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Speed Control of Synchronous Machine by Changing Duty Cycle of DC/DC Buck Converter

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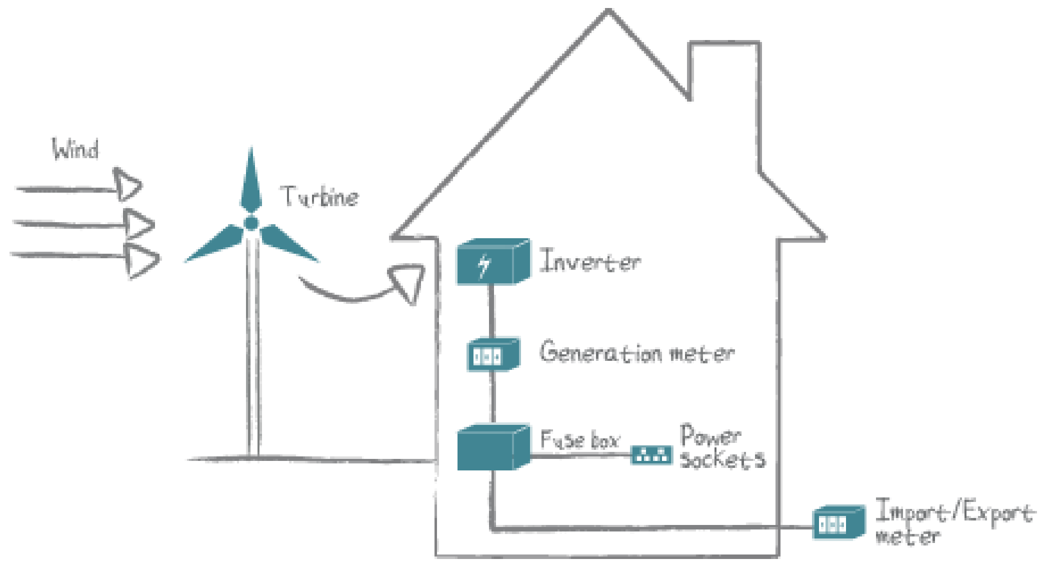
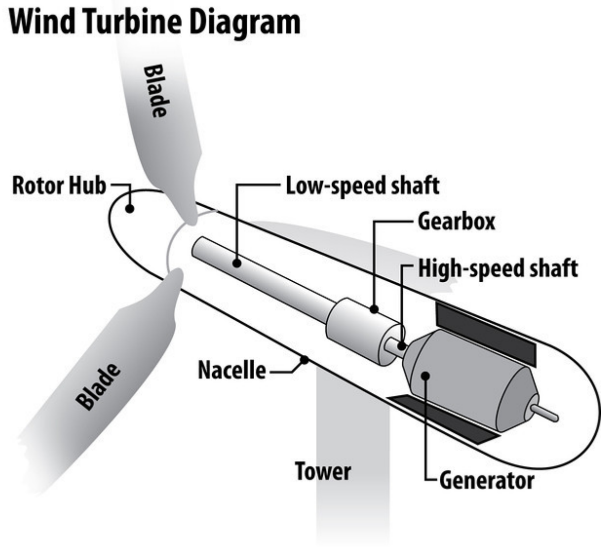
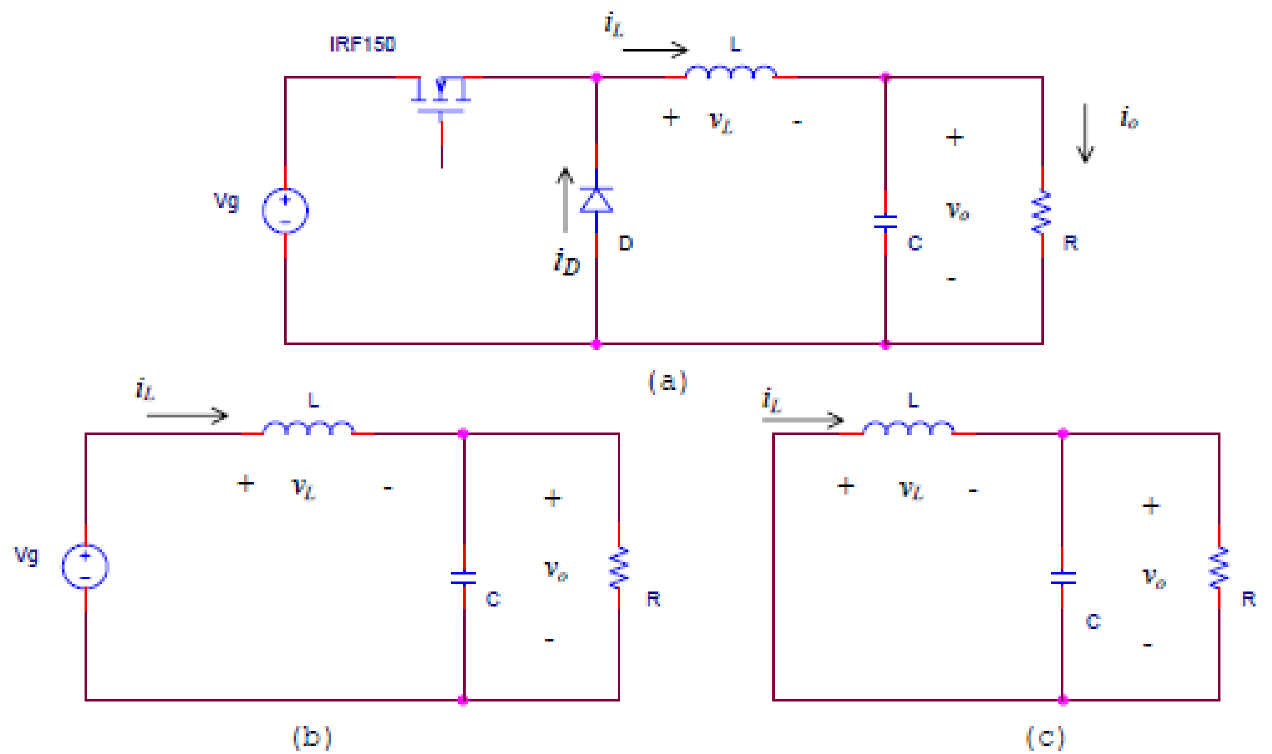

