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Asynchronous Grid Power Transfer Using VFT

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***Abstract:** Variable frequency transformer (VFT), introduced recently is a flexible asynchronous ac link which is used in power transferal process between asynchronous power system grids. VFT was first installed at Langlois substation, which interconnects the Hydro-Québec (Canada) and New York (USA) systems. The torque of the rotary transformer is externally altered in order to control the direction and magnitude of power transfer. MATLAB Simulink model of VFT is designed, which is used to indicate power transmission between two asynchronous grids and also to control the power flow direction. MATLAB Simulink model of VFT along with its control system is developed and the result has been studied thoroughly. Simulation results for different torque and frequency conditions have been discussed. Moving further, power transfer and torque graphical representations are also obtained and results are compared. Thus, the working concept of VFT and its power flow conditions are verified by MATLAB simulation results.*

***Keywords:** Asynchronous Interconnection, Flexible Asynchronous Ac Link, Matlab Simulink, Variable Frequency Transformer, Wound Rotor Induction Machine.*

I. INTRODUCTION

Nowadays, power system networks are totally interconnected associating interconnections between inter-city, inter-state, and even inter-country [1]. It is useful in reducing cost and increases the reliability of the system. Apart from power transfer, the motive of interconnection in power system is to feed load centers and pool power plants that result in minimum fuel cost and capacity of generation. Basically, interconnection can be done in two ways: One way is to connect directly to synchronous AC transmission lines and the other way is to install a device between two asynchronous grids. Synchronous grid interconnection is easy and cost effective but the difficulty level of power system operation increases and under faulty condition stability decreases. Due to this demerit of AC interconnection led to the development of Back-to-Back HVDC (High Voltage Direct Current) [2]. At present Asynchronous grids are connected via HVDC. These systems are economical for bulk transmission of power for long distances but since it uses power electronic devices, harmonics are generated. Also, the converter and inverter used in HVDC plants are expensive. The technology which has been recently developed is called as VFT (Variable Frequency Transformer) [2] which provides an alternate option for interconnection in between asynchronous grids.

II. FUNDAMENTALS AND CONCEPT OF VFT

A VFT is a bidirectional power transmission device. Power transmission between two non-synchronous grids is thus made possible by the use of VFT. The physical geometry of VFT is same as that of a 3-phase Induction Motor but the only difference is, here we give 3-phase supply to the rotor also. So the two grids in which power transfer should take place is connected accordingly- one to the stator side and the other grid is connected to the rotor of VFT. Transfer of power takes place between the

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two grids which are electrically isolated and the power transfer is due to the phenomena of magnetic coupling through the air gap of the VFT.

VFT can be used at different phase angles during operation thus it is also called as a phase angle regulating transformer. Following are the main components of VFT: a bidirectional rotary transformer for power transfer action, a driver motor which is able to control the rotor movement or the rotor speed and also controls the power exchange. The relative position between rotor and stator is controlled through drive motor by applying torque to the rotary transformer. Hence, direction and amount of power flow can be controlled through the VFT.VFT was first commissioned and installed in Hydro-Quebec's Langlois substation. The manufacturer of that VFT was GE (General Electric). The plant has a capacity to transfer 100MW of power between New York (USA) and Quebec (Canada) [1].

Power transfer between two grids which are not in synchronism is facilitated by governing the torque and speed fed to the rotor, which is externally varied by the driver motor. When two grids are in synchronism, the rotor of the VFT aligns itself in the position in which the voltages of rotor and stator remain in phase. Transfer of power from one grid to another is carried out by the rotation of the rotor of VFT. The direction of torque decides the direction of power flow. The transfer of power takes place from rotor side to stator side if the torque is applied in a particular direction (say clockwise). The transfer of power is from stator side to rotor side if torque is applied in the opposite direction (anticlockwise) [4]. The magnitude of power flow depends on the applied torque and its value varies in proportion to the applied torque. The direction of power flow is also proportional to the torque applied [3]. The design of the driver motor is done in such a way that, even when the rotor of VFT is a standstill, it continues to produce the torque without any interruption. When grid loses its synchronism, the rotor of the rotary transformer will rotate continuously at a speed proportional to the difference in magnitudes of frequencies between both the connected power grids. The continuous power flow is maintained during whole operation irrespective of the frequency difference of the grids in operation. The VFT has the ability to transfer power without any interruption with changing frequency of grids [5]. Even in the case of asynchronous power flow, the rotor adjusts itself to track the difference in phase angle inflicted by the two grids which are non-synchronous.

