



Before the  
Pennsylvania Public Utility Commission

**DAUPHIN - COPPERSTONE  
#1 & #2 138/69 kV LINE**

RECEIVED  
2010 MAR 16 PM 3:48  
SECRETARY'S BUREAU

**EXHIBITS AND APPENDICES IN SUPPORT OF THE  
LETTER OF NOTIFICATION**

Application Docket No. \_\_\_\_\_

Submitted by: PPL Electric Utilities Corp.

## SUMMARY

This filing is submitted by PPL Electric Utilities Corporation (PPL Electric), pursuant to the Pennsylvania Public Utility Commission's (PUC or the Commission) regulations at 52 Pa. Code §§ 57.71 through 57.77, for Commission approval to reinforce the 230 kV and 69 kV systems in central Dauphin County. As part of this reinforcement, PPL Electric proposes to construct the Copperstone 230-69 kV Substation ("Copperstone Substation"). This Project involves the construction of three separate transmission lines. Each transmission line will be connected to the Copperstone Substation. Each transmission line will be the subject of a separate filing.

Here, PPL Electric seeks the Commission's approval of Part 2 of the Project, the construction of the new Dauphin - Copperstone #1 & #2 138/69 kV Transmission Line, which will be approximately 0.53 miles. This Project is located in South Hanover and Lower Paxton Townships, Dauphin County. Studies conducted for PPL Electric's transmission system, in conjunction with the PJM Regional Transmission Expansion Process ("RTEP"), revealed several transmission line thermal overload violations pertaining to the Bulk Electric System ("BES," generally defined as 100 kV and above), as well as PPL Electric's underlying 69 kV transmission system and substation equipment in the summer of 2012.

The estimated cost to site, design, and construct the transmission facilities for Part 2 of the Project is \$1,857,000. Construction is scheduled to begin in March 2011, to support the project's in-service date of May 2012.

This document, which describes the need for the project and discusses the engineering and siting analysis for the proposed construction, consists of the following exhibits and appendices:

**Exhibit “A”-Necessity Statement**

**Exhibit “B”-Engineering Description**

**Exhibit “C”-Environmental Assessment**

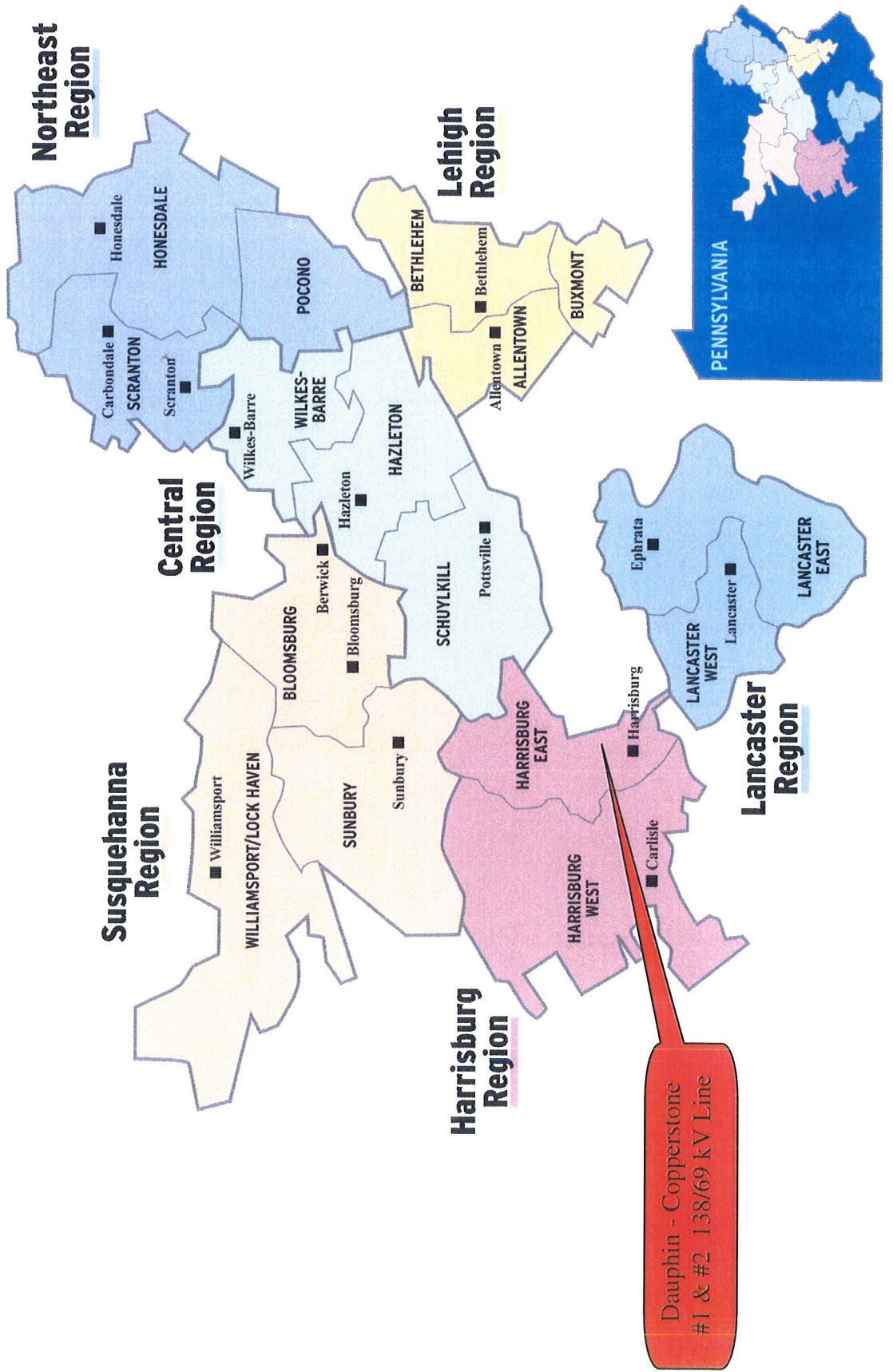
**Appendix A-PPL Design Criteria and Safety Practices**

**Appendix B-Magnetic Field Management at PPL Electric**

**Appendix C- List of property owners within the proposed Right-of-Way**

**Appendix D -List of Involved Governmental Agencies, Municipalities, and Other Public Entities**

# PPL ELECTRIC UTILITIES SERVICE TERRITORY



# **Exhibit**

# **A**

**EXHIBIT "A"**

**DAUPHIN - COPPERSTONE #1 & #2 138/69 kV LINE**

**NECESSITY STATEMENT**

---

**TABLE OF CONTENTS**

<b><u>SECTION</u></b>	<b><u>TOPIC</u></b>	<b><u>PAGE</u></b>
A.	INTRODUCTION.....	1
B.	EXISTING SYSTEM.....	2
C.	DEFINITION OF THE PROBLEM.....	3
D.	PROPOSED SOLUTION.....	4
E.	FUNCTIONAL ALTERNATIVES.....	5

**LIST OF FIGURES**

FIGURE 1 EXISTING ONE-LINE DIAGRAM

FIGURE 2 FUTURE ONE-LINE DIAGRAM

**MAP**

MAP 1 PPL ELECTRIC SYSTEM MAP

Exhibit "A"  
Map Pocket

## EXHIBIT "A"

### DAUPHIN - COPPERSTONE #1 & #2 138/69 kV LINE

#### NECESSITY STATEMENT

---

##### A. INTRODUCTION

PPL Electric proposes to construct the Copperstone 230-69 kV Substation ("Copperstone Substation") to reinforce the 230 kV and 69 kV systems in central Dauphin County. This Project involves the construction of three separate transmission lines that will connect to the Copperstone Substation. Each transmission line will be the subject of a separate filing with the Commission.

In Part 2 of the Project, which is the subject of this filing, PPL Electric requests Commission approval to construct the proposed 0.53 mile Dauphin - Copperstone #1 & #2 138/69 kV Transmission Lines. The proposed Dauphin - Copperstone #1 & #2 138/69 kV Transmission Lines will connect with the proposed Copperstone 230-69 kV Substation. The Dauphin - Copperstone #1 and #2 138/69 kV Transmission Lines will tie into the existing Hummelstown-Harrisburg #3 & #4 69 kV Transmission Lines, just west of the proposed Copperstone substation, and also utilize the existing Dauphin - Paxton 69 kV Transmission Line. The resulting line, including this portion of the existing Hummelstown-Harrisburg #3 & #4 69 kV Transmission Lines and the existing Dauphin - Paxton #1 and #2 69 kV Transmission Line will be renamed the Dauphin - Copperstone- #1 & #2 138/69 kV Transmission Lines. This line will be designed for 138 kV operation, although it initially will be operated at 69 kV. Conversion to 138 kV operation will occur when increasing demand for electricity approaches the limit of operation at 69 kV, at which time PPL Electric will seek Commission approval to reconstruct for 138 kV operation the portions of the Dauphin-Copperstone Line that were formerly named the Hummelstown-Harrisburg #3 & #4 69 kV and Dauphin-Paxton #1 & #2 69 kV Transmission Lines.

In Part 1 of the Project, a different portion of the existing Hummelstown-Harrisburg #3 & #4 69 kV Transmission Lines will be connected with the proposed Copperstone 230-69 kV Substation

by constructing approximately 1.33 miles of new double circuit 138/69 kV line, initially operated at 69 kV. This will create the new Copperstone - Harrisburg #1 & #2 138/69 kV Transmission Lines. On February 12, 2010, a Letter of Notification was filed at Docket No.# A-2010-2159604, requesting PUC approval of Part 1 of the Project.

Finally, in Part 3 of the Project, PPL Electric proposes to construct two new 230 kV taps to connect with the proposed Copperstone 230-69 kV Substation. One tap will be the proposed Middletown Junction–Copperstone 230 kV Tap, and the second tap will be the proposed Copperstone–North Lebanon 230 kV Tap. These 230 kV taps will connect the proposed Copperstone Substation to the existing Metropolitan Edison Middletown Junction- North Lebanon 230 kV Transmission Line by splitting this line in the area of the proposed Copperstone Substation. These 230 kV taps will be the subject of a subsequent filing with the Commission.

The estimated costs to site, design, and construct the transmission facilities for Part 2 of the Project are approximately \$1,857,000. Part 2 has a scheduled construction start date of March 2011, to meet a required in-service date of May 2012. The required in-service date is defined as the date that the proposed facility must be placed in service to prevent overloads or unacceptable voltage levels that could potentially damage equipment and result in service interruptions to customers.

A PPL system map showing existing transmission facilities with a design voltage of 35 kV or greater is included in the Exhibit “A” map pocket. This filing addresses only the existing and proposed transmission system in central Dauphin County.

## **B. EXISTING SYSTEM**

Presently, central Dauphin County receives the bulk of its electric power from two sources, the Hummelstown 230-69 kV Substation and the Dauphin 230-69 kV Substation. The existing 69 kV transmission lines that exit these substations deliver electric power to various 69-12 kV substations throughout central Dauphin County. The existing transmission arrangement is shown in Figure 1.

### **C. DEFINITION OF THE PROBLEM**

Studies conducted for PPL Electric's transmission system, in conjunction with the PJM RTEP (Regional Transmission Expansion Process), revealed several transmission line thermal overload violations pertaining to the Bulk Electric System (BES, generally defined as 100 kV and above) in central Dauphin County, as well as the PPL Electric underlying 69 kV transmission system and substation equipment in the summer of 2012.

