Power Flow Control of Wound Rotor Induction Motor based Variable Frequency Transformer (VFT)

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Introduction

VFT is a new alternative power transmission device, where the power flow through the VFT is controllable and bidirectional. The core components of the VFT are a rotary transformer, a drive motor, and a collector.

In this project, the mathematical model of VFT is built in MATLAB/Simulink, a drive motor controller, which can be used to maintain the power flow, VFT phase angle and mechanical speed during system disturbance, is designed to provide a load torque to the VFT. The VFT with proposed controller is simulated in MATLAB/Simulink and different disturbance are added to test the drive motor controller performance.

Model Description

VFT Power Flow

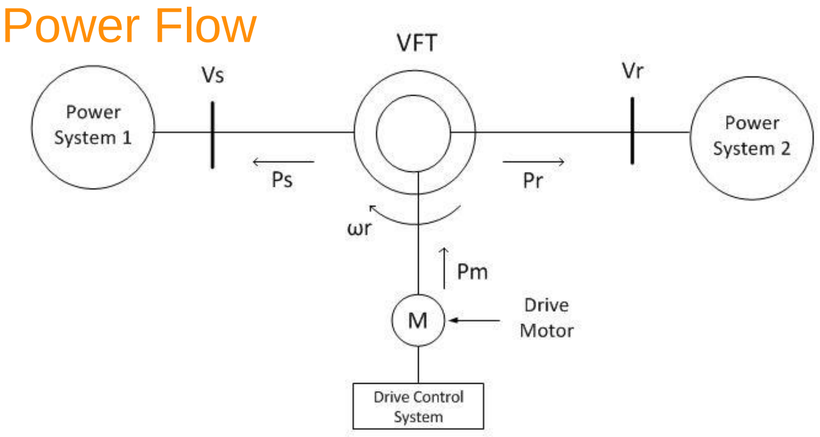

Figure 1: VFT Power Flow [1]

- The power flow relationship of the VFT is:

$$P_s + P_r + R_s\left(i_{qs}^2 + i_{ds}^2\right) + R_r\left(i_{qr}^2 + i_{dr}^2\right) = P_m$$

- A lossless VFT model is considered here, which results in:

$$R_s = R_r = 0 \; and \; P_s + P_r = P_m$$

Basic Equations

$$P_{VFT} = \frac{V_s V_r}{X_s + X_r} sin\theta_{net}$$ For stage 1: Power Control

$$\theta_{r,act} = \int \omega_{rm}\, dt$$ For stage 2: Phase angle control

$$\frac{d\omega_{rm}}{dt} = \frac{1}{2H}\left(T_l - T_e\right)$$ For stage 3: Speed control

$$f_{rm} = f_s - f_r$$ For calculating rotor mechanical speed based on stator or rotor frequency change