III.MATLAB SIMULATION

A. *MATLAB Simulink Model*

In MATLAB, VFT is shown as WRIM, which is double fed and simulated in Simulink software. Both the power systems are voltage source of three phases, as shown in Fig.The stator of the VFT is connected to Grid 1 of supply whereas the rotor of VFT is connected to Grid 2 of supply.

The simulation of VFT is done by manually entering various values of torque T_d and various sets of graphical output are obtained accordingly (as shown below).

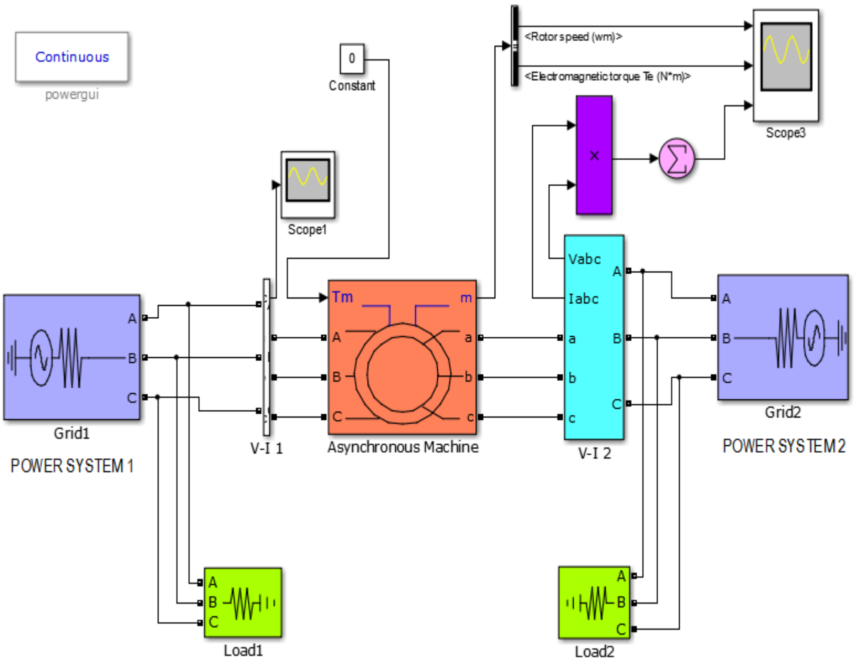

Fig. MATLAB Simulation model of VFT

B. *Explanation of MATLAB Outputs*

The various blocks in the MATLAB model were individually designed and integrated for simulation process. In the first five graphical outputs shown below (Fig1-Fig5), the value of frequency was kept constant at 50Hz and a different value of torque T_d was manually entered. Thus direction and magnitude of power flow between the two grids were observed.

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C. *MATLAB Simulation Results*

a) For T_d=0Nm. Fig. 1 shows the relevant waveforms.

