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Real time impact of voltage variation on variable frequency transformer during asynchronous power transfer

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Abstract

Nowadays, Variable Frequency Transformer (VFT) has gained significant interest for regulating power transfer between two asynchronous networks. VFT is a controllable, bidirectional transmission device which integrates the principles of both rotatory transformer and phase shifting transformer, in order to regulate the power flow between two power grids. The research studies indicate that, the operation of VFT has previously only been studied under constant voltage conditions. Keeping this gap in view, this paper provides a detailed analysis of power transfer through VFT operating under variable voltage conditions. The two asynchronous grids, one operating at a frequency of 60 Hz and the other one operating at 50 Hz, are connected to the stator and rotor of the VFT, respectively. The power flow is initially examined for constant voltage and variable torque conditions. The results demonstrate that the power flow between the two asynchronous grids varies linearly with the applied torque and reverses as the torque direction is reversed. The developed system was then modified to account for voltage variation. In order to analyse the impact of voltage variation on power flow through VFT, both the rotor and stator side of VFT are subjected to varying voltages. The results show that when the voltage on one side of the VFT is reduced, power flow towards that side increases while power flow towards the other side decreases. This indicates that the power flow through VFT can be effectively controlled by controlling both torque and the voltage on the rotor and stator side of VFT. Further, the simulation results achieved are validated through a real-time hardware in loop (HIL) implementation using Typhoon HIL emulator.

1. Introduction

Grid interconnection has become a viable option to suffice the growing energy demands, this reduces the fuel costs while improving the efficiency, dependability and protection. Majority of the power grids around the world operate at a frequency of either 50 or 60 Hz. Conventionally, a high voltage direct current (HVDC) system is used for the interconnection of two independent grids operating at different frequencies. Various HVDC topologies such as HVDC light [1], current source converter (CSC) based HVDC [2], voltage source converter (VSC) based HVDC [3], multi-link HVDC system [4] and modular multilevel (MMC) based HVDC [5] are present in the literature. However, the use of costly converters, huge reactive power requirement and generation of harmonics, limits the use of HVDC system. Virtual synchronous machine (VSM) serves as another alternative for implementing asynchronous grid interconnection, but it suffers from the fundamental drawback of generating low frequency oscillations [6].

In the recent times, a new device namely variable frequency transformer (VFT) has consistently demonstrated itself to be an effective solution for grid interconnection. The first 100 MW VFT unit was installed and commissioned in Hydro-Quebec's Langlois 315/120 kV substation, to achieve the interconnection between New York (USA) and Quebec (Canada) power grids [7]. The electromagnetic design, dynamic and transient