Investigation of bird induced outages on Montana Power Companys 500kv transmission lines
by David Robert Maehl

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Electrical Engineering
Montana State University

Abstract:
An unexpectedly high number of unexplained outages on Montana Power Company's 500kV transmission lines resulted in an investigation into the cause of the outages. Nearly all of the outages were of the single-phase-to-ground type, and they were self clearing with little or no evidence left behind as to the cause of the fault. It was hypothesized that birds were a source of the outages because of the large number of raptors seen perching and nesting on the transmission line towers. The most significant birds seen in the area include Golden Eagles, Red-Tailed Hawks, and Ravens.

Previous investigations into the cause of outages on Montana Power Company's 500kV lines as well as other utilities high voltage transmission lines were analyzed. Also, trends observed from the historical outage data on Montana Power's lines were examined and compared to the raptor activity along the transmission line corridor. Furthermore, 29 miles of transmission line towers were equipped with bird perches in an attempt to modify the behavior of the raptors and thus reduce the number of unexplained outages.

Although no outages have occurred on towers equipped with bird perches since their installation, not enough time has passed to classify the perches as statistically significant in reducing the outages. However, substantial data were gathered through this two-year study to suggest that birds are a likely source of faults on Montana Power Company's 500kV lines.

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Dr. Daniel N. March — Daniel N March — 4/9/96
Date

Approved for the Department of Electrical Engineering

Dr. Victor G. Gerez — [signature] — 4/9/96
Date

Approved for the College of Graduate Studies

Dr. Robert L. Brown — R L Brown — 4/11/96
Date

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TABLE OF CONTENTS

TABLE OF CONTENTS--Continued

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES-- Continued

ABSTRACT

An unexpectedly high number of unexplained outages on Montana Power Company's 500kV transmission lines resulted in an investigation into the cause of the outages. Nearly all of the outages were of the single-phase-to-ground type, and they were self clearing with little or no evidence left behind as to the cause of the fault. It was hypothesized that birds were a source of the outages because of the large number of raptors seen perching and nesting on the transmission line towers. The most significant birds seen in the area include Golden Eagles, Red-Tailed Hawks, and Ravens.

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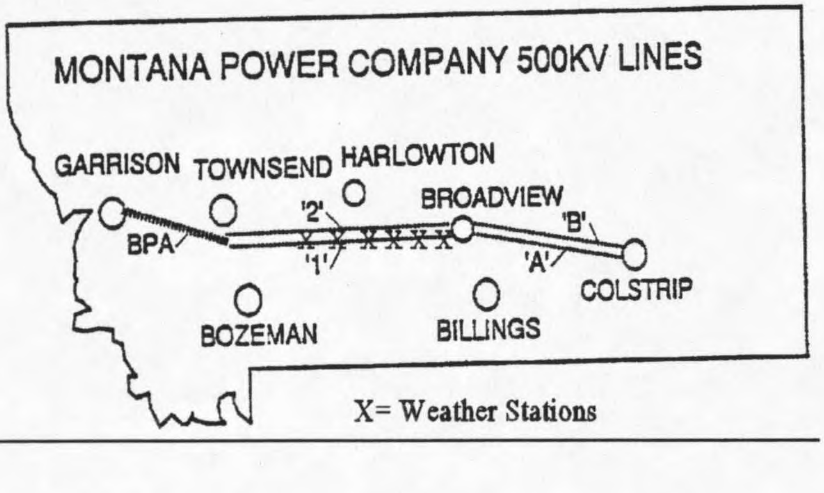
CHAPTER 1

INTRODUCTION

Montana Power Company 500kV Line History

Montana Power Company (MPC) maintains and operates two 500kV transmission lines between Colstrip, MT and Townsend, MT. The lines become Bonneville Power Administration's (BPA's) possession near Townsend and extend to the West coast. Figure 1 illustrates the location of the 500kV lines across Montana (Major 1993),[1].

Figure 1. MPC 500kV Line Route



Most of the electric power transmitted on the lines is generated at the Colstrip, coal-fired generating plant which consists of two, 350 MW generators and two, 750 MW generators. Each transmission line is capable of carrying approximately 2500 amps at a nominal voltage rating of 525kV. Two substations, Broadview and Garrison, are located along the line route in Montana.

