GUIDE TO EVALUATING ELECTRIC TRANSMISSION STRUCTURES FOR THE NATIONAL REGISTER OF HISTORIC PLACES

Jeremy Daniel Adams
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GUIDE TO EVALUATING ELECTRIC TRANSMISSION STRUCTURES FOR THE NATIONAL REGISTER OF HISTORIC PLACES

A Project

by

Jeremy Daniel Adams

Approved by:

__________________________________, Committee Chair
Lee Simpson Ph.D

___________________________________
Date

__________________________________, Second Reader
Christopher Castaneda Ph.D

___________________________________
Date

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Student: Jeremy Daniel Adams

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__________________________
, Department Chair

Christopher Castaneda Ph.D

Date

Department of History
Abstract

GUIDE TO EVALUATING ELECTRIC TRANSMISSION STRUCTURES FOR THE NATIONAL REGISTER OF HISTORIC PLACES

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Jeremy Daniel Adams

Statement of Problem

This study is an attempt to develop a statewide systematic approach to the surveying and evaluation of electric transmission structures in California to determine their eligibility for inclusion on the National Register of Historic Places. As federal and state regulations on historic preservation dictate, these structures are recognized cultural resources and therefore require consideration for their historic significance. Electric transmission structures are regularly evaluated in California though there is an apparent lack of cohesiveness in the determinations by the evaluators. A systematic evaluation approach helps develop a more objective evaluation of these structures rather than leaving the determinations subjective to each evaluator. This approach benefits the State Historic Preservation Officer (SHPO) with providing concurrence for each evaluation as well as assists the evaluators and their clients by lowering the time, effort, and cost needed for extensive research because the information needed is already compiled in this study.
Sources of Data

Numerous sources of data were gathered and used for the production of this document. The National Environmental Policy Act (NEPA) and California Environmental Quality Act (CEQA) laws and regulations were reviewed with particular focus given to Section 106, 110, 111, of the National Historic Preservation Act (NHPA), the National Register of Historic Places (NRHP) criteria, and publications and interpretations of those laws including the National Parks Service (NPS) Bulletin 15, and Secretary of the Interior’s Standards for Preservation of an Historic Property.

Conclusions Reached

It is the determination of this study that electric transmission structures can be considered historically significant under any criteria for the National Register of Historic Places. It is unlikely that a transmission line or structure that was among the first electrical transmission systems built in California is still in operation. Additionally, transmissions structures are often repaired, replaced, or designed to have a short lifespan and often do not even reach the required fifty years of age to become historically significant. In any case, the recommendations for evaluating these structures given in this study should be used in practice by all researchers conducting cultural resources investigations so that there is a workable systematic approach in California.

____________________, Committee Chair
Lee Simpson Ph.D

____________________
Date

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I am honored to thank my beautiful and loving wife Erin for her genuine love, respect, and support through my academic career, thesis project, and all aspects of my life, without whom I would not have succeeded. I truly look forward to a completely happy and utterly fulfilled life with her. I also would like to thank my parents Robert and Veronica for their guidance and support, credit them for the achievements I have made and the person I have grown to be. Additional thanks is given to my brothers Eric and Aaron for providing fun and entertainment during much needed breaks from constant academic work of which they were happy to oblige. Finally, I would like to thank all other friends, family, and faculty who have helped me through my life and academic career; it cannot be measured the strength and support which I received from all of them. Thank you!
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Chapter 1

INTRODUCTION

1.1 Purpose of the Study

This study is an attempt to develop a statewide systematic approach to the surveying and evaluation of electric transmission structures. As the federal and state regulations on historic preservation dictate, these structures are recognized as cultural resources and must be considered for their historic significance. Transmission structures are regularly encountered and evaluated in California though researchers have few resources and information to help them make an appropriate evaluation.

It is essential that a systematic approach to surveying and evaluating these structures is taken because the current methods employed by researchers lack cohesiveness and often end up being poorly conducted. These structures can be historically significant and therefore need evaluation like any other cultural resource using the National Register criteria. Generally, electric transmission structures and their corresponding systems are extensive, spanning many miles while a particular project which may interfere with the line may only intersect with a small area of the entire system. However, entire electric transmission structures and line systems may be reconducted, removed, or replaced thus requiring an evaluation of the entire system. In both situations, researchers must develop a basic understanding of the historical context to allow them to work with a platform of existing knowledge during their evaluation. A good sense of existing knowledge includes how to apply the laws and regulations when evaluating transmission structures, a good sense of how they are built and function, as
well as a better understanding of their historic context and historic setting. Existing
knowledge on electric transmission structures provided in this study helps researchers
with their need for appropriate information without forcing them to waste additional
resources or effort conducting extensive background research.

California has an array of natural resources, history, topography, and climate
throughout its landscape. This fantastic combination requires a multitude of different
types of electric transmission structures to satisfy the requirements of the California
landscape. Little information has been gathered at either the national, state, or regional
level about electric transmission structures thus allowing California to create its own
historic context and methodology. Enough research and information has been gathered
on electric transmission structures as a result of this study to develop an appropriate
methodology and historic context to provide researchers a good sense of existing
knowledge for structures built in California. Electric transmission structures built in
other states may have different engineering codes and requirements, histories, or laws and
regulations so are therefore not examined for the purpose of this study. This existing
knowledge will help researchers take into account the effects of all government
undertakings and other projects on historic electric transmission structures.

Part of the requirements and responsibilities of an appropriately conducted
historical evaluation includes the consideration of the effects of a given undertaking or
project on any property eligible for listing on the National Register of Historic Places. In
this case, an eligible property may include an electric transmission structure. The laws
and regulations, which support these requirements, are from the National Historic
Preservation Act (NHPA) and the California Environmental Quality Act (CEQA).

Section 106 of the National Historic Preservation Act (NHPA) of 1966 sets forth rules and regulations for federal agencies preparing for an undertaking, or project, which has the potential to affect buildings or structures in the project area.\footnote{King, Thomas F, \textit{Cultural Resource Laws and Practice: 3rd Edition}. (Lanham: Alta Mira Press, 2004), 109.} In its most basic sense, Section 106 states that the federal agency involved in the undertaking is required to do two things: take into account the impact the project has on buildings and structures; and inform the Advisory Council on Historic Preservation (ACHP) of any findings.\footnote{King, 109.} In any situation where a government undertaking or other project has potential for an effect on an electric transmission structure, a specific study of the affected structures is required.

The electric transmission structures affected must be included in the project’s Area of Potential Effect (APE). A project or government undertaking that has the possibility to affect a \textit{crucial element} of an electric transmission structure includes visual obstructions, physical alterations to the frame design, important part replacements, system rerouting, reconductoring, or removal. In most situations, improvement or replacement of not crucial components of a transmission structure, or other minor modifications, should not be included in the project’s APE and a study of the structure is not necessary. Such minor modifications may include bolt or bracket replacement or unimportant wire modifications.

In addition to National regulations, cultural resource requirements also are affected by individual state laws. This study includes the requirements of the state of...
California which includes the California Environmental Quality Act and its Public Resources Code 5024. These regulations and requirements are discussed further in the rules and regulations subsection of the methodology chapter of this study.

Not all electric transmission structures that fall inside a project area require evaluation. There are a few different types of initial surveys that can be conducted. A pedestrian survey is basically a walk-by observation of the structure without conducting a complete criteria evaluation. An intensive survey is one in which a complete National Register of Historic Places criteria evaluation takes place.\(^3\) In any case that it can be reasonably concluded in a pedestrian survey that an electric transmission structure lacks ability to have historic significance then no intensive survey study is needed. In many cases, a visual inspection of the structure is enough to determine that the tower or pole has been altered, changed, or lost integrity and therefore has lost or lacks historical significance. Additionally, no study is required if the government undertaking or project has no adverse effect or potential for effect on the property.\(^4\) In most cases, however, a small amount of research is necessary to uncover any historical importance or association with the electric transmission structure in question. This is done in order to reach a decision as to whether the electric transmission structure should be evaluated under the National Register criteria.

Generally electric transmission structures require some form of evaluation but intensive surveys, surveys requiring application to the National Register criteria, are not

\(^3\) King, 126.
\(^4\) King, 126.
generally needed. Electric transmission structures that may need to undergo intensive surveys include those that are associated with early structure design; major transmission structure projects; critically important structures and lines; those that possess distinct engineering construction or design; those associated with significant historical events such as the first electric transmission line; the first structure designs of its type; or those which best represent the work of a significant engineer in structure design. Any structure which does not possess one or any of these associations, or is not less than fifty years old, most likely does not need to be evaluated.

In any situation whereby an evaluation of an electric transmission structure property is deemed necessary for a project, cultural resource professionals are welcome and encouraged to review and use the historic context, engineering information, and methodology provided in this study to assist in their evaluations. This study is designed to provide a systematic approach to identifying and evaluating potentially historic electric transmission structures in California but is not designed to be entirely comprehensive for each transmission structure under evaluation. Additional research for each individual structure is necessary to determine the specific history and engineering of that structure. An electric transmission pole or tower structure is designed to support high-voltage electric transmission lines. These structures are built in varying designs specifically for the requirements of the location, electric voltage transmission, and setting of any given project. These structures come in the forms of poles, and towers.

5 King, 126.
The historic context of these electric transmission structures is based on California’s most common types of electric transmission systems. These systems cover thousands of miles from north to south and east to west. The historic context encompasses the discovery of electricity, the advancement to electrical machines, the first electric transmission, the transition to American electricity, the telegraph, the first pole structures, and the transition to California electric transmission. The study provides examples of many different types of electric transmission structures, designs, and histories but it is important to note that this study is not comprehensive and does not cover or identify all systems that have been created. Instead, the study focuses on the most significant electric transmission structure designs as possible historic resources.

The focus of this study is on electric transmission structures and does not encompass electric transmission lines, power plants, electric transmission companies, or other buildings associated with electric transmission. The study does briefly touch on these resources to provide a general context but the information provided should not be used as a tool for evaluating any resource other than electric transmission structures. For example, in order to properly evaluate an electric transmission structure it is important to understand how the structure fits in with the rest of the system. Therefore, an understanding of the basic function and concepts of any given electric transmission line, power plant, or specific company is imperative for a cultural resource evaluator to consider. A basic overview of the function of an electric transmission system is discussed in the study but, as mentioned, should only be used as a guide to better evaluate the structure and not the other resources.
For this study, a multitude of existing information, methods, and approaches to evaluating electric transmission structure was reviewed. The purpose of reviewing existing information was to find if any trends or consistent methods currently exist in the way of evaluating electric transmission structures. Currently, there are many varying forms of evaluation methods employed by both public and private agencies. Variations include uses of Department of Parks and Recreation (DPR) 523 forms, identification methods, evaluation approaches, and treatment of such properties. The lack of a systematic or centralized approach is detrimental to the quality of evaluations being presented to and passed through the State Historic Preservation Office (SHPO). Additionally, the quality of information used in current evaluations has the possibility of being incomplete or virtually incorrect thus complicating comparative or future research.

A broad, systematic approach to evaluating electric transmission structures is beneficial to the quality of evaluations and information sent to SHPO and dispersed to the appropriate California Historic Resource Information System (CHRIS) center. CHRIS and the California OHP provide the important service of inventorying historic site records and survey reports completed in California. The documentation they maintain includes previously conducted records and reports which can be regularly accessed and reviewed for any current evaluation. Each information center (IC) contains documentation for the corresponding counties they represent. For example, the North Central Information Center (NCIC) located in the Adams building at Sacramento State University, maintains records for Amador, El Dorado, Nevada, Placer, Sacramento, and Yuba counties. Other information centers in California include: North Coastal Information Center (CIC),
Northeast Information Center (NEIC), Northwest Information Center (NWIC), Central Coast Information Center, Central California Information Center (CCIC), South Central Coast Information Center (SCCIC), Southern San Joaquin Valley Information Center, South Coastal Information Center (SCIC), San Bernardino Archaeological Information Center (AIC), Eastern Information Center, and the previously discussed North Central Information Center (NCIC). Research at the appropriate IC for the project area is necessary until an all encompassing database is created by the California Office of Historic Preservation (OHP).