Wind
Turbine
Inverter
Generation meter
Fuse box
Power sockets
Import/Export meter

Objectives

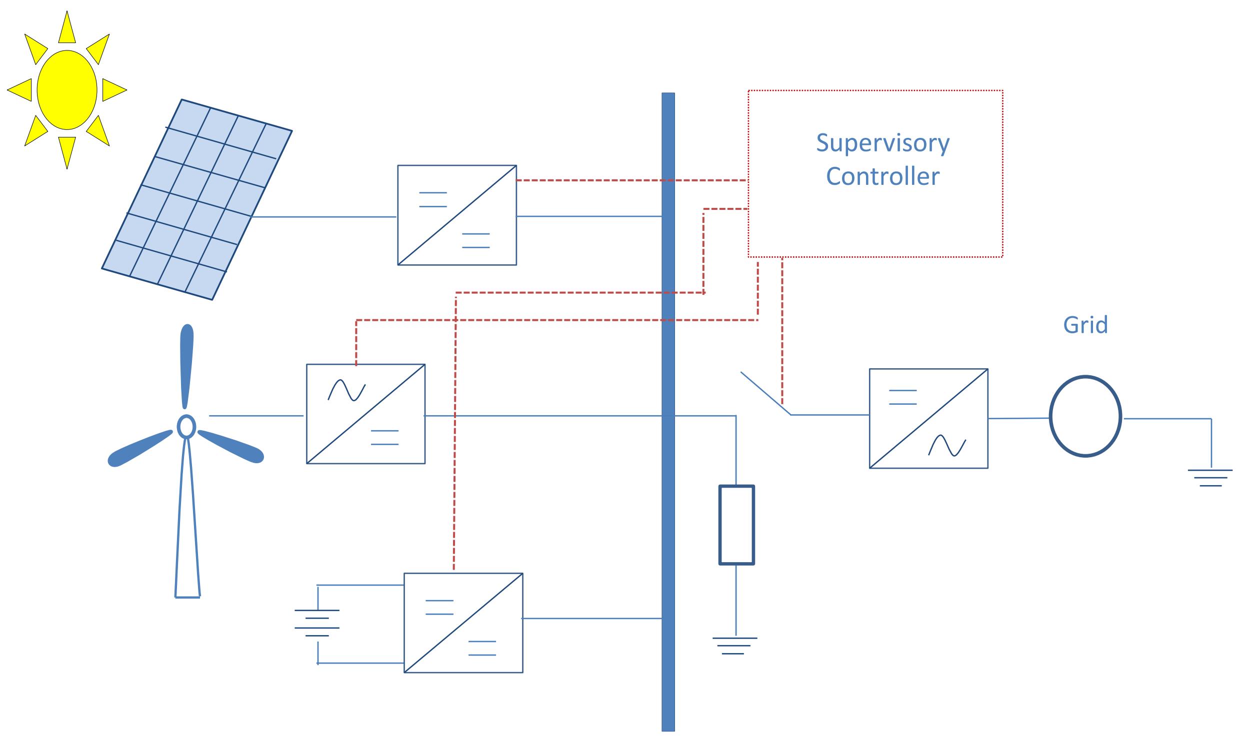


- **Develop wind system model.**
- **Measure wind speed.**
- **Develop two models to control turbine speed.**
