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Direct Testimony

J. Michael Silva

Before the Public Service Commission of
The State of North Dakota

In the Matter of the Application of
BASIN ELECTRIC POWER COOPERATIVE
For a Waiver of Procedures and Time Schedules
and a Consolidated Certificate of Corridor Compatibility
and Route Permit for the
AVS-Neset 345-kV Transmission Project

Case No. PU-11-696

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Exhibit 37 of September 4, 5, and 12, 2013 formal hearing

J. Michael Silva

1. Q. Could you please state your name and occupation for the Commission?

A. Yes. My name is J. Michael Silva. I'm a research engineer and President of Enertech Consultants.

2. Q. And what is your business address?

A. My business address is 494 Salmar Avenue; Campbell, California.

3. Q. Mr. Silva, would you please indicate the purpose of your testimony today?

A. Yes. I was asked by Basin Electric Power Cooperative to perform two tasks related to the proposed Antelope Valley Station to Neset 345 kV transmission line. First, I was asked to evaluate the electric and magnetic field or EMF levels from the proposed 345 kV Project. Second, I was asked to comment on use of the Global Positioning System, or GPS, for agricultural operations near the proposed 345 kV transmission line Project.

4. Q. Could you please briefly outline your education and experience for the Commission?

A. I received a Bachelor's degree in engineering from the University of Alabama and a Master's degree in engineering from Auburn University. I am a registered professional engineer in Electrical Engineering in eight states. I have 42 years of experience related to electric power facilities and applied research projects and have designed transmission lines up to 500 kV.

I founded Enertech Consultants in 1982. The focus of my work has been applied research on electric and magnetic fields, electromagnetic compatibility, instrumentation and software development and scientific consulting on new technologies, such as the Global Positioning System.

5. Q. Mr. Silva, I show you what is labeled as Exhibit ____. Can you please identify it for the Commission?

A. It is my biographical outline.

6. Q. Could you describe some of the work Enertech has done with EMF and GPS in the past?

A. Enertech has performed most of the large US EMF assessments, including the One Thousand Home Study for the Electric Power Research Institute and the One Thousand Person EMF measurement study for the US Department of Energy. Enertech Consultants also designs, manufactures and sells precision scientific instruments in 59 different countries for measurement of EMF.

I've also performed work that focused on the use and accuracy enhancements of GPS technology and I performed research to evaluate the use of GPS near electric power lines.

7. Q. Could you please explain what EMF is?

A. EMF is a generic term that refers to electric and magnetic fields.

Electric fields are a result of the voltage or the electrical potential that's on the line. The strength of the electric field is related to the line voltage, how the wires or conductors are arranged, and distance away.
Magnetic fields are as a result of the flow of electric current on the transmission line. The strength of the magnetic field is related to the line loading in amperes, how the wires or conductors are arranged, and distance away.

8. Q. What did you do to evaluate EMF levels for the proposed AVS-Neset 345 kV transmission line?

A. Basin Electric provided us with the transmission line engineering and electrical loading information necessary to perform computer calculations of EMF levels for the different possible line configurations and the minimum ground clearance for maximum line sag (which typically occurs near midspan). We performed EMF calculations for typical and peak electrical loading conditions using the Bonneville Power Administration EMF calculation program. This program is widely used since the 1970's and its accuracy has been validated many times.

9. Q. Did you prepare a report on your EMF calculations?

A. Yes. My results are contained in an EMF Report that describes our methodology and the calculated EMF levels for the different line configurations and electrical loading conditions.

10. Q. Mr. Silva, I show you what is labeled as Exhibit ____. Can you please identify it for the Commission?

A. It is the Antelope Valley Station to Neset 345 kV Transmission Project EMF Report prepared by myself and others under my direction.

11. Q. Could you please describe the findings in this Report?

A. Yes. The calculated EMF levels are contained in tables and plots within the report. There is nothing unusual or different about the EMF levels from the proposed 345 kV Project. The calculated EMF levels are similar to or lower than other transmission lines of this voltage class that have been in service since the 1950's.

12. Q. Mr. Silva, how many miles of high voltage transmission lines are in service in North America?

A. There are over 300,000 miles of high voltage transmission line in North America rated at 115 kV and above.

13. Q. What frequency do electric power transmission lines operate in North America?

A. Electric power lines operate at 60 Hertz, or 60 cycles per second. This low frequency is the same as the electricity used in a house. This is the extremely low frequency portion of the range of frequencies that engineers call the electromagnetic spectrum.

