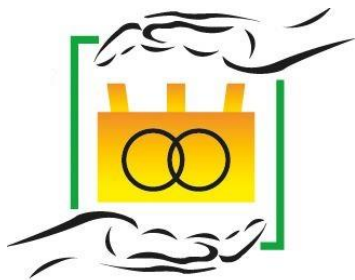


# TRANSFORMER PROTECTOR

**The only proven solution against transformer explosions.**

## **TP Description to be used for Customer Technical Specifications**



**SERGI**

**TRANSFORMER PROTECTOR**

**Transformer, On Load Tap Changer, Oil Cable Boxes  
Explosion and Fire Prevention, from 0.1 MVA**

# TRANSFORMER PROTECTOR

The only proven solution against transformer explosions.

## TP Description to be used for Customer Technical Specifications

### Document revisions

Rev	Ref.	Date	Done	Checked	Approved	Revision Subject
1	fTPd01e	24/09/01	DS	FM	PM	Creation
Check revision 33 for revision history						
12	ATPdd12e	19/07/07	DB	ES	PM	Document general update
13	SrTPdb13e	13/09/07	DB	ES	PM	Drawings Legend Update
14	SrTPdb14e	05/17/09	PFT	FrCa	PhMa	TP evolution
Revision not issued for coherency with other TP documentation						
31	SrTPdb31e	02/15/11	BrOB	PFTa	Amcc110516PhMa1	TP Evolution
32	SrTPdb32e	06/12/12	PFTa	FrCa	Amcc120616PhMa16	Template and content update
33	SrTPdb33e	005/06/14	FrCa	AnMa	Amcc140506PhMa15	Inclusion of NFPA Codes
34	SrTPdb34e	08/31/15	OmAh,AnGo	PhMa	Amcc150901PhMa12	Content update
35	SrTPdba35e	04/11/15	MeMe	PhMa	Amcc151104PhMa8	Text modification and annex

**REFERENCED DOCUMENTS AVAILABLE ON REQUEST FROM SERGI TP**

No.	Reference	Marketing Documents
[1]	AtTPga	TP description to be used for customers Technical Specifications
[2]	AtTPgfa	TRANSFORMER PROTECTOR (TP) Brochure
[3]	AtTPgda	World Reference
[4]	AtTPgg	TP Presentation Outline

No.	Reference	Technical Documents
[5]	AtTPpa	Adaptation on New Transformers
[6]	AtTPpb	Adaptation on Existing Transformers
[7]	AtTPpc	On Site Installation, Commissioning, and Testing
[8]	AtTPpd	Operation, Maintenance, and Periodical Test

No.	Reference	TP Qualifications
[9]	AtTPrtfa	Attestation from CEPEL Laboratory
[10]	AtTPrdab	"Recommended Practice for Fire Protection for Electric Generating Plants and High Voltage Direct Current Converter Stations", NFPA 850, 2015 edition

Note\* AtTPrdab document can be requested ONLY from [www.NFPA.org](http://www.NFPA.org)

No.	Reference	Scientific Publications
[11]	Amrpi2001.3e	"Transformer Relief Valves efficiency calculations by comparison to the TRANSFORMER PROTECTOR during short-circuits"
[12]	Amrpi2004.2e	"Transformer Explosion and Fire Incidents. Guideline for Damage Cost Evaluation. Transformer Protector Financial Benefit"
[13]	Amrpi2008.8e	"PWG Europe 2008, An Answer to Prevent Transformer Explosion and Fire, Live Test and Stimulations"
[14]	Amrpi2013.1a	"Development of Two-Way Fluid Structure Coupling for Studying Power Transformers Subjected to Internal Dynamic Over-Pressure"
[15]	Amrpi2015.1a	"Case Study on Mechanical Depressurization of Live Transformer Subject to Internal Arc"
[16]	Amrpi2015.4ae	"Transformer Fast Tank Depressurization with Oil Bushing Cable Box Protections"

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Model reference: Fmpxd33e

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## SUMMARY

The objective of this document is to help the electrical authorities, industries, consultants and engineering companies to include the TRANSFORMER PROTECTOR (TP) in their Technical Specifications. This technology of Transformers or Reactors Explosion and Fire Prevention complies with the 2015 edition of NFPA 850 norm.

