PQSoft Case Study

Effect of Distribution Feeder Loading on Harmonic Resonance

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Abstract:

A utility operates 1200 kVAr and 600 kVAr capacitor banks on a 25.56kV distribution feeder. The utility uses frequency scan simulations to determine the effect of the capacitor banks and seasonal load levels on the impedance vs. frequency response characteristics for the feeder. It is assumed that the results will be more severe for the low load condition because there are lower levels of damping.

This case study evaluates the effect of seasonal load variation on the frequency response characteristic of a 25.56kV distribution feeder.

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RELATED STANDARDS

IEEE Std. 519-1992
IEEE Std. 1036-1992

GLOSSARY AND ACRONYMS

ASD	Adjustable-Speed Drive
CF	Crest Factor
DPF	Displacement Power Factor
PF	Power Factor
PWM	Pulse Width Modulation
THD	Total Harmonic Distortion
TPF	True Power Factor

INTRODUCTION AND MODEL DEVELOPMENT

The effect of seasonal load variation on the frequency response characteristic of a 25.56kV distribution feeder was studied for the system shown in Figure 1. The accuracy of the system model was verified using three-phase and single-line-to-ground fault currents and other steady-state quantities, such as capacitor bank rated current and voltage rise. Frequency scan analysis was used to determine the impedance vs. frequency characteristic for the feeder for various operating conditions.

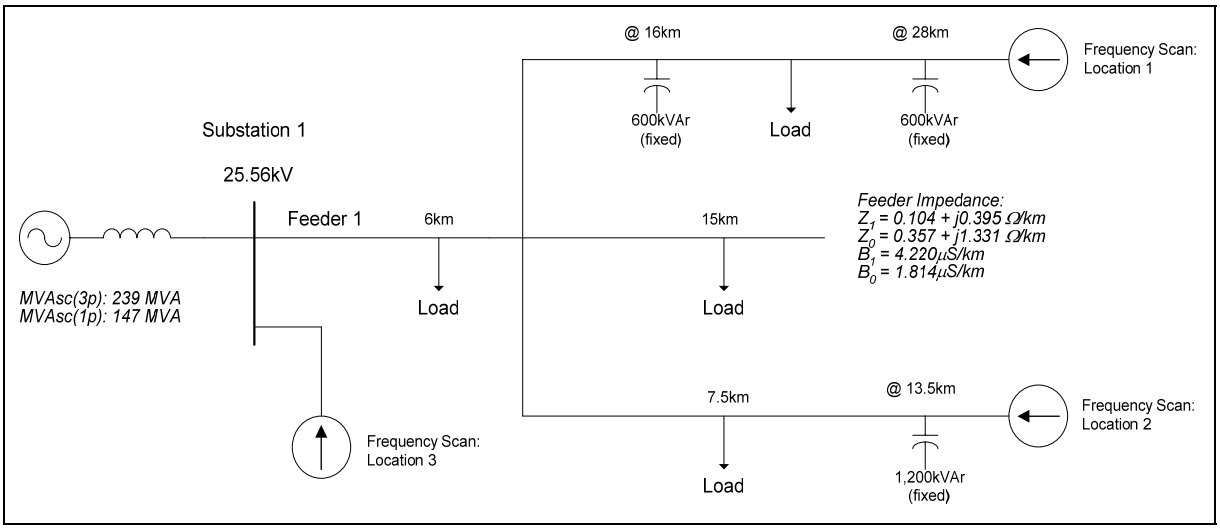

Figure 1 - Oneline Diagram for the Feeder Resonance Case Study

SIMULATION RESULTS

The following frequency scan cases were completed for the case study:

Case Number	Scan Location	Load Condition	Capacitor Bank Status
Case 1a	1	Full Load	All Off
Case 1b	1	Full Load	All On
Case 1c	2	Full Load	All Off
Case id	2	Full Load	All On
Case 1e	3	Full Load	All Off
Case 1f	3	Full Load	All On
Case 1g	1	30% Load	All Off
Case 1h	1	30% Load	All On
Case 1i	2	30% Load	All Off
Case 1j	2	30% Load	All On
Case 1k	3	30% Load	All Off
Case 1l	3	30% Load	All On

The frequency range for these cases was 60 Hz to 5,000 Hz (1 Hz increment). The load on the feeder for the “full load” condition was approximately 10.4 MVA at 98% power factor.

