Retrofitting OPGW on Existing Overhead Transmission Lines — Structural, Electrical, and Operational Challenges

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Abstract – *Retrofitting or replacing Optical Ground Wire (OPGW) on existing lattice steel overhead transmission lines is one of the most common procedures, as the energy utilities upgrade the older networks to meet the increasing communication bandwidth requirements. Many older transmission lines were originally equipped with low-fiber OPGW or conventional OGW intended mainly for shielding, and therefore lack the mechanical capacity required for modern high-fiber OPGW. Their supporting lattice steel towers were not designed for the larger diameter, higher weight, and higher mechanical strength of today's higher fiber OPGW. While newly designed and current towers are capable of these demands, retrofitting older structures poses major engineering challenges. These challenges are further compounded by the frequent absence of reliable as-built data, requiring diverse approaches such as reverse engineering of on-site actual transmission line conditions by means of field sag measurements, tension reverse-calculation using PLS-CADD, and structure modeling of existing towers using PLS-Tower. This paper recognizes the noteworthy structural, electrical, and operational issues associated with OPGW retrofitting and presents appropriate engineering measures to evaluate the stability and suitability of old transmission structures under the increased loads imposed by larger OPGW.*

Keywords: *optical ground wire retrofitting, PLS CADD, PLS TOWER, reverse engineering, transmission line*

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I. Introduction

Retrofitting Optical Ground Wire (OPGW) on existing overhead lattice steel transmission lines has become a common practice in modern power systems [1], [2]. Most energy utilities are upgrading their older lines where either low fiber OPGW or traditional overhead ground wire (OGW) that was formerly installed. The primary driver for these upgrades is the ever-growing need for higher communication bandwidth since transmission lines can last for several decades, around 40-60 years. This approach is the most practical one, since transmission lines are already interconnecting major cities and towns. Retrofitting OPGW is generally considered as a more practical and cost-effective than providing a new underground fiber optic cable link.

All newly designed transmission towers are completely compatible with the large size of modern higher fiber OPGW. However, the main engineering challenge occurs when retrofitting OPGW on an older transmission line, which were typically designed only for lighter OGW and therefore may not safely accommodate the increased loads of modern high-fiber OPGW.

This challenge is further increased by the fact that many old transmission lines do not have complete or dependable as-built documentation. In many cases, the available documentation is either missing or incomplete. Missing sag & tension charts, inadequate tower drawings, and missing stringing records make it necessary to perform reverse engineering to accurately simulate the existing mechanical situation of the transmission line. This includes measuring actual sags in selected section, back-calculating tensions using measured sag using PLS-CADD and modeling existing lattice steel towers in PLS-Tower, either using available shop and erection drawings or site measured member dimensions to evaluate the impact of increased vertical, transverse or longitudinal loads resulting from the OPGW retrofitting.

This paper presents the key structural, electrical, and operational challenges associated with retrofitting OPGW on aging overhead transmission lines and outlines suitable engineering measures to verify the stability and adequacy

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of existing lattice tower structures.

II. Research Gap and Contribution

Although OPGW retrofitting is widely practiced, most published work still concentrates on installation procedures, vibration issues, fiber performance, or general safety guidelines. Existing documents such as IEEE 524 and IEEE 1138 provide useful background [1], [2], but they do not explain how engineers should evaluate older towers when original sag–tension charts, loading diagrams, or fabrication drawings are missing. In practice, many utilities face exactly this situation on lines built several decades ago.

Recent studies have examined conductor behavior and tension reconstruction using field measurements [3], [4], but they do not combine these methods into a unified assessment process suitable for aging transmission lines. Likewise, CIGRÉ reports discuss upgrading strategies but stop short of offering a practical workflow for cases where documentation is incomplete [5].

This paper attempts to fill that gap by bringing together three practical elements. First, it outlines a reverse-engineering workflow that uses field sag measurements and PLS-CADD tension back-calculation to rebuild the mechanical state of the line [3], [4]. Second, it provides corrected load formulations for vertical, transverse, and longitudinal forces, with clear definitions and tower-type distinctions supported by recent mechanical studies [6], [7]. Third, it proposes a combined decision process that links structural checks, electrical performance, hardware compatibility, and construction feasibility, forming a realistic method for evaluating OPGW retrofitting on aging lines [8], [9].

