Effects of Harmonic Distortion II

4.8.4 Impact on Telecommunications

Harmonic currents flowing on the utility distribution system or within an end-user facility can create interference in communication circuits sharing a common path. Voltages induced in parallel conductors by the common harmonic currents often fall within the bandwidth of normal voice communications. Harmonics between 540 (ninth harmonic) and 1200 Hz are particularly disruptive. The induced voltage per ampere of current increases with frequency. Triplen harmonics (3^{rd}, 9^{th}, 15^{th}) are especially troublesome in four-wire systems because they are in phase in all conductors of a three-phase circuit and, therefore, add directly in the neutral circuit, which has the greatest exposure with the communications circuit.

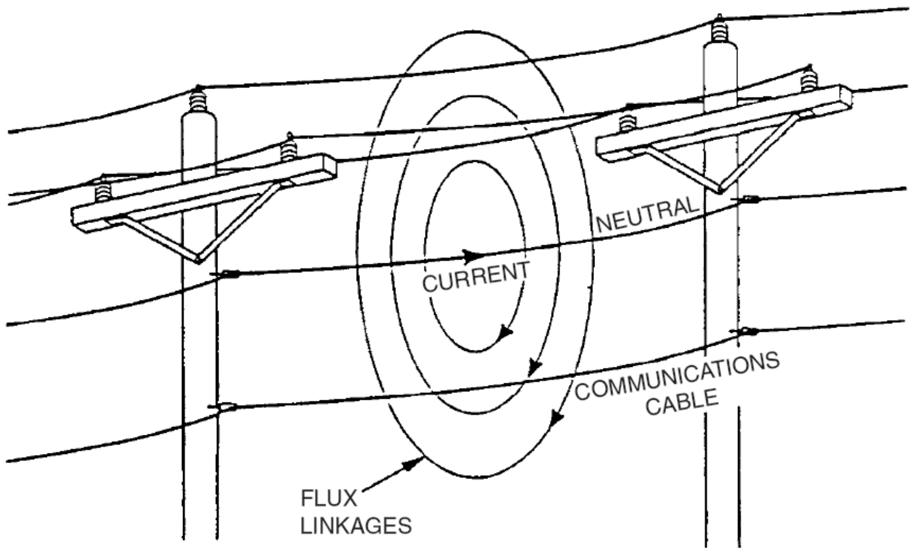
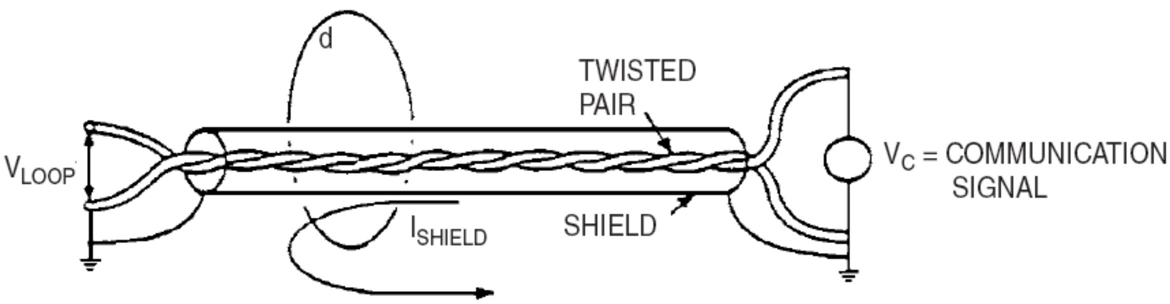


Figure 4.30 Inductive coupling of power system residual current to telephone circuit.

Harmonic currents on the power system are coupled into communication circuits by either induction or direct conduction. Figure 4.30 illustrates coupling from the neutral of an overhead distribution line by induction. This was a severe problem in the days of open wire telephone circuits. Now, with the prevalent use of shielded, twisted-pair conductors for telephone circuits, this mode of coupling is less significant. The direct inductive coupling is equal in both conductors, resulting in zero net voltage in the loop formed by the conductors.

Inductive coupling can still be a problem if high currents are induced in the shield surrounding the telephone conductors. Current flowing in the shield causes an *IR* drop (Fig.4.31), which results in a potential difference in the ground references at the ends of the telephone cable.

Shield currents can also be caused by direct conduction. As illustrated in Fig. 4.32, the shield is in parallel with the power system ground path. If local ground conditions are such that a relatively large amount of current flows in the shield, high shield *IR* drop will again cause a



potential difference in the ground references at the ends of the telephone cable.

Figure 4.31 IR drop in cable shield resulting in potential differences in ground references at ends of cable.

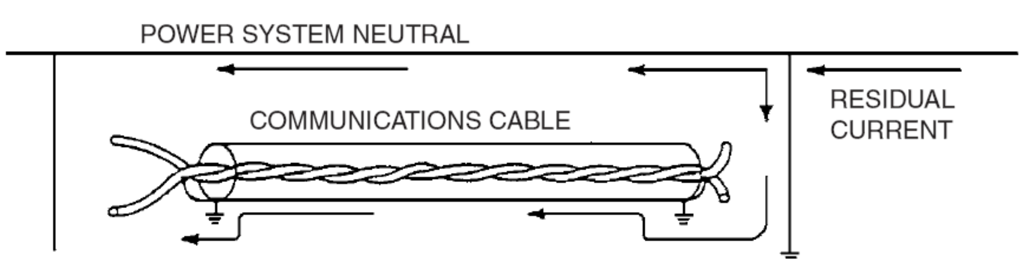


Figure 4.32 Conductive coupling through a common ground path.