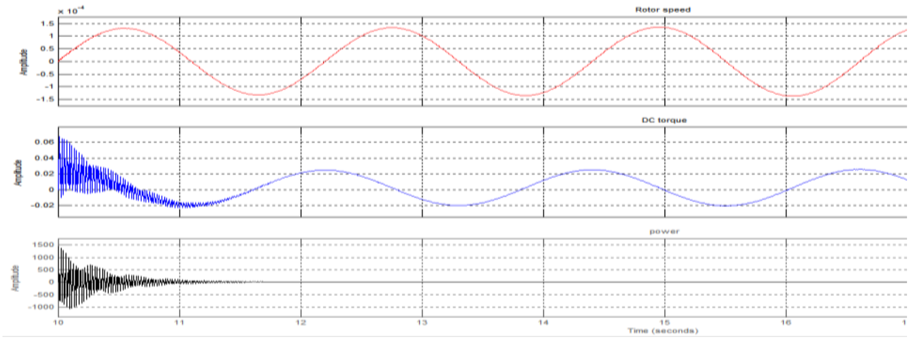

Fig. 1. DC torque & Power waveforms of VFT

For Td=10Nm. Fig. 2 shows the relevant waveforms

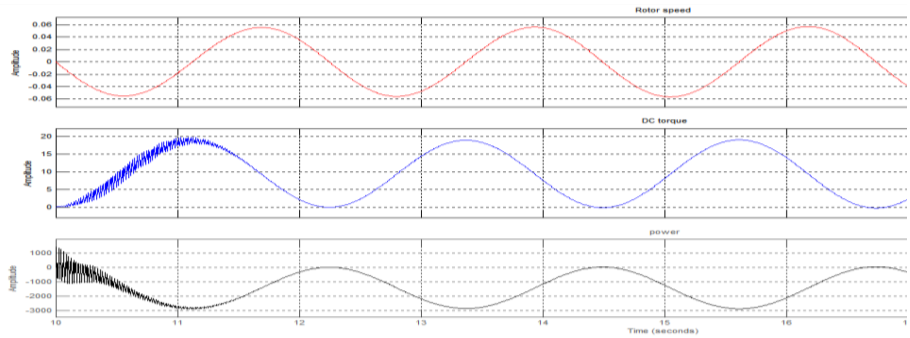

Fig. 2. DC torque & Power waveforms of VFT

c) For Td=-10Nm.Fig. 3 shows the relevant waveforms

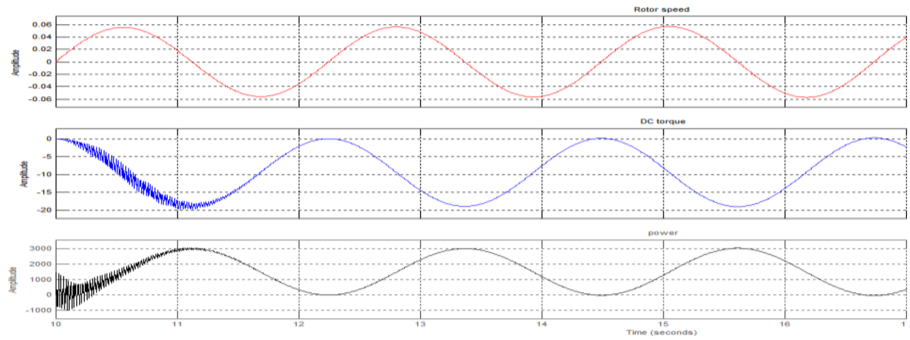

Fig. 3. DC torque & Power waveforms of VFT

d) For Td=20Nm. Fig. 4 shows the relevant waveforms.

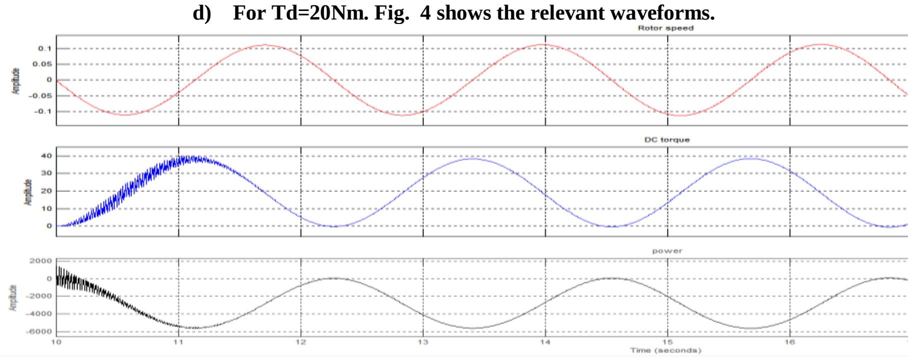

Fig. 4. DC torque & Power waveforms of VFT

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e) For Td=-20Nm.Fig. 5 shows the relevant waveforms.

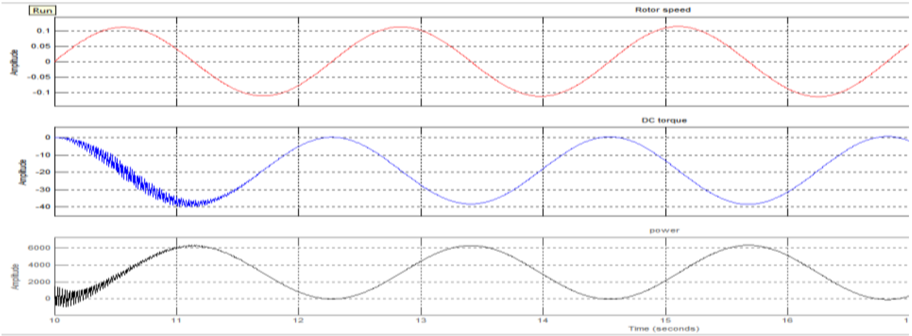

Fig. 5. DC torque & Power waveforms of VFT

CONCLUSIONS

From the above simulated results, it is perceptible that the external torque given to the rotor of VFT is directly proportional to the power flow. Besides, by varying the value of torque applied, the direction of the power flow through the asynchronous grids as well as the magnitude of power flow are both controllable. So VFT is a feasible technology for attaining transfer control of real power between two or more asynchronous grids. The MATLAB model of VFT simulated is used to demonstrate the power flow through asynchronous power grids. The rotor speed, DC torque waveforms are also obtained. Thus, simulation results verified the fundamentals and advantages of VFT. It has different advantages over FACTS devices and HVDC technologies as it does not produce harmonics and it is also cost effective.

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