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WTS-4 SYSTEM VERIFICATION UNIT FOR WIND/HYDROELECTRIC INTEGRATION STUDY

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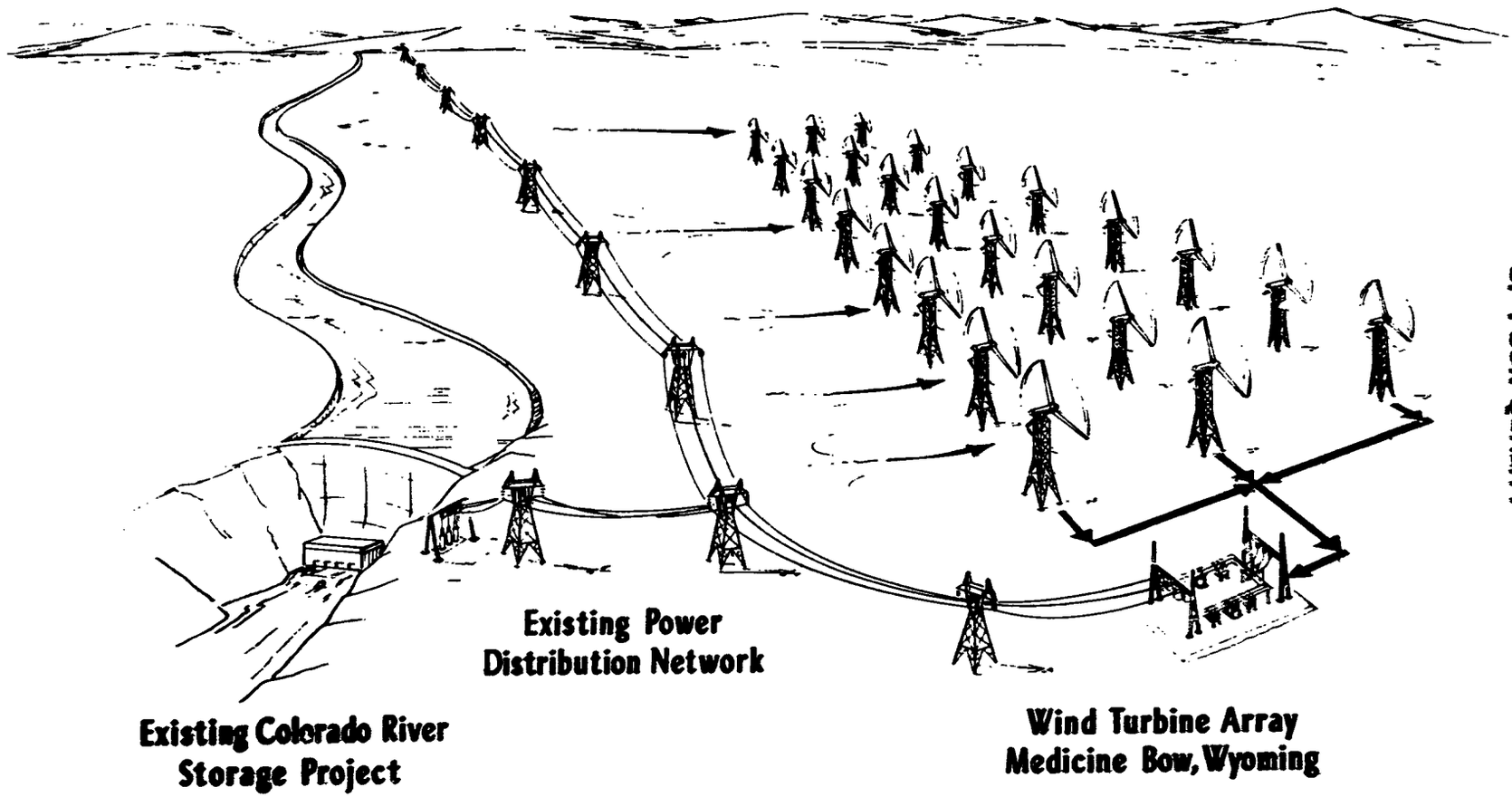
ABSTRACT

The Bureau of Reclamation (Reclamation) initiated a study to investigate the concept of integrating 100 MW of wind energy from megawatt-size wind turbines with the Federal hydroelectric system. As a part of the study, one large wind turbine was purchased through the competitive bid process and is now being installed to serve as a system verification unit (SVU). Reclamation negotiated an agreement with NASA to provide technical management of the project for the design, fabrication, installation, testing, and initial operation. Hamilton Standard was awarded a contract to furnish and install its WTS-4 wind turbine rated at 4 MW at a site near Medicine Bow, Wyoming. The purposes for installing the SVU are to fully evaluate the wind/hydro integration concept, make technical evaluation of the hardware design, train personnel in the technology, evaluate operation and maintenance aspects, and evaluate associated environmental impacts. The SVU will be operational in June 1982. Data from the WTS-4 and from a second SVU, Boeing's MOD-2, will be used to prepare a final design for a 100-MW wind farm if Congress authorizes the project.