The studies indicated that NERC and PJM violations are likely to occur on PPL Electric's 230 kV electric system in central Dauphin County under N-1-1 conditions. An N-1-1 condition is defined as one 230 kV line outage, followed by a subsequent second 230 kV line outage. The studies conducted for PPL Electric's summer peak transmission system for the year 2012 indicated the following N-1-1 conditions are likely to cause overloads on the BES system in central Dauphin County:

- By the summer of 2012, under forecasted summer peak load conditions, a forced outage of the Dauphin–Juniata 230 kV Transmission Line and a subsequent outage of the Hummelstown–Middletown Junction #1 230 kV Transmission Line would overload the Hummelstown-Middletown Junction #2 - Steel Tap 230 kV Transmission Line.
- By the summer of 2012, under forecasted summer peak load conditions, a forced outage of the Dauphin–Juniata 230 kV Transmission Line and subsequent outage of Hummelstown–Middletown Junction #2 - Steel Tap 230 kV Transmission Line would overload Hummelstown-Middletown Junction #1 230 kV Transmission Line.

The studies also indicated that, in violation of PPL Electric Reliability Principles and Practices (RP&P), the following overloads will occur on PPL Electric's 69 kV system in central Dauphin County for single contingency operations:

- The Dauphin 230-69 kV Substation is designed with two 230-69 kV transformers. By the summer of 2012, under forecasted summer peak load conditions, a forced outage of either transformer at the Dauphin 230-69 kV Substation would overload the remaining transformer.
- The Hummelstown 230-69kV Substation is designed with three 230-69 kV transformers. By the summer of 2012, under forecasted summer peak load conditions, a forced outage of one transformer at the Hummelstown 230-69 kV Substation would overload the remaining 230-69 kV transformers.
- By the summer of 2012, under forecasted summer peak load conditions, a forced outage of the Hummelstown–Harrisburg #1 and #2 69 kV Transmission Line would cause overloads on the Hummelstown–Harrisburg #3 and #4 69 kV Transmission Line .
- By the summer of 2012, under forecasted summer peak load conditions, a forced outage of the Hummelstown–Harrisburg #4 69 kV Transmission Line or the Harrisburg Substation 69 kV bus section #3, would cause overloads on the Hummelstown–Harrisburg #3 69 kV Transmission Line.

#### **D. PROPOSED SOLUTION (SEE FIGURE 2)**

To resolve the issues discussed above, PPL Electric, with the Commission’s approval, proposes the following:

Construct the new Copperstone 230-69kV Substation. The Copperstone Substation would be constructed with a 230 kV four breaker ring bus and will be supplied power via two short 230 kV single circuit taps from the existing Middletown Junction-North Lebanon 230 kV Transmission Line. The single circuit 230 kV taps will supply two 230-69 kV 150 MVA transformers that will provide power supply to the 69 kV system. From the 69 kV system, four short 138/69 kV

overhead transmission lines (two double circuit lines) will be constructed and sectionalized into the existing Hummelstown – Harrisburg #3 and #4 69 kV Lines: one double circuit line approximately 1.3 miles and one double circuit line approximately half a mile long.

This reinforcement alternative resolves all the overloads explained in section C above, and provides additional capacity for future electric system load growth.

This alternative will have the least amount of impact because it requires the construction of relatively short overhead transmission lines utilizing mostly existing rights-of-way and a small amount of recently acquired rights-of-way. Further, this project will not require extensive outages of the existing facilities, which would maintain reliable electric service to the customers in the area during construction. Hence, this option is considered the preferred option.

The estimated cost of this Alternative is \$28 million, which includes the total estimated cost to site, design, and construct all overhead transmission facilities and the 230-69 kV substation.

## **E. FUNCTIONAL ALTERNATIVES**

Alternative 2 – Upgrade the following substations and 69kV transmission lines:

- Add a 3<sup>rd</sup> 230-69 kV transformer at the Dauphin 230-69 kV Substation.
- Add a 3<sup>rd</sup> 230-69 kV transformer at the West Shore 230-69 kV Substation.
- Rebuild the West Shore–Harrisburg #1 and #2 69 kV Transmission Lines.
- Build a new double circuit 69 kV line from the Hummelstown 230-69 kV Substation to the Duke 69kV tap.
- Build a new 230 kV line from the Hummelstown 230-69 kV Substation to the Middletown Junction 230 kV Substation.

The total estimated cost of the Alternative 2 projects would be approximately \$43.0 million.

This reinforcement alternative also resolves the contingency overloads explained in section C above and provides long term capacity upgrades for future growth. However, Alternative 2 has

several deficiencies when compared to the preferred option. Specifically, Alternative 2 was not selected as the preferred option due to the following:

- More expensive.
- Requires extensive new rights-of-way for 230 kV and 69 kV transmission lines.
- Requires extensive outages at several substations and on the 69 kV transmission systems, thus reducing reliability to customers supplied from these transmission lines.

### Alternative 3

Construct a new 230-69 kV substation at the PPL Electric's existing Steelton 230 - 69 kV Substation. Construct four new 138/69 kV lines from the new 230-69 kV substation and sectionalize them into the existing West Shore–Harrisburg #1 and #2 69 kV Transmission Lines.

In addition, Alternative 3 would require the following upgrades:

- Install a 3<sup>rd</sup> 230-69 kV transformer at the Dauphin 230-69 kV Substation.
- Rebuild 2 miles of the West Shore–Harrisburg #1 and #2 69 kV Transmission Lines from the Harrisburg 69 kV Substation to the Steelton–Harrisburg 69 kV Transmission Line tap point.
- Rebuild the Steel 230 kV Tap from the Hummelstown-Middletown Junction #2 230 kV Transmission Line to Steelton Substation with higher capacity conductors.
- Build a new 230 kV line between the Hummelstown 230-69 kV Substation and the Middletown Junction 230kV Substation.

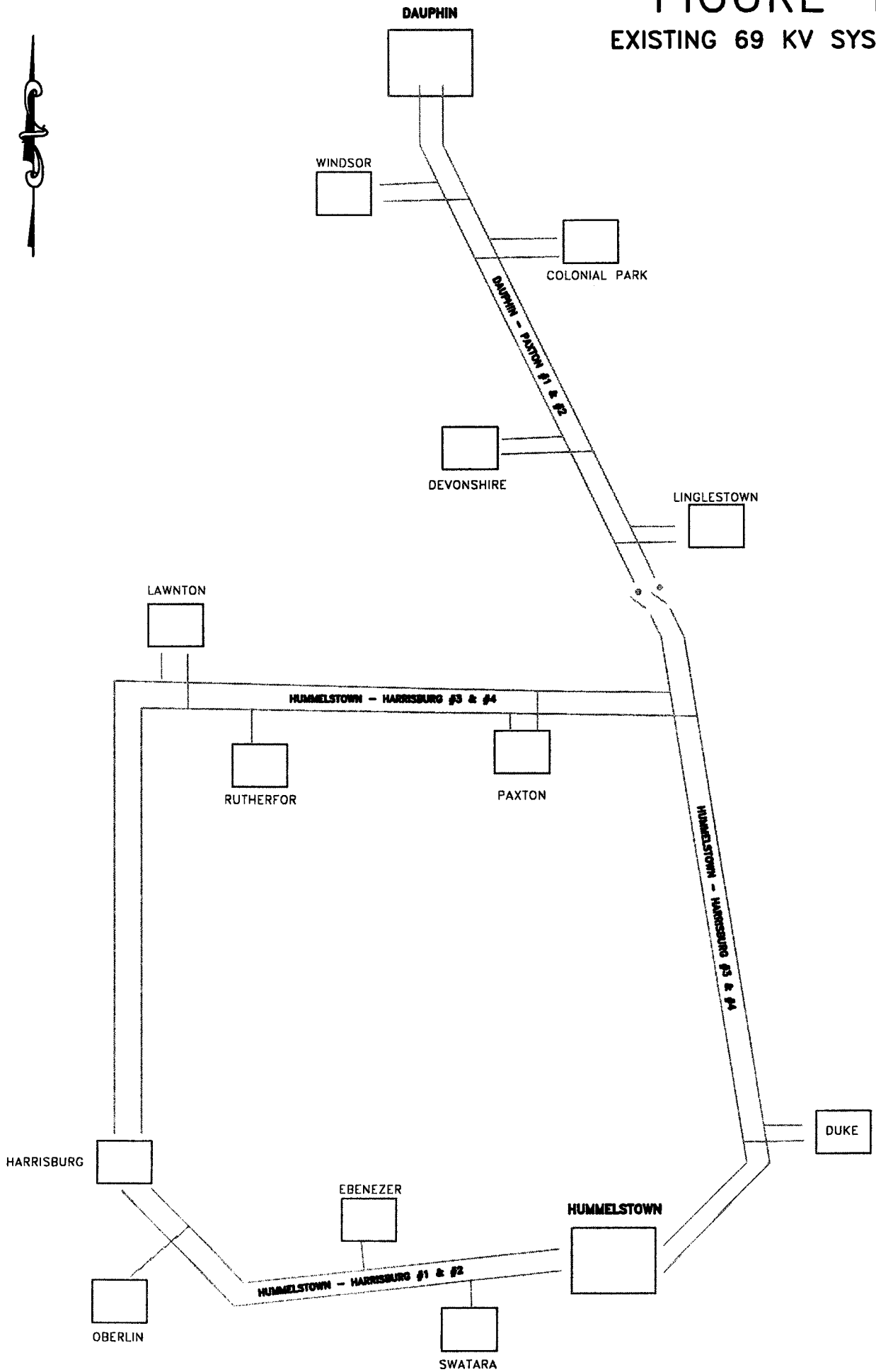
The total estimated cost of the Alternative 3 projects would be approximately \$58.85 million.

This reinforcement alternative also resolves the contingency overloads explained in section C above and provides long term capacity upgrades for future growth. However, Alternative 3 has several deficiencies when compared to the preferred option. Specifically, Alternative 3 was not selected as the preferred option due to the following:

- More expensive.
- Requires new rights-of-way for 230 kV and 69 kV transmission lines.

- Requires extensive outages at several substations and on the 69 kV transmission system reducing reliability to customers supplied from these transmission lines.