- **Use measured wind speed as input for wind turbine.**
- **Use duty ratio of DC/DC buck converter to control speed of wind system.**

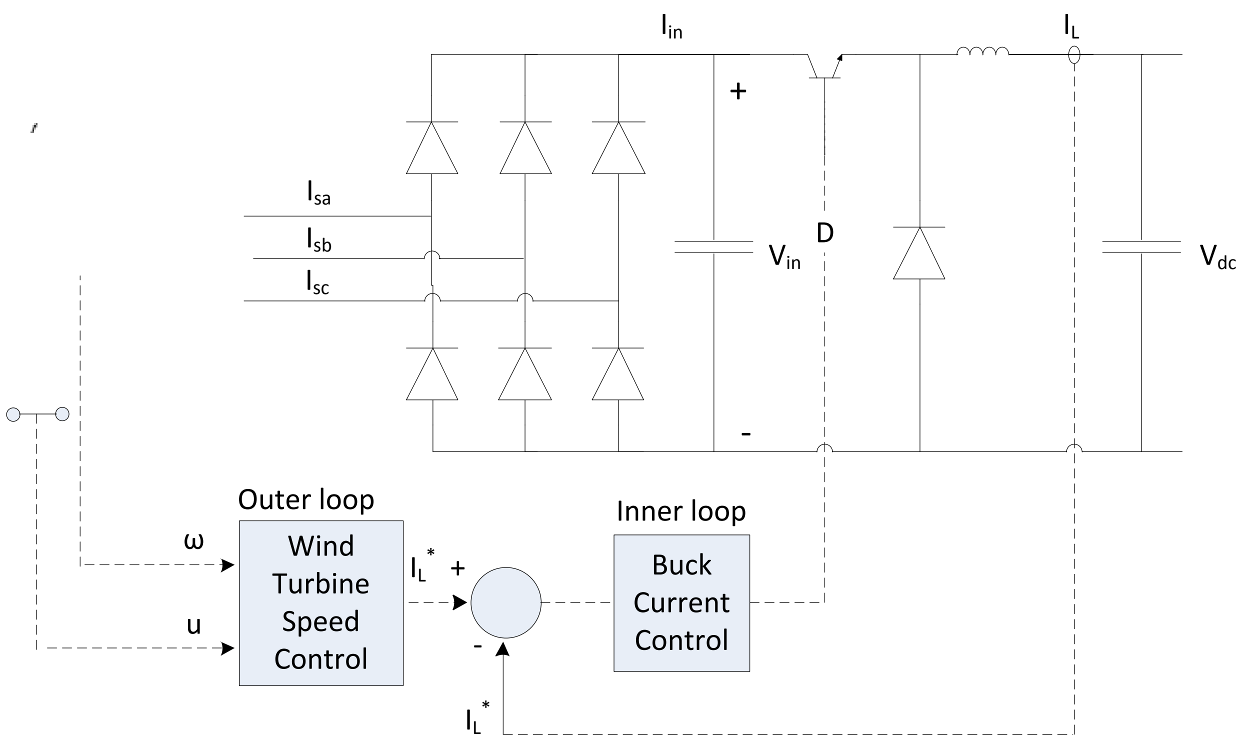
What is DC/DC buck converter ?



