Induced Stray Voltages from Transmission Lines

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Introduction

- Conventional stray voltage sources include unbalanced loads, neutral impedances, and high earth voltage gradients.
- Non-conventional sources include triplen harmonic neutral currents and induction from nearby transmission lines.

Induced Stray Voltages - Parameters

- Currents in transmission lines
- Proximity to distribution line
- Length of parallel section
- Additive phase angle between induced and load currents in the grounded neutral system
- Soil resistivity

Concern

- Stray voltage on a single phase tap line (7.2 kV) caused by a 500 kV transmission line
- Parallel section – Approximately 1 mile
- Average Distribution Pole Spacing – Approximately 350’
- Approximately 14 volts at the faucet of a customer at the end of the tap line

Project Scope

- **NEETRAC and prior measurements**
- **Identification of various sources**
- **Computer modeling and validation with the measured data**
- **Performing studies to evaluate effectiveness of various stray voltage mitigation methods**

Measurements by NEETRAC

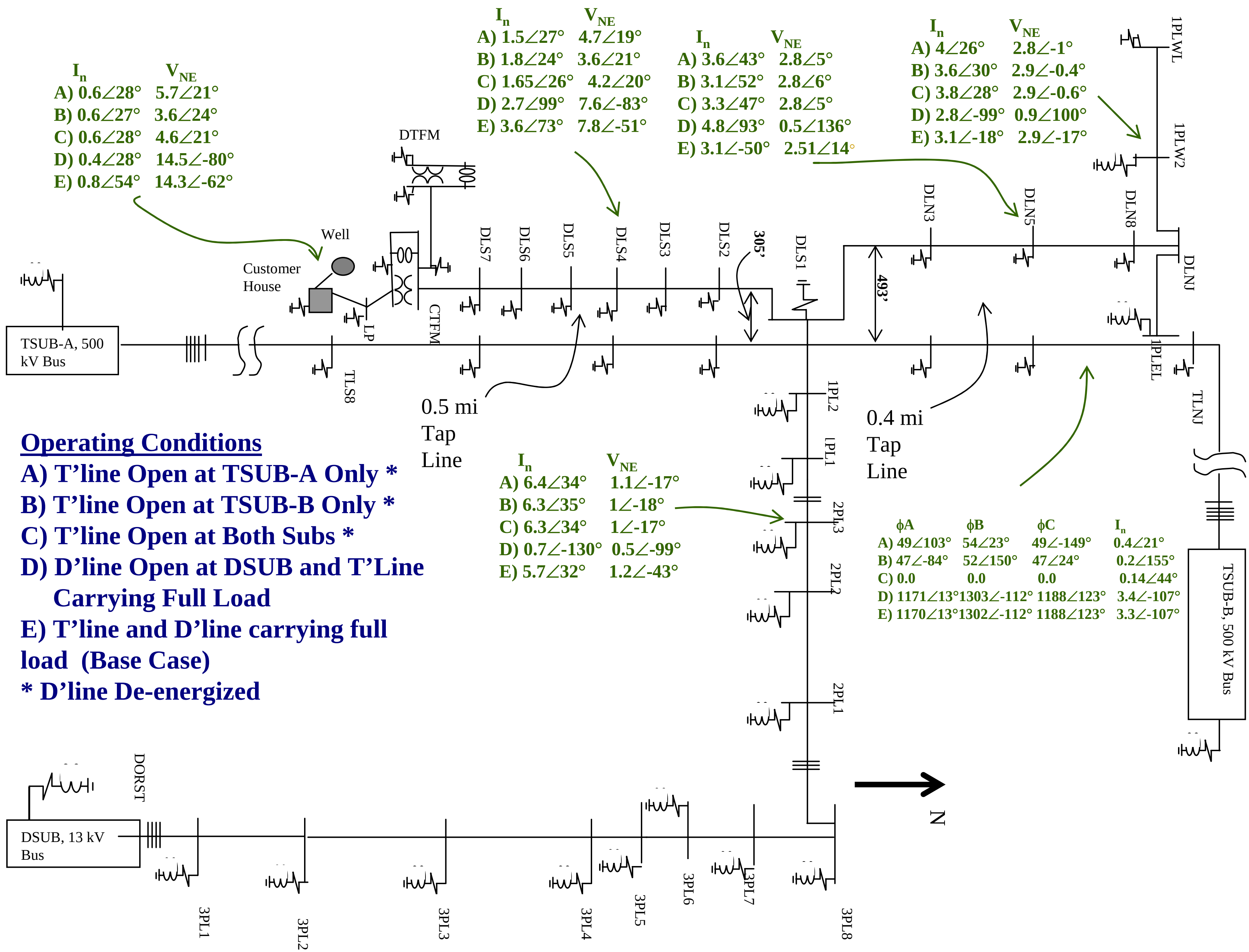
- **First set of measurements involved identifying house wiring, secondary neutral and buried 120/240 volt service related sources, if any. None was found.**
- **Second set of measurements included primary profiling from the substation to the customer – phase/neutral currents, NEVs and pole ground resistances**

