Wind Turbine Control

B. Control Basics

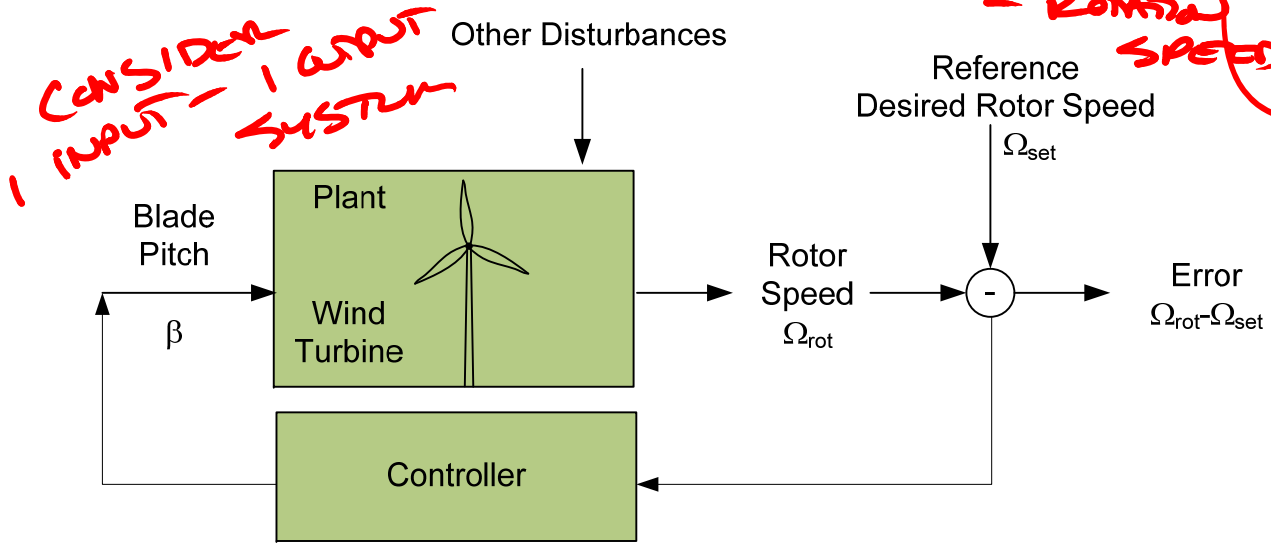
5. Wind Turbine Control

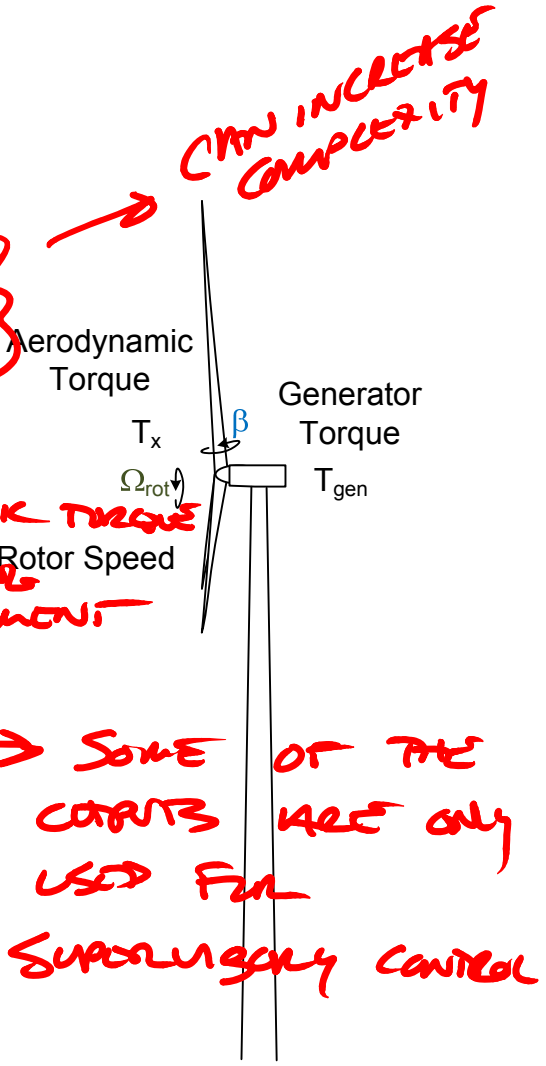
A WIND TURBINE → MULTIPLE INPUTS
→ MULTIPLE OUTPUTS
CAN INCREASE COMPLEXITY

INPUTS – BLADE PITCH ANGLE
– GENERATOR TORQUE
– YAW ANGLE

OUTPUTS –
– AERODYNAMIC TORQUE
– BLADE BENDING MOMENT
– ROTOR SPEED

CONSIDER 1 INPUT – 1 OUTPUT SYSTEM