Four kinds of Technical Specifications are proposed: complete, simplified, concise, and short versions. In the proposed Technical Specifications, the wording «Transformer or Reactor, On Load Tap Changer (OLTC), and Oil Cable Box (OCB) / Oil Bushing Cable Box (OBCB) or Bushing Turrets (BT) Explosion and Fire Prevention» is being replaced by the term «***Fast Depressurization System***».

As tests and sizing computation are the ***Fast Depressurization System*** cornerstone, gas generation during short-circuit, the resulting dynamic pressure peak, pressure gradient and depressurization calculations are highlighted.

Also, the ***Fast Depressurization System*** must comply with NFPA Code, the ***Fast Depressurization System*** must be passive - mechanical and must be activated without sensors or electrical actuators.

The Appendix Table shall be used to evaluate each transformer and reactor, and depending on its components, must be adapted to points B2 and B3 of section B, “Depressurization Set (DS) with Rupture Disk (RD) for all transformer and reactor elements”. This table shall guarantee that the explosion and fire prevention system complies with the Technical Specification of the ***Fast Depressurization System***.

## 1 COMPLETE TECHNICAL SPECIFICATION

### 1.1 TRANSFORMER OR REACTOR EXPLOSION AND FIRE, ORIGINS, CAUSES AND CONSEQUENCES

Power transformers or reactors are among the most expensive equipment located in power plants and substations. They contain a large quantity of combustible substance, which can spray fire to nearby installations. Special attention should therefore be given to their protection.

Transformer or reactor explosion and fire generally result from a fault inside the tank. This may be caused by overloads, short-circuits, or failure of the associated equipment such as On Load Tap Changer (OLTC), and Oil Cable Box (OCB) / Oil Bushing Cable Box (OBCB) or Bushing Turrets (BT).

For an electrical arc, a huge volume of explosive gas is created during the first millisecond, 2.3 m<sup>3</sup> (81.2 ft<sup>3</sup>) for the first mega joule. This gas generation creates one dynamic pressure peak and the transformer or reactor tank is violently shaken by accelerations reaching 400 g. This shockwave is travelling in the tank at a speed of the sound inside oil, 1,200 m/s (3937 ft/s). The first pressure peak of the resulting shockwave, initial amplitude greater than 10 bars, activates the Depressurization Set (DS) of the Transformer or Reactor, of the On Load Tap Changer (OLTC), and Oil Cable Box (OCB) / Oil Bushing Cable Box (OBCB) or Bushing Turrets (BT) before static pressure increases inside the tank and provokes tank explosion.

Transformers and reactors are exploding because they are not protected against fast static pressure increase. The Pressure Relief Valve (PRV) is ineffective during short-circuit as every destroyed transformer or reactor tank is equipped with. In addition as transformer or reactors tanks do not comply with the ASME Codes, modifications of tank structure such as Local Tank Reinforcement or relying on tank elasticity are not likely to be effective explosion prevention solutions. Mechanical tank resistance versus time has never been studied, and adopting such solutions is therefore very risky.

The **Fast Depressurization System** shall comply with the NFPA 850 Code. The **Fast Depressurization System** shall allow the depressurization of the transformer or reactor after a few milliseconds from the time the electric fault has occurred. In order to avoid delays that will caused a transformer or reactor explosion, the **Fast Depressurization System** shall not depend on any sensor or electrical actuators coming from other protection.

### 1.2 EQUIPMENT DESCRIPTION

The **Fast Depressurization System** shall be made of several sets, each playing a different role:

- The Depressurization Set (DS) with Rupture Disk (RD) shall prevent Transformer or Reactor, On Load Tap Changer (OLTC), and Oil Cable Box (OCB) / Oil Bushing Cable Box (OBCB) or Bushing Turrets (BT) explosion following a short circuit. Each Depressurization Set (DS) shall relieve the dynamic pressure within milliseconds and a Decompression Chamber (DC) favors high-speed depressurization. The depressurization time is the critical parameter. Therefore, the Depressurization Set (DS) diameter shall be calculated individually for each Transformer or Reactor type.
- The Inert Gas Injection Set (IGIS) is required for personal safety to avoid the bazooka effect caused by the explosive gas in contact with air (oxygen) when the tank is opened after the incident. The IGIS creates a safe environment in the Transformer or Reactor and the On Load Tap Changer (OLTC) after the depressurization process by injecting an inert gas flow, which also cools the tank.
- An Oil-Gas Separation Tank (OGST) shall collect the depressurized oil and explosive flammable gas to separate oil from gases.
- The Explosive Gas Evacuation Pipe (EGEP) shall then channel the gas to a safe and remote area.

The efficiency and reliability of the **Fast Depressurization System** shall be ensured by the Depressurization Set (DS), which shall be opened by the first dynamic pressure peak of the pressure wave, avoiding transformer explosions before static pressure build-up.

No sensors and no electrical actuators shall be involved in the depressurization process because they add unacceptable operating delays.

It is possible to separate the OGST from the transformer or reactor but the installation cost will be higher because:

- When the OGST function is integrated with the conservator there is no need for local installation;
- When independent from the transformer conservator, an additional tank and piping are necessary.

The Transformer or Reactor, On Load Tap Changer (OLTC), and Oil Cable Box (OCB) / Oil Bushing Cable Box (OBCB) or Bushing Turrets (BT) Explosion Prevention Depressurization Set (DS) shall preferably be type Vertical (VDS) and located on the tank cover.

If problems with high voltage clearances render impossible to fit the VDS on the tank cover, then a 45 degrees Depressurization Set (45 DS) or a Horizontal Depressurization Set (HDS) shall be installed. For smaller transformers, typically below 6 MVA such as bunker transformers, the TP can be installed without problem.

The transformer manufacturer shall integrate the OGST in the conservator; the transformer conservator partition devoted to the OGST should have a volume of 0.5 m<sup>3</sup> - 17.6 ft<sup>3</sup>. If such configuration cannot be offered, the OGST can be remote but in this case the top of the OGST shall always be located 10 cm - 4 inches above the top of the transformer conservator. Several OGST arrangements are possible:

- SOGST, Sliced OGST, recommended and located in a slice of the conservator.
- WOGST, Wall mounted OGST, attached to the transformer or reactor firewalls.
- EOGST, Elevated OGST, elevated above the transformer conservator.

Two types of injection of inert gas are possible, manual injection or automatic injection, depending on customer choice:

- The manual injection can be triggered from:
  - The control room. However, alarms should remind operators of the necessity to inject inert gas before a maintenance team starts working (bazooka effect).
  - The Inert Gas Injection Set (IGIS), close to the transformer or reactor in a safe area. Upon request, the Inert Gas Injection Quick Connector (option) can be provided to completely disconnect and cancel all risk of spurious injection into the transformer or reactor.
- For the automatic injection, two signals shall be required simultaneously to start up the Inert Gas Injection:
  - The integrated Rupture Disk Burst Indicator confirming the dynamic pressure and the beginning of the depressurization process;
  - One of the electrical protection signals, confirming the electrical fault of the protected Transformer or Reactor, of the On Load Tap Changer (OLTC), of the Oil Cable Box (OCB) / Oil Bushing Cable Box (OBCB) or Bushing Turrets (BT).

The inert gas flow shall prevent air (oxygen) to be in contact with the explosive gases and shall further cool down the Transformer or Reactor, the On Load Tap Changer (OLTC), and the Oil Cable Box (OCB) / Oil Bushing Cable Box (OBCB) or Bushing Turrets (BT) as inert gas injection should run for 45 minutes. As a result, no more explosive gases remain when the inert gas injection is over. Then, maintenance teams can start working.

The oil fire extinguishing system “Inert Gas Drain and Stir” shall back up the explosion and fire prevention for transformers with power range starting at 6MVA.

The fire extinction backup “Inert Gas Drain and Stir” shall be activated by other signals than those used for the prevention method, except for the electrical protections:

- One from the Linear Heat Detector located on the transformer or reactor;
- One of the transformer or reactor electrical protections.