Prior Measurements

- **Prior to NEETRAC's involvement, the utility company measured stray voltages at the customer's faucet both with and without energizing the transmission line.**
- **The measurements indicated that the transmission line contributed approximately 73% of the total stray voltage. The remainder was produced by the load current.**

Computer Modeling

- Modeled the subject feeder from the substation to the customer including the parallel transmission line.
- Validated the model by comparing the results with the measured data.
- Identified the sources by simulating various operating conditions.



In VNE
A) 0.6∠28° 5.7∠21°
B) 0.6∠27° 3.6∠24°
C) 0.6∠28° 4.6∠21°
D) 0.4∠28° 14.5∠-80°
E) 0.8∠54° 14.3∠-62°
In VNE
A) 1.5∠27° 4.7∠19°
B) 1.8∠24° 3.6∠21°
C) 1.65∠26° 4.2∠20°
D) 2.7∠99° 7.6∠-83°
E) 3.6∠73° 7.8∠-51°
In VNE
A) 3.6∠43° 2.8∠5°
B) 3.1∠52° 2.8∠6°
C) 3.3∠47° 2.8∠5°
D) 4.8∠93° 0.5∠136°
E) 3.1∠-50° 2.51∠14°
In VNE
A) 4∠26° 2.8∠-1°
B) 3.6∠30° 2.9∠-0.4°
C) 3.8∠28° 2.9∠-0.6°
D) 2.8∠-99° 0.9∠100°
E) 3.1∠-18° 2.9∠-17°
1PLWL
1PLW2
DTFM
Well
Customer House
LP
CTFM
DLS7
DLS6
DLS5
DLS4
DLS3
DLS2
305'
DLS1
493'
DLN3
DLN5
DLN8
DLNJ
1PLEL
TLNJ
TSUB-A, 500 kV Bus
TLS8
0.5 mi Tap Line
0.4 mi Tap Line
1PL2
1PL1
2PL3
2PL2
2PL1
Operating Conditions
A) T'line Open at TSUB-A Only *
B) T'line Open at TSUB-B Only *
C) T'line Open at Both Subs *
D) D'line Open at DSUB and T'Line Carrying Full Load
E) T'line and D'line carrying full load (Base Case)
* D'line De-energized
In VNE
A) 6.4∠34° 1.1∠-17°
B) 6.3∠35° 1∠-18°
C) 6.3∠34° 1∠-17°
D) 0.7∠-130° 0.5∠-99°
E) 5.7∠32° 1.2∠-43°
φA φB φC In
A) 49∠103° 54∠23° 49∠-149° 0.4∠21°
B) 47∠-84° 52∠150° 47∠24° 0.2∠155°
C) 0.0 0.0 0.0 0.14∠44°
D) 1171∠13° 1303∠-112° 1188∠123° 3.4∠-107°
E) 1170∠13° 1302∠-112° 1188∠123° 3.3∠-107°
TSUB-B, 500 kV Bus
DSUB, 13 kV Bus
DORST
N
3PL1
3PL2
3PL3
3PL4
3PL5
3PL6
3PL7
3PL8

Evaluation of Mitigation Methods

Install neutral isolators

- Initially, blocker ratings will be exceeded during high loading conditions.
- Replaced with 3 kV surge arrester with reduction in stray voltage from 14.3 volts to 0.01 volts.
- The primary NEV increased from 14.3 volts to 15.7 volts.

