Annexure-E

BSES

Technical Specification of Nitrogen Injection Fire Protection System (NIFPS)

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Generic Technical Specifications of the Nitrogen Injection Fire Prevention and Extinguishing System (NIFPES) applicable for Oil filled Transformers and Reactors

1. Introduction

1.1 Electrical transformers are the main pillars of the power system network for enabling the transformation of voltage/ current and conveyance of electrical energy (electricity) so that the Utilities are able to supply electricity to consumers with a good degree of reliability and quality. At the same time, the Utilities endeavour to keep their assets in safe and secure conditions by providing protective equipment/systems which would help in properly maintaining the health and preventing damage to the equipment.

1.2 Any failure of transformer would have an adverse impact on the supply of power and satisfactory operation and performance of the power system. In cases involving fire in transformers, power outages, damage to assets, life and property are the common consequences. Transformer may fail because of many reasons, sometimes the failure of transformer leads to the emergence of fire, which becomes quite dangerous resulting into loss of assets, nearby equipment, living beings, and ecology. NIFPES is one of the measures to prevent and extinguish the fire taking place in the transformers.

2. Scope

2.1 Nitrogen Injection Fire Prevention and Extinguishing System (NIFPES) provided by the manufacturer/ vendor shall be complete in all respects. The scope shall cover design, supply, installation, connections, testing, commissioning and after-sales service of the system all associated items specified in these specifications.

2.2 The scope also includes the provision of heat/ fire detectors (sensors) herein after referred as the detector, required pipes, cable connections etc.

2.3 All other components meant for activation and successful operation of the NIFPES shall be provided by the manufacturer.

2.4 Transformer manufacturer/client will provide all the necessary support for the effective installation of NIFPES to each other and the purchaser shall make available the required transformer tripping signals as needed for the successful functioning of the NIFPES. Requisite drawings etc will also be provided by the utilities/manufacturer of the transformer/reactor (to the OEM of NIFPES).

3. Specifications

3.1 Nitrogen Injection Fire Prevention and Extinguishing System (NIFPES) shall be designed to prevent the fire from taking place in the transformer and possible explosion of the transformer tank due to internal faults/ arcing etc. In case of fire inside the transformer tank, the NIFPES shall be capable of mitigating the fire, minimizing the damage to the transformer and thus avoiding the spread of fire.

3.2 NIFPES system shall work on the principle of 'drain and stir' method of transformer oil. On activation of NIFPES, it shall isolate conservator tank oil from the oil in the main transformer tank, drain a pre-determined quantity of oil from the tank top through drain valve to reduce the tank pressure, and inject nitrogen gas from the bottom side of the tank through the inlet valves to create stirring action and reduce the temperature of oil to prevent/ mitigate the fire. On the operation of NIFPES, the quantity of oil removed from the tank shall be such that adequate amount of oil shall remain in the transformer to cover the active part of the transformer i.e. the 'core-coil' assembly. The NIFPES shall be designed in such a way that in case of external fire, the NIFPES may be operated manually, after electrically isolating the transformers from all sides. During operation of NIFPES, the oil flow pumps should also be tripped in case of OFAF/OFWF cooling of transformers in line with discussion with the end user / utilities.

3.3 The detection set point of the detector shall be site configurable.

3.4 Electrical isolation of transformer through master trip in addition to breakers shall be an essential pre-condition for activation of NIFPES

3.5 Operational Controls

The system operation shall be automatic and shall be activated when the pre-set conditions of activation of the system are attained / triggered. The maximum time period for extinction of fire from commencement of nitrogen injection into the transformer shall be 30 second. In addition to automatic operation, facility for remote operation from the control room / remote control center (RCC) and manual operation from the Fire Extinguishing Cubicle (FEC) shall also be provided. The system shall operate in the following situations:

3.5.1 System Activation in Fire Prevention Mode

3.5.1.1 To prevent fire and explosion in the transformer including that from internal fault/ arcing, signals from the following shall be used to activate the NIFPES:

(i) Operation of any of the protective relays i.e. differential or restricted earth fault (REF) or over current;

AND

(ii) Operation of any of the protective relays [Buchholz Relay or Pressure Relief Valve (PRV) or the signal from Rapid Pressure Rise Relay (RPRR)]

AND

(iii)Operation / Feedback of tripping of associated circuit breakers or Master Trip

3.5.1.2 Transformer shall be electrically isolated and then only the NIFPES shall operate. In case of some problem in main protection system, the NIFPES shall derive the activation signal from the backup protection system.

