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Dynamic Modeling and Grid Interaction of a Tidal and River Generation

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Objectives

- Develop river/tidal generator dynamic model.
- Represent turbine characteristics.
- Provide detailed representation of electrical power conversion.
- Provide detailed representation of diesel generator.
- Model village load.
- Demonstrate frequency and voltage regulations.
- Demonstrate resistive and inductive loads.
- Operate beyond maximum efficiency of the turbine.
- Show active control of river/tidal generator to support the grid functionalities.

Resources

TABLE 1. Total Available Resources and Equivalent Percentages of U.S. Electricity Generation in 2012

	Total Resource (TW-h/yr)	Equivalent % of 2012 Generation
Ocean Wave	2,640	65%
Ocean Current	200	5%
Tidal Current	445	11%
River Current	1,381	34%

Typical Configuration of a Tidal and River Generator

Fig. 1. Typical configuration of a river and tidal generator.
Photo from Ocean Renewable Power Company

Village Power Systems

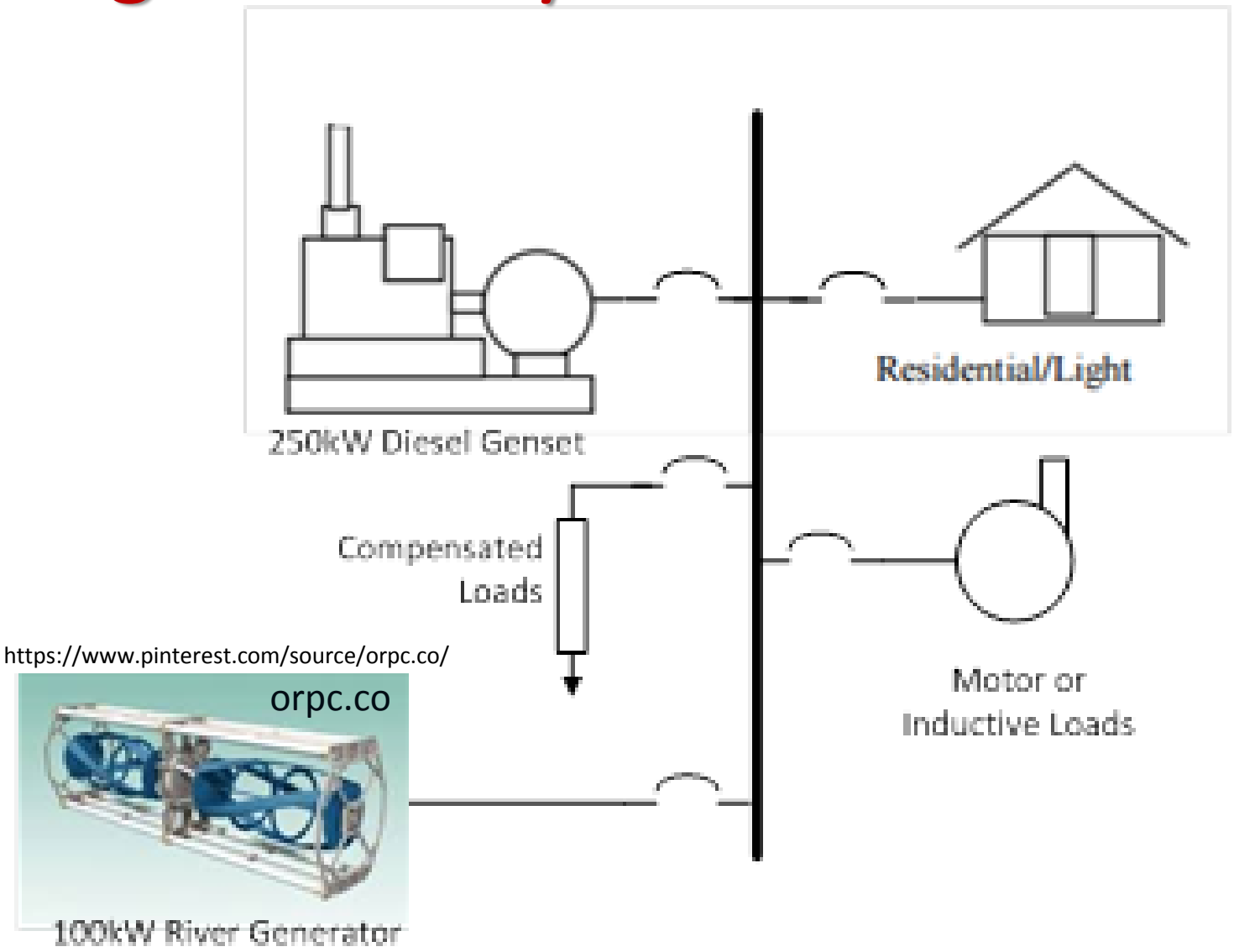


Fig. 2. Illustration of a small village power system

Turbine–Generator–Power Converter

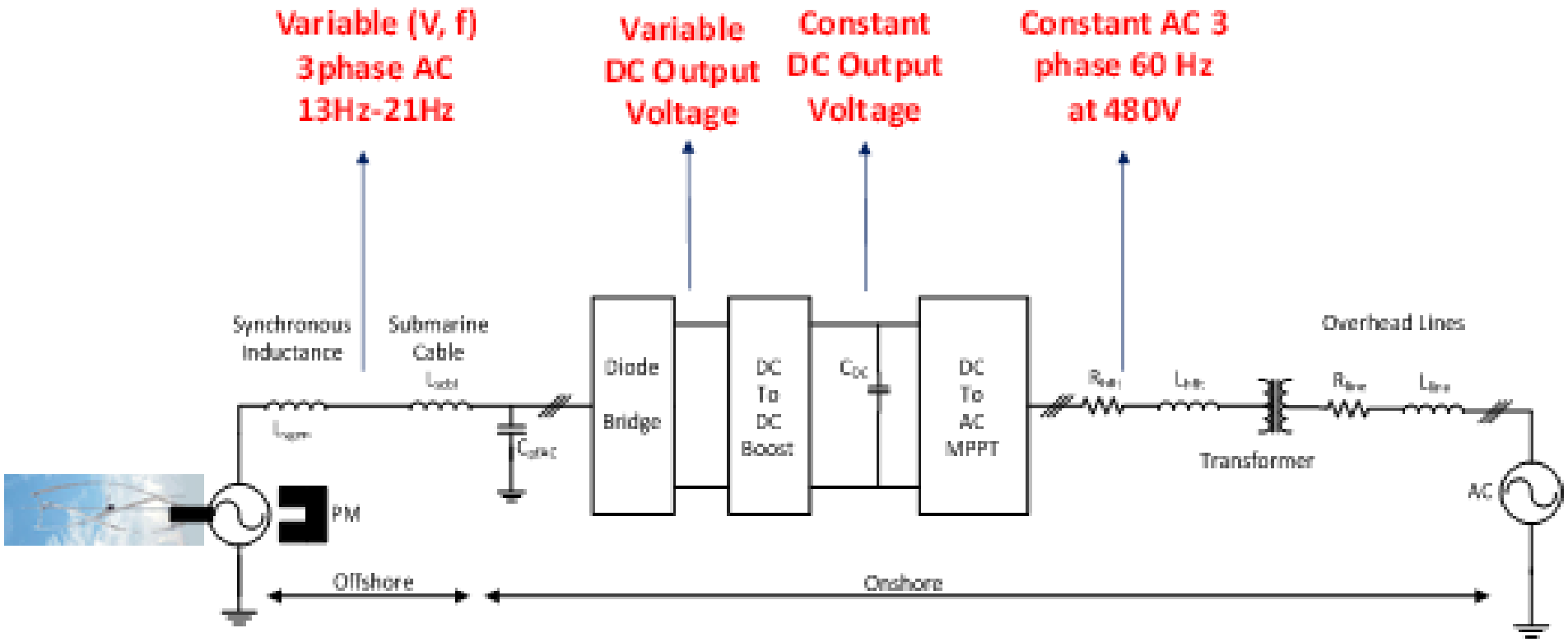
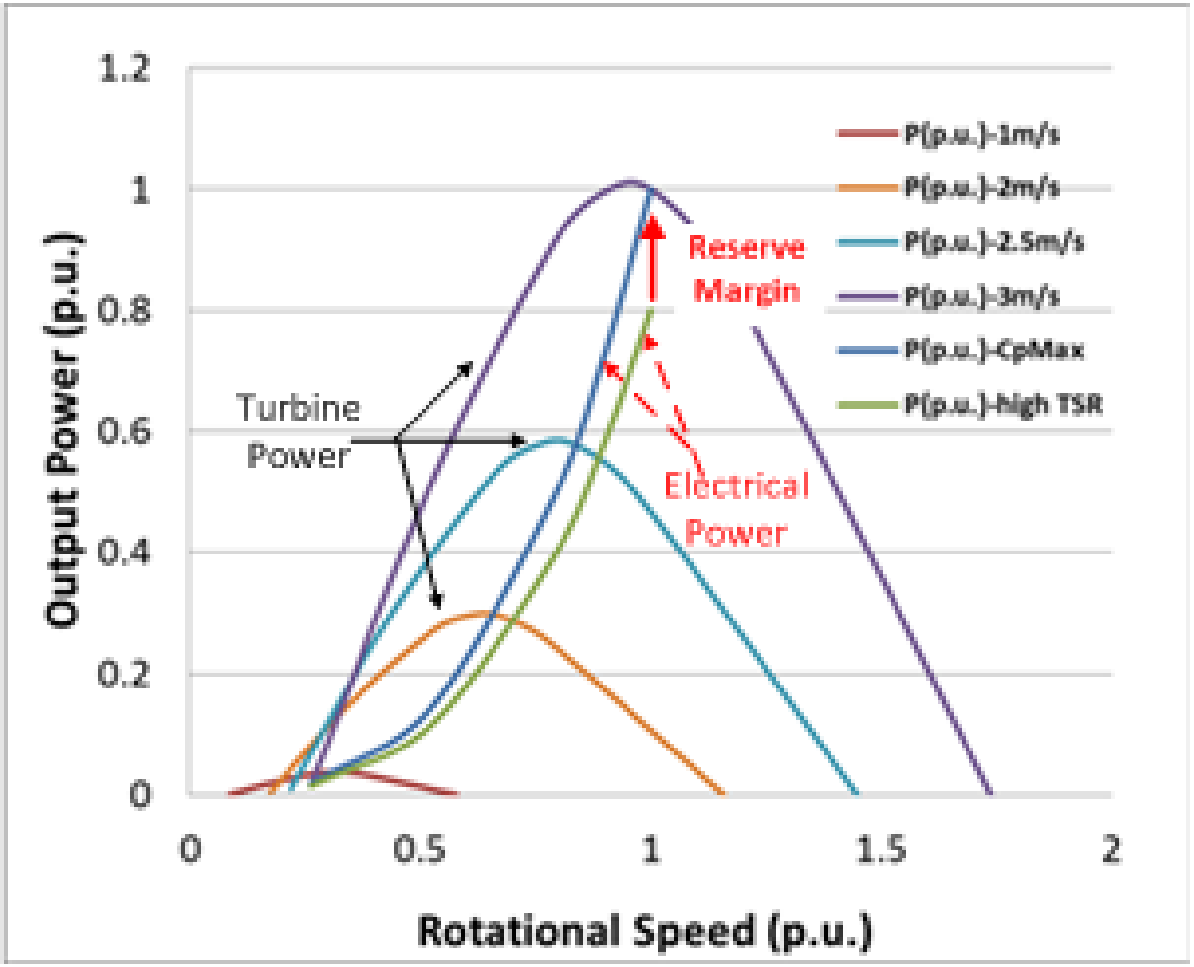