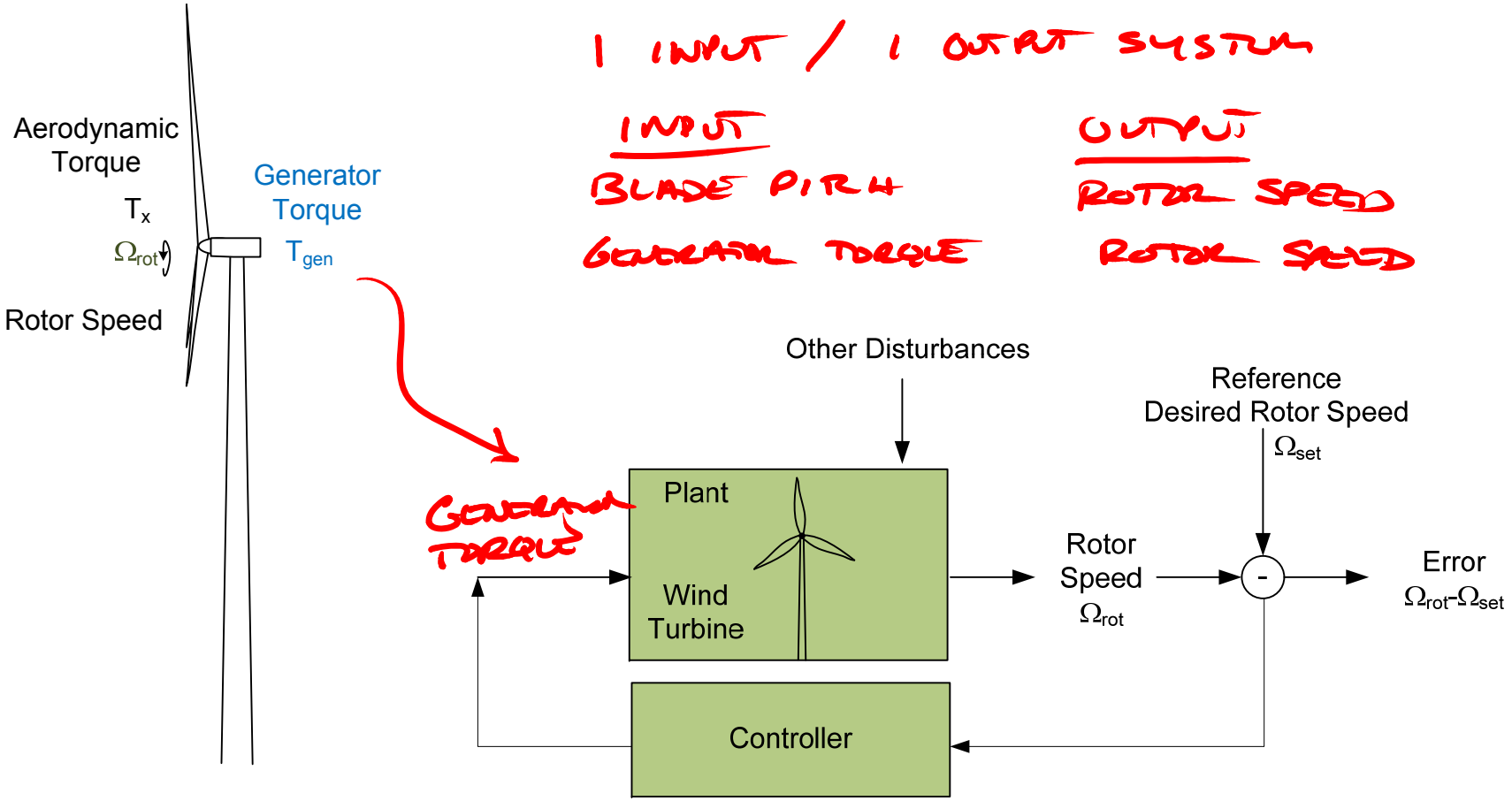


SOME OF THE OUTPUTS ARE ONLY USED FOR SUPERVISORY CONTROL

Wind Turbine Control

B. Control Basics

5. Wind Turbine Control

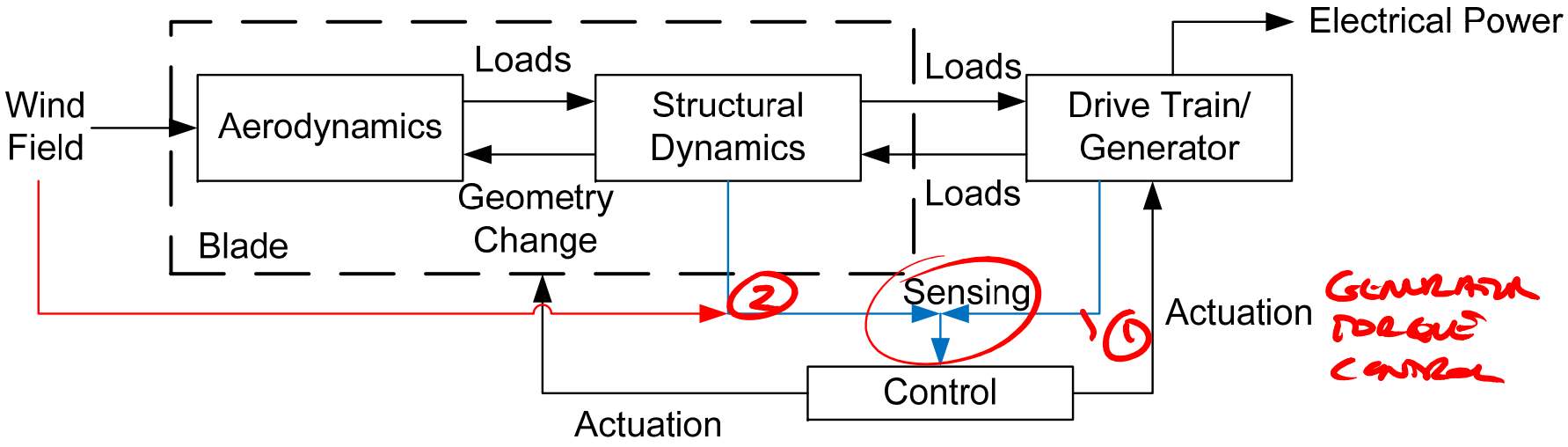


Wind Turbine Control

B. Control Basics

5. Wind Turbine Control

REAL WIND TURBINE – MUCH MORE COMPLICATED



GENERATOR TORQUE CONTROL

PITCH CONTROL

SYSTEMS INVOLVED

BLADE → AERODYNAMICS

BLADE → STRUCTURAL DYNAMICS

DRIVE TRAIN

GENERATOR

3 INFLOW VELOCITY

SENSING 1 DRIVE SHAFT TORQUE / SPEED

2 AERODYNAMIC TORQUE

BLADE ROOT BENDING MOMENTS

Wind Turbine Control

B. Control Basics

5. Wind Turbine Control

CONSIDER A SIMPLE WIND TURBINE

$X_1 = \frac{1}{3}(M_{B,1} + M_{B,2} + M_{B,3})$ BLADE FLAP

$X_2 = \frac{1}{3}(\dot{M}_{B,1} + \dot{M}_{B,2} + \dot{M}_{B,3})$ BLADE FLAP RATE