III. Technical Parameters

Before selection of the proposed OPGW, we need to understand the loading effects of an OPGW on the existing towers. See Fig. 1 for the loading tree. During the operation of the OPGW, the loads are resolved into three directions: vertical, transverse, and longitudinal.

A. Vertical Load

The vertical load applied to the tower peak is calculated using the weight span, the unit weight of the OPGW, and the applicable factor of safety (FOS), as expressed in (1).

$$V = W_s \,.\; w.\, FOS \tag{1}$$

where W_s is the weight span and w is the unit weight of the OPGW.

If the original tower loading data for the existing transmission line is available, the engineer can directly compare the new OPGW-induced loads with the allowable vertical capacity of the tower peak. This enables a straightforward assessment of whether the existing structure can safely accommodate the increased weight and mechanical stiffness of the proposed OPGW.

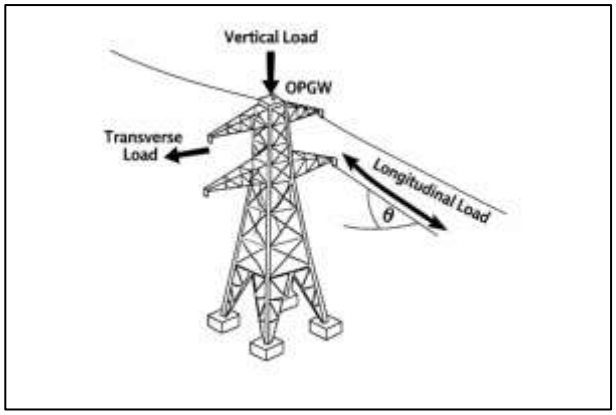


Fig. 1. Tower Loading Tree

B. Transverse Load

The transverse load represents the horizontal force acting on the tower due to wind pressure on the OPGW. When retrofitting an existing transmission line, this parameter becomes critical because modern high-fiber OPGW typically has a larger diameter and therefore experiences higher wind drag compared to older OGW or low-fiber OPGW.

The total transverse load acting on the tower is the combined effect of wind drag and the horizontal tension component resulting from the line angle. The transverse load is calculated using (2) and (3).

$$T_{x,wind} = L_s \cdot p_w \cdot d \cdot FOS \tag{2}$$

$$T_{x,\theta} = 2\,.T.\sin\left(\frac{\theta}{2}\right) \tag{3}$$

Where:

- L_s = wind span
- p_w = wind pressure
- d = cable diameter
- FOS = factor of safety
- T = horizontal tension
- θ = line deviation angle

The total transverse load applied to the tower peak is therefore,

$$T_{total} = T_{x,wind} + T_{x,\theta} \tag{4}$$

C. Longitudinal Load

Under normal operating conditions, for suspension towers, there is no longitudinal load. However, in some designs the longitudinal load is calculated as the difference between the horizontal tensions of the adjacent spans. For suspension towers under normal conditions, it can be expressed as,

$$T_{y,normal} = [T_1 - T_2] \quad (5)$$

For suspension towers with balanced spans, the longitudinal load is instead the difference between adjacent span tensions, as expressed in (5). Full tension applies only to dead-end, broken-wire, unbalanced-span, or stringing conditions. For angle/dead-end towers the basic longitudinal load is equal to the horizontal component of the OPGW tension, which can be expressed as,

$$T_{y,DE}=T \quad (6)$$

Where: T is obtained from tower loading or from reverse engineering sag–tension calculations in PLS-CADD, which shall be discussed later.

Line angles also contribute to longitudinal loading. This angle-induced longitudinal load is calculated as,

$$T_{y,\theta}=2\ .\ T\ .\ cos\left(\frac{\theta}{2}\right) \quad (7)$$

Where θ is the line deviation angle at the tower.

IV. Retrofitting challenges

Research on retrofitting OPGW is limited compared to studies on new line design. Existing work focuses primarily on:

- Live line installation techniques
- Safety procedures
- Fiber optic performance
- Vibration mitigation

However, few studies address structural impacts on aging lattice towers, especially those originally designed for lighter steel GW.

