Reliability of cable based transmission grids operated based on temperature limits

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The Danish transmission system operator (TSO), Energinet.dk, is investigating the options for controlling the transmission grid, based on utilisation of the components temperature limitations instead of the presently used steady state ampacity limitations. The aim is, of course, to get a better cost optimisation in connection with purchasing of components but, equally important, it is also the aim to increase the flexibility within transmission grid control. However, since the raison d'être of TSOs is a high security of power supply, it is important for Energinet.dk that the transmission system reliability, as a minimum, will not be reduced during the transition from steady state current based operation to dynamic temperature based operation. In addition, the reliability investigations described in the present paper should be seen in the light of the Danish transmission cable policy. The Danish parliament has decided to underground most of the Danish transmission system within the coming 25 years, which makes focus on transmission system reliability with high shares of underground cables highly relevant.

Much research within reliability of transmission grids is concerned solely with radial power systems, parallel power systems and power systems where a redundant component can be connected in case of failures. For modern transmission systems, where meshed structures rule, such analyses are of limited use and more comprehensive methods must be utilised.

In the present paper are described investigations on how a Monte-Carlo approach, based on Markov processes, can be used to calculate the reliability of a power system, where the majority of the transmission lines are underground power cables. It is shown that the reliability of a cable based transmission grid can be greatly enhanced by utilising real time temperature calculations in the daily operation of transmission grids, as compared to the normally used steady state IEC ampacities. These analyses should stimulate global considerations in the direction that controlling transmission grids based on the real time thermal state of the system, instead of static current ratings, can lead not only to economic benefits, but also to an increased security of supply.

The theoretical considerations are collected in a simple method for evaluating the reliability of cable based transmission grids. The method is proven to be implementable with the load flow software DigSilent PowerFactory, commonly used all over the world by TSOs, universities and research institutions. The evaluation of the transmission system reliability is thus proven to be straight forward for all power grids, which are already modelled in this or similar software.

The theoretical method is tested against a modified version of the standard IEEE 14-bus test system and a significant increase in system reliability is proven, when utilising the real time thermal approach to controlling cable based transmission system as compared to steady state ampacity control.