3.5.1.3 The exact logic for operation of NIFPES activation shall be finalized during detailed engineering and in consultation with the end user.

3.5.2 System Activation in Fire Detection Mode

3.5.2.1 In case of fire detection mode, signals from the following shall be used to activate the NIFPES:

(i) Heat / fire detectors (sensors);

AND

(ii) Operation of any of the protective relays [Buchholz relay or Pressure Relief Valve (PRV) or Rapid Pressure Rise Relay (RPRR)]

AND

(iii) Operation / Feedback of tripping of associated circuit breakers or Master Trip

3.5.2.2 Transformer shall be electrically isolated and then only the NIFPES shall operate. In case of some problem in main protection system the NIFPES shall derive the activation signals from the backup protection system.

3.5.2.3 The exact logic for system activation in fire detection mode shall be finalized during detailed engineering and in consultation with the end user.

3.5.3 Manual operation switch with a proper cover to avoid inadvertent operation of the switch, shall be provided in the control room / remote center and in FEC. Interlock shall be provided so that manual operation shall work only when the transformer is completely electrically isolated. NIFPES shall operate once the circuit breakers are isolated and feedback signal for isolation of breakers is received on NIFPES panel. The manual operation of NIFPES shall override the automatic operational mode and the operator shall ensure the complete isolation of the transformer before activation of the NIFPES.

3.5.4 The NIFPES manufacturer should provide the warning information on the Control Box and Fire Extinguishing Cubicle (FEC) that *"Ensure that HV, IV and LV breakers are open before operating in Manual Mode"* both in Hindi and English and the local language as prevalent.

3.6 Operation of System

3.6.1 On receiving the activation signal, the system shall:

i. Open the quick opening drain valve of the transformer to drain its top layer oil (pre-determined quantity) and shut off the transformer conservator isolation valve (TCIV) to prevent flow of oil from the conservator tank to the main transformer tank; and
ii. Open the valve to inject Nitrogen into the transformer tank to create stirring of oil.

3.6.2 There shall be interlock to prevent activation of the NIFPES, if the transformer is not

electrically isolated. There shall also be provision for isolating the NIFPES during maintenance and /or testing of the transformer.

3.6.3 The system shall be designed in such a manner that Nitrogen purging shall commence only after ensuring that the oil draining and TCIV operation has commenced.

3.7 Technical Particulars

3.7.1 The OEM of NIFPES shall be responsible for design of the complete system and shall submit the drawings and design calculations for the number of detectors, sizing of drain pipe, Nitrogen injection pipe, Nitrogen cylinder capacity, number of injection points etc and get approval from the user. The facility shall be provided to test the system by operation of valves [Nitrogen injection valve, TCIV and Oil Drain Valve (ODV)] when the transformer is in service, without actually draining the oil and injecting Nitrogen in real time operation by obtaining the feedback signal from the valve. The Nitrogen injection scheme shall be designed in such a way that the Nitrogen shall not enter the transformer tank even in case of passing/leakage of valve.

3.7.2 The oil drain mechanism may or may not be a part of the fire extinguishing cubicle.

3.7.3 The user shall provide two distinct station auxiliary DC / AC supplies for control power supply purposes. The system shall work on station DC / AC supply with voltage variation as per relevant standards. The control box of nitrogen injection fire prevention and extinguishing system shall have facility to receive these DC / AC supplies for auto changeover of supply. It shall be the Supplier's/ NIFPES OEM's responsibility to further distribute power to the required locations. In case system operational DC / AC power supply requirement is different than station auxiliary DC / AC supply, then all necessary converters shall be provided by the NIFPES OEM.