To complete the study an inspection of existing documentation of electric transmission structures was reviewed. The repositories in which documents were reviewed include: the North Central Information Center, the Sacramento State University Library and Special Collections, the California State Library and History Reading Room, and the Center for Sacramento History formerly known as the Sacramento Archives and Museum Collection Center.

Electric transmission structures and systems have previously been evaluated for their historical significance. A sample of these reports were gathered from the North Central Information Center and Northwestern Information Center to be used as a guide to better understand what cultural resource specialists have done in the past to evaluate these type of resources. Some of the studies reviewed include the Newark-Kifer 115kV Transmission Line evaluated by JRP Historical Consulting Services in 2002, a Historic Resources Inventory and Evaluation Report of transmission lines in the Stanislaus Corridor by JRP in 2000, Results of Supplemental Historical Data Gathering for the

This study is semi-comprehensive in nature for the use of cultural resource historians, archaeologists, and anthropologists. The methods provided cover the scope of the National Historic Preservation Act and California Environmental Quality Act regulations. Additionally, the National Register of Historic Places criteria are covered to


. Site Record for the PG&E Newark-San Jose Transmission Line, 2002. On file at the Northwest Information Center, Sonoma State University.

. Results of Supplemental Historical Data Gathering for the Boulder-San Bernardino Transmission Line (CA-SBR-10315H) and Linear Archaeological Feature CA-SBR-12574. On file at the California Energy Commission.


Garcia and Associates. Final Cultural Resources Survey and Historic Properties Inventory for the Russell City Energy Project, Alameda County, California, 2008. On file at the Northwest Information Center, Sonoma State University


provide the reader an appropriate understanding of how to evaluate these transmission structures and determine their historic significance. The historic overview is detailed enough to give the reader an appropriate context for most transmission structures in California to better understand the past. Finally, the engineering overview of this study was designed to cover the fundamental ‘architectural’ components of these transmission structures so that an evaluation can more easily determine the design styles, types, and forms used for any given structure. This study was formatted in a fashion for readers to easily find the information they are seeking. It best serves historic preservation and cultural resource management if this study is used as a semi-comprehensive guide for research and evaluation purposes only when determining the historic significance of electric transmission structures. This study does not cover individual structures significance on a local level but instead provides an overview of how that structure may fit into the setting of others similarly built in California.
Chapter 2

METHODOLOGY

2.1 Regulations

National Historic Preservation Act

Section 106 of the National Historic Preservation Act (NHPA) requires federal agencies to consider the potential effects of agency undertakings on historic properties. Historic properties are cultural resources listed on or eligible for inclusion on the NRHP for their significance in American history, archaeology, engineering, architecture, or cultural values (Part 60.4 of Chapter 1 of Title 36 of the Code of Federal Regulations, herein 36 CFR 60.4). Two scenarios exist relative to the effects a potential undertaking may have on an historic property; 1) No historic properties affected, or 2) Historic properties are affected.

If the federal agency official finds that there are historic properties which may be affected by the undertaking, the agency shall notify all consulting parties, invite their views on the effects, and assess adverse affects. An adverse effect is found when an undertaking may alter, directly or indirectly, any of the characteristics of a historic property that qualify the property for inclusion in the National Register in a manner that would diminish the integrity of the property’s location, design, setting, materials,

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8 King, 110.
workmanship, feeling, or association.\textsuperscript{10} Adverse effects may include reasonably foreseeable effects caused by the undertaking that may occur later in time, be farther removed in distance or be cumulative.\textsuperscript{11} Examples of adverse effects include:

- Physical destruction of or damage to all or part of the property,
- Alteration of a property, including restoration, rehabilitation, repair, maintenance, stabilization, hazardous material remediation and provision of handicapped access, that is not consistent with the Secretary’s of the Interior’s Standards for the Treatment of Historic Properties (contained within 36 CFR part 68) and applicable guidelines,
- Removal of the property from its historic location,
- Change of the character of the property’s use or physical features within the property’s setting that contribute to its historic significance,
- Introduction of visual, atmospheric or audible elements that diminish the integrity of the property’s significant historic features, and
- Neglect of a property which causes its deterioration, except where such neglect and deterioration are recognized qualities of a property of religious and cultural significance to an Indian tribe or Native Hawaiian organization.\textsuperscript{12}

A finding of no adverse effect may be issued if the proposed undertaking’s effects do not meet the above-listed examples pursuant to 36 CFR part 800.5(a)(1), or if the undertaking is modified or conditions are imposed, such as the subsequent review of plans for

\textsuperscript{10} King, 119.
\textsuperscript{11} Advisory Council on Historic Preservation. CFR Part 800.
\textsuperscript{12} King, 157.
rehabilitation by the State Historic Preservation Office (SHPO) to ensure consistency with *The Secretary of the Interior’s Standards for the Treatment of Historic Properties* and applicable guidelines, in order to avoid adverse effects.\(^\text{13}\)

In order for a property to qualify for the National Register of Historic Places it must meet one of the four National Register Criteria for Evaluation listed below by being associated with an important historic context and retaining historic integrity of those features necessary to convey its significance. According to *National Register Bulletin 15*; and as stated at 36 CFR 60.4;

The quality of significance in American history, architecture, archeology, engineering and culture is present in districts, sites, buildings, structures, and objects that possess integrity of location, design, setting, materials, workmanship, feeling, and association, and;

(a) that are associated with events that have made a significant contribution to the broad patterns of our history; or

(b) that are associated with the lives of persons significant in our past; or

(c) that embody the distinctive characteristics of a type, period, or method of construction, or that represent the work of a master, or that possess high artistic values, or that represent a significant and distinguishable entity whose components may lack individual distinction; or

(d) that have yielded, or may be likely to yield information important in prehistory or history.\(^\text{14}\)

**California Environmental Quality Act**

The California Environmental Quality Act (CEQA) of 1970 was created to be a supplement to the federal National Environmental Policy Act (NEPA) as a statewide

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\(^{13}\) King, 162.

regulation for environmental protection in California. Just like the federal regulation, CEQA provides stipulations and laws for the protection of historic cultural resources. Under CEQA, public agencies must consider the effects of their actions on both “historical resources” and “unique archaeological resources.” Pursuant to the Public Resource Code (PRC) a “project that may cause a substantial adverse change in the significance of an historical resource is a project that may have a significant effect on the environment.”\textsuperscript{15} The PRC requires agencies to determine whether proposed projects would have effects on “unique archaeological resources.” \textsuperscript{16}

“Historical resource” is a term with a defined statutory meaning. The term embraces any resource listed in or determined to be eligible for listing in the California Register of Historical Resources (CRHR).\textsuperscript{17} The CRHR includes resources listed in or formally determined eligible for listing in the NRHP, as well as some California State Landmarks and Points of Historical Interest.

Properties of local significance that have been designated under a local preservation ordinance or that have been identified in a local historical resources inventory may be eligible for listing in the CRHR and are presumed to be “historical resources” for purposes of CEQA.\textsuperscript{18} Unless a resource listed in a survey has been demolished, lost substantial integrity, or enough evidence indicates that it is otherwise not

\textsuperscript{17} United States Department of the Interior, National Parks Service, Public Resource Code 21083.
\textsuperscript{18} United States Department of the Interior, National Parks Service, Public Resource Code 21083.
eligible for listing, a lead agency should consider the resource to be potentially eligible for the CRHR.

In addition to assessing whether historical resources potentially affected by a proposed project or undertaking are listed or have been identified in a survey process, lead agencies have a responsibility to evaluate them against the CRHR criteria prior to making a finding as to a proposed project’s impacts to historical resources.\(^\text{19}\) According to the PRC, a historical resource is defined as any object, building, structure, site, area, place, record, or manuscript that:

- Is historically or archeologically significant, or is significant in the architectural, engineering, scientific, economic, agricultural, educational, social, political or cultural annals of California; and

- Meets any of the following criteria:
  
  - Is associated with events that have made a significant contribution to the broad patterns of California’s history and cultural heritage;
  
  - Is associated with the lives of persons important in our past;
  
  - Embodies the distinctive characteristics of a type, period, region, or method of construction, or represents the work of an important creative individual, or possesses high artistic values; or
  
  - Has yielded, or may be likely to yield, information important in prehistory or history.\(^\text{20}\)

PRC 5024 also requires consultation with the Office of Historic Preservation when a project may impact historical resources located on state-owned land.\(^\text{21}\)


As noted above, CEQA also requires lead agencies to consider whether projects will affect “unique archaeological resources,” an archaeological artifact, object, or site about which it can be clearly demonstrated that it meets any of the following criteria:

- Contains information needed to answer important scientific research questions and that there is a demonstrable public interest in that information.
- Has a special and particular quality such as being the oldest of its type or the best available example of its type.
- Is directly associated with a scientifically recognized important prehistoric or historic event or person.\(^{22}\)

Electric transmission structures may not be considered unique archaeological resources but they do have the potential to affect unique archaeological resources, particularly pole structures because they are set deep into the ground. Therefore, understanding what unique archaeological resources are is essential for projects or undertakings which involve the removal or replacement of transmission structures because they have the potential to affect these archaeological resources.

**Secretary of the Interior Standards**

The Secretary of the Interior is responsible for the establishment of historic preservation standards. These standards are codified in 36 CFR 67. Rehabilitation is defined in the standards as “the process of returning a property to a state of utility, through repair or alteration, which makes possible an efficient contemporary use while preserving those portions and features of the property which are significant to its historic,

architectural, and cultural values.”23 There are ten standards each which require minimal
to no change of the defining features of an historic property. These standards also require
taking into consideration the economic and technical feasibility of preserving the
property.24 The Secretary of the Interior standards should only be considered after an
electric transmission structure is considered eligible for inclusion on the National
Register of Historic Places, but they do not need to be considered prior to the
determination of historical significance.

2.2 Research

Any time an electric transmission structure is identified within a project’s Area of
Potential Effect (APE), research must be conducted. Research should begin with
determining the appropriate historic context.25 This study provides a quality historic
context for electric transmission structures which will fulfill the general research
requirements for any evaluation. For any further research; resources, repositories, and
further documentation can be found using the sources provided in the bibliography of this
study.

The first element of research for an evaluation should identify the fundamental
information about the electric transmission structure in question. This basic information
includes specific construction elements, potential significance of the structure, location
and setting specifics, and any important associated resources. Associated resources

23 United States Department of the Interior, National Parks Service. “Secretary of the Interior’s Standards
24 United States Department of the Interior, National Parks Service, Secretary of Interior Standards for
Rehabilitation, 8.
25 King, 263.
include other transmission structures, transmission lines, or power plants in the same system as the structure in question.\textsuperscript{26} The historic context provided in this study should supplement the basic information about the resource being evaluated and the theme of the property should be identified. The theme is the historic period and construction type in which the electric transmission structure fits. For example, a theme could be the pioneer period of lattice style electric transmission structure design. After the historic theme is identified, research should focus on the specific electric transmission structure’s historical developments. These historical developments include the construction timeline of the structure including repairs and any people associated with the structure in terms of design or construction. Specific historical developments that absolutely should be considered include design or construction plans and maps involving the layout of the electric transmission system which may provide insight into the original design and basic formation of the transmission structure when it was first built.\textsuperscript{27} Additionally, all dates of construction, repairs, alterations, and the length or period of operation must be included where information is available.\textsuperscript{28} All of this information is essential in identifying the electric transmission structure’s period of significance. The other important aspect of identifying this information is determining the electric transmission structure’s integrity. Repositories and sources that will contain the specific information on the historical

\textsuperscript{26} JRP Historical Consulting Services and California Department of Transportation. \textit{Water Conveyance Systems in California: Historic Context Development and Evaluation Procedures}, (Davis, California, 2000), 90.

\textsuperscript{27} JRP, \textit{Water Conveyance Systems}, 90.

\textsuperscript{28} JRP, \textit{Water Conveyance Systems}, 91.
developments of an electric transmission structure will vary. Much of this depends on the specific structure, its type, location, and ownership.

2.3 Field Inspection and Recordation

A field inspection and site recordation is required for any complete evaluation of a property. The important things to determine in a field inspection of electric transmission structures are probable significance, a degree of understanding in determining whether the property appears to meet the National Register criteria, reviewing the initial integrity of the structure, and understanding the affects the project will most likely have on the structure.