14. Q. I show you what is marked as Exhibit ____. Can you identify it please?

A. Yes. It is a sketch of the electromagnetic spectrum. It depicts the range of frequencies that make up the electromagnetic spectrum. Frequency is important because it affects the characteristics of electromagnetic waves. The various frequencies are depicted in Hertz, or cycles per second. The frequencies range from extremely low to high frequencies to extremely high frequencies. Also depicted are devices that operate at different frequencies across the spectrum.

15. Q. Could you explain the frequencies of the various objects depicted in Exhibit ____?

A. Yes. On the far left is what's called the extremely-low frequency part of the spectrum. One example would be where many appliances and electric power lines operate, at 60 Hertz. AM radios, for example, operate at a higher frequency, approximately one million Hertz. FM radio operates at an even higher frequency, approximately 100 million Hertz. Television operates at several hundred million Hertz.

Next is the microwave frequency range, which starts at about a billion Hertz. This is the frequency range that GPS operates at (1.2 billion and 1.5 billion Hertz). Cell phones also operate in microwave bands at about 0.9 and 1.8 billion Hertz.

16. Q. Can the operation of a high voltage electric power line sometimes generate noise that interferes with an AM radio?

A. Yes. Occasionally when it rains, radio noise close to transmission lines can be heard as static, primarily on the lower-frequency AM radios. The intensity of the noise decreases rapidly at higher frequencies, so it generally has little or no effect on devices designed to operate at frequencies above AM radio. Interference to an AM radio can also be caused by broken or damaged equipment (such as a damaged insulator) on any power line, including a low voltage distribution line. These sources of noise can be located and repaired.

17. Q. What about use of GPS equipment near the proposed transmission line?

A. There might be concerns that GPS receivers may not work in close proximity to transmission lines because they won't be able to receive signals from satellites, which would then negatively affect agricultural operations that rely on GPS.

18. Q. In your opinion, is that a problem that is likely to occur?

A. No, I do not think it is likely to occur.

19. Q. Could you discuss GPS in precision farming applications?

A. GPS was originally designed by the US military to provide year-round navigation and positioning data. The primary components in use of GPS are the GPS satellites, the GPS receiver (sometimes called the rover) and there may be a source used for GPS error correction that is broadcast to the user to improve accuracy. There are many modern applications that rely on GPS, including the US military, precision agriculture, maritime navigation, mining operations, commercial and general aviation, automobile and truck navigation, and emergency services guidance and location functions.

The GPS space segment consists of a constellation of satellites transmitting microwave radio signals to users. The Air Force manages the constellation to ensure the availability of at least 24 GPS satellites, 95% of the time. For the past several years, the Air Force has been flying 31 operational GPS satellites, plus 3-4 decommissioned satellites ("residuals") that can be reactivated if needed.

These satellites are used by GPS receivers to determine position, velocity and time. There are always some systematic errors in using GPS. These are caused by things like atmospheric effects and small errors in the satellite orbits and in their clocks. The errors are not important for many GPS applications, but these errors must be minimized for precision applications in agriculture, surveying, aviation, etc.

20. Q. How is the accuracy of GPS improved for precision applications?

A. Many modern applications, such as precision agriculture, or agricultural aviation, require greater accuracy than the earlier GPS receivers could deliver. Accuracy improvements were generally developed by evaluating the systematic errors that I mentioned earlier at some fixed location and broadcasting corrections to significantly reduce these errors for the user. This is generally called differential corrections. Another popular approach to improving accuracy is accomplished by a method called Real Time Kinematic or RTK.

21. Q. Could you describe RTK for the Commission?

A. RTK is an improved method for determining location that is also used in precision GPS applications. With RTK, the GPS satellite signals are used in a different way than was originally intended in GPS design and this can greatly enhance the accuracy. With RTK, GPS users rely on the basic GPS satellite signals and supplemental microwave radio signals that are broadcast from a base station source on the farm or at a local farm dealership or farm cooperative. This supplemental signal is used with the satellite signal to greatly improve accuracy. With the best use of RTK, some receivers can achieve a GPS accuracy of one inch.