WIND/HYDROELECTRIC INTEGRATION STUDY

The Bureau of Reclamation (Reclamation) has under construction two megawatt-size wind turbines at its Medicine Bow, Wyoming, site to serve as system verification units (SVU). One unit is the Hamilton Standard 4-MW unit designated as WTS-4. The second unit is the Boeing 2.5-MW unit designated as the MOD-2. Reclamation engineers, late in 1976, developed a concept for integrating large quantities of wind energy with the Federal hydrosystem for a wholesale power supply, see Figure 1. A 3½-year feasibility study of this concept, based on an installation of 100 MW, was completed in June 1981. The study and the installation of two SVU's were designed to accomplish the following objectives:

INTEGRATION OF WIND AND HYDROELECTRIC POWER



Wind/Hydro Integration Concept
Figure No. 1

1. Measure and evaluate the wind resource in the Medicine Bow area;

2. Test the concept of integrating wind and hydroelectric generation facilities for production of wholesale power;

3. Determine the environmental impacts of wind generation within the study area;

4. Evaluate the feasibility and justification for constructing a large-scale wind farm;

5. Measure the acceptance and reaction of the public to the plan, and

6. Train personnel in the technology.

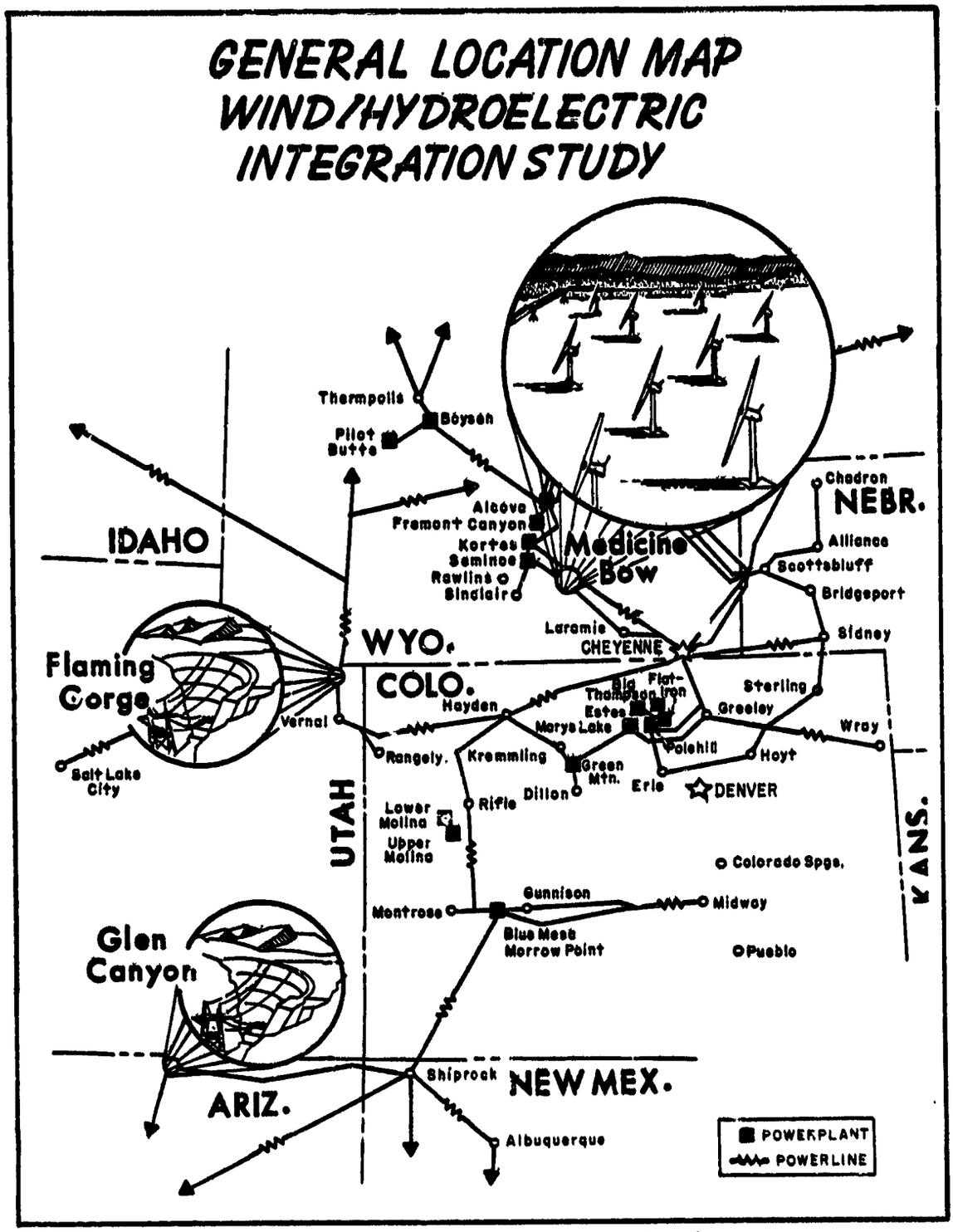
Since the use of multiple large wind turbines at a site for central station-type power supply is a new technology and there is no precedent for validating data for the study, it was determined early in the study that one or more SVU's operating at the site were needed before a definite plan report could be prepared for the 100-MW wind farm.

The wind resource is in an area in south-central Wyoming near the town of Medicine Bow. The hydroelectric system is the Colorado River Storage Project (CRSP). This relationship is shown in Figure 2. The characteristics of these two resources offer a good opportunity to determine the feasibility of integrating a large amount of energy from the nonfirm energy supply produced by large wind turbines with the firming capability and energy storage in reservoirs provided by the existing hydrosystem to produce a large block of wholesale electric power. The two largest hydro developments are shown, Glen Canyon and Flaming Gorge.

There are 22 other existing hydroelectric plants in the Federal system associated with the study.