**FIGURE 1**  
**EXISTING 69 KV SYSTEM**

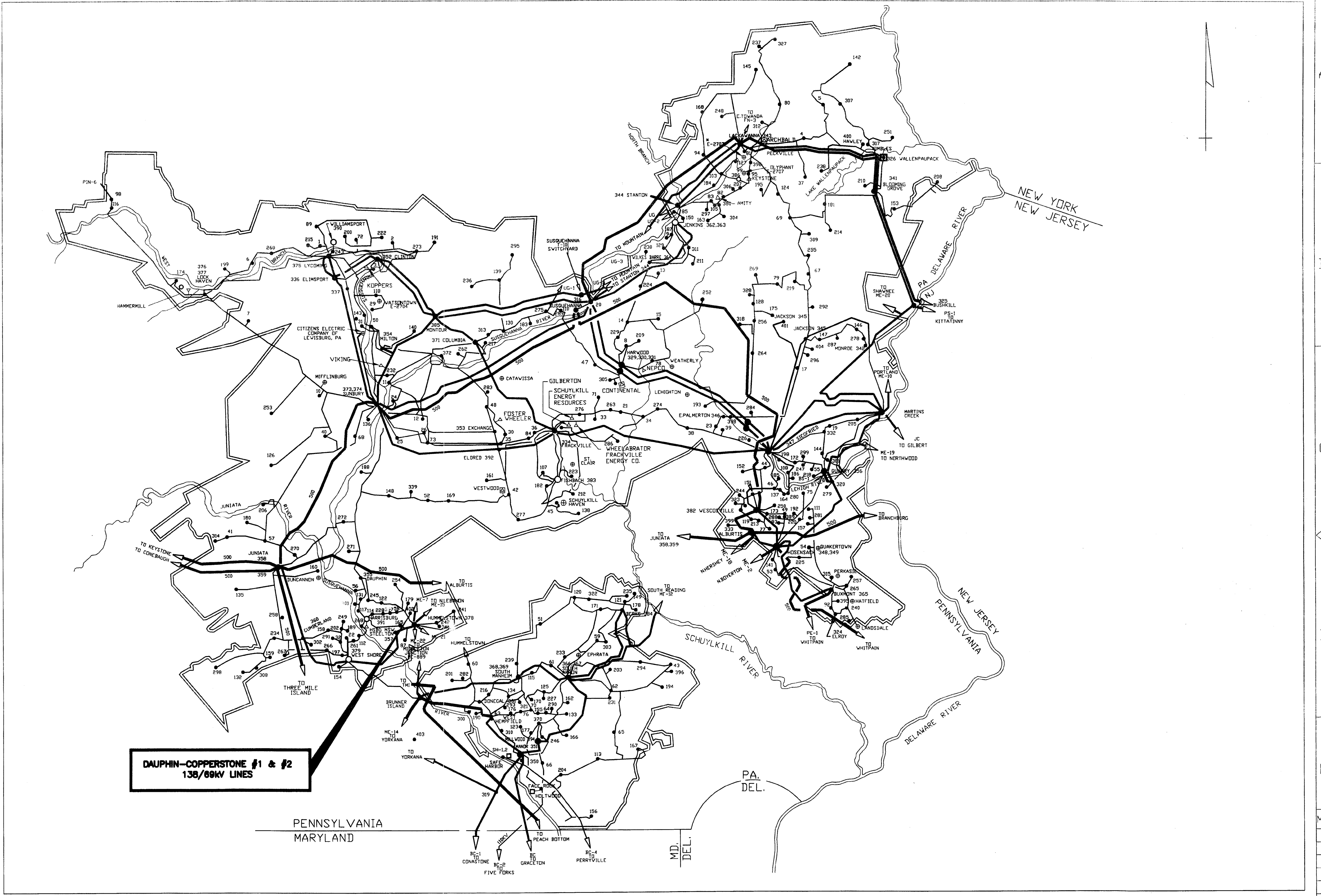




# SUBSTATION LISTING

1	WEST WILLIAMSPORT	151	CRACKERSPORT	301	CENTER CITY
2	FAIRFIELD	152	FAIRFIELD	302	NEW KINGSTOWN
3	MONTGOMERY	153	HEMLOCK	303	REAMSTOWN
4	VARDEN	154	MT. ALLEN	304	DUPONT
5	HINESDALE	155	PRINCE	305	HUMBOLDT
6	JERSEY SHORE	156	WAKEFIELD	306	CEDAR AVE.
7	LOGANTON	157	COOPERSBURG	307	INDIAN ORCHARD
8	VALMONT	158	VERTIZVILLE	308	NETTINGHAM
9	RIVER	159	WEST CARLISLE	309	NORTH COULBAUGH
10	LIMESTONE	160	BENVENUE	310	LEFORT
11	NORTHUMBERLAND	161	LEOLA	311	EAST MOUNTAIN
12	WRIGHT	162	YATESVILLE	312	JERMYN
13	ST. JOHNS	163	CENTRAL ALLENTOWN	313	BLOOMSBURG
14	REGLAND	164	OBERSHIRE	314	MIFFLINTOWN
15	GILBERT	165	STRASBURG	315	RIDGE ROAD
16	CHERRY HILL	166	ATGLEN	316	SUSQUEHANNA
17	SUSQUEHANNA 230KV	167	BROOKSIDE	317	T-10 SW YD.
18	TAMANENDI	168	WILLIAMSTOWN	318	KIMBLES
19	WHITE HILL	169	C. PETERSBURG	319	CHRISTMANS
20	PALMERTON	170	WERNERSVILLE	320	OTTER CREEK
21	HAMILTON	171	N. BETHLEHEM	321	STEELE
22	HUNTER	172	W. ALLENTOWN	322	MCGOVERNVILLE
23	FAIRVIEW	173	FLEMINGTON	323	ROBESONIA
24	MONROE	174	MELLSVILLE	324	SIDGELSVILLE
25	MONTOUR PUMP	175	DONERVILLE	325	ELROY
26	MT. CARMEL	176	MILLERSVILLE	326	BUSHKILL
27	KINGSTOWN	177	SHILLINGTON	327	WALLENPAUPACK
28	PORTING HILL	178	DUKE	328	ELK MOUNTAIN
29	MAHANDY CITY	179	MCALLISTERVILLE	329	JACK FREST
30	GREENWOOD	180	WOLFENDLAND	330	HARWOOD 230/69KV
31	MOWRY	181	MARLIN	331	HARWOOD CTG
32	ALTA MOUNT	182	WEST BERWICK	332	HARWOOD 69/12KV
33	HAMLIN	183	KEYSER AVENUE	333	NAZARETH
34	SOUTH SLATINGTON	184	MICKLEYS	334	ALBURTIS
35	SOUTH MIDDLEBURG	185	EAST ALLENTOWN	335	FRACKVILLE
36	WALKER	186	DAVE RIDGE	336	ELMSPORT
37	FRILEY	187	PINE RIDGE	337	ALLENTOWN
38	MORGANTOWN	188	DAVE RIDGE	338	ALLENTOWN
39	EGYSTONA	189	PENNSBURD	339	ALLENTOWN
40	SOUTH WHITEHALL	190	NORTH COLUMBIA	340	HOCKERSVILLE
41	BEAR GAP	191	HUGHESVILLE	341	BLOOMING GROVE
42	SALISBURY	192	WEISSPORT	342	MONROE
43	SOUTH MILTON	193	HORN BROOK	343	LACKAWANNA ##
44	HEIDELBERG	194	MOSCOW	344	NORTHAMPTON
45	LYKENS	195	ROSSMOYNE	345	WOLDRICH
46	UPPER HANDOVER	196	NORTHAMPTON	346	JACKSON
47	RICHLAND	197	WOLDRICH	347	EAST PALMERTON
48	MACADA	198	FAMON	348	SIEGFRIED
49	ROCKVILLE	199	ELIZABETHTOWN	349	HOSSENSACK 230/69KV
50	THOMPSON TOWN	200	ENDLA	350	HOSSENSACK 500KV
51	PAXTON	201	TERRE HILL	351	CONESTOGA
52	COCALCO	202	BURK	352	MANDR
53	EAST ELIZABETHTOWN	203	MT. BETHEL	353	CLINTON
54	WARWICK	204	RICHFIELD	354	EXCHANGE
55	EARL	205	SCRANTON	355	MILTON
56	HEMPFIELD	206	TWIN LAKES	356	DAUPHIN SUB.
57	EAST LANCASTER	207	HARLEIGH	357	STEELETON
58	KINZER	208	TAYLOR	358	JUNIATA 500/230KV
59	MT. NEBO	209	BEAR CREEK	359	JUNIATA 230/69KV
60	POCONO	210	ORWIGSBURG	360	CUMBERLAND
61	PENNS	211	EAST TEXAS	361	DONEGAL
62	GULLSBORO	212	CANDENIS	362	JENKINS 230/69KV
63	DILLERSVILLE	213	LINDEN	363	JENKINS CTG
64	GIRARD MANDR	214	MT. JOY	364	WILKES-BARRE
65	GOVEN CITY	215	WEST BLOOMSBURG	365	BUXMONT
66	ELLIOT HEIGHTS	216	MINI TRAIL	366	SOUTH AKRON 230/138/69KV
67	ROHRERSTOWN	217	LAKE NADMI	367	SOUTH AKRON 69/12KV
68	MACUNIE	218	LAKE NADMI	368	SOUTH MANHEIM 69/12KV
69	EAST HAZLETON	219	LAKE NADMI	369	SOUTH MANHEIM 230/69KV
70	WAGNERS	220	LAKE NADMI	370	ENGLESLIDE
71	EAST CARBONDALE	221	LAKE NADMI	371	COLUMBIA
72	LYNDEN	222	LAKE NADMI	372	DANVILLE
73	MINDOKA	223	LAKE NADMI	373	SUNBURY
74	OLD FORGE	224	LAKE NADMI	374	HUMMELS WHARF
75	FOUNTAIN SPRINGS	225	LAKE NADMI	375	LYCOMING
76	SULLIVAN TRAIL	226	LAKE NADMI	376	LOCK HAVEN CTG
77	WATARA	227	LAKE NADMI	377	LOCK HAVEN 69/12KV
78	HEPBURN	228	LAKE NADMI	378	HUMMELSTOWN
79	FRANCONIA	229	LAKE NADMI	379	WEST SHORE
80	EMMAUS	230	LAKE NADMI	380	MONTAGE
81	MORGAN	231	LAKE NADMI	381	SOUTH FARMERSVILLE
82	THROOP	232	LAKE NADMI	382	WESCOSVILLE
83	CASS	233	LAKE NADMI	383	FISHACH
84	CATASAUQUA	234	LAKE NADMI	384	BERKACH
85	SUSQUEHANNA 500KV	235	LAKE NADMI	385	MONTOUR
86	SEIDERSVILLE	236	LAKE NADMI	386	SUBURBAN YARD
87	ROSEMONT	237	LAKE NADMI	387	EDELA
88	QUARRYVILLE	238	LAKE NADMI	388	SUMMERDALE
89	LAWNTON	239	LAKE NADMI	389	DORNEYVILLE
90	TITZ	240	LAKE NADMI	390	BOHEMIA
91	RENO	241	LAKE NADMI	391	WHITE HAVEN
92	WALNUT	242	LAKE NADMI	392	HARRISBURG
93	WATSON	243	LAKE NADMI	393	ELDRED
94	TREXERTOWN	244	LAKE NADMI	394	MILLWOOD
95	LAVING	245	LAKE NADMI	395	TELFORD
96	SPRING	246	LAKE NADMI	396	TWIN VALLEY
97	COLONIAL PARK	247	LAKE NADMI	397	DEVONSHIRE
98	WEST LANCASTER	248	LAKE NADMI	398	JESSUP
99	MADISONVILLE	249	LAKE NADMI	399	BELTZVILLE
100	NEFFSVILLE	250	LAKE NADMI	400	SCHDENECK
101	BEAVER TOWN	251	LAKE NADMI	401	HAWLEY
102	BELMONT	252	LAKE NADMI	402	EFFORT MOUNTAIN
103	LAKE HARMONY	253	LAKE NADMI	403	COOPERSSTONE
104	GEORGETOWN	254	LAKE NADMI	404	RED FRONT
105	SCOTT	255	LAKE NADMI	404	APPENZELL
106	N. HARRISBURG	256	LAKE NADMI		
107	MOUNT ROCK	257	LAKE NADMI		
108	GREENLAND	258	LAKE NADMI		
109	LANDSVILLE	259	LAKE NADMI		
110	GREEN PARK	260	LAKE NADMI		
111	SELINSGRÖVE	261	LAKE NADMI		
112	SUNNER	262	LAKE NADMI		
113	AUBURN	263	LAKE NADMI		
114	ROHRSBURG	264	LAKE NADMI		
115	DERRY	265	LAKE NADMI		
116	EAST GREENVILLE	266	LAKE NADMI		
117	WEST DAMASCUS	267	LAKE NADMI		
118	NEW COLUMBIA	268	LAKE NADMI		
119	FARMERSVILLE	269	LAKE NADMI		
120	GREENFIELD	270	LAKE NADMI		
121	NORTH STROUDSBURG	271	LAKE NADMI		
122	TANNERSVILLE	272	LAKE NADMI		
123	ELIZABETHVILLE	273	LAKE NADMI		
124	WYOMISSING	274	LAKE NADMI		
125	EXETER	275	LAKE NADMI		

\* - SUBSTATIONS THAT HAVE BEEN RETIRED.  
 ## - SITE OF THE EXISTING 230KV SUBSTATION AND PROPOSED 500KV SUBSTATION



**DAUPHIN-COPPERSTONE #1 & #2  
 138/69KV LINES**

## INTERCONNECTIONS

PS PUBLIC SERVICE ELECTRIC AND GAS CO. OF N.J.  
 ME METROPOLITAN EDISON CO. (FIRST ENERGY)  
 PE PHILADELPHIA ELECTRIC CO. (FECO ENERGY)  
 BC BALTIMORE GAS AND ELECTRIC CO.  
 SH SAFE HARBOR WATER POWER CORPORATION  
 UP THE UNITED GAS IMPROVEMENT CO. - LUZERNE ELECTRIC DIVISION  
 PN PENNSYLVANIA ELECTRIC CO. (FIRST ENERGY)  
 JC JERSEY CENTRAL POWER AND LIGHT CO. (FIRST ENERGY)

