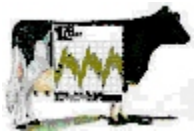

Electric and Magnetic Fields (EMF) Affect Milk Production and Behavior of Cows; Results Using Shielded Neutral Isolation Transformer

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SUMMARY

In 2002 we reported that behavior, health, and milk production of cows were impaired by transients and by the 3rd, 5th, 7th, and triplen harmonic electrical currents from utility power lines. Kaune et al., concurred in that 180 Hz currents and the 3rd, 5th, and 7th harmonics in the living areas of homes were associated with cancer deaths of former residents in Denver, CO. Subsequently, our investigations revealed that a cellular telephone signal generator located at the base of an antenna tower, was charging the neutral-ground with 10+ V and the 3rd, 5th, 7th and other harmonics were on the neutral conductors and water lines of homes, schools, and workplaces in the area, causing harmonic distortion of the power supply. Primary neutral voltage and 3rd, 5th, 7th and other harmonics on dairy farms were reduced to near zero when a shielded neutral isolation transformer was installed between the utility and the dairy. Animal behavior improved immediately, and milk production which had been depressed for 3 years, gradually returned to normal within 18 months after installation of the shielded transformer. Shielding prevents transients and harmonics on the utility primary from induction onto the user neutral and likewise prevents user harmonics and transients from getting onto the utility electrical line. Changes in concentrations of several blood and cerebrospinal fluid components, energy and fat metabolism, and reduced milk have been reported for cows exposed to EMF from overhead powerlines in Canada. Consequences are related to the time and intensity of exposure to EMF.

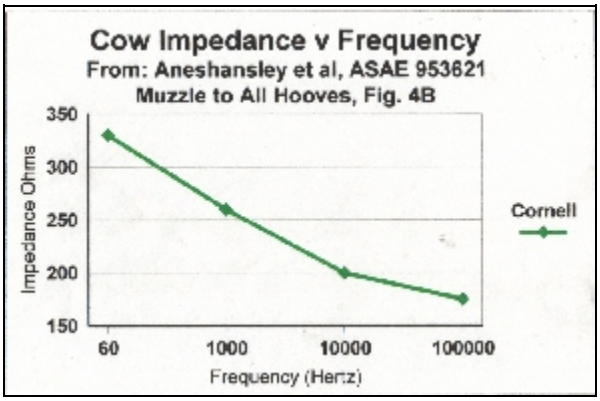
INTRODUCTION

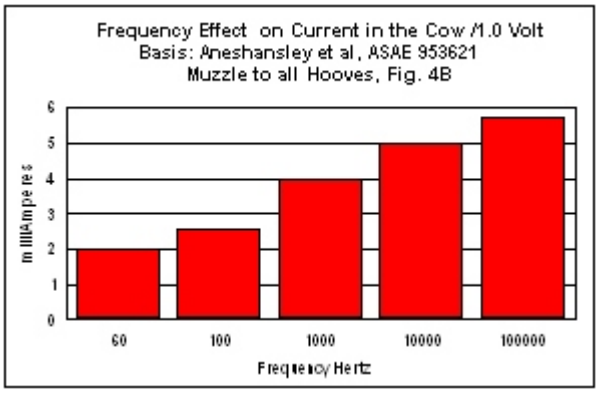
Farm investigations revealed that transient and harmonic voltages and currents were related to animal behavior, health, and milk production of dairy cows on 12 farms. Details of methods and materials were reported previously (Hillman 2003) and results are in the DVD presentation that accompanies this article.

Briefly, the farm studies revealed that:

- Transients and harmonics were prevalent on rural electric power lines and were commonly called “noise” or “dirty” electricity in the electrical industry.
- Neutral-to-ground distorted non-sinusoidal transients averaged 280 ± 60.2 V on 3 farms for 165 days, and 79.9 V on five farms for 385 of 515 days as recorded by Fluke® EventRecorder VR-101.
- The concentration of transients and harmonic impulses varied greatly from farm to farm, day to day, and time of day.
- Milk per cow/d decreased as the number of transient events, hot-to-neutral and neutral-to-ground, transients (oscillations, spikes on the power supply) increased daily.
- Milk was negatively correlated with phase-shift degree angle of transients.
- Step-potential oscilloscope voltage readings from the floor of milking stalls averaged 0.0628 V (62.8 mV ± 39.8 mV) and ranged from 0 to 0.1516 V (151.6 mV) on five farms for 515 days.
- Cow movement (steps/min) increased as the voltage differential (minimum - maximum) increased from 0.9 to 6.0 millivolts during the same minute and as the voltage standard deviation increased..
- Milk per cow/d decreased as the number of 3rd, 5th, 7th, 21st, 28th, and 42nd, harmonics increased/d. Harmonics were correlated with the number of transients per day.
- Milk decreased as the sum of triplen harmonics (3rd, 9th, 15th, 21st, 33rd, and 39th) increased/d ($P < 0.003$).
- Cow impedance decreased as frequency increased.
- Current in the cow increased as frequency increased.
- Public Utility Commission (PUC, PSC) standards and use of 500-ohm resistors in test circuits adopted in Wisconsin and some other states underestimate effects on cow behavior, health, and milk production of non-sinusoidal, inferior-quality power on rural power lines.
- IEEE 519, 1992 recommended 5% Total Harmonic Distortion (THD%) on the utility side of the meter, and 5% Total Distortion Demand (TDD%) on the end-user side of the meter, limits that were set for protection of electrical and electronic equipment must be applied for protection of livestock and humans as well.
- The Grounded-Y distribution/transmission system uses the earth as a return conductor for neutral current resulting in earth currents that could be avoided by hard-wiring the neutral back to the substation.

Relationships between frequency of voltages and current passing through the cow were reported by Aneshansley et al. (1990, 1995) and are illustrated below. Voltage at harmonic frequencies increases amperage two to three times compared to sinusoidal 60 Hz voltage because of the reduced impedance of the cow at higher frequencies.





Sources of Inferior Quality Electrical Power

Wiring Faults: Causes of uncontrolled electrical voltage and current, commonly called "stray voltage" often include improper grounding, loose or corroded connections, poor condition of insulation on wires, wiring faults on motors and equipment, unbalanced loads on primary or secondary circuits, and tree branches brushing electrical lines. These faults may occur on-farm, on a neighbor's farm, or on utility lines. Experts claim that faulty wiring accounts for some 80% of stray voltage problems on farms. However, if the electrical system in a building is sound, i.e., no faults and meets code, the only source of AC current for producing uncontrolled voltage is the neutral (grounded) conductor via the bonding with the grounds. Bonding allows current to flow to metal water pipes, lightning protection, and branch circuit equipment ground wires according to Ludington et al. (1987). The cow is almost always in the current path in series and in parallel with other resistances as the current seeks a return path to the substation of a grounded -Y, or to the transformer of a Delta system.

Power Quality Problems: The other 20% of electrical problems on dairy farms have not been described publicly, although a large volume of information concerning "dirty" electricity vs "clean" appears in scientific journals, and the standards for hospitals and electronics manufacturers are higher than for other users. "Power quality problems" are simply pollution of the power supply as surely as contaminated milk is considered polluted milk, but milk producers are shut-off from the market by law. No such regulation has been applied to utilities.

USDA-ARS Publication 696, (1991) *Effects of Voltage or Current on Farm Animals*: *How to Detect and Remedy Problems*, contains no information about the presence or effects of power quality on dairy cows, nor other species.

Barry Kennedy in his book, *Power Quality Primer* (2000), gives vivid descriptions of the effects of modern electrical and electronic control devices on the quality of electricity on power lines, and effects of power quality on operating equipment. A paucity of published reliable research has prevented valid conclusions regarding cause:effect relationships of electricity and animal performance from appearing in the agricultural literature. Secondly, facts and the testimony of knowledgeable witnesses in court testimony, when settled without completion of a trial is sealed (sequestered) by the Court, thus denying the public of knowing the cause or outcome of such decisions. Nevertheless, very few court decisions have been favorable to utilities. Reasonable standards of power quality and responsibilities of both parties should help to provide efficient justice for both parties, and reduce the burden on the overloaded court system.

Power quality is defined by electrical engineers in terms of compliance of the power supply with nominal voltage and current. Deregulation has not improved the quality of electric power.

A transient voltage (transient or spike) is a temporary, unwanted voltage in an electric circuit. Transient voltages may range from a few volts to several thousand volts and last from a few microseconds to a few milliseconds. Oscillatory transient voltages are commonly caused by switching OFF high inductive loads and by switching large utility power factor correction capacitors for balancing loads on a power line. Impulse transients are commonly caused by lightning strikes and are distinguishable from oscillatory transients by the shape of the waveform distortion and by the number of oscillations unless allowed to resonate in the circuit by capacitors. Lightning arresters mounted on top of poles and substations are used by utilities to dampen impulse transients. Transients averaged 10 oscillations per transient event recorded by Fluke Event Recorder VR101 in these studies.