Fig. 3. Illustration of a river generator and its power converters connected to the grid

Turbine Characteristics



$$P_e = k_p \, k_{Cpmax} \, \omega_m^3$$

Fig. 4. Turbine power and electric power of the river generator per unit of rated power generation and rotational speed

Governor Model—Diesel Genset—Frequency Regulation

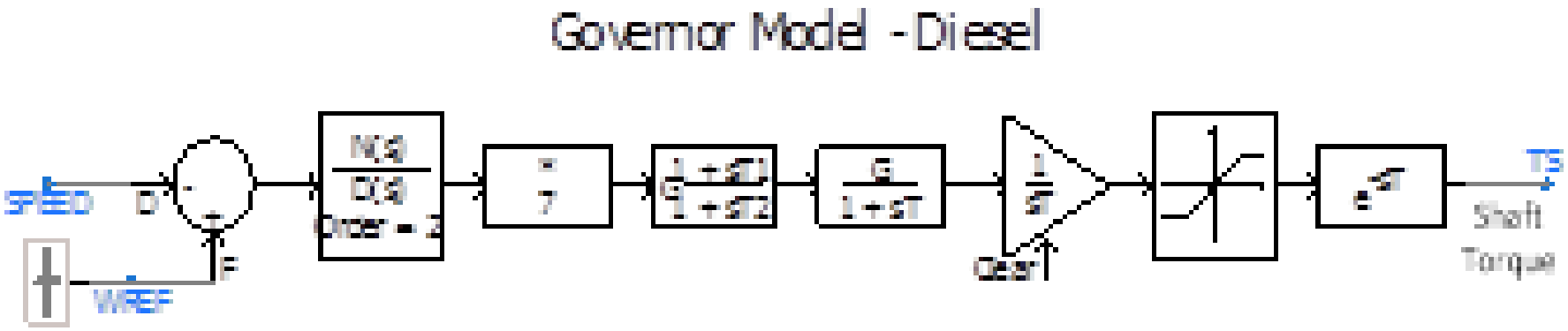


Fig. 5. Block diagram of a governor of the diesel engine

Synchronous Generator—Exciter—Voltage Regulation

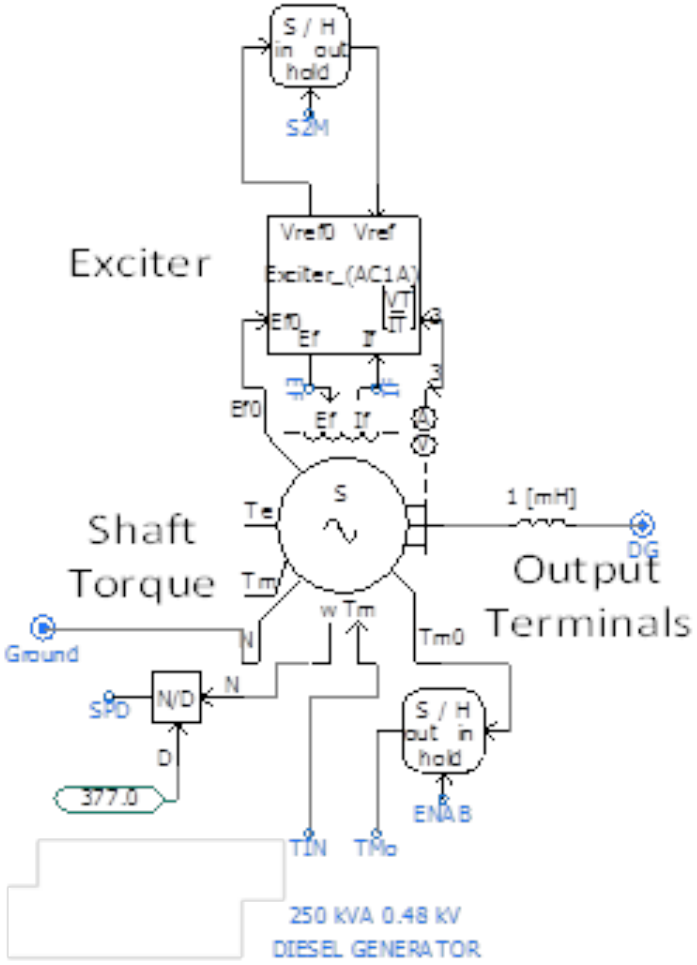
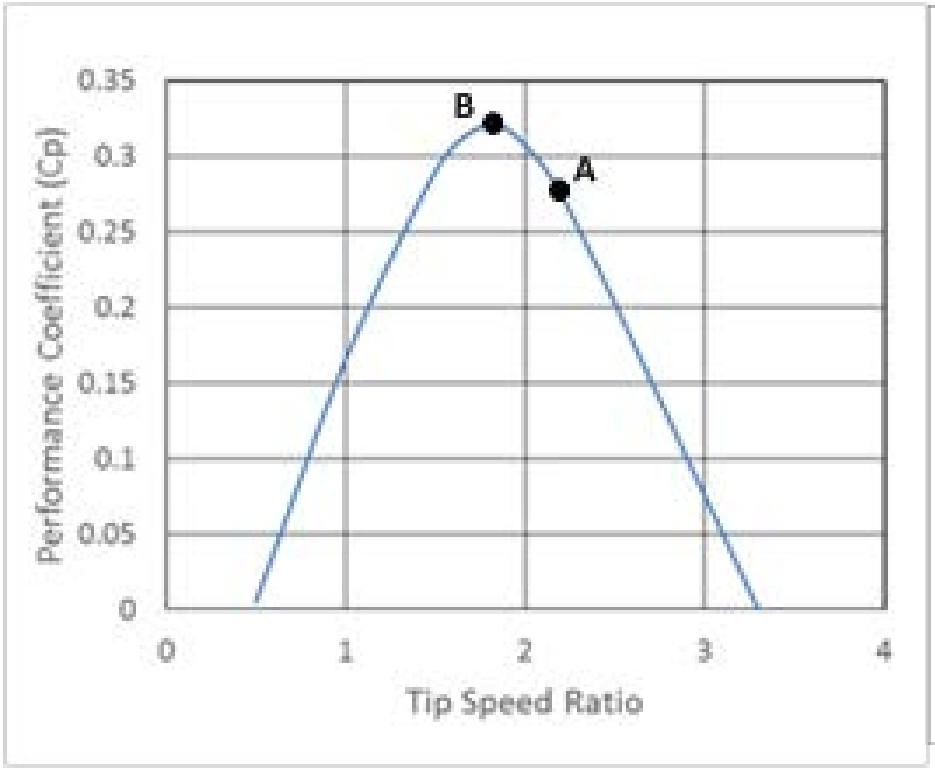
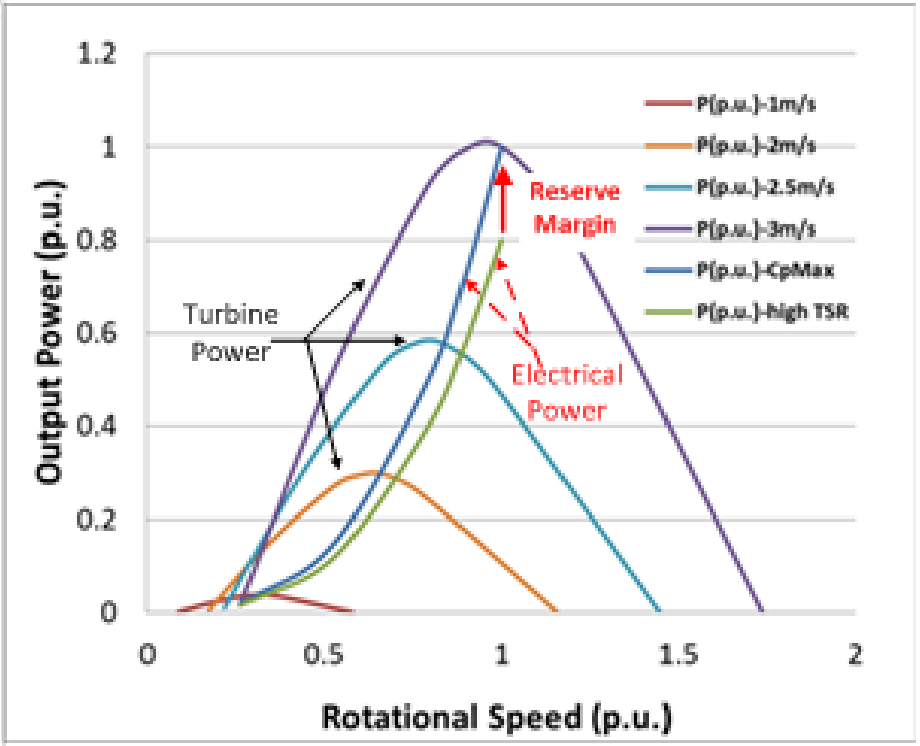