VFT Drive Control System Controllers

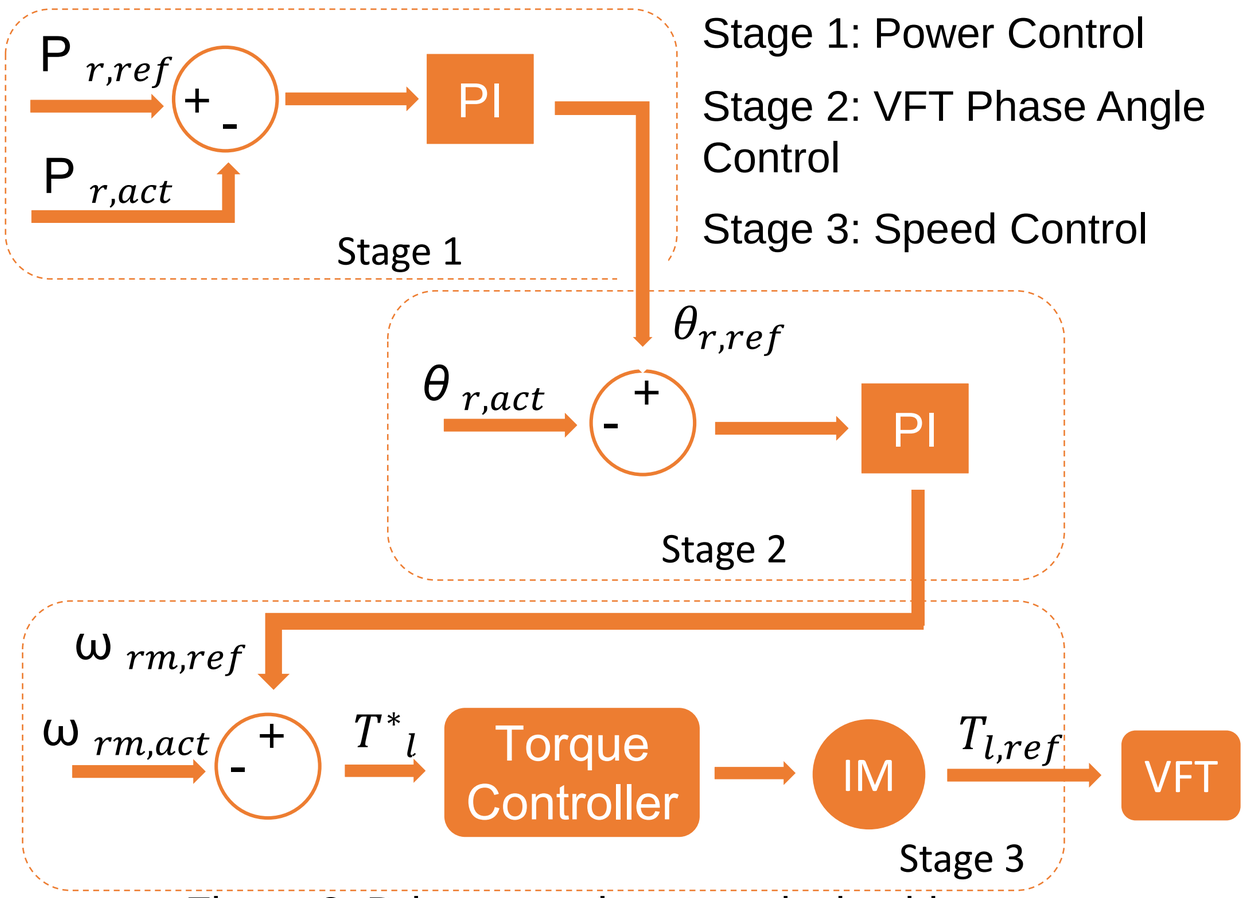

Figure 2: Drive control system design idea

Table 1: Stator and rotor side electrical frequency initialisation

f_s	f_r	ω_r
50	50	0
60	50	0.1667
50	60	-0.2

Results and Discussion

Voltage Disturbance

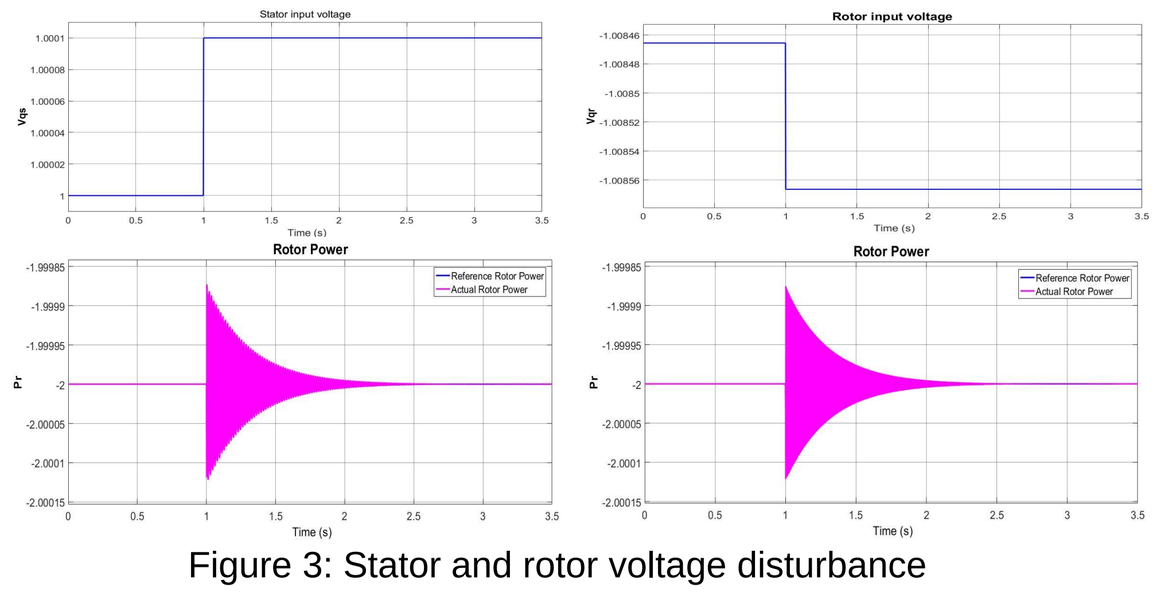

Figure 3: Stator and rotor voltage disturbance

Frequency Disturbance

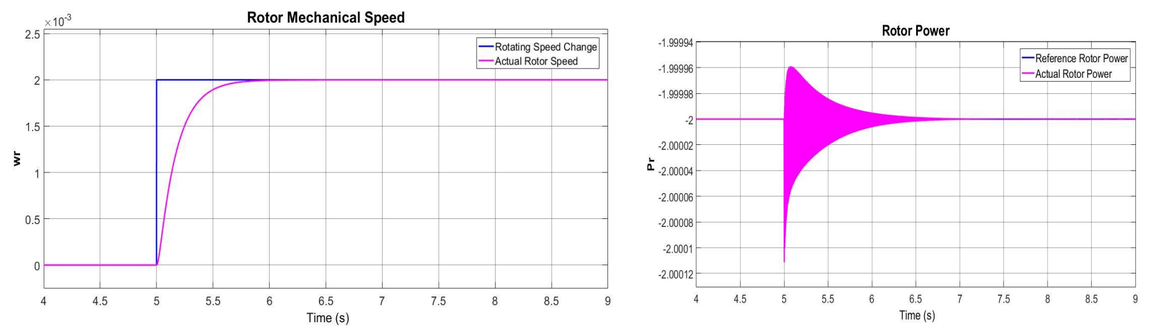

Figure 4: Frequency disturbance under synchronous power systems

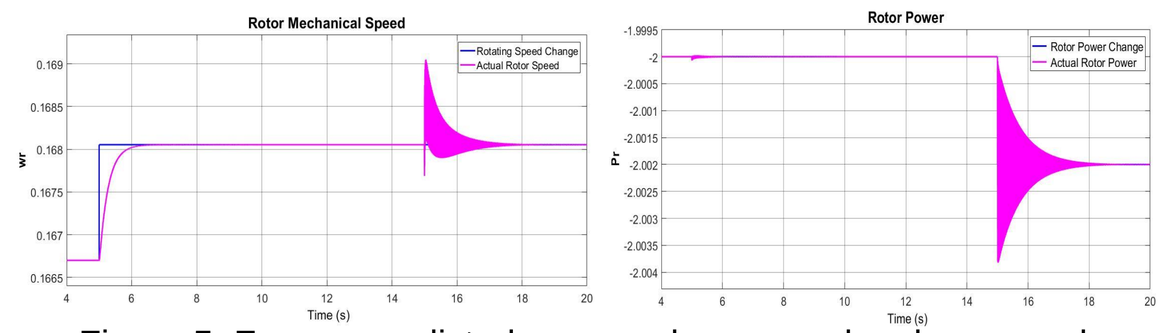

Figure 5: Frequency disturbance and power order change under asynchronous power systems

Phase Angle Disturbance

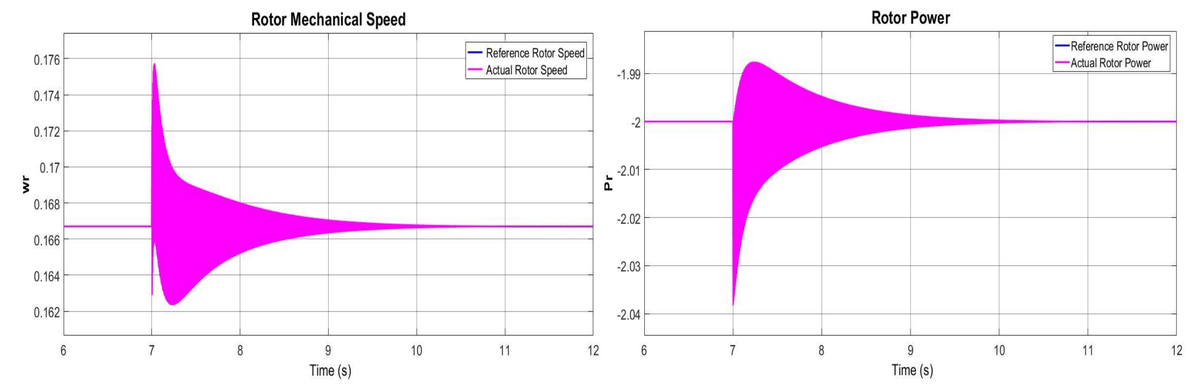

Figure 6: VFT phase angle disturbance under asynchronous power systems

- According to figure 3, 4 and 6, rotor mechanical speed and rotor power can be controlled and maintained to their respective initial operating points under voltage, frequency and phase angle disturbance for both synchronous and asynchronous power systems.
- Figure 5 shows that a new reference power order can be achieved during its operation.

Conclusion

In conclusion, a VFT model was built in MATLAB/Simulink. The drive control system controllers were designed and applied to the VFT to maintain a reference rotor power, speed and VFT phase angle. The performance of the VFT with proposed controller under system disturbance were applied and it showed the VFT system is stable under multiple system disturbance. This kind of VFT drive control system can make the VFT more reliable and applicable for bidirectional power flow between different future power networks.

Reference

[1] F. I. Bakhsh and D. K. Khatod, "Variable frequency transformer - state of the art review," in *2013 International Conference on Energy Efficient Technologies for Sustainability (ICEETS)*, 2013, pp. 1012-17.