Harmonics are the major source of sine waveform distortion. The increased use of nonlinear equipment have caused harmonics to be more common. EPRI, Electric Power Research Institute, financed by utilities estimated that one-half of all electricity used in the United States would pass through electronic equipment by the year 2000. Because of the increased adverse effects of harmonics, the IEEE (Institute of Electrical and Electronic Engineers) adopted a standard for harmonics in 1992. The standard is referred to as *IEEE Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems* (IEEE 519-1992 ©1993) according to Kennedy (2000).

The IEEE standards were devised to prevent harmonic damage to transformers, motors, and electronic circuits. Cows, other livestock, and humans ought to be added to the damage list.

Harmonic currents are usually caused by nonlinear loads like adjustable speed drives, solid-state heating controls, electronic ballasts for fluorescent lighting, switched-mode power supplies in computers, printers, static UPS (uninterruptible power supply) systems, electronic and medical test equipment (Magnetic Radiation Imaging), rectifiers, filters, and electronic office machines. Nonlinear loads cause harmonic currents to change from a sinusoidal current to a non-sinusoidal current by drawing short bursts of current each cycle or interrupting the cycle. This causes the sinusoidal current waveform to become distorted. The total distorted wave shape is cumulative. The resulting non-sinusoidal wave shape is a combination of the fundamental 60-Hz sine wave and the various harmonics.

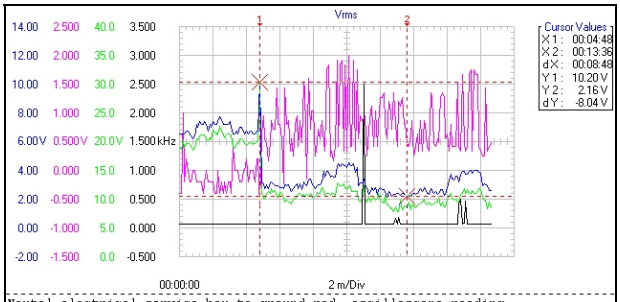
The switched-mode process results in a pulsed square wave which distorts the sine wave and produces harmonics (Kennedy 2000).

Further, single-phase nonlinear loads that draw current only during the peak of the voltage waveform, combine in a 3-phase circuit and produce triplen harmonics (multiples of the third order harmonics, like 3rd, 9th, 15th, etc). Triplen harmonics do not cancel but are additive and return exclusively on the

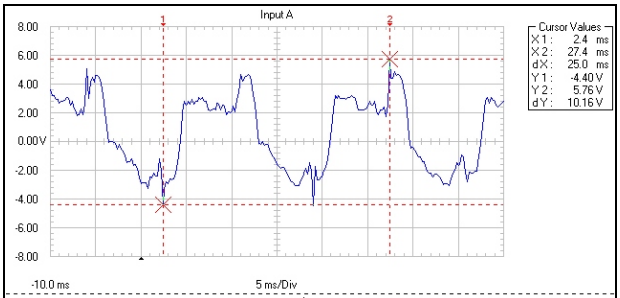
neutral conductor. The resulting magnitude of the neutral current may increase to 173 percent of the rms phase current. Thus the neutral current may exceed the capacity of the neutral conductor. Triplens cause overheating of the primary neutral conductor and may cause fires since there is no fuse or circuit breaker in the neutral circuit. Harmonics also cause the WATT meter to turn faster, thus inflating the electric bill.

A Source of Environmental Pollution was identified in East Lansing, MI. Flukeview prints of oscilloscope readings, waveform and harmonics are presented below.

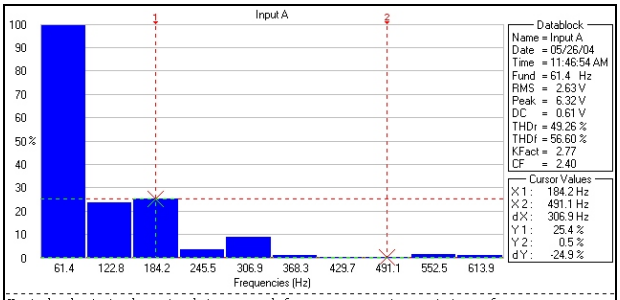
A service-box neutral-ground of a cellular telephone generator/base-station with six antennae on the tower registered 10.16 V ac on the oscilloscope as in the Flukeview print-out. Nextel had taken a big bite out of the peak of the waveform and the frequency spectrum had 56% Total Harmonic Distortion with 2nd, 3rd, 5th, and 7th harmonics. They were also carried into electrical outlets and waterlines in homes and schools in the area.