- COMBUSTION TURBINE
- HYDRO ELECTRIC
- COMBINATION
- FIRM SALES
- SUBSTATION / SWITCHING STATION
- STEAM ELECTRIC
- NON-UTILITY GENERATION
- INDEPENDENT POWER PRODUCERS

- 500KV OPERATION
- 230KV OPERATION
- 138KV OPERATION
- 69KV OPERATION

ACCT - 805201	ELECTRICAL SYSTEM MAP	
SCALE - NONE	DAUPHIN-COPPERSTONE #1 & #2	
BY - CDW	138/69KV LINES	
APPROVED G. HAKUN III	DATE 7/1/85	PPL ELECTRIC UTILITIES
PPL DRAWING NO. D191830	SHEET NO. 1	REV. 66

NO.	DATE	ACCT.	DESCRIPTION	BY	REVIEWED	APPROVED
63	1/11/79	389331	ADDED RED FRONT 115 KV TAP LINE.	RRC		KBK
64	10/30/80	169983	ADDED COPPERSTONE-HARRISBURG #1 & #2 138/69KV LINES.	RRC		DH
66	3/10/10	169983	ADDED DAUPHIN-COPPERSTONE #1 & #2 138 KV LINES	RRC		DH
65	3/4/10	169020	ADDED APPENZELL #1 & #2 138KV TAPS.	RRC		DH

# **Exhibit B**

## **EXHIBIT "B"**

### **DAUPHIN – COPPERSTONE #1 & #2 138/69 kV LINE**

#### **ENGINEERING DESCRIPTION**

---

#### **TABLE OF CONTENTS**

<b><u>SECTION</u></b>	<b><u>TOPIC</u></b>	<b><u>PAGE</u></b>
A.	DESCRIPTION OF PROPOSED PROJECT	1
B.	MAGNETIC FIELD MANAGEMENT	3
C.	RIGHT-OF-WAY STATUS	3
TABLE 1	DESIGN MINIMUM CONDUCTOR CLEARANCES DAUPHIN – COPPERSTONE LINE	2
TABLE 2	CONDUCTOR THERMAL RATINGS	3
MAP 1	AERIAL SHOWING THE OVERALL PROJECT	EXHIBIT "B" MAP POCKET

## EXHIBIT "B"

### DAUPHIN - COPPERSTONE #1 & #2 138/69 kV LINE

#### ENGINEERING DESCRIPTION

---

##### A. DESCRIPTION OF THE PROPOSED LINE

PPL Electric proposes to construct a portion of the new Dauphin - Copperstone #1 & #2 138/69 kV Transmission Line. The proposed line will exit the new Copperstone 230-69 kV Substation and will extend approximately 0.53 miles to connect with the existing Hummelstown-Harrisburg #3 and #4 69 kV Transmission Line just west of the proposed Substation. The proposed line is being constructed for double circuit 138 kV, but will be operated at 69 kV until future load growth in the area requires upgrade to 138 kV. Conversion to 138 kV operation will occur when increasing demand for electricity approaches the limit of operation at 69 kV.

The new line will consist of single and multi-pole fabricated weathering steel structures. These structures will be equipped with upswept weathering steel arms, polymer 138 kV insulator assemblies, (6) 795.0 kcmil, 30/19 stranding, ACSR conductors, and one 3/8 inch high-strength steel overhead ground wire. All new poles for the proposed Dauphin - Copperstone #1 & #2 138/69 kV Transmission Line will be either direct embedded or installed on concrete foundations with an approximate above-ground height of 85 to 100 feet. Line angles and tap structures could be guyed. This work will be completed on PPL Electric fee owned property and on existing and newly acquired PPL Electric right-of-way agreements.

This project is located in South Hanover and Lower Paxton Townships, Dauphin County. An aerial plot plan for the proposed transmission line project is provided in the Exhibit "B" map pocket.

The proposed line facilities will be designed to, and generally exceed, National Electrical Safety Code (NESC) standards. Design specifications and safety rules practiced by PPL Electric are included in Appendix A. The minimum conductor to ground clearance will be 30 feet on all new line facilities. Those clearances occur at a maximum thermal conductor temperature of 125 degrees Celsius.

The designed minimum conductor clearances and conductor thermal ratings for the line are as follow:

**TABLE 1**

**DESIGN MINIMUM CONDUCTOR CLEARANCES  
FOR 795 KCMIL, 30/19 STRANDING ACSR\***

**DAUPHIN - COPPERSTONE #1 & #2 138/69 kV LINE**

<u>Condition</u>	<u>Double-Circuit Design Clearance-to-Ground</u>
Normal load; average weather (16°C ambient temperature)	33.3 feet
Predicted extreme thermal load (125°C conductor temperature)	30.0 feet
Predicted NESC Extreme wind load (100 mph, 16°C)	31.8 feet
Predicted extreme weather conditions (1 inch ice, 4 lbs. wind, -18°C)	32.3 feet

\*Clearances based on a maximum tension of 10,000 pounds, at 1 inch ice, 0° F, 4 lb wind, and a ruling span of 390 feet.

**TABLE 2**  
**CONDUCTOR THERMAL RATING**  
**795 KCMIL 30/19 STRANDING ACSR**  
**(257°F) 125°C MAXIMUM CONDUCTOR TEMPERATURE**

Condition	<u>Ambient Temperature</u> °C	<u>Wind Speed</u> Knots	<u>Ampacity</u> Amps
Summer Normal	35	0	1056
Winter Normal	10	0	1217
Summer Emergency	35	1 1/2	1347
Winter Emergency	10	1 1/2	1517

**B. MAGNETIC FIELD MANAGEMENT**

PPL Electric’s Magnetic Field Management Program, summarized in Appendix B, is applied to new and reconstructed transmission line projects. To reduce magnetic field exposures, the program generally prescribes the use of a line design that provides five feet higher ground clearance and reverse phasing of new double circuit lines where it is feasible to do so at low or no cost. The implementation of additional modifications should be considered, provided those modifications can be made at low or no cost.

Increased ground clearance and reverse phasing are included in the design of the new double circuit Dauphin - Copperstone #1 & #2 138/69 kV Transmission Line.

**C. RIGHT-OF-WAY STATUS**

Most of the work for the new Dauphin - Copperstone #1 & #2 138/69 kV Transmission Line will be completed on PPL Electric fee-owned property and under existing PPL Electric right-of-way agreements with defined right-of-way widths. Although some additional rights-of-way were required to construct the Dauphin - Copperstone #1 & #2 138/69 kV Transmission Line, PPL Electric has successfully negotiated with the relevant property owners and secured right-of-way agreements necessary to construct this overhead line section. A list of property owners within the existing right-of-way is presented in Appendix C.



# **Exhibit C**

**EXHIBIT "C"**

**DAUPHIN - COPPERSTONE #1 & #2 138/69 kV LINE**

**ENVIRONMENTAL ASSESSMENT**

---

**TABLE OF CONTENTS**

<b><u>SECTION</u></b>	<b><u>TOPIC</u></b>	<b><u>PAGE</u></b>
A.	INTRODUCTION.....	1
B.	LAND USE.....	1
C.	CULTURAL RESOURCES.....	2
D.	NATURAL FEATURES.....	3
E.	THREATENED AND ENDANGERED SPECIES.....	3

## EXHIBIT "C"

### DAUPHIN - COPPERSTONE #1 & #2 138/69 kV LINE

#### ENVIRONMENTAL ASSESSMENT

---

##### A. INTRODUCTION

PPL Electric proposes to reinforce the 230 kV and 69 kV electric delivery system in central Dauphin County. To accomplish this, PPL Electric requests Commission approval to construct approximately 0.53 miles of the new Dauphin - Copperstone #1 & #2 138/69 kV Transmission Line, which will be initially operated at 69 kV. This new double circuit 138/69 kV line will tie into the existing Hummelstown-Harrisburg #3 & #4 69 kV Transmission Line, west of the proposed Copperstone Substation. A portion of the existing Hummelstown-Harrisburg #3 & #4 69 kV Transmission Line will be renamed the Dauphin - Copperstone #1 & #2 138/69 kV Transmission Line. Although there are other parts to the project, PPL Electric only seeks Commission approval for the proposed 0.53 mile Dauphin - Copperstone #1 & #2 138/69 kV Transmission Line at this time.

This proposed project was reviewed with South Hanover and Lower Paxton Townships and Dauphin County. Neither the Townships or County Officials have any objection to the project. A list of involved governmental agencies, municipalities, and other public entities is presented in Appendix D.

##### B. LAND USE

The Dauphin - Copperstone #1 & #2 138/69 kV Transmission Line will create minimal new land use impacts. This line section will be constructed in close proximity to other existing overhead transmission facilities. The line will be reconstructed entirely on PPL Electric fee owned property and within newly acquired PPL Electric rights-of-way.

The proposed Dauphin - Copperstone #1 & #2 138/69 kV Transmission Line is generally located in woodland, farmland, and a low volume residential area. There are 2 properties that will be traversed by the proposed project one being PPL Electric. No nearby railroads, communication towers, pipelines or other utilities will be affected by the proposed project. Existing field access roads will be used, although new roads may be needed in some cases for construction. All disturbed areas will be returned to their original condition after construction.

### **C. CULTURAL RESOURCES**

This project was reviewed with the Pennsylvania Historical and Museum Commission (PHMC). PHMC has determined that, due to the absence of historical sites and the small project size, no further archaeological investigations are required so long as construction activities are located outside a 300-foot buffer of any watercourse. Because of the close proximity to Beaver Creek PPL Electric has hired Dr. Frank Vento, Clarion University to conduct a Phase 1 presence/absence survey for any possible Cultural or Archaeological features. A report will be submitted upon completion of this survey.

The following lists were reviewed for the presence of historical districts and structures in the area:

- National Historic Landmarks in Pennsylvania
- National Register Historic Districts in Pennsylvania
- National Register Individual Properties and Historic Districts in Pennsylvania
- National Register/Listed and Eligible Properties in Pennsylvania

There are several structures of historical interest in the vicinity of this project. Impacts to these historical structures are not expected due to the distance between the structures and this project. The Reservoir Park Overlook is located approximately 5.5 miles west of the project area, and the Landis Mill Millers House located at the intersection of N. Railroad

Street and Duke Street, Hummelstown is approximately 2.2 miles south of the project area.

**D. NATURAL FEATURES**

The proposed project will not affect any unique geological, scenic, or natural areas. No parks or recreational facilities are located near the project area. Tree clearing is required for the construction of this line segment through woodlands. However, PPL Electric will apply its “Specifications For Initial Clearing and Control of Vegetation on or Adjacent to Electric Line Right-of-Way Through Use of Herbicides, Mechanical and Hand Clearing Techniques” to Mitigate the Impacts of This Clearing Work.

The lines will cross Beaver Creek and some wetlands. All wetlands and waters have been delineated and added to the construction drawings. All are easily spanned and, therefore, no impacts are anticipated. All required permits will be obtained from the Pennsylvania Department of Environmental Protection and the United States Army Corps of Engineers prior to construction.

