ME/ESE 4470
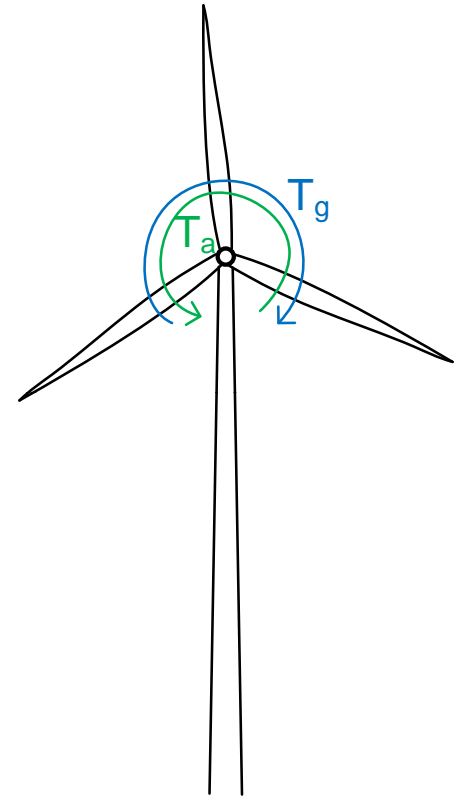# Wind and Tidal Power
Wind Turbine Control
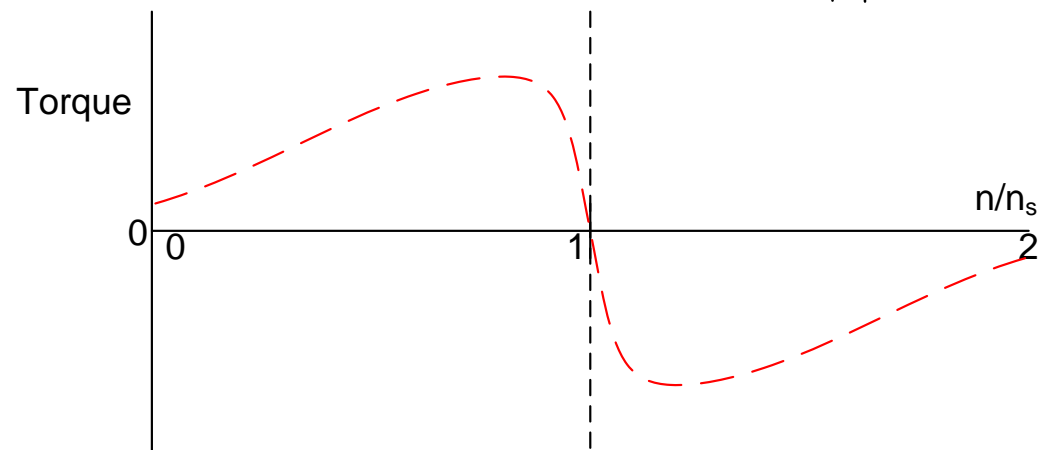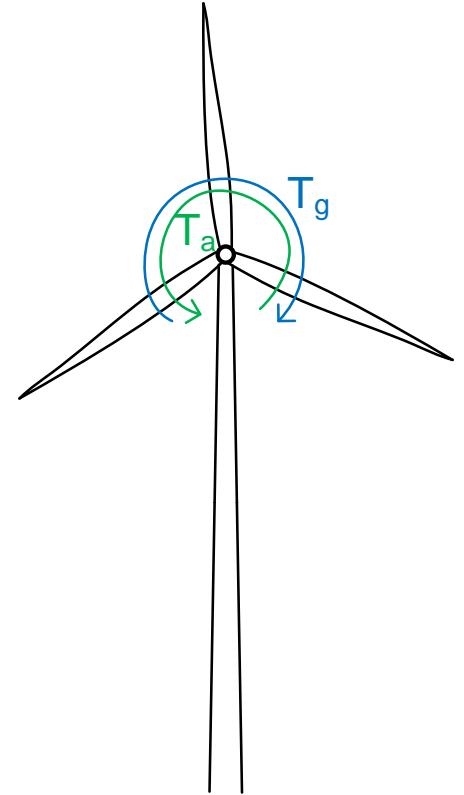
Wind Turbine Control

A. Introduction

Wind Turbine Control

A. Introduction

Torque

n/n_s

0

0   1   2

Wind Turbine Control
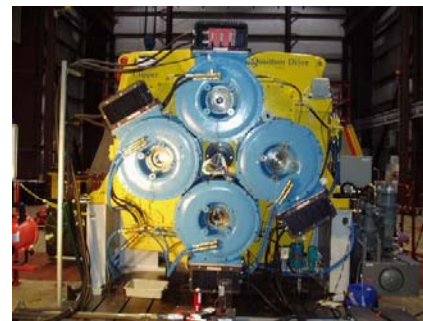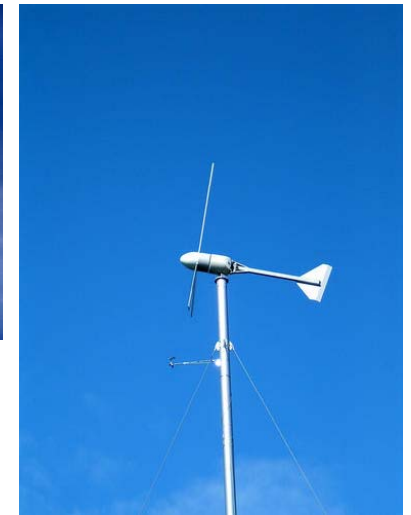
A. Introduction