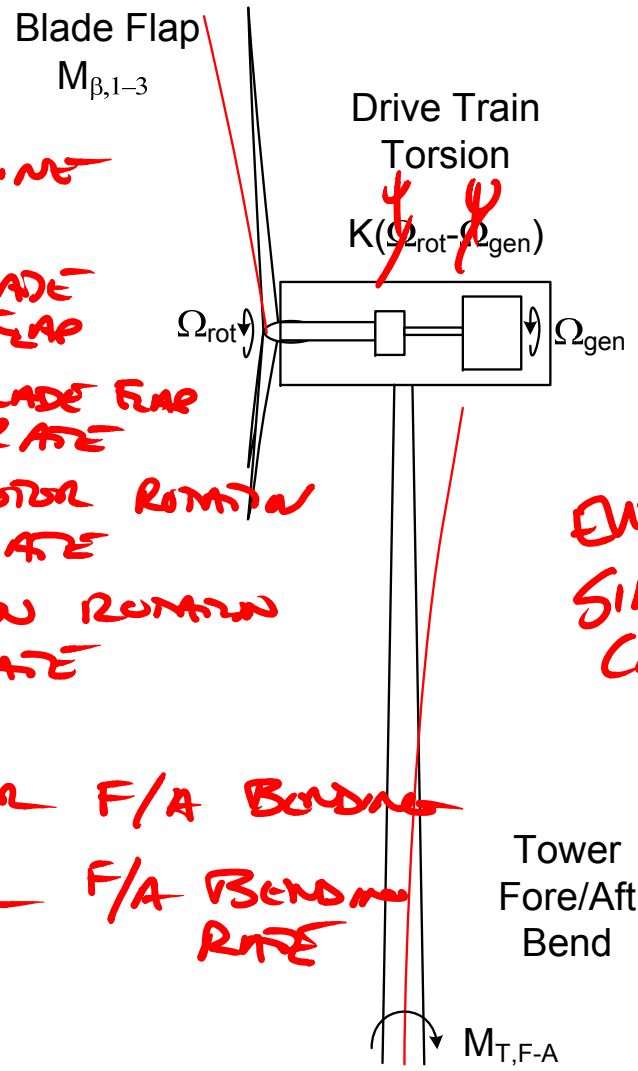
$X_3 = \Omega_{ROT}$ ROTOR ROTATION RATE

$X_4 = \Omega_{GEN}$ GEN ROTATION RATE

$X_5 = K(\psi_{ROT} - \psi_{GEN})$

$X_6 = M_{T,F-A}$ TOWER F/A BENDING

$X_7 = \dot{M}_{T,F-A}$ TOWER F/A BENDING RATE



EVEN A SIMPLE MODEL CAN BE COMPLEX

Wind Turbine Control

C. Typical Control Approaches

1. Constant speed

SOME TYPICAL IMPLEMENTATIONS

HISTORICALLY → MOST COMMON DESIGN

GENERATOR DESIGN
GEARBOX DESIGN
ROTOR DESIGN
} DETERMINE SPEED

a) Stall regulated

FAIRLY SIMPLE DESIGN
RIGID BLADES & STIFF HUB

BLADE IS DESIGNED TO CONTROL TORQUE

FIXED PITCH

OPERATE NEAR OPTIMAL λ AT LOW WIND SPEEDS

AS WIND SPEED INCREASES, α INCREASES

BLADE ROOT STALLS

STALL MOVES OUTWARD WITH INCREASING WIND SPEED

LIFT & TORQUE LIMITED

OPERATION

- DISENGAGE BRAKE
- SPIN UP TO OPERATING SPEED (WIND/GENERATOR)
- ENGAGE GENERATOR WHEN OPERATING SPEED REACHED