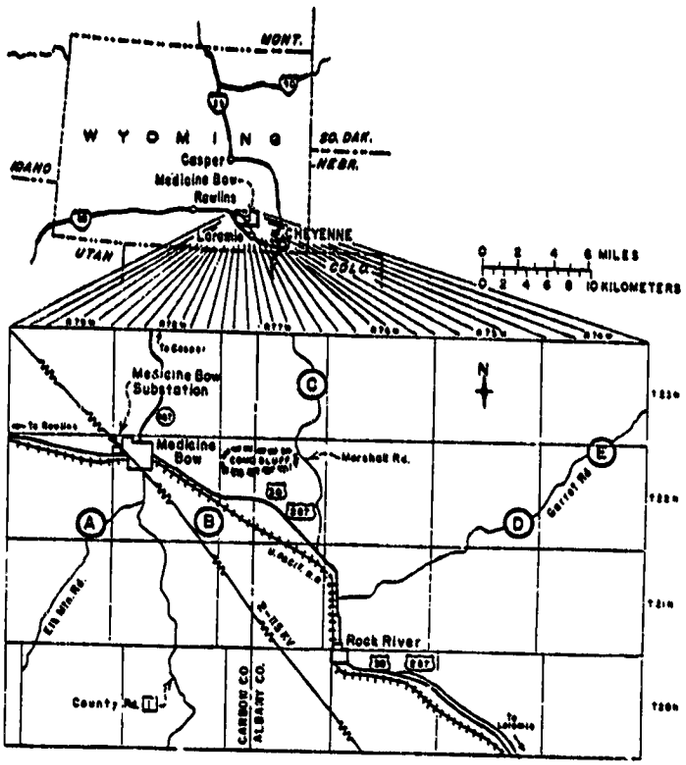
The wind resource selected for this study is a large land area near Medicine Bow, Wyoming, shown in Figure 3. The location is a high, arid plateau area about 2.133 km (7,000 feet) and is located near existing Federal transmission lines and has a high average annual wind potential. A major factor of the wind/hydroelectric integration concept is to locate the wind turbines at the best possible wind resource site in the same manner that hydrodams are located at the best hydrosite. The wind turbines can be a great distance from the hydrogeneration as long as the transmission system has the capacity to serve the loads from the various generating locations.

Eight years of wind data taken in the 1930's at the Medicine Bow airport are available. The University of Wyoming, under contract with Reclamation, started taking wind data at the same site in December 1976. At the initiation of the special study in 1977, an area about 32.19 by 64.37 km (20 by 40 miles), as shown in Figure 3, was delineated and five 3.66 m (12 feet) anemometer towers were installed



Location of Wind Resource and Hydroplants
Figure No. 2

WIND/HYDROELECTRIC INTEGRATION STUDY
MEDICINE BOW, WYOMING



Study area showing locations of the five anemometer towers designated Ⓐ Ⓑ Ⓒ Ⓓ and Ⓔ.

Medicine Bow, Wyoming, Wind Area
Figure No. 3

to gather information to evaluate a specific site to install the SVU's. After several months of data collection and evaluation of all factors at the five sites, site A southwest of the town of Medicine Bow was selected to install a 60.35 m (198 feet) meteorological tower, which was later extended to 109.7 m (360 feet) to measure the vertical wind characteristics at three levels. The SVU's will be installed near the meteorological tower.