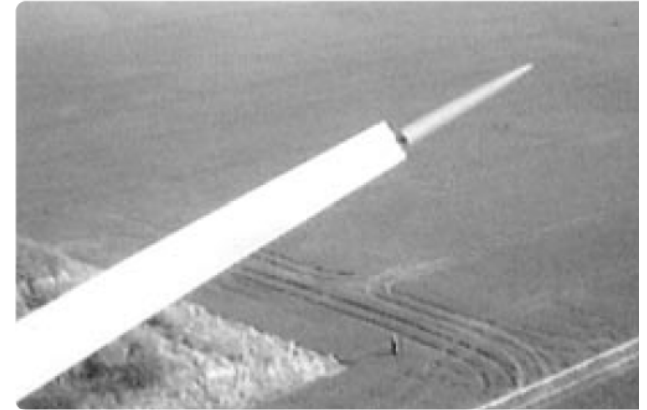   1. Means of Control

Wind Turbine Control

A. Introduction

    1. Means of Control

Wind Turbine Control

A. Introduction

    2. Control Inputs (Sensors)

Wind Turbine Control

A. Introduction

   3. Interactions between Controller and Electro-Mechanical Systems

Wind Turbine Control
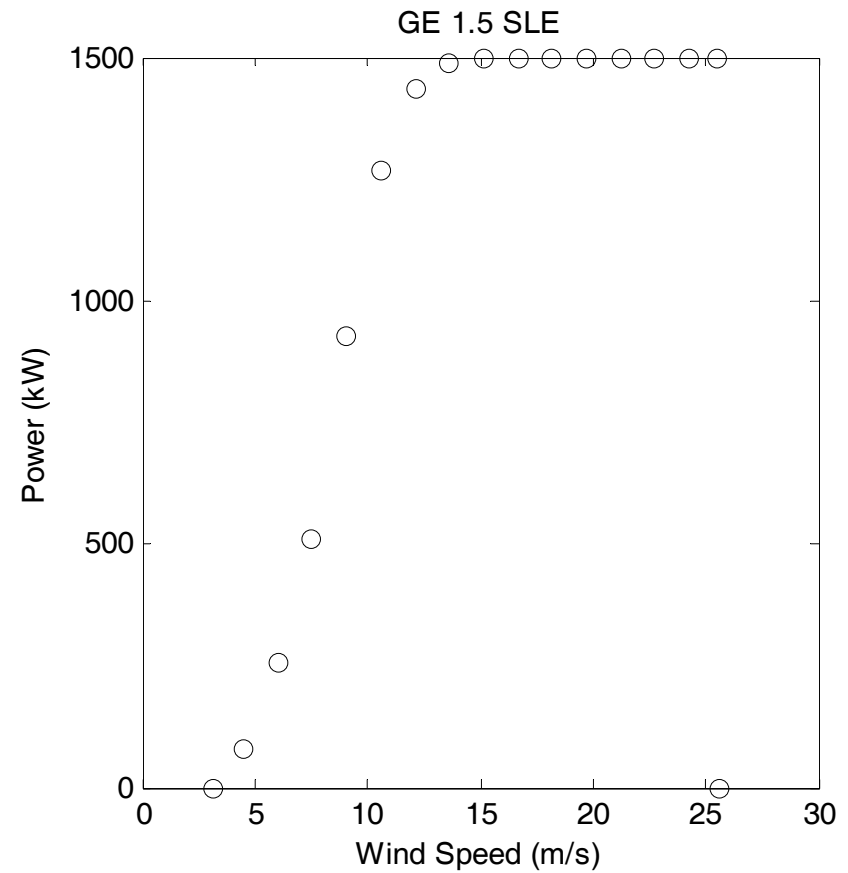
A. Introduction

   3. Different Control Purposes

      • Supervisory Control

      • Dynamic Control

Wind Turbine Control

A. Introduction

    5.   Control Regions

GE 1.5 SLE

(plot of Power (kW) vs Wind Speed (m/s) with data points)

