cigre | PARIS 2022

HITACHI
Inspire the Next

Hitachi Energy

Study Committee A2

Power Transformer and Reactors

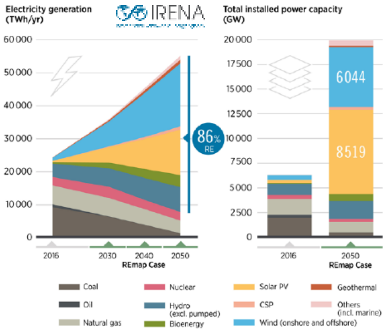
Paper ID_10127

ADVANTAGES OF LOADING AND AMBIENT PROFILE ASSESSMENTS FOR SOLAR POWER TRANSFORMER

Wílerson CALIL[1]*, Eduardo COSTA[2], Tor LANERYD[3], Andreas GUSTAFSON[3]
[1]Hitachi Energy, Brazil
[2]University of São Paulo, Brazil
[3]Hitachi Energy, Sweden

Motivation

- The future of power system will be the electric and powered by renewable energy.
- Renewable Energy will grow substantially to reach 2050 scenario according to IRENA source.



- An economic analysis in combination with fulfilling technical requirements can be used during the procurement process to reduce the installation cost and promote the faster expansion of renewable power generation.

Methodology

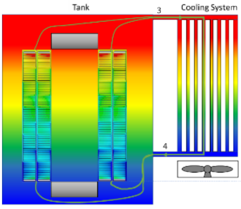
- The study is designed as a practical verification of the loading and temperature profile where dynamic loading modeling based on the well-known IEEE Std C57.91-1995 method is applied to calculate the hotspot accurately.
- The proposed methodology of applying dynamic loading models applied in combination with Total Ownership Cost (TOC) analysis can substantially reduce the weight and footprint of the transformer, bringing better cost-benefit, and longer service life with higher reliability to the investor.

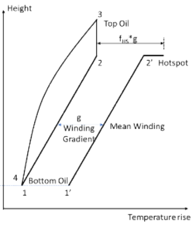
Objects of investigation

- How to optimize transformer size with real loading and temperature profile.
- Is transformer size, technically optimized, to fulfill all economic/financial criteria?

Temperature Correction

- Ambient temperature at site intallation

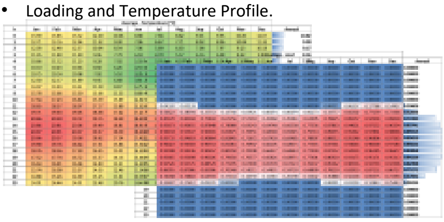




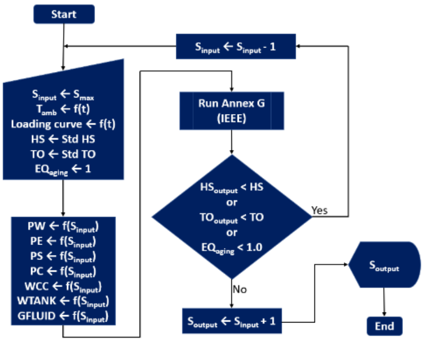
- The method corrects the effect of the losses on the equipment lifetime.
- During colder months, losses are lower than other months comparing with the same load.
- Due to the thermal inertia of the whole equipment, in cold days, the transformer does not reach the higher temperature because there is insufficient time to stabilize the oil temperature.

Case Study

- 100 MVA Transformer was used as experimental test.
- Loading and Temperature Profile.



- Workflow of the technical optimization



Study Committee A2

Power Transformer and Reactors

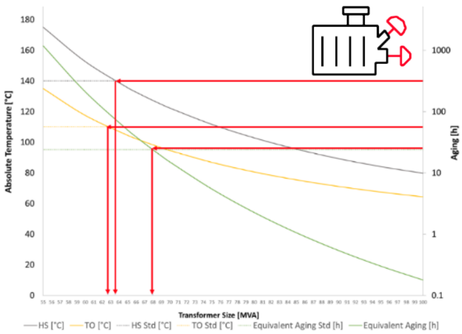
Paper ID_10127

ADVANTAGES OF LOADING AND AMBIENT PROFILE ASSESSMENTS FOR SOLAR POWER TRANSFORMER

Wílerson CALIL[1]*, Eduardo COSTA[2], Tor LANERYD[3], Andreas GUSTAFSON[3]
[1]Hitachi Energy, Brazil
[2]University of São Paulo, Brazil
[3]Hitachi Energy, Sweden

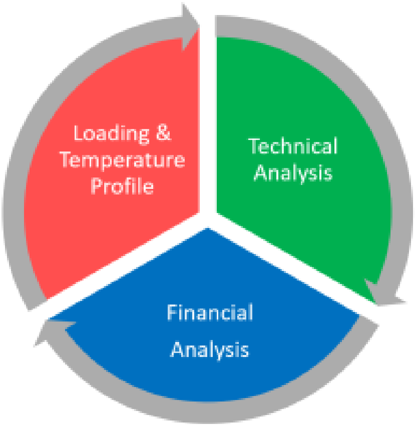
Comparison

- 100 MVA Transformer input (First approach)
- Optimum technical design: 68MVA
- Both design fulfill technical standards.
  - Top Oil
  - Hotspot
  - Equivalent Aging