A major challenge in retrofitting OPGW on older transmission lines is the frequent absence of complete and reliable as-built documentation. Essential design information required for evaluating the feasibility of OPGW replacement is often missing, outdated, or inconsistent with actual field conditions. Critical data typically includes but is not limited to:

- Technical specifications of the existing OPGW/OGW
- OPGW Sag and Tension data
- Tower loading diagrams
- Tower Fabrication Drawings
- Stringing charts
- Plan and Profile drawings
- Phase Conductor sag–tension charts (to verify mid-span clearances)

Without these inputs, engineers cannot accurately determine existing mechanical tensions, conductor behavior, or tower loading capacity.

V. Reverse Engineering for unavailable data

A. Existing OGW/OPGW weight and diameter

An actual sample of the existing installed OGW/OPGW should be collected from site, typically from the jumper loops at angle towers. The unit weight of this sample is then determined (e.g., by weighing a known length), and the outer diameter is measured using appropriate instruments such as a vernier caliper. These measured properties provide a reliable starting point to assess whether the proposed OPGW is mechanically equivalent to the existing ground wire. If the proposed OPGW has equal or lower unit weight and diameter compared to the existing OGW/OPGW, no increase in structural loading is expected and a detailed tower loading reassessment may not be required [10].

After determining the weight and diameter of the installed OGW/OPGW, the values can be compared if these correspond to a standard size of OGW/OPGW from online data or PLS CADD library, see Fig. 2, helping us to gather additional data such as cross-sectional area, material type, polynomial coefficients etc.



Fig. 2. Cable Library - original screenshot from PLS-CADD

B. Design tensions and field sag measurement

When design tensions are not available (sag & tension calculations or Tower Loadings), field sag measurements at known temperatures can be used to back-calculate the existing OGW/OPGW tensions and model the line accurately in PLS-CADD [3],[4]. The OGW/OPGW cable file can be generated using measured field data or reconstructed from available as-built information. Representative spans are selected along the route, and the sag of the ground wire is measured using approved survey methods while recording the conductor temperature (or ambient temperature with appropriate assumptions). Using the measured span length, sag, and temperature, the corresponding tension is back-calculated in PLS-CADD, shown in Fig. 3 by iteratively adjusting the tension until the calculated sag matches the field value. The same procedure is done for various sections of the transmission line, for example different span lengths, terrain, or tower types, consequently each section would be modeled with precise design tensions.

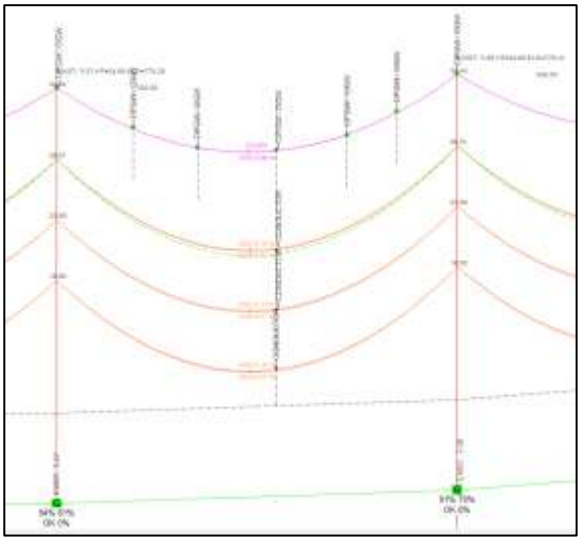


Fig. 3. PLS CADD Screenshot for matching surveyed sag

VI. Holistic Approach for OPGW Retrofitting on old Transmission Lines

Retrofitting OPGW on old transmission lines involves more than independent engineering checks. It requires an elaborate approach that combines structural, electrical, functioning, and reliability checks. Old transmission lines often do not present uniform conditions due to years of environmental changes and effects, undocumented alterations, relocations, and no consistent maintenance procedures [11]. Therefore, linking all independent assessment and authentication methodologies is critical to ensure that the retrofitting to be planned is both technically possible and operationally safe.