Evaluation of Mitigation Methods

Move the tap line away

- **The tap line would have to be relocated approximately 2,500’ from the transmission line to reduce the stray voltage by 40%. This result is partly due to extremely high soil resistivity in the area.**
- **Besides the cost, this solution was impractical for existing customers.**

Evaluation of Mitigation Methods

Install 5 Ohms ground well at each pole

- **Study showed that the stray voltages can be reduced by 40%.**
- **Drilling a ground well at eight locations is expensive.**
- **There is no guarantee that the resistance will be reduced to 5 Ohms.**

Evaluation of Mitigation Methods

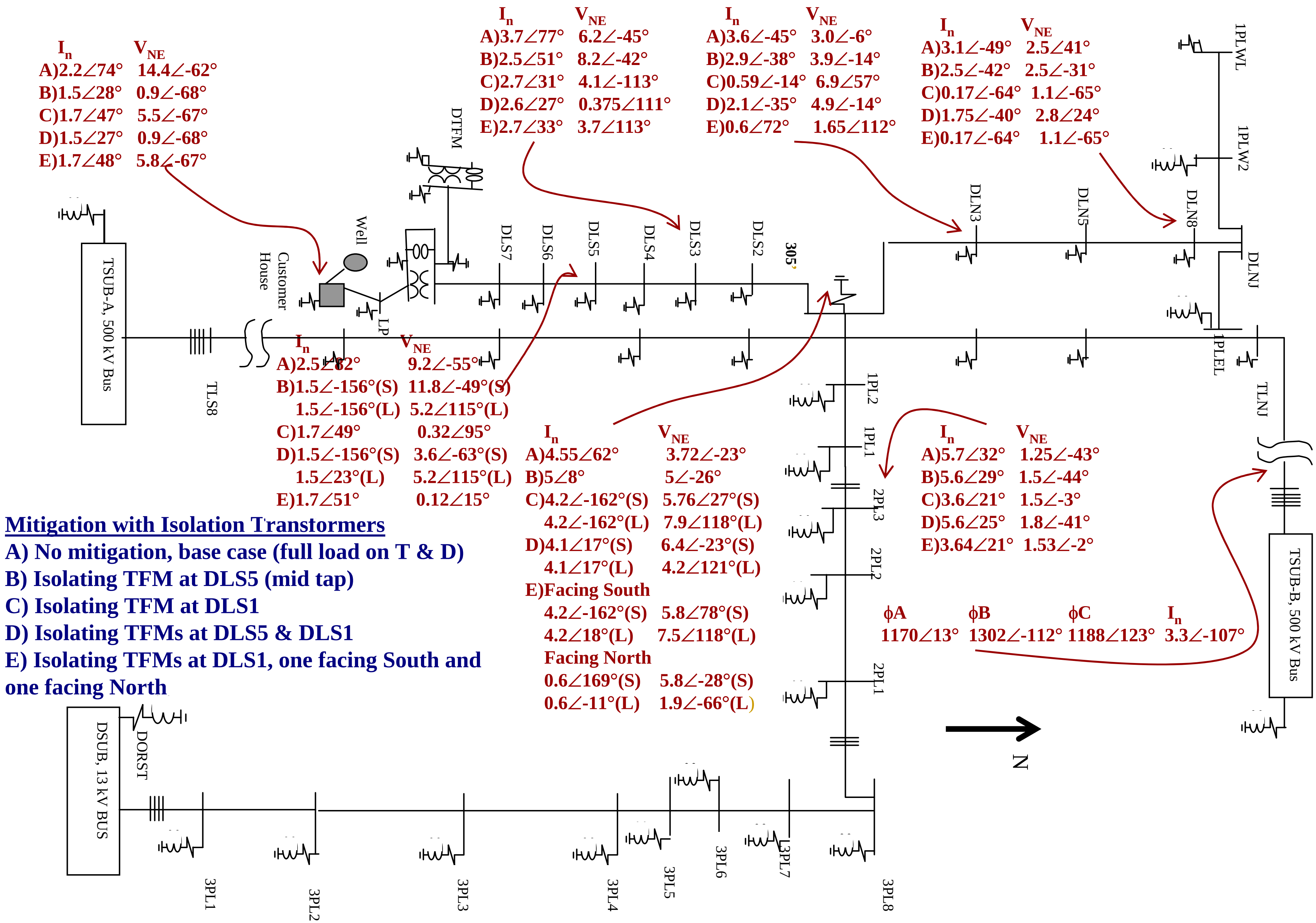
Convert the tap to a three phase line and balance the load.