## 1.1 SIZING

### 1.1.1 PRESSURE RISE CALCULATIONS

To avoid Transformer or Reactor, On Load Tap Changer (OLTC), and Oil Cable Box (OCB) / Oil Bushing Cable Box (OBCB) or Bushing Turrets (BT) explosion and fire, the supplier shall have specified likely locations of dielectric failure and subsequent arcing events within the oil-filled tank. These locations should be compared to Depressurization Set (DS) position and sizing to maximize the efficiency of depressurization.

Using a physical model capable of describing a multi-phase compressible fluid, quantitative predictions should be made for the following:

- The creation of high-pressure explosive and flammable gas within the tank during a low-impedance fault;
- The resultant pressure waves' speed and amplitude;
- The subsequent increase in static, or average, pressure throughout the tank prior to the activation of the *Fast Depressurization System*.

## 1.1.2 DEPRESSURIZATION CALCULATIONS

The physical model should accurately represent the following in order to properly simulate the *Fast Depressurization System*:

- The temporal and pressure gradient dependence of the opening of the Rupture Disks (RD);
- Transformer tank pressures as a function of time, taking into account relevant energy sinks such as thermal diffusion, viscosity, tank deformation, etc.;
- Resultant stresses and deformations on the transformer tank during the pressure drop;
- Oil-gas mixture volume to be evacuated to avoid transformer explosion and fire as a function of time.

The *Fast Depressurization System* supplier shall provide Computerized Fluid Dynamic (CFD) and Fluid Structure Interactions (FSI) simulations for the transformer most probable low impedance energy fault (Mega Joule).

## 1.2 TESTS AND EXPERIENCE

The supplier shall prove that the *Fast Depressurization System*:

- 10 years of experience with increased sales to 1,000 units.
- Certify that the *Fast Depressurization System* is activated with the first dynamic pressure peak before the static pressure rises and the transformer or reactor tank explode.
- A Test Certificate showing a campaign of at least 25 successful live tests of electric arcs events inside the transformer or reactor tank closed and full with oil, from which at least 5 have been done with arcs of more than 1 Mega Joule.  
This Test Certificate must be granted by a recognized and independent high voltage laboratory from a country different than the country of manufacture of the explosion and fire prevention system.
- Evidence that the explosion and fire prevention system has prevented the explosion of at least 8 transformers or reactors over 60MVA in 6 different countries with 8 Certificates of Successful Activation signed by the transformer or reactor owner.
- Insurance Policy over USD 10 million dollars to cover damages in case of transformer or reactor explosion with the *Fast Depressurization System* installed.

## 1.3 NFPA CODE

The *Fast Depressurization System* must comply with the description for all Power Plants and Substations of the National Fire Protection Association, Code NFPA 850, 2015 edition. Therefore, the *Fast Depressurization System* must be "passive – mechanical" and activated without sensors or electrical actuator.

## 1.4 TECHNICAL SPECIFICATION VERIFICATIONS

The Appended Table should be used to evaluate each transformer or reactor and depending on its components it will be adapted as per B2 and B3 of Section B, "Depressurization Set (DS) with Rupture Disc (RD) for all elements of the transformer or reactor". This ensures that the explosion and fire prevention system complies with the Technical Specifications of the *Fast Depressurization System*.



## 2 SIMPLIFIED TECHNICAL SPECIFICATION

### 2.1 EQUIPMENT DESCRIPTION

The *Fast Depressurization System* shall be made of several sets, each playing a different role:

- The Depressurization Set (DS) with Rupture Disk (RD) shall prevent a Transformer or Reactor, an On Load Tap Changer (OLTC), and Oil Cable Box (OCB) / Oil Bushing Cable Box (OBCB) or Bushing Turrets (BT) explosion following a short circuit. Each Depressurization Set (DS) shall relieve the dynamic pressure within milliseconds and a Decompression Chamber (DC) favors high-speed depressurization. The depressurization time is the critical parameter. Therefore, the Depressurization Set (DS) diameter shall be calculated individually for each Transformer or Reactor type.
- The Inert Gas Injection Set (IGIS) is required for personal safety to avoid the bazooka effect caused by the explosive gas in contact with air (oxygen) when the tank is opened after the incident. The IGIS creates a safe environment in the Transformer or Reactor, and the On Load Tap Changer (OLTC) after the depressurization process by injecting an inert gas flow, which also cools the tank.
- An Oil-Gas Separation Tank (OGST) shall collect the depressurized oil and explosive flammable gas to separate oil from gases.
- The Explosive Gas Evacuation Pipe (EGEP) shall then channel the gas to a safe, remote area.