Figure 2 shows the impedance vs. frequency simulation results for scan location number 1 (600kVAr, full load) without and with the feeder capacitor banks in service.

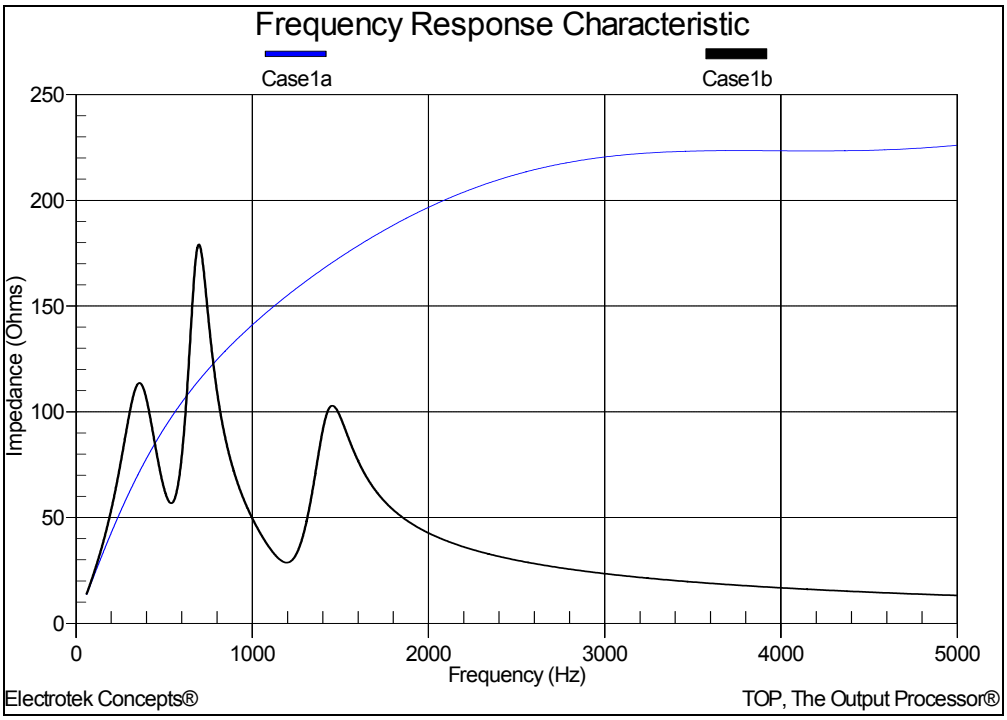

Figure 2 - Frequency Response at Scan Location Number 1 with Full Load

Figure 3 shows the impedance vs. frequency simulation results for scan location number 2 (1,200kVAr, full load) without and with the feeder capacitor banks in service.