Nextel electrical service box-to-ground rod, oscilloscope reading, 5/26/04; 11:25 AM, 8.04 Volts (peak-peak) high frequency spikes. Rise in Voltage (blue) occurred each time generator/transmitter started roaring and gradually increased until it stopped. DC voltage (pink) followed a similar rise.



Nextel box-bolt Neutral from generator/transmitter under water tower, Patriarche Park, E. Lansing waveform, 10.16 Volt(peak-peak) Distorted flat notched waveform typically produced by switch-mode electronic devices such as pulse rectifiers signal generators that draw their current from the peak of the waveform and pollute the living environment 5/26/04, 11:47 a.m.



Nextel electrical neutral-to-ground frequency spectrum at transformer near water tower in Patriarche Park, East Lansing, MI 5/26/04 12:19 PM. The 7-signal transmitter/receiver antenae are on top of tower. Generator and transmitting equipment are below the water tower. Total Harmonic Distortion (THDf%)56.6% exceeds IEEE 5% max THD standard. The odd numbered 3rd Harmonic (180 Hz), 5th harmonic (300 Hz) and 7th harmonic (420 Hz) have been associated with human cancer in studies at Denver, CO, impaired health and milk production of cattle in MI, WI, and MN. These harmonics are carried on water lines and neutral conductors into homes, schools, and workplaces of East Lansing/Okemos users.

Cows on a dairy farm in mid-Michigan were dancing (stepping, lifting feet, shifting body, and tail-switching) to avoid the pain of electrical shock. Oscilloscope Flukeview prints showed 8 to 12 V and harmonic distortion with 3rd, 5th, 7th, and 9th harmonics on the utility PN-to-ground. The secondary neutral carried 1.43 V tested by utility meters. The floor registered 300 to 400 mV, and leads from divider pipes to the floor of the operators' pit in the milking parlor carried 480 mV. The farmer observed that cows were not disturbed when the primary neutral-to-ground wire had been disconnected.

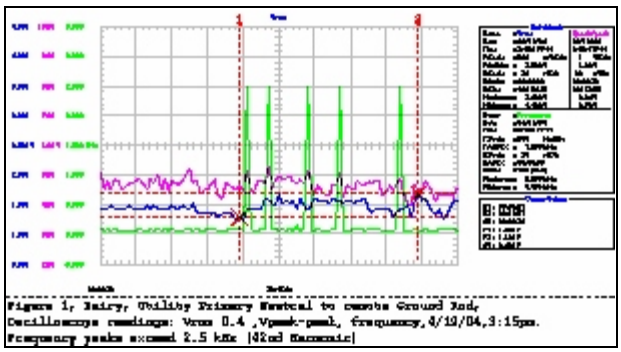
A neighbor had experienced the problem of cows dancing, stepping, tail-switching, and kicking off milkers (see the video), resulting in incomplete milking, declining milk production, and impaired health performance when 12 Vs were on the primary neutral and 1 V at cow contact. Utility experts claimed the voltage was too low to be "problematic." The neighbor had the power company move their service pole with transformer and down-ground about 200 feet from the milking parlor to the edge of the property. The dairy was served by 480-V single-phase service to the dairy, and an isolation transformer was installed by the dairyman. Cow behavior and milk production improved immediately and progressed to 29,200 lbs. per cow/year by 2004. However, when they tried to install a variable speed drive milk pump, the problem returned and the pump was removed. The transformer was not shielded to prevent harmonics and high frequency transients from passing from the primary to the secondary winding of the transformer.

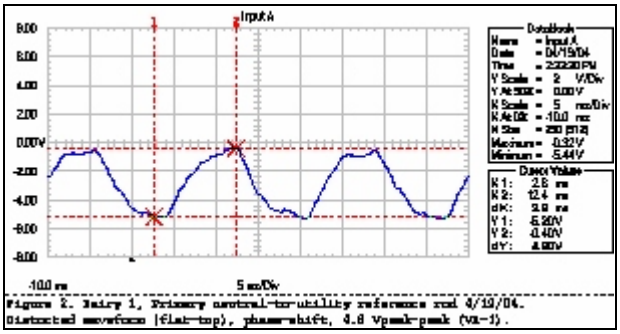
A Virginia dairyman had the problem of cows dancing and milk production had decreased to nearly one-half over a three-year period. The utility measured voltage for 6 days and reported about 2/3 of the PN-G reading were between 2.4 and 3.0 V, while the remainder ranged from 3.6 to 4.8 V. Experts could find no cause for the poor performance of the herd. The primary neutral was bonded to cow contact metal pipes and reinforcements in the floor of the milking parlor to form an equal-potential environment in the dairy. An electrical engineer found the primary-neutral averaged 0.96 V and 1.0 V, (maximum 2.08 V) equivalent to 2 to 5 mA, assuming 500 ohms cow resistance, for periods of 16 days and 19 days.

Oscilloscope Flukeview readings at the Virginia Dairy Farm revealed 2.5 kHz spikes (green) accompanied by a 400 mV rise (blue line), and about 5.5 V (peak to peak) (red lines).

The peak of the waveform is chewed off and resembles the Nextel waveform.

The Frequency spectrum shows the neutral is loaded with 3rd, 5th, and 7th harmonics, indicating inferior quality power, and the herd was a victim of power supply pollution.





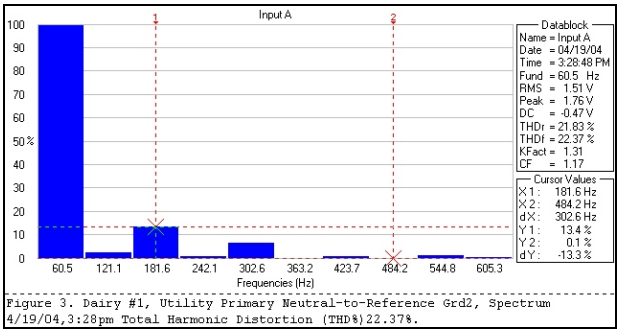
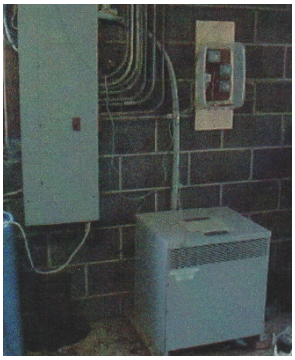


Figure 3. Dairy #1, Utility Primary Neutral-to-Reference Grd2, Spectrum 4/19/04,3:28pm Total Harmonic Distortion (THD%)22.37%.



Transformer Electric Company, Roanoke, VA, built a shielded neutral isolation transformer (SNIT) and connected it between the utility and the dairy, with the center tap serving as the ground for the dairy.

After installing the SNIT: Voltage was reduced to 0.002 V (0.004 mA). Cows stopped dancing, and milk production gradually recovered to its highest previous level after about 18-months. In the interim, many good cows and replacements had been lost from the operation.

New Discoveries from on-farm research include:

- Farm electricity is not always clean--Powerlines are polluted with transients and harmonics.
- Cow resistance goes down as frequency goes up.
- EMF < 1 Volt at cow contact may damage cows.
- Cow behavior is affected at frequencies < 1000 Hz.
- Cows need not be touching metal for harmonics.
- Milk decreases as transients and harmonics increase.
- Shielded neutral isolation transformer reduces harmonic voltage and current through the cow.
- Behavior, health, and milk production improved when the primary neutral was isolated in problem herds.

Related University EMF Research

Burchard et al. at McGill University, Montreal, Quebec, Canada, have been studying effects of EMF on dairy cows for several years. Cows were exposed to 10 kV/m electric fields and 30 µTesla magnetic fields, for 28-day periods in reversal trials. Intensities are equivalent to standing under a 735 kV electrical transmission line. They reported in Bioelectromagnetics (2003).

- Milk production decreased 5% from exposed cows compared to controls
- Fat-corrected milk decreased 14%compared to controls
- Milk fat decreased 16% compared to controls
- Dry matter intake increased 5% compared to controls.

Physiological effects from Burchard et al. include:

- Melatonin, a hormone produced in the Pineal gland in the brain, decreased in cows exposed to EMF.
- Melatonin has strong oncostatic immunological, and antioxidant properties in the blood. It normally follows the pattern of light:dark nocturnal exposure.
- Progesterone increased in lactating pregnant cows.
- Length of estrus cycle increased 3 days.
- Insulin-like growth factor (IGF-1) increased in blood.
- Growth hormone was modified during part of the nocturnal cycle.
- Macro and trace element changes in blood – Calcium, magnesium, iron, and copper were affected by EMF exposure.
- Cerebrospinal fluid (CSF) changes in concentrations of Ca, P, Mg, Mn and Na occurred.
- Quinolinic acid increased in CSF, tryptophan tended to increase in CSF.
- CSF changes were consistent with weakening of blood-brain barrier.

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