High Voltage Transmission and Environmental Effects

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The expanding role of electric energy in the United States' economic, health, environmental and social development necessitates the construction of more high voltage (HV) transmission lines. Today, HV transmission lines have been the only vehicle to not only bring electric energy from far away power plants, but it has been done at great savings when used in economic dispatch and power pools' capacity exchanges. In the future, as the cost of energy increases, there will be an even greater demand to upgrade the transmission system to higher voltages in order to reduce the energy loss in these lines, improve reliability, and insure cost reduction by taking advantage of regional, time, and weather related differences.

Recently, however, it is becoming more difficult to acquire the necessary right of way for the development and construction of the necessary transmission system. Environmental issues and concerns about possible impact of electric field on living things and farm machinery are often used to object to giving the needed right of way for construction of new lines or upgrading existing ones. Some of these concerns are legitimate and must be addressed properly by research.

To address the concerns of transmission line effects in rural areas, Iowa State University in cooperation with ten local utilities including Central Iowa Power Cooperative, Cedar Rapids; Corn Belt Power Cooperative, Humboldt; Eastern Iowa Light and Power Cooperative, Wilton; Interstate Power Company, Dubuque; Iowa Electric Light and Power Company, Cedar Rapids; Iowa-Illinois Gas and Electric Company, Davenport; Iowa Power and Light Company, Des Moines; Iowa Public Service Company, Sioux City; Iowa Southern Utilities Company, Centerville; and Northwest Iowa Power Cooperative, LeMars, have established the Iowa Test and Evaluation Facility (ITEF), High Voltage Research and Demonstration. The major objectives of the research facility are:

a. Accumulation of pertinent data on EHV-UHV transmission systems to allow long-range evaluation of the suitability of higher voltage lines in the State of Iowa.
b. Accurate measurement of electrostatic and electromagnetic effects on the environment within or near the right of way.
c. Prediction of long-range effects on plants and animals from model development and analysis of data from well designed experiments.
d. Education of public by demonstrations of high voltage field effects and other sources of radio and television interference.
e. Serving as a high voltage laboratory for training utility engineers and ISU students.

Thus, one purpose of this facility is to study and report scientifically what the fields within the right of way of extra high voltage and ultra high voltage transmission lines do. Although the ten utility companies involved have partially financed portions of this program, they have no power to control the research or the information published as a result of studies undertaken at this facility.

The Iowa Test and Evaluation Facility is located in Webster County just east of the City of Fort Dodge, Iowa. A modular building providing office space and a large demonstration area was placed beneath a 345 kV transmission line running south to the Des Moines area, and a 161 kV transmission line running east from the substation toward Webster City. A 69 kV transmission line is also available at this same substation. The availability of these three transmission voltage levels was one of the factors determining the site location since they

represent the three major voltage levels used in the State of Iowa.

Besides the structure used for lectures and demonstrations, the facility includes a 150-ft wide area running south for three-quarter mile beneath the 345 kV line and access to the other right of way areas for experimental use. The owners and operators of the farms have been very cooperative in providing farm equipment for some demonstrations and monitoring crop performance. They have also been helpful by suggesting areas of concern to other farmers in the region.

The ITEF building itself is the center of most of the activity and is used to store the necessary equipment for taking measurements of electric and magnetic fields as well as electromagnetic radio wave levels from 10 kHz to 1.0 GHz. This radio frequency interference equipment is used to monitor suspected radio noise generation on HV lines and to determine any effect of new transmission lines on local radio and television reception in the vicinity of such lines. This also makes it possible to train graduate students both in the effective use of such instruments in the field and in analyzing all kinds of new data.

The HV demonstration usually lasts about five or six hours and includes a slide presentation and a number of simple high voltage and physical phenomena experiments both indoors and outdoors. These experiments are designed to teach guests what electric and magnetic fields are and what the numbers used to describe their magnitude really mean. These magnitudes are related to their common experiences with household appliances, machinery and other electrical equipment that they may have in their homes or on their farms. For instance, a Tesla coil is used to demonstrate corona discharges and the generation of ozone. A static generator provides an opportunity to feel what a 50 kV/m electric field is like. The sources of radio frequency interference (RFI) and television interference (TVI) within the household and their propagation from house to house via power lines are discussed, and how to differentiate between these external sources and those that may exist on the power line itself. Safety in the handling and use of electrical appliances and the tolerance limits are stressed throughout these presentations.