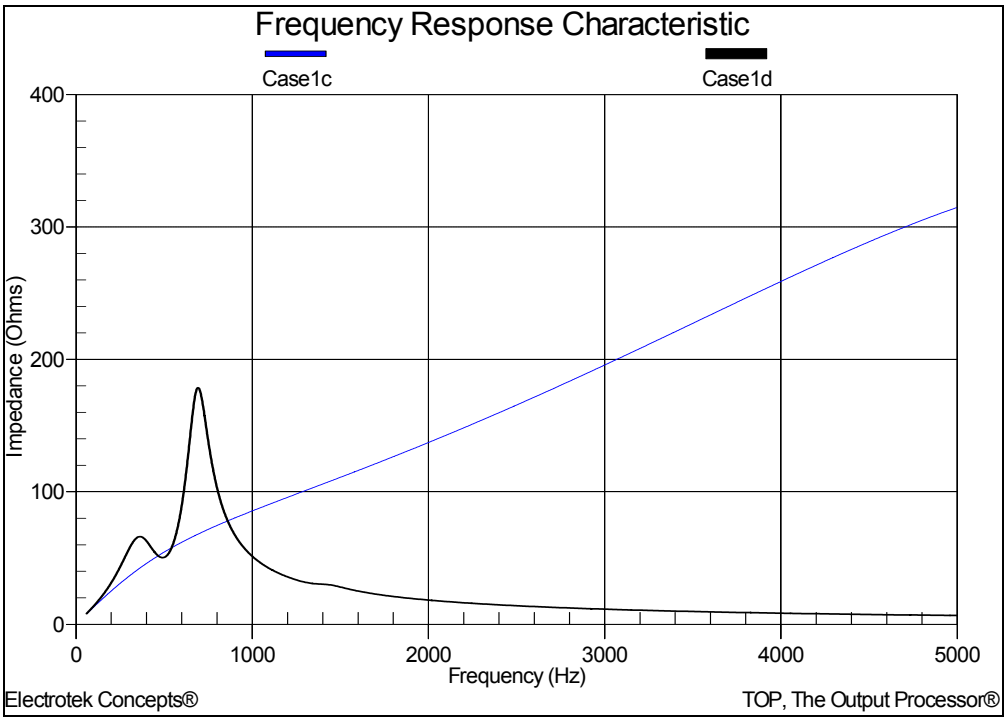

Figure 3 - Frequency Response at Scan Location Number 2 with Full Load

Figure 4 shows the impedance vs. frequency simulation results for scan location number 3 (substation bus, full load) without and with the feeder capacitor banks in service.

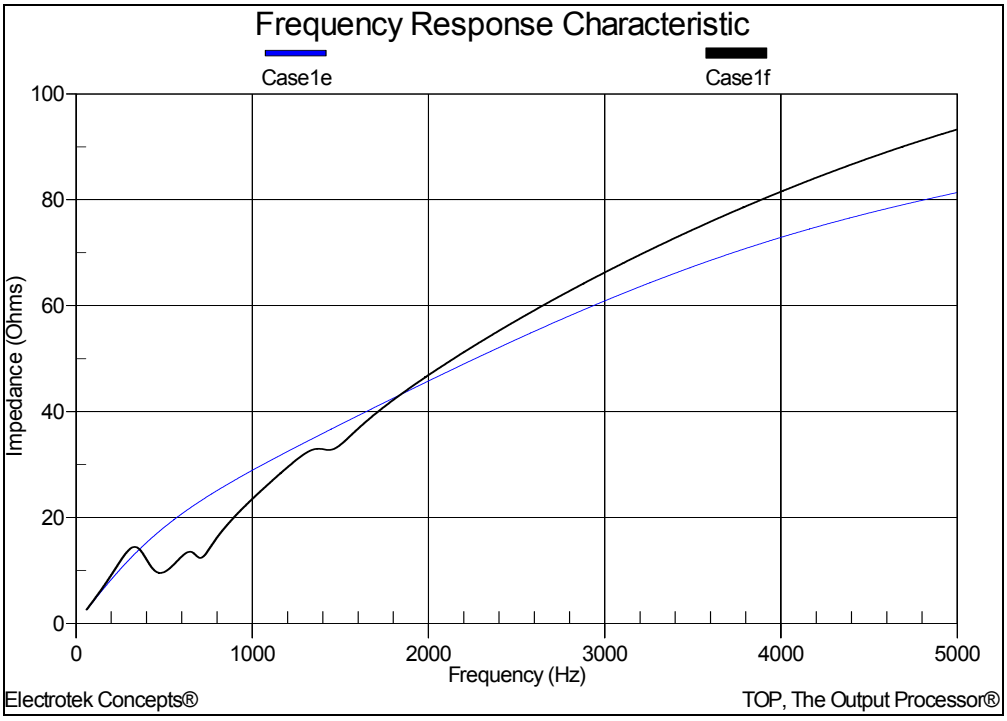

Figure 4 - Frequency Response at Scan Location Number 3 with Full Load

Figure 5 shows the impedance vs. frequency simulation results for scan location number 1 (600kVAr, 30% load) without and with the feeder capacitor banks in service.