It is possible to separate the OGST from the transformer, but the installation costs are higher because:

- When the OGST function is integrated with the conservator there is no need for local installation;
- When independent from the transformer conservator, an additional tank and piping are necessary.

The Transformer or Reactor, On Load Tap Changer (OLTC), and Oil Cable Box (OCB) / Oil Bushing Cable Box (OBCB) or Bushing Turrets (BT), explosion prevention Depressurization Set (DS) shall preferably be type Vertical (VDS) and located on the tank cover.

If problems with high voltage clearances render it impossible to fit the VDS on the tank cover, then a 45 degrees Depressurization Set (45 DS) or a Horizontal Depressurization Set (HDS) shall be installed. For smaller transformers, typically below 6 MVA (such as bunker transformers), the TP can be installed.

The transformer manufacturer shall integrate the OGST in the conservator; the transformer conservator slice devoted to the OGST should have a volume of 0.5 m<sup>3</sup> - 17.6 ft<sup>3</sup>. If such configuration cannot be offered, the OGST can be remote but in this case the top of the OGST shall always be located 10 cm - 4 in above the top of the conservator. Several OGST arrangements are possible:

- SOGST, Sliced OGST, recommended and located in a slice of the conservator.
- WOGST, Wall mounted OGST, attached to the transformer or reactor firewalls.
- EOGST, Elevated OGST, elevated above the transformer conservator.

Two types of Inert Gas Injection are possible, manual injection which can be provided upon request with the Inert Gas Injection Quick Connector to completely cancel spurious injection into the transformer or automatic injection, depending on customer choice.

The inert gas flow shall prevent air (oxygen) to be in contact with the explosive gases and shall further cool down the Transformer or Reactor, the On Load Tap Changer (OLTC), and the Oil Cable Box (OCB) / Oil Bushing Cable Box (OBCB) or Bushing Turrets (BT) as inert gas injection should run for 45 minutes. As a result, no more explosive gases remain when the inert gas injection is over. Then, maintenance teams can start working.

The oil fire extinguishing system "Inert gas Drain and Stir" shall back up the explosion and fire prevention for transformers with power range starting at 6 MVA.

## 2.2 SIZING

### 2.2.1 PRESSURE RISE CALCULATIONS

To avoid Transformer or Reactor, On Load Tap Changer (OLTC), and Oil Cable Box (OCB) / Oil Bushing Cable Box (OBCB) or Bushing Turrets (BT) explosion and fire, the supplier shall have specified likely locations of dielectric failure and subsequent arcing events inside the oil-filled tank.

Using a physical model capable of modeling a multi-phase compressible fluid, quantitative predictions should be made for the gas volume generation as a function of arc energy, the resultant pressure wave speed and amplitude, and the subsequent increase in static, or average, pressure throughout the tank prior to the activation of the *Fast Depressurization System*.

### 2.2.2 DEPRESSURIZATION CALCULATIONS

The physical model should accurately represent the following in order to simulate the *Fast Depressurization System*:

- The creation of explosive and flammable gas within the tank during a low-impedance fault;
- The temporal and pressure gradient dependence of the opening of the Rupture Disks (RD);
- Transformer or reactor tank pressures as a function of time, taking into account relevant energy sinks such as thermal diffusion, viscosity, tank deformation, etc.;
- Resultant stresses and deformations on the transformer tank during the pressure drop;
- Oil-gas mixture volume evacuated to avoid transformer explosion and fire as a function of time.

The *Fast Depressurization System* supplier shall provide Computerized Fluid Dynamic (CFD) and Fluid Structure Interactions (FSI) simulations for the transformer most probable low impedance energy fault (Mega Joule).