Wind Turbine Control

B. Control Basics

   1. The System

Other Factors that Affect
the System

Disturbances

Inputs → Plant → Outputs

Produce
Changes
in System

System Needing Control

Observations
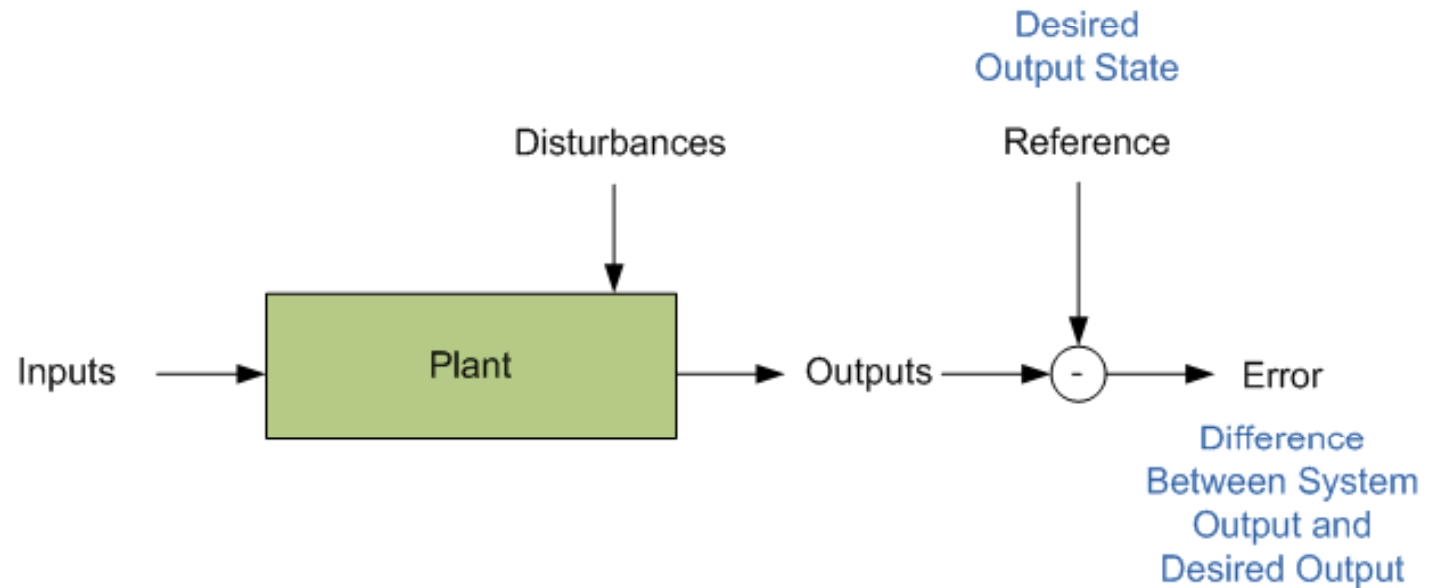of System
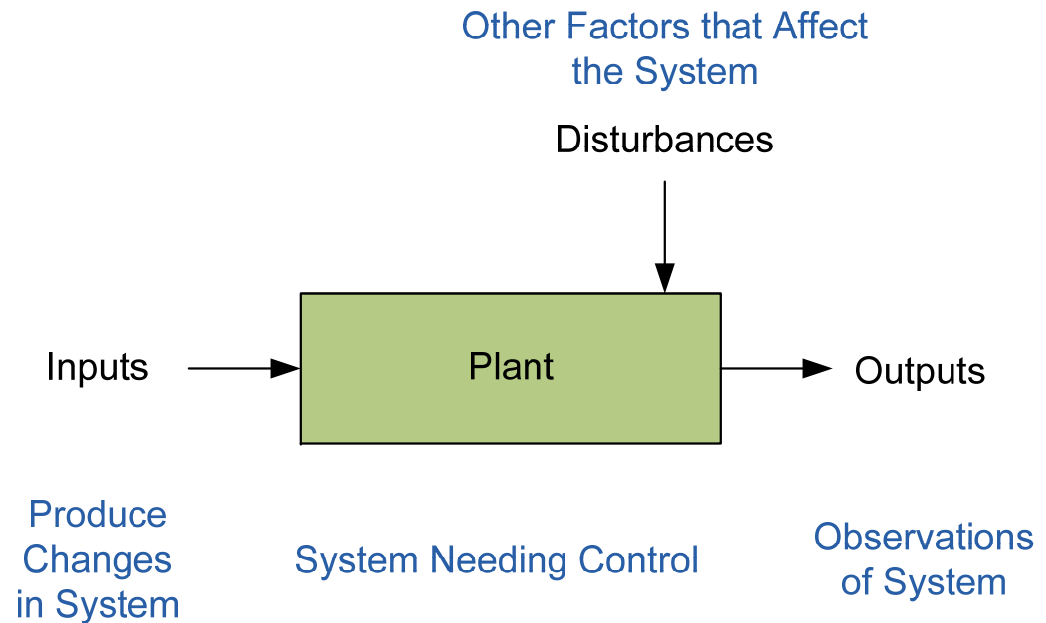
Wind Turbine Control

B. Control Basics

2. What is Control?

Wind Turbine Control

B. Control Basics

   3. Closed-Loop Control

Changes input to
System to Reduce Error
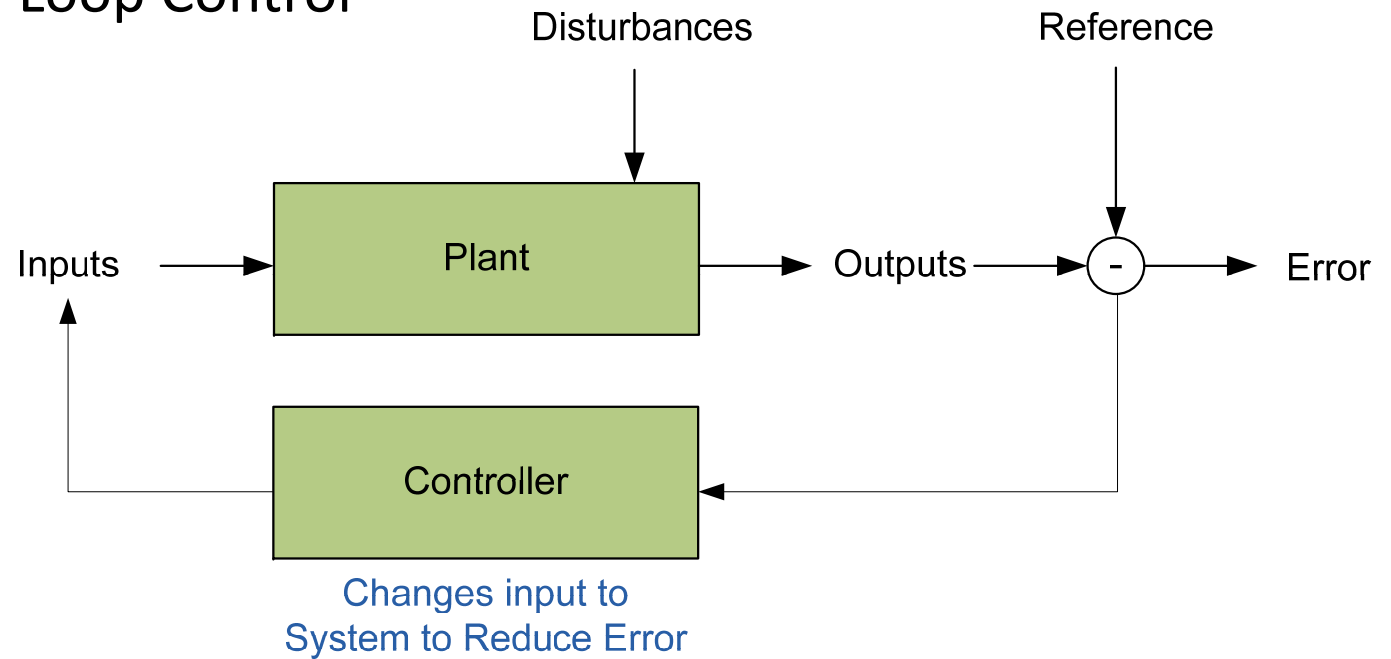
Wind Turbine Control