- **The NEV at the customer's transformer pole increased from 14.3 volts to 16.3 volts.**

Evaluation of Mitigation Methods

Install isolation transformers on the tap line

- **Breaks the length of the parallel section**
- **Effective solution for the entire tap**
- **Cable TV or telephone shields across the isolation transformers must be isolated to increase mitigation effectiveness.**
- **Proper fuse coordination is required.**



In VNE
A)2.2∠74° 14.4∠-62°
B)1.5∠28° 0.9∠-68°
C)1.7∠47° 5.5∠-67°
D)1.5∠27° 0.9∠-68°
E)1.7∠48° 5.8∠-67°
In VNE
A)3.7∠77° 6.2∠-45°
B)2.5∠51° 8.2∠-42°
C)2.7∠31° 4.1∠-113°
D)2.6∠27° 0.375∠111°
E)2.7∠33° 3.7∠113°
In VNE
A)3.6∠-45° 3.0∠-6°
B)2.9∠-38° 3.9∠-14°
C)0.59∠-14° 6.9∠57°
D)2.1∠-35° 4.9∠-14°
E)0.6∠72° 1.65∠112°
In VNE
A)3.1∠-49° 2.5∠41°
B)2.5∠-42° 2.5∠-31°
C)0.17∠-64° 1.1∠-65°
D)1.75∠-40° 2.8∠24°
E)0.17∠-64° 1.1∠-65°
1PLWL
1PLW2
DTFM
Well
Customer House
LP
DLS7
DLS6
DLS5
DLS4
DLS3
DLS2
305
DLN3
DLN5
DLN8
DLNJ
1PLEL
TSUB-A, 500 kV Bus
TLS8
In VNE
A)2.5∠82° 9.2∠-55°
B)1.5∠-156°(S) 11.8∠-49°(S)
1.5∠-156°(L) 5.2∠115°(L)
C)1.7∠49° 0.32∠95°
D)1.5∠-156°(S) 3.6∠-63°(S)
1.5∠23°(L) 5.2∠115°(L)
E)1.7∠51° 0.12∠15°
In VNE
A)4.55∠62° 3.72∠-23°
B)5∠8° 5∠-26°
C)4.2∠-162°(S) 5.76∠27°(S)
4.2∠-162°(L) 7.9∠118°(L)
D)4.1∠17°(S) 6.4∠-23°(S)
4.1∠17°(L) 4.2∠121°(L)
E)Facing South
4.2∠-162°(S) 5.8∠78°(S)
4.2∠18°(L) 7.5∠118°(L)
Facing North
0.6∠169°(S) 5.8∠-28°(S)
0.6∠-11°(L) 1.9∠-66°(L)
1PL2
1PL1
2PL3
2PL2
2PL1
TLNJ
In VNE
A)5.7∠32° 1.25∠-43°
B)5.6∠29° 1.5∠-44°
C)3.6∠21° 1.5∠-3°
D)5.6∠25° 1.8∠-41°
E)3.64∠21° 1.53∠-2°
φA φB φC In
1170∠13° 1302∠-112° 1188∠123° 3.3∠-107°
TSUB-B, 500 kV Bus
N
Mitigation with Isolation Transformers
A) No mitigation, base case (full load on T & D)
B) Isolating TFM at DLS5 (mid tap)
C) Isolating TFM at DLS1
D) Isolating TFMs at DLS5 & DLS1
E) Isolating TFMs at DLS1, one facing South and one facing North
DSUB, 13 kV BUS
DORST
3PL1
3PL2
3PL3
3PL4
3PL5
3PL6
3PL7
3PL8

Conclusions

- Stray voltages due to induction can be significantly higher compared to those due to load currents.
- Stray voltages due to induction are typically spread along the parallel section serving several customers.
- Most of the traditional mitigation means will not be effective.

Conclusions

- **Installation of one or more isolation transformers along the parallel section is an effective solution for the customers served by the tap.**
- **For effective mitigation, Cable TV and telephone shields must be isolated across the isolation transformers.**