A Case Study of Pipeline Induced AC Mitigation on a Complex Right-of-Way

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ABSTRACT

Co-location of a new transmission line with an existing pipeline Right-of-Way particularly, in urban areas, can have many benefits including lower costs and quicker acquisition of easements. Indeed, in many instances the Public Utility Commission or other governmental agencies may suggest or direct co-location with other utilities. However closely aligning HVAC transmission lines with O&G pipelines will result in inducing Voltages and currents into the pipeline(s). These induced Voltages and currents may have very undesirable consequences for the pipeline(s) including: unsafe touch and step potentials, damage to the pipeline's protective coatings, damage to the pipeline steel including the possibility of pipeline puncture and product loss, and accelerated corrosion of the pipeline steel. There are many techniques available to mitigate these effects, but mitigation costs may be very costly, adding complexity and probable construction delays to the project. It is far better to assess these costs and complexities during the route selection process rather than to be committed to a preferred route only to discover that IAC mitigation will be complex, costly and will result in delaying completion of the project.

This paper presents a case history from a recent pipeline induced AC mitigation project in southern California. The presentation fully illustrates the complexity, time delays and costs associated with mitigation of induced AC effects on four closely spaced large diameter natural gas pipelines from a newly constructed 220 kV wind farm transmission line after the preferred route had been selected and Right-of-Way had been purchased.

INTRODUCTION

More and more pressure is being placed upon transmission line designers and support staff to site new transmission lines on rights-of-way that are co-located with underground utilities. Some of the considerations that affect route selection include: cost of right-of-way (ROW), particularly in urban areas; land utilization issues; aesthetics and other issues associated with NIMBY; directives by BLM and other governmental entities; rulings by public utility commissions; and other difficulties associated with ROW acquisition. The net result is that it has become common practice to site new transmission lines on common corridors with other utilities. Most frequently the other utilities are underground pipelines. With many fast track projects little, if any, thought is given to AC induction effects on nearby or paralleling underground utilities until route selection has been finalized and circuit engineering is well underway. This is extremely shortsighted and can be very costly to the electric utility in the form of excessively complex, extensive, and costly AC mitigation measures. When collocating a new circuit with existing underground utilities, the power company becomes liable for the full costs on the studies, design, and installation of any pipeline mitigation that may be required. These difficulties and related costs can most easily be minimized during the route selection process. But, project management must be proactive in engaging the services of an experienced consultant during the early stages of the project. This paper presents a case history where excessive engineering and construction costs and startup delays resulted from lack of forward thinking during route selection in the early stages of the project.

PIPELINE AC INDUCTION

At this day and time AC induction into underground pipelines is a well understood phenomenon by experienced practitioners in the industry and has been well documented in the industry. [a, b, c, d, e, f, g, h, I, j, k, l] Unfortunately the phenomenon is not well known by most T&D engineers responsible for siting new circuits. AC induction may be an issue on any metallic pipeline on the collocated ROW. This includes municipal water lines although municipal operators are generally less sophisticated and demanding than are the oil and gas (O&G) utility operators. AC induced corrosion of O&G pipelines has become a topic of serious discussion within the industry and is looked at closely whenever a new transmission line (TL) is proposed close to their ROW.

Mitigating against the probability of AC Corrosion on underground O&G pipelines is now far more of an issue than it was a decade ago. Mitigation to overcome the probability of AC induced corrosion is generally more extensive, and therefore costlier, than just mitigating for personnel safety or against direct pipeline damage alone. But, that is the world that we now live in. If the power company is not proactive with investigating the issue, the pipeline company(s) will. In that case, they will be far less concerned with the cost of the required mitigation scheme than the power company who will be responsible for reimbursement of all costs. In some instances, a pipeline operator might escalate the projected costs in an attempt to convince the power company to change the route segment. Therefore, it is generally in the power companies' best interest to proactively select a consultant to investigate the ROW segments in question during the early stages of route selection.

A CASE STUDY ON A COMPLEX RIGHT-OF-WAY

NextEra Energy began construction of a large wind farm project in eastern Kern County, California over a decade ago. Southern California Edison (SCE) proposed a 220 kV, 1,414 megawatt circuit to transport the energy to the grid and to allow for future load growth. Initial load, with the wind farm only, would be 240 megawatts. Therefore, the initial load would be only seventeen percent of circuit design. Part of the route along Segment 3B, was designed to cross and closely parallel four large diameter natural gas pipelines. Two of the lines were owned and operated by Pacific Gas and Electric Company (PG&E). The other two lines were owned and operated by El Paso Natural Gas Company, later becoming Kinder-Morgan Company (KM). Figure 1 shows the layout of the ROW. Total length of the close parallelism was 4.43 miles.