All electric transmission structures which fall in the project’s area of potential effects should be evaluated, although an evaluation and recordation of the entire electric transmission system which the applicable structures are associated with does not need to be completed. A field inspection should include a visual inspection and recordation of components within the project APE. For some evaluations, additional recordation of sample structures in the same system but located outside the project APE should be included. This is done to provide a general reference point of information such as integrity comparisons for the transmission structure in question.\(^{29}\) Key components of a structure that should be visually observed include the structure design, location in comparison to the system (near beginning or end), number and design of conductors, number of transmission lines, and any additional features which stand out for the specific

\(^{29}\) JRP, *Water Conveyance Systems*, 93.
structure. All structures located in the project area of potential effects should always be recorded using the DPR 523 series of forms.

It is common to evaluate electric transmission structures as an historic district and not just a particular individual property. Deciding whether to evaluate an electric transmission structure as an individual property or together with others in its system as an historic district depends generally on the size of the project area of potential effects. If a given project encompasses the entire electric transmission system then the system’s structures should all be evaluated together as contributing components to an historic district. In many cases reconductoring, replacing, or rerouting the path of an electric transmission system involves the evaluation of the entire system. These types of projects should consider evaluating the properties as components of an historic district rather than individual properties. If a project encompasses only a few electric transmission structures or portion of the system, then it may be beneficial to consider evaluating the structures as individual properties. Something to consider is the fact that electric transmission structures are built to function as a single component of an entire electric transmission system. In no case is an electric transmission structure built to function as a single entity. If an electric transmission structure contains components, design, or function significantly unique to the other structures in the system then the structure should be evaluated as an individual property. It is important to understand that differences in transmission structures must be significantly unique and not simply

30 JRP, Water Conveyance Systems, 94.
31 JRP, Water Conveyance Systems, 94.
32 JRP, Water Conveyance Systems, 94.
different. All transmission structures have minor differences in their construction and design due to varying requirements of location in the system. Significant differences are those that include differences in design, function, conductors, or anything unique beyond that of the rest of the system.\(^{33}\) In any case, however, an electric transmission structure may be evaluated as both an individual property and contributor to an historic district.

Generally there are two types of forms which need to be filled out when evaluating electric transmission structures. These two types of documentation are Inventory Forms and Survey Reports.\(^{34}\) An inventory form requires property specific information such as location, significance of the property, and physical characteristics. A survey report explains the methods employed in the survey, describes the historic context used, and presents a comparative analysis. DPR 523 series of forms created by the State Historical Resources Commission in 1995 are the type of inventory forms that should be used. Guidance for filling out these forms is provided by the California OHP in “Instructions for Recording Historical Resources.” The DPR 523 primary record, location map, and linear site record are generally the forms that should be filled out when evaluating electric transmission structures.\(^{35}\)

2.4 Significance Evaluation

An electric transmission structure may only be determined *eligible* or *ineligible* for inclusion in the National Register of Historic Places. An evaluation may find an electric transmission structure eligible or ineligible as an individual property or as a

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\(^{33}\) JRP, *Water Conveyance Systems*, 95.

\(^{34}\) JRP, *Water Conveyance Systems*, 96.

\(^{35}\) JRP, *Water Conveyance Systems*, 97.
component of an historic district. An evaluation may encompass only the structure within the project APE or it may encompass all the structures in the entire system.  

Electric transmission structures which lack integrity are generally found ineligible for listing on the National Register. Additionally, if the structure is not associated with a significant historical period or does not have the ability to significantly contribute to an historic district than it generally is found ineligible. In any case where new information may affect the eligibility determination, the property may need to be reevaluated.

If the evaluator determines that the best way to evaluate the given electric transmission structure is as an individual property and not a component of an historic district than the resource name listed on the inventory forms should clearly label it as such. This should be done so there is little confusion whether the evaluation encompasses the entire system or an individual property. A good resource name would generally depict the structure’s location in the transmission line system. An example of an electric transmission structure resource name could be either “2/4” or “Main Street and 1st Avenue 115 kV tower.” The name “2/4” is an exact description of the structure’s location along the electric transmission line system. The “2” represents the structure being in the second mile away from the substation. The “4” represents it as the fourth structure in that mile. Therefore, a transmission structure labeled “2/4” describes that it is

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37 Advisory Council on Historic Preservation, Section 106.
the fourth structure in the second mile section away from the substation. In either case, appropriate resource names should be used.

2.5 Application of the NRHP Criteria

In order for an electric transmission structure to be deemed eligible for inclusion on the National Register of Historic Places, the system must meet one or more of the criteria and retain integrity. The National Register criteria require a property to:

- be associated with events that have made a significant contribution to the broad patterns of our history;
- be associated with the lives of persons significant in our past;
- embody the distinctive characteristics of a type, period, or method of construction, or represent the work of a master, or possess high artistic values, or represent a significant and distinguishable entity whose components may lack individual distinction; or
- have yielded, or may be likely to yield, information important in prehistory or history.

As with any property, an electric transmission structure may be deemed eligible for inclusion on the National Register of Historic Places under any of the National Register criteria.

Criteria A:

One of the most important things to understand when evaluating any type of public works facility is that they are inherently important to the community. Water conveyance systems, such as dams, powerhouses, ditches, canals, reservoirs, diversions, etc., and gas pipelines, among other types of public works facilities, provide a service that

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39 JRP Historical Consulting Services, Transmission Lines in Stanislaus Corridor.
40 King, 90.
naturally assists in the growth, development, and expansion of the community it serves.\textsuperscript{41} For example, a small town may put in a form of water conveyance system which both develops electricity and helps to provide a consistent and controlled water supply for the community. This development will most likely help to expand the town because it provided jobs, helped electrify businesses, and supported housing with water and power. Therefore, the water conveyance system is inherently important to the community; however, it is not \textit{significant} to the historical development of the community.\textsuperscript{42}

Electric transmission structures, and their correlating systems, function in a similar way. Any city, town, or smaller community across California most likely has some form of electric transmission line system. Also, most likely the first high voltage electric transmission system that was built was important to the community because it provided a much needed service. In this case, it is important to focus on the significant features of the electric transmission system that contribute historically to the development of the community. Important contributing components include the power provider station, the conductor wires, and the structure’s supporting the conductors. A complete evaluation of an electric transmission structure in a project area must be researched and considered under National Register criterion A.

In order for an electric transmission structure to be eligible under criterion A, it needs to be associated with a significant event or pattern of events.\textsuperscript{43} An example of a significant event of an electric transmission structure would be the first lattice electric

\textsuperscript{41} JRP, Water Conveyance Systems, 96.  
\textsuperscript{42} JRP, Water Conveyance Systems, 96.  
\textsuperscript{43} King, 91.
transmission structure built in California. An example of a significant pattern of events could be the development of wood pole transmission structure technology over time. This study compiled an appropriate historic context to determine these themes of significance.

In addition to being associated with a significant event or pattern of events, an electric transmission structure must not merely coexist with a significant event. Instead, an electric transmission structure must demonstrate being significantly associated with the event or pattern of events. For example, if an electric transmission structure was built as a part of a small transmission system in a town which previously had electric transmission, but was constructed during the pioneer period of electric transmission systems; it will most likely be considered not eligible under criterion A. However, if that structure was built as part of an important electric transmission system which was the first one in the town and was constructed during the pioneer period of electric transmission systems, then it will most likely be considered eligible for inclusion under criterion A. This is because it is a significant representation of that period in time which led to the development of not only the town but electric transmission in California and the United States.

Criteria B:

In order for an electric transmission structure to be considered eligible for inclusion on the National Register under criterion B, it must be associated with a

\[44\] King, 91.
\[45\] King, 91.
significant person’s life and must be the structure that is most closely related to that person or a contributor to a system of structures that is most closely related to that person.\textsuperscript{46} The most important thing to consider is that a single electric transmission structure almost never is the most closely associated property with any significant individual. A significant person most likely is associated with an electric transmission structure in terms of design or construction but this consideration should be made using criterion C because the designer is considered a master craftsman or engineer which is a criterion C consideration. In this sense, it would best benefit an evaluator to consider criterion B when evaluating an electric transmission system as an historic district and considering each structure as a significant component of that system because a significant person will most likely be associated with the development of an entire electric system rather than that of a single tower or pole. An electric transmission structure if evaluated as a component of an historic district could be found eligible under criterion B if, for example, a significant person is highly associated with the system, more so than with any other property.\textsuperscript{47} Since the property must represent the closest association with that person, the person must be important for reasons associated with the electric transmission structure or system specifically. The person and the structures association with that person must be equally important. When an evaluator researches associations with

\textsuperscript{46} King, 91.
\textsuperscript{47} King, 91.
important people for any electric transmission structure they should be careful to consider that the structure is the most closely associated property with that person.48

Criteria C:

Electric transmission structures are most likely found eligible for inclusion on the National Register of Historic Places under criterion C. The most significant features of an electric transmission structure are its engineering design and construction. An electric transmission structure can also be considered the work of a master engineer and best represent that work through a particular style or design that the engineer used. Also an electric transmission structure may represent a period or method of construction.49

In order for an electric transmission structure to be considered a good representation of a type, period, or method of construction; it must have noticeable, or distinctive, features that are representative of that type, period, or method of construction.50 Distinctive characteristics of an electric transmission structure must illustrate a specific pattern of features which is common to a particular type of historic resource. For example, it must have all the components which classify it as one of the first lattice designed steel towers. Features of an electric transmission structure range from the type of metal used, how it was molded, the angle formations, and the conductors used, among other things.51 Another representation of distinctive characteristics includes the development over time of that type or design. For example, it must be a good representation of the “evolution” of lattice designed steel towers and maintain features

48 King, 91.
49 King, 91.
50 JRP Historical Consulting Services, Transmission Lines in Stanislaus Corridor.
51 JRP Historical Consulting Services, Transmission Lines in Stanislaus Corridor.
which demonstrate that evolution period. Any time that an electric transmission structure is established as a good example of a particular design or type of structures, it is important to create a comparative framework in the structure’s relation to other structures. This will help establish credibility in the evaluation because it shows how the structure is uniquely distinct or different from others and therefore historically significant.

An electric transmission structure can also be considered eligible as the work of a master engineer. Someone who is considered a master engineer in the design and construction of electric transmission structures must be recognized and acknowledged as distinguished from other engineers in the same field.\textsuperscript{52} In addition to being acknowledged as distinguished, the specific structure(s) in question must be the best representation of the engineer’s work. Not all electric transmission structures that were designed or constructed by a notable or distinguished engineer may be considered eligible for inclusion on the National Register. For example, an electric transmission structure that was designed by a master engineer as a fundamental component of a significant electric transmission system and is considered a good representation of the engineer’s unique design style may be considered eligible for inclusion on the National Register.\textsuperscript{53} However, an electric transmission structure which was designed by a master engineer but is a single structure of many similar structures in the system and is not closely associated

\textsuperscript{52} King, 91.
\textsuperscript{53} JRP Historical Consulting Services, Transmission Lines in Stanislaus Corridor.
specifically with the engineer’s unique design style, then it most likely will be considered not eligible for inclusion on the National Register.

An electric transmission structure can also be considered eligible by means of aesthetic or artistic value. Though many structures will most likely be considered not highly artistic, aesthetic value has become an important consideration by engineers in the design and construction of an electric transmission structure. Companies in California, such as Pacific Gas and Electric (PG&E) company, consider the aesthetics of an electric transmission structure and how it fits with the portion of the town or city in which it resides. For example, PG&E will generally attempt to avoid constructing structures in residential areas that have a “commercial” design appeal to them. They do this to avoid complaints from the residents of the neighborhood and to keep relations between the town and the electric provider good. Engineers have become particularly creative in designing aesthetically pleasing electric transmission structures. To be considered eligible for aesthetic or artistic value, a structure’s design must represent that value more than any other structures of its type.

Criteria D:

In order for an electric transmission structure to be considered eligible for inclusion on the National Register under criterion D, it must yield or be likely to yield information important in history or prehistory. The most important thing to consider

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56 King, 91.
when evaluating under criterion D is that a structure must be evaluated in the appropriate context. Additionally, a structure must possess the ability to answer a specific question(s) in history or prehistory. If the specific question in history or prehistory is realized, then the structure may no longer be found eligible under criterion D.  