MPC operates approximately 362 km (225) miles of parallel 500kV transmission lines, illustrated in Figure 1, which consist of separate, single-circuit, 500kV lines on steel towers. BPA uses double-circuit 500kV towers for transmission. As seen in Figure 1, the MPC lines between Colstrip and Broadview are labeled as 'A' and 'B' and the lines between Broadview and Townsend are labeled as '1' and '2'. The B-Line and Lines 1 and 2 are built exactly the same and the construction of these lines was completed in 1983. The A-Line is somewhat different in construction compared to the B-Line and Lines 1 and 2, however the lines are similar in voltage and phase configuration. The A-Line was converted from a double-circuit 230kV line to a single circuit 500kV line, also in 1983. Figures 2, 3, and 4 illustrate the different types of 500kV towers used by MPC and BPA. Similar type glass insulators (5-3/4" by 10") made by the Sedivar Company are used on both tower designs, although the A-Line towers have 25 insulators per string, compared to the B-Line and Lines 1 and 2, which have 22 insulators per string. Other differences exist in the tower constructions. The minimum air gap between a conductor and tower on the A-Line is 350.5 cm (138 inches), while the other lines have a minimum air gap of 294.6 cm (116 inches). Furthermore, the A-Line has no horizontal sections of angle iron above any of the phase wires, while the B-Line and Lines 1 and 2 do have a horizontal section above the top "window" phase. All of the tower heights vary between 30.5 m (100 ft) and 45.7 m (150 ft), depending on the change in elevation between the closest towers. Lines 1 and 2 are both 214 km (133 miles) long, compared to the B-Line and A-Line which are approximately 184 km (114 miles) in length.

Figure 2. B-Line, Line #1, and Line #2 Tower

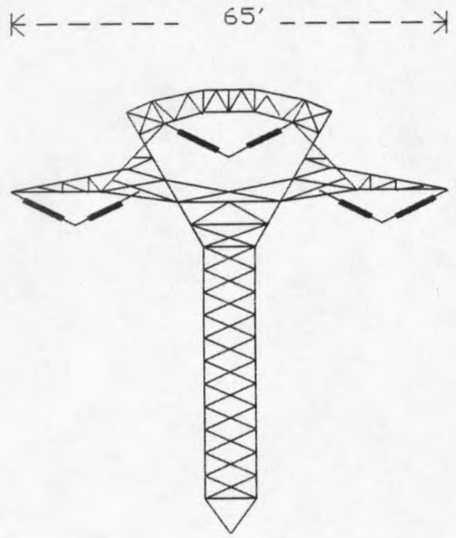


Figure 3. A-Line Tower

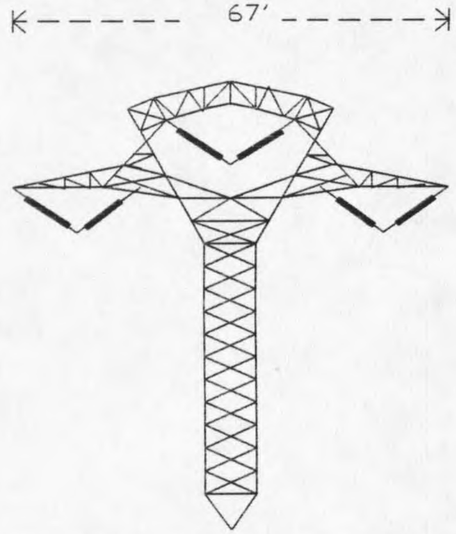


Figure 4. BPA Double-Circuit Tower

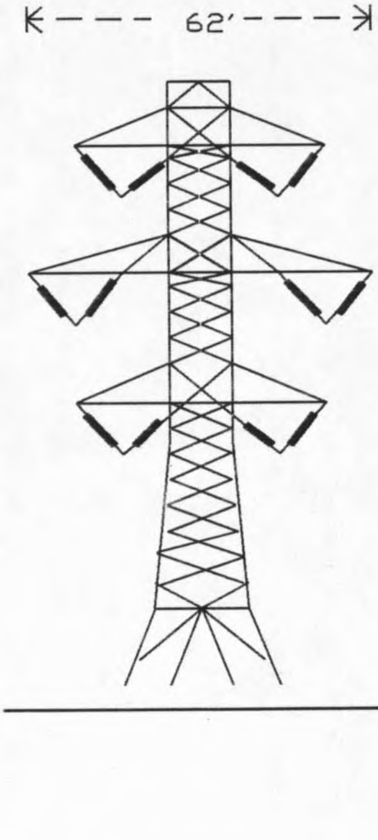
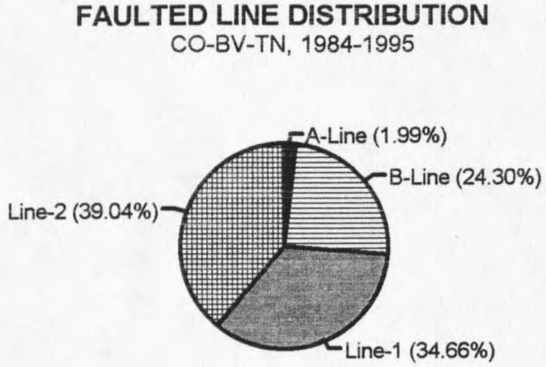


Figure 5 shows the fault activity on each MPC line and clearly, the A-Line is faulted less than all of the other lines. The BPA lines have experienced unexplained outage activity, although not as severe as MPC's B-Line and Lines 1 and 2.

