

# Cables Scab, A Scientific Characterization of The Degradation of XLPE and HV/HR-PVC Insulation Under the Influence of Ultraviolet Radiation and Excessive Mechanical Stress in An Environment Extremely Hostile to Polymers

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## Abstract

Excellent standard polymer-insulated resistive electrical cables suffer from outer layer deterioration due to excessive mechanical stress, which leads to damage to the jacket (the outer layer of the insulation). Prolonged exposure to ultraviolet (UV) radiation causes physical and chemical changes that affect the adjacent cables, compromising the reliability of the electrical system.

This paper presents a scientific and field description of a condition called "cable scab," a term that refers to a pattern of gradual surface deterioration affecting adjacent cables. This term does not cause immediate failure but rather represents an early indicator of critical deterioration. The concept is extended to include poor implementation during laying. The description is supported by a physical explanation using Einstein's photochemical breakdown equation, an analysis of the effect of UVA,B,C on XLPE and HR-PVC, and technical recommendations for inspection and treatment are provided.

**Keywords:** Cable Scab, Cable plague, Cable Pest, Tin Pest, Networks Insulation Collapse, Cable Testing

## 1. Introduction

Modern power distribution systems rely on cables with outer insulation layers made of polymers such as XLPE, HR-PVC, or both.

Despite their thermal and electrical advantages, these materials are susceptible to gradual deterioration in exposed environments due to prolonged exposure to ultraviolet radiation, as well as excessive mechanical stress during laying.

A field pattern of this deterioration has been observed, resembling scabies in terms of scaling and fragility. Therefore, it has been suggested that this phenomenon be termed "cable scab" as a diagnostic descriptor in field tests, similar to the globally

recognized tin scab phenomenon.

### 1.1. Photochemical Breakdown – Einstein's Equation

When polymer molecules absorb energy from UV photons, they may break the chemical bonds between the atoms, causing the polymer chain to break down over time.

The photon energy depends on the wavelength and is calculated from Einstein's equation:

$$E = h \cdot f = \frac{h \cdot c}{\lambda} ;$$

## 2. E: Photon Energy

### 2.1. Planck's Constant: $h = 6.626 \times 10^{-34} \text{ J}\cdot\text{s}$

$C$ : Speed of light in a vacuum =  $3.00 \times 10^8 \text{ m/s}$   $\lambda$  = wavelength.  
At 254 nm, the photon energy is about 4.89 electron volts (eV), which is sufficient to break C–C and C–H bonds [1,3].

## 3. The Effect of Ultraviolet Rays on XLPE and PVC Insulation

### 3.1: XLPE

- Polymer chain breakdown → brittleness and loss of elongation
- Surface oxidation and formation of carbonyl groups
- Color change and gray spots
- Deterioration is often slow and delayed

Carbon black is used as a UV stabilizer to improve the resistance of XLPE [3]

- H|CL removal (dehydrochlorination) → yellowing and peeling
- Free radical formation → accelerated structural deterioration
- A sharp decrease in tensile strength and elasticity

Note that PVC is more sensitive to photodegradation than XLPE [4,5].

### 3.2. XLPE/PVC Comparison

PVC/XLPE Status

UV resistance to UVA, B, and C: Poor, Medium

Deterioration rate: Slow and delayed, rapid and visible

Visible changes: Brittleness, gray spots, yellowing, peeling

Status	HV-PVC	XLPE
UV resistance to UV <sub>A,B,C</sub>	Poor	Medium
Deterioration rate	rapid and visible	Slow and delayed
Visible changes	Brittleness, gray spots	yellowing, peeling

## 4. Cable Scab

### 4.1. Definition and Comparison

Cable scab is a condition characterized by the gradual deterioration

of the insulation of electrical cables, characterized by gradual peeling, discoloration, and brittleness without any immediate electrical failure.



**Figure 1:** A Picture of Insulator Being Damaged Due to Excessive Mechanical Tension and Extreme Heat, Which Is Beginning to Affect the Adjacent Cables

The phenomenon is similar in nature to Tin scab (Tin Pest), which transforms from a reactive material to a brittle one under stressful environmental conditions [6].

This term is extremely useful for physical and field characterization in maintenance programs.

### 5. Laboratory Testing and Analysis

- FTIR: Appearance of carbonyl (C = O) peaks and disappearance of CH and CH<sub>2</sub> peaks
- Tensile Testing: 30–50% decrease in tensile strength

- Thermogravimetric Computed Tomography (TSCT) shows microcracks and surface corrosion structures
- These tests are used to distinguish cable scabbing from accidental or structural formality.

## 6: Service Life Modeling

### 6.1. Arrhenius Equation

The Arrhenius equation is used to calculate the deterioration rate:

$$k = A \cdot e^{-\frac{E_a}{RT}} ;$$

- $k$ : degradation rate
- $A$ : reaction coefficient
- $E_a$ : energy activation
- $R$ : free-gas constant
- $T$ : absolute temperature (Kelvin)

## 7: Cable Damage Due To Excessive Mechanical Tension And Poor Implementation

### Symptoms:

- Tears in the outer jacket
- Unnatural creases or folds
- Changes in cable cross-section

### Causes

- Excessive pulling forces
- Absence of rollers for pulling and tightening
- Insufficient lubricants
- Pulling on sharp corners or directly onto the ground

## 7.1. The Negative Results

- Sheathing exposed to moisture
- Possible partial or complete discharge (leakage or short circuit)
- Reduced cable life

## 7.2. Recommendations

- Monitor tensile forces during installation
- Use appropriate pulling heads and tension meters
- Perform insulation tests on all damaged cables.
- Cut and reconnect damaged areas according to international standards before operation.
- Prevent cables from being exposed to direct sunlight and rain.
- Include the term "cable Scab" as a visual and tactile field inspection indicator during performance tests each time.
- Train teams on safe cable pulling.

## 8: Classification of Cables Scab According to the Severity of the Condition

Classification	superficial appearance	Insulator color	Recommendation
Mild Effect	Minor Peeling/Slight Roughness	Pale Gray	Periodic Monitoring
Middle	Small Cracks/Fragility	Clearly Gray	Tensile Test / FTIR
Hardly	Heavy Peeling/Tearing	Dark/Charred	Cut and reconnect

## 9: Limitations and Data Restrictions (Study Limitations and Confidentiality Constraints)

Due to confidentiality agreements and company-level restrictions, access to detailed numerical data, case-specific photographs, and project identifiers was prohibited.

While this limitation reduced the extent of quantitative modeling and comparative analysis, the study focused on general field observations and scientifically established mechanisms supported by literature and controlled laboratory testing.

The absence of direct case citations does not affect the general validity of the "Cable Scab" phenomenon as a reproducible and observable condition in hostile environments.

Further studies using anonymized datasets or simulations are recommended to deepen the statistical understanding of this deterioration mode.

## 10: Conclusion

This paper presents a scientific and field description of the condition of "cable scab," resulting from the effects of ultraviolet radiation and/or excessive mechanical stress in a hostile, high-temperature environment.

The physical and chemical mechanisms of deterioration are

analyzed and linked to field practices, providing technical recommendations for prevention and early detection.

The concept of "cable scab" serves as an early visual and tactile indicator for insulation deterioration and can enhance preventive maintenance strategies in power systems.

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