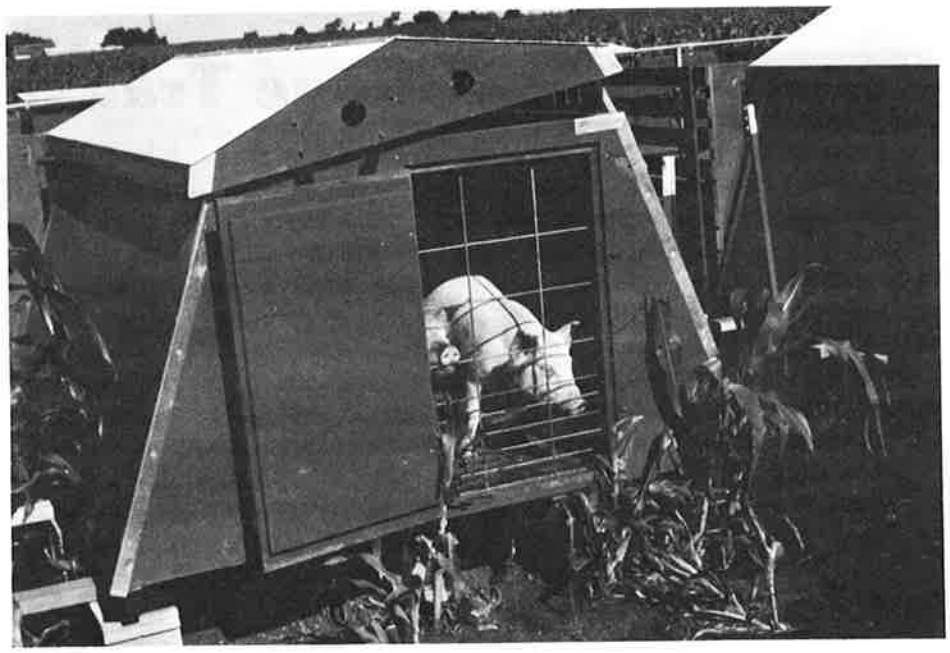

Figure 1. All "volunteers" reached a weight of over 200 pounds.

In the field demonstrations, actual field strengths are measured and short circuit current and open circuit voltages are measured on typical farm machinery mounted on insulating plates of polystyrene as well as a simulated insulated fence section. The short circuit currents are then compared to standard "safe" tolerance limits.

In 1981, Magne Waskaas published a summary of literature study on "Biological Effects of Electric and Magnetic Fields" in which he concluded that very little truly scientific data is available in spite of the numerous publications on the subject and that such data as is offered is often controversial and contradictory. Unwarranted extrapolations of data from one specie to another only served to confuse the issue.

It was in such a climate of uncertainty that the ITEF experiment on swine was begun, with full cooperation from the Animal Science and Veterinary Medicine faculties at Iowa State University and personnel from the Land O'Lakes Research Farm. Swine were chosen over beef cattle for this experiment for several reasons. First, perhaps, was the importance of pork production to the average Iowa farmer who is ultimately supporting our studies. More important scientifically, however, were the shorter life cycle required for swine studies and the fact that swine are normally confined to small areas where the electric fields would be uniform, whereas beef cattle normally graze over a large area and would create a considerable problem in calculating the extent of their exposure to the subject fields.

Swine Experiment and Set-Up

Sixty cross-bred pigs of similar breeding were chosen from the herds at Iowa State University Swine Nutrition Research Farm. As nearly as possible, littermate pairs of similar body weight were randomly allotted to the exposed and control groups. Five confinement units housing six pigs each were placed beneath the 345 kV transmission line in the region of maximum electric field ($\cong$ 4.2 kV/m) and an identical five units were placed approximately one-half mile away from the transmission line on the same farm.

The confinement units were typical commercial units with a 6×8-ft shelter, a 6×9-ft feeding floor constructed with oak slats, a nipple

waterer, and a two-space self feeder. The shelter roof and the self feeder lids were changed to fiberglass to eliminate any electrostatic shielding by the corrugated iron roofs. Water to the five exposed units was supplied by an underground plastic pipe. The metal pipe connecting the units and the nipple waterers were grounded by placing grounding rods at each end of the row.