A. Assessment of Tower Aging and Degradation

Before calculation of the new OPGW loads, the physical state of existing lattice towers must be evaluated. This includes:

- Corrosion mapping of members and connections
- Checking for missing bolts, bent members, or damaged bracings
- Evaluating the tower foundation settlement
- Inspecting peak plates, attachment points, and ground wire supports
- Identifying any undocumented reinforcements or field modifications

These evaluations would ensure that the loading calculations exhibit the real structural capacity, rather than the original theoretical design capacity of the originally installed tower.

B. Verification of Existing Hardware and Accessories

OPGW retrofitting requires compatibility with existing hardware. Engineers must verify:

- Condition and rating of suspension clamps, angle fittings, and vibration dampers
- Adequacy of existing ground wire supports for larger-diameter OPGW
- Integrity of insulator strings and crossarm attachments

This step prevents mechanical unsuitability that could lead to premature wear or failure.

C. Electrical and Lightning Performance Evaluation

Replacing OGW with OPGW influences the transmission line's electrical performance. A collective evaluation would include:

- Shielding angle checks
- Grounding resistivity measurement at each tower
- Assessment of tower footing
- Review of fault current dissipation capability

This ensures that the retrofitting does not compromise lightning protection or grounding performance [12].

D. Dynamic and Environmental Loading Analysis

The modern high fiber OPGW cables exhibit different aerodynamics and consequently vibration behavior. A

combined analysis would include:

- Aeolian vibration study
- Galloping evaluation
- Span-based wind pressure variation (Finite Element Analysis)
- Ice loading checks for cold regions
- Type Tests for clamps and fittings

These effects must be evaluated together to ensure long-term reliability.

E. System Reliability and Communication Integration

Optical Fiber Ground Wire (OPGW) is not just a mechanical component of the tower, but also mainly a communication backbone. A complete retrofitting approach would include:

- Fiber Optic Splicing and joint box locations
- Integration with the existing SCADA and telecommunication systems
- Verifying that fiber attenuation remains within acceptable limits across long spans.
- Coordination with protection and communication engineers

This would ensure that the new OPGW meets both the mechanical and communication operation requirements.

F. Construction Feasibility and Safety Planning

In many cases, OPGW replacement is performed on energized lines due to operational constraints and limited outage availability. Getting power shutdown is almost impossible, especially if the transmission line has only one circuit. A combined feasibility review would include:

- Live-line work assessment
- Design stringing load assessment
- Verification of safe working clearances for workers and equipment
- Planning outages for critical sections
- Identifying risks involved with phase conductor swing and induced voltages

This ensures the retrofit would be safely executed and without compromising any system reliability.

VII. Final Integrated Decision Framework

Retrofitting OPGW on older lines requires more than checking a few load values. The process works best when the assessments are done in a clear sequence. The framework below reflects how utilities usually approach such projects when documentation is limited and tower aging is a concern [8], [13].

A. Stage 1 — Collect Field Information:

This includes sampling the existing OGW/OPGW, measuring its weight and diameter, recording sag at known temperatures, and inspecting tower members for corrosion, missing bolts, or undocumented repairs. These observations form the baseline for later calculations [11].

B. Stage 2 — Rebuild Mechanical Data:

Using the measured sag and span lengths, tensions are back-calculated in PLS-CADD. Each representative section is modeled until the calculated sag matches the field value. This step recreates the mechanical behavior of the line when original charts are unavailable [3], [4].

C. Stage 3 — Structural Evaluation:

The towers are modeled in PLS-Tower using actual member dimensions. The corrected vertical, transverse, and longitudinal loads are applied, and member utilization ratios are checked. Any overstressed bracing or peak plates are identified, and reinforcement needs are noted [8], [14].

D. Stage 4 — Electrical and Lightning Checks:

Shielding angle, grounding resistance, and fault current dissipation are reviewed to ensure that replacing OGW with OPGW does not reduce lightning performance [12].

E. Stage 5 — Hardware and Dynamic Behavior:

Suspension clamps, angle fittings, and dampers are checked for compatibility with the new cable diameter. Aeolian vibration, galloping risk, and wind-pressure variations are also reviewed, especially on long spans [6], [15], [16].

F. Stage 6 — Construction Feasibility:

Since many retrofits are done on energized lines, safe working clearances, stringing loads, and outage requirements are evaluated. Risks related to conductor swing and induced voltages are also considered [14].

