Transmission Lines
vs.
EMF and Stray Voltage

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EMF and Stray Voltage are two different topics

EMF is typically a concern for people.

Stray Voltage is typically a concern for dairy animals.
EMF and Stray Voltage

I will try to give you an idea on how I check for EMF or Stray Voltage.

I will give you my opinion on what you would expect to find, and what I considered acceptable.
Let’s discuss EMF first as it relates to you in the area in and near Buffalo County, WI.

In this case the concern is what EMF levels will be produced by a proposed 345 kV transmission line.
Electromagnetic Field

An electromagnetic field (also known as an EMF or EM field) is a physical field that exists around a wire carrying electrical current.

The EMF field can be viewed as the combination of an electric field and a magnetic field.
The ELECTRIC field portion of EMF

The electric field as it relates to a transmission line used to be a concern for dairy cows that were grazing outdoors under a transmission line.

Many years of testing show this is no longer a concern.
This does not mean there is no concern about the ELECTRIC field.

Large farm equipment, supported by rubber tires, operating under a high voltage transmission line can result in a voltage between the metallic equipment and the earth.

When entering or departing the equipment, a person with wet boots might feel an electrical tingle.

Solution: If you have to stop directly under a transmission line, drop a chain connected to the equipment on the ground to discharge the voltage from equipment to earth.
Large metal buildings directly under or very near a high voltage transmission line can experience a voltage between the metal building and the earth.

Solution: Install ground rods at all corners of the building and ground the metal siding to the earth.
The MAGNETIC field portion of EMF

Current flowing in the wires of a transmission line creates a MAGNETIC field.

This magnetic field is exactly the same as a magnetic field caused by current flowing in the wires of your home.
The MAGNETIC field portion of EMF (continued)

The amount of current in a large transmission line is greater than the current flowing in your house wiring, but the distance between you and the transmission line is much greater.

Magnetic fields drop off very fast as you move away from the wires.
I would expect the level of the magnetic field at the edge of a 345 kV transmission line right-of-way to be in the range of 50-60 milli-gauss with a heavy load of about 600 amperes at a distance of 40 feet.

The typical home creates magnetic fields of 2 to 30 milli-gauss at normal working distances from electrical items in the home.
The MAGNETIC field portion of EMF (continued)

<table>
<thead>
<tr>
<th>Appliances</th>
<th>At 10 - 12 Inches</th>
<th>At Working Distance (19 - 22 Inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Microwave</td>
<td>17 - 236</td>
<td>5 - 28</td>
</tr>
<tr>
<td>Electric range</td>
<td>1.8 - 2.9</td>
<td>0.4 - 10</td>
</tr>
<tr>
<td>Refrigerator</td>
<td>1.3 - 15.7</td>
<td>0.6 - 11.4</td>
</tr>
<tr>
<td>Color TV</td>
<td>3.5 - 18.6</td>
<td>0.9 - 8.2</td>
</tr>
<tr>
<td>Fluorescent light</td>
<td>1.2 - 56.7</td>
<td>0.3 - 15</td>
</tr>
<tr>
<td>Ceiling fan</td>
<td>0.3 - 49.5</td>
<td>0.0 - 6</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Power Tools</th>
<th>At 1 - 4 Inches</th>
<th>At Working Distance (12 - 20 Inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cordless drill</td>
<td>8</td>
<td>5 - 8</td>
</tr>
<tr>
<td>Table saw</td>
<td>760 (at motor)</td>
<td>12</td>
</tr>
<tr>
<td>Plunge router</td>
<td>300</td>
<td>30</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Power Lines**</th>
<th>At Center Line</th>
<th>At 40 Feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>46 kV (138 amps)</td>
<td>9.6</td>
<td>3.7</td>
</tr>
<tr>
<td>69 kV (167 amps)</td>
<td>23</td>
<td>7</td>
</tr>
<tr>
<td>115 kV (90 amps)</td>
<td>15</td>
<td>5.5</td>
</tr>
<tr>
<td>138 kV (300 amps)</td>
<td>39</td>
<td>17</td>
</tr>
<tr>
<td>345 kV (628 amps)</td>
<td>95.8</td>
<td>56.4</td>
</tr>
</tbody>
</table>
Where I have found the greatest annoyances due to magnetic fields:

Right next to electrical equipment rooms in buildings.

Right next to circuit breaker panels in homes and offices

Notice that I said “annoyances”, not “concerns”.

Most times the magnetic fields, even though low, would make older computer monitor screens wiggle causing eye strain.

Solution: Find a way to locate people and sensitive equipment to another location.

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A good source of information on EMF

I have provided a copy of this document to your host. More good information can be found at:

http://psc.wi.gov/utilityinfo/electric/construction/emf.htm
How do you measure EMF magnetic fields?

There are numerous good meters on the internet to make these measurements.

Some of the meters display microtesla versus milligauss.

1 microtesla = 10 milligauss
How do you minimize EMF magnetic fields?

The most practical way is to create more distance between you and the source of the magnetic field.

Use common sense and evaluate the relative measurements between different areas that concern you.
How many milligauss is OK?

My opinion is up to 15 milligauss for long term exposure is about average for all of us.

The levels we experience in today’s world does not seem to have created any concerns at this point.

When working with people that have more concern for magnetic fields than I do, I have always managed to fine a reasonable solution using common sense and respect for the concern of others.
By the way:

Some photos of transmission lines and substations from the front porch of my house.
Stray Voltage

One of the most significant effects of REAL stray voltage is that the cows do not want to drink water.

This is bad for a dairy cow.