3.7.4 Following minimum indications and alarms shall be provided in the control cubicle in the control room:

(a) DC supply 'ON'
(b) AC supply 'ON'
(c) Total System Healthy
(d) DC supply fail
(e) AC supply fail
(f) System out of Service
(g) Differential relay trip
(h) Restricted Earth Fault (E/F) Relay Trip
(i) Overcurrent Relay Trip
(j) PRV trip / RPRR trip
(k) Buchholz Relay trip
(l) Master Relay trip [(HV, IV and LV (Tertiary Voltage)]
(m) Nitrogen cylinder pressure low
(n) Pre-Fire alarm

(o) Heat / Fire detector / Sensor faulty Signal
(p) Heat / Fire Detector / Sensor alarm signal
(q) Nitrogen injection Valve open
(r) Nitrogen injection Valve close
(s) Nitrogen injection Valve leakage
(t) Oil drain Valve open
(u) Oil drain Valve Close
(v) Leakage in Oil drain valve
(w) TCIV Open
(x) TCIV Closed
(y) Cable fault signal for interconnecting cable for transformer trip signals
(z) Auto operation failed
(aa) NIFPES system in Auto Mode
(bb) NIFPES system in Manual Mode
(cc) NIFPES system in Test / Maintenance mode

3.7.5 Other indicators, which supplier / user consider necessary shall also be provided.

3.7.6 The following push buttons shall be provided as a minimum:

(a) Mode Selection Switch, Auto / Manual / (test / Off)
(b) Lamp test push buttons
(c) System reset push button
(d) Detector reset push button, if applicable.
(e) Manual extinction push-button for manual operation of the system
(f) Hooter reset push button

3.7.7 The above indications may be in the form of Lamps / Annunciator Window / Human Machine Interface (HMI) as desired by end user.
3.7.8 Apart from the above list, Nitrogen cylinder pressure indication manometer with adequate number of adjustable 'Normally Opened (NO)' contacts shall also be provided in FEC. In addition to manometer for local reading a transmitter shall also be provided to monitor the reading to be displayed on control box in control room.
3.7.9 In case of fire in the transformer and fulfilling the conditions of defined logic for NIFPES operation for fire extinguishing mode or fire prevention mode, alarm (Audio & Visual) will be available in control room.

3.8 Technical Data Sheet:

3.8.1 The following are the technical requirements of the NIFPES:

Sl. No.	Item	Requirements
1.	Fire detection period on commencement of fire	Maximum 10 second
2.	Fire Extinction period on commencement of Nitrogen	Maximum 30 second

	injection	
3.	Fire detectors'/ sensors' "heat sensing" temperature	Flash point temperature of the transformer oil minus 5 ^{0}C with tolerance of +/- 2^{0}C.
4.	Power supply source (uninterrupted) for: a) Control Box b) Fire extinguishing cubicle	110/220 V DC (+10% /-15%) / 230 V AC 110/220 V DC (+10%/-15%) / 230 V AC
5.	Nitrogen Cylinder and Valve (PESO approved)	Cylinder as per IS:7285 (Part 2) and Valve as per IS:3224 (latest) both having the BIS Mark
6.	Nominal Cylinder Pressure	150 kg /cm² (+/- 10%)
7.	Minimum Cylinder Pressure for refilling	50 kg /cm²
8.	Degree of protection of: (a) FEC (b) Heat (fire) detector / sensor and Signal / Junction box	(a) IP 65 (b) IP 65
9.	Steel Sheet of FEC, Control Box and Signal Box	All panels shall be fabricated from corrosion resistance Stainless Steel (SS 304) grade. The thickness of sheet shall be 3.0 mm minimum.
10.	Color of all panels and Nitrogen Injection pipes	Shade 538 of IS: 5
11.	Heat (fire) detector / sensor	OEM shall furnish the technical details
12.	Minimum distance of FEC from the Transformer	FEC should be at a safe distance from Transformer (preferably 5-7 meters). Firewall (minimum 2 hrs fire withstand capacity) will be provided around FEC with the height of 600 mm from the top of FEC to protect it from fire of the transformer.
13.	For conservator valve of flow-based mechanism, flow rate for closing of flow-based conservator isolation valve	Between 60-70 Ltrs. / Minute (lpm).
14.	Pipes (Oil Drain and Nitrogen Injection)	MS, GI coated, Class C as per IS: 1239, latest Standard.

3.8.2 In case the pressure in the nitrogen cylinder exceeds the rated pressure, there shall be a provision for extracting the excess nitrogen to attain the safe pressure in the nitrogen cylinder.

