Study of the Monitoring Systems for Dynamic Line Rating

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Abstract

Power system components usually have standard static ratings that determine the load constraints. Load constraints are designed for extreme conditions and are one of the reasons, why power systems do not use all of their potential transmission capacity. In the 21st century, efficiency and the cost of energy production and distribution have become a very popular topic, because the energy production and its transmission cost has a direct influence on sustainability. Dynamic Rating is a smart grid application, which allows using more of the system capacity by monitoring system conditions. This paper presents a literature review on the topic of Dynamic Rating. We focus on Dynamic Rating of overhead lines. Overhead lines are of great interest for Dynamic Rating applications, because of their high cost and high potential for further improvement. Different tools for analysis of real time data and ways of application of Dynamic Rating to the power system are taken into consideration.

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Keywords: Dynamic rating; overhead line monitoring; ampacity

1. Introduction

The term Dynamic Rating needs more detailed explanation. In this paper we define Dynamic Rating as the technique that allows increasing (decreasing) the capacity of the power system component, without violation of the safety margins. Dynamic Rating uses data about physical and electrical properties of power system components to improve power system transmission capability [1] [2]. Dynamic Rating can be used when connecting power plants with variable production capacity to the grid, such as solar power stations, wind farms, tidal or wave power plants [1] [2] [3].

A brief illustration of Dynamic Rating applications profitability could be done considering the example of a wind farm production. Usually, power lines connected to wind power plants are operated under static...
ratings. Static ratings are chosen for the power capacities close to the worst case scenarios. However, wind speeds are usually not constant and power production rarely reaches the maximum rate that it is designed for. In this case Dynamic Rating can be implemented to facilitate line transmission capability in order to be able to transfer more energy. This effect can be obtained, because there is direct dependence between wind speed and cooling of the overhead line [2].

Together with the influence from power fluctuations in the system, it is also interesting to investigate the correlation between wind speed, wind direction, wind power production and cooling of power transmission components such as overhead lines and power transformers. Moreover, the effectiveness of the Dynamic Rating application depends on the tools used to monitor the system conditions, and the accuracy of real time measurements [2]. Electric power customers demand constant, sustainable power supply. The popularity of intermittent energy sources and the increasing power consumption require researchers to come up with new solutions to increase transmission capacity and improve power quality. Power systems are usually designed for extreme conditions and have standardized steady-state ratings. This factor allows to increase transmission capacity by the monitoring of environmental and operating conditions, which can increase transmission capabilities, fulfilling safety requirements [3] [4].

2. Dynamic Rating of the Overhead Lines

The dynamic rating of overhead lines is usually referred to as the Dynamic Line Rating. The correct application of the Dynamic Line Rating requires the calculation of the heat balance of the conductor. There are different ways to calculate the heat balance, presented in the literature [5] [6] [7]. According to the IEEE Standard for calculating the current-temperature relationship of bare overhead conductors the heat balance can be expressed as in (1) [8].

\[ P_J + P_s = P_c + P_r \]  

where \( P_J \) is the Joule heating; \( P_s \) is the solar heating; \( P_c \) is the convective cooling and \( P_r \) is the radiative cooling.

According to the CIGRE standard, heat balance equation for the overhead conductor is extended with the magnetic heating \( P_M \) the corona heating \( P_l \) and the evaporative cooling \( P_w \) [5] [9]. The heat balance equation according to CIGRE is shown in (2).

\[ P_J + P_M + P_s + P_l = P_c + P_r + P_w \]  

The comparison of these two methods for the heat balance calculation is presented in [5]. The maximum allowed conductor current can be calculated using (3), which is proposed in [1] [10] [11] [12].

\[ I^2R_{TC} + q_s = q_r + q_c \]  

where \( I \) is the current in the conductor; \( R_{TC} \) is the conductor resistance at the temperature \( T_C \); \( q_s \) is the solar heating; \( q_r \) is the radiative cooling; \( q_c \) is the heat loss due to forced convection.

In other sources equation for the current allowed in the conductor is expressed with heat losses from radiation and wind flow [11].

\[ I = \sqrt{\frac{h_w + (h_r - (\omega_2/\pi \theta) n) \pi D \theta}{R_{ac}}} \]  

where \( h_w \) is the heat dissipated due to wind velocity; \( h_r \) is the heat dissipated due to radiation.

In equation (3) an element of a great interest is the heat loss due to forced convection \( q_c \). The forced convection is highly dependent on the wind speed and wind direction. At low wind speeds (5) should be used, however, equation (5) is not applicable for high wind speeds. Equation (6) should be used, for calculation of heat balance at high wind speeds [2] [8] [13]. However, there is no clear definition between
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