22. Q. I show you what is labeled as Exhibit ____. Can you identify it for me please?

A. Yes. Exhibit ____ depicts GPS accuracy improvement. It shows a GPS user or rover, in this case a tractor with a GPS antenna on top. The rover is receiving a GPS signal from a satellite in space. In actuality, multiple satellites are used but for the purposes of the demonstration, I only have only depicted one. There are also GPS base stations depicted; one option is on the farm on a tripod and the other option is located off the farm, at a farm equipment dealership or cooperative, for example. The tractor GPS unit receives the GPS satellite signals and also communicates with a local base station using microwave radios (900 MHz or 450 MHz) to receive additional information to allow RTK accuracy.

23. Q. What are some common ways a GPS satellite signal could be affected?

A. One way is when the satellite signal is blocked since use of GPS requires an unobstructed view of the sky. Another problem can be when there's some electronic interference that's very close to the same frequency at which GPS operates.

24. Q. Can you provide examples of obstructions or electronic interference that would affect use of the GPS satellite signal?

A. Very dense foliage or the walls of buildings or tall fences or other objects can partially block a satellite signal so the GPS receiver may temporarily lose its lock or lose the information from one satellite. The most common causes of electronic interference to GPS satellites are things like the quartz oscillator in a computer or a clock radio, some vehicle ignition systems, and certain two-way radios, including walkie-talkies, have interfered with GPS. The harmonics of certain TV, FM radio stations and marine aviation and military radars have also been known to interfere with GPS.

25. Q. In what situations could an obstruction affect use of the GPS signals?

A. The obstruction would have to be close to the GPS antenna and large enough and exactly in line of sight with one of the satellites. But in general losing one satellite is not a problem because GPS receivers track and use several satellites at once. Also, modern GPS software has methods to compensate for temporary "loss of lock".

26. Q. Have you performed any research to reach the conclusion that high voltage transmission lines are not likely to interfere with a GPS satellite signal?

A. Yes. I evaluated the potential for high voltage power lines to affect GPS signals in two ways. I did a theoretical analysis of GPS signals in relation to transmission lines. I also completed a number of practical measurements at different locations in the United States directly under power lines up to 500 kV and including 345 kV lines. The theoretical work and the practical measurements were conducted together as part of the same research projects.

27. Q. What were the results of your research to evaluate GPS satellite signal use under transmission lines?

A. The results of my theoretical analysis indicate it is unlikely that high voltage transmission lines can interfere with GPS satellite signals. We evaluated the potential for interference due to partial blocking of the satellite signals by overhead wires or the overhead conductors, a process called signal scattering. The result of this analysis showed that interference was not possible due to the small electrical size of power line conductors relative to a GPS microwave signal wavelength and the relatively large height above ground of electrical wires. In other words, because power line conductors are much smaller than the GPS signal wavelength, little blocking of the signals would occur when they pass around the conductor or conductors. And the conductors are high enough above the ground that any blocking is insignificant.

28. Q. Could you please discuss your direct measurements to evaluate GPS satellite signal use under transmission lines?

A. Yes. I conducted many practical experiments in which I performed measurements using a precision agriculture GPS receiver under transmission lines up to 345 kV and higher. This was done to see if there was any change in the positioning accuracy or the strength of the received satellite signals while driving under power lines. I performed this test in both fair and in rainy weather.

29. Q. I show you what is labeled Exhibit ____. Can you please identify it?

A. Exhibit ______ shows some of the results of my practical measurements of the satellite signal strength under 345 kV transmission lines.

30. Q. Could you discuss the results of your practical measurements as depicted in Exhibit ____?

A. Yes. Exhibit ________ depicts some of the results I collected in which I took GPS satellite strength measurements while driving under 345 kV lines at two different locations with double circuit 345 kV transmission lines. On the top is a sketch of five satellites I was tracking when I was measuring and logging this data at site #1 that has a double circuit 345 kV line. The numbers are designations that the U.S. Air Force gives to the GPS satellites. The dark line labeled 345 kV depicts the double circuit line location for site #1. You can see the constellation of satellites dispersed on both sides of the power line. I drove under the 345 kV power line, logging the strength of the signals that I received using a commercially available precision Ag GPS receiver. I was looking to see if there would be any change in the strength of the received GPS satellite signals.