3.9 Details of Supply of System/ Equipment and Other Related Activities:

3.9.1 The fire extinguishing cubicle (FEC) with base frame and containing at least the following. (However, all other components that are necessary for fast, reliable and effective

working of the fire protection system shall deemed to be included in the scope of supply):

(i) Nitrogen gas cylinder and cylinder valve having the Petroleum and Explosive Safety Organization (PESO) certificates of sufficient capacity.
(ii) Pressure regulator with indicators for nitrogen pressure of the cylinder and actual injection pressure through nitrogen cylinder and manometer with sufficient number of adjustable 'Normally Open (NO)' contacts.
(iii) Oil Drain Assembly including oil drain valve and its equipment for operation, oil drain pipe extension of suitable size and strength for connecting pipes to Oil Storage Tank, along with level switch / oil seepage detecting sensor for detecting leakage in oil drain valve;
(iv) Mechanical release device for oil drain and nitrogen gas release;
(v) Limit switches for monitoring of the systems;
(vi) Panel lighting;
(vii) Flanges on top of the panel for connecting oil drain in case of oil drain mechanism is part of fire extinguishing cubicle (FEC) and nitrogen injection pipes for transformer;
(viii) Fire Extinguishing Cubicle (FEC) shall have proper illumination.
(ix) The heater with thermostat shall be provided in the FEC. Heater shall be operated as per the setting of the thermostat.
(x) Mandatory spares as applicable.

In case, oil drain mechanism is not a part of FEC – the related items shall be as per the Original Equipment Manufacturer's (OEM's) design however, the functional requirements shall have to be met.

The FEC shall be provided with canopy / shed protected from 3 sides to avoid water ingress and protect the FEC from direct sunlight and radiant heat. The canopy / shed shall be designed to cover almost more than half of the FEC height from top.

3.9.2 Control box / cubicle shall be installed in the control room of the substation for monitoring the NIFPES operation, automatic control and remote operation with alarms, indications, switches, push buttons, audio signal etc. Control Box / Cubicle should be microprocessor based / Programmable Logic controller (PLC) based, compatible to be interfaced with user's Supervisory Control and Data Acquisition (SCADA) system in the Substation / Switchyard.

3.9.3 The required number of detectors shall be located at strategic locations as finalized during detailed engineering. The location of detector shall be as per the design of OEM.

3.9.4 All the control / power cables between the NIFPES panel and the transformer, shall be Fire Survival Cable type up to the thermal limit (in case of fire and or explosion). Fire survival cables shall be suitable to withstand a temperature of 750 °C. Further, Technical Data sheet and applicable valid type test report as per applicable latest IS shall be submitted to the user during detailed engineering.

All cables shall be laid in GI conduits / pipes, if desired by the user.

3.9.5 Transformer Conservator Isolation Valve (TCIV) shall isolate the conservator oil from the main tank's oil. This valve shall be located in the piping between the conservator and the Buchholz relay.

3.9.6 The nitrogen gas cylinder shall be of sufficient capacity considering the actual quantity of the transformer oil. The margin of safety shall be 3 times the oil to be drained (as per OEM design), for example if the oil quantity to be drained is 1500 litres (i.e. 1.5 m^3) then 4.5 m^3 volume of nitrogen is required. Considering the rated pressure of the gas filled in the cylinder as150 kg/cm^2, accordingly the capacity of the nitrogen cylinder shall be decided by the OEM of NIFPES in consultation with transformer manufacturer.

3.9.7 SCADA compatibility

i. The NIFPES shall be provided with IEC 61850 / RS 485 / TCP IP compatible port or using suitable converters for integration with user's SCADA system.

ii. The ethernet switch, patch cord, Light Interface Unit (LIU) and Fibre Optic (FO) cable are not included in the present scope.

3.9.8 Drain Oil Storage Tank

A drain oil storage tank for each transformer shall be provided at suitable location with appropriate construction material having appropriate capacity (as decided by the user). All precautions shall be taken so that there is no overflow/spill of the drained oil. Design of the drain system and storage thereof to be provided by the OEM. In case the user has his own design of the drainage system, he can opt for the same.

