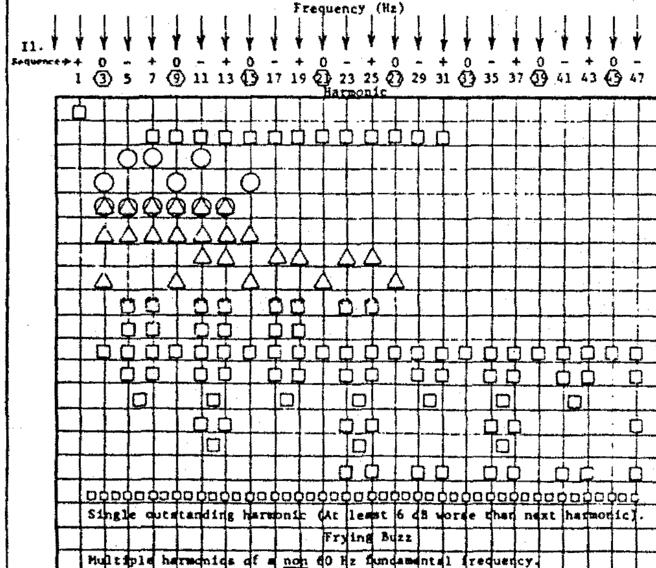


SAMPLE

IV. NOTES (See "Notes" Column Lower Center)

- #1 Usually one (or two adjacent) sets of odd, nontriple harmonics.
- #2 Each higher harmonic deviating more from norm (assuming that all influence harmonics exist at same level).
- #3 Usually observed below 15th harmonic. Can often be helped by moving capacitors closer to substation or using a nongrounded capacitor configuration.
- #4 Seldom produces harmonics above the 13th.
- #5 One (1) adjacent pair of nontriple harmonics is sufficient to suggest rectifier problems.
- #6 420 or 660 Hz may not appear predominately.
- #7 Sometimes accompanied by protector "dusting" or shorting. Protector problems are common where power companies experience "ground-fault" earth-potential-rise conditions.
- #8 For long single ℓ situations, a 1:1 power transformer may provide a solution. See III-11.
- #9 Usually occurs during periods of "low demand" for power.
- #10 Ninth harmonic is often predominant.
- #11 Usually occurs during periods of peak power demand.
- #12 If observed frequencies are not exact harmonics of 60 Hz this may indicate "slot" harmonics from induction motors. If a ripple (120 Hz-from the resonance of two adjacent slot frequencies) is present, this may be caused by slot effects of "rotating field" generators.
- #13 High 3rd harmonic may come from ballast operated gaseous-discharge lamps (fluorescent, mercury vapor, etc.).
- #14 Customer voltages in excess of 125 - 126V suggest overexcited power transformer(s).

II.



SEE NOTES (IV)	III.	PROBABLE CAUSE	V. Continental Telephone Noise Index Reference(s)
#7, #8	1.	Poorly balanced 3Ø power system or too much exposure to single Ø power circuits, or one or two capacitors of a 3Ø capacitor installation not working.	I-10, III-73, III-93, III-96, III-46
#2	2.	Open cable shield.	III-5, III-6, III-57
#6	3.	Malfunctioning capacitor banks.	I-88, III-46, III-90, III-93, III-99
#3, #13	4.	Circuit resonance. Usually aggravated by presence of capacitor banks.	I-10, I-63, I-88, III-11, III-19, III-73, III-46, III-106, III-107, III-109, III-119
#4, #14	5.	Exciting currents of distribution transformers (silicon iron core). Possibly aggravated by circuit resonance resulting from presence of shunt capacitors.	III-45, III-46, III-83, III-99, III-107, III-109, III-119
#9 #10 #14	6.	Overexcited power transformer.	III-46, III-90, V-6
	7.	Defective power step-down transformer.	III-45
#13	8.	Grounded 3Ø transformer or transformer equipped with no (or inadequate) tertiary or could be a grounded-Y autotransformer - often aggravated by grounded capacitors.	I-11, III-19, III-83, III-99
#1, #12	9.	Balanced harmonics from generator or synchronous motor or condenser.	III-11, III-99
	10.	SCR control devices.	I-56, I-78, III-33, III-95
	11.	Defective and/or overexcited power transformer(s).	III-11, III-99
#5	12.	AC side of 6Ø rectifier or SCR control devices.	III-45, III-56, III-95
	13.	DC side of 6Ø rectifier.	III-45, III-56
#5	14.	AC side of 12Ø rectifier.	III-45
	15.	DC side of 12Ø rectifier.	III-45
#5	16.	Other multiphase rectifier (AC side).	III-45
#13	17.	Saturable reactor devices in 1Ø rectifiers, "vapor" lamps, welders, frequency changers, power tools, induction heaters, etc.	III-99, III-119
#3	18.	Resonance in balanced or residual circuit of power system (may be due to shunt capacitors).	III-46, III-106, III-107, III-109, III-119
#11	19.	Ringer gas tubes firing (also usually related to cause 1. above).	I-62, I-72
	20.	Electronic frequency converters (cycloconverters).	III-119

○ = Capacitor Related; △ = Transformer Related; □ = Other; ▢ = May vary from precise harmonic - See Note #12; ◯ = Odd triple harmonics

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