Fig. 6. Synchronous generator and its corresponding exciter

Turbine Characteristics—Cp vs. Tip-Speed Ratio





Cp-TSR Turbine Characteristic and Power Curves

Turbine Characteristics—During Transition

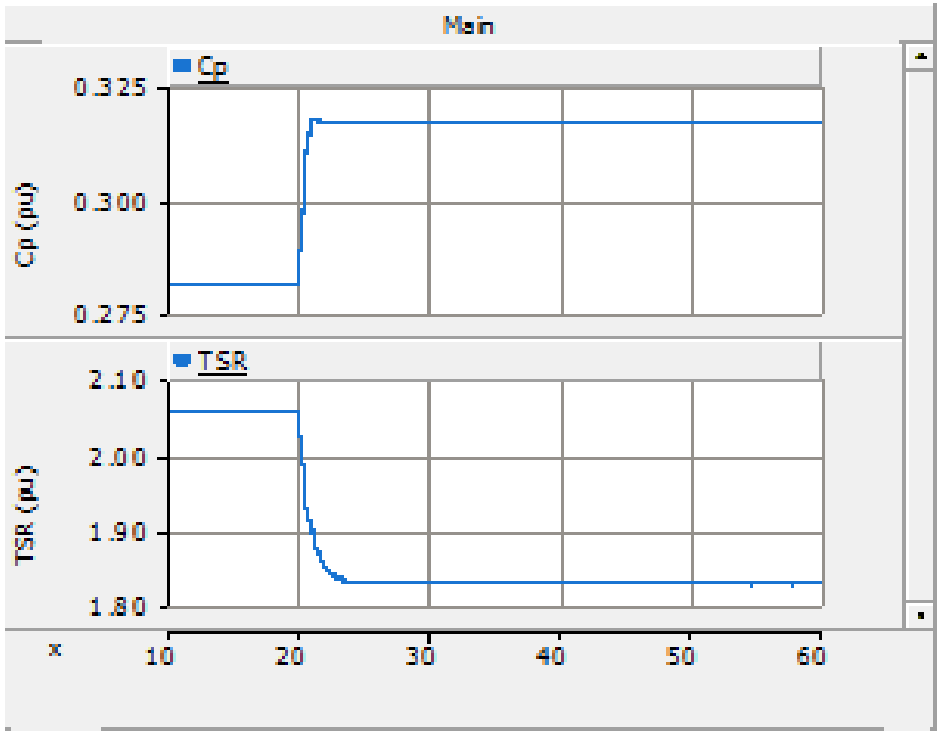


Fig. 8. Typical performance coefficient, Cp, as a function of the tip-speed ratio of the river generator