B.   Control Basics

4.   Example – Control of Building Temperature

Wind Turbine Control

B. Control Basics

    5. Wind Turbine Control

Aerodynamic Torque

T_x

Ω_{rot}

Rotor Speed

β

Generator Torque

T_{gen}

Other Disturbances

Reference
Desired Rotor Speed
Ω_{set}

Plant

Blade
Pitch

β

Wind
Turbine

Rotor
Speed
Ω_{rot}

Error
Ω_{rot}-Ω_{set}

-

Controller

Wind Turbine Control

B. Control Basics

    5.   Wind Turbine Control

Aerodynamic
Torque

T_x

Ω_{rot}

Rotor Speed

Generator
Torque

T_{gen}

Other Disturbances

Reference
Desired Rotor Speed

Ω_{set}

Plant

Wind
Turbine

Rotor
Speed
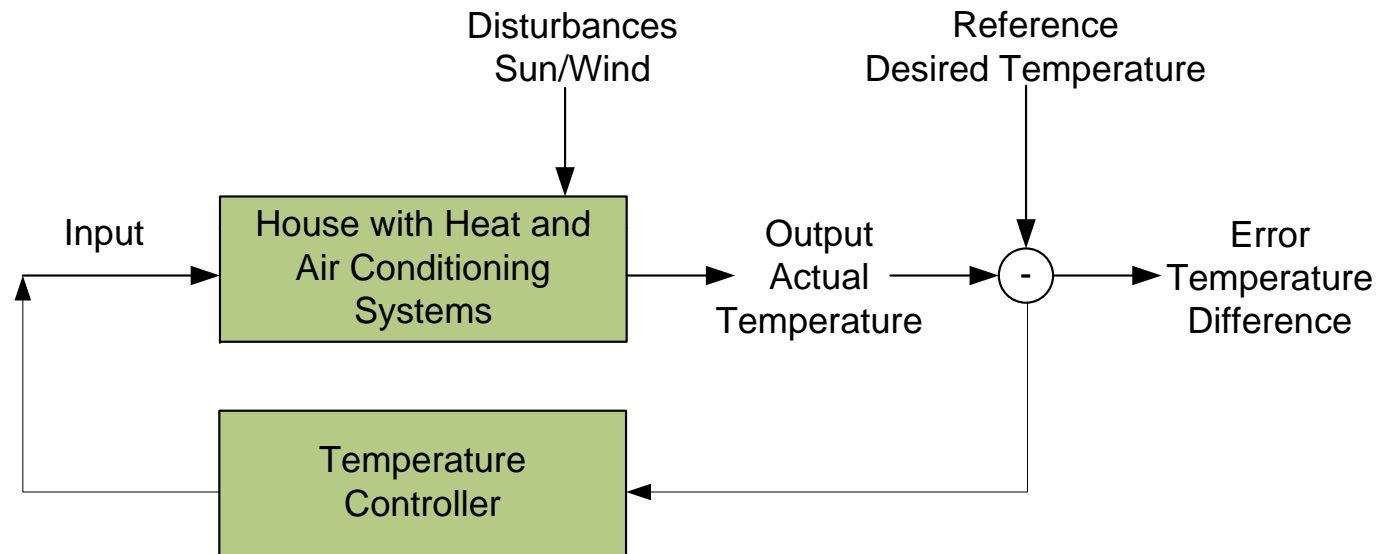Ω_{rot}

-

Error
Ω_{rot}-Ω_{set}
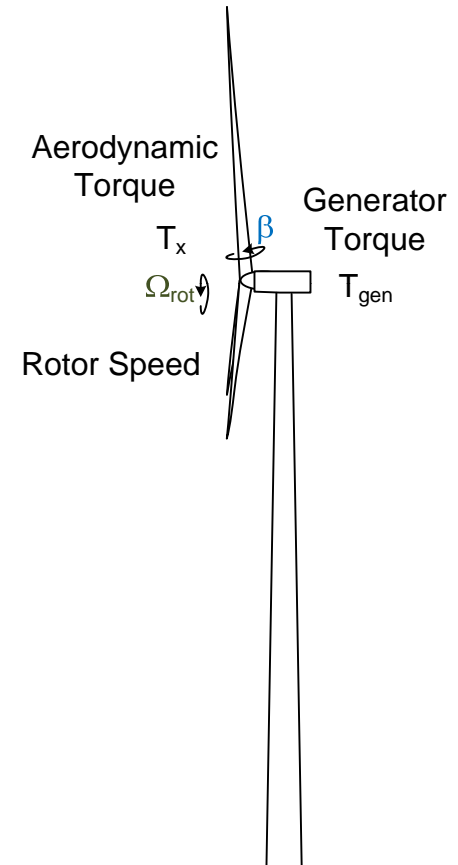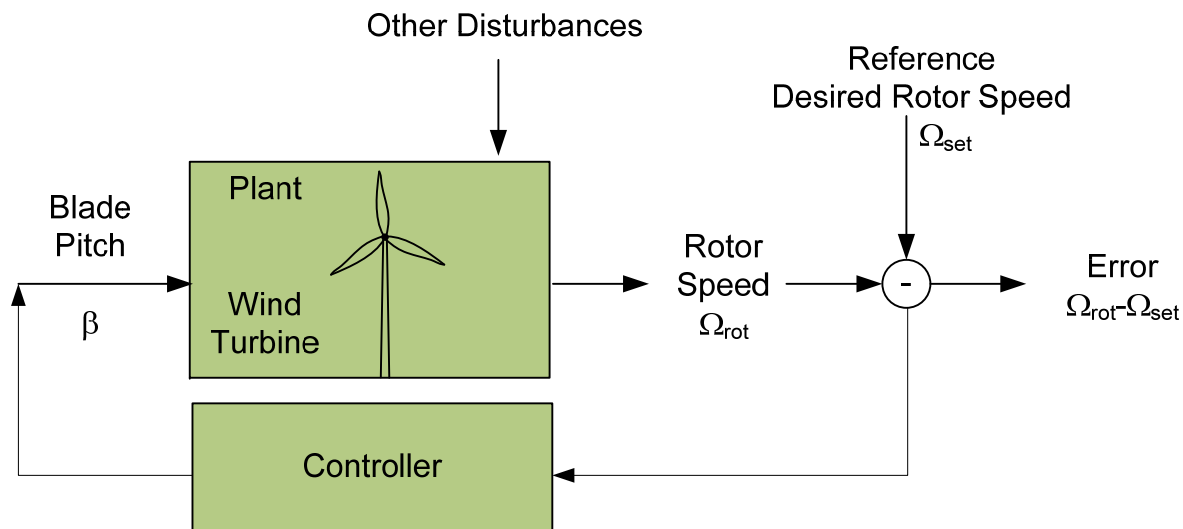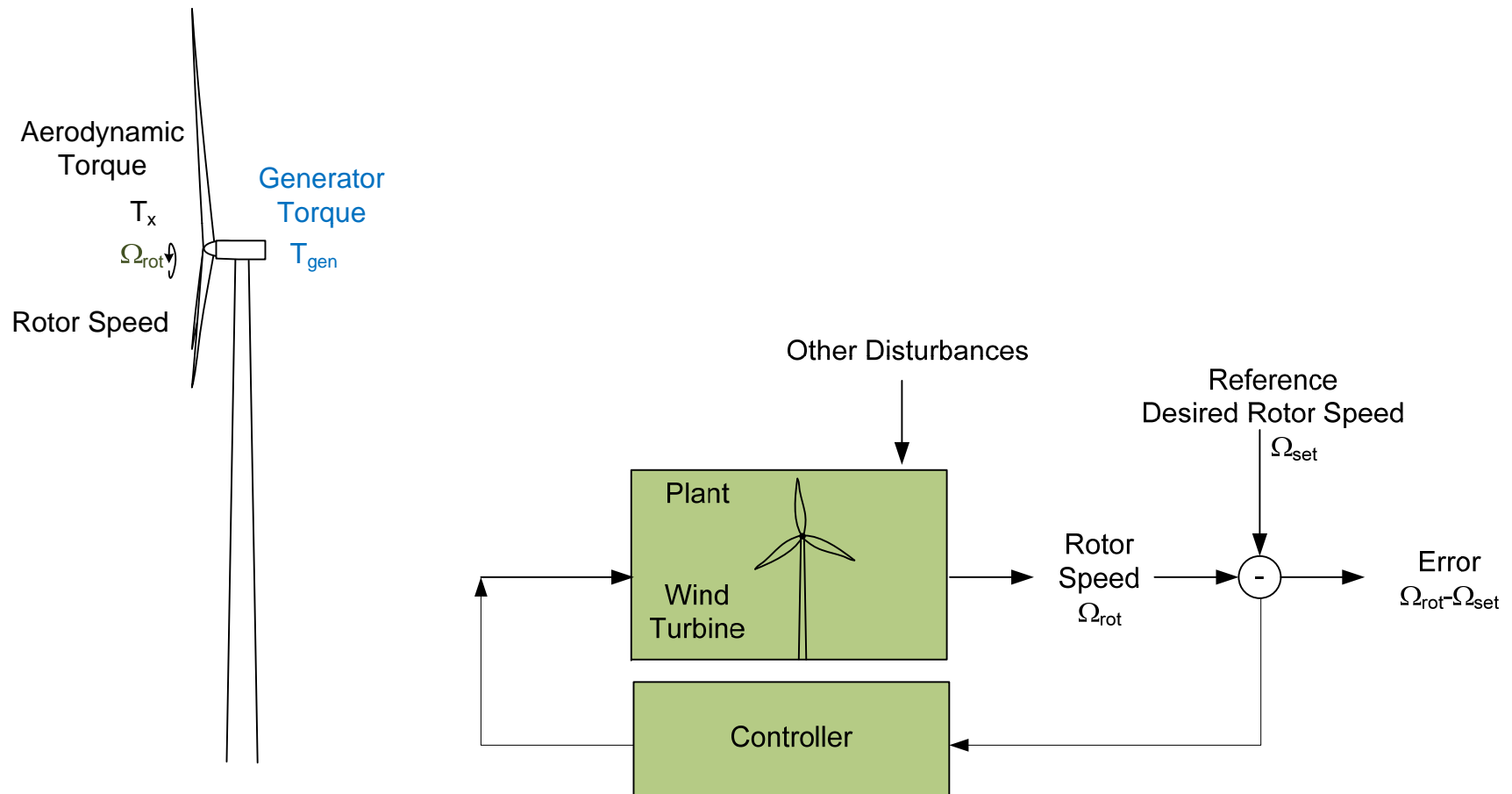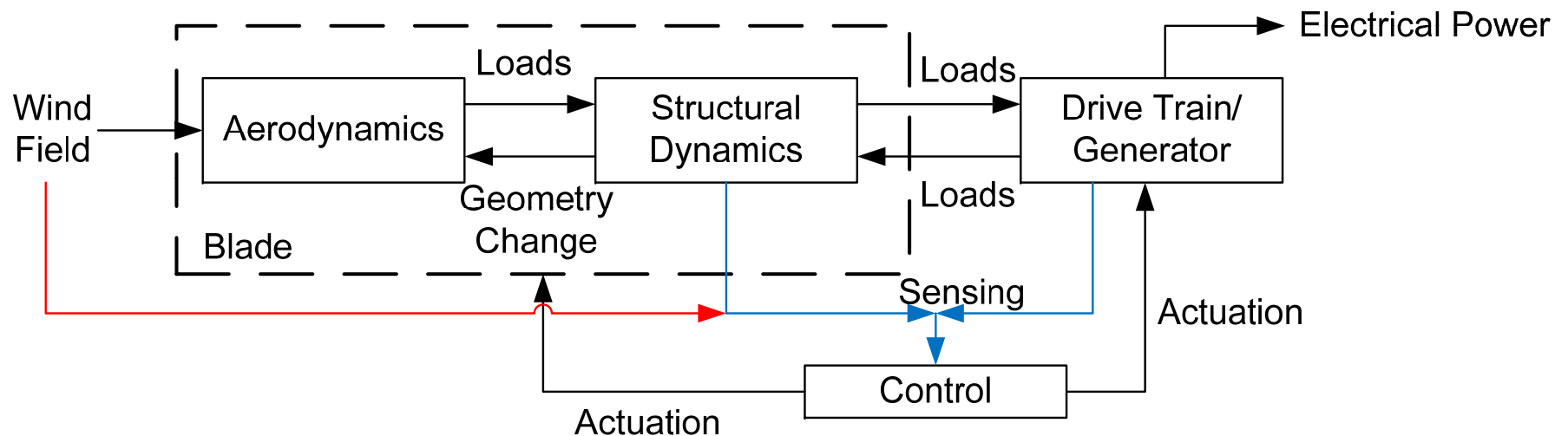
Controller