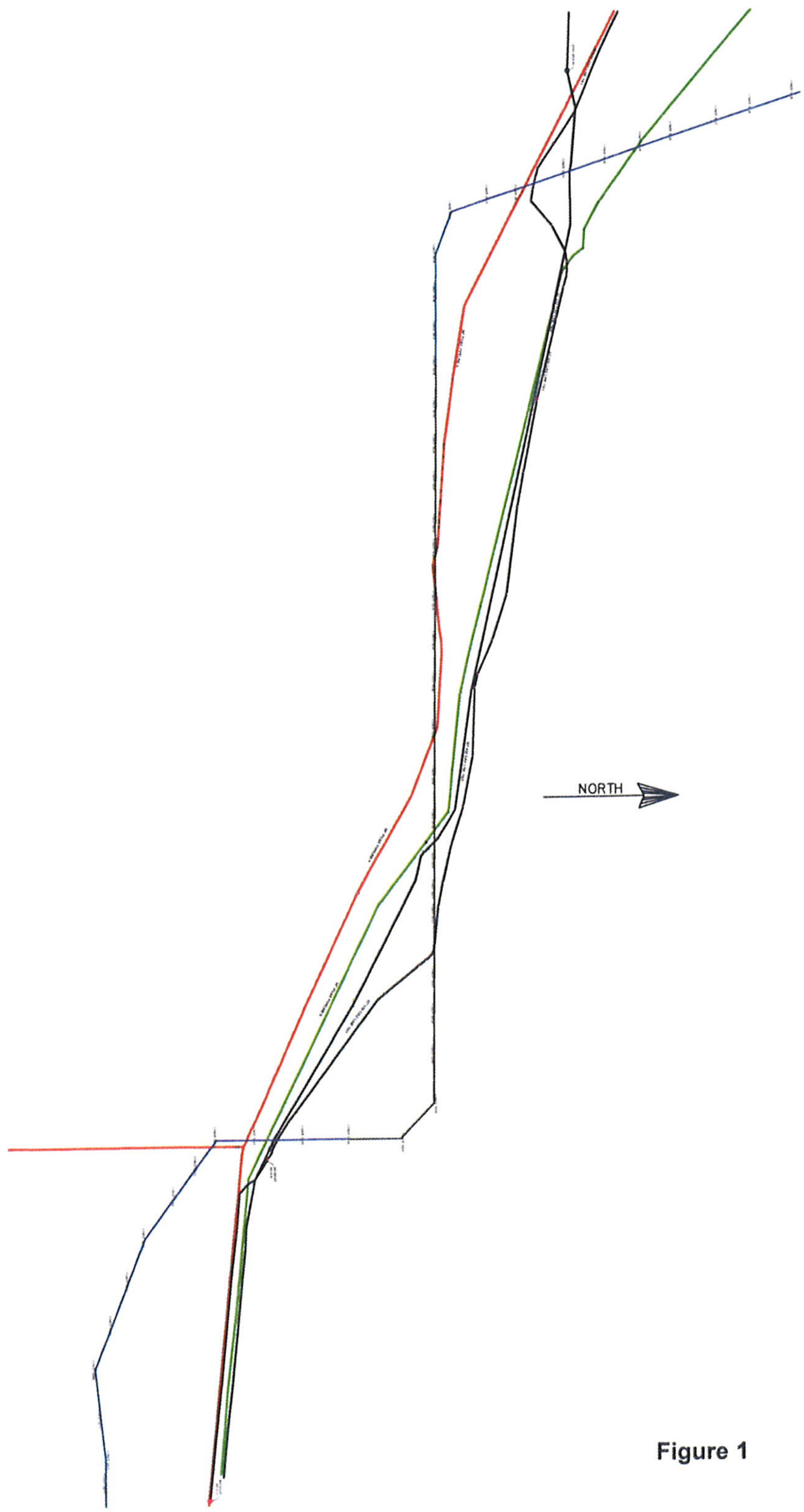

Figure 1

By the time that our firm was engaged to perform an induced AC mitigation study, the transmission line (TL) route had been finalized and the individual towers had already been staked with no chance for any relocation.