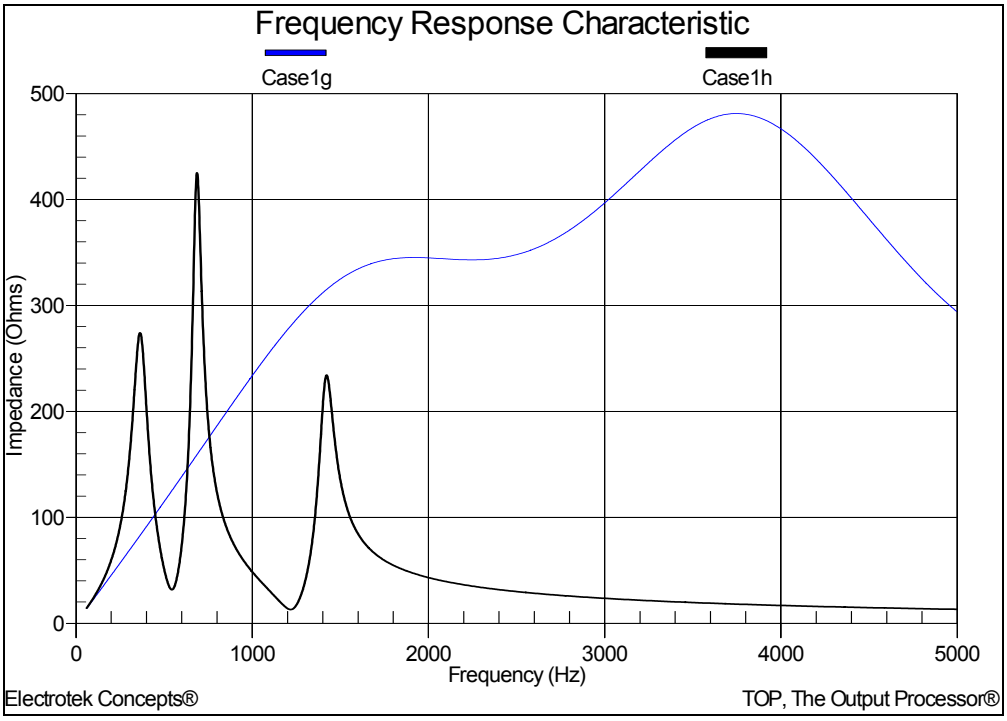

Figure 5 - Frequency Response at Scan Location Number 1 with 30% Load

Figure 6 shows the impedance vs. frequency simulation results for scan location number 2 (1,200kVAr, 30% load) without and with the feeder capacitor banks in service.

