Reliability of Supply of Cable Based Transmission Grids Using Dynamic Thermal Rating

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ABSTRACT

Investigations have been conducted on the reliability of supply when utilising Electrothermal Coordination (ETC) in cable based transmission grids. Increasing the loadability of cables with online dynamic thermal rating calculations will increase the flexibility in the transmission system, and thus also the reliability of supply. It is shown that a high reliability of supply can be maintained, even when expecting a highly loaded transmission system in the coming hours.

INTRODUCTION

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 that the Danish parliament has decided to underground most of the Danish transmission system within the coming 25 years. This 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 subsystems 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 based approach, founded 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.

AMPACITY AND DYNAMIC LINE RATING OF HIGH VOLTAGE CABLES

In order to give a picture of load affected reliability in cable based transmission grids, this section will briefly describe the ideas behind ampacity calculations and how to perform dynamic ampacity calculations which can be utilised for reliability studies.

Traditionally TSOs have dimensioned their high voltage cables as if they were to carry the maximum possible load for the entire lifetime of the component, and the most popular tool for calculating the steady state ampacity has been described in the the IEC standard series 60287, [1]. The varying nature of the load on most transmission lines, and the thermal inertia in the cables and surroundings, though means that the maximum operating temperature normally will not be reached during normal operation. Different research studies has therefore attempted to develop methods for utilising the thermal inertia actively in daily operation of the transmission cables. E.g. the IEC standard series 60853, [2], gives a suggestion to evaluating the dynamic loadability, however the present study utilises the method discussed in [3].

As described in [4] it may be beneficial to operate the transmission system based on the Electrothermal Coordination (ETC) concept, where the current limitations of the individual lines are changed dynamically (in the present study the current which the cable can carry for 40 hours is utilised). By using the dynamically changing 40 hours loadability as the operational limit instead of the steady state loadability, the operator will not experience any changes in the daily work. Furthermore, by utilising the 40 hours loadability it will be possible to buy regulating services on the day-ahead market instead of the intra-day market, which will decrease operational costs, [4].

Besides the economic benefits of operating the transmission system based on ETC instead of the current (steady state loadability), also the security of power supply may increase, as discussed in the following.

DEFINITION AND EVALUATION OF TRANSMISSION SYSTEM RELIABILITY

System reliability can be measured and evaluated in many different ways. In order to limit the scope of this paper it is described how it is chosen to focus on one reliability measure (reliability index) and it is shown how the reliability can be predicted based on simulations.

Reliability Indexes

Early in the analysis it was chosen to utilise a reliability measure which is already used in the evaluation of the reliability of modern transmission systems. A lot of literature describes different reliability indexes, where the most dominating are summarised in e.g. [5] and [6], and listed in the following.