

# Study on Fire Hazard Assessment of Solar PV Modules Installed in Hydrocarbon Processing Plants

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## Abstract

The integration of solar photovoltaic (PV) systems into hydrocarbon processing plants represents a significant step toward sustainable energy adoption. However, the coexistence of electrical systems with highly flammable hydrocarbon environments introduces complex fire hazards. This study evaluates the fire risks associated with solar PV modules installed in hydrocarbon facilities, identifies ignition sources, analyzes fire propagation mechanisms, and assesses mitigation strategies. The research highlights that while PV systems are generally safe, improper installation, electrical faults, and interaction with hydrocarbon vapors can significantly increase fire and explosion risks. The paper concludes with recommendations for fire safety design, risk mitigation, and regulatory compliance.

## Keywords

Solar PV systems, fire hazard, hydrocarbon industry, risk assessment, ignition sources, process safety

## 1. Introduction

The hydrocarbon processing industry, including oil refineries, petrochemical plants, and gas processing units, is inherently prone to fire hazards due to the presence of flammable substances. Major historical incidents such as refinery fires and explosions emphasize the need for stringent safety systems.

With the growing emphasis on renewable energy, solar PV systems are increasingly installed within such facilities to reduce carbon emissions and energy costs. However, PV systems introduce additional electrical and thermal hazards that must be carefully evaluated.

Although photovoltaic technology is generally considered safe, it still presents fire risks due to its electrical nature and material composition.

## 2. Literature Review

### 2.1 Fire Risks in Photovoltaic Systems

Studies indicate that PV-related fires are primarily caused by:

- Electrical faults (DC arcing, short circuits)
- Hot spots due to module defects
- Poor installation and maintenance
- Environmental factors such as dust, heat, and moisture

PV modules consist of combustible materials such as polymers (EVA, backsheet layers), which can contribute to fire spread and toxic smoke generation when ignited.

Recent research shows that although the frequency of PV fires is relatively low, incidents still occur due to system faults and inadequate safety measures.

## 2.2 Fire Hazards in Hydrocarbon Processing Plants

Hydrocarbon industries face unique fire risks due to:

- Flammable gases and vapors
- High-pressure systems
- Potential for jet fires, pool fires, and explosions

Jet fires and vapor cloud explosions are particularly dangerous in oil and gas facilities and require detailed hazard analysis.

## 2.3 Combined Risk: PV Systems in Hydrocarbon Environments

The integration of PV systems into hydrocarbon facilities creates compound risks, where:

- Electrical ignition sources from PV systems interact with flammable atmospheres
- PV infrastructure may obstruct fire suppression or emergency access
- Fire propagation may be intensified due to additional combustible materials

Fire hazard assessment models suggest that risk increases when multiple hazard systems interact without integrated safety design.

## 3. Objectives of the Study

1. To identify fire hazards associated with solar PV modules in hydrocarbon plants
2. To analyze ignition sources and fire propagation mechanisms
3. To evaluate risk levels using fire hazard assessment techniques
4. To recommend fire prevention and control strategies

## 4. Methodology

This study uses a descriptive and analytical approach:

### 4.1 Data Sources

- Secondary data from research papers, industry reports, and safety guidelines
- Case studies of PV fire incidents and hydrocarbon fires

### 4.2 Risk Assessment Techniques

- Hazard Identification (HAZID)
- Fault Tree Analysis (FTA)
- Qualitative Risk Assessment (QRA)

Fault tree analysis is widely used to determine failure probabilities in PV fire incidents.

## 5. Fire Hazard Identification

### 5.1 Electrical Hazards in PV Systems

- DC arc faults (major cause of PV fires)
- Inverter failures
- Cable insulation degradation
- Ground faults

### 5.2 Thermal Hazards

- Hot spot formation in modules
- Overheating of components
- Heat accumulation due to poor ventilation

### 5.3 Hydrocarbon-Related Hazards

- Presence of flammable vapor clouds
- Leakage from pipelines and storage tanks
- Ignition sensitivity of hydrocarbon-air mixtures

### 5.4 Combined Hazards

The most critical hazard arises when:

- Electrical sparks from PV systems ignite hydrocarbon vapors
- Heat from hydrocarbon fires damages PV modules, causing secondary fires

## 6. Fire Propagation Mechanisms

PV system fires can propagate through:

- Cable trays and wiring networks
- Module-to-module flame spread
- Structural mounting systems

PV modules can release toxic gases and smoke when exposed to fire, contributing to environmental and health hazards.

In hydrocarbon plants, fire escalation can occur rapidly due to:

- High fuel load
- Confined spaces
- Delayed detection

## 7. Risk Assessment

### 7.1 Likelihood of Fire

- Moderate under normal conditions
- High in case of poor installation or maintenance

## 7.2 Consequence Severity

- Severe due to potential explosion
- Risk of cascading failures across plant units

## 7.3 Risk Matrix Evaluation

| Risk Factor          | Level     |
|----------------------|-----------|
| Ignition probability | Medium    |
| Fire propagation     | High      |
| Consequence severity | Very High |
| Overall risk         | High      |

## 8. Fire Prevention and Control Measures

### 8.1 Engineering Controls

- Intrinsically safe electrical design
- Use of flame-retardant materials
- Proper grounding and bonding
- Installation of arc fault detection systems

### 8.2 Layout and Design Considerations

- Separation distance from hydrocarbon units
- Zoning based on hazardous area classification
- Elevated mounting to reduce vapor exposure

### 8.3 Detection and Suppression Systems

- Gas detection systems
- Fire detection (heat/smoke sensors)
- Water spray and foam systems

### 8.4 Maintenance and Inspection

- Regular inspection of cables and connectors
- Thermal imaging for hot spot detection
- Preventive maintenance programs

### 8.5 Administrative Controls

- Safety training for personnel
- Emergency response planning
- Compliance with standards (IEC, NFPA, OISD)

## Discussion

The study reveals that while PV systems are not inherently dangerous, their installation in hydrocarbon environments significantly increases fire risk due to the interaction of electrical and flammable hazards.

Key findings:

- Electrical faults are the primary ignition source
- Hydrocarbon vapors significantly amplify fire consequences
- Poor installation practices are a major contributing factor

Thus, an integrated safety approach combining electrical safety and process safety is essential.

## Conclusion

The integration of solar PV modules into hydrocarbon processing plants introduces complex fire hazards that must be carefully managed. Although PV systems contribute to sustainable energy goals, their deployment in hazardous environments requires strict adherence to fire safety principles.

Effective hazard assessment, proper system design, and continuous monitoring are critical to minimizing fire risks and ensuring worker and plant safety.

## References

1. Sinha, P. et al. (2017). *Human Health Risk Assessment Methods for PV Fire Risks*. National Renewable Energy Laboratory.
2. Umar, A. S., & Hamid, Y. K. (2022). *Causes and Prevention of Solar Electric Fire Incidents*.
3. Journal of Cleaner Production (2021). *Fire Safety of Photovoltaic Systems*.
4. Yang, R. (2019). *Risk Assessment of Fire Accidents in Hydrocarbon Processing Industry*.
5. Fire Journal (2026). *Critical Review on Photovoltaic Fire Safety*.
6. El-Harbawi, M., & Al-Mubaddel, F. (2020). *Fire and Explosion Risks in Electrical Systems*.
7. Journal of Loss Prevention in Process Industries (2025). *Hydrocarbon Fire Simulation and Safety Assessment*.
8. Process Safety and Environmental Protection (2007). *Hydrocarbon Jet Fire Hazards*.
9. Journal of Building Engineering (2022). *Fault Tree Analysis of PV Fires*.