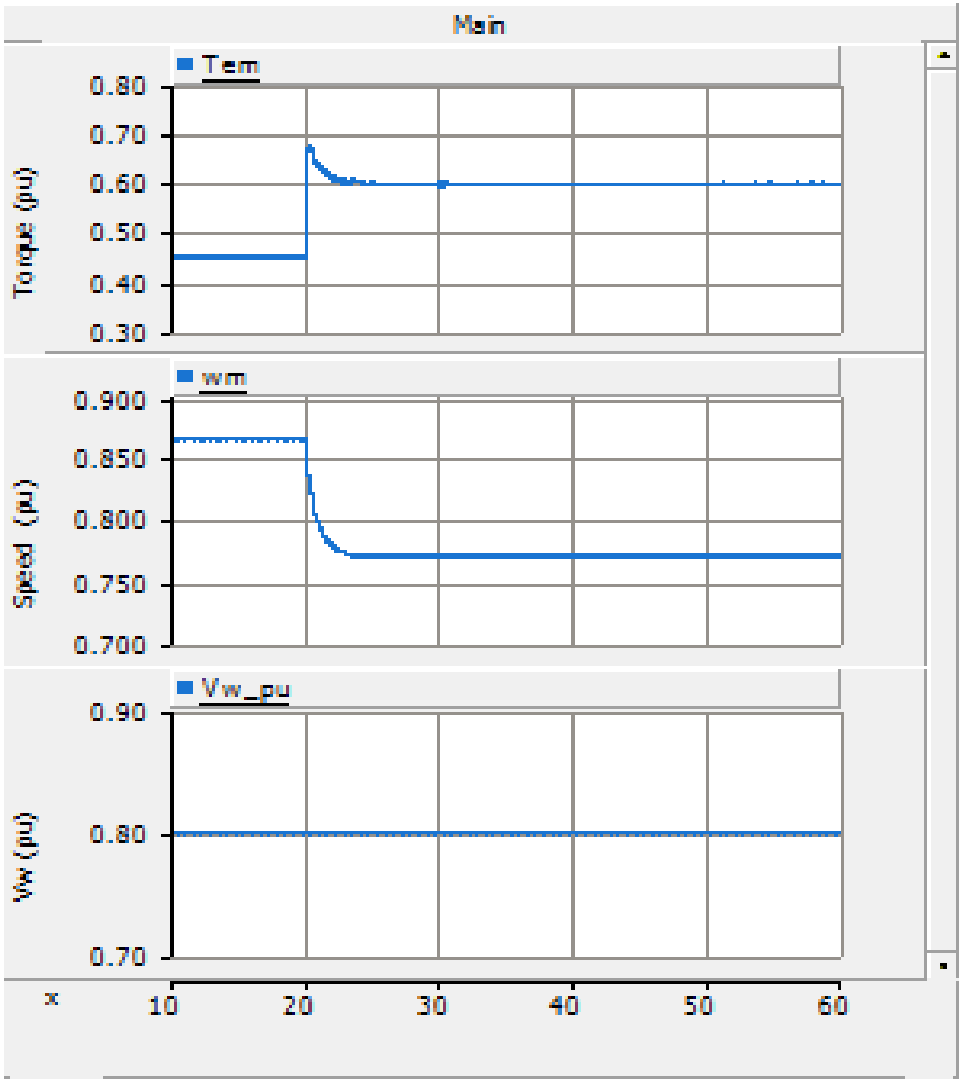
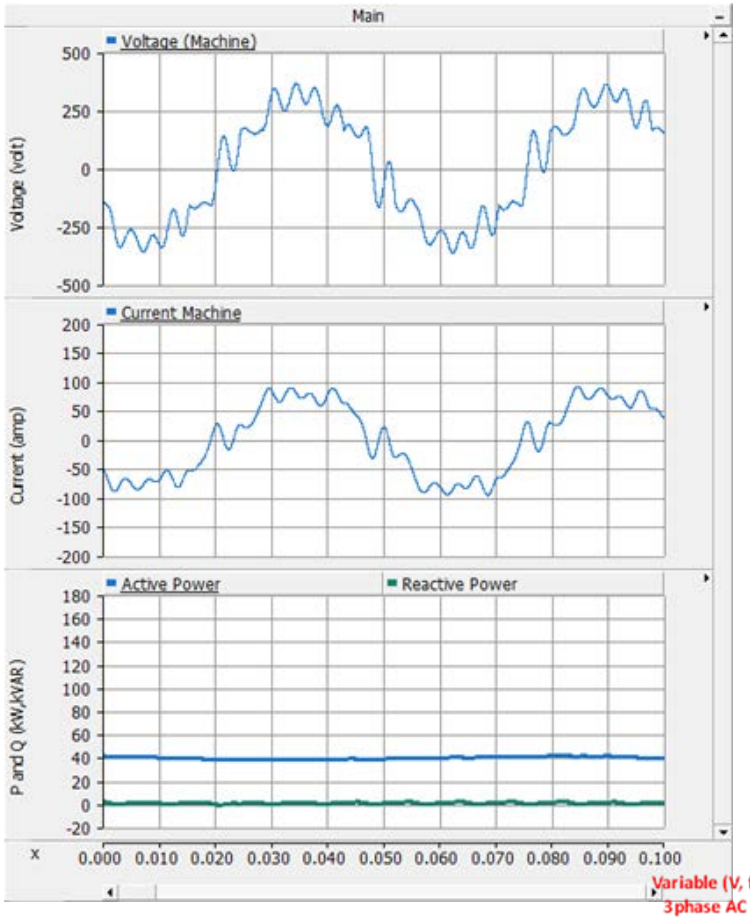
