Electrothermal Coordination in Cable Based Transmission Grids, Operated under Market Based Conditions

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ABSTRACT

Electrothermal coordination (ETC) is a fairly novel concept, where the temperature of all cables in the transmission grid is monitored in real time and can be predicted on the basis of measured and predicted load conditions. Until now ETC has been of mainly academic interest, but this paper describes how ETC can be implemented in transmission systems as they look today, taking into account both political decisions and market based conditions. The description of implementation strategies is supplemented by studying real cases from the Danish cable based transmission system, and it is shown that great operational benefits can be achieved.

INTRODUCTION

This paper shortly describes Electrothermal Coordination (ETC) and addresses then issues that must be considered when implementing ETC in transmission systems, which are operated under market based conditions. As described in [1], ETC is a concept which enables the Transmission System Operator (TSO) to utilise the varying loadability of transmission systems in a way that combines dynamic thermal studies with knowledge about the flow of electric power.

Because the Danish transmission system operation is subjected to market based conditions, the fundamental Optimal Power Flow (OPF) concept, which optimises parameters such as transmission losses and/or total costs, cannot be applied.

The reason is that the market dictates all stakeholders to be provided with equal access to the grid no matter where they are located and it is the responsibility of the TSO to transport the energy from the sites of generation to the sites of consumption. Costs related to transporting the energy are not considered, when deciding which units are allowed to provide the grid with power, as only the price of the energy itself is included in this decision.

In [2] the authors showed how it is theoretically possible to implement ETC in cable based transmission systems, including the thermal calculations and the necessary load flow simulations. This paper builds another layer to the methodology and shows that ETC is not only of academic interest, but that TSOs can benefit directly by implementation of it.

It should be noted that [2] is solely concerned with real-time operation of transmission systems as it focusses on how ETC can be beneficial during contingencies. This paper will therefore mainly be concerned with investigating how ETC can contribute to day-ahead planning and grid expansion planning of transmission systems. This will show that ETC can benefit several areas of expertise within the TSO and on time scales ranging from minutes to years.

In order to verify the methodology, this paper will use the Danish transmission system, owned by the Danish TSO Energinet.dk, as an example. Actual cases are analysed with ETC in order to increase validity and ensure that the method can be implemented in real operational transmission systems.

Because the future Danish transmission system will consist mainly of cables, this paper has focused on modelling transmission grids with high shares of cables.

ETC OF CABLE BASED TRANSMISSION GRIDS

For the overall understanding of ETC, it is important to be familiar with the methodology of combining thermal calculations, of transmission system components, and load flow simulations. However as it was described in detail in [2] only a brief summary is given in the following.

Loadability of Power Cables

Firstly it must be acknowledged that the loadability of a power cable is limited by the maximum insulation temperature which consequently sets a limit on the conductor temperature. In addition some cable owners sets a limit on the jacket temperature in order to avoid moisture migration of the surroundings which could cause thermal runaway. In Denmark the steady state ampacity of cables is limited to be the current resulting in a jacket temperature of 50^{o}C, as moisture migration is assumed negligible below this temperature.

During contingencies in the Danish transmission system, the current in cables is presently allowed to increase to 200% of the steady state loadability as it is assumed that short durations of high temperatures will not jeopardise cable integrity or cause significant drying of the surroundings. This ‘emergency loadability’ is allowed for up to 1 hour.

The steady state and the emergency loadability are presently only calculated during designing of the cable. In this design phase, the loadability is for safety reasons evaluated conservatively by assuming high ambient temperature, low moisture content, etc. which means that there is a potential for increasing the value of the loadability if the actual cable temperature is known.

On this background the challenge of ETC is therefore to dynamically evaluate the ampacity available under real time thermal and electrical conditions.

Dynamic Temperatures by Thermoelectric Equivalents

It was shown in [3]-[4] that Thermoelectric Equivalents (TEE) are suitable for modelling of the dynamic