The signal strength measurements started about 240 ft away from the 345 kV line and then driving directly toward and under the power line and across the whole right-of-way. You can see on the top plot of site #1 that one of the satellite signals started to decrease as I drove under some large trees off the right-of-way. I repeated the measurements at a second location (site #2: bottom plot) that has two double circuit 345 kV lines, a double circuit 120 kV line, and a small 13.2 kV distribution line. When I say double circuit 345 kV, it means that there are two sets of three phase wires, so two of these double circuit 345 kV lines would be the equivalent of four times as many 345 kV lines as this Project is proposing to use. This bottom plot of signal strength in this exhibit shows that there is no effect on the received GPS signal strength due to the multiple 345 kV transmission lines. This is what we would have expected due to our theoretical calculations that indicated no effect on GPS signals. Our results were published in a paper in the Institute of Electrical and Electronics Engineers Transactions on Power Delivery.

31. Q. Could you provide practical examples of other microwave frequency devices similar to GPS being successfully used near high voltage transmission lines?

A. Yes. There is extensive use of GPS by the cell phone industry. GPS is used for the precise timing standards in the operation of cell phone networks and some cell phone companies use a same signal modulation scheme that is similar to GPS. One practical example of successful use of GPS and microwave signals near powers lines is the common practice of mounting cell phone base station antennas and high accuracy GPS antennas directly onto high voltage transmission line towers throughout North America. Cell phones are just small microwave radios that operate at frequencies of around 1 to 2 billion cycles per second, very similar to GPS. Across the USA and in Canada, cell phone base station antennas are mounted directly on transmission line towers and poles. This is significant, because the microwave cell phone signals from distant users are received by the base station antennas which are located on towers much closer to high voltage conductors than a tractor on the ground. In addition to cell phone antennas, GPS antennas are also mounted on high voltage towers as well. Given the fact that the cell phone industry is mounting their GPS and cell phone antennas on transmission line towers clearly indicates that power line interference is not a concern for them.

32. Q. Do electric power companies use GPS near high voltage transmission lines?

A. Yes. Electric power companies themselves use GPS for many applications, such as precision timing, and system control and data collection applications.

GPS is used for system frequency monitoring, protective relaying and is used for many other important applications. These GPS antennas are sometimes mounted inside high voltage substations.

33. Q. Can you comment on the potential for transmission line structures to affect GPS?

A. Yes. It could be possible, under certain circumstances, that if the line of sight between one satellite and the user could be briefly affected while passing close to a large steel tower.

34. Q. Is this line-of-sight signal blockage likely for the proposed transmission line?

A. For the proposed transmission line, this is not as likely due to the use of tubular steel poles; the steel poles are much smaller than large steel lattice towers. Operating a GPS receiver close to any obstruction, such as a building, a tall fence, silo, tree or farm equipment, such as a crop wagon, could also potentially temporarily block a satellite, depending on the instantaneous alignment of the satellite and the user. These satellites are moving all the time, so the amount of time that the potential blockage lasts would be brief. Blocking a satellite may or may not affect GPS use, depending upon how many satellites are being used. If blocking did occur, it would be temporary. The reality is that there are many satellites and the temporary loss of say, one out of seven or eight satellites would not affect the use of GPS.

35. Q. Have you seen a change in the capability and design of GPS equipment over the years?

A. Yes. GPS equipment is constantly improving. It is a very competitive market; each company is seeking to provide the best and the most robust guidance system they can. Whenever there is a new design feature, it is not long before all the other companies have the new or equivalent technology.

36. Q. Do GPS design companies take in to account the environment in which the equipment will be used?

A. Yes. In general, high-quality GPS manufacturers supply GPS units that are designed to function in the environment for which they're intended to be operated. Since there are over 300,000 miles of high voltage transmission lines in the United States, GPS manufacturers can reasonably anticipate that an electric power line would be one part of a diverse operating environment for their GPS equipment.

In addition, there are continuing improvements to the GPS system itself. The Air Force is adding new and stronger signals for the next generation of satellites, which they started launching two years ago. These new changes will enhance reception and performance.

37. Q. Mr. Silva, what is your conclusion with respect to the concern that GPS devices may experience interference when in proximity to the proposed transmission line?

A. Based on the theoretical work I did and the practical measurements that I performed, I believe GPS receivers will be able to receive the satellite signals near the proposed 345 kV transmission line. The fact that the cell phone industry mounts cell phone base stations and high accuracy GPS antennas directly onto high voltage transmission towers, further supports my conclusion.

38. Q. Does this conclude your testimony?

A. Yes.