TOC – Total Ownership Cost

- Financial Inputs Consideration.
- Capitalization of NLL & LL to calculate Total Owership Cost - TOC
- Temperature correction at site installation

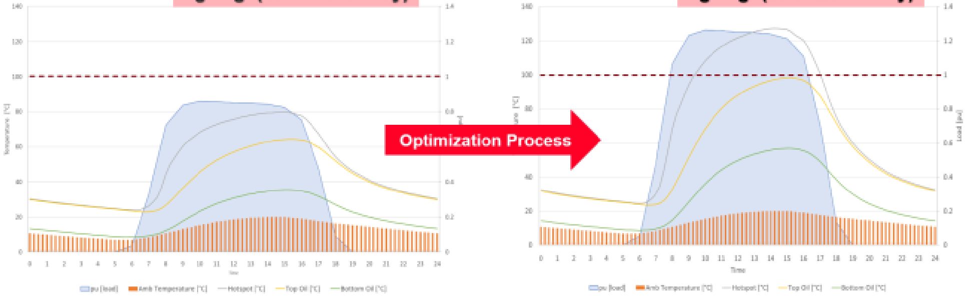


100 MVA

Ageing: (10min 44s / day)

68 MVA

Ageing: (23h 52min / day)



Financial & Temperature Correction

Power [MVA]	100	95	90	85	80	75	70	65	60	55
TOC [p.u.] - RMS	1.000	0.934	0.916	0.894	**0.877**	0.878	0.904	0.927	0.950	1.006
TOC [p.u.] - RMS with temperature correction	1.004	0.937	0.918	0.895	0.875	**0.874**	0.897	0.915	0.931	0.976

cigre PARIS 2022

HITACHI Inspire the Next

Hitachi Energy

Study Committee A2

Power Transformer and Reactors

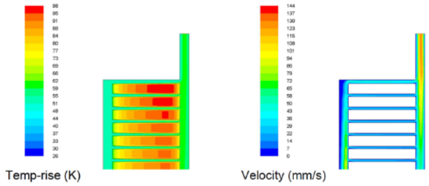
Paper ID_10127

ADVANTAGES OF LOADING AND AMBIENT PROFILE ASSESSMENTS FOR SOLAR POWER TRANSFORMER

Wílerson CALIL[1]*, Eduardo COSTA[2], Tor LANERYD[3], Andreas GUSTAFSON[3]
[1]Hitachi Energy, Brazil
[2]University of São Paulo, Brazil
[3]Hitachi Energy, Sweden

Validation of winding hotspot CFD

- The IEEE Annex G is a simplified thermal model. It is therefore recommended in those cases where needed, to validate the predicted winding hotspot temperature by state-of-the-art methods such as Computational Fluid Dynamics (CFD).
- Although the transformer is not in steady state, at 14h15 when the maximum winding hotspot occurs according to the IEEE Annex G dynamic thermal modeling shown above.



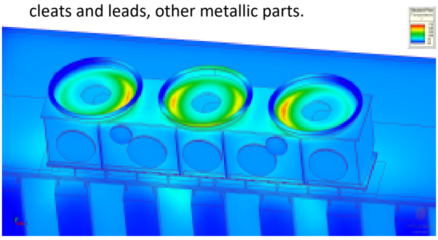
- This is slightly higher than what was predicted by the IEEE Annex G, 91.4 K. However, the value is lower than the maximum temperature in terms of ageing which means that the 75 MVA transformer is confirmed to fulfill all the required criteria.

Full Design

- The method described in this paper is based on the electrical and cooling design of the active part of the collector GSU power transformer
- When perform a full design of the transformer it is critical to consider all components and materials being able to handle the expected temperature and load.
- Bushings and tap changers must be dimensioned accordingly because the maximum rate of this transformer should not be a bottleneck for these main accessories.
- Internal lead connections and crimping also must be dimensioned to the maximum overload rate.
- High temperatures materials might be used to fulfill the material class temperature without occurring non-controlled gas generation.
- Heat run test and thermo-scan cameras under normal and overload are encouraged for a prototype unit.
- Fiber optic probes should be installed on windings.
- Monitoring and digitalization are encouraged.

Simulation Software

- FEM to be handle with high-temperature when overload.
- Engineering numerical software such as electromagnetic could help the manufacturers to prove, during the design stage, whether the temperature of the tank and metallic parts are below the standard limit values.
- Tank, cover, magnetic tank shunt.
- Mechanical parts and accessories: Tank, painting, cleats and leads, other metallic parts.



Conclusion

- How to optimize transformer size in a new project with real loading and temperature curve; and this technically optimized transformer fulfill all economic criteria. Both items together fit the final cost-effective transformer for a new installation.
- This method is efficient and more appropriate for its intended purpose because find the most suitable technical equipment comparing its financial inputs data like the price of energy, WACC of the investor and transformer life expectance, therefore, it is an original method that has great potential to assist in the design of transformers for systems with intermittent loading.
- To avoid a reduction in the revenue of electricity production, a deep analysis in this context was done which has demonstrated the importance to take into account the loading profile and the huge difference between capitalization of no-load and load losses.
- Ultimately, when specifying a transformer according to the proposed method, it is important to validate the thermal performance using state-of-the-art methods such as CFD and fiber optic temperature measurement, and to consider all the other aspects of a full transformer design.