Wind Turbine Control

B. Control Basics

    5. Wind Turbine Control

Wind Turbine Control

B. Control Basics

    5. Wind Turbine Control

Blade Flap
$M_{\beta,1-3}$
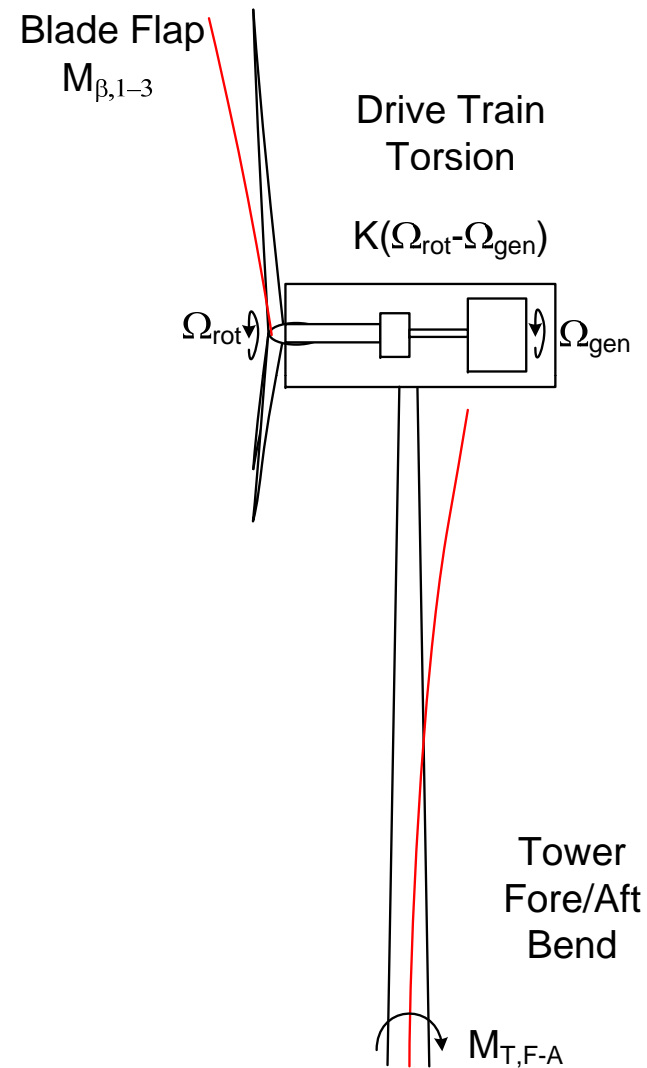
Drive Train
Torsion