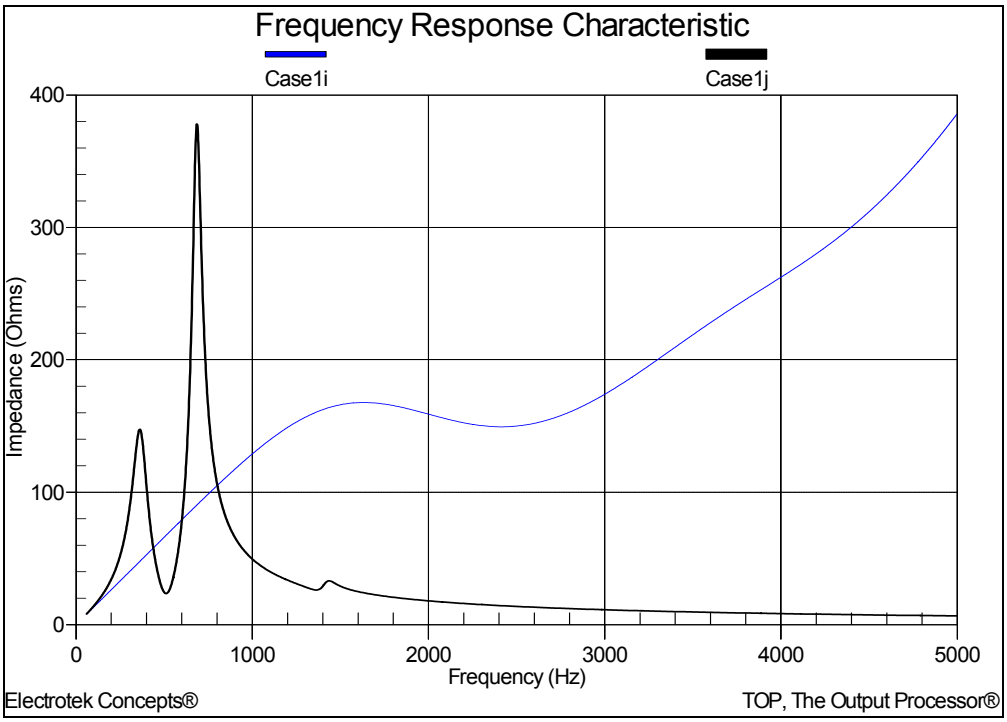

Figure 6 - Frequency Response at Scan Location Number 2 with 30% Load

Figure 7 shows the impedance vs. frequency simulation results for scan location number 3 (substation bus, 30% load) without and with the feeder capacitor banks in service.

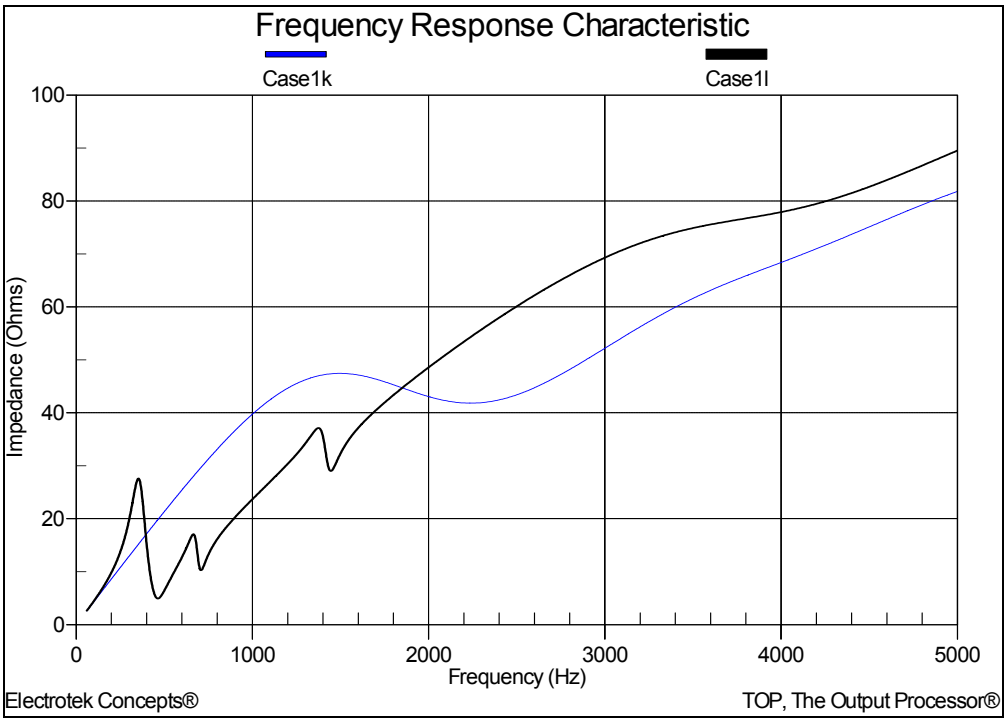

Figure 7 - Frequency Response at Scan Location Number 3 with 30% Load

Figure 8 shows the amplification factors for scan location number 1 (600kVAr) for the full load and 30% load conditions. Amplification factor is defined as the ratio of impedance with capacitor banks to the impedance without capacitor banks (e.g., Case 1b divided by Case 1a).