Hybrid System with DC Microgrid



Wind energy system



Wind Turbine Modelling

- **Power generated P_m by wind turbine:**

$$P_m = \frac{1}{2}\rho\pi R^2 u^3 C_P$$

P_m : Turbine mechanical power

ρ : Air density

R : Turbine rotor radius

u : Wind speed

C_P : Turbine performance coefficient (function of tip speed ratio λ and pitch angle β in a pitch controlled system)

$$\lambda = \frac{R\omega}{u}$$

ω is turbine rotational speed

$$\omega = \frac{1}{J}\int (T_m - T_e)\, dt$$

T_m : Turbine mechanical torque

T_e : Turbine electrical torque

J : Rotational inertia

Wind Turbine Modelling

- **Mechanical torque T_m can be calculated:**

$$T_m = \frac{P_m}{\omega}$$

P_m : Turbine mechanical power

ω is turbine rotational speed

- **Electrical torque T_e can be calculated:**

$$T_e = K_I I_s$$

K_I : Machine torque constant

I_s : Machine stator current

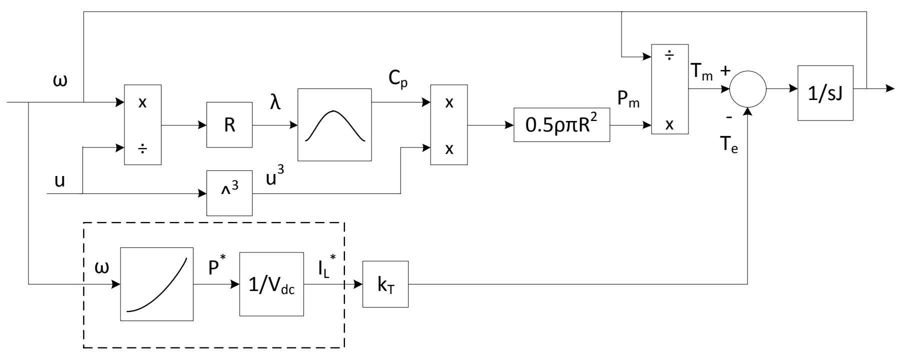
In this system, electrical torque is controlled by buck output current I_L.