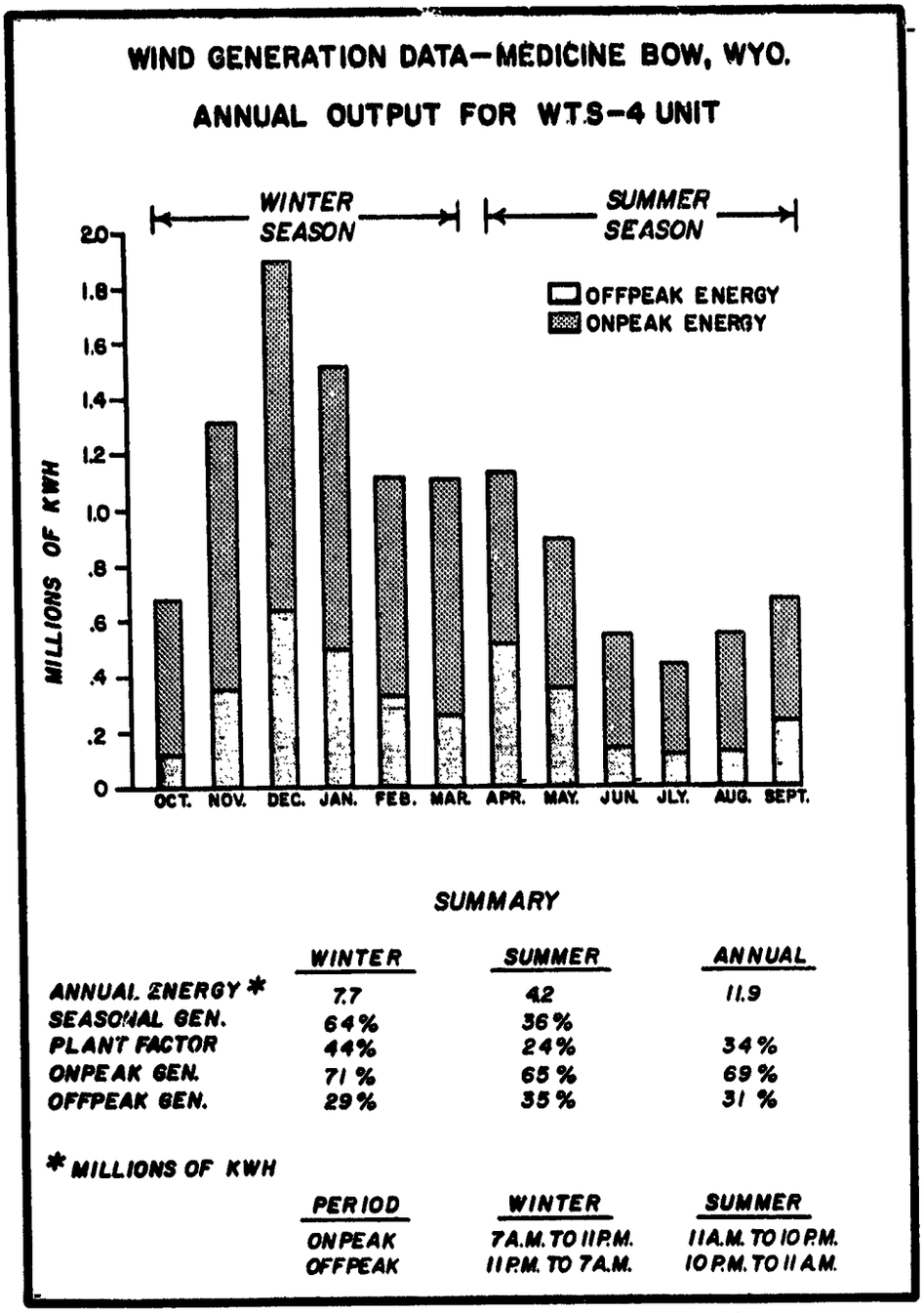
A computer model of the Medicine Bow wind regime has been developed using the 10 years of data now available to simulate an average wind year by providing the wind speed each hour in the year. Inputting the performance curve from a wind turbine unit, the annual generation can be determined by calculating the output each hour in the year. Figure 4 summarizes the results of inputting the predicted performance curve for the Hamilton Standard WTS-4 wind turbine. The monthly energy production is plotted on a water year, October through September, and onpeak and offpeak generation quantities are shown separately. The total average annual energy production for one unit is 11.9 million kWh. The significant data in this summary are that 69 percent of the generation occurs during onpeak hours and 31 percent occurs offpeak. The onpeak generation has the most value to a power system and makes the resource at the Medicine Bow site highly compatible for integration with a hydrosystem. There is more wind generation during the winter months which complements the hydrosystem which has the greatest generation during the summer due to the spring runoff from the snowmelt in the Rocky Mountains.

PROCUREMENT OF WTS-4 WIND TURBINE

Reclamation is a rather large engineering organization that designs and constructs large hydroelectric projects. However, after the decision was made to procure a wind turbine SVU, it was felt that the organization did not have sufficient expertise in the wind technology and assistance would be needed. The National Aeronautics and Space Administration (NASA) was agreeable to provide Reclamation with the support needed to procure a wind turbine and the two agencies executed an interagency agreement. NASA would provide the technical management for the design, fabrication, installation, testing, and initial operation of the wind turbine SVU. Also, NASA would train Reclamation personnel in wind turbine technology.

A number of wind turbine manufacturers had indicated an interest in furnishing equipment for the Medicine Bow site; therefore, the decision was made to procure the first SVU by competitive bidding. The chronology of events for the first SVU is as follows:

1.	Interagency Agreement with NASA signed	May	1979
2.	Request for proposals issued	July	1979
3.	Contract signed - Hamilton Standard	February	1980



Annual Generation Pattern for WTS-4
Figure No. 4

4.	Final design review - Unit	September 1980
5.	Final design review - foundation and tower	November 1980
6.	Start of construction at site	May 1981
7.	Scheduled first rotation	June 1982