Figure 5. MPC Line Fault Activity

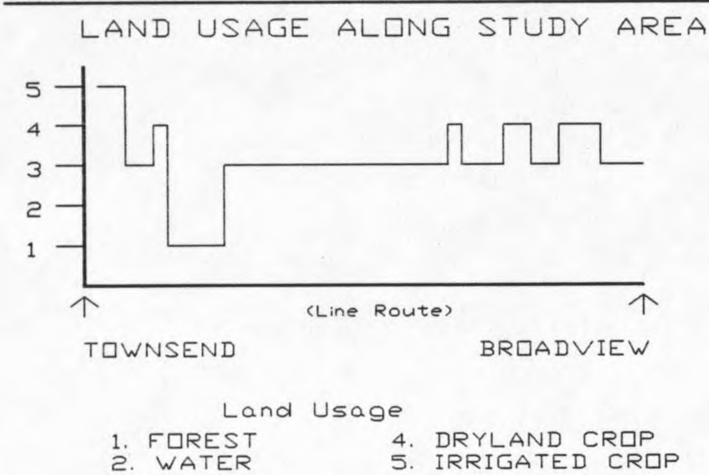


The towers illustrated in Figures 2 and 3 comprise approximately 88% of the towers used by MPC, while the other 12% of the towers are dead-end type structures that are used when the line changes direction and horizontal tension must be taken up on one or more of the phases, which consist of four conductors and are called conductor bundles. The dead-end structures are self supporting towers and a combination of horizontal and vertical insulator strings are used with this type of configuration to suspend the conductor bundles. The standard towers in Figures 2 and 3 use V-string insulators to suspend the conductor bundles and are supported by guy wires. Four strings of insulators (two on each side of the "V") are typically used to hold up each conductor bundle, although lighter mechanical loading of the lines may call for only one string of insulators on each side of the "V".

The main study area considered in this research is between Broadview, MT and Townsend, MT. This 214 km (133 mile) section consists of 553 towers per line with the towers being separated by approximately a quarter of a mile. There are several reasons that the studies were focused in this area. First, it is near Bozeman, home of Montana State University (MSU) and furthermore, 75% of the unexplained outages have occurred in this area. The MSU Electrical Engineering Dept. also has six weather stations spread out along the transmission line in this area. The weather stations are discussed in detail in Chapter Four, Experimental Procedures.

The transmission lines in the study area pass through a variety of terrain including semi-arid rangeland, grassland, and a few areas where there is agricultural activity. Most of the line passes through rangeland with few or no trees. Figure 6 depicts the land usage along the transmission line route. The elevation along the line route ranges from approximately 1066 m to 2133 m (3500 ft to 7000 ft).

Figure 6. Transmission Line Land Use



Historical Fault Data (1984-1995)

Nearly all of the disturbances on MPC's 500kV lines are single-phase-to-ground faults. Any type of arc or conductive path between the grounded, metal tower and the hot phase wires could create this type of fault. Virtually all of the faults are self-clearing, within a few cycles of the disturbance, and little or no evidence is left behind as to the cause of the fault. The faults can become expensive to the utility because of excessive use of the equipment (i.e. circuit breakers and relays) and the stress put on the Colstrip generators created from the transients associated with the faults. Also, there is always the chance of loss of system stability whenever a fault occurs. Power system stability may be broadly defined as that property of a power system that enables it to remain in a state of operating equilibrium under normal operating conditions and to regain an acceptable state of equilibrium after being subjected to a disturbance (Kundar 1993),[2]. In the event that the power system does not return to an acceptable state of equilibrium, the utility can experience loss of generation and/or severe damage to their equipment resulting in millions of dollars of losses. A fault on the MPC 500kV lines could initiate a transient into the western U.S. power grid. Additionally, it is becoming increasingly important for utilities to have a reliable transmission system because customers are demanding transient free, reliable power.

Design standards for typical high voltage transmission lines are for 1-2 unexplained outages/100 mi (161 km)/year (Sandhu et al. 1988),[3]. Table 1, on the following page, examines the outage rates (outages/100mi/yr) on MPC's different 500kV lines. The high outage rates (6 times the expected rates) are what prompted an investigation into the cause of the outages. The first step in reducing the number of unexplained outages is determining the cause of the outages.

***Table 1. Unexplained Outage Rates for BV-TN 500kV Line**

YEAR	LINE #1	LINE #2
1984	5.26	3.01
1985	5.26	1.50
1986	3.01	6.02
1987	6.02	9.77
1988	3.76	4.50
1989	6.77	9.02
1990	9.77	6.77
1991	5.26	12.03
1992	6.77	7.52
1993	6.77	5.26
1994	4.51	3.01
1995	2.26	6.02
AVERAGE	**5.45**	**6.20**

* (outages/100 miles/year)

Whenever a fault occurs, Montana Power Company engineers supply Montana State University (MSU) researchers with the following data; date, time, line, phase, cause (if known), location, and the generators and series capacitors that were in service at the time of the fault. All of these data are entered into a spreadsheet for analysis to determine any trends in the data. Several histograms and descriptions pertaining to the historical fault data can be