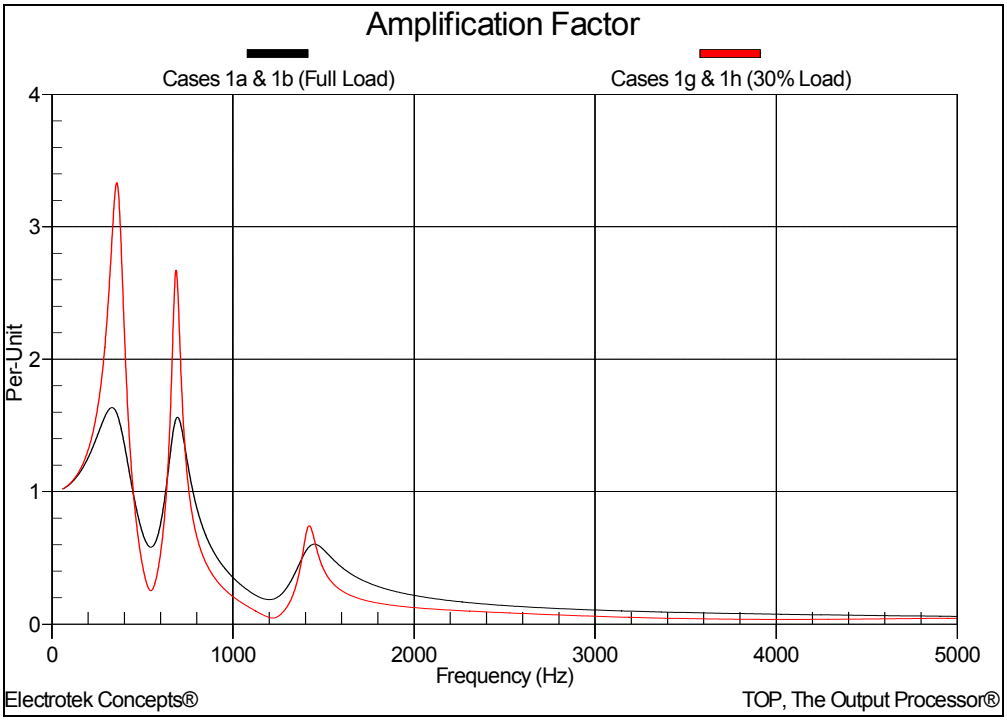

Figure 8 - Amplification Factors for Scan Location Number 1

Figure 9 shows the amplification factors for scan location number 2 (1,200kVAr).