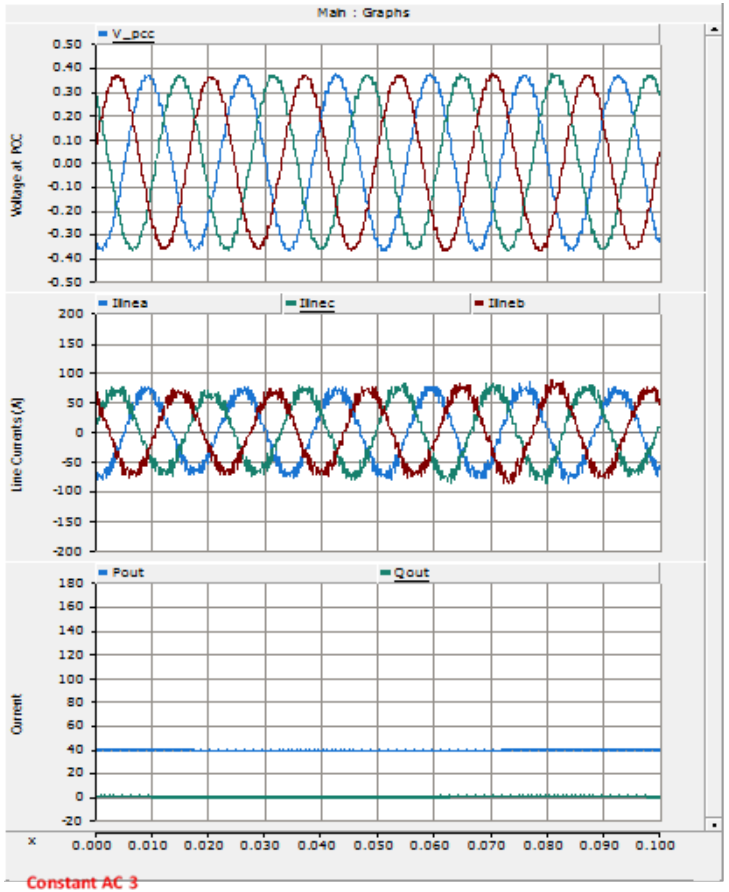


