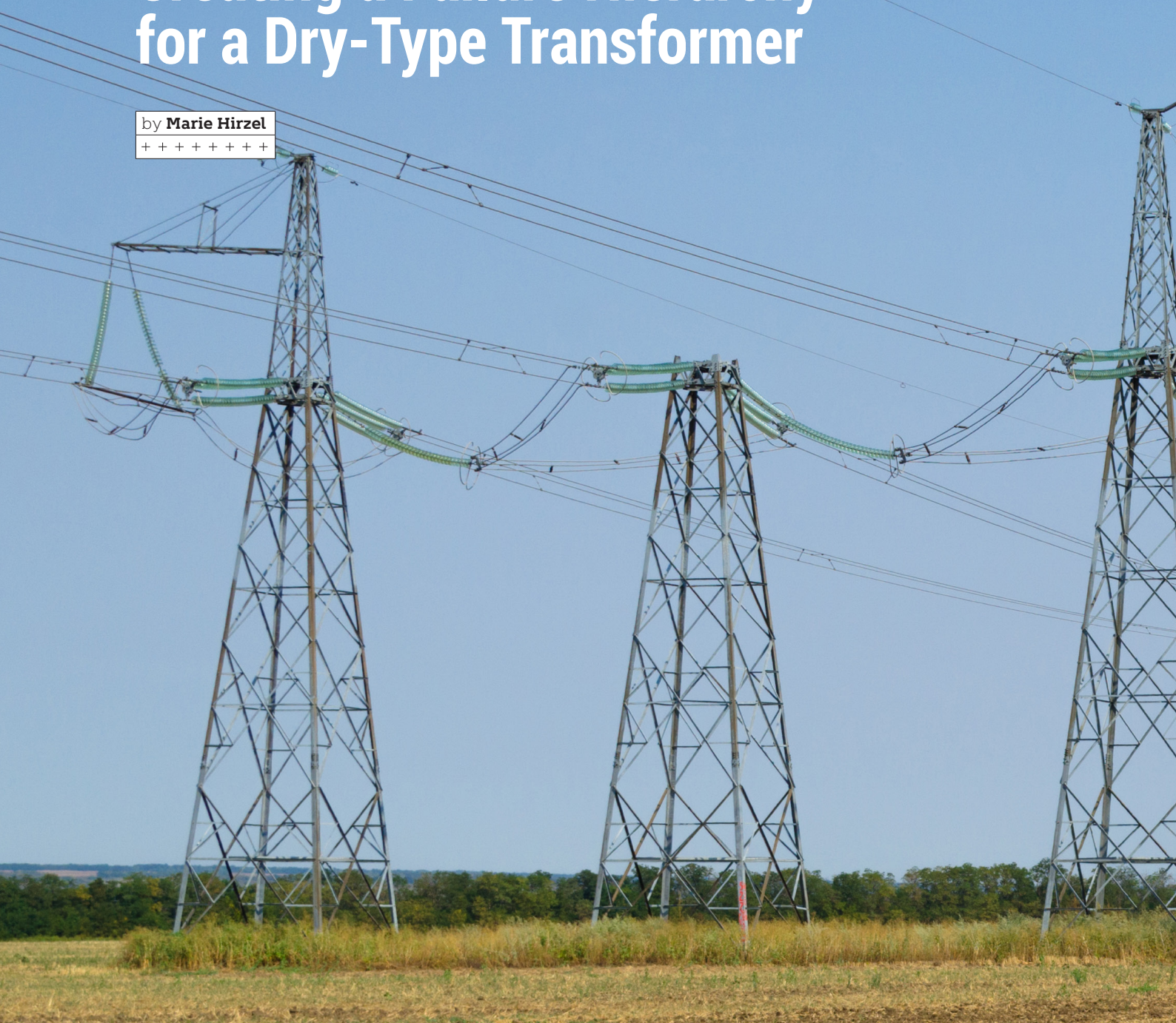


# Creating a Failure Hierarchy for a Dry-Type Transformer

by **Marie Hirzel**  
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Computerized Maintenance Management Systems (CMMS) allow you to track and trend equipment breakdowns through Failure Hierarchies. Once a Failure Hierarchy has been entered into the CMMS for a specific type of equipment, maintenance personnel are able to identify the failure(s) they found during maintenance work, and how they fixed it. A recurring set of similar failures, causes, or remedial actions can then be identified using the CMMS.