In general, properties that are most likely to be found eligible under criterion D are archeological sites because the potential information that these sites yield or may be likely to yield is greater than with buildings, structures, or objects. Therefore, an electric transmission structure that is positioned on or near an archeological site should be researched further. In most cases, an electric transmission structure will be considered not eligible for inclusion on the National Register of Historic Places.  

**Integrity**

When an electric transmission structure appears to meet any one of the National Register of Historic Places criteria, it must also maintain integrity. Integrity is the ability of the property to convey its significance. There are seven aspects of integrity which must be considered in order for a structure to maintain historic integrity which include: location, design, setting, materials, workmanship, feeling, and association. Additionally, the structure’s significant features which associate the property to an historic period or design construction must be visible and present.  

To determine the integrity of a structure, the original appearance and setting during its historic period of significance must be researched and known.  

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57 King, 92.
58 King, 92.
59 King, 93.
must meet the features of its historic period of significance as well as have maintained the design, materials, and workmanship of the original construction. Also the structure must be situated in an appropriate setting which does not hinder the historic qualities which make it significant. For example, a wooden pole transmission structure built in a rural area of a small mining town in 1914 that is still in operation today and is considered eligible under criterion A because of its association with the town, most likely does not maintain historic integrity of setting because the paved roads and tall buildings which reside around the structure now hinder the historic value that the rural mining town used to provide. Integrity of setting is closely associated with integrity of feeling and association. Using the previous example of the old rural structure in the new setting; the structure is surrounded by paved roads and tall buildings, so therefore the feeling and association of the structure in the rural town is lost. The location aspect of integrity focuses mainly on whether the structure has been moved from its original location. If a structure has been relocated, then it will almost always be considered to have lost integrity.

The fundamental test of integrity of an electric transmission structure rests on comparing the current appearance of the structure with its appearance during the historic period of significance with which it is associated. Most likely, integrity will be lost if there are recognizable differences with the important features of the structure which make it historically significant. However, integrity will not be lost if changes made on the

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60 King, 93.
61 King, 93.
62 King, 93.
structure were done during the period of historic significance, or are considered the contributing features which make the structure historically significant. In most cases, changes made to an electric transmission structure are done to help prevent the structure from destruction, deterioration, or becoming unusable. Therefore, modifications are made in the fundamental features which make the structure historically significant and thus have an effect on the structure’s integrity. 63 Electric transmission structures that have not been maintained and are deteriorating may not have lost integrity because the fundamental features of the structure which makes up the integrity, such as location, design, setting, materials, workmanship, feeling, and association are not lost. 64

**Eligibility**

If an electric transmission structure appears to be eligible for inclusion on the National Register of Historic Places, specific details regarding boundaries, the level and period of significance, and contributors and noncontributors should be identified. 65

**Boundaries**

Generally, the boundaries of an electric transmission structure and its associated system will include the power station, or substation, and all the structures in the transmission line system from the station to the end. In many cases, an entire system will only be evaluated if the project or undertaking involves changes made to the entire system and each component thereof. If a single or small number of electric transmission structures fall in the APE of a given project or undertaking, then the boundary should

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63 King, 94.
64 JRP, *Water Conveyance Systems*, 95.
only include those structures as well as a sample of other structures in that system that are outside of the established boundary for comparison. The boundary should also include associated features that contribute to the construction or maintenance of the structure, such as maintenance roads. The integrity of setting is naturally outside the boundaries because it is not physically associated with the property and should not be included as part of it.\textsuperscript{66}

Level of Significance

An electric transmission structure’s period of significance is basically the period of time with which the structure is associated with the important features that make it significant. Features which make it significant include the National Register criteria such as important events or people, design, engineering or construction, or possibility to yield information. When considering a tower or pole’s period of significance, it is important to make appropriate assumptions with supporting research because the assumption becomes virtually the foundation for which the structure is assessed against the criteria and features of integrity.\textsuperscript{67}

The period of significance of an electric transmission structure starts with the time it was constructed or is associated with an historic event and ends with the time when the important features that make it significant, such as events, people, or design period no longer apply.\textsuperscript{68} For example, if a structure is built in 1925 and is associated with the new engineering design of steel lattice towers, then the period of significance would run from

\textsuperscript{66} JRP, \textit{Water Conveyance Systems}, 96.
\textsuperscript{67} JRP, \textit{Water Conveyance Systems}, 96.
\textsuperscript{68} Garcia, \textit{Russell City Energy Project}. 
1925 until the end of the pioneer period of steel lattice tower designs. Or, if a structure is associated historically as the first structure built in California, then the period of significance would run from its construction date to the time the second structure was built in California.

It is important to establish a period of significance for the electric transmission structure being evaluated. Once the period of significance is established, then the research conducted on the historic context should not significantly consider the history prior to the structure’s construction date.\(^{69}\) It is not uncommon for an electric transmission structure to have a different period of significance than other structures in the same transmission line system. This is because structures and poles are regularly built at different times as the electric transmission system expands. If it is the case that a project or undertaking encompasses multiple structures each with different established periods of significance, then appropriate research should be substantially done for each different period.

Generally, an electric transmission structure should be over fifty years old and be deemed to have gained historic significance to be considered eligible for inclusion on the National Register of Historic Places. If the structure is not over fifty years old or the period of significance continues into the most recent fifty years, then the structure must be considered exceptionally significant to be eligible for inclusion on the National Register. In order to be deemed exceptionally significant, an electric transmission structure must be associated with an extraordinary event, or be an especially rare or good

\(^{69}\) JRP, *Water Conveyance Systems*, 95.
example of a design type that has the possibility of deteriorating completely prior to becoming fifty years old.\textsuperscript{70}

**Contributors and Noncontributors**

If an electric transmission system is deemed eligible for inclusion as an historic district then it is important to determine the contributing and noncontributing structures to that district. Simply because a system is considered eligible as a district, does not mean that all the structures in the system are contributing components to that system. Only the structures that are associated with the previously established period of significance of the district are considered contributing components.\textsuperscript{71} An important consideration when determining contributing structures is the integrity of the structures within the period of significance. Only structures within the period of significance that maintain integrity should be contributing components. In most cases there should be more contributing structures in the electric transmission system than noncontributing structures.\textsuperscript{72}

### 2.6 Conclusion

This outline was designed to function as a guide for evaluating electric transmission structures and applying the National Register of Historic Places criteria. Variations in evaluation methods and approaches may occur to satisfy the specific needs of any given project. The regulations and methods provide a systematic approach to evaluating these electric transmission structures in California for government agencies.

\textsuperscript{70} JRP, *Water Conveyance Systems*, 96.

\textsuperscript{71} JRP Historical Consulting Services. *Results of Supplemental Historical Data Gathering for the Boulder-San Bernardino Transmission Line (CA-SBR-10315H) and Linear Archaeological Feature CA-SBR-12574*. On file at the California Energy Commission.

\textsuperscript{72} JRP, *Water Conveyance Systems*, 96.
and private companies to consider for their undertakings or projects. The following engineering and history sections of this study are meant to supplement the methods as a background of existing knowledge.
Chapter 3
ENGINEERING

3.1 Basics for understanding Transmission line system designs

The National Electrical Safety Code (NESC) governs the structural design of high voltage electric transmission lines in the United States. These NESC rules are mainly based on successful field experience of electrical safety engineers and are complemented by the individual utility’s agenda. The NESC rules, however, are not designed to be “catch-all” criteria to produce safe and economically successful designs.

Transmission lines that are overdesigned or meant to be too reliable and have very few structural failures during their lifetime are not necessarily the most efficient for a particular company to use. The overdesigned transmission line generally has too much capital invested into the design making it an economic failure to the company using the structure. On the reverse side, an under-designed line with low reliability will experience many structural failures during its lifetime. The cost of these structural failures is generally too high for the company to sacrifice on a regular basis. Just like any business model, the most efficiently designed transmission structure is one that provides a balance between cost and risks.

According to Alain Peyrot of the American Society of Civil Engineers, “A practical design procedure allows the designer to select the reliability of any component in a line … through a procedure known as the Load and Resistance Factor Design

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74 American Society of Civil Engineers, Innovations, 1.
75 American Society of Civil Engineers, Innovations, 1.
In its most basic form, the LRFD shows the designer how to view an electric transmission line as an entire system consisting of many subsystems, each with its own components. An entire line, for example, can be made up of conductors, ground wires, insulators, a tangent structure, an angle structure, a dead-end structure, etc., each of which are considered individual subsystems. Each of these subsystems are made up of many components such as steel angle members, gusset plates, bolts and foundations, etc. The LRFD procedure takes the engineer into each individual component when evaluating an entire transmission line system. Understanding the LRFD is essential in understanding the practical considerations in the construction of any electrical transmission structure design. The reliability of a transmission line depends on the reliability of each of its subsystems which in turn depend on the reliability of all the components, particularly the weakest. Therefore, when used properly the LRFD can be used to understand and control the reliability of electrical transmission structures.

3.2 Getting to the design of transmission structures

Electric transmission towers and poles are considered “overhead” transmission while transmission lines that run underground are considered “underground” transmission. Overhead transmission line systems are significantly less costly to construct than underground electric transmission systems but they take up land and are visually unappealing. There are benefits to both types of transmission but for the purpose of this study, only overhead transmission structures will be discussed.

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76 American Society of Civil Engineers, Innovations, 1.
77 American Society of Civil Engineers, Innovations, 2.
The basics of electric transmission tower and pole construction focus on safety and structural load considerations. The tower or pole must be able to withstand specific loads depending on its surroundings. A structure built in a valley must be able to withstand the structural loads of heavy winds while a structure built on a high mountain must be able to withstand the structural loads of heavy ice. A structure also has to withstand heavy stresses that are imposed on it. These stresses include the tension of the wires it is supporting, weight of a conductor, stress of a guy wire pulling it, and even the angles in the lines. Additionally, the components themselves such as insulators, conductors, and foundations of a tower or pole must also be able to withstand similar stresses and structural loads.

Safety considerations are set forth by the National Electric Safety Code (NESC). The NESC sets requirements for height, location, and voltage. Of these safety requirements, the height of the structure is the most considered when constructing towers or poles. Structures must be tall enough so the wires they support have adequate ground clearance during maximum load conditions. For example, the height of a structure must be tall enough so that the wires it supports clear the ground in both sunny, no wind situations as well as heavy snow and high wind situations. In addition, wires must be able to clear all buildings and other objects during these maximum load conditions.

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79 Gonen, 641.
81 Gonen, 641.
Transmission structures represent about 40 percent of the total cost of an entire transmission line project. An electric transmission structure supports the conductors that make up a transmission line. There are two main types of electrical transmission structure designs. Most electric transmission structures are lattice towers or wood poles. Lattice towers are generally made of steel angled sections whereas poles can be made of steel, wood, or even concrete. Lattice towers are used in areas with more severe climates and/or have high voltage lines. Lattice towers cost more than wood poles but their economic benefit in terms of longevity and durability for the climate and voltage they can withstand outweighs that of a traditional pole. Wood poles are generally used for short electric transmission line spans and/or lower voltages.

Transmission towers and poles are designed with a number of considerations. Each structure design is built to satisfy the requirements of the location or setting. For example, lattice tower may be designed in such a way to overcome the stresses of being located on a hillside while a differently designed lattice tower may be designed in such a way to overcome the stresses of below freezing temperatures. The alternate designs which function differently for each situation make it easier to design a transmission line than starting from scratch. When a design is created that satisfies the requirements of, for example, a hillside, then that design can be repeated in similar locations throughout the entire system. It can easily vary to satisfy the requirements of a slightly different

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84 Gonen, 38.
hillside without changing the fundamental features of the design. Therefore, a structure may visually look the same as another in the system and have the same fundamental design features but still be strengthened in different parts of the structure as needed. Though transmission structures can be structurally changed, most are not because it is more costly to construct individual structures than it is to construct a series of similar structures. Instead, transmission lines are planned to accommodate the changing scenery and locations along the line.\textsuperscript{85}

\textbf{Pole Types}

Poles come in generally four different types; wood poles, steel poles, aluminum poles, and concrete poles. In California, and most of the United States, wood poles are used and preferred over the other three pole types. Wood poles are used more than metal or concrete poles because wood is in more abundance, they are easier to construct and handle, and they cost significantly less than metal or concrete poles. Generally, concrete poles and steel poles have been used in street lighting and to support trolley lines because they have a nicer appearance but they are not used very often for electric transmission distribution lines. Aluminum poles are also most commonly used for street lighting because they are hollow through which electric wiring can run from the ground up to the light and back down without being seen.\textsuperscript{86} Aluminum poles have also been used for electric transmission distribution in the United States but in California, wood poles are the most common. If an evaluation includes an aluminum, concrete, or steel transmission

\textsuperscript{85} Gonen, 39.
\textsuperscript{86} Gonen, 651.
pole in California, than special consideration should be given to its significance and an intensive historic background should be explored.