4.8.5 Impact on Energy and Demand Metering

Electric utility companies usually measure energy consumption in two quantities: the total cumulative energy consumed and the maximum power used for a given period. Thus, there are two charges in any given billing period especially for larger industrial customers: energy charges and demand charges. Residential customers are typically charged for the energy consumption only.

The energy charge represents the costs of producing and supplying the total energy consumed over a billing period and is measured in kilowatt-hours. The second part of the bill, the demand charge, represents utility costs to maintain adequate electrical capacity at all times to meet each customer's peak demand for energy use. The demand charge reflects the utility's fixed cost in providing peak power requirements. The demand charge is usually determined by the highest 15- or 30-min peak demand of use in a billing period and is measured in kilowatts.

Harmonic currents from nonlinear loads can impact the accuracy of watt-hour and demand meters adversely. Traditional watt-hour meters are based on the induction motor principle. The rotor element or the rotating disk inside the meter revolves at a speed proportional to the power flow. This disk in turn drives a series of gears that move dials on a register.

Conventional magnetic disk watt-hour meters tend to have a negative error at harmonic frequencies. That is, they register low for power at harmonic frequencies if they are properly calibrated for fundamental frequency. This error increases with increasing frequency. In general, nonlinear loads tend to inject harmonic power back onto the supply system and linear loads absorb harmonic power due to the distortion in the voltage. This is depicted in Fig. 4.33 by showing the directions on the currents.

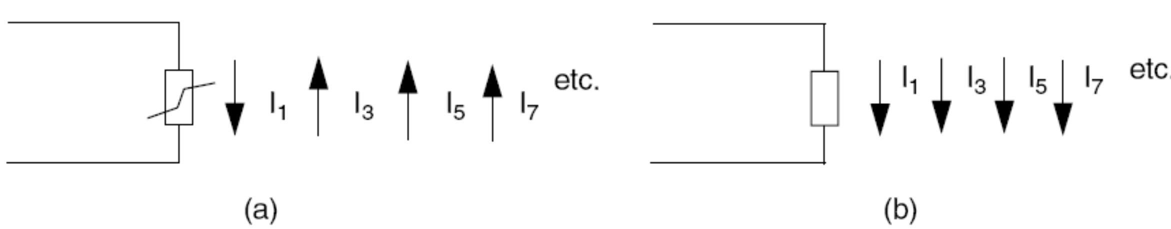


Figure 4.33 Nominal direction of harmonic currents in (*a*) nonlinear load and (*b*) linear load (voltage is distorted).

Thus for the nonlinear load in Fig. 4.33, the meter would read

$$P_{measured} \square P_1 \square a_3 P_3 \square a_5 P_5 \square a_7 P_7 \square \ldots\ldots\ldots\ldots \qquad \ldots\ldots (4.23)$$

Where *a*3, *a*5, and *a*7 are multiplying factors (1.0) that represent the inaccuracy of the meter at harmonic frequency. The measured power is a little greater than that actually used in the load because the meter does not subtract off quite all the harmonic powers. However, these powers simply go to feed the line and transformer losses, and some would argue that they should not be subtracted at all. That is, the customer injecting the harmonic currents should pay something additional for the increased losses in the power delivery system.

In the case of the linear load, the measured power is

$$P_{measured} \square P_1 \square a_3 P_3 \square a_5 P_5 \square a_7 P_7 \square \ldots\ldots\ldots \qquad \text{------------------- (4.24)}$$

The linear load absorbs the additional energy, but the meter does not register as much energy as is actually consumed. The question is, does the customer really want the extra energy? If the load consists of motors, the answer is no, because the extra energy results in losses induced in the motors from harmonic distortion. If the load is resistive, the energy is likely to be efficiently consumed.

Fortunately, in most practical cases where the voltage distortion is within electricity supply recommended limits, the error is very small (much less than 1 percent). The latest electronic meters in use today are based on time-division and digital sampling. These electronic meters are much more accurate than the conventional watt-hour meter based on induction motor principle. Although these electronic watt-hour meters are able to measure harmonic components, they could be set to measure only the fundamental power. The user should be careful to ascertain that the meters are measuring the desired quantity.

The greatest potential errors occur when metering demand. The metering error is the result of ignoring the portion of the apparent power that is due solely to the harmonic distortion. Some metering schemes accurately measure the active (*P*) and reactive power (*Q*), but basically ignore *D*. If *Q* is determined by a second watt-hour meter fed by a voltage that is phase-shifted from the energy meter, the *D* term is generally not accounted for—only *Q* at the fundamental is measured. Even some electronic meters do not account for the total apparent power properly, although many newer meters are certified to properly account for harmonics. Thus, the errors for this metering scheme are such that the measured kVA demand is less than actual. The error would be in favor of the customer.

The worst errors occur when the total current at the metering site is greatly distorted. The total kVA demand can be off by 10 to 15 percent. Fortunately, at the metering point for total plant load, the current distortion is not as greatly distorted as individual load currents. Therefore, the metering error is frequently fairly small. There are, however, some exceptions to this such as pumping stations where a PWM drive is the only load on the meter. While the energy meter should be sufficiently accurate given that the voltage has low distortion, the demand metering could have substantial error.

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