**E. THREATENED AND ENDANGERED SPECIES**

PPL Electric has coordinated with different state and federal agencies to obtain information regarding endangered and threatened species in the study area. A review of the Pennsylvania Natural Diversity Inventory (PNDI) records indicates that the Pennsylvania Department of Conservation and natural Resources (DCNR) has recorded one potential conflict in the project area. At the request of DCNR, PPL Electric hired Mr. Richard Mellon, Mellon Biological Services to perform a presence/absence survey for the *Triosteum angustifolium* (Tentatively Undetermined, Proposed PA Endanger), which did not detect the presence of any such species. Based on this study a final report from DCNR, dated January 7, 2008, indicated that no impact was likely. Because the report has since expired, PPL Electric has re-submitted its report and on February 24, 2010, DCNR has indicated no impacts are likely (Reference PNDI # 20071017113376 and 20100217229700).

# Appendices

## **LIST OF APPENDICES**

- APPENDIX A - PPL Electric Design Criteria and Safety Practices
- APPENDIX B - Magnetic Field Management at PPL Electric
- APPENDIX C - List of property owners within the existing Right-of-Way
- APPENDIX D - List of Involved Governmental Agencies, Municipalities, and Other Public Entities

## APPENDIX "A"

### PPL DESIGN CRITERIA AND SAFETY PRACTICES

The National Electrical Safety Code (NESC) is a set of rules to safeguard people during the installation, operation, and maintenance of electric power lines. The NESC contains the basic provisions considered necessary for the safety of employees and the public. Although it is not intended as a design specification, its provisions establish minimum design requirements. PPL Electric Utilities Corp. (PPL Electric) has developed design specifications and safety rules which meet or surpass all provisions specified by the NESC.

#### Engineering Design Criteria and Parameters

The NESC includes loading requirements and clearances for the design, construction, and operation of power lines. The "loads" on conductors and supporting structures are the mechanical forces that develop from the weight of the conductors, the weight of ice on the conductors, plus wind pressure on the conductors and supporting structures. Loading requirements are the loads on the conductors and structures that are anticipated assuming certain ice and wind conditions. Loading requirements always contain "safety factors" to allow for unknown or unanticipated contingencies. The clearances and loading requirements contained in the NESC were developed to ensure public safety and welfare.

PPL Electric transmission line design standards meet or surpass the NESC standards. For example, the relative order of grades of construction for conductors and supporting structures is B, C, and N; Grade B being the highest. According to the NESC standards, construction Grades B, C, or N may be used for transmission lines (except at crossings of railroad tracks and limited access highways where Grade B construction is specified). However, PPL Electric designs all of its transmission lines for Grade B construction. The use of Grade B design and construction specifies such things as larger-minimum cross-arm dimensions, larger-minimum conductor size, and increased safety factors.

Another example is the design parameters utilized to account for ice and wind loadings on the overhead ground wire (OHGW) and power conductors. The NESC standard ice and wind design magnitudes for the PPL Electric territory are 0.5 inch thickness of radial ice combined with four pounds per square foot horizontal wind pressure (equivalent to 40-mile per hour wind velocity). The conductor sags and tensions used in line designs are the result of various ice and wind combinations, depending on the elevation at the line location and line design voltage. The conductor sags and tensions used in the design of all PPL Electric transmission lines are at least 0.5-inch ice combined with eight pounds wind pressure (equivalent to 57 miles per hour wind velocity). This means that PPL Electric lines are designed to operate safely and reliably during inclement weather even more severe than assumed by the NESC. In addition, PPL Electric transmission lines are designed with more clearance to the ground than required by the NESC. The tables below compare PPL Electric and NESC ground clearances for lines of various voltages.

**138 kV**

<u>Surface Underneath Conductors</u>	<u>Vertical Clearance to Ground</u>	
	<u>NESC Standard</u>	<u>PPL Electric Design</u>
Roads, streets, alleys	21 Ft.	30 Ft.
Other land traversed by vehicles (such as cultivated field, forest, etc.)	21 Ft.	30 Ft.
Spaces accessible to pedestrians only	17 Ft.	30 Ft.
Railroad tracks	31 Ft.	35 Ft.

**230 kV**

<u>Surface Underneath Conductors</u>	<u>Vertical Clearance to Ground</u>	
	<u>NESC Standard</u>	<u>PPL Electric Design</u>
Roads, streets, alleys	23 Ft.	32 Ft.
Other land traversed by vehicles (such as cultivated field, forest, etc.)	23 Ft.	32 Ft.
Spaces accessible to pedestrians only	19 Ft.	32 Ft.
Railroad tracks	31 Ft.	36 Ft.

## 500 kV

<u>Surface Underneath Conductors</u>	<u>Vertical Clearance to Ground</u>	
	<u>NESC Standard</u>	<u>PPL Electric Design</u>
Roads, streets, alleys	28 Ft.	53 Ft.
Other land traversed by vehicles (such as cultivated field, forest, etc.)	28 Ft.	53 Ft.
Spaces accessible to pedestrians only	24 Ft.	53 Ft.
Railroad tracks	38 Ft.	53 Ft.

A relay protection system is used to protect the public safety and welfare as well as equipment and the transmission system. Relay protection is installed for all transmission lines to automatically de-energize the line in the unlikely event that the line or supporting structure fails and the line contacts the ground.

### Periodic Maintenance Program on All Transmission Lines

To ensure continued public safety and integrity of service, a periodic maintenance and inspection program is implemented for every transmission line. The program is administered through the use of helicopter patrols, with supplemental foot and structure climbing patrols. A number of helicopter patrols are performed on all lines annually. The two-man helicopter crew flies parallel, to the left, and above the line so that the observer can look for signs of line damage or deterioration and observe clearances between vegetation and conductors. The observations are included in a report that is forwarded to the appropriate department for corrective action.

Foot and structure climbing patrol programs for a transmission line begin approximately three to five years after the line is energized, unless a helicopter patrol reports a need for earlier action. The frequency of foot patrols varies from once every year to once every several years depending on line type and age.

An assigned foot patroller checks right-of-way conditions, including access roads, bridges, pole washouts, tower footers, vegetation height and clearance to conductors, pole and tower deterioration

and, with the use of binoculars, insulators, and condition of hardware. Identified problems are included in a report that is forwarded to the appropriate department for corrective action.

A scheduled line outage is required to perform an overhead patrol because of "hands-on" inspection of hardware. Overhead patrols are conducted on a schedule determined by line age, operating record, and observed general condition. The necessary repairs are also done during the inspection outage.

### Personnel Safety Rules

The following are a few of the PPL Electric safety rules that demonstrate the Company's concern for employee safety:

- Work procedures have been developed to allow work to be performed on energized facilities in a safe manner. When lines or apparatus are removed from service to be worked on, the Energy Control Process system is applied. This system provides that a red tag must be physically placed on the control handle of the de-energized equipment. The red tag may be removed only after proper authorization to energize the equipment. Various other tags are used for limited operations and informational purposes. Employees will not apply or remove a tag or change the status of tagged equipment unless authorized.
- Temporary safety grounds are used on de-energized facilities for employee safety during maintenance, construction, or reconstruction work. Safety grounds are wires connecting the de-energized facility to an electrical ground. If the facility should be energized, the safety grounds will divert the current directly to ground and reduce the likelihood of personal injury. The conductor size and attachment clamps of temporary safety grounds must be capable of conducting anticipated fault currents. Rubber gloves, rubber sleeves, and additional rubber protective equipment are used as required when applying or removing temporary safety grounds to or from the lines or apparatus to be grounded. An approved nonconductive working stick of sufficient length to allow workers to maintain the following required minimum clearances is used to test that the line has been de-energized and to apply temporary safety grounds:

Voltage-kV

Minimum Clearance

138

3'-7"

230

5'-3"

500

11'-3"

Before applying grounds, a test is done to confirm that the line is de-energized. The voltage test device is checked before and after use to assure reliability. When ground pins are used to establish proper ground points, they are driven to a depth of not less than four feet as near vertical as possible.

- Poles or structures are inspected and examined for structural integrity before climbing. If there is any reason to believe that a pole is unsafe, it is stabilized before work is performed. Appropriate safety gear in the form of body belts, safety straps, hard hats, gloves, etc., is worn by linemen during line work activity.



**MAGNETIC  
FIELD  
MANAGEMENT**  
**PPL Electric Utilities  
Corporation**

**APPENDIX B**

**DECEMBER 2004**

**TABLE OF CONTENTS**

INTRODUCTION ..... 1

DEVELOPMENT OF PPL EU's MAGNETIC FIELD MANAGEMENT PROGRAM..... 6

VARIABLES THAT AFFECT MAGNETIC FIELDS ..... 6

    Effect of Phase Current on Magnetic Fields ..... 6

    Effect of Conductor Configuration on Magnetic Fields ..... 7

    Effect of Distance from the Magnetic Field Source ..... 7

SUMMARY OF PPL EU's MAGNETIC FIELD MANAGEMENT PROGRAM..... 8

MAGNETIC FIELD MANAGEMENT PROGRAM GUIDELINES ..... 9

    Overhead Lines ..... 9

        New or Rebuilt Transmission Lines ..... 9

        Reconductoring or Adding Additional Circuits to Existing Transmission Lines ..... 14

        Distribution Lines ..... 14

    Underground Transmission Lines ..... 15

CHARTS..... 16

## **INTRODUCTION**

At PPL Electric Utilities Corp. (PPL EU), magnetic field management means investigating and implementing methods at low or no cost to reduce magnetic fields in new or rebuilt transmission and distribution lines. This document explains PPL EU's Magnetic Field Management Program, which is part of PPL EU's larger Electric and Magnetic Fields (EMF) policy.

### **PPL EU's View**

Some people are worried that electric and magnetic fields are harming their health. Others think the scientific research does not show a problem at all, and still others believe there's just too much scientific uncertainty to draw any conclusions.

Here's what we do know now. Various panels of scientists that have reviewed the EMF research generally have drawn two main conclusions. First, the large body of evidence does not demonstrate that EMF are harmful. Second, additional research is recommended to explore questions raised in some studies.

Given these conclusions, PPL EU is taking a reasoned approach in responding to the EMF issue. PPL EU's approach to the EMF issue consists of five elements:

- Providing EMF information to customers and employees
- Providing magnetic field measurements
- Establishing and implementing a magnetic field management program to reduce magnetic fields in new or rebuilt facilities when it can be done at no, or low, cost
- Integrating EMF in the public involvement process that PPL EU undertakes in the siting of transmission lines
- Have supported additional research

## **EMF Are All Around Us**

Electric and magnetic fields occur in nature and in all living things. The earth, for instance, has a magnetic field, which makes the needle on a compass point north.

Electric fields and magnetic fields of a different type also surround every wire that carries electricity. In everyday life, these EMF arise from several basic sources, including power lines, electrical appliances, home and building wiring, other utility lines and cables, and currents flowing on water pipes. Though they often occur together, EMF are made up of two separate components:

### **Electric Fields**

Electric fields are produced by the voltage—or electrical pressure—on a wire. The higher the voltage, the higher the electric field. As long as a wire is energized—has voltage present—an electric field is present (see Figure 1). In other words, an appliance, or an electric power line, doesn't actually have to be turned on to create an electric field. It just has to be plugged in. Electric fields diminish with distance and can be blocked or partially shielded by objects such as trees and houses.

### **Magnetic Fields**

Magnetic fields are created by the current or flow of electricity through a wire. Generally speaking, the higher the current, the higher the magnetic field. Because they only occur when current is flowing, magnetic fields are present only when the power is turned on (see Figure 1). Magnetic fields also diminish with distance, but—unlike electric fields—are not blocked by common objects. In recent years, public and scientific interest has turned toward the magnetic field component of EMF because of some scientific studies regarding these fields.