This information allows maintenance personnel to apply new preventive maintenance, adjust the frequency of existing preventive maintenance, or make other adjustments (for example, switching to a different type of grease) to address the trend.

The matrix to the right shows the terms I will use in this article, and the various Failure Hierarchy field names for some of the popular CMMS software packages.

To create the Failure Hierarchy for an indoor dry-type transformer, begin by identifying the "Class" and "Subclass" of the equipment. Class identifies the component. Example Classes include: pump, circuit breaker, motor, transformer, etc. The Class for this equipment is "transformer". Subclass consists of an adjective(s) used to uniquely describe the component. Example Subclasses for a transformer include: dry, oil filled, etc. The Subclass for this equipment is "dry".

This information allows maintenance personnel to apply new preventive maintenance, adjust the frequency of existing preventive maintenance, or make other adjustments.



Article Term	Maximo	SAP	Oracle
Class	Location / Class	Catalog Description	Asset
Subclass	Subclass	Object Part	Child Asset
Problem	Problem	Problem	Failure Sets
Cause	Cause	Cause	
Remedy	Remedy	Action	

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FMEA Failure Mode	FMEA Cause
Loose Cable/ Connections	INDUCED - Incorrect installation
	WEAR OUT - Due to age, heat, and vibration
Connection or Cable Failure	INDUCED - Dirt or other contaminant build-up
	INDUCED - Electrical or thermal overload
Transformer Insulation Failure	WEAR OUT - Corrosion or other age related degradation
	INDUCED - Electrical or thermal overload
Transformer Winding Failure	WEAR OUT - Age related degradation
	INDUCED - Electrical or thermal overload
Cooling System Failure	INDUCED - Dirt, corrosion, or other contaminant build-up
	INDUCED - Insufficient fan lubrication
	INTERMITTENT - Temperature relay or fan motor starting switch failure
	WEAR OUT - Age related degradation

Failure Hierarchies are typically created for each subclass. The simplest way to create the Failure Hierarchy is from a Failure Modes and Effects Analysis (FMEA). For instructions on how to perform an FMEA, refer to the article entitled "Performing a Failure Modes and Effects Analysis on a Dry-Type Transformer" in the June 2019 issue of Transformer Technology Magazine. I will use the FMEA created in that article to write the Failure Hierarchy. The pertinent fields from that FMEA are "Failure Mode" and "Cause" which are shown above.

For the Class/Subclass of Dry Transformer, I will now populate the remaining 3 Failure Hierarchy fields:

FAILURE	CAUSE	REMEDY
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There can be multiple "Failures", multiple "Causes" for each "Failure", and multiple "Remedies" for each "Cause". I will begin by using the Failure Modes from the FMEA to populate the "Failure" field in the Hierarchy. The first 2 Failure Modes, "Loose Cable/Connections" and "Connection or Cable Failure", can be combined into a single Failure of "Transformer Cable/Connection Failure". The remaining 3 Failure Modes can be entered as is, resulting in the following entries:

FAILURE
Transformer Cable/Connection Failure
Transformer Forced Air Cooling Failure
Transformer Insulation Failure
Transformer Windings Failure

**The simplest way to create the Failure Hierarchy is from a Failure Modes and Effects Analysis.**

Next, I will use the FMEA Causes to write the Failure Hierarchy Causes. For the Hierarchy Failure "Transformer Cable/Connection Failure", the applicable FMEA Causes are:

FMEA Failure Mode	FMEA Cause
Loose Cable/ Connections	INDUCED - Incorrect installation
	WEAR OUT - Due to age, heat, and vibration
Connection or Cable Failure	INDUCED - Dirt or other contaminant build-up
	INDUCED - Electrical or thermal overload
	WEAR OUT - Corrosion or other age-related degradation

Three FMEA Causes come directly over:

- Incorrect installation
- Dirt or other contaminant build-up
- Electrical or thermal overload

The remaining FMEA Causes are for "age" and "corrosion". In the Failure Hierarchy, corrosion can be added as-is, but I list age related degradation as "damage". Last, I will add a Cause for a "loose connection" as follows:

- Cable/Connection Corroded
- Cable/Connection Damaged
- Loose Connection

The complete list of Failure Hierarchy Causes for "Transformer Cable Connection Failure" then becomes:

FAILURE	CAUSE
Transformer Cable/ Connection Failure	Cable/Connection Corroded
	Cable/Connection Damaged
	Dirt or Contaminant Build-Up
	Electrical or Thermal Overload
	Incorrect Installation
	Loose Connection