Electrical torque can be related to buck current by new defined constant K_T

$$T_e = K_T I_L$$

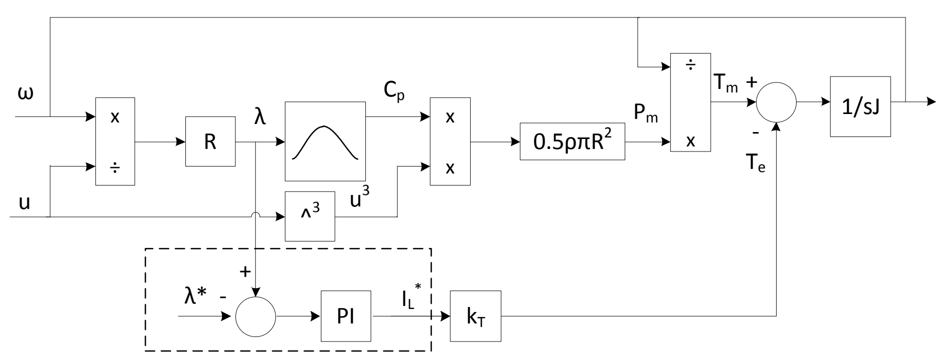
Speed Control of Wind Turbine

a) Stored Power curve



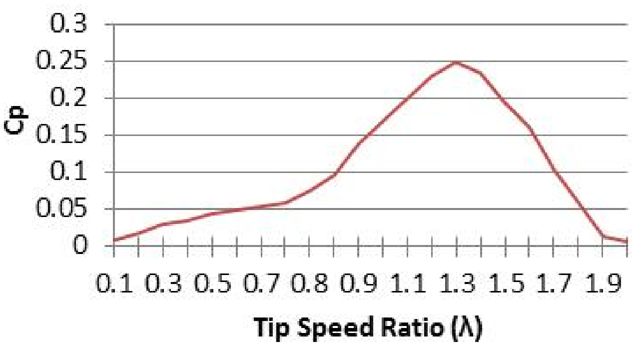
Stored Power Curve

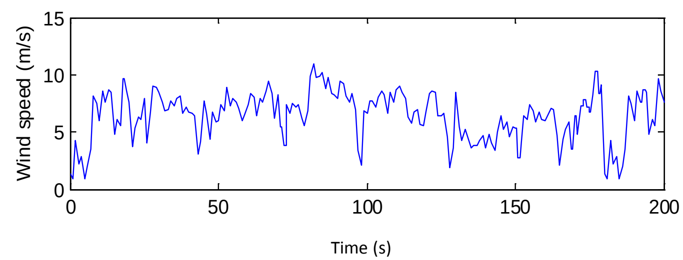
b) PI Control of the TSR

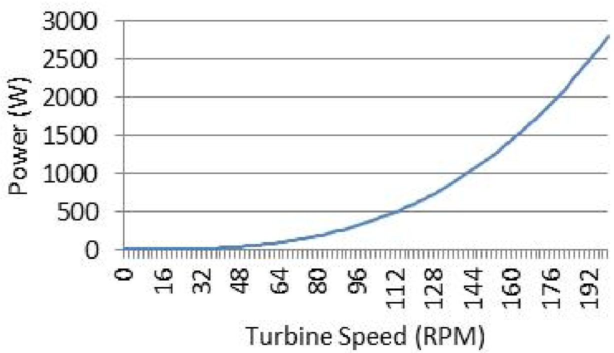