$K(\Omega_{rot}-\Omega_{gen})$

Ω_{rot} Ω_{gen}

Tower
Fore/Aft
Bend

$M_{T,F-A}$

Wind Turbine Control

C. Typical Control Approaches

   1. Constant speed

      a) Stall regulated

Wind Turbine Control

C. Typical Control Approaches

   1. Constant speed

      b) Pitch regulated

Wind Turbine Control

C. Typical Control Approaches

   2. Variable speed

      a) Stall regulated

Wind Turbine Control

C. Typical Control Approaches

    2. Variable speed
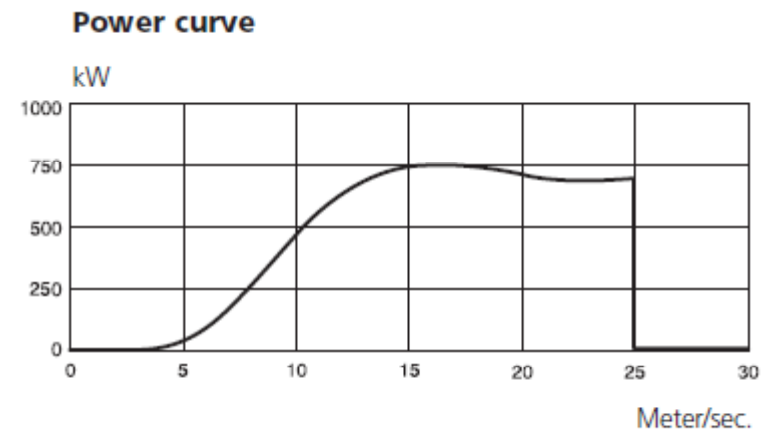
        b) Pitch regulated

Wind Turbine Control

C. Typical Control Approaches

   3. Examples

      a)   NEG-Micon 750

- Stall Regulated
- Constant Speed

Power curve

Wind Turbine Control

C. Typical Control Approaches

   3. Examples

      a) Siemens SWT-1.3

- Stall Regulated
- Variable Speed

Wind Turbine Control

C. Typical Control Approaches

    3. Examples

        a) Vestas V47

            • Pitch Regulated

            • Constant Speed

V47-660 kW power curves
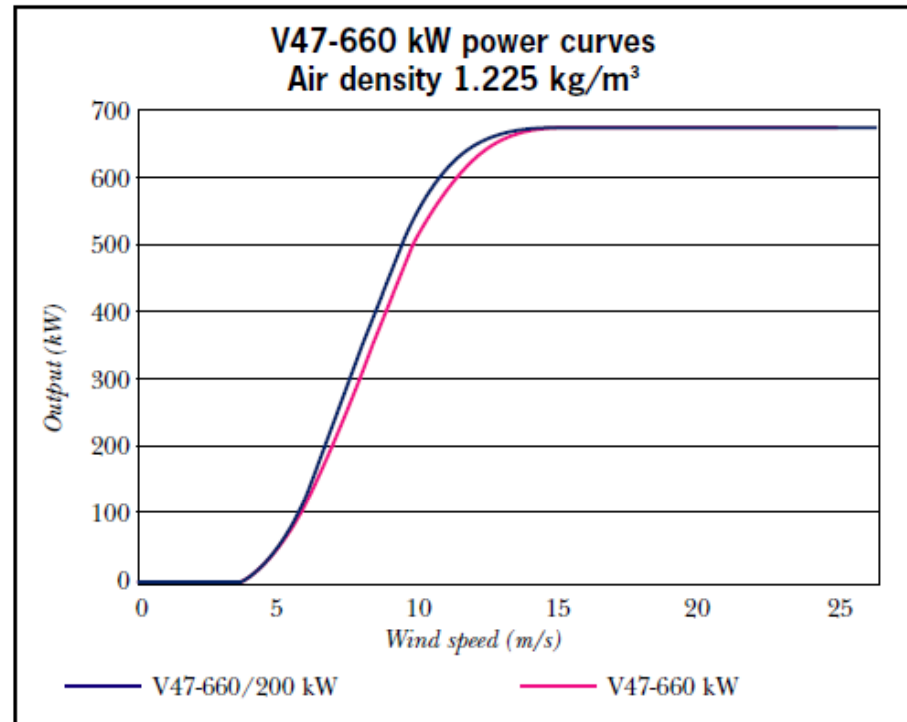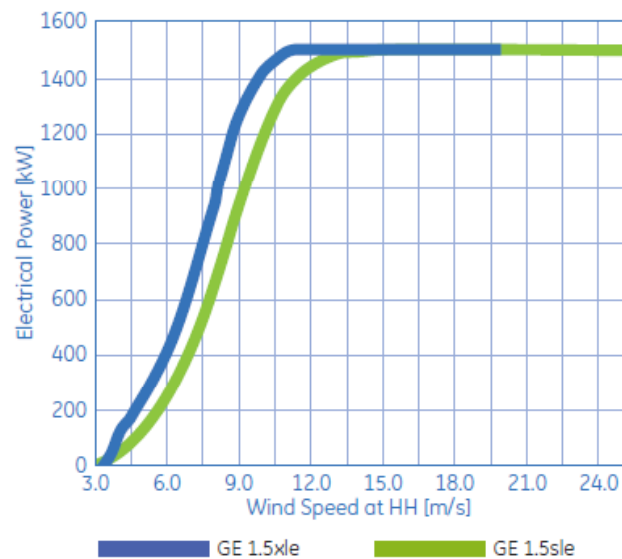Air density 1.225 kg/m³