A pelletted diet was provided by the Land O'Lakes Agricultural Services and Research Farm near Fort Dodge, Iowa. After the first six weeks, the protein content of the diet was reduced from 16% to 14% for the finishing period. Land O'Lakes also provided personnel to measure feed consumption and individual body weights biweekly. Observations of animal behavior were also made almost daily. No vaccinations were given to prevent disease but an anthelmintic was included in the diet for the first six weeks. Only one sow in the control group required any attention from the veterinary services: this was due to an abscess on a leg.

The pigs averaged 47 lbs and 79 days of age at the beginning of the 90-day first phase experimental period and were marketed on the weight-day that they individually reached a minimum of 200 lb body weight. No unusual behavior was noted throughout the experiment (see Figure 1).

Carcasses were graded at a commercial slaughter house where no distinction was made between exposed and control animals. This grading was done according to USDA guidelines. Backfat thickness and other carcass quality measurements were also made. Comparison of the exposed and control groups by using the average performance of the animals in each confinement unit shows no significant differences between the two groups. Tables 1 and 2 summarize these results. The slightly better feed efficiency for the exposed group is statistically insignificant.

A portion of the amounts in this first phase were saved alive to continue the experiment for several

Table 1. Effect of electrical field under a 345 kV line on growing-finishing pig performance

Replication	*Grower period*[b] Control	Hi-volt	CV, %	*Finisher period* Control	Hi-volt	CV, %	*C-F period* Control	Hi-volt	CV, %
				Avg. daily gain, gram					
1	774	703		839	825		809	771	
2	825	739		753	890		787	814	
3	811	857		918	912		866	883	
4	726	753		784	845		757	800	
5	693	705		734	807		719	760	
Avg	766	751	5.6	806	856	5.3	788	806	2.9
				Avg. daily gain, gram					
1	1712	1559		2563	2356		2165	2043	
2	1870	1785		2657	2821		2280	2297	
3	1820	1964		2854	2782		2345	2337	
4	1720	1732		2522	2640		2147	2193	
5	1609	1580		2379	2450		2044	2054	
Avg	1747	1724	4.6	2595	2610	4.1	2196	2188	2.1
				Feed; gain					
1	2.21	2.22		3.05	2.94		2.68	2.65	
2	2.27	2.41		3.53	3.17		2.90	2.82	
3	2.24	2.29		3.11	3.05		2.71	2.65	
4	2.37	2.30		3.23	3.12		2.84	2.74	
5	2.32	2.24		3.22	3.04		2.84	2.70	
Avg	2.28	2.29	2.9	3.23	3.06	2.7[2]	2.79	2.71	1.1[a]

[a] *Feed: gain ratios differed ($P < .05$) between treatments for the finisher and the G-F periods. CV: Statistical Coefficient of Variation.*

[b] *High volt is the exposed group.*

Table 2. Effect of electrical field under a 345 kV line on pig carcass estimates

Replication	*Treatments* Control	Hi-volt	CV, %	*Treatments* Control	Hi-volt	CV, %	*Treatments* Control	Hi-volt	CV, %
				Carcass grade[a]			*Carcass yield, %*		*Backfat, cm*
1	1.25	1.25		73.8	73.2		2.70	2.73	
2	1.75	1.50		73.1	72.4		3.37	3.18	
3	2.00	1.50		74.1	73.2		3.10	3.18	
4	1.50	1.00		73.4	72.6		3.04	2.95	
5	1.00	1.00		76.1	73.0		2.54	2.76	
Avg	1.50	1.25	12.9	74.1	72.9	1.0	2.95	2.96	3.8

[a] *Grades from 1-best to 5-poorest.*

generations. The second phase of this experiment is nearly completed and the results appear to confirm the original conclusion that these electric fields have no observable or measurable effect on the performance of the cross-bred swine used on these experiments. The experiments will be continued for several more generations to test for any possible genetic abortions although none have been observed in this second generation herd.

Grower-Finisher Performance

The offspring born under the line of the exposed gilts that were mated in the electric field environment were used in this growing-finishing study. Pigs were allotted at random to pens within each environmental treatment group from litters in the exposed and control group. Similar to the earlier experiments, each group was divided into five replications. However, one litter from each environmental treatment group was considerably younger and lighter in body weight than other pigs at the beginning of the grower period. Therefore, pigs from these two litters were used to form a sixth replication. Animal care, diets and observation were performed with the cooperation of Land O'Lakes Research Farm.