4.0 Tests

i. Factory Acceptance Test (FAT)

Functional verification of the offered parameters of NIFPES shall be conducted at the works of NIFPES manufacturer. The Test procedure shall be as per **Annexure – A.**

ii. Type Test for Detector:

Type test report of the detector shall be submitted to the user along with the design/drawing documents. The detector shall be tested as per the procedure given below:

Test	Type	Procedure	Requirement	Observed Value

Testing of the detector	Type of the detector along with its make and model number is to be mentioned in this column	1. Detector is to be tested by immersing it in the heating liquid with temperature measurement arrangement or by suspending in hot air oven with temperature measurement. 2. The temperature of the liquid / air is to be increased at the rate of 1 ^{0}C per minute and reading of the thermocouples to be noted. 3. Thermocouple for measuring the temperature is to be provided at the tip / surface of the detector. 4. The temperature of the liquid / air is to be increased till the detector activates.	The detector shall activate at the flash point temperature of the transformer oil minus 5 ^{0}C with tolerance of +/- 2^{0}C	The temperature, at which the detector activates, is to be recorded.

iii. Site Acceptance Test (SAT) /Performance Test

a) SAT / Performance test of the NIFPES shall be carried out after the completion of installation at site. It shall also be ensured that the interfacing of NIFPES with SCADA has been completed by the user before SAT. These tests shall include simulation and verification of the response of the complete system without actual draining of the oil and injection of the Nitrogen gas. In addition to the above, additional mutually agreed tests as considered necessary shall be conducted. SAT shall also include to test the provisions as specified in Para-3.6 "**Operation of System**" above.

b) SAT shall also include demonstration of the system checking by simulation method when transformer is in online condition as mentioned in Para- 3.7 "**Technical Particulars**" above.

c) For flow based TCIV vendor to demonstrate the locking / closing of TCIV valve at specified flow rate as per technical data sheet. Necessary arrangements to demonstrate the requisite flow rate and measuring instruments as required shall be made available by OEM for conducting SAT.

d) Installation and pre-commissioning test after installation of the system shall be carried out jointly by the OEM and the user's representative before the system is put in service. All the system checks as per approved SAT procedure shall be performed to the satisfaction level of the end user / client.

Annexure – A

Format for the Factory Acceptance Test

1. **Visual Inspection:** Visual examination of the NIFPES equipment i.e. Fire Extinguishing Cubicle, Control box/cubicle, Signal Box, Transformer Conservator Isolation Valve, heat/fire detectors, cables, etc shall be made as per the approved drawings.

2. **Functional Test:** Functional test shall be carried out on one (1) set out of the total manufactured lot for the respective order as minimum in presence of user / user nominated inspection agency. Following are the list of critical items to be used in FAT out of manufactured lot for the respective Purchaser Order:

   (i) Fire Extinguishing Cubicle with its internals, Nitrogen cylinder meant for internal testing can be used during FAT testing. However, connection of cylinder shall be in line with regulator valve intended for dispatch.
   (ii) Control Box with its internal components and accessories.
   (iii) Signal box with its internal components and accessories.
   (iv) Detector
   (v) TCIV Valve.
   (vi) ODV Valve.
   (vii) SCADA compatibility of all the signals over RS 485 / IEC protocol as applicable.
   (viii) Pressure and leakage test on Oil storage Tank

3. Functional Test of Transformer Isolation Conservator Valve (TCIV):

Sl. No.	Test	Procedure	Requirement	Remarks
1.	Leakage Test	Immerse the TCIV (Valve body) in the oil at the inlet pressure of 4 kg/cm^2 for 6 hours.	There should be no leakage from TCIV body	
2.	TCIV Close test (A or B as per the Design of TCIV)	**A.** For oil flow rate based TCIV: i. Mount TCIV with approx. 3 degree inclination on test jig ii. Switch ON oil Pump iii. Increase oil flow rate gradually	➢ TCIV should close at flow rate specified herein. ➢ Flap closing shall be visible through transparent glass inspection window. ➢ Normally open (NO) contacts in TCIV should close / TCIV Close indication in control Box should be reflected.	

		B. For electrically operated TCIV: i. Mount TCIV with approximately 3 degree inclination on test jig ii. Generate a set of input signal for the activation of NIFPES system.	➢ TCIV should close. ➢ Flap closing shall be visible through transparent glass inspection window. ➢ Normally open (NO) contactsin TCIV should close/TCIV Close indication in control Box should be reflected.	
3.	Reset Test	Reset the TCIV in the normal position.	➢ Close contact in TCIV should become open/ TCIV open indication in control Box should be reflected. ➢ Flap opening shall be visible through transparent glass inspection window.	
4.	High voltage test	Apply 2 kV AC for 1 minute between terminals and body of TCIV	TCIV should withstand.	