## 2.3 TESTS AND EXPERIENCE

The supplier shall prove that the *Fast Depressurization System*:

- 10 years of experience with increased sales to 1,000 units.
- A Test Certificate showing a campaign of at least 25 successful live tests before electric arcs events inside the transformer or reactor tank closed and full with oil, from which at least 5 have been done with arcs of more than 1 Mega Joule.

This Test Certificate must be granted by a recognized and independent high voltage laboratory from a country different than the country of manufacture of the explosion and fire prevention system.

- Evidence that the explosion and fire prevention system has prevented the explosion of at least 8 transformers or reactors over 60MVA in 6 different countries with 8 Certificates of Successful Activation signed by the transformer or reactor owner.
- Insurance Policy over USD 10 million dollars to cover damages in case of transformer or reactor explosion with the *Fast Depressurization System* installed.

## 2.4 NFPA CODE

The *Fast Depressurization System* must comply with the description for all Power Plants and Substations of the National Fire Protection Association, Code NFPA 850, 2015 edition. Therefore, the *Fast Depressurization System* must be “passive – mechanical” and activated without sensors or electrical actuator.

## 2.5 TECHNICAL SPECIFICATION VERIFICATIONS

The Appended Table should be used to evaluate each transformer or reactor and depending on its components it will be adapted as per B2 and B3 of Section B, "Depressurization Set (DS) with Rupture Disc (RD) for all elements of the transformer or reactor". This ensures that the explosion and fire prevention system complies with the Technical Specifications of the *Fast Depressurization System*.

### 3 CONCISE TECHNICAL SPECIFICATION

#### 3.1 EQUIPMENT DESCRIPTION

The *Fast Depressurization System* shall be made of several sets, each playing a different role:

- The Depressurization Set (DS) with Rupture Disk (RD) shall prevent a Transformer or Reactor, On Load Tap Changer (OLTC), and Oil Cable Box (OCB) / Oil Bushing Cable Box (OBCB) or Bushing Turrets (BT) explosion following a short circuit. Each Depressurization Set (DS) shall relieve the dynamic pressure within milliseconds and a Decompression Chamber (DC) favors high-speed depressurization.
- The Inert Gas Injection Set (IGIS) is required for personal safety to avoid the bazooka effect caused by the explosive gas in contact with air (oxygen) when the tank is opened after the incident. The IGIS creates a safe environment in the Transformer or Reactor and the On Load Tap Changer (OLTC) after the depressurization process by injecting an inert gas flow, which also cools the tank.
- An Oil-Gas Separation Tank (OGST) shall collect the depressurized oil and explosive flammable gas to dissociate oil from gases. It is recommended to locate the OGST in the transformer or reactor conservator where a slice shall then be devoted for the OGST as often done for the On Load Tap Changer (OLTC) oil conservator. This transformer conservator slice shall have a volume of 0.5 m<sup>3</sup> - 17.6 ft<sup>3</sup>.
- The Explosive Gas Evacuation Pipe (EGEP) shall then channel the gas to a safe and remote area.

It is possible to separate the OGST from the transformer. In this case, the top of the OGST must always be located 10 cm - 4 inches above the top of the conservator.

The Inert Gas Injection can be manual, and including as an option the Inert Gas Injection Quick Connector, or automatic, depending on customer choice.

#### 3.2 SIZING

To avoid Transformer or Reactor, On Load Tap Changer (OLTC), and Oil Cable Box (OCB) / Oil Bushing Cable Box (OBCB) or Bushing Turrets (BT) explosion and fire, the supplier shall have specified likely locations of dielectric failure and subsequent arcing events inside the oil-filled tank.

Using a physical model capable of describing a multi-phase compressible fluid, quantitative predictions should be made for the gas volume generation as a function of arc energy, the resultant pressure waves' speed and amplitude, and the subsequent increase in static, or average, pressure throughout the tank prior to the activation of the *Fast Depressurization System*.

The physical model should accurately model the opening of the Rupture Disks (RD), the oil-gas mixture outflow, the time-dependent transformer tank pressure drop, and the resultant stresses and deformations on the transformer tank.