The final decision combines all six stages and determines whether the towers can carry the new OPGW, whether reinforcement is needed, or whether certain towers must be replaced. Refer to Fig. 4 showing the complete flowchart which presents all major decision points beginning with the required input data and

progressing through tension reconstruction, structural evaluation, electrical checks, hardware verification, and construction feasibility.

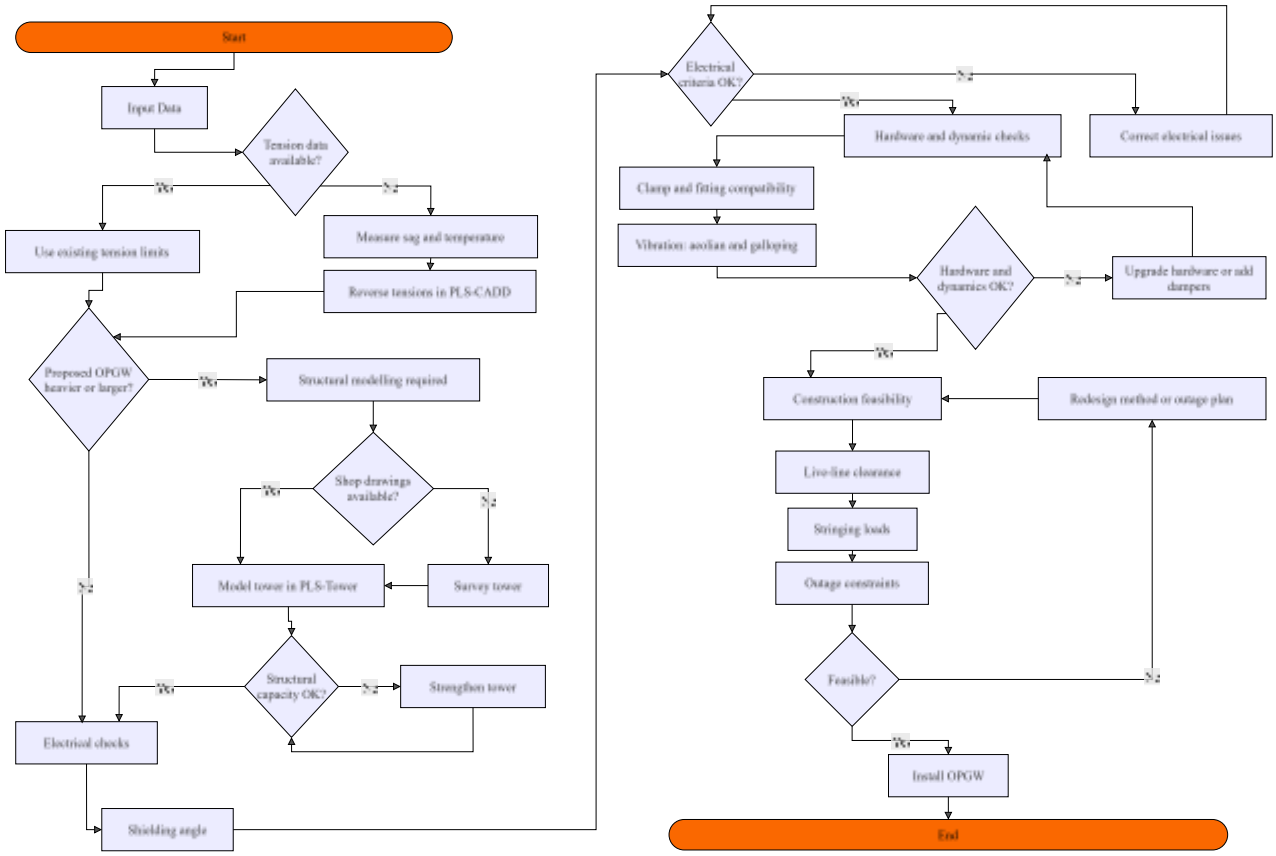


Fig. 4. Integrated decision flowchart for evaluating OPGW retrofitting feasibility on aging transmission lines

VIII. Conclusion

Retrofitting OPGW on existing lattice transmission lines introduces structural, electrical, and operational challenges that must be evaluated using realistic field data and validated mechanical simulations. The modern higher fiber OPGW could induce an increased vertical, transverse and longitudinal loads that may compromise the original design criteria of older lattice steel structures. Absence of proper as-built drawings and documentation increases the complications in the evaluation process, which makes reverse engineering crucial for analyzing the actual mechanical tension criteria, OPGW behavior, and tower loading calculations.