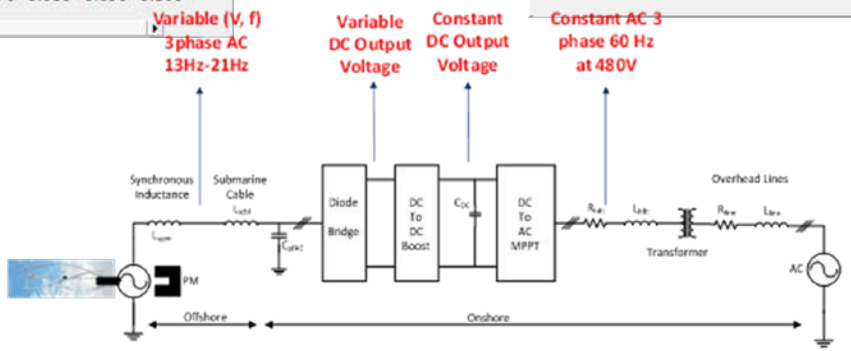
Fig. 9. Electromagnetic torque and the corresponding rotational speed while the river generator is controlled under constant water flow

Generator Side

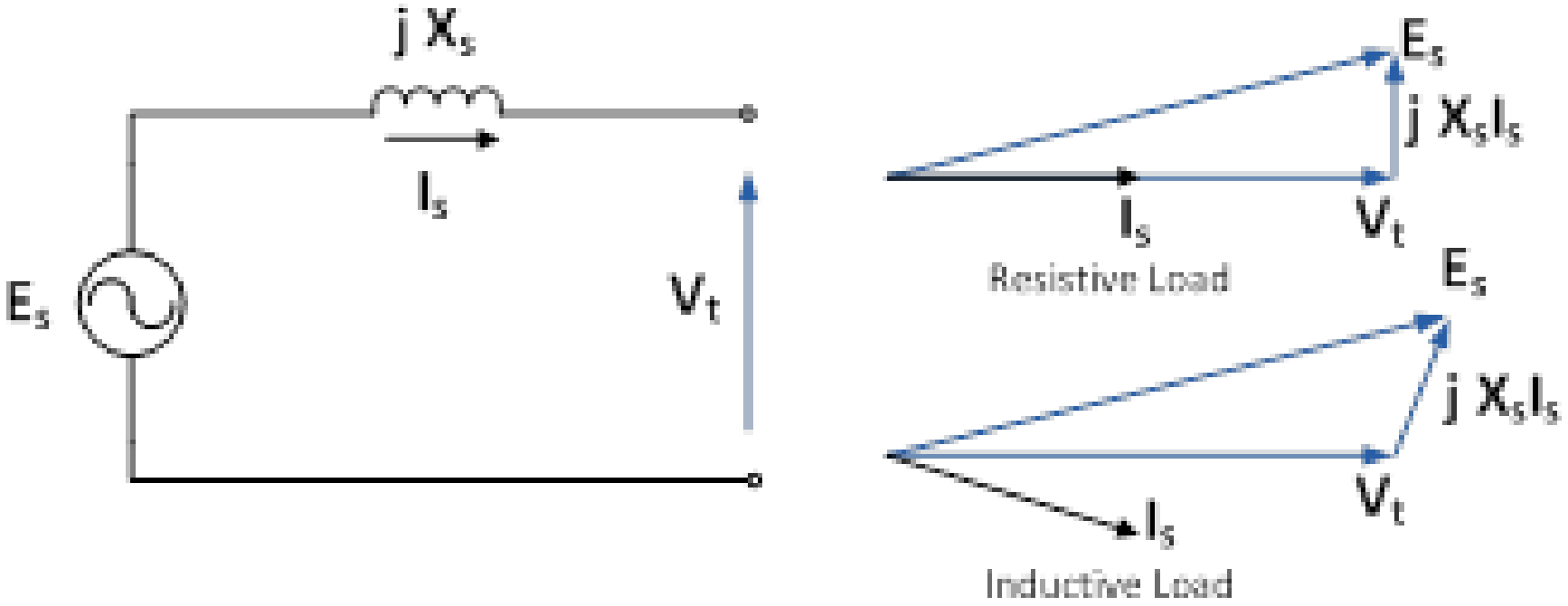


Grid Side





Voltage Regulation—Impact of Different Loads