I'm going to write the Causes for the Failure Mode "Transformer Forced Air Cooling Failure" next. The applicable FMEA Causes are:

FMEA Failure Mode	FMEA Cause
Cooling System Failure	INDUCED - Dirt, corrosion, or other contaminant build-up
	INDUCED - Insufficient fan lubrication
	INTERMITTENT - Temperature relay or fan motor starting switch failure
	WEAR OUT - Age related degradation



These FMEA Causes come directly over, with age related degradation listed as damage:

- Dirt/Contaminant Build-Up
- Insufficient Grease
- Fan Electronic Controls Failure
- Fan Damaged

Giving us:

FAILURE	CAUSE
Transformer Cable/ Connection Failure	Cable/Connection Corroded
	Cable/Connection Damaged
	Dirt or Contaminant Build-Up
	Electrical or Thermal Overload
	Incorrect Installation
Transformer Cable/ Connection Failure	Loose Connection
	Dirt/Contaminant Build-Up
	Insufficient Grease
	Fan Electronic Controls Failure
	Fan Damaged

Moving on to the next Failure Mode, "Transformer Insulation Failure", the applicable FMEA Causes are:

FMEA Failure Mode	FMEA Cause
Transformer Insulation Failure	INDUCED - Electrical or thermal overload
	WEAR OUT - Age related degradation

In the Failure Hierarchy, I express age related degradation as "damage". These Causes then become:

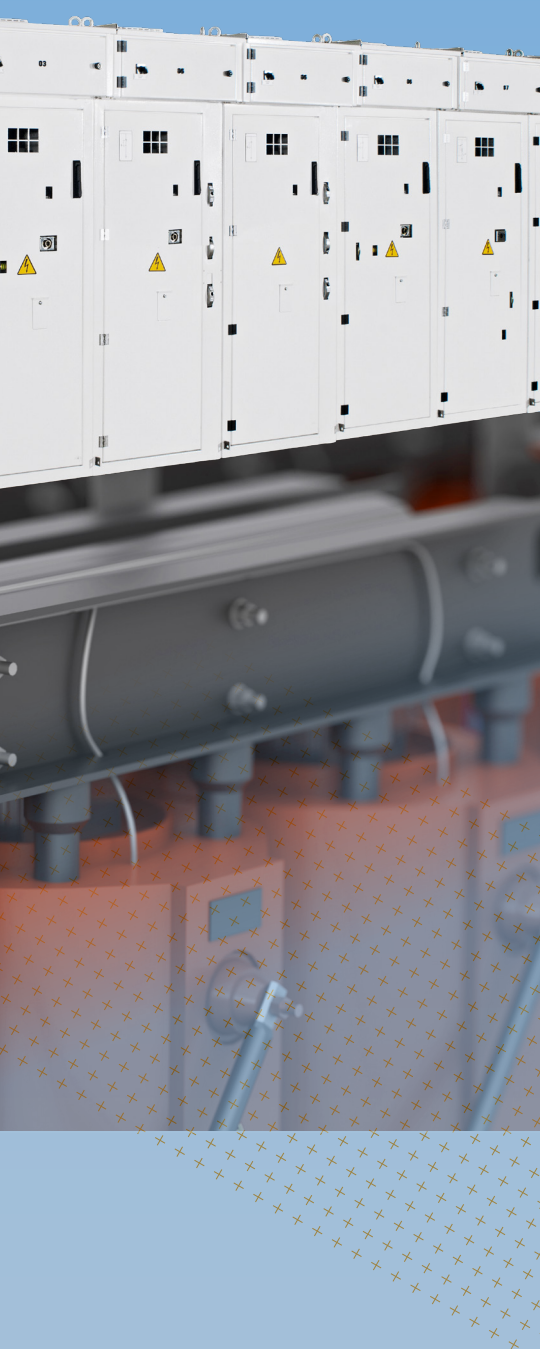
- Electrical or Thermal Overload
- Insulation Physically Damaged

Giving us:

FAILURE	CAUSE
Transformer Cable/ Connection Failure	Cable/Connection Corroded
	Cable/Connection Damaged
	Dirt or Contaminant Build-Up
	Electrical or Thermal Overload
	Incorrect Installation
Transformer Forced Air Cooling Failure	Loose Connection
	Dirt/Contaminant Build-Up
	Insufficient Grease
	Fan Electronic Controls Failure
	Fan Damaged
Transformer Insulation Failure	Electrical or Thermal Overload
	Insulation Physically Damaged