Using the systematic site sag measurements, tension back calculation using PLS-CADD, and lattice steel structure modeling using PLS-TOWER, engineers can accurately analyze the practicality of OPGW retrofitting and identify if any towers require reinforcement or replacement.

Proper identification of the existing OGW/OPGW parameters, in combination with realistic simulation of wind, tensions, and weight spans, would ensure that the retrofitting would not compromise the existing transmission line reliability and operation. Effective OPGW retrofitting requires a structured methodology that integrates field measurements, reverse-engineered tensions, and tower capacity assessments. When implemented appropriately, it enables energy utilities to upgrade existing communication network while sustaining the integrity of older transmission lines.

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Conflict of Interest

I declare that there is no conflict of interest in this research article.

References

[1] IEEE Standard 524-2016, *IEEE Guide for the Installation of Overhead Transmission Line Conductors*, IEEE, 2016.

[2] IEEE Standard 1138-2009, *IEEE Standard for Testing and Performance for Optical Ground Wire (OPGW) for Use on Electric Utility Power Lines*, IEEE, 2009.

[3] A. R. AlQahtani, "Reverse engineering of transmission line mechanical parameters using field sag measurements," *IEEE Transactions on Power Delivery*, vol. 36, no. 4, pp. 1892–1901, 2021.

[4] T. Nguyen and P. R. Bhatt, "Evaluation of conductor sag and tension using field measurements and computational methods," *IEEE Access*, vol. 8, pp. 145321–145330, 2020.

[5] CIGRÉ Technical Brochure 798, *Assessment and Upgrading of Existing Overhead Transmission Lines*, 2020.

[6] M. A. S. Masoum, S. Jamali, and M. E. Hamedani, "Mechanical performance evaluation of OPGW cables under combined loading conditions," *IET Generation, Transmission & Distribution*, vol. 14, no. 12, pp. 2341–2349, 2020.

[7] R. S. Ghosh and M. K. Deb, "Dynamic response of overhead ground wires under turbulent wind," *Journal of Wind Engineering and Industrial Aerodynamics*, vol. 206, p. 104115, 2020.

[8] M. R. Islam and M. A. Hoque, "Structural integrity assessment of aged lattice towers using finite element modeling," *Engineering Structures*, vol. 228, p. 111–122, 2021.

[9] L. Chen, Y. Sun, and F. Guo, "Mechanical behavior of composite OPGW under extreme weather conditions," *Composite Structures*, vol. 252, p. 112–124, 2020.

[10] CIGRÉ Technical Brochure 244, *Mechanical Aspects of Ground Wires and OPGW*, 2004.

[11] K. M. AlHamad and S. AlMutairi, "Condition assessment of aging transmission towers in arid environments," *Arabian Journal for Science and Engineering*, vol. 46, pp. 11231–11242, 2021.

[12] J. P. A. Bastos and A. C. S. Lima, "Lightning performance of transmission lines with OPGW shielding," *Electric Power Systems Research*, vol. 213, p. 108–118, 2023.

[13] K. M. AlHamad and S. AlMutairi, "Condition assessment of aging transmission towers in arid environments," *Arabian Journal for Science and Engineering*, vol. 46, pp. 11231–11242, 2021.

[14] A. K. Singh and R. K. Jarial, "Assessment of overhead transmission line components using field inspection and structural analysis," *Electric Power Systems Research*, vol. 189, p. 106–118, 2020.

[15] Y. Zhang, L. Wang, and H. Li, "Wind-induced vibration analysis of OPGW cables using field measurements and numerical simulation," *IEEE Transactions on Power Delivery*, vol. 35, no. 5, pp. 2194–2203, 2020.

[16] L. Chen, Y. Sun, and F. Guo, "Mechanical behavior of composite OPGW under extreme weather conditions," *Composite Structures*, vol. 252, p. 112–124, 2020.