The *Fast Depressurization System* supplier shall provide Computerized Fluid Dynamic (CFD) and Fluid Structure Interactions (FSI) simulations for the transformer most probable low impedance energy fault (Mega Joule).

#### 3.3 TESTS, EXPERIENCE, AND NFPA CODE

The supplier shall prove that the *Fast Depressurization System*:

- 10 years of experience with increased sales to 1,000 units.
- A Test Certificate showing a campaign of at least 25 successful live tests of electric arcs events inside the transformer or reactor tank closed and full with oil, from which at least 5 have been done with arcs of more than 1 Mega Joule.  
This Test Certificate must be granted by a recognized and independent high voltage laboratory from a country different than the country of manufacture of the explosion and fire prevention system.
- Evidence that the explosion and fire prevention system has prevented the explosion of at least 8 transformers or reactors over 60MVA in 6 different countries with 8 Certificates of Successful Activation signed by the transformer or reactor owner.

- Complies with the description for all Power Plants and Substations of the National Fire Protection Association, Code NFPA 850, 2015 edition. This norm requires that the *Fast Depressurization System* must be “passive – mechanical” and activated without sensors or electrical actuator.
- Insurance Policy over USD 10 million dollars to cover damages in case of transformer or reactor explosion with the *Fast Depressurization System* installed.

### **3.4 TECHNICAL SPECIFICATION VERIFICATIONS**

The Appended Table should be used to evaluate each transformer or reactor and depending on its components it will be adapted as per B2 and B3 of Section B, "Depressurization Set (DS) with Rupture Disc (RD) for all elements of the transformer or reactor". This ensures that the explosion and fire prevention system complies with the Technical Specifications of the *Fast Depressurization System*.

## 4 SHORT TECHNICAL SPECIFICATION

### 4.1 EQUIPMENT DESCRIPTION

The *Fast Depressurization System* shall be made of several sets, each playing a different role. The Depressurization Set (DS) shall prevent a Transformer or Reactor, On Load Tap Changer (OLTC), and Oil Cable Box (OCB) / Oil Bushing Cable Box (OBCB) or Bushing Turrets (BT) explosion following a short circuit. The Inert Gas Injection Set (IGIS) is required for personal safety to avoid the bazooka effect caused by the explosive gas in contact with air (oxygen) when the tank is opened after the incident. An Oil-Gas Separation Tank (OGST) shall collect the depressurized oil and explosive flammable gas to separate the two. The recommended OGST location is a partition of the transformer conservator, as is often done for the OLTC oil conservator. The Explosive Gas Evacuation Pipe (EGEP) shall then channel the gas to a safe, remote area.

### 4.2 SIZING, TESTS, EXPERIENCE AND NFPA CODE

To avoid Transformer or Reactor, On Load Tap Changer (OLTC), and Oil Cable Box (OCB) / Oil Bushing Cable Box (OBCB) or Bushing Turrets (BT) explosion and fire, the supplier shall have specified likely locations of dielectric failure and arcing inside the oil-filled tank. A physical model describing a multi-phase compressible fluid should predict the gas generated by the arc, the resultant pressure waves' speed and amplitude, and the subsequent increase in static, or average, pressure throughout the tank prior to the activation of the *Fast Depressurization System*. The model should describe the opening of the Rupture Disks (RD), the oil-gas mixture outflow, the time-dependent transformer tank pressure drop, and the resultant stresses and deformations on the transformer or reactor tank.

The *Fast Depressurization System* supplier shall provide Computerized Fluid Dynamic (CFD) and Fluid Structure Interactions (FSI) simulations for the transformer most probable low impedance energy fault (Mega Joule).

The supplier shall prove that the *Fast Depressurization System*:

- 10 years of experience with increased sales to 1,000 units.
- A Test Certificate showing a campaign of at least 25 successful live tests of electric arcs events inside the transformer or reactor tank closed and full with oil, from which at least 5 have been done with arcs of more than 1 Mega Joule.  
This Test Certificate must be granted by a recognized and independent high voltage laboratory from a country different than the country of manufacture of the explosion and fire prevention system.
- Evidence that the explosion and fire prevention system has prevented the explosion of at least 8 transformers or reactors over 60MVA in 6 different countries with 8 Certificates of Successful Activation signed by the transformer or reactor owner.
- Complies with the description for all Power Plants and Substations of the National Fire Protection Association, Code NFPA 850, 2015 edition. This norm requires that the *Fast Depressurization System* must be "passive – mechanical" and activated without sensors or electrical actuator.
- Insurance Policy over USD 10 million dollars to cover damages in case of transformer or reactor explosion with the *Fast Depressurization System* installed.