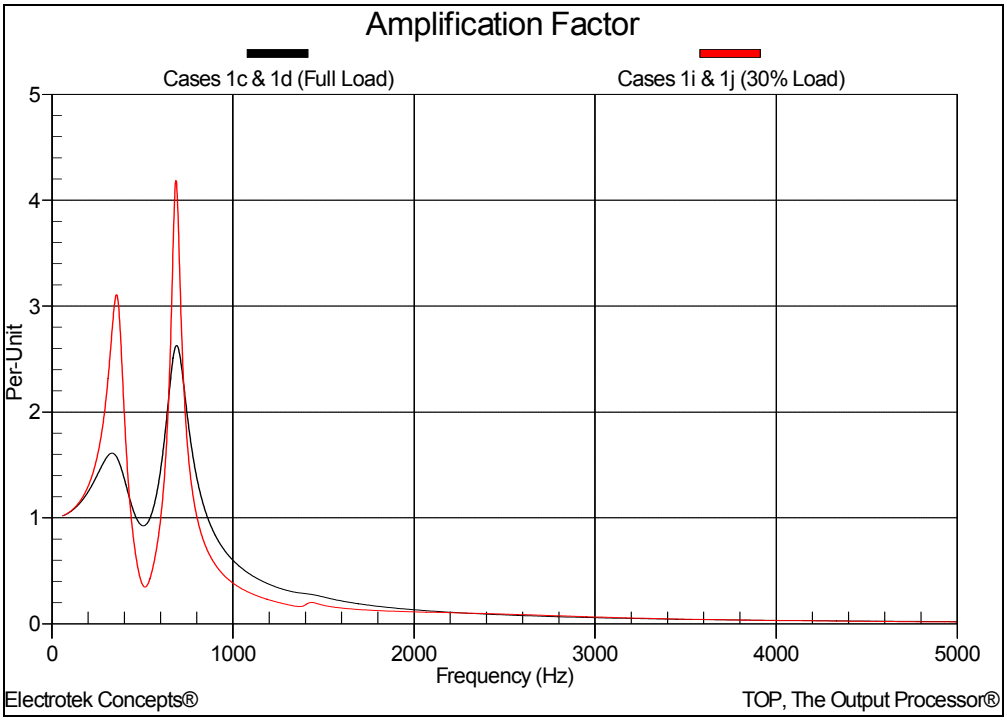

Figure 9 - Amplification Factors for Scan Location Number 2

Figure 10 shows the amplification factors for scan location number 3 (substation bus).

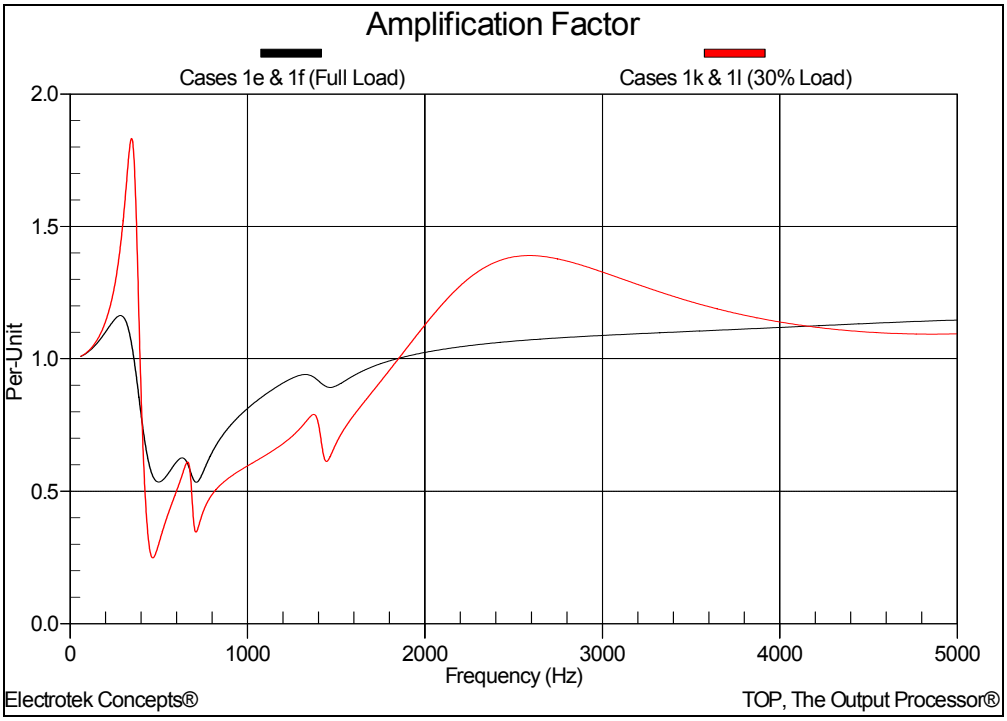

Figure 10 - Amplification Factors for Scan Location Number 3

SUMMARY

The simulation results show that the impedance vs. frequency response characteristics for the feeder are more severe for the low load condition due to the fact that there are lower levels of damping (resistive elements).

Additional observations include:

1. For scan location number 1, the simulated parallel (high impedance) resonant frequencies were approximately 360 Hz, 700 Hz, and 1420 Hz. The series (lower impedance) resonant frequencies were approximately 540 Hz, and 1,200 Hz. The amplification factor range was between 0 and 3.4.

2. For scan location number 2, the parallel resonant frequencies were approximately 360 Hz and 700 Hz. The series resonant frequency was approximately 500 Hz. The amplification factor range was between 0 and 4.2.

3. For scan location number 3, the parallel resonant frequencies were approximately 360 Hz, 660 Hz, and 1380 Hz. The series resonant frequencies were approximately 460 Hz, 700 Hz, and 1440 Hz. The amplification factor range was between 0 and 1.83.

REFERENCES

Power System Harmonics, IEEE Tutorial Course, 84 EH0221-2-PWR, 1984.