Virtual Synchronous Machine Control for Wind Turbines: A Review

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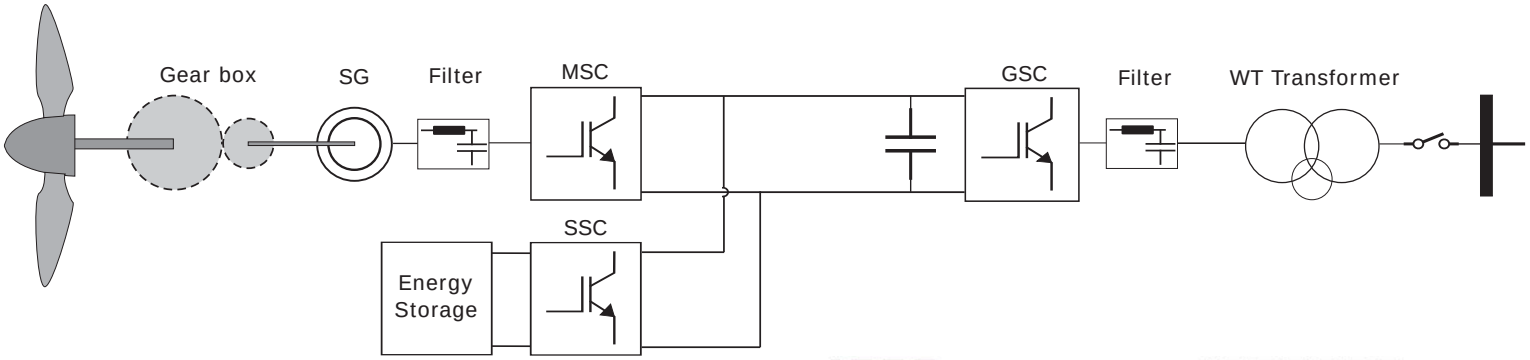
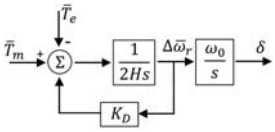
1 VSM Control Schemes for WTs



Swing equations

$$\frac{d\Delta\bar{\omega}_r}{dt} = \frac{1}{2H}(\bar{T}_m - \bar{T}_e - K_D\Delta\bar{\omega}_r)$$

$$\frac{d\delta}{dt} = \omega_0\Delta\bar{\omega}_r$$

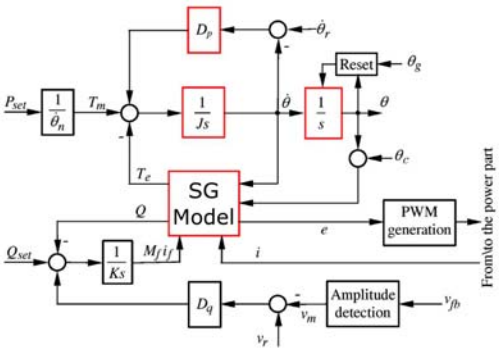


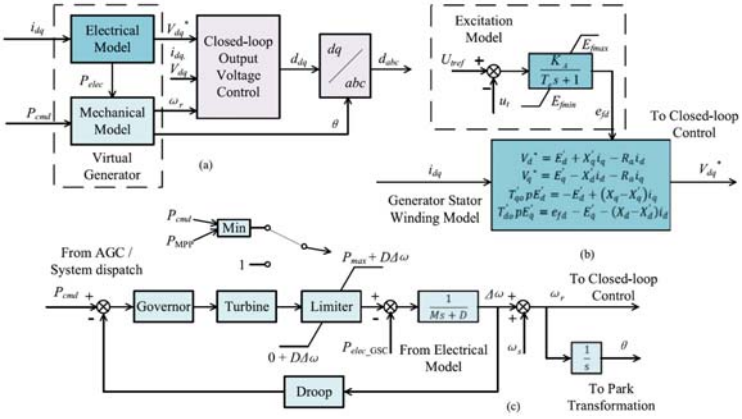
Electrical equations

$$T_e = M_f i_f\langle i, \widetilde{\sin\theta}\rangle$$

$$e = \dot{\theta}M_f i_f\widetilde{\sin\theta}$$

$$Q = -\dot{\theta}M_f i_f\langle i, \widetilde{\cos\theta}\rangle$$





Electrical equations

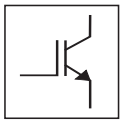
$$U_d = -x'_q I_q + E'_d$$

$$U_q = x'_d I_d + E'_q$$

$$T'_{q0}\dot{E}'_d = -E'_d - (x_q - x'_q)I_q$$

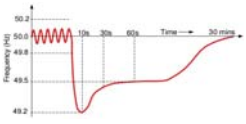
$$T'_{d0}\dot{E}'_q = E_f - E'_q + (x_d - x'_d)I_d$$

2 Further Research Work



VSM

Field tests of availability
Performance and stability comparison of different schemes
Special requirements like parameter design and tuning
Standardisation of control parameters, interface etc.
Influence on WTs in mechanical load and stress

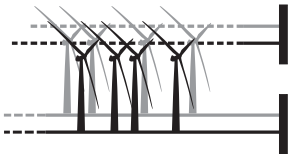


Frequency control

Frequency second drop
Performance indexes to be defined quantitatively
Assessment methods to be developed
Optimized control from a WPP

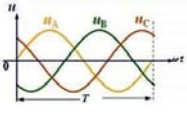
ES

Techno-economic analysis
Advantage of MPPT+frequency control
Suitability of different types
Locations, especially in WPPs
Control stategy of SoC
Optimization of capacity



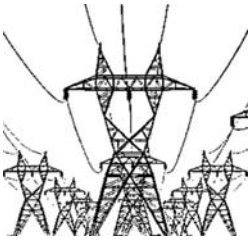
WPP application

Coordinated control & stable operation of multiple VSM-controlled WTs
Optimization of ES configuration and layout



Voltage control

Well-founded verifications
Availability in different grid conditions
Fault ride-through capability



Grid conditions

Voltage sags
Unbalanced voltages
Grid faults
Weak grids
Islanded systems with black start

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