Since wood decays at a faster rate than metals or concrete, wood poles are impregnated with wood preservatives to extend their lifespan. Wood poles that are impregnated with preservatives to resist decay have a life expectancy of a minimum of 35 years. In California, cedar, pine, and fir are the most commonly used and best suited for electric transmission distribution structures because of their strength, proportions, and other properties. Wood poles are most often used to support low voltage lines because they are smaller in construction and cannot support multiple wires or conductors as large steel towers can. They generally support single or double circuit lines with voltages of 115kV through 345kV, though wood towers built in the design of an H-Frame can support lines up to 765kV.

Like all transmission structures, wood pole designs are based on the calculated stresses and loads they must withstand in the system or location in which they work. Even the wood type, or species, is considered because different types of wood have different degrees of strength and durability. Wood poles, because of the material they are made of, have an inherent flexibility that rigid steel structures do not possess. This flexibility allows a degree of cushioning for the considerations of structure loads that are imposed on the pole.88

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87 Gonen, 651.
88 Gonen, 651.
A typical wood pole contains a single column-like pole as the body and a number of arms which support the conductors and wires. Most wood pole structures have one or two arms at the top of the structure. An arm is a wood cross-bar which holds the conductors. An arm may span across both sides of the pole body like a cross and hold one or a couple of conductors or extend across only one side of the pole body and hold multiple conductors. On most wood transmission poles, wood cross-arms are used but occasionally metal arms have been used. Single column wood poles generally support three conductors. Two examples of the formation of wood pole cross-arms are provided by Turan Gonen in Figures 1 and 2.

The height of a wood transmission pole is entirely dependent on the NESC requirements which focus on ground clearance. There are four main factors which determine pole height. These factors are: “length of vertical pole space required for wires and equipment; clearance required above ground or obstructions for wires and equipments; sag of conductors; and, depth of pole to be set in ground.” Wood transmission poles in California are almost always at least 35 feet long, and very rarely are poles under 30 feet used. Occasionally 30 foot poles are used when the span of the transmission line is extraordinarily short or the poles are located in alleyways. For obvious reasons, poles that are longer than 35 feet are used to allow adequate clearance over buildings or other obstructions, or to support heavier structural loads. The diameter of a pole is determined by the structural loads it must endure. Wood poles are separated

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90 Anderson, 230.
91 Anderson, 230
into classes in accordance to the circumference of 6ft from the bottom of the pole and the top of the pole. These classes were established by the American Standards Association and are numbered from 1 to 10. Class 1 is the largest ground circumference and class 7 is the smallest while classes 8 through 10 specify minimum top circumferences only.\textsuperscript{92}

Wood poles are set in the ground rather than on foundations like transmission towers. In order for the pole to be stable it must be set deep enough in the ground to support the height of the pole and the stresses against it. Depth of the pole is not the only important factor of the pole setting but the type of ground it is set in also is considered. For example, if the ground is moist or if the soil is soft, then different settings are used for the poles. In general, poles are set at a minimum of 5 feet deep, and average of 6 feet deep, and a maximum of 7.5 feet deep.\textsuperscript{93} Figure 3 is a good representation of different types of pole structure foundations created by Turan Gonen.

Wood transmission poles also need to withstand the same mechanical forces that all structures need to withstand. In their nature, poles are strong against vertical forces but weak for horizontal forces. Horizontal forces that affect wood transmission poles consist of wires pulling the pole if on a corner, unbalanced or broken conductors, and mainly wind. All of these forces put horizontal tension on the wood and often causes the pole to bend. The NESC provides minimum safety requirements for wood poles which

\textsuperscript{92} Anderson, 651.
\textsuperscript{93} Anderson, 653.
consider the circumference of the pole in the ground and type of wood for strength purposes.\textsuperscript{94}

**Lattice Towers**

Lattice designed towers for transmission lines generally have been built with hot-rolled or cold-rolled steel.\textsuperscript{95} Hot-rolled steel is basically steel that is rolled into its final dimensions while it is still hot; generally over 1700 degrees Fahrenheit.\textsuperscript{96} A steel sheet is sent through two rollers while it is still pliable and then formed into the angles needed for the particular function of the steel. In the case of latticed transmission towers, the hot rolled steel is formed into angles. Cold-rolled steel is done in the same fashion as hot-rolled steel in that the metal is sent through two rollers; only the steel is at a cool temperature where it is not pliable anymore. An advantage of cold rolled steel is the ability to form it into shapes rather than only angles like that of hot rolled steel. The multitude of shapes in cold rolled steel allow for the flexibility of design variations to satisfy the requirements of location, load, and other inclement factors for each individual transmission tower.\textsuperscript{97}

Hot rolled steel lattice frame structures are more prominently seen because they were mass produced during the engineering and economic boom period of transmission tower design. Most lattice frame transmission towers were designed using hot-rolled

\textsuperscript{94} Anderson, 658.
\textsuperscript{95} American Society of Civil Engineers. *Innovations*. 37.
\textsuperscript{97} Lewis, 11.
steel angles. The main difficulty with using hot-rolled steel angels is the inability to make thin, lightweight pieces for cost efficiency. Code restrictions on allowable thickness of bars also factor into the decline in use of hot-rolled steel frame structures. Cold formed shapes are generally formed with a minimum thickness of 3 mm and general upper limit of 8 mm. Different steel shapes are chosen according solely to the requirements of location, shape and dimension of specific transmission towers in order to improve the strength, flexibility, warping, torsion, and overall durability of the tower. These cold rolled shapes also can manage more efficient unsupported lengths and therefore are significantly less heavy than hot rolled steel. Transmission towers which are built using cold rolled steel are generally lighter and consist of less cross bars. The lower number of bars used to construct the transmission tower means the lower number of gusset plates, or holding and connecting plates, and bolts used to hold the steel frame together. In terms of cost of a tower, the features which make up cost include design, fabrication, transportation, and erection. The cost of these features which make up building a transmission tower are dependent entirely on the weight and number of pieces used. Since cost of the tower is determined by weight and number of pieces, cold rolled steel transmission towers are generally more affordable because they require less pieces to build and are relatively light.

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98 Levy, Introduction.
99 Levy, Introduction.
100 Gridley, 38.
101 Gridley, 39.
102 Gridley, 40.
103 Gridley, 41.
Lattice tower types are designed with multiple angles each built to resist the forces against them. The angles are calculated and the design is built as such. There are a number of different design types of lattice towers but they are all built using the fundamental angle requirements to withstand the forces of the location in which they are placed. Though there are a multitude of styles, they all are built fundamentally the same and thus no particular design type is more prominent in lattice towers than another. This is important to understand when evaluating a tower for its significance because the design of a tower is almost completely dependent on calculations and engineering specifications and therefore each tower is designed to function in almost a completely different way.

Once the angles are determined, the tower is built similarly to pole structures in that they are designed to withstand structural loads. The structural loads on lattice towers are the same as the structural loads of pole towers which consist of different things such as the number of conductors and their size, transmission line tension, guying wires, ice, wind, and other inclement weather. The same resistance calculations and requirements to these loads are met in both poles and towers except that the angles in towers generally are designed to more heavily withstand the forces rather than relying on guy wires or deep set foundations.\textsuperscript{104} For example, a pole built in a high wind location needs to be set deep in the ground and possible have a guy wire acting as a counter balance to the force of the wind so the pole does not snap. A lattice tower is designed in such a way that the angles

\textsuperscript{104} Gridley, 42.
of the steel work as counter balances in themselves to withstand the wind load rather than needing deep set foundations or additional guy wires.\textsuperscript{105}

One of the fundamental differences between poles and towers are their foundations. As explained earlier, poles are set deep in the ground. Transmission tower foundations are built to withstand different types of structural loads than poles. Since towers span over a variety of environments in the long transmission system, foundations are determined mainly on soil data of the area where the particular tower is going to be placed. The NESC also regulates the requirements of structural designs for tower foundations. Since towers generally stand on four angled legs, the foundation they sit on mainly is designed to cover a small surface. These foundations are called spread foundations.\textsuperscript{106} Spread foundations contain steel grillages and pressed plates set in concrete. The grillages and concrete hold the tower and prevent it from flying up and off during wind updraft loads. The angles in the lattice design type work against all other forces from other directions so the foundation only really needs to work against extremely heavy horizontal loads and updraft loads.\textsuperscript{107} Examples of common lattice tower structures are provided in Figures 4, 5, 6, and 7 by Turan Gonen.

3.3 Mechanical Loads

Mechanical loads are the external conditions that put stress forces on the transmission lines, conductors, and other support such as poles or towers.\textsuperscript{108} Other types

\textsuperscript{105} American Society of Civil Engineers. \textit{Foundations for Transmission Line Towers}. (Developed by the ASCE Technical Convention in Atlantic City, New Jersey, 1987), 17.

\textsuperscript{106} American Society of Civil Engineers, \textit{Foundations}, 18.

\textsuperscript{107} American Society of Civil Engineers, \textit{Foundations}, 21.

\textsuperscript{108} Gonen, 644.
of mechanical loads include the weight of the structures themselves. There are five types of mechanical load stresses that are considered when choosing electrical transmission towers and all of their components: tensile stress, compressive stress, shearing stress, bending stress, and twisting stresses or torque. Tensile stress is a force that acts in opposite directions away from the pole or tower body. For example, a guy wire pulling a tower in a certain direction is considered a tensile stress on the tower. Compressive stress is basically the opposite of tensile stress in that the force acting on the tower or pole is directed towards the structure rather than away from the structure. Shearing stress comes in the form of bolts or other connecting pieces that cut the body of the tower or pole in two causing a shearing type of stress. Bending stress occurs when a pole or tower is being pulled by a transmission line on the top but is not counterbalanced by a guy line on the opposite site, therefore is subject to bending. Twisting stress or torque occurs when the line tension is not the same on both sides. This occurs when a conductor breaks between the supports on the line thus causing a twisting effect.

3.4 Components of an Electric Transmission Tower or Pole

There are several components of electric transmission towers and poles that are significantly contributing pieces to the structure. It is incorrect to consider these components as elements which are indicative of an architectural style. Unlike components of a building such as dormers, finials, columns, etc., that contribute to the style of the building, the size and design type of conductors, insulators, wires, guys, and foundations all vary depending on the requirements and needs of the system or section of

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109 Gonen, 644.
the system and therefore do not serve a similar purpose in determining the design type. An appropriate evaluation should consider these components in similar ways as would be done when evaluating the engineering features of a dam. The components which make a dam a particular design type, such as multiple arch dam, only consist of the formation of the structure itself regardless of the hundreds of other significant components of the dam that contribute to its function such as generators, penstocks, spillways, and other things. For example, a multiple arch dam is considered as such if its shape is representative of multiple arches regardless of the number or type of generators, penstocks, spillways, or other contributing components to the dams function. An electric transmission tower should be evaluated in a similar fashion. If the tower is in the design of a steel lattice structure, it should be considered as such regardless of the size or type of conductors, insulators, wires, guys, or foundation.\textsuperscript{110}

Instead of considering these components in the determination of the design type or style of an electric transmission tower or pole, they should only be considered as contributors to the integrity of the structure. If a wire is replaced or insulator is removed from a steel lattice transmission tower, the tower is still a steel lattice tower but the integrity of materials is compromised because the original material insulator component is gone. Towers may still be considered eligible if the insulator is replaced with a similar looking and functioning insulator, but in most cases where a tower is found eligible, all components will most likely need to be intact. In any case, an evaluator must consider

\textsuperscript{110} JRP, \textit{Water Conveyance Systems}, Introduction.
the function and engineering style of these components in order to better understand the
transmission tower or pole being evaluated.