4. Functional Tests for detector:

4.1 The operating temperature shall be as per the requirement mentioned in technical data sheet.

4.2 Live demonstration test: To verify the working of the system, live demonstration is to be conducted in both fire prevention and extinguishing mode. Following are to be ensured:

(i) Demonstration is to be carried out at the works of NIFPES Manufacturer. It shall be the responsibility of NIFPES manufacturer to arrange a suitable location for live testing.

(ii) A dummy tank of minimum 5000 litres oil capacity and filled with oil, should be used as a transformer tank for testing.

(iii) The detector for testing shall be placed as per the design of OEM.

(iv) The FEC and Control Box manufactured for the said Purchase Order are to be used for live testing.

(v) Separate filled Nitrogen cylinder should be used for live tests.

(vi) Testing shall be conducted as per procedure mentioned below:

5. Testing in Fire Prevention Mode

5.1 Procedure:

(i) Oil Drain Pipe, Nitrogen Injection pipe, FEC, Control box / Cubicle, Signal box, TCIV, oil storage tank with all necessary pipes and cable

connections shall be connected with transformer tank.

(ii) Nitrogen gas Cylinder pressure should be recorded.

(iii) The NIFPES System shall be made ON.

(iv) Any one set of input of the fire prevention mode shall be generated by a suitable method.

5.2 Observations/ Results:

(i) After fulfilling of required condition, system gets activated in auto mode.

(ii) Oil Drain shall be started and TCIV shall start closing.

(iii) Nitrogen should be injected.

5.2.1 Following Indications on control box will turn on:

a)	Differential trip / PRV trip/RPRR trip / Buchholz Relay trip / Master Relay trip [HV, IV and LV to ensure that the Circuit Breakers are open] Restricted Earth Fault (REF) Relay Trip / Overcurrent Relay Trip as per logic
b)	Nitrogen Injection valve open
c)	Oil Drain valve open
d)	TCIV Valve closed
e)	Audio Alarm activated

5.2.2 For flow based TCIV valve the LPM at which it closes shall be measured, which shall be in line as mentioned in technical specifications, and the recorded values to be noted.

5.3 Testing in Fire Detection Mode (By igniting the transformer oil of the tank)

5.3.1 **Procedure:**

i. There should be an opening on the dummy transformer tank to ignite the transformer oil.

ii. The detector for testing shall be placed as per the design of OEM.

iii. Oil Drain Pipe, Nitrogen Injection pipe, FEC, Control box, Signal box, TCIV, oil pit with all necessary pipes and cable connections shall be connected with dummy transformer tank.

iv. The NIFPES shall be made ON.

v. The Buchholz Relay or PRV or RPRR Trip and Master Relay trip (HV, IV and LV) Signal shall be activated by a suitable method.

vi. Ignite the transformer oil by any method such as pouring any flammable liquid or any suitable chemical spray and igniting the flame.

vii. Note the time taken between commencement of fire and fire detection (Fire Alarm signal is received) takes place.

viii. Note the time taken between commencement of Nitrogen injection and fire gets extinguished.

5.3.2 **Observations:**

(i) After fulfilling of required conditions of fire extinguishing mode system should get activated in auto fire extinguishing mode.
(ii) TCIV shall start closing and Oil Drain should start.
(iii) Nitrogen injection shall begin.
(iv) Following Indications on control box will turn on:

i)	PRV trip/RPRR trip / Buchholz Relay trip / Master Relay trip [HV, IV and LV] / Fire / Heat Detector as per logic
ii)	Nitrogen Injection valve open
iii)	Oil Drain valve open
iv)	TCIV Valve closed
v)	Audio Alarm activated

5.3.3 **Results:**

Sl. No.	Details	Requirement	Observations
1.	Fire detection period upon commencement of Fire	Maximum 10 seconds	..... Seconds
2.	Fire Extinction period on commencement of Nitrogen injection	Maximum 30 seconds	..... Seconds

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