Figure 1

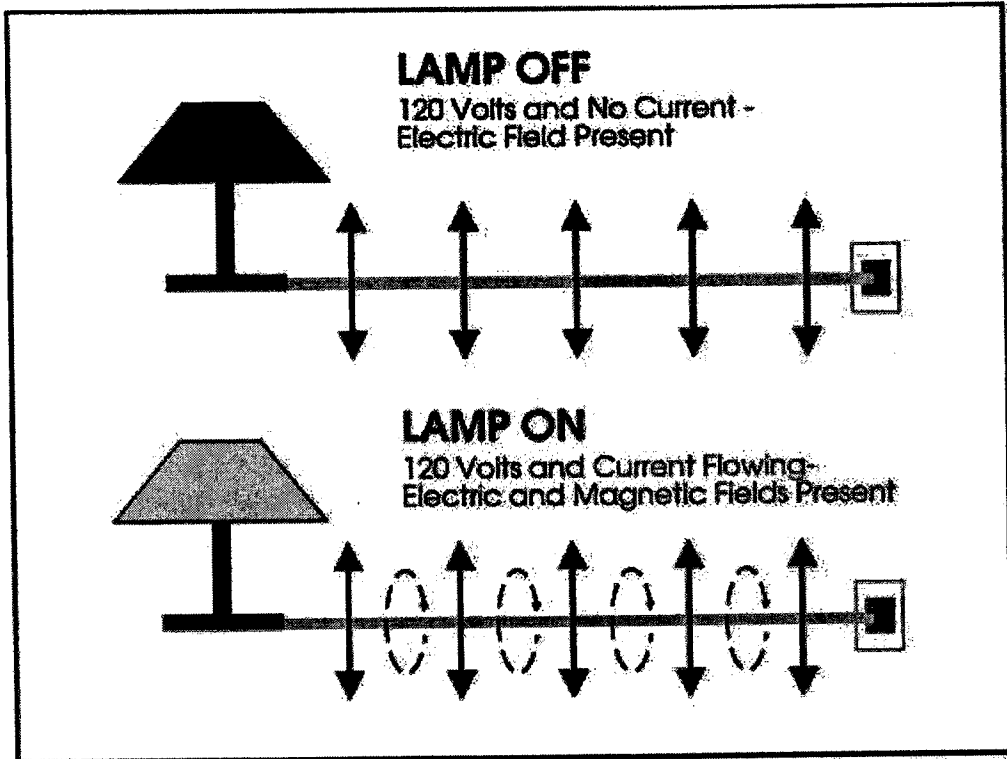


Figure 2









Magnetic field strengths decrease with distance Magnetic fields are measured in milligauss		Source: "EMF in Your Environment", U.S. Environmental Protection Agency 1992		
		At 6 inches	At 1 foot	At 2 feet
Clothes dryer		2 to 10	* to 3	*
Microwave oven		100 to 300	1 to 200	1 to 30
Toaster		5 to 20	* to 7	*
Power drill		100 to 200	20 to 40	3 to 6
Can opener		500 to 1500	40 to 300	3 to 30
Mixer		30 to 600	5 to 100	* to 10
Hair dryer		1 to 700	* to 70	* to 10
Color television		Data not available	* to 20	* to 8

FIGURE 2 \* The magnetic field measurement at this distance from the operating appliance could not be distinguished from background measurements taken before the appliance had been turned on.

### Measuring Magnetic Fields

Magnetic fields usually are measured in a unit called a milligauss. Magnetic field levels found in the living areas of homes typically range from less than 1 milligauss to about 4 milligauss according to the U.S. Environmental Protection Agency. They can be higher in some cases. The levels next to appliances can exceed 1,000 milligauss (1 gauss). Figures 2 and 3 show how the strength of the field falls off as you move away from the source, just as the heat of a campfire grows weaker as you walk away from it. For overhead power lines, the strength of the magnetic fields is dependent upon a number of factors that will be explained later. Those factors produce a magnetic field that drops off rapidly as you move away from the power line.

Figure 3

<b>Sample Magnetic Field Levels in Milligauss</b>				
<b>Type of Overhead Power Line</b>	<b>Distance from the line</b>			
	<b>Under the line</b>	<b>50 ft.</b>	<b>100 ft.</b>	<b>200 ft.</b>
220 kV and 500 kV	5-400	5-250	1-75	0.5-20
69 kV and 138 kV	3-80	0.5-2.5	0.1-10	0.1-3
12 kV and below	0.4-20	0.1-1	-	-

The magnetic field values provided in this table represent a general range of values associated with the types of overhead power lines listed and are provided for illustration. There will be circumstances in which there will be magnetic field levels above or below the range of values provided due to variations in such factors as height of the wires, current flow and so on.

## **DEVELOPMENT OF PPL EU's MAGNETIC FIELD MANAGEMENT PROGRAM**

One element of our response to EMF concerns expressed by some of our customers is PPL EU's Magnetic Field Management Program. The program was initiated in March 1991 because PPL EU believes it makes good sense, as a matter of policy, to respond to the concerns expressed by some of our customers and to reduce magnetic fields in new and rebuilt facilities where it can be done with either no-cost or low-cost design changes.

This document updates the original program which has been revised several times since 1991. These guidelines were developed by PPL EU's EMF Working Group.

### **VARIABLES THAT AFFECT MAGNETIC FIELDS**

Magnetic fields from transmission and distribution lines are a function of a number of design variables. The following parameters affect the magnetic field levels produced by transmission and distribution lines:

- Current
- Height of conductors above ground
- Configuration of conductors
- Distance from the line

### **EFFECT OF PHASE CURRENT ON MAGNETIC FIELDS**

At power frequencies (i.e., 60 hertz), the magnetic field level is a function of the current or flow of electricity through a wire. Keeping all other parameters the same, the magnetic field is proportional to the current. Hence, if the current increases by 25 percent, the resulting magnetic field level will increase by 25 percent.

The overall load current on any line varies with the demand for power. It's usually highest during daytime hours and lowest at night. There also are weekly, monthly, seasonal and yearly variations.

The difference in the currents between each phase in a multiphase line also can affect the magnetic field. This difference is called phase unbalance. For a constant load, a statistical analysis of this phase unbalance can be made to determine its effect on the magnetic field. Close to the line, there is very little effect. However, the phase unbalance slows the rate at which the magnetic field decreases with distance from the line.

### **EFFECT OF CONDUCTOR CONFIGURATION ON MAGNETIC FIELDS**

In the transmission and distribution of power, utilities like PPL EU presently use both three-phase and single-phase lines. Each phase on a three-phase power line has either a single conductor or a bundle of two or more conductors. In a three-phase system, the ground-level magnetic field is a result of the fields produced by the currents in each of the phases. Placing the three phases as close together as possible (compaction) creates some field cancellation, and the ground-level magnetic field is reduced. However, appropriate phase separation is required for the reliable operation of the line. In addition, the arrangement of the phases can create some; field cancellation and reduction of the ground-level magnetic field.

### **EFFECT OF DISTANCE FROM THE MAGNETIC FIELD SOURCE**

Magnetic field strength diminishes with the vertical and lateral distances from the magnetic field source. Increasing the height of the conductors above ground is useful for magnetic field reduction at ground level, but may result in increased structure costs and increased aesthetic impact of the structures. Another possible method of increasing the distance to the magnetic field source is to increase the right-of-way requirements. By keeping buildings off increased rights of way, thereby requiring the public to live and work further away from lines, exposure to magnetic fields produced by the lines can be reduced. Increases in right of way are not always practical and may increase costs significantly, however.

## **SUMMARY OF PPL EU's MAGNETIC FIELD MANAGEMENT PROGRAM**

Under its Magnetic Field Management Program, PPL EU has changed the way it builds and rebuilds some of its transmission and distribution lines. These design changes reduce magnetic field levels (assuming balanced circuit loadings and phase currents) by up to 69 percent in most of the company's new transmission lines. These guidelines now are being applied to new and reconstructed transmission facilities, based on this program.

The distribution component of the program focuses on 12 kV lines, the company's standard distribution voltage. It concentrates on the three-phase, primary 12 kV lines, since these are the most heavily loaded facilities and often are located in densely populated areas. The guidelines in this program are being applied to these three-phase, primary 12 kV lines.

A maximum 3-5 percent change in estimated cost was used as the limit for the guidelines since this value is consistent with low cost, is within estimating accuracy and is likely to have little impact on overall line costs.

The magnetic field calculations used in this document for the design of PPL EU's overall magnetic field management plan assume balanced load conditions among the phases and a fixed level of current, not necessarily representative of specific transmission or distribution lines. These levels were calculated using the Electric Power Research Institute's ENVIRO computer program. Under actual operating conditions, the magnetic field levels that result may vary due to such things as actual load per circuit, overall current on each phase conductor and the electrical configuration and operation of each line.

# MAGNETIC FIELD MANAGEMENT PROGRAM GUIDELINES

The guidelines for magnetic field management are noted below, with discussion points for each.

## **OVERHEAD LINES**

---

### **NEW OR REBUILT TRANSMISSION LINES**

- 1. Balance transmission circuit loads and phase currents as much as possible.**
  - PPL EU should continue to make every effort to balance loadings between the two circuits of a double circuit line when planning new or rebuilt facilities to maximize the effects of reverse phasing.
  - PPL EU should continue the practice of balancing single-phase loads across the three phases of the distribution system. (Unbalanced phase currents on the distribution system are reflected through to the transmission system.)
    - Unbalanced phase currents result in higher magnetic fields that do not drop off as quickly with distance as do the fields resulting from balanced phase currents.
    - For a 5 percent phase current unbalance, the magnetic field 50 feet from the centerline of a single circuit 138 kV line could be more than twice the value than if the same line had balanced phase circuits.
  - Balanced phase currents on each three-phase distribution circuit also reduce magnetic fields from the distribution circuits themselves. In addition, they reduce magnetic fields on the transmission system from which the distribution system circuits are supplied and connected through substations.
  - Apart from magnetic field considerations, balanced phase currents on each three-phase distribution circuit also reduce line losses and improve the system voltage.

**2. Continue with the present practice of using long-span construction as the PPL EU 138/69 kV standard**

- Structure designs for short-span and long-span construction are illustrated on Charts I and II, respectively.
  - Short-span design does not significantly reduce magnetic fields when compared to long-span design even though it is more compact than long-span design. Comparison of the magnetic field values from Chart III indicates essentially the same values. Therefore, short-span design should not be used solely to reduce magnetic fields.
  - PPL EU will continue to use long-span construction for 138/69 kV double-circuit lines and for single-circuit/future-double-circuit lines.
  - For single-circuit/future-double-circuit lines, PPL EU will continue to install two conductors on the top positions and one in the middle position as shown in Chart IV.
    - This arrangement minimizes magnetic fields as shown in Chart V by placing the three initial conductors higher on the structure, which increases the ground clearances, and by placing the conductors in a triangular configuration.

**3. Compact design structures are not a low-cost alternative and should be used for magnetic field reduction only in special applications.**

Chart VI illustrates the compact design structure.

- The compact design increases the initial installation costs by 79 percent when compared to the long-span design but reduces the magnetic field from 9 mG to 3 mG (about 67 percent) at the edge of the 100-foot-wide right of way as shown on Chart III.

**4. Reverse phase new or rebuilt double-circuit transmission lines for all voltage levels.**

- Reverse phasing was adopted by PPL EU in March 1991 for double-circuit 138/69 kV transmission lines and in April 1992 for all other double circuit transmission lines. Reverse phasing is shown in Chart VII. Reverse phasing will reduce the magnetic fields when the current flow on both circuits is in the same

direction. Calculated values contained here are based on balanced and equal phase currents on both circuits.