SITE ARRANGEMENTS

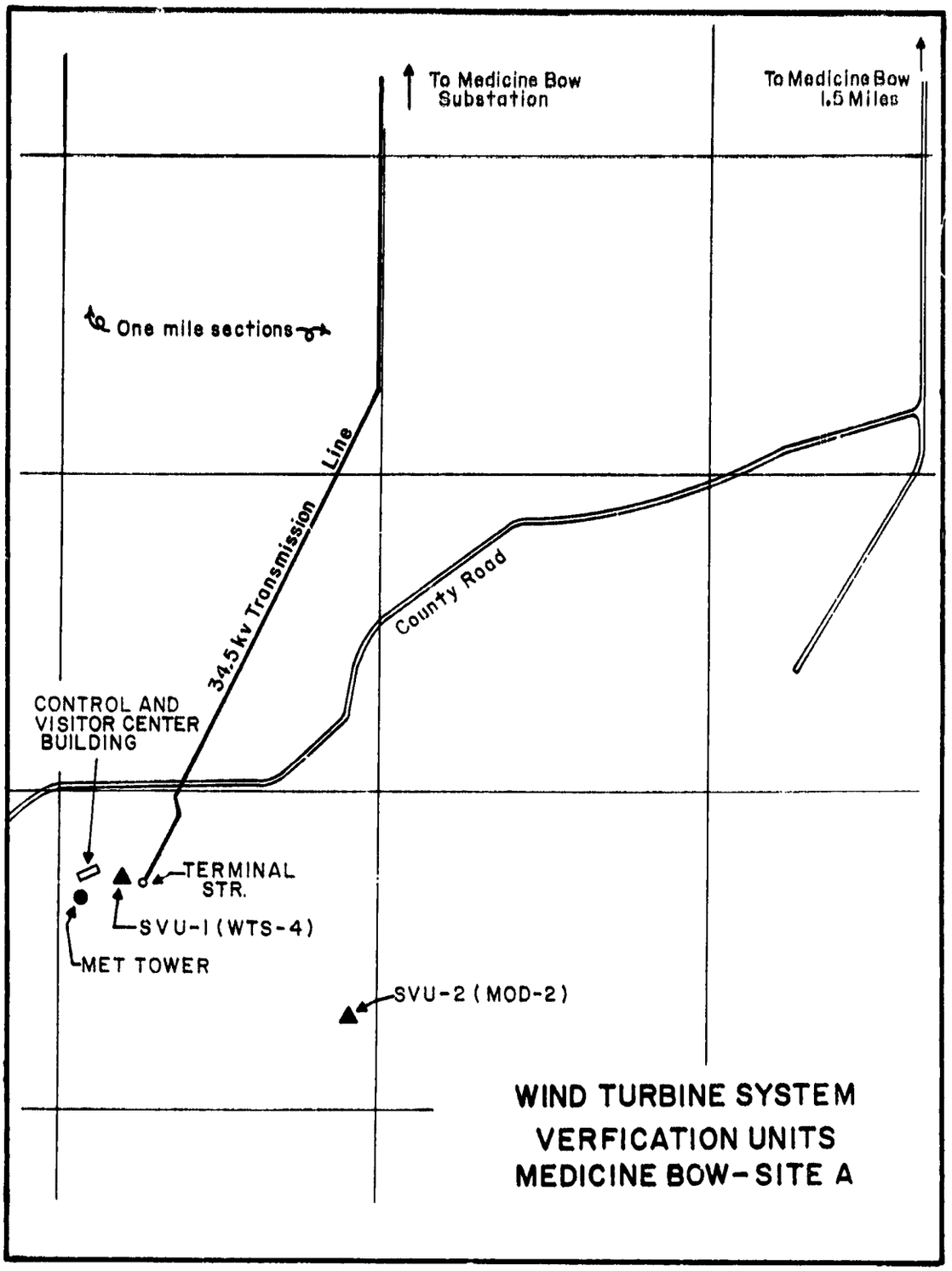
The site plan for the first two SVU's is shown in Figure 5. The area is surveyed for 1 square mile sections. The location for the first SVU is about 8.25 km (5½ miles) southwest of the town of Medicine Bow, situated near an existing county road. The WTS-4 wind turbine is about 251.5 m (825 feet) downwind from the meteorological tower. The prevailing winds are from west southwest at a bearing of about 250 degrees, which provide 90 percent of the generation. The control and visitor center building is near the meteorological tower and near the edge of the development area to minimize visitor disturbance of private land.

The second SVU, MOD-2, is located 1.37 km (4,500 feet) downwind, 15 blade diameters using 91.4 m (300 feet) rotor, and offset downwind from the first SVU. The 15 diameter spacing was an arbitrary spacing since we do not have specific information on the affects of wind wake produced by large wind turbines. We believe the selected spacing is conservative and hope that more positive data on turbine spacing will be available in the near future before we do the final design on the wind farm. We have awarded a contract to the Scientific Technologist in Pasadena, California, to do a study to assess affects of wind wake from an array of wind turbines. The results of the study will be available later this year.