### 4.3 TECHNICAL SPECIFICATION VERIFICATIONS

The Appended Table should be used to evaluate each transformer or reactor and depending on its components it will be adapted as per B2 and B3 of Section B, "Depressurization Set (DS) with Rupture Disc (RD) for all elements of the transformer or reactor". This ensures that the explosion and fire prevention system complies with the Technical Specifications of the *Fast Depressurization System*.

## 5 APPENDIX

### 5.1 FAST DEPRESSURIZATION SYSTEM TABLE FOR TECHNICAL SPECIFICATION VERIFICATIONS

N°	DESCRIPTION	REQUIERED	GUARANTEE
	<b>EXPLOSION AND FIRE PREVENTION SYSTEM ON TRANSFORMER AND REACTOR</b>	Yes	
<b>A.</b>	<b>Fast Depressurization System</b>	Yes	
A.1	Complies with NFPA 850, 2015 Edition	Yes	
A.2	"Passive - Mechanical" activated without sensors or electrical actuators	Yes	
<b>B.</b>	<b>Depressurization Set (DS) with Rupture Disk (RD) for all transformer or reactor elements</b>	Yes	
B.1	Tank	Yes	
B.2	On Load Tap Changer (OLTC)	Yes	
B.3	Oil Cable Box (OCB) / Oil Bushing Cable Box (OBCB) or Bushing Turrets (BT)	Yes	
<b>C.</b>	<b>Additional depressurization functions to avoid the bazooka effect</b>	Yes	
C.1	Inert Gas Injection Set (IGIS)	Yes	
C.2	Oil-Gas Separation Tank (OGST)	Yes	
C.3	Explosive Gas Evacuation Pipe (EGEP)	Yes	
<b>D.</b>	<b>For physic and mathematic investigations</b>	Yes	
	<b>A multi-physic model must calculate the depressurization based on time and energy</b>		
D.1	Fluid Structure Interaction (FSI) Simulations	Yes	
D.2	Computerized Fluid Dynamic (CFD) Simulations	Yes	
<b>E.</b>	<b>Test Certificate for electrical arcs inside a transformer or reactor tank closed full of oil granted by a recognized and independent High Voltage Laboratory from a country different than the country of manufacture</b>	Yes	
E.1	Twenty - Five (25) Succesful Live Tests	Yes	
E.2	Five (5) Tests with electrical arcs of more than 1 Mega Joule	Yes	
<b>F.</b>	<b>Successful Activations during the transformer or reactor operation</b>	Yes	
	<b>Successful Activation Certificates signed by the owner of the transformer or reactor</b>		
F.1	Eight (8) Certificates of six (6) different countries	Yes	
<b>G.</b>	<b>Insurance Policy</b>	Yes	
G.1	Insurance Policy for more than USD ten (10) million american dollars covering damages in case of transformer or reactor explosion equipped with the Fast Depressurization System.	Yes	

#### AFFIDAVIT

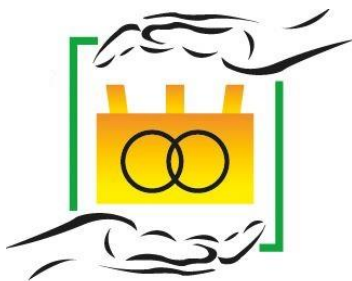
The company and its legal representative guarantees and certifies that the explosion and fire prevention system for the transformers/reactors complies with what it is in the table above, assuming the responsibility of the legal and economic consequences for declaring false data.

Company Name: \_\_\_\_\_

Legal Representative Name: \_\_\_\_\_

Identification Card Number: \_\_\_\_\_

Signature of the Company Legal Representative: \_\_\_\_\_



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