IEEE Transformer Conference
Bushing Subcommittee

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By

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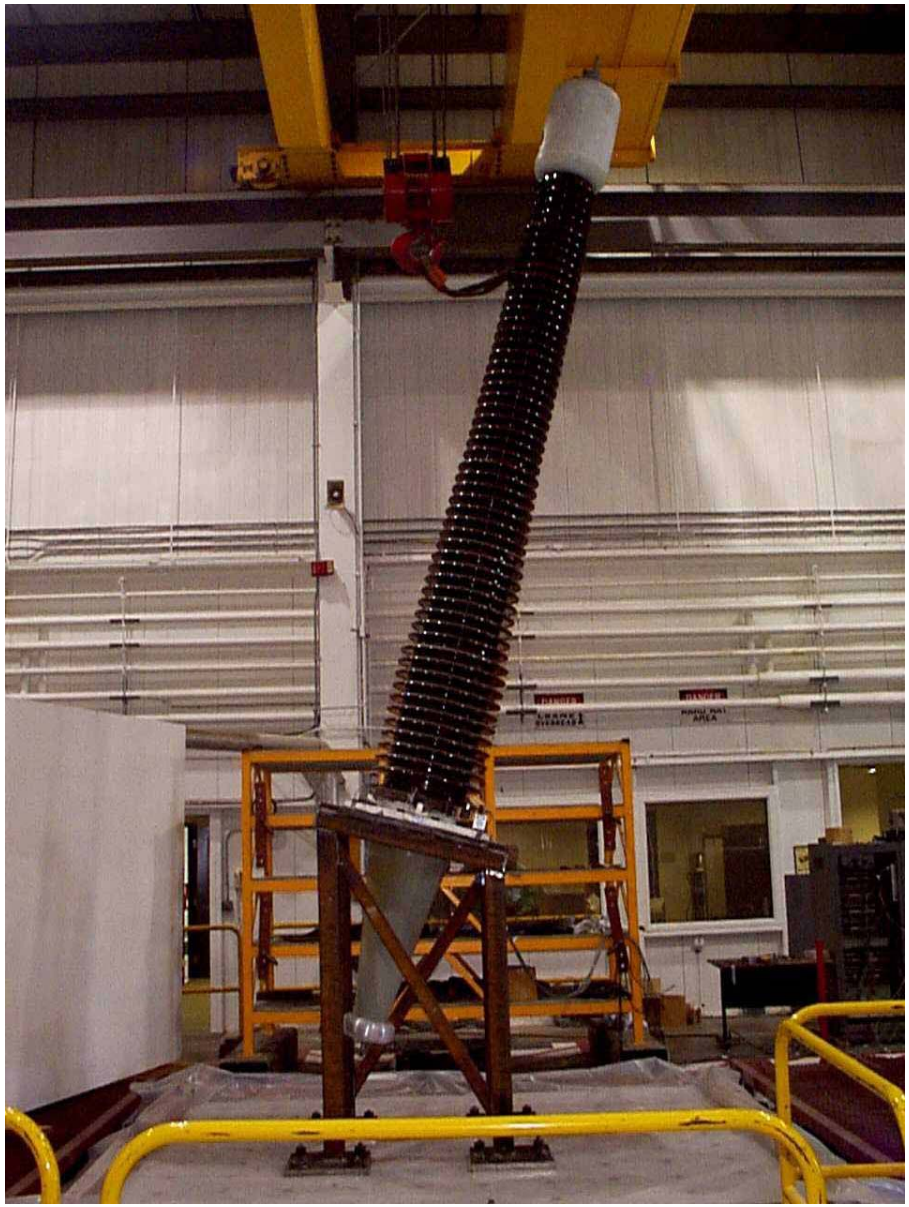
Executive Summary

- The procedure for seismic qualification of transformer-bushing system in IEEE 693 is being revised
- The new procedure, as currently being conceptualized, will impact the design and construction of transformer tank covers
- The new requirements will likely be related to stiffening the transformer's support of bushings
- There is need for technical input and guidance from transformer manufactures for developing a protocol to be used in IEEE 693 by participating in related research and in IEEE 693 committee meetings

Review of Current IEEE Test Procedure

- For testing, the bushing is mounted on a stiff support structure
- The bushing is positioned at about 20 degrees from vertical
- The amplification between the transformer base and bushing mounting flange is assumed to be 2
- The flange is subjected to twice the 0.5g Required Response Spectrum (RRS) (The RRS defines the excitation used to qualify substation equipment.)
- Thus, bushing support structure is subjected to 2.0g RRS
- No turret is used

500 kV Bushing on Typical Test Stand



History of Tests and Related Earthquake Performance

- 500 kV center-clamped, non-cemented bushing
  - Shake-table test of 500 kV center-clamped, non-cemented type bushing failed (leaked) at about 0.3g Required Response Spectrum (RRS)
  - In Hector Mine Earthquake a similar bushing failed (leaked oil) at 0.11g
- 230 kV center-clamped, non-cemented bushing
  - Shake-table test of 230 kV center-clamped, non-cemented type bushing was undamaged at about 1.25 Performance Level (2.5g RRS)
  - Bushing was then mounted on 1/2" thick, 5' square plate and failed below high seismic level
  - In Northridge Earthquake about 25 of this type of bushing failed (leaked)
- Mexico earthquake (peak site acceleration of 0.38g)
  - 400 kV: 6 of 29 cemented-type bushings failed (cracked porcelain)
  - 230 kV: 6 of 7 center-clamped, non-cemented-type bushings failed (offsets and leaked)