Wind Turbine Control

C. Typical Control Approaches

    3. Examples

        a) GE 1.5 SE

- Pitch Regulated
- Variable Speed
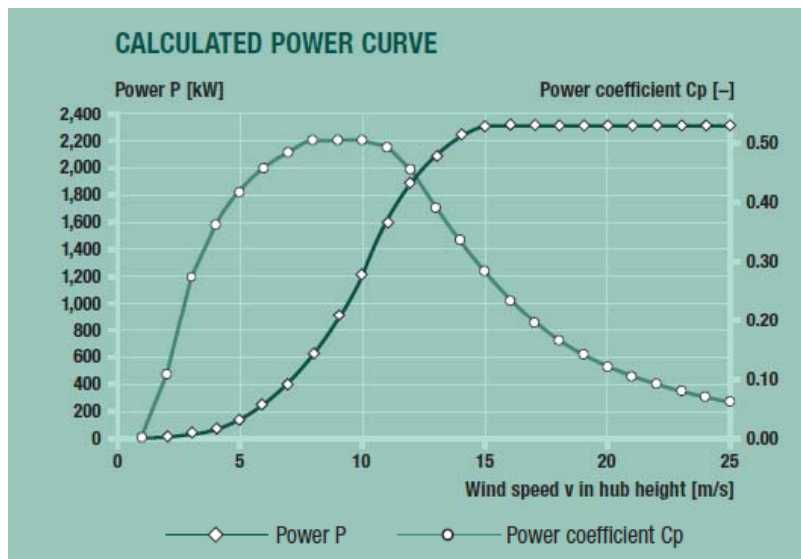
Wind Turbine Control
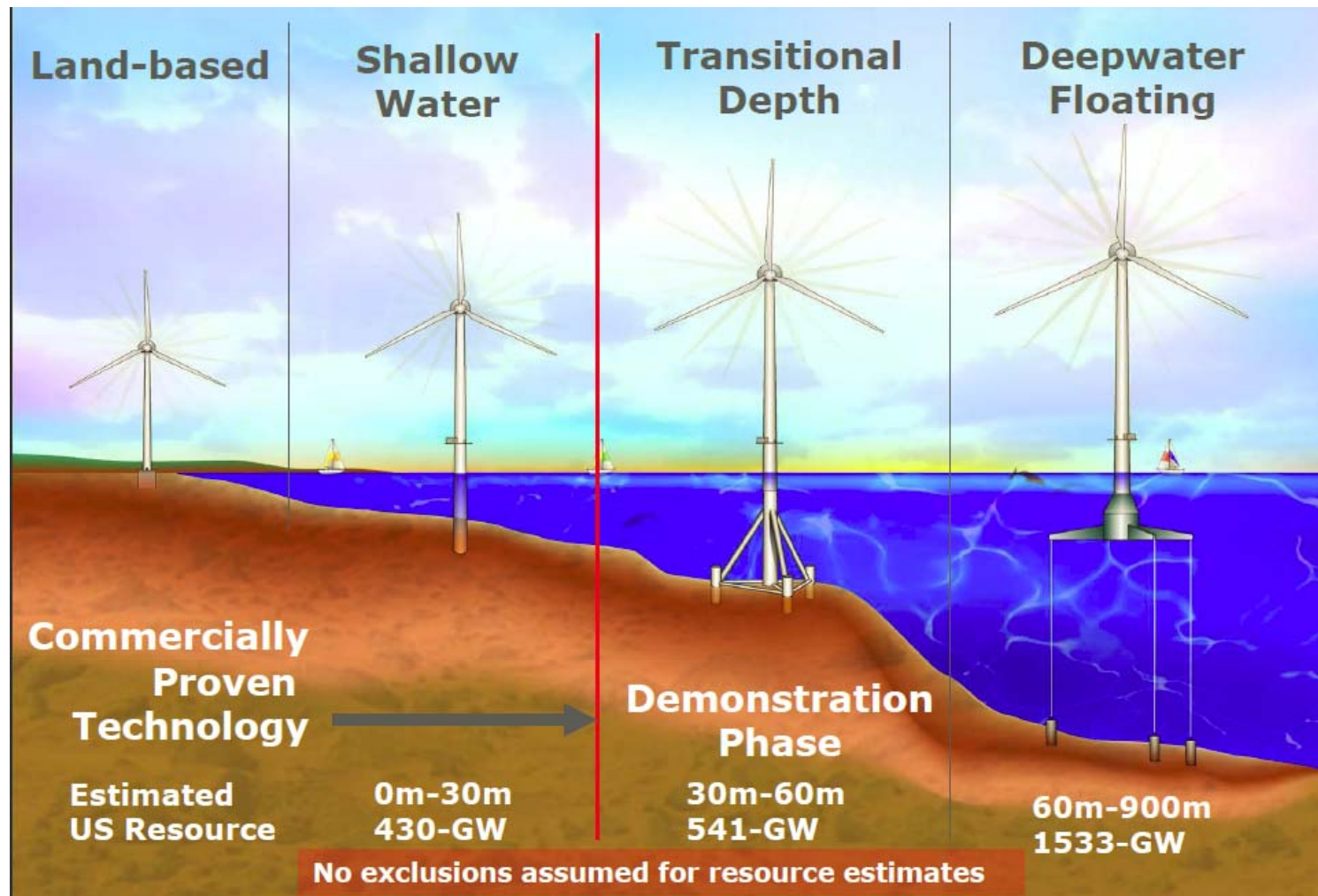
C. Typical Control Approaches

   3. Examples

      a) Enercon E70/2300

         • Pitch Regulated

         • Variable Speed

         • Direct Drive

Wind Turbine Control

D. New Challenges for Wind Turbine Control

Wind Turbine Control

D. New Challenges for Wind Turbine Control

Understand External Conditions To Define the Design Conditions

Credit: NREL