Conductors

Conductors are generally made up of copper and aluminum metals.\textsuperscript{111} Like all
other components of an electric transmission system, the type of conductor chosen to be
used depends on the fundamental requirements of the power company choosing them.
These selection criteria are the conductivity, mechanical strength, cost, and weight of the
conductor. In most cases, the copper conductor is the best choice because it provides the
best conductivity and is the least expensive. Aluminum, however, is about 70% lighter
than copper for the proportionate size and much stronger. Other important factors that
are considered in the selection of conductors are the possibilities of voltage drops, power
loss, and mechanical strength to prevent excessive sag in the overhead line.\textsuperscript{112} For
example, transmission structure heights are dependent on the conductor size because
conductors with low tensile strength require more sag in the transmission line than
conductors with high tensile strength. Tensile strength is the strength that any given
conductor can manage without breaking or significantly wearing down. Copper
conductors are more conductive of the electricity but are smaller in size and strength thus
causing the line to sag more because it cannot hold the same structural load that
aluminum conductors can. Structural load stresses that can affect wire lines include wind

\textsuperscript{111} Sevick, Jerry. \textit{Transmission Line Transformers. 4\textsuperscript{th} Edition.} (Atlanta: Noble Publishing Corporation,
2001), 225.
\textsuperscript{112} Sevick, 226.
and ice loads.\footnote{Gonen, 670.} Because copper conductors cannot hold heavy structural loads, when using those types of conductors taller towers and shorter line spans are used.\footnote{Sevick, 227.}

The most common types of conductors in California are the ACSR, ACSR/AW, ACSR-SD, ACAR, AAC-1350, and AAAC-201.\footnote{Gonen, 59.} The ACSR contains a central core of steel surrounded by aluminum strand layers. They are labeled differently depending on the number of strands of steel and wires surrounding the core. For example, a conductor ACSR 26/7 means the conductor has 26 strands of aluminum wires around the core and 7 strands of steel wires inside the core. They are also classified by the thickness of the coating; Class A is normal thickness, Class B is medium, and Class C is heavy duty.\footnote{Gonen, 59.} The thickness of the coating is designed to keep the conductor functioning in the surrounding weather conditions. The ACSR/AW is the same as the ACSR except that its core is made of high-strength steel clad surrounded by an aluminum coating. It is designed to withstand more corrosive weather conditions than the ACSR but it is more expensive to build. The ACSR-SD contains two layers of trapezoidal-shaped strands around a steel core. These conductors are built differently to withstand very high tensions without needing auxiliary dampers. The dampers are designed to prevent aeolian (wind) vibration on the transmission lines. The ACAR conductor is lighter than the standard ACSR and has a stronger aluminum core but it is more expensive. It is designed to last longer than most standard conductors without corroding. The AAC-1350 is meant for short transmission line spans that need good conductivity. The AAAC-6201......
contains high-strength aluminum alloy strands but is a lot lighter than the standard ACSR. It is also used for long transmission line spans but is more expensive than the ACSR.117

The standard conductors previously mentioned all vary in size and are chosen depending on the needs of the system. The size of the conductor is also important because the conductor must withstand the same forces as the towers such as wind resistance and other inclement weather. For example, large conductors are generally more stable than small conductors when up against wind and ice loads because of their high inertia. Conductor sizes are based on circular mil, otherwise known as the area of a circle that has the diameter of 1 mil. The American Wire Gauge (AWG) standard, also known as the Brown and Sharpe Wire Gauge (B&S) sets the standards for the sizes of conductors by classifying small, medium, and large sizes. The sizes are described in gages. When the gage size increases the wire size decreases, and when the gage size decreases the wire size increases. The smallest gage size is 40 which is equal to a wire diameter size 3.145 mils and the largest size is number 1000 and is equal to 37 wires stranded together with a diameter size of 1,000,000 mils.118

Insulators

Insulators are exactly what their name implies; a device that stops the flow of an electric current from spreading beyond the wire and conductor. The insulator provides the clearance necessary between the conductors and ground, and conductors and towers

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117 Gonen, 59.
118 Gonen, 59.
or poles. Because insulators are designed to prevent the flow of electricity, they are generally made up of porcelain, fiberglass, and glass treated with epoxy resins. In most cases, porcelain is the common material used for insulators.  

There are several types of insulators which include the pin type, suspension type, and strain type insulators. Pin insulators are designed as they sound; the pin holds the insulator and the insulator is connected to the conductor. Pin type insulators are meant for small voltage transmission lines. Usually one piece pin insulators are used for voltages below 23 kV, two pieces are for voltages from 23 to 46 kV, three pieces for voltages from 46 to 69 kV, and for pieces for voltages from 69 to 88 kV. In most cases glass pins are used for low voltage circuits while porcelain pins are used on primary mains. Pin insulators are not used on transmission towers holding lines with voltages above 44 kV. Another version of a pin type insulator is the post type insulator. The post insulators are often installed on wood, concrete, and steel poles. Post insulators are also constructed for vertical or horizontal mounts and are made up of solid porcelain pieces. The difference between post insulators and suspension insulators is that suspension insulators contain several porcelain pieces strung together to block against higher voltages. Generally, seven disks of porcelain are used on 115-kV lines and eighteen disks are used on 345-kV lines. Suspension insulators are suspended from the pole or tower which they are connected and bound to the conductor on the other end. Finally, strain insulators, also known as dead end insulators, are used at the end of a circuit or

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119 Gonen, 63.
120 Gonen, 63.
where a transmission line system turns a curve or crosses a river. Also as the name implies, strain insulators are designed to withstand the closing off of the circuit which puts a lot of strain on the insulator.\textsuperscript{121}

Another feature used on insulators to stop surges of electricity from traveling from the conductor to the tower or pole are arcing horns or rings. Arcing horns or rings are often installed on insulators to help prevent arcs of electricity due to lightening strikes. Arcing horns stop the ‘arc’ of electricity that is surged through the wires and the conductor from reaching the towers or poles. The arc allows the electricity to travel through the horn and back to the closest point of discharge which is back to the conductor. Control rings are used in a similar manner as the arcing horns. The rings are meant for single conductor lines.\textsuperscript{122} Two good examples of types of insulators and horns on insulators are provided by Turan Gonen in Figures 8 and 9.

**Radio Noise**

Nearly all electric transmission lines give off some sort of radio noise. Radio noise is simply electromagnetic interference due to electric discharges that produces a humming or buzzing sound.\textsuperscript{123} As electricity travels through the wires of a system, it consistently discharges at points were there are gaps in the line. These gaps occur at the connections with insulators and conductors which are part of the transmission tower or pole. This noise is not directly caused by the structure of an electric transmission tower or pole but it still must be considered because it occurs as a result of the structure’s

\begin{footnotesize}
\begin{enumerate}
\item[Gonen, 63.]
\item[Gonen, 63.]
\item[Institute of Electrical and Electronics Engineers, Inc. \textit{IEEE Standard for the Measurement of Audible Noise from Overhead Transmission Lines.} (An American National Standard publication, 1985)]
\end{enumerate}
\end{footnotesize}
existence and therefore contributes to the integrity of the system. For example, when an historic building is updated by replacing its original single pane windows with new dual pane windows, the building loses integrity. Similarly, replacing transmission wires that have significant radio noise with wires that have little to no significant radio noise causes the system to lose part of its historic integrity. Therefore radio noise from overhead transmission wires still must be considered in relation to their aspects of integrity when evaluating electric transmission towers or poles.

3.5 The Guyed Tower

Any transmission line system generally has several angles where the system turns such as crossing a road or moving around a building. In many cases where an electric transmission tower or pole is not strong enough to support itself against the stresses that it must endure it must be guyed. Towers are guyed when they have little to no foundations and when there is a dramatic bend or change in the transmission line system. The guy strength acts against the horizontal stress of the tower. For example, where a transmission line system turns at a ninety degree angle, the tower placed at the corner of that turn usually has guyed support at the opposite end of the angle counterbalancing the pull of the lines on the tower. The guyed tower is generally used on flat terrain and is rigid in construction. They are designed to be lightweight and with little foundation so they are easily erected by cranes.

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124 Institute of Electrical and Electronic Engineering, *IEEE Standards.*
125 American Society of Civil Engineers. *Innovations,* 43.
There are many different types of guying techniques that are used. They are generally classified as four types: anchor guy, stub guy, pole-to-stub-to-anchor guy, and pole-to-pole guy.\footnote{Gonen, 665.} In all of these types, the guy wires are generally made of copperweld, galvanized, or bethanized steel.\footnote{Gonen, 665.} An anchor guy consists of a guy wire firmly attached to the pole by a guy clamp which is situated at the point of the pole or tower where the most force is working against the guy. The wire runs deep into the ground and is anchored down by a solid steel chunk at the end of the wire. Anchored guy wires used to be attached to a burring log, known as dead-men, but this was switched with chunks of metal when it was determined that the burring logs deteriorated too quickly to provide adequate support. Located along the guy wire away from the tower is a strain insulator. A strain insulator is designed to prevent the lower part of the guy wire from becoming electronically charged if for some reason the upper part touched a conductor or was subject to leakage. Stub guy types consist of a guy wire connected to a guy clamp at the point of most resistance with a strain insulator along the center of the wire. At the opposite end of a stub guy type is a short metal pole angled away from the tower and anchored into the ground. The guy wire is clamped to anchor guy types are built exactly as they are named. The guy wire is clamped to the pole at the point of most resistance and runs to the tip of the stub, or short metal pole. From the tip of the stub pole it then runs into the ground and is anchored with a chunk of metal. These types of guying are generally found at the end of a line for the last tower in the line because these
towers only have transmission line forces pulling them in one direction rather than two
directions and so the tower needs a more stable support. The pole-to-pole guy type is
also only used at the end of a transmission line. The guy wire is similarly clamped to the
point of most resistance on the tower but runs to another clamp on the lower end of the
previous tower in the system. This way, the last tower in the system is supported by a
stub and ground anchored guy on one end, and a guy wire clamped to the previous pole
on the other. Figure 10 created by Turan Gonen shows how a guy wire acts against the
opposing stresses of the transmission line. Figure 11 also created by Turan Gonen is a
good representation of a guy wire and its components. Figure 12 by Turan Gonen shows
the four methods how a guy wire can be used to offset the stresses on a pole.

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128 Gonen, 665.
Chapter 4

HISTORY

4.1 Discovery of Electricity

The use of electricity dates back thousands of years into prehistory. Amber, which is essentially fossilized tree resin, was the first object to be associated with electricity. Amber was first used as decoration in the form of a bead or jewel. It has brilliant gold colors which make it attractive. Amber was first used as beads by Mycenae people towards the coast of what are now Russian provinces nearly two thousand years ago. Phoenicians also traded amber jewels but it was Rome who monopolized the amber industry in ancient time. Eventually, amber developed into a popular commodity with the Greeks who valued its brilliant color. The color of the stone reminded the Greeks of the sun, which was named “Elector.” So, in Hellenic speech, the amber jewel was called “electron.”

Amber’s electric potential was discovered around the same time that it was named. Amber jewelry was worn generally by wealthy women who could also afford a spindle. As a spindle is used, the device descends at the same time it is whirling around. Regularly, the spindle would rub against a woman’s clothing and garments, notably the amber jewelry. As amber is rubbed it becomes electrified and so the rubbing motion of the spindle on the amber caused the stone to become electrified. Naturally, the woman using the spindle would notice that if she set her stone on the ground after using the spindle, dust or bits of leaves that were close would be attracted to the amber and clutch

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on to it. It was with this observation that amber jewelry began to be called the “clutcher” because it would clutch onto loose particles by invisible means.\textsuperscript{130} Most likely, this was the first intelligent observation of electricity at work.