PI Control of λ

Speed Control of Wind Turbine



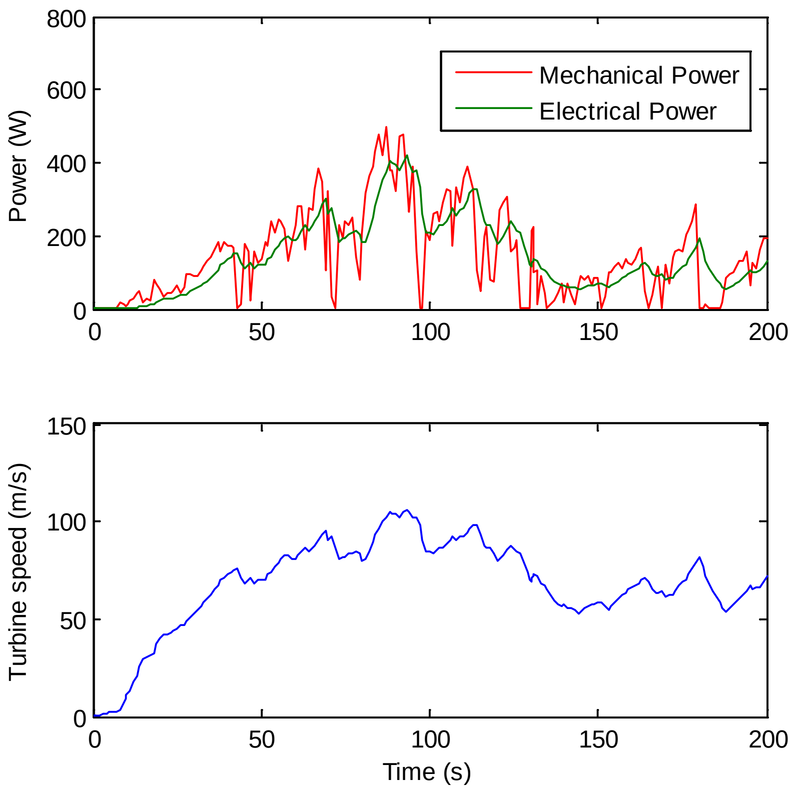




Simulation Results

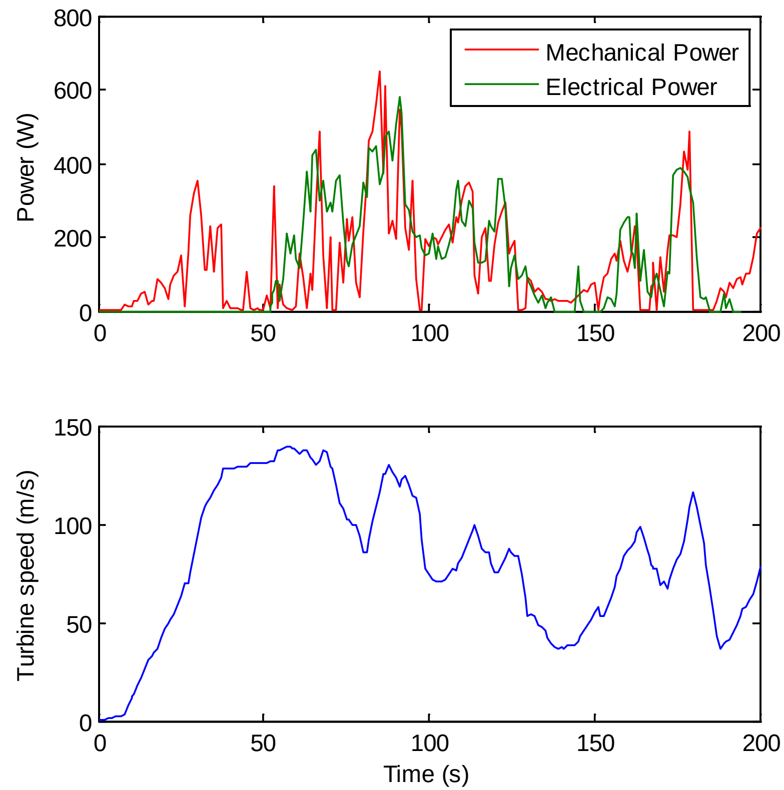
a) Stored Power curve

- **Generated electrical energy = 28.81 kJ**



b) PI Control of the TSR

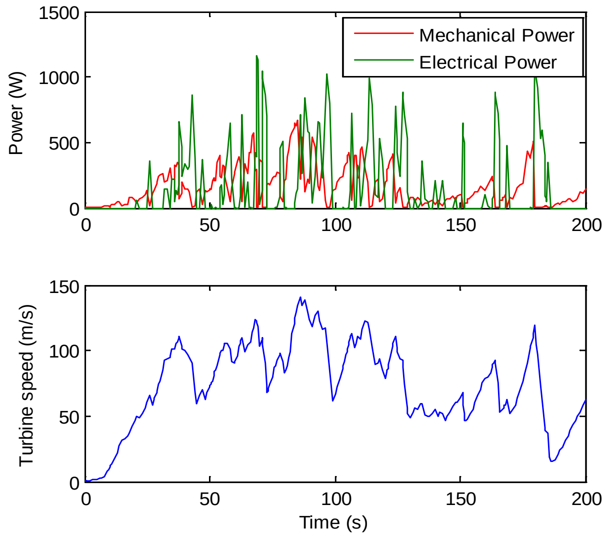
- **Generated electrical energy = 24.75 kJ**