EXCESSIVE COST OF MITIGATION

Acquisition cost for independent ROW across essentially arid pasture land for less than 4.5 miles of alternate circuit route in an arid, undeveloped region of southern California is unknown but certainly would be only a small fraction of the expenditures outlined below. Provided that the circuit had been relocated with an adequate separation distance of two hundred to four hundred feet from the existing pipelines, no induced AC mitigation would have been required. However, since the ROW alignment was fixed, we were obligated to mitigate against all of the following effects:

- Personnel protection against unsafe step and touch potentials under "steady state" conditions [m]
- Damage to the pipeline wall and/or protective coatings under fault conditions
- Personnel protection against unsafe step and touch potentials under fault conditions [m]
- Corrosion damage to the pipe wall from induced Voltage under "steady state" conditions

For the short section of concern within the bounds of the Segment 3B alignment the following mitigation features were required to fully mitigate all of the concerns stated above:

- 48 shallow and deep ground rods ranging in depth from 75 feet to 887 feet. These rods were drilled into solid granite beneath a shallow overburden.
- 3,631 lineal feet of zinc ribbon installed as a horizontal mitigation wire close to the pipe. Backhoe excavation was required due to the rocky overburden.
- Gradient control mats were required for personnel safety at ten aboveground valve sites.
- Sixty cathodic decoupling devices were required between the pipelined and the installed grounding features.
- Sixteen specialized test stations were required to monitor AC discharge densities.
- A fifty-foot segment of 34-inch diameter pipeline, where a power line tower had been installed too close, had to be backfilled and provided with drainage culverts to assure safe touch potentials on the pipeline.

Due to the very close and complex interactions between the proposed TL and the existing pipelines, minimal separation distances between some of the TL structures and the pipelines, and multiple crossings; very extensive computer modeling was required to find acceptable and constructible solutions to the various exposures. Our engineering services on this project extended over about a six-year interval involving initial studies, electronic modeling of the ROW with and without mitigation features, design of all required mitigation in two phases, multiple sets of For-Construction plan and specifications, construction support, and acceptance testing. Total cost for all of our provided services was $931, 661. or $210,307. per mile of parallelism.

Total billing for construction of the required Phase Two only mitigation features was $4,029,000. or $909,481. per mile of parallelism. Added to this are the additional costs for in-house engineering, additional surveying and field investigations, constructability reviews, environmental impacts, administrative burden, etc. for both the TL designer and for SCE, and the complete costs of the Phase One mitigation program. None of these additional costs have been estimated for the case history under discussion here.

Initial computer modeling effort clearly showed the magnitude of the problem and the project management team was so advised. Project management's (PM) response was that it was no longer possible to relocate any of the towers and that we must mitigate against the IAC effects to the pipeline operator's satisfaction. Open and very cooperative dialog was maintained between all parties during the succeeding efforts. This was absolutely essential to successful conclusion of the project. The pipeline company's demands were firm but reasonable and studies proceeded post haste. Mid way through the project we recommended constructing the mitigation features in two phases in order to keep the project on track to meet the initial delivery requirements from the wind farm project. Due to personnel safety issues, it would not even be possible to back feed the circuit until at least some of the mitigation features were installed.

Phase One design was sufficient to assure safe operation of the pipelines with a maximum load of only 240 megawatts. Once all of these mitigation features had been constructed it was possible to back feed and subsequently transmit the wind farm load. Taking this two phase approach resulted in only delaying the initial back feed by a few weeks. Designing the Phase Two mitigation requirements was much more demanding and time consuming. Multiple conference calls with all project team members, involving more than twenty individuals, were required to discuss the various mitigation options available to us. Principal concerns during these discussions were constructability, cost, time to construct, and impact on the existing structures. A very large number of mitigation schemes were explored during the design effort. A considerable amount of additional field work was required by ELK, a subcontractor to ELK, and the TL designer. All of this design effort took well over a year to complete. No additional load could be added to the circuit until after all of the Phase Two mitigation features had been constructed and commissioned.

CONCLUSION

It is far more cost effective and will create far less schedule impacts during design and construction to investigate AC induction impacts during the route selection process rather than waiting until after a preferred route selection has been finalized. When making a preferred route presentation to the utility commission, the high cost for induced AC mitigation on particular segments can argue strongly in favor of the power company's preference for different segments.

Studies conducted during the route selection phase may be more general and less detailed, not requiring a For-Construction package. The only requirement is to identify the mitigation features that would be required for the proposed alignment and structure type(s) and to estimate construction costs. Many times minor adjustments in alignment, structure type(s) and/or conductor phasing can make significant differences in the overall complexity and costs for mitigation. One may anticipate preliminary study costs in the range of $2,000. To $15,000. per mile of parallelism, depending on length and complexity. For the case of a single pipeline and a single circuit, a long parallelism, and minimal changes in geometry. Cost would be at the low end. For the case of parallelisms that are short, in remote locations, or complex with multiple pipelines and multiple circuits; cost per mile will be considerably higher than is the case for similar rights-of-way.

Once final route selection has been made and TL design is in progress, the consultant that performed the preliminary assessment can be retained to finalize the mitigation design and to provide a complete For-Construction Package. Many times it may be advantageous for the consultant to provide construction support and/or acceptance testing of the final installation.

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