Impact of short time overloading power transformers on the reliability analysis of power systems

This poster is based on the thesis “Impact of dynamic component parameters on the reliability analysis of power systems“ and is part of a research project in availability management systems.

Motivation

Modern transformer monitoring systems allow to calculate detailed information about inner component conditions. Based on those capabilities these systems allow more complex operating modes with dynamic calculated limit values for power transformers. The grid operator can get information in real-time quality, for example, about the allowed overloading for a given duration. These operation strategies can increase the supply of grid customers when the grid is in critical system condition as effect of a utility fault. For planning the grid, a quantification of these operating modes can help to reduce investment costs in hardware. Enhancing reliability analysis with methods to consider complex operating modes allow a better economic rating in grid planning.

An other use of the enhanced reliability analysis is the use in determining critical indices for grid components and adapting operation strategies to minimize risk of supply deficits.

Method

For the reliability analysis different calculation methods are available. In this project a strategy for calculating the effect of short time overloading power transformers using the state enumeration method is in focus. One benefit of this method is in examining single system states separately without need to calculate all other possible system states. This is important, when reliability analysis is used to generate online extra information for operation. Computing time can be reduced.

In this thesis also a method to calculate a expected pre-load condition in the state enumeration method for the use in thermal equipment models is developed. The pre-load condition means the load factor of an device before a fault occurs. If not calculated, the load factor before the examined fault is in worst case equal one.

In the examination the exponential model from standard DIN IEC 60076-7 is used as thermal model. Parameters for allowed hot spot temperature and maximum time in operation mode are also from this standard.

For the analysis a script for reliability analysis in MATLAB® was developed to get control over used probalistic models and error

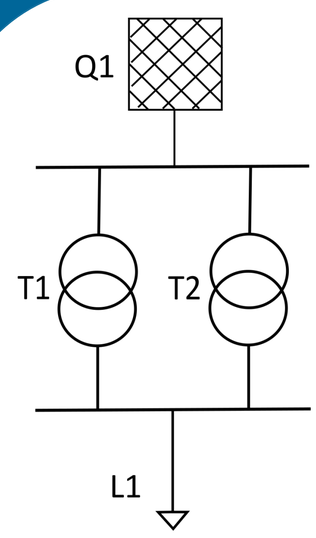

Fig. 1: Grid example for examination of impact

Results

To examine the impact of the used thermal model in reliability analysis of power systems a simple grid is used. This grid is not designed on the (n-1) - criteria, so the result is not influenced by this deterministic planning criteria.

In the test case unavailability of system is reduced by short time overloading with continuous characteristic curve with a factor of 4.5 (compared to a stepped characteristic curve) resp. 5.0 compared to a system without short time overloading power transformers (Fig. 2).

Consideration of an estimated pre-load state reduces unavailability of system at 2.7 % resp. 4.1 % (cont. curve with time limits for operation mode) compared to a pre-load of 100 %.

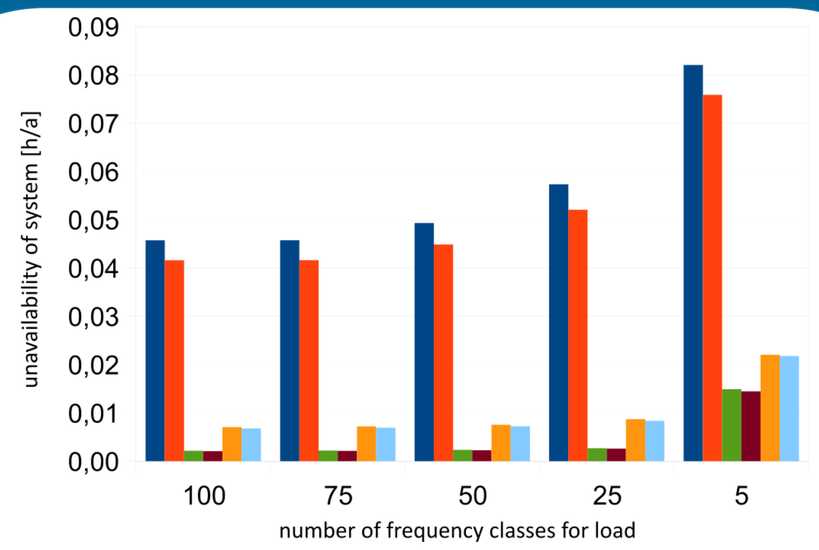

Fig. 2: Results for static overloading characteristics vs. dynamic overloading characteristics

- unavailability of system
- unavailability of system, stepped characteristic curve for fixed ambiant temperature
- unavailability of system, continuous characteristic curve
- unavailability of system, continuous characteristic curve, consideration of preload state
- unavailability of system, continuous characteristic curve, consideration of time limits for allowed hotspot temperatures
- unavailability of system, continuous characteristic curve, consideration of preload state and time limits for allowed hotspot temperatures

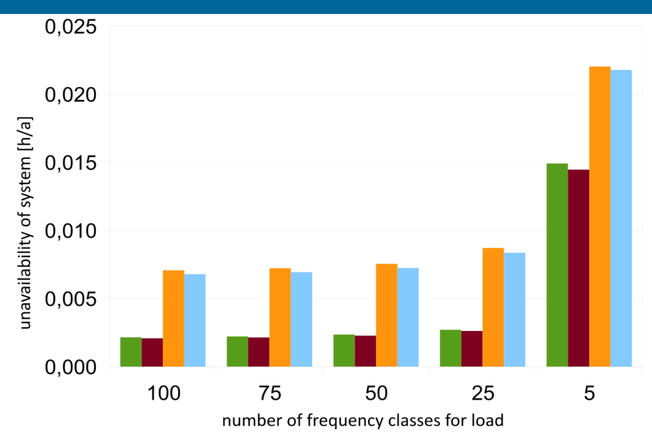

Fig. 3a: Sensitivity of reliability analysis on the number of frequency classes for the system load.

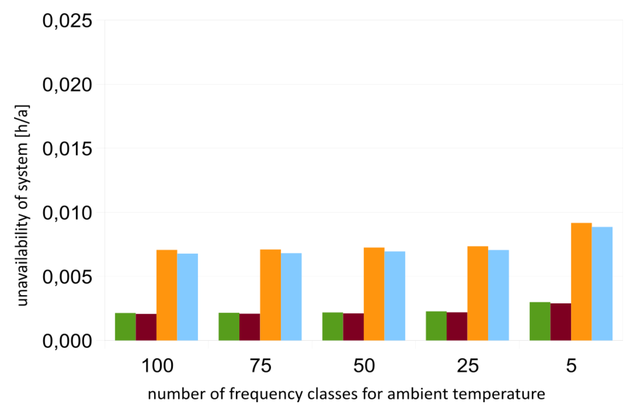

Fig. 3b: Sensitivity of reliability analysis on the number of frequency classes for the ambient temperature

The examined system is more sensitive to the variation of the number of frequency classes for load compared to a variation in ambient temperature (Figure 3a and 3b).

Conclusions & Outlook

Short time overloading power transformers take a significant effect in reliability analysis. The low sensitivity of the tested network to the number of frequency classes for ambient temperature allows to take this operation mode in account without a massive increase in computation time.

Actual a software tool for the reliability analysis supporting thermal models for short time overloading is in development. The impact of short time overloading transformers in larger grids will be analysed. Further steps in research are the use of enhanced reliability analyses to optimize the equip of transformers with monitoring systems in the field, determining the critical index of equipment in the power system and developing preventive strategies to reduce risk of system unavailability in case of equipment fault.

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