**The Remedies are standard repair practices for dry-type transformers used by electrical maintenance crews.**



For the final Failure Mode "Transformer Windings Failure", the applicable FMEA Causes are:

FMEA Failure Mode	FMEA Cause
Transformer Winding Failure	WEAR OUT - Age related degradation
	INDUCED - Electrical or thermal overload

In the Failure Hierarchy, these Causes become:

- Electrical or Thermal Overload
- Windings Physically Damaged

This completes the first 2 fields of our Failure Hierarchy:

FAILURE	CAUSE
Transformer Cable Connection Failure	Cable/Connection Corroded
	Cable/Connection Damaged
	Dirt or Contaminant Build-Up
	Electrical or Thermal Overload
	Incorrect Installation
Transformer Forced Air Cooling Failure	Loose Connection
	Dirt/Contaminant Build-Up
	Insufficient Grease
	Fan Electronic Controls Failure
Transformer Insulation Failure	Fan Damaged
	Electrical or Thermal Overload
	Insulation Physically Damaged
Transformer Windings Failure	Electrical or Thermal Overload
	Windings Physically Damaged

Finally, I will write the "Remedies" for each Cause. The Remedies are standard repair practices for dry-type transformers used by electrical maintenance crews, which the FMEA does not contain. These are written in past tense because the electrician will select the Remedy implemented after the work has been completed, not before. Examples of common Remedies include greasing a fan, cleaning a connection, replacing a cable, etc.

Beginning with the "Transformer Cable/Connection Failure", and first Cause "Cable/Connection Corroded", there are 2 possible Remedies:

FAILURE	CAUSE	REMEDY
Transformer Cable/Connection Failure	Cable/Connection Corroded	Cleaned the Cable/Connection
		Replaced the Cable/Connection

For the same Failure, second Cause of "Cable/Connection Damaged", there is only one Remedy:

FAILURE	CAUSE	REMEDY
Transformer Cable/ Connection Failure	Cable/Connection Corroded	Cleaned the Cable/Connection
	Cable/Connection Damaged	Replaced the Cable/Connection

For the same Failure, third Cause of "Dirt or Contaminant Build-Up", there is only one Remedy:

FAILURE	CAUSE	REMEDY
Transformer Cable/ Connection Failure	Cable/Connection Corroded	Cleaned the Cable/Connection
	Cable/Connection Damaged	Replaced the Cable/Connection
	Dirt or Contaminant Build-Up	Cleaned the Connection

For the same Failure, fourth Cause of "Electrical or Thermal Overload", there is also only one Remedy:

FAILURE	CAUSE	REMEDY
Transformer Cable/ Connection Failure	Cable/Connection Corroded	Cleaned the Cable/Connection
	Cable/Connection Damaged	Replaced the Cable/Connection
	Dirt or Contaminant Build-Up	Cleaned the Connection
	Electrical or Thermal Overload	Replaced the Cable/Connection

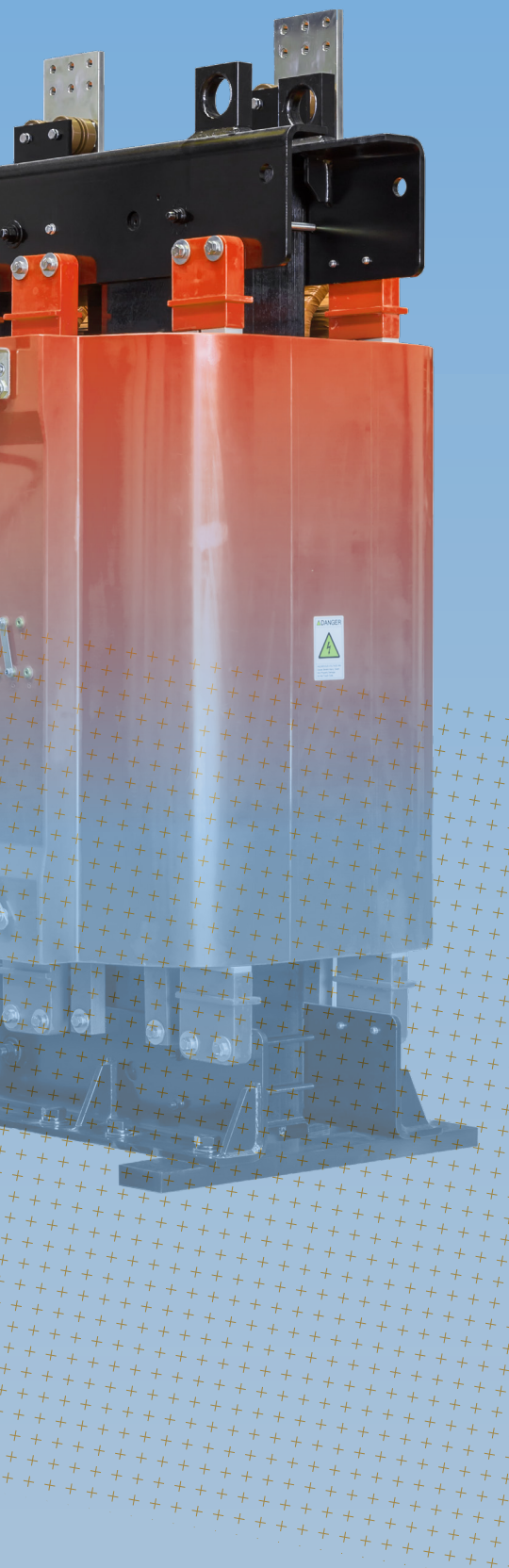
For the same Failure, fifth Cause of "Incorrect Installation", again, there is only one Remedy:

FAILURE	CAUSE	REMEDY
Transformer Cable/ Connection Failure	Cable/Connection Corroded	Cleaned the Cable/Connection
	Cable/Connection Damaged	Replaced the Cable/Connection
	Dirt or Contaminant Build-Up	Cleaned the Connection
	Electrical or Thermal Overload	Replaced the Cable/Connection
	Incorrect Installation	Installed Correct Cable and Terminations

For the same Failure, sixth Cause of "Loose Connection", once again, there is only one Remedy:

FAILURE	CAUSE	REMEDY
Transformer Cable/ Connection Failure	Cable/Connection Corroded	Cleaned the Cable/Connection
	Cable/Connection Damaged	Replaced the Cable/Connection
	Dirt or Contaminant Build-Up	Cleaned the Connection
	Electrical or Thermal Overload	Replaced the Cable/Connection
	Incorrect Installation	Installed Correct Cable and Terminations
	Loose Connection	Tightened Connection





For the same Failure, sixth Cause of "Loose Connection", once again, there is only one Remedy:

FAILURE	CAUSE	REMEDY
Transformer Cable/ Connection Failure	Cable/Connection Corroded	Cleaned the Cable/Connection
	Cable/Connection Damaged	Replaced the Cable/Connection
	Dirt or Contaminant Build-Up	Replaced the Cable/Connection
	Electrical or Thermal Overload	Cleaned the Connection
	Incorrect Installation	Replaced the Cable/Connection
	Loose Connection	Installed Correct Cable and Terminations
		Tightened Connection

Moving on to the "Transformer Forced Air Cooling Failure", for the first Cause "Dirt/Contaminant Build-Up", there is only one Remedy:

FAILURE	CAUSE	REMEDY
Transformer Forced Air Cooling Failure	Dirt/Contaminant Build-Up	Cleaned and Repaired Fan

For the same Failure, second Cause of "Insufficient Grease", there is only one Remedy:

FAILURE	CAUSE	REMEDY
Transformer Forced Air Cooling Failure	Dirt/Contaminant Build-Up	Cleaned and Repaired Fan
	Insufficient Grease	Greased Fan

For the same Failure, third Cause of "Fan Electronic Controls Failure", there is only one Remedy:

FAILURE	CAUSE	REMEDY
Transformer Forced Air Cooling Failure	Dirt/Contaminant Build-Up	Cleaned and Repaired Fan
	Insufficient Grease	Greased Fan
	Fan Electronic Controls Failure	Replaced Fan Controls

For the same Failure, fourth Cause of "Fan Damaged", there are two Remedies:

FAILURE	CAUSE	REMEDY
Transformer Forced Air Cooling Failure	Dirt/Contaminant Build-Up	Cleaned and Repaired Fan
	Insufficient Grease	Greased Fan
	Fan Electronic Controls Failure	Replaced Fan Controls
	Fan Damaged	Repaired Fan
		Replaced Fan

Moving on to the "Transformer Insulation Failure", for the first Cause "Electrical or Thermal Overload", there are three possible Remedies:

FAILURE	CAUSE	REMEDY
Transformer Insulation Failure	Electrical or Thermal Overload	Replaced the Insulation
		Replaced the Windings
		Replaced the Transformer

For the same Failure, second Cause of "Insulation Physically Damaged", the same three possible Remedies exist:

FAILURE	CAUSE	REMEDY
Transformer Insulation Failure	Electrical or Thermal Overload	Replaced the Insulation
		Replaced the Windings
		Replaced the Transformer
	Insulation Physically Damaged	Replaced the Insulation
		Replaced the Windings
		Replaced the Transformer

Moving to the "Transformer Windings Failure", for the first Cause "Electrical or Thermal Overload", there are two possible Remedies:

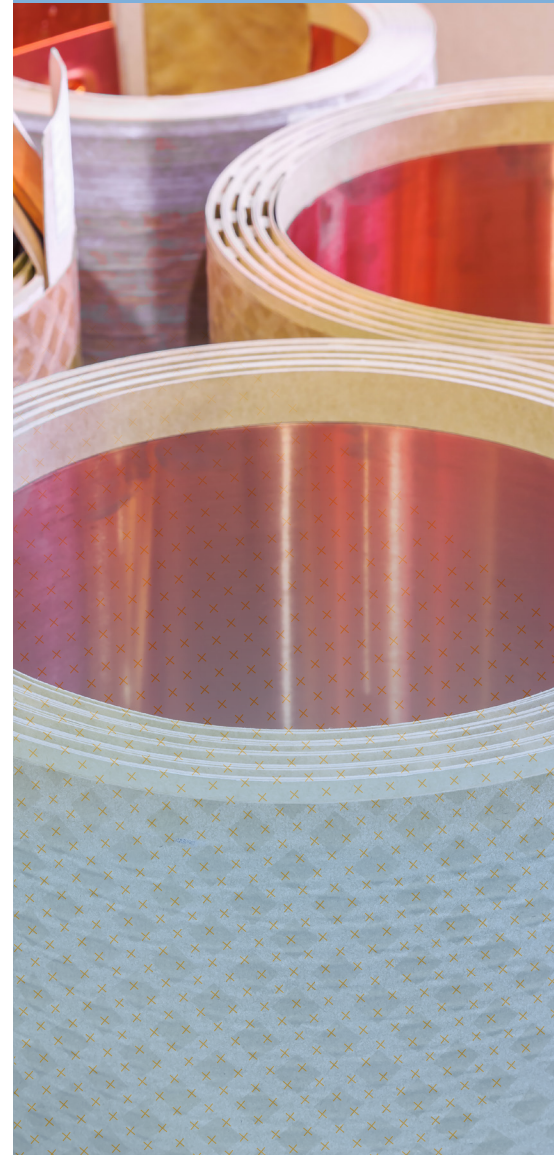
FAILURE	CAUSE	REMEDY
Transformer Windings Failure	Electrical or Thermal Overload	Replaced the Windings
		Replaced the Transformer

For the same Failure, second Cause of "Windings Physically Damaged", the same two possible Remedies exist:

FAILURE	CAUSE	REMEDY
Transformer Windings Failure	Electrical or Thermal Overload	Replaced the Windings
		Replaced the Transformer
	Windings Physically Damaged	Replaced the Windings
		Replaced the Transformer

This completes the Failure Hierarchy:

FAILURE	CAUSE	REMEDY
Transformer Cable/ Connection Failure	Cable/Connection Corroded	Cleaned the Cable/Connection
		Replaced the Cable/Connection
	Cable/Connection Damaged	Replaced the Cable/Connection
	Dirt or Contaminant Build-Up	Cleaned the Connection
	Electrical or Thermal Overload	Replaced the Cable/Connection
	Incorrect Installation	Installed Correct Cable and Terminations
Transformer Forced Air Cooling Failure	Loose Connection	Tightened Connection
	Dirt/Contaminant Build-Up	Cleaned and Repaired Fan
	Insufficient Grease	Greased Fan
	Fan Electronic Controls Failure	Replaced Fan Controls
Transformer Insulation Failure	Fan Damaged	Repaired Fan
		Replaced Fan
	Electrical or Thermal Overload	Replaced the Insulation
		Replaced the Windings
Replaced the Transformer		
Transformer Windings Failure	Insulation Physically Damaged	Replaced the Insulation
		Replaced the Windings
	Replaced the Transformer	
Transformer Windings Failure	Electrical or Thermal Overload	Replaced the Windings
		Replaced the Transformer
	Windings Physically Damaged	Replaced the Windings
		Replaced the Transformer



It is ready to be entered into the CMMS and used to adjust your dry-type transformer maintenance strategy, making it more effective and resulting in better reliability.