Table 4 summarizes the results of the grower-finisher performance experiment. A much more detailed data is available from Iowa State University's Iowa Test and Evaluation Facility report. The data shows that the average daily gain was 1.63 lb for the control group and 1.7 lb for the exposed group. The average daily feed for the control and exposed groups were 4.96 lb and 5.11 lb respectively.

The feed to gain ratios were 3.05 for the control group and 3.01 for the exposed group respectively.

Analyses of the above results show that no significant differences exist between the control and exposed groups in the average daily feed, average daily gain and the feed to gain ratio. No apparent behavioral changes were detected or observed in either of the groups.

Table 3. Reproductive performance[a]

Replication	Control Group	Exposed Group	CV, %
No. of gilts	12	12	---
No. of pregnancies	7	12	---
No. pigs born alive	10.0	9.5	30.7
Average birth wt, lb	2.8	3.2	17.0
21-day litter wt, lb	87.3	95.7	43.0
21-day gain/pig, lb	9.6	9.3	22.3
No. pigs at 20 days	6.7	8.0	37.4
Malformation[b]	0	0	---

[a]Twelve control and 12 exposed gilts were bred, beginning December 28, 1981. Seven control and 12 exposed gilts farrowed litters between April 23 and May 21, 1981.

[b]No malformation has been observed in either group.

Table 4. Effects of electric field under a 345 kV line on growing-finishing performance of pigs conceived, born and raised in the high voltage line environment vs control group[a]

Item	Control Group	Exposed Group	CV, %
Average daily gain (lb)	1.63	1.70	4.8
Average daily feed (lb)	4.96	5.11	3.6
Average feed/average gain ratio	3.05	3.01	1.6

[a]There were 72 pigs; 6 replicate pens with 6 pigs per pen. Performance was measured over average weights of 48 to 215 lb.

Table 5. Effect of electric field under 345 kV line on carcass estimates of pigs conceived, born and raised in the high voltage environment vs control group

Item	Control Group	Exposed Group	CV, %
Average carcass yield, %	70.74	70.73	2.3
Average carcass grade*	1.4	1.5	11.8
Average backfat thickness	1.14	1.2	7

**Subject scoring (done in a blind fashion) from 1 to 3; with 1 being leanest and 3 being fattest.*

Table 5 summarizes the results of the pig carcass estimates. All carcass analyses were done by a USDA-approved slaughter house and in a blind fashion. The average carcass yield or dressing percentage were

70.47% for the control group and 70.73% for the exposed group. Carcass grades averaged 1.4 for the control group and 1.5 for the exposed group. Backfat thicknesses were 1.14 and 1.2 inches for the control and exposed groups, respectively.

Again, analyses of the carcass estimates data show no significant differences in carcass yield, grade or backfat thickness.

Experiments are now being planned to determine field effects on growing crops although observations of the corn and soybean crops raised within the right of way indicate no apparent difference in plant health or yield. It is hoped that in the near future several well-designed experiments can begin in cooperation with the horticulture and plant pathology departments to test for any possible effects on plant life that might be attributed to the electric fields or ground currents.

Some experiments to determine the electric field configurations around farm machinery are still underway. The use of microprocessors to control such machinery has raised some questions of their susceptibility to electric and magnetic interference. These experiments are currently progressing to determine if these effects have any basis.

So far, this unusual facility for research and demonstration has done a great deal to alleviate the fears expressed by farmers concerning the dangers existing in the vicinity of HV and EHV transmission lines. By carefully monitored experiments with open and honest communication, much of the fear of EHV lines engendered by lack of knowledge can be overcome. Any dangers that might exist must be honestly faced and put in perspective with respect to hazards encountered in other areas or even the hazards of not having such a reliable electric system.

Conclusions

Observations of the effects of electric field from 345 kV transmission lines on swine show no negative effects on their reproductive performance. No negative effects have been observed on the rate of pregnancies, number of pigs born alive, and the average birth weight. Also, there were no statistical differences between the control and the exposed groups for 21-day average gain per pig and the average number of pigs alive at 21 days. No malformation has been observed in either group.

Experiments on pigs born and raised under the line show that electric field due to 345 kV lines does not have negative effects on their performance, apparent behavior, and carcass quality in the growing-finishing period. There were no treatment differences for body weight gain, feed intake, carcass grade, and backfat thickness. It was also found that no apparent behavioral changes had occurred.

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