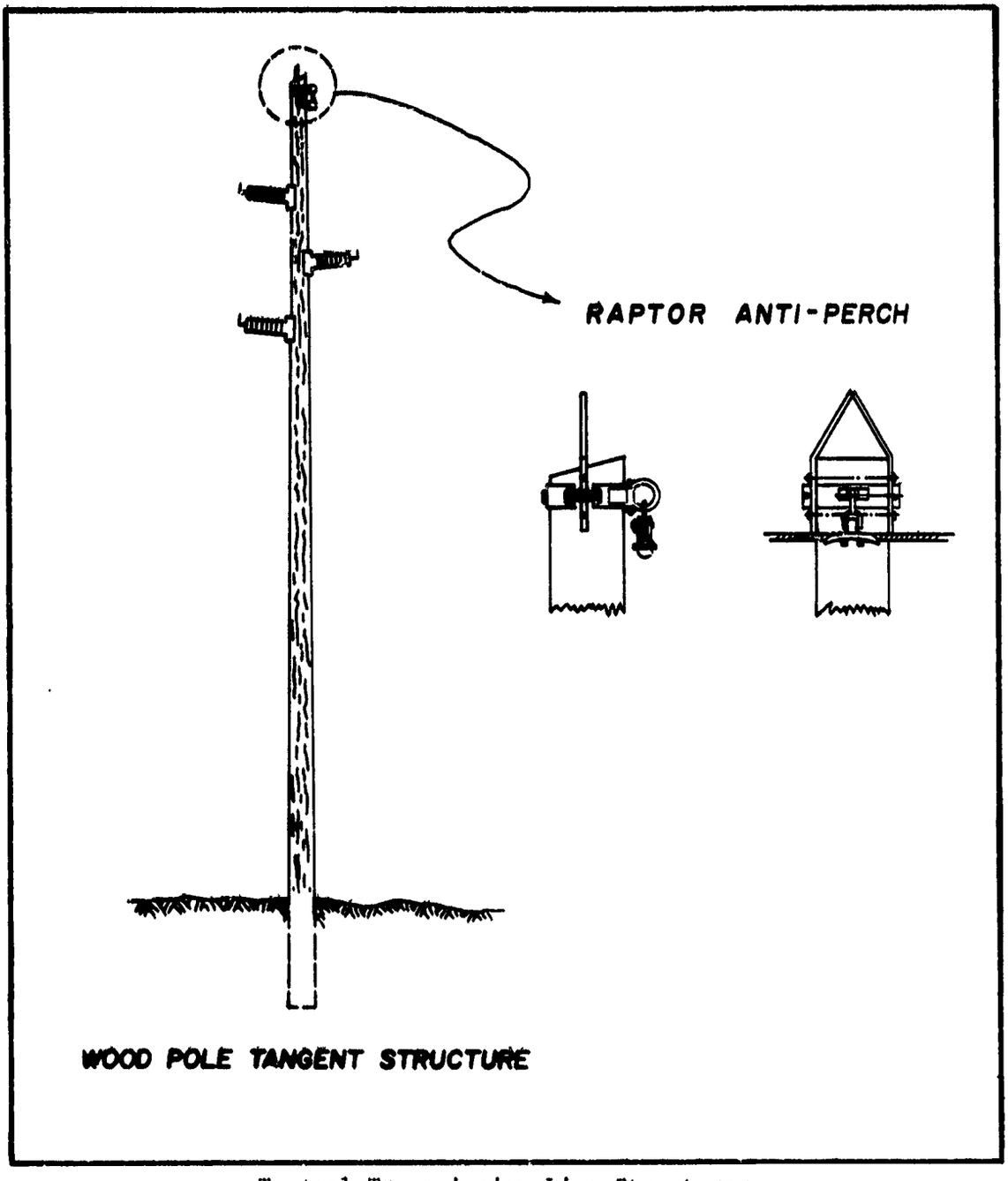
TRANSMISSION SYSTEM INTERFACE

The transmission line is designed for future operation of 115 kV for the wind farm application and will be initially operated at 34.5 kV. The line will be interconnected to the Federal transmission system at the existing Medicine Bow Substation, which is about 8 km (5 miles) north of the SVU's. Since there are eagles and other birds of prey in the Medicine Bow area, the transmission structures will be single pole types, with conductor spacing to prevent eagle electrocution and a raptor antiperch device mounted on top of the pole. The details of a typical structure are shown in Figure 6.

Figure 7 is a perspective view of the site showing the relationship of the turbine, control building, transformer, and switchgear near the base of the unit and the transmission line terminal structure.