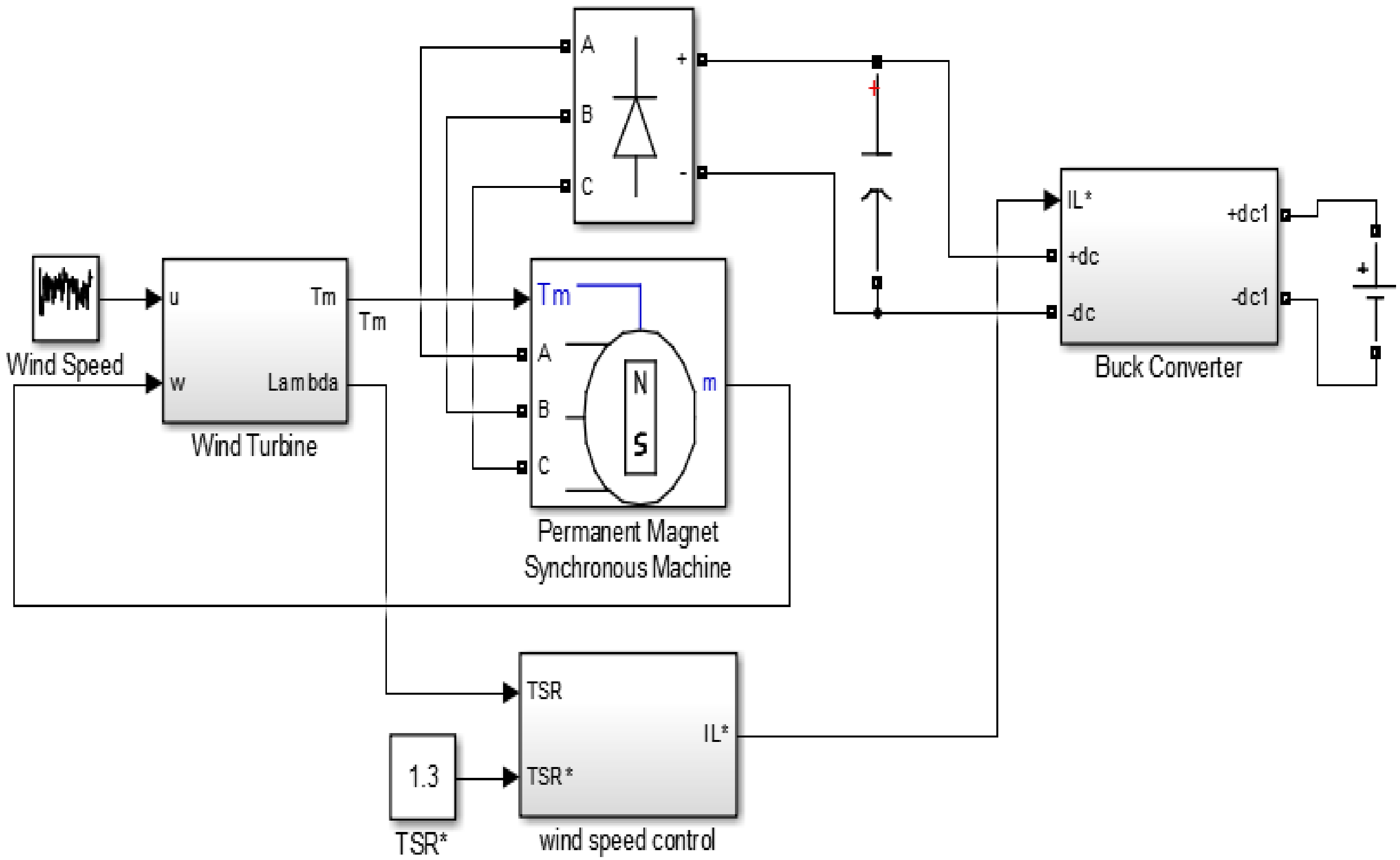
Simulation Results

PI Control of the TSR

Generated electrical energy = 30.39 kJ



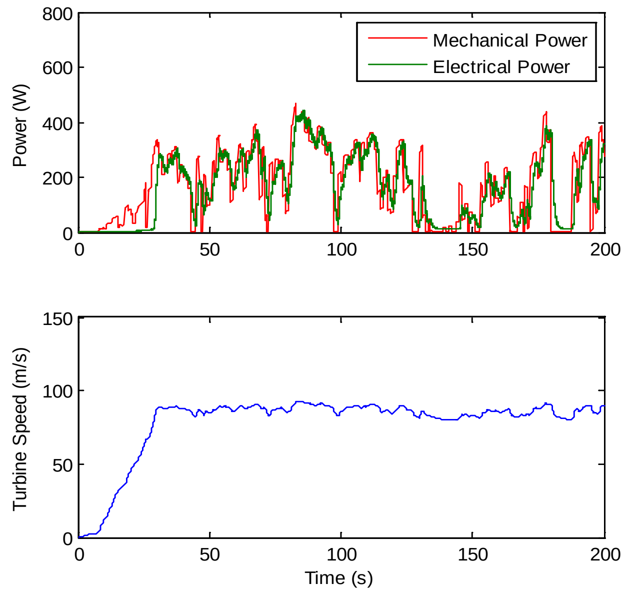
Detailed Overall System of Wind Turbine



Simulation Results

Power & speed for detailed model with machine torque constant equal to 5.308 N.m / A_{peak}

Generated electrical energy = 32.05 kJ



Conclusion

- A wind turbine connected to a PMSM was modelled in Simulink.
- DC/DC buck converter was used at the load side.
- A comparison between two methods of controlling a wind turbine in a microgird was done:
  1. Stored power curve
  2. PI control of the speed tip ratio

- PI method provides more controllability, but it requires an anemometer to measure wind speed.
- Stored energy method is easier to implement, but amount of energy extracted can be less.

Q & A

Thanks for Your Kind Attention

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