The next object that sparked the use of electricity in ancient times is the lodestone, or magnetite, which is an ore of iron. Since lodestone has what is now called a magnetic pull, the first discoverer most likely had iron with him in order to discover the magnetic pull at all. Not only does lodestone attract iron objects but it also has polarity. Polarity is seen when opposite ends of the stone effect each other and forces itself nearly in the line of a meridian of the earth, which are the north and south direction.\textsuperscript{131} The first recorded use of lodestone by ancient civilizations was by emperor Huang-ti of China in 2637 B.C. Huang-ti had a chariot where a figure of a woman was mounted with her hand outstretched and pointing. The woman figure was suspended so that it was free to turn and the outstretched arm contained lodestones so that it always pointed south. Chinese historians also have written about similar vehicles used with magnetic properties from lodestones. The Chinese also discovered that steel needles could be permanently magnetized by lodestones and they became the first compasses used.\textsuperscript{132}

The earliest written record of the electrical properties of amber came from Theophrastus around 300 B.C. Theophrastus was a student of Aristotle and eventually succeeded him as teacher at Lykeum.\textsuperscript{133} Theophrastus was the first to bring amber and lodestone into the same class of stone because of the attractive qualities they both

\textsuperscript{130} Benjamin, 18.
\textsuperscript{131} Benjamin, 19.
\textsuperscript{132} Meyers, Herbert W. \textit{A History of Electricity and Magnetism}. (Norwalk: Burndy Library, 1972), 2.
\textsuperscript{133} Benjamin, 39.
possessed. Theophrastus wrote how amber, like lodestone, when rubbed could attract many different types of tiny objects, while lodestone could only attract iron. Among the earliest known written record that mentions the use of electrical properties was between 23-79 A.D.\textsuperscript{134} Pliny the elder wrote about electric properties in his \textit{Natural History} when he mentioned Etruscans, who lived about 600 B.C., were able to use amber to draw lightening down, though he does not mention how this was done.\textsuperscript{135} Greek and Roman thinkers continued to work with the electric properties of amber and lodestone until Rome began to fall. The developments of electricity halted after the fall of Rome and Greece and became limited almost entirely to the Chinese, though little advancements were made by them. The period of European history known as the Dark Ages, or Middle Ages, saw little development in electrical properties until the period known as the Renaissance. The Renaissance, named for the rebirth of classical Greece and Rome antiquity in Europe, was marked with more rapid intellectual progress than any other time in human history. Among the invention and use of gunpowder, printing, telescope, and even the new world; electric properties were also experimented with.

\textbf{Electric Machines}

William Gilbert, an Englishman from Colchester, practiced mainly medicine at St. Johns College in Cambridge, London in the late 1500s.\textsuperscript{136} William Gilbert also spent nearly seventeen years of his life researching the available writings on electric properties. He compiled his research into a large volume entitled \textit{De Magnete, Magneticisque}

\textsuperscript{134} Meyers, 4.
\textsuperscript{135} Meyers, 5.
\textsuperscript{136} Meyers, 8.
Corporibus, et de Magno Magnete Tellure; Physiologia Nova, Pluribus et Argumentes et Experimentis Demonstrata, also more commonly known as De Magnete.\textsuperscript{137} He published his research in 1600, only three years before his death. The Latin volume contains a long list of materials that could be electrified as well as a description of a devise he created called a versorium. The devise was similar to that of an electroscope which detects the amount of electric charge in a body. Gilbert was the first person to use the term “electricity” which he created from his research on the Greek use of the word “electron.” Gilbert died in 1603, only two years after he was appointed court physician to Queen Elizabeth.\textsuperscript{138}

The first electrical machine was created in 1660 by Otto von Guericke. His machine contained a sulfur ball that is cast in a glass globe mounted on a shaft that passed through its center. The ball was rotated with a crank and excited by friction when dry hands or a cloth touched it. The machine made crackling noises and produced sparks that von Guericke noted. This experiment also marked the first transmission of electricity. Von Guericke attached a piece of string several feet long to the machine and wrote how the electricity traveled through the string to the opposite end.\textsuperscript{139} Though there is evidence of this experiment in von Guericke’s notes, the official discovery of electric transmission was not until the seventeenth century.

4.2 First Electric Transmission

\textsuperscript{137} Meyers, 8.
\textsuperscript{138} Meyers, 10.
\textsuperscript{139} Meyers, 12.
Stephen Gray is the noted discoverer of electrical transmission. Like most scientists during this period, his early experiments consisted of rubbing certain materials to build static electricity. Eventually, Gray began a series of small experiments that led to the discovery of electrical transmission. In 1729, he first came up with the idea of electric communication, or transmission, while experimenting with electric currents in glass tubes. He used a flint glass tube and electrified it by rubbing it, as had been for years prior to Gray to electrify materials. The glass tube was corked at each end so dust would not be allowed inside because this would have reduced the electric charge build up in the tube.\textsuperscript{140} Gray then noticed that when he applied a feather to the tube to be attracted, as previous experiments had shown, the feather was attracted to the cork rather than the glass. He called this phenomenon “attractive Vertue” and attempted the transfer of electric currents with many different materials, particularly metals. Gray succeeded in discovering that metals possessed the ability to transfer electric currents far greater than other materials. With this discovery, Gray began experimenting with longer and longer poles and lengths until May of 1729 when he reached 52 vertical feet. He suspended 34 feet of thread from an 18 foot pole inserted in the tube. Up to this point, vertical transmission was the only plausible form of electric transmission because there was no invention capable of horizontally supporting the string (or other material used in the transmission) that would not take the charge away from the line. In other words, there

\textsuperscript{140} Heilbron, J. L. \textit{Electricity in the 17th and 18th Centuries: A Study in Early Modern Physics}. (Mineola: Dover Publications, Inc., 1979), 245.
was no insulator. Stephen Gray then brought his discoveries to his wealthy friend and scientist Granville Wheler in 1729.\textsuperscript{141}

Granville Wheler and Stephen Gray attempted to transmit electricity horizontally using the same thread that Gray had used in his vertical transmission experiments. Wheler thought that using silk supporters to hold up the thread would help keep the electric current from losing its “Vertue” because silk was so small (narrow). This experiment worked, expanding the electric transmission from 52 feet to several hundred feet. Eventually, the silk broke under the strain of the thread and a sturdier support system was needed. Wheler and Gray then attempted to use a brass wire because it was stronger and could support the weight of the thread. This experiment did not work but instead led to the discovery that the material supporting the thread was just as important as the thread transmitting the current itself. Gray stated “The success we had before, depended upon the lines that supported the line of communication, being silk, and not upon their being small.”\textsuperscript{142} This discovery led to the determination by Gray that some materials acted as conductors of electric current while others were nonconductors.\textsuperscript{143}

\textbf{Franklin and American Electricity}

Many scientists experimented with electricity and its different properties during the 18\textsuperscript{th} century. Benjamin Franklin was the first American to make a contribution to the study of electric properties.\textsuperscript{144} His experiments focused solely on the demonstration that lightning was an electric discharge given from the atmosphere. He performed a kite

\textsuperscript{141} Heilbron, 246.
\textsuperscript{142} Quoted in Heilbron, 247.
\textsuperscript{143} Meyers, 17.
\textsuperscript{144} Meyers, 22.
experiment in 1752 in which he successfully charged a Leyden Jar attached to a kite string during a thunderstorm. A Leyden Jar is basically a condenser that concentrates electricity and stores it in fluid in a glass jar. The Leyden Jar was created by E.G. von Kleist of Germany, but was credited to professor Pieter van Musschenbroek and his assistant Cunaesus from Leyden, Holland. Franklin’s kite experiment occurred months after French scientists Dalibard and Delor had successfully conducted the same experiment charging Leyden Jars with metal rods elevated high in the air during a thunderstorm. Franklin performed many other experiments with electricity and became known for being the first true American scientist in the field.

4.3 Telegraph

The potential of electric transmission to perform a variety of significant tasks was understood almost instantly. The telegraph was invented in many different forms by a number of scientists all around the same time. In 1749, John Winkler created a telegraph that traveled only from one room to another and consisted of as many wires as there were characters to transmit. In 1787, Lomond created a single wire telegraph with a pith ball electroscope at the receiving end and in 1794 Reizen built one with multiple wires in which sparks were emitted from the receiving end and used to identify the character. Several other telegraphs were invented between 1794 through 1837 when Samuel Morse demonstrated his simple, yet most long lasting telegraph.

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145 Meyers, 24.
146 Meyers, 95.
Samual F. B. Morse was both an artist and scientist. He acquired his undergraduate degree at Yale University, spent four years in England studying art, and founded the National Academy of Design in 1825.\textsuperscript{148} Two years later studied electromagnetism at Columbia College which revived his interest in science. Morse’s telegraph machine was built to send and receive messages by mechanical means. His device was basic and operated by means of impulses which caused a pendulum to swing which held a pencil causing the pencil to draw a line. The mark on the paper then was translated into a dash and dot which correlated with a code of numbers. Those numbers then correlated into words by means of a dictionary, thus Morse code was created. It was with the demonstration of this telegraph on September 2, 1837 that Morse caught the interest of Alfred Vail, owner of Speedwell iron Works of New Jersey. Samual Morse and Alfred Vail entered into a partnership in which the Speedwell Iron Works would construct the Morse telegraph and produce it for use. This was the first instance which involved the partnership agreement between two interested parties resulting in the production and distribution of a device containing electric transmission components. Alfred Vail improved the Morse telegraph and in New York in January 1838, the first public demonstration of the telegraph was held. Ten miles of insulated copper wires were used to transmit the electricity.\textsuperscript{149}

4.4 First Pole Structures

\textsuperscript{148} Meyers, 97.
\textsuperscript{149} Meyers, 103.
The government first came involved in electric transmission in 1842 when Congress submitted a bill appropriating $30,000 for the construction of a telegraph line by Samuel Morse and his associates. The bill was passed in February the next year by a vote of eighty-nine to eighty-three in the House. It based the Senate in March that same year without opposition. The line was proposed to be between Washington and Baltimore and laid underground. The construction of the underground line proved too difficult because welding the pipes together caused the wires inside to become destroyed. Approximately 2/3rds of the budget appropriated by the government was spent before the construction of the underground line was halted. Morse and his associates then determined that the best method to hold the wires was to erect poles and align them with the Baltimore and Ohio Railroad right-of-way. He used the materials that were purchased to encase the wire underground as the poles. These consisted of metal tubing and insulators around the conductors. This is the first instance where a pole structure was used to hold an electric transmission wire. Morse and his associates called the new pole towers “spars.” They were described as 30 feet high and placed at intervals of 200 to 300 feet. Since the copper wire used for the electric transmission was generally very small in size, and the distance between the poles was so great, there were many issues with the wires breaking and becoming entangled with each other during high winds or storms. The money appropriated to Morse was sufficient enough for him to purchase enough wire to span four times the distance between Baltimore and Washington which proved to be plenty to make the necessary repairs in the system. The copper wires were insulated from

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150 Meyers, 106.
the poles, but no description of these insulators was recorded by Morse or the
construction team but most likely glass was used. The line was completed in 1844 and
the first official test was held in May of that year. The first message came from Miss
Ellsworth as a request by Morse. Miss Ellsworth selected a passage from the Book of
Numbers in the Bible and transmitted it from Washington with Morse and many others
present; “What hath God wrought!” which was replied by Alfred Vail from the Baltimore
end with the same message.151

4.5 California Electric Transmission

The telegraph expanded electric transmission in a great many ways over the next
several years. By the mid-1800’s most of the significant developments in electric
transmission were made and in use. It was in 1879 when Thomas Alva Edison invented
the incandescent light bulb, that electric transmission began its next great set of
developments in modern history. Edison contributed to the development of new systems
of power generation and distribution which initiated the development of the electric
utility industry.152

After Edison invented the light bulb, the 1880’s saw a splurge of electric utility
companies develop in California.153 Edison’s Read Street Station began operating in
1882. Most of these electric utility companies used low-voltage direct current (D.C.)
dynamos which could only transmit electricity about three miles. Since the transmission
distance was not too great, only urban areas where populations were dense could

151 Meyers, 107.
153 JRP Historical Consulting Services, Transmission Lines in Stanislaus Corridor.
economically be served by these early companies. The California Electric Light Company from San Francisco was the first to begin running long distance electric transmission lines in California starting in 1879. The California Electric Light Company had difficulty with their long distance lines because the D.C. system only allowed for short transmission. Nikola Tesla and William Stanley were the first to develop an alternating current (A.C.) for electric lighting. The A.C. system allowed higher voltages of electricity to be transmitted through the line than the D.C. system could handle. In 1890, four California cities; Santa Barbara, Visalia, Pasadena, and Highgrove, began to use this new technology in their power plants. Also introduced was the “converter,” now called a transformer. The transformer reduced the high distribution voltage from the transmission line to a lower voltage to be used in houses with interior wiring.