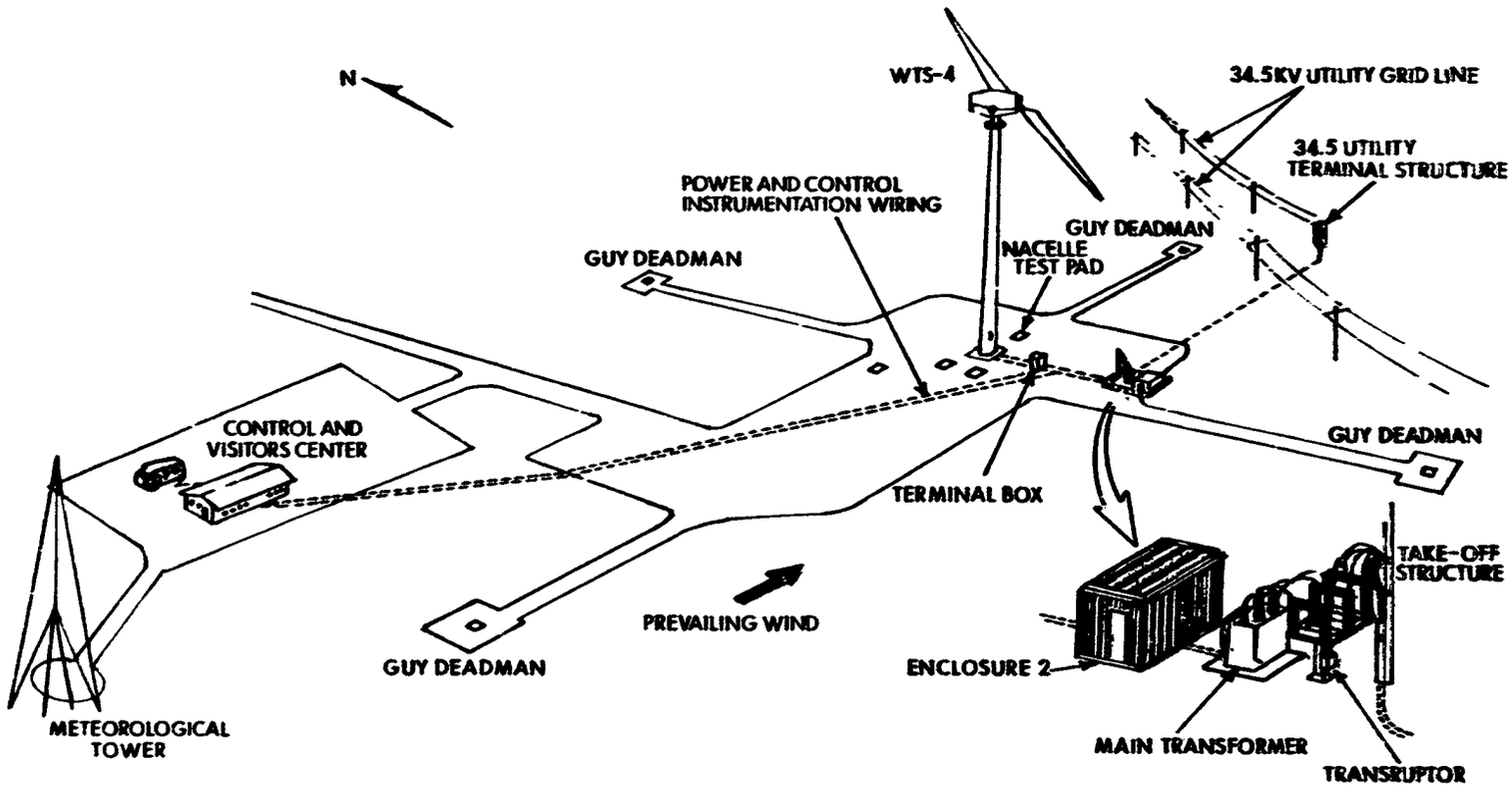


Site Location of Wind Turbines
Figure No. 5



Typical Transmission Line Structures
Figure No. 6

WTS-4/SYSTEM INTERFACE
PERSPECTIVE VIEW
MEDICINE BOY, WYOMING



Perspective View of WTS-4 Site
Figure No. 7

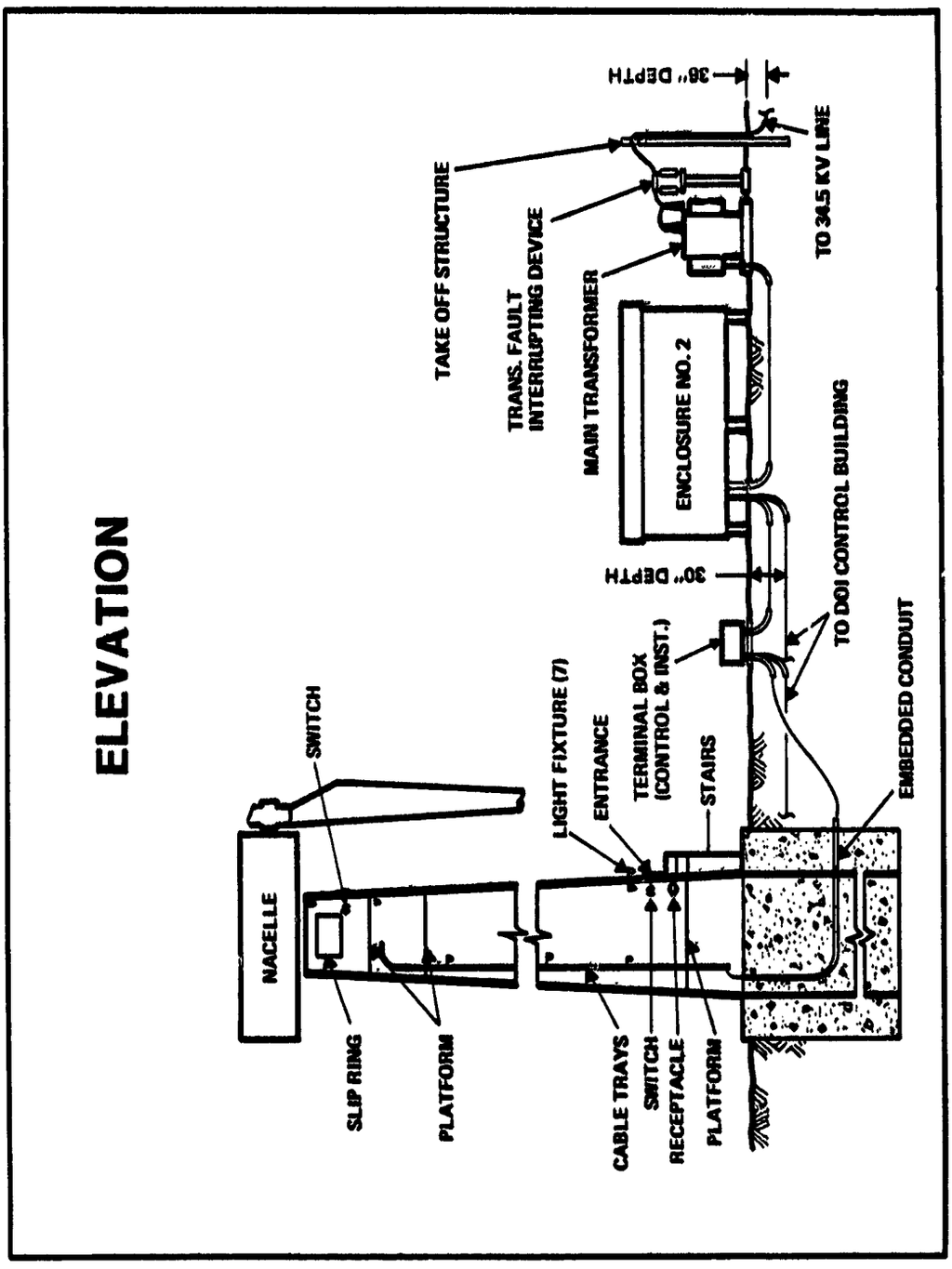
Figure 8 is an elevation view of the power circuit showing the routing of the power cable down the inside of the tower, underground to Enclosure no. 2 that houses the circuit breaker, underground to the 4.16/34.5-kV transformer, through the interrupter switch and then underground, at 34.5 kV, to the terminal structure.