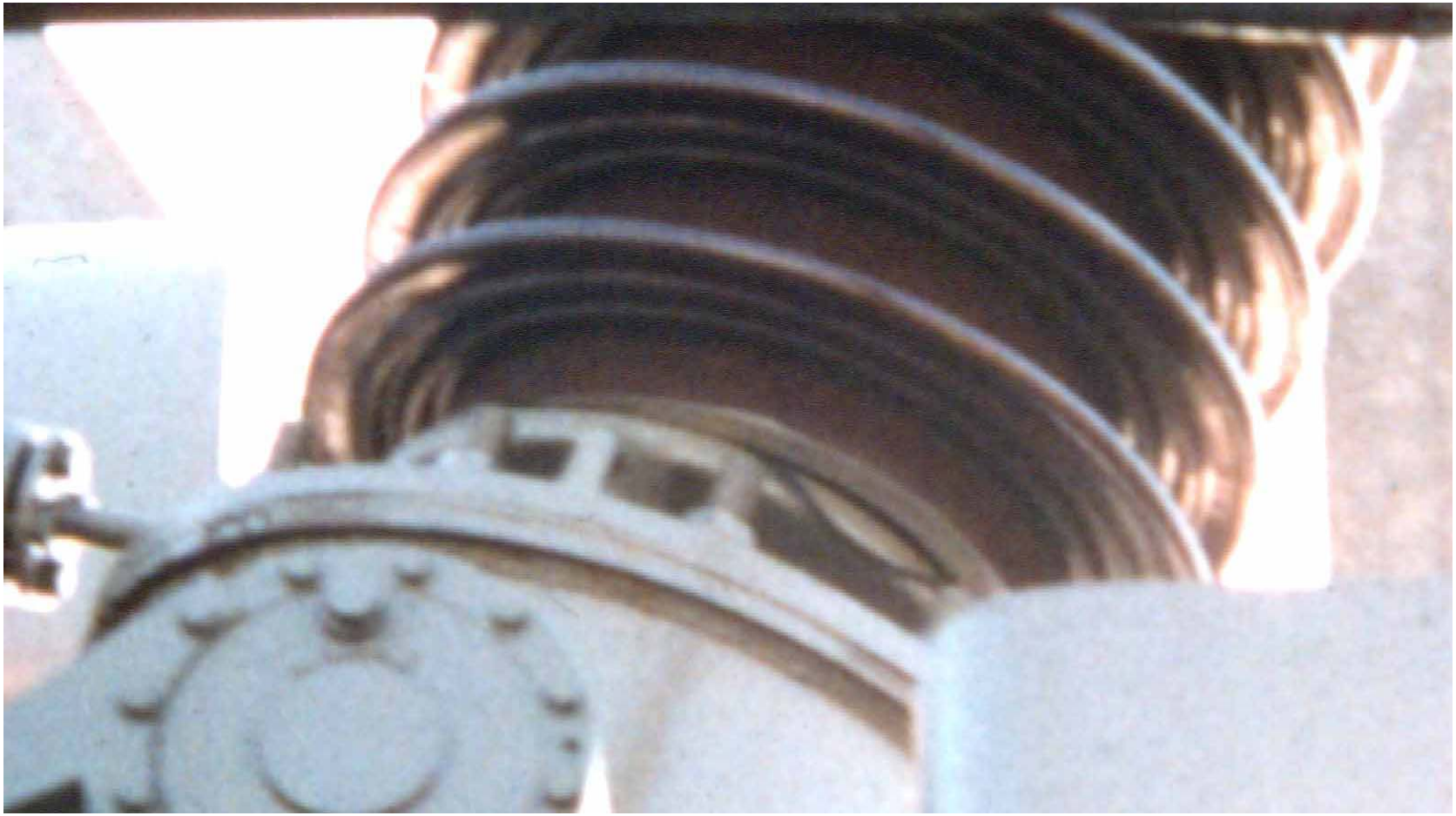
Implications of Tests and Earthquakes

- IEEE Standard does not capture effect of transformer on bushing response
- The flexibility of transformer cover is a major factor that influences performance of the bushings
- A new protocol that captures the effects of the transformer on bushings will probably demonstrate that existing bushings are more vulnerable than indicated using current test method

Center- Clamped Type Bushings

- Most common type bushing used in US and has had seismic failures
- Stiffly supported bushing in tests has observed frequencies:
  - 230 kV 14Hz & 19Hz,
  - 500 kV 6-1/2Hz & 8-1/2Hz
- Transformer-installed bushing frequencies: 2-1/2Hz - 6Hz?
- The frequency of the as-installed bushing is controlled by stiffness of transformer cover and possibly the turret height
- Failures Modes
  - Temporary oil leak (common)
  - Offset without permanent oil leak (clearance issue for large offset)
  - Offset with permanent oil leak (common)
  - Gasket extrusion with permanent oil leak (common)
  - Cracked porcelain (rare)

Offset Bushing and Extruded Gasket



Implications of Tests and Earthquakes

- Current bushing qualification procedure used in IEEE 693 does not capture effect of transformer on the bushing response
- There is interaction between the bushing and the transformer so that qualification will have to consider this interaction
- Generally, bushing performance is reduced as support stiffness is reduced
- Bushings will have to be qualified without regard to specific transformers so that bushing support (transformer cover) stiffness may have to have minimum allowed design value

Research Effort Planned to Establish IEEE 693 Protocol

- Researchers need technical guidance from transformer and bushing manufacturers in formulating research and protocol
- Issues that may have to be considered in design of qualification protocol include:
  - Transformer cover size, plate thickness, internal or external stiffeners
  - Current practice in transformer cover design
  - Position of bushing relative to edge of cover
  - Tilt of bushing
  - Turret height and footprint size
  - Operating voltage
  - Affect of lower conductor restraint on bushing dynamics
  - Can the same qualification protocol be used for all bushing types (porcelain, composite) and designs.
- For additional information and to participate contact:
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