- Reverse phasing reduces the magnetic field of a double circuit 138 kV single pole transmission line from 29 mG to 9 mG (about 69 percent) at the edge of the 100-foot-wide right of way as shown on Chart III.
- Reverse phasing reduces the magnetic field of a double circuit 230 kV single pole transmission line from 49 mG to 16 mG (about 67 percent) at the edge of the 150-foot-wide right of way as shown on Chart VIII.
- Reverse phasing reduces the magnetic field of a double-circuit 500 kV single pole transmission line from 37 mG to 21 mG (about 43 percent) at the edge of the 200-foot-wide right of way as shown on Chart IX.
- When new or rebuilt double-circuit lines require tapping existing double-circuit lines, PPL EU will review the existing lines to determine if reverse phasing can be provided at low cost.
- Computer modeling is required to develop the optimum phasing and overall conductor arrangements for lines added to, or rebuilt in, multiple-line corridors.
  - Merely adding a reverse-phase double-circuit line to an existing transmission line corridor or reverse phasing a rebuilt line in the multiple-line corridor will not necessarily produce lower magnetic field levels at the edge of the corridor right of way.
  - The corridor must be computer modeled with all the lines, existing phase conductor locations and currents. Then, magnetic field calculations must be made varying the phase arrangements of the new or reconstructed line to determine the appropriate phasing arrangement.
  - Current flow direction on a line also must be considered. For example, a reverse-phased line should have the current flowing in the same direction on both circuits. If the current flow is in the opposite direction for one circuit, reverse phasing will not produce the lowest magnetic field and another phase arrangement that produces lower fields may need to be utilized.

**5. Increase the minimum ground clearance for all new transmission lines.**

**138/69 kV Transmission Lines**

- Increasing the minimum line design ground clearance from 25 feet to 30 feet may add up to about 5 percent to the installed cost of a new double-circuit single pole 138/69 kV line. For a given project, such cost may be substantially less, however. In fact, PPL EU frequently uses higher-than-minimum ground clearances due to such features as road crossings, line crossings and site-specific terrain. With long-span reverse-phase design, the magnetic field is reduced from 9 mG to 7 mG (about 22 percent) at the edge of a 100-foot-wide right of way as shown in Chart X.
  - In the actual design of transmission lines to include higher minimum ground clearances, there may be limited segments (such as highway crossings, severe slopes and transmission line crossing locations) where National Electrical Safety Code (NESC) minimum ground clearances may need to be used. The NESC minimum ground clearances are less than the increased ground clearance discussed previously.

**230 kV Transmission Lines**

- Increasing the minimum line design ground clearances from 27 feet to 32 feet may add up to about 5 percent to the cost of a single-circuit single-pole line (current standard). For a given project, such cost may be substantially less, however. In fact, PPL EU frequently uses higher-than-minimum ground clearances due to such features as road crossings, line crossings and site-specific terrain. By increasing the clearances, the magnetic field is reduced from 30 mG to 28 mG (about 7 percent) at the edge of a 150-foot-wide right of way.
- Increasing clearances from 27 feet to 32 feet could theoretically add up to about 2.8 percent to the cost of a double-circuit single-pole line (current standard) and reduce the magnetic field of a reverse-phase line from 16 mG to 15 mG (about 6 percent) at the edge of a 150-foot-wide right of way. Chart XI is a summary of this data.
- Studies are required for each new 230 kV line to determine optimum structure types, ground clearances, configurations and designs to reduce field levels. Such

studies could include analysis of reduction measures such as additional minimum ground clearances, increasing conductor tensions, using reduced phase spacing (a "Delta" configuration on a single-circuit line), installing the second circuit initially, and/or adding a second set of conductors that are reverse phased and operated in parallel with the first set (bundled/split phase).

#### **500 kV Transmission Lines**

- Increasing ground clearances from 33 feet to 53 feet may add up to about 4.5 percent to the cost of a single-circuit "H-frame" line (current standard). For a given project, such cost may be substantially less, however. In fact, PPL EU frequently uses higher-than-minimum ground clearances due to such features as road crossings, line crossings and site-specific terrain. By increasing the clearances, the magnetic field is reduced from 42 mG to 35 mG (about 17 percent) at the edge of a 200-foot-wide right of way.
- Increasing ground clearances from 33 feet to 53 feet could theoretically add up to 2.8 percent to the cost of a double-circuit "H-frame" line (current standard) and reduces the magnetic field of a reverse-phase line from 21 mG to 16 mG (about 24 percent) at the edge of a 200-foot-wide right of way. Chart XII is a summary of this data.
- Studies are required for each new 500 kV line to determine optimum structure types, ground clearances, configurations and designs to reduce field levels. Such studies could include analysis of reduction measures such as additional minimum ground clearances, increasing conductor tensions, using reduced-phase spacing (a "Delta" configuration on a single circuit line), installing the second circuit initially, and/or adding a second set of conductors that are reverse phased and operated in parallel with the first set (bundled/split phase).

## **RECONDUCTORING OR ADDING ADDITIONAL CIRCUITS TO EXISTING TRANSMISSION LINES**

**When reconductoring or adding additional circuits to existing transmission lines, PPL EU will evaluate low-cost or no-cost options for magnetic field management on a case-by-case basis.**

When reconductoring existing transmission lines or adding additional circuits, low-cost alternatives may not exist; however, the following steps will be taken:

- For a single-circuit line, the use of a Delta arrangement or other modifications on the existing structure, with reduced-phase spacing, will be evaluated.
- For double-circuit lines, application of reverse phasing may reduce the magnetic field under the line and within the right of way and will be evaluated.
- For single- and double-circuit lines, evaluate using higher conductor tensions that can increase the minimum line design ground clearance.

## **DISTRIBUTION LINES**

**At the 12 kV distribution level, new main three-phase lines will continue to be constructed with five feet of additional ground clearance.**

- Main lines are the most heavily loaded sections of a distribution line and therefore have the highest magnetic fields associated with them.
- Increasing the ground clearance by five feet reduces the magnetic field under the line from 14 mG to 11 mG using the standard eight-foot crossarm design. These values are based on increasing pole heights from 45 feet to 50 feet and a typical operating current of 300 amps per phase.
- Chart XIII is a summary of this data. Increasing ground clearance by five feet could theoretically add about 5 percent to the cost of a typical distribution line.

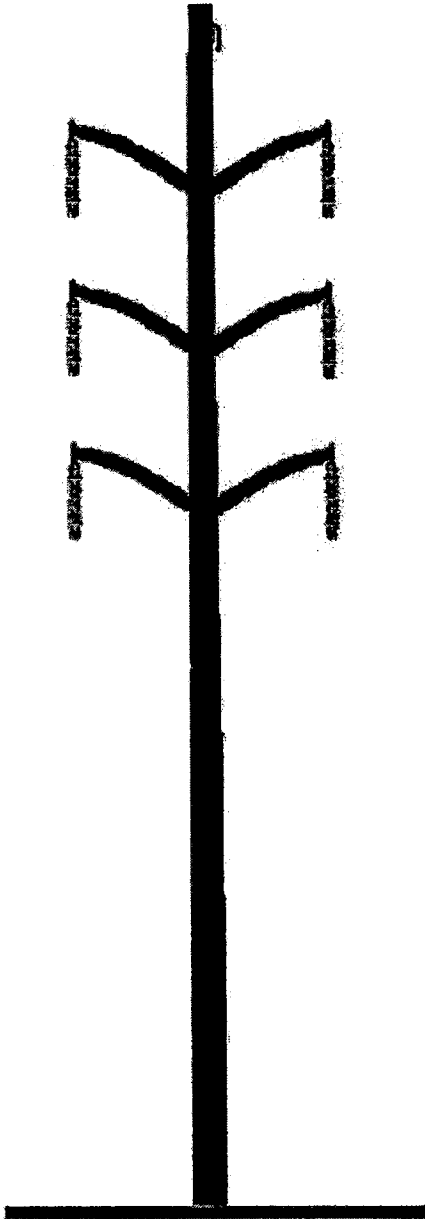
## **UNDERGROUND TRANSMISSION LINES**

---

**Underground transmission lines are required due to environmental or land use factors or restrictions on available clearances, PPL EU will evaluate options for magnetic field management techniques on a case-by-case basis.**

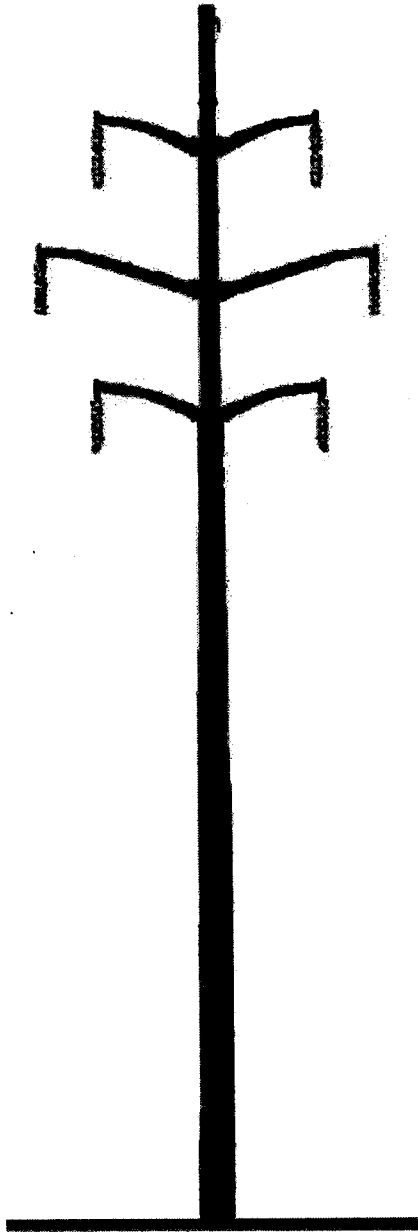
- The phase arrangement that produces the lowest field will be determined.
- The depth of burial of the line will be determined considering the cost of excavation and the location of other buried utilities in the area.
- The use of steel pipe ferromagnetic shielding that reduces magnetic fields will be evaluated.

# Short-Span Construction



- **More compact design**
- **Should not be used solely to reduce magnetic fields**
- **Typical conductor data:**
  - 1 3/8" HS steel overhead ground wire - 7.3 feet sag
  - 6-556.5 KCMIL 24/7 ACSR power conductors - (PARAKEET) 10.0 feet sag
  - Average span - 400 feet

# Long-Span Construction Remains PPL EU 138 kV Standard



- Lower cost alternative
- Reduces magnetic fields due to higher structures
- Typical conductor data:
  - 1 3/8" HS steel overhead ground wire - 17.3 feet sag
  - 6-556.5 KCMIL 24/7 ACSR power conductors - (PARAKEET) 23.0 feet sag
  - Average span - 600 feet

**138/69 kV REVERSE-PHASE TRANSMISSION LINES  
CALCULATED MAGNETIC FIELDS AT 400 AMPERES**

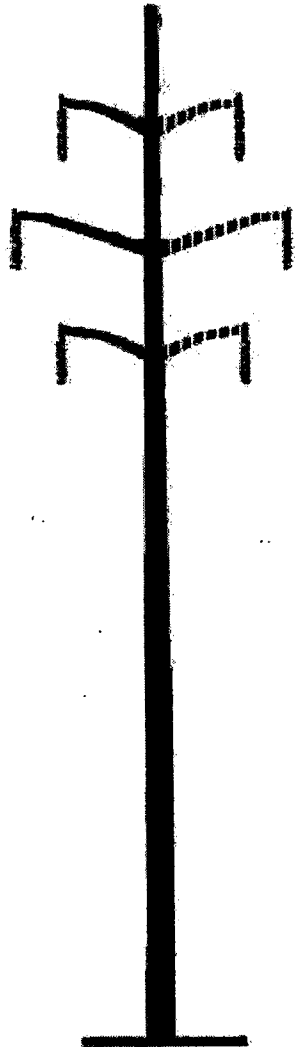
TYPE CONSTRUCTION	MAGNETIC FIELD IN MILLIGAUSS AT THE EDGE OF THE RIGHT OF WAY
SHORT SPAN (CHART I)	30
SHORT SPAN (REVERSE PHASE)	8
LONG SPAN (CHART II)	29
LONG SPAN (REVERSE PHASE)	9
COMPACT (CHART VI)	14
COMPACT (REVERSE PHASE)	3

The edge of right of way is 50 feet from the line centerline.  
 The 400 ampere phase current is balanced between phases.  
 Calculations are based on a minimum ground clearance of 25 feet.  
 LONG SPAN, SHORT SPAN and COMPACT are double-circuit lines.