The 1890’s saw even greater advancements in electric transmission. The San Antonio Light and Power company began using an oil-filled “step-up” transformer. The “step-up” transformer was created 1892 by Almarius William Decker and was used to convey 10,000 volts of A.C. current about fourteen miles from San Antonio Canyon to Pomona. Before Decker’s invention, 1,000 volts was the largest voltage that lines could transmit. Shortly after this fourteen-mile line, a twenty-eight mile line was built by the same company and extended from San Antonio Canyon to San Bernardino. In 1899, the Edison Electric Company built the longest line to date, an eighty-three mile

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154 JRPHistorical Consulting Services, *Transmission Lines in Stanislaus Corridor.*
156 JRPHistorical Consulting Services, *Transmission Lines in Stanislaus Corridor.*
157 JRPHistorical Consulting Services, *Transmission Lines in Stanislaus Corridor.*
transmission line from the Santa Ana River to Los Angeles. They were able to achieve the extraordinary lengths by using glazed porcelain insulators which could handle up to 40,000 volts of electricity. The length of transmission lines only continued to expand into the 20th century. Bay Counties Power Company built a 142 mile long transmission line in 1901 which brought power from the Colgate Powerhouse in the Sierra Nevada to Oakland. They used cedar poles as the structure support which held copper and aluminum wires. This transmission line was even more impressive by the 4,427 foot expansion it made crossing the Carquinez Straits. The construction engineer responsible for the project was John Debo Galloway. Galloway is given credit for designing and constructing the cable span which was the longest in the world at the time. Galloway’s transmission line was also the first electrical power produced in the Sierra Nevada and crossed the mountains into the Sacramento Valley. The power from this transmission line was then used by Bay Area residents. Galloway lived from 1869-1943 and is recognized as one of the major pioneers in the design of electric transmission facilities, lines, and towers in California.

The hydroelectric industry of the early 20th century was a major contributor to the development of electric transmission in California. Between 1900 and 1910 California’s population increased by 60 per cent and with that expansion came the high demand for electricity. California’s first hydroelectric plant was the Folsom Powerhouse on the

159 JRP Historical Consulting Services, *Boulder-San Bernardino Transmission Line.*
160 JRP Historical Consulting Services, *Boulder-San Bernardino Transmission Line.*
American River in Sacramento County which began service in 1895. From this period until the end of World War II, hydroelectric systems evolved heavily in design and engineering. Hydroelectric companies in California provided a network of long distance electric transmission lines. The Bay Counties Power Company and the Standard Electric Company in 1902 had nearly complete electric coverage of the Bay Area and places like Stockton, Amador City, and Marysville.

The Edison Electric Company built a 118 mile long transmission line in 1907. This transmission line carried 75,000 volts to Los Angeles from the Kern River No. 1 hydroelectric plant. This transmission line system was the first line to use steel towers as the supporting structure. The towers were built by the Wind Engine Company which was a windmill manufacturer.

Some of the largest and most significant hydroelectric projects in California started in the late 1920s. The Big Creek Hydroelectric System is owned by the Southern California Edison Company. The Central Valley Project is owned by the federal government but was conceptualized by the State of California. The Big Creek Hydroelectric system, in 1929, generated a total of 424,500 kw operating across 36 miles of tunnels; a huge project in California during that time in hydro engineering. The project employed John Eastwood, a pioneer in dam engineering and design, for a number

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164 JRP Historical Consulting Services, *Boulder-San Bernardino Transmission Line*.
165 JRP Historical Consulting Services, *Boulder-San Bernardino Transmission Line*. 
of years during the project. The Central Valley Project was one of the largest water conveyance projects ever undertaken. It was constructed as a reaction to the growing state of California’s population including water and electricity needs. The CVP originally consisted of five central units; Shasta Dam, Delta-Mendota Canal, Friant Dam, Friant-Kern Canal, and the Contra Costa Canal. The main operation of these units was to deliver Sacramento River Water from the north of California to the dry San Joaquin Valley. It now operates over 11 divisions/units across California. The Nevada Irrigation District (NID) began the Yuba-Bear river project in 1963, harnessing the Yuba and Bear rivers. PG&E partnered with NID on the Yuba-Bear river hydroelectric project which now provides enough electricity to power 60,000 homes. Today, Southern California Edison Company and PG&E own and operate a large share of hydroelectric systems in California. The Central Valley Project, owned by the Bureau of Reclamation, is still the largest multi-purpose hydroelectric project in California. PG&E currently owns and operates nearly 500 miles of hydroelectric systems throughout California with a generating capacity of 3,896 megawatts powering over 4 million homes. In recent decades electric companies throughout California, led by industry giants PG&E and Southern California Edison Company, continue to expand their electric transmission systems to reach further and provide greater energy than ever before.

166 JRP, Water Conveyance Systems, 67.
167 JRP, Water Conveyance Systems, 74.
168 Coleman, 257.
Chapter 5

CONCLUSION

As a result of this study it is concluded that electric transmission structures in California may be considered eligible for inclusion on the National Register of Historic Places. In accordance with the National Historic Preservation Act (NHPA) and the California Environmental Policy Act (CEQA), these structures may be considered historic properties or historic resources and should be treated as such for any government undertaking or agency project. California history shows that advancements in electric transmission have provided a much-needed service to the State and its communities. The engineering styles and designs of these electric transmission structures are also significant contributors to their historic integrity and overall significance. The systematic approach to evaluating these types of structures for the National Register of Historic Places provided in this study should be used by both government and private agencies when conducting their undertakings or projects in California. All evaluations in California should follow this guide in order to establish a more objective rather than subjective review process. The State Historic Preservation Officer (SHPO) benefits from a systematic approach to evaluating these properties because this allows for a consistent concurrence process from his office with the findings. The platform of existing knowledge on evaluating electric transmission structures that this guide provides is a benefit to historic preservation and everyone involved in the process’ that occur to protect and preserve the cultural resources of California.
ACRONYMS AND ABBREVIATIONS

ACHP Advisory Council on Historic Preservation
APE Areas of Potential Effect
CEQA California Environmental Quality Act
CFR Code of Federal Regulations
CHRIS California Historic Resources Information System
CRHR California Register of Historic Resources
DPR Department of Parks and Recreation
NEPA National Environmental Policy Act
NHPA National Historic Preservation Act
NRHP National Register of Historic Places
OHP Office of Historic Preservation
PRC Public Resources Code
SHPO State Historic Preservation Officer
GLOSSARY OF TERMS AND DEFINITIONS

Area of Potential Effects (APE) – The APE is the geographic area or areas where an undertaking may cause changes in the character or use of historic properties.

Cultural Resources – Refers to those nonrenewable remains of human activity, occupation, artifacts, ruins, works of art, architecture, and areas of religious significance that were of importance in human events. These resources consist of physical remains and areas where significant human events occurred – even though physical evidence of such events no longer exists and the physical setting immediately surrounding the actual resource has changed.

District – A district, or historic district, possesses a significant concentration, linkage, or continuity of sites, buildings, structures, or objects united historically or aesthetically by plan or physical development. A district derives its importance from being a unified entity, even though it is often composed of a wide variety of resources, and from its significance. It must be important for historical, architectural, archaeological, engineering, or cultural values.

Guideline - A statement of recommended, but not mandatory, practice in typical situations, with deviations allowed if professional judgment or scientific/engineering study indicates the deviation to be appropriate.

Historic – Referring to the time after written records or after the Europeans first came and wrote about the people and events in America.

Historic Buildings and Structures – Also known as Architectural and Engineering Properties. Resources that could include districts, sites, buildings, structures, or other objects associated with or that convey some aspect of American history, architecture, engineering, and/or culture.

Historic Preservation – The research, excavation, protection, restoration, and rehabilitation of buildings, structures, objects, districts, areas, and sites significant in the history, architecture, archaeology, or culture of the local area or the nation.

Historic Properties – Those properties determined eligible for listing on the National Register of Historic Places. These may include historic and prehistoric archaeological sites, districts, buildings, structures, and objects.

Integrity – The ability of a property to convey its significance through seven aspects which contribute to the character defining features of a property or resource; which are location, design, setting, materials, workmanship, feeling, and association.
Preservation – The act or process of applying measures necessary to sustain the existing form, integrity, and materials of an historic property. Work, including preliminary measures to protect and stabilize the property, generally focuses upon the ongoing maintenance and repair of historic materials and features rather than extensive replacement and new construction. New exterior additions are not within the scope of this treatment; however, the limited and sensitive upgrading of mechanical, electrical, and plumbing systems and other code-required work to make properties functional is appropriate within a preservation project.

Properties Eligible for Inclusion in the National Register – Properties that have been formally determined to be eligible and all other properties that meet the National Register criteria.

Rehabilitation – The act or process of making possible a compatible use for a property through repair, alterations, and additions while preserving those portions or features that convey its historical, cultural, or architectural values.

Standard - A statement of required, mandatory, or specifically prohibitive practice regarding land management, safety, or other procedures.
APPENDIX A

Explanation of Appendix

As part of this study, previous cultural resource reports that evaluated electric transmission structures needed review. The California Historic Resources Information System (CHRIS) contains all the documentation on previous cultural resource reports, site records, and maps in their system available for review. Normally, the Information Centers charge a fee based by the hour for research and information gathered from their locations. A graduate student at a California State University is allowed free cultural resource investigations at the Information Centers with a written notification of attendance at the University. The North Central Information Center at Sacramento State University and the Northwest Information Center at Sonoma State University were visited with this written notification and free research was conducted. **APPENDIX A** is a copy of the written notification from Professor Lee Simpson which was provided to the Information Centers upon arrival.
Feb. 11, 2010

RE: Access to CHRIS Information Centers for Jeremy Adams

Dear IC representatives,

Jeremy Adams is a graduate student in the Public History Program at California State University, Sacramento. He is currently conducting historical research for his thesis project tentatively titled “Guide to Evaluating Electric Transmission Towers in California; Historical Context, Section 106, and the National Register Criteria.” It will benefit his research to have access to the California Historical Research Information System to gather reports, site records, and survey information on previously evaluated electric transmission systems. Please grant him access to your Information Center as a student without charge from this date until the end of the semester May 21, 2010. If you have any questions, comments, or concerns please do not hesitate to contact me.

Sincerely,

Lee Simpson
Director, Public History Graduate Program
Figure 1: Pole Structure Arm Configurations 1

(a)  
(b)  
(c)  

(d)  
(e)  

Figure 2: Pole Structure Arm Configurations 2

(a)  
(b)  
(c)  
(d)  
Figure 3: Pole Foundation Types
Figure 4: Lattice Tower Structure Types 1
Figure 5: Lattice Tower Structure Types 2
Figure 6: Lattice Tower Structure Types 3
Figure 7: Lattice Tower Structure Types 4
Figure 8: Insulator Configurations

Figure 9: Insulator Types
Figure 10: Guy Wire Force Exertion

(a) 

(b)

Figure 11: Guy Wire Components

Thimble-eye 

Strain insulator

Guy wire

Pole

Guy guard

Anchor rod

Anchor
Figure 12: Guy Wire Angles

(a) Guy clamp → Strain insulator

(b) Guy clamp → Strain insulator

(c) Anchor guy → Guy → Dead ended line

(d) Through line → Guy → Dead ended line
REFERENCES


______. Site Record for the PG&E Newark-San Jose Transmission Line, 2002. On file at the Northwest Information Center, Sonoma State University.

______. Results of Supplemental Historical Data Gathering for the Boulder-San Bernardino Transmission Line (CA-SBR-10315H) and Linear Archaeological Feature CA-SBR-12574. On file at the California Energy Commission.