Figure 9 shows a simplified schematic of the power circuit from the wind turbine generator to the interconnection to the transmission line at the terminal structure. Underground power cables were selected to reduce the clutter near the base of the wind turbine and minimize the visual impact from overhead lines. A new transmission line was constructed to serve the SVU's although an existing utility 34.5-kV distribution line is near the site serving loads in the area. The new line dedicated to the SVU's will optimize availability by eliminating the exposure of the longer distribution line. Disconnect switches will be used to interconnect the first two SVU's to the terminal structure. If Congress authorizes the 100-MW wind farm, the turbines will be grouped in clusters of four to seven units for interconnection to the 115-kV transmission line. Reclosures or circuit breakers will be used in each of the turbine circuits ahead of the transformation to 115 kV.

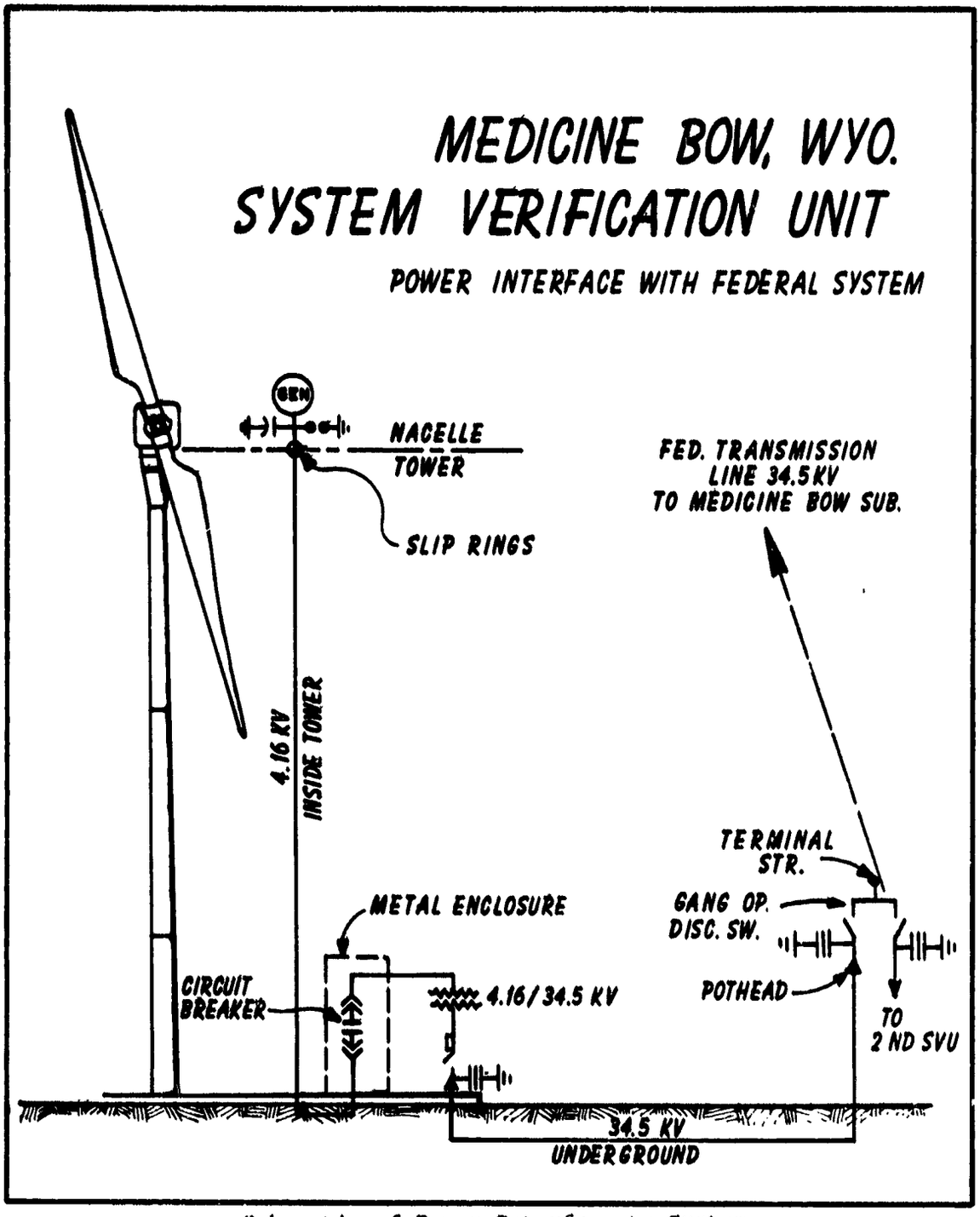
SUMMARY ——-

A brief summary of the turbine supplier's progress to date is as follows: The site preparation and excavation for the tower foundation are complete. The fabricated tower sections have been delivered to the site. The fabrication of the first fiberglass blade is complete. The assembly of the nacelle in the Swedish factory is almost complete. Although the scheduled first rotation date of June 1, 1982, has slipped 8 months from the original date due to the accumulation of delays, we believe the design and construction of the WTS-4 will result in a quality product.

NASA's previous experience in managing the Department of Energy's large wind turbine program has been invaluable to Reclamation by providing technical management for the SVU project at the Medicine Bow site.



WTS-4 Power Circuit
Figure No. 8



Schematic of Power Interface to System
Figure No. 9