# Typical Single-Circuit Structure Designs



**Top/Middle**



**Vertical**



**Top/Middle/Bottom**

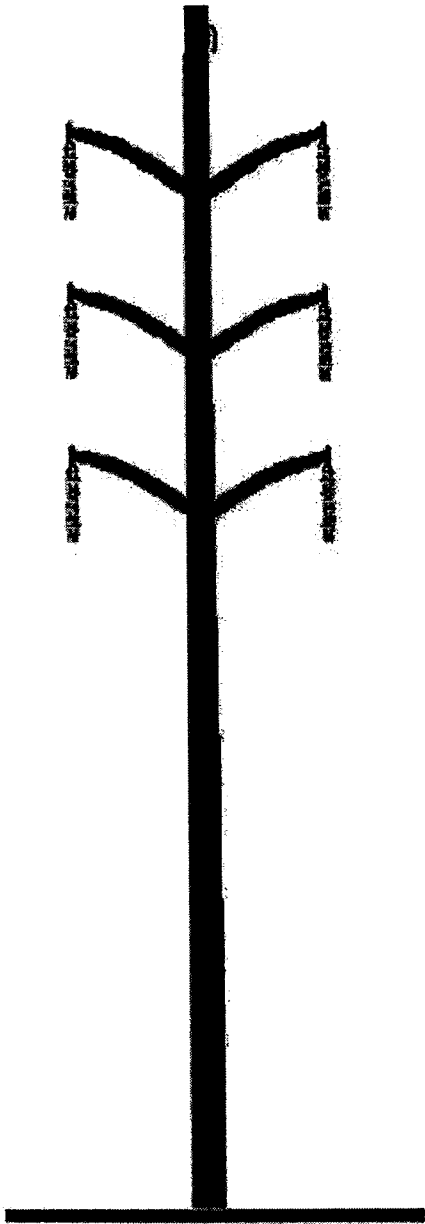
——— initial single circuit  
- - - - future second circuit

**138/69 kV SINGLE CIRCUIT TRANSMISSION LINES  
CALCULATED MAGNETIC FIELDS AT 400 AMPERES**

TYPE CONSTRUCTION	MAGNETIC FIELD IN MILLIGAUSS AT THE EDGE OF THE RIGHT OF WAY
TOP/MIDDLE/BOTTOM	20
VERTICAL	17
TOP/MIDDLE	12

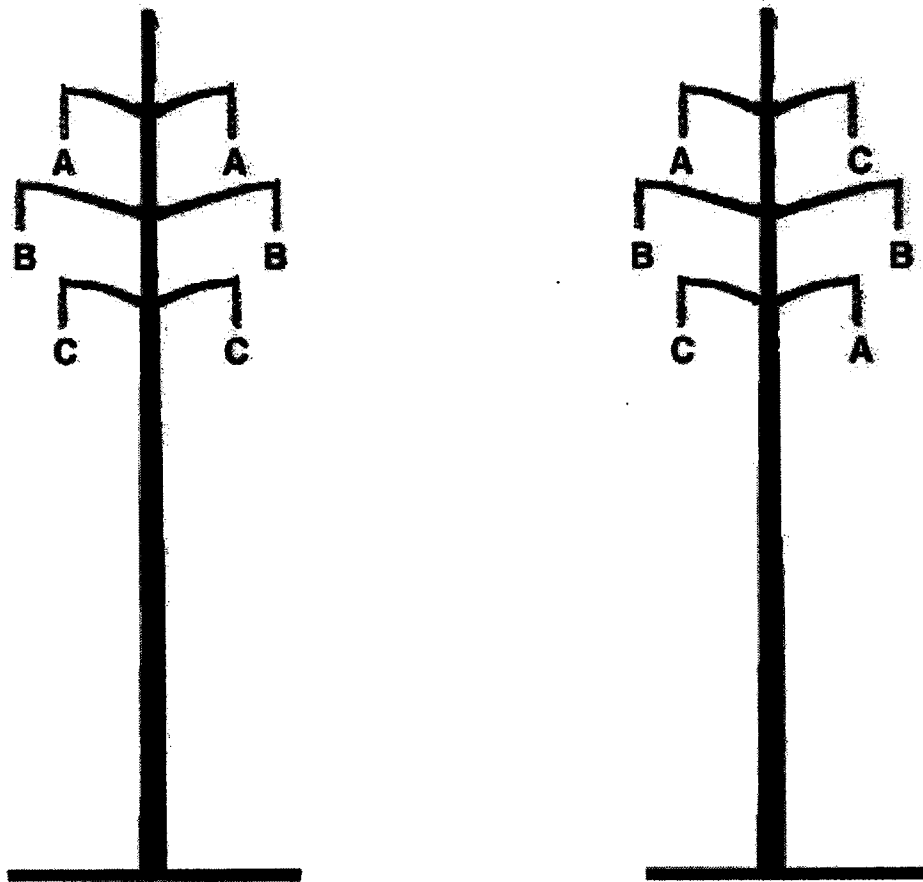
The edge of right of way is 50 feet from the line centerline.  
 The 400 ampere phase current is balanced between phases.  
 Calculations are based on a minimum ground clearance of 25 feet.

# Compact Design Structure



- **Minimize magnetic fields due to compact design**
- **Not a low-cost alternative**
- **Typical conductor data:**
  - 1 3/8" HS steel overhead ground wire - 9.0 feet sag
  - 6-556.5 KCMIL 24/7 ACSR power conductors - (PARAKEET) 9.0 feet sag
  - Average span - 300 feet

# Reverse Phasing of Double-Circuit Transmission Lines



From: → → → → To:

Reverse phasing also can be one of the following phase arrangements:

A	B		B	A		B	C		C	A		C	B
C	C	or	C	C	or	A	A	or	B	B	or	A	A
B	A		A	B		C	B		A	C		B	C

**230 kV REVERSE-PHASE TRANSMISSION LINES  
CALCULATED MAGNETIC FIELDS AT 800 AMPERES**

TYPE CONSTRUCTION	MAGNETIC FIELD IN MILLIGAUSS AT THE EDGE OF THE RIGHT OF WAY
DOUBLE CIRCUIT POLE	49
DOUBLE CIRCUIT POLE (REVERSE-PHASE)	16

The edge of right of way is 75 feet from the line centerline.  
The 800 ampere phase current is balanced between phases.  
Calculations are based on a minimum ground clearance of 27 feet.

**500 kV REVERSE-PHASE TRANSMISSION LINES  
CALCULATED MAGNETIC FIELDS AT 1100 AMPERES**

TYPE CONSTRUCTION	MAGNETIC FIELD IN MILLIGAUSS AT THE EDGE OF THE RIGHT OF WAY
DOUBLE CIRCUIT POLE	37
DOUBLE CIRCUIT POLE (REVERSE PHASE)	21

The edge of right of way is 100 feet from the line centerline.  
The 1,100 ampere phase current is balanced between phases.  
Calculations are based on a minimum ground clearance of 33 feet.

**INCREASED 138/69 kV MINIMUM GROUND CLEARANCE  
CALCULATED MAGNETIC FIELDS AT 400 AMPERES**

TYPE CONSTRUCTION	MINIMUM GROUND CLEARANCE FEET	MAGNETIC FIELD IN MILLIGAUSS AT THE EDGE OF THE RIGHT OF WAY
SINGLE CIRCUIT TOP/MIDDLE	25	12
SINGLE CIRCUIT TOP/MIDDLE	30	10
LONG SPAN	25	29
LONG SPAN	30	26
LONG SPAN (REVERSE PHASE)	25	9
LONG SPAN (REVERSE PHASE)	30	7

The edge of right of way is 50 feet from the line centerline.  
The 400 ampere phase current is balanced between phases.

**INCREASED 230 kV MINIMUM GROUND CLEARANCE  
CALCULATED MAGNETIC FIELDS AT 800 AMPERES**

TYPE CONSTRUCTION	MINIMUM GROUND CLEARANCE FEET	MAGNETIC FIELD IN MILLIGAUSS AT THE EDGE OF THE RIGHT OF WAY
SINGLE CIRCUIT TOP/MIDDLE	27	30
SINGLE CIRCUIT TOP/MIDDLE	32	28
DOUBLE CIRCUIT POLE	27	49
DOUBLE CIRCUIT POLE	32	46
DOUBLE CIRCUIT POLE (REVERSE PHASE)	27	16
DOUBLE CIRCUIT POLE (REVERSE PHASE)	32	15

The edge of right of way is 75 feet from the line centerline.  
The 800 ampere phase current is balanced between phases.

**INCREASED 500 kV MINIMUM GROUND CLEARANCE  
CALCULATED MAGNETIC FIELDS AT 1,100 AMPERES**

TYPE CONSTRUCTION	MINIMUM GROUND CLEARANCE FEET	MAGNETIC FIELD IN MILLIGAUSS AT THE EDGE OF THE RIGHT OF WAY
SINGLE CIRCUIT "H" STRUCTURE	33	42
SINGLE CIRCUIT "H" STRUCTURE	53	35
DOUBLE CIRCUIT POLE	33	37
DOUBLE CIRCUIT POLE	53	31
DOUBLE CIRCUIT POLE (REVERSE PHASE)	33	21
DOUBLE CIRCUIT POLE (REVERSE PHASE)	53	16

The edge of right of way is 100 feet from the line centerline.  
The 1,100 ampere phase current is balanced between phases.

**12 KV DISTRIBUTION LINES  
CALCULATED MAGNETIC FIELDS AT 300 AMPERES**

TYPE CONSTRUCTION	POLE HEIGHT FEET	MAGNETIC FIELD IN MILLIGAUSS*	
		AT CENTERLINE	AT 30 FEET FROM CENTERLINE
STANDARD CROSSARM	45	14	7
STANDARD CROSSARM	50	11	6

\* Field level under the line at mid-span based on 300 amps, balanced loading, one meter above ground level.

**APPENDIX "C"**

**LIST OF PROPERTY OWNERS WITHIN THE AFFECTED RIGHT-OF-WAY**

Glenn L. & Barbara R. Cassel  
6611 Union Deposit Rd.  
Harrisburg, PA 17111-4807

PPL Electric Utilities  
2 N 9<sup>th</sup> Street  
Allentown, PA 18101

## **APPENDIX "D"**

### **LIST OF INVOLVED GOVERNMENTAL AGENCIES, MUNICIPALITIES AND OTHER PUBLIC ENTITIES**

---

Pennsylvania Historical and Museum Commission  
Bureau for Historic Preservation  
Commonwealth Keystone Building, Second Floor  
400 North Street  
Harrisburg, Pennsylvania 17120-0053  
Attn: Mr. Douglas C. McLearn, Chief

Pennsylvania Department of Transportation  
Commonwealth Keystone Building  
400 North Street, 8<sup>th</sup> Floor  
Harrisburg, Pennsylvania 17120  
Attn: The Honorable Allen D. Biehler, P.E., Secretary

Department of Environmental Protection  
P.O. Box 2063  
Market Street State Office Building  
Harrisburg, Pennsylvania 17105-2063  
Attn: Office of Field Operations

South Hanover Township Board of Supervisors  
111 West Third Street  
Hershey, Pa 17033-2498

South Hanover Township Planning Commission  
c/o Penny Pollick, Township Manager  
111 West Third Street  
Hershey, Pa 17033-2498

Lower Paxton Township Board of Supervisors  
425 Prince Street  
Harrisburg, Pa 17109

Lower Paxton Township Planning Commission  
425 Prince Street  
Harrisburg, Pa 17109

Dauphin County Planning Commission  
112 Market Street, 2<sup>nd</sup> Floor  
Harrisburg, Pa 17101-2015

Dauphin County Commissioners  
PO Box 1295  
Harrisburg, Pa 17108