There are other reasons a cow might not want to plunge it’s nose into a water trough.

I came across this poor animal while riding in the desert a few years ago.
What causes Stray Voltage?

If you have a situation where the electric power to the farm is perfect, and the farm wiring is perfect, you can still have a concern for stray voltage.
What causes Stray Voltage? (Continued)

Sometimes just the relative location of power poles, buildings, wells, and other farm facilities can result in a stray voltage level that should be given attention.

Every farm has some stray voltage.

The important point is “how much”.

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How does “Stray Voltage” affect a cow?

Cows respond to electric CURRENT flowing through the animal.

In order to have CURRENT flow thru the animal, you must have a VOLTAGE across the cow at what are called “Cow Contact Points”
The most common contact points are mouth to rear feet.

This is the most common situation
Front feet to rear feet are also a concern:

This is called a "Step Potential". It is the second most common concern.
Mouth to teat is usually not a concern due to the electrical resistance of a milk filled hose:

Current through the cow

CC Point 1

Watering Unit

CC Point 2

This is not a real concern since the milking equipment hoses that connect to the cow's udder limit the flow of current to minimal values
So, we need a voltage across the cow to create a current through the cow:

Finding voltages where a cow hangs out is relatively easy.

Stray voltage is easy to detect.

Stray voltage is easy to correct.
The most important thing to look for on a farm is voltage at cow contact points.
How much voltage?

The States of Wisconsin, Michigan and Idaho took considerable time to review scientific based research and concluded that current levels of 4 to 8 milli-amperes thru a cow would produce a recognizable change in behavior in the animal.
4 to 8 milli-amperes through a cow will not kill a cow or necessarily prevent the animal from drinking, but it is a “Level of Concern”.

Most states took the lower 4 ma level and reduced it to 2 ma. This provides a safety factor of 2 to 4.

Since both utilities and farms can contribute to stray voltage, the utility is typically limited to causing 1 milli-ampere or less to the cow. This provides a safety factor of 4 to 8.
I started talking about voltage and now I am talking about current.

Today it is difficult to accurately record current through the cow. In the 1980’s it was even more difficult to measure current accurately.

If we connect a resistor across the two cow contact points and measured the voltage across the resistor with a voltmeter, we would know what the current would be if the resistance of the cow and it’s mouth/feet connection points equal to 500-ohms.
The resistance of a cow varies from about 250 to 1100 ohms.

If a cow is standing in fresh manure or standing on a bed of dry straw, the resistance of the cow’s connection to the surrounding electrical environment will vary.

When we make our measurements we create low resistance connections to the source of stray voltage.
That’s why a safety factor of 4 to 8 allows you to use a 500-ohm resistor.

If you use a 500-ohm resistor and assume a current of 1 milli-ampere is flowing thru the “cow resistor”, the voltage across the resistor will be 0.5 volts
That’s where the 0.5 volt limit you may have heard about came from.

The regulatory departments in most states are responsible for regulating the operation of electric utilities.

Electric utilities distribute electrical power at a frequency of 60-Hertz (cycles per second). The voltage is an alternating current (AC) and it is measured as an RMS value.

That’s the logic for measuring stray voltage at the cow contact points as 60-Hertz, AC, RMS values.

Since there may be some voltage distortion in utility power caused by customer loads, newer meters measure in “True” RMS values.
How can one measure stray voltage levels on a dairy farm?

You can ask your local utility to perform measurements. If they are not equipped to do the investigation, have them contact me and I can assist them.

You and your local electrician can also perform good tests at a reasonable cost.

Better yet, both of you make the measurements. It a very good idea to monitor stray voltage levels on a farm continuously.
You can do your own stray voltage measurements.

Go to my website
www.phasorlabs.com

Download the documents on the “Do it yourself stray voltage checks” tab.

The equipment required will be about $600-700. I do not sell equipment, but it is easy to purchase on the internet.

You can only measure one (1) cow contact location at a time. That is not a problem.

If you have problems, email me at cforster@phasorlabs.com

I do not charge to answer questions via email. I do not save email correspondence to protect your privacy.
What about the other tests performed by utilities?

When investigating a farm, there are three (3) areas to review:
1. The supply of power to the farm.
2. The distribution of electricity on the farm.
3. The level of stray voltage at the cow contact points.
For the transmission line project you are concerned about....

The Public Service Commission of Wisconsin requires the utility to perform complete tests on each farm within 500 feet of a transmission line or within 1.5 miles of a substation.

These investigations must be performed prior to and repeated after construction.
As I mentioned earlier, cow contact voltage is the main concern.

You can do that yourself.

Work with your local electrician. You both will learn more about stray voltage and you can have the satisfaction of working with someone you know.
What if you find a cow contact voltage that is too high?

The good point is that you found a voltage to get your attention.

Call your utility and see if they have a team to investigate the entire electrical system including your farm.

Normally the problem area can be identified and stray voltage can be reduced.
Am I making the solution to stray voltage concerns seem too easy to resolve?

Yes, I am.

But the most important information to gather is a summary of what the voltages at cow contact points are.

You can do that, if no one else can.
Does everyone agree with what I have said?

Some people do not.

You will hear people tell you that the 60-Hertz, AC, RMS voltage is not the concern, but “high frequency” voltages are the real concern.

I have monitored “high frequency” electrical events on farms for the last 30 years.

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High frequency electrical events come from many sources.

The most significant sources are electric fencers, fencers used in crowd gates and cow trainers.

In 30 years I have not found a significant “high frequency” or short “duration” electrical event other than that caused by a mis-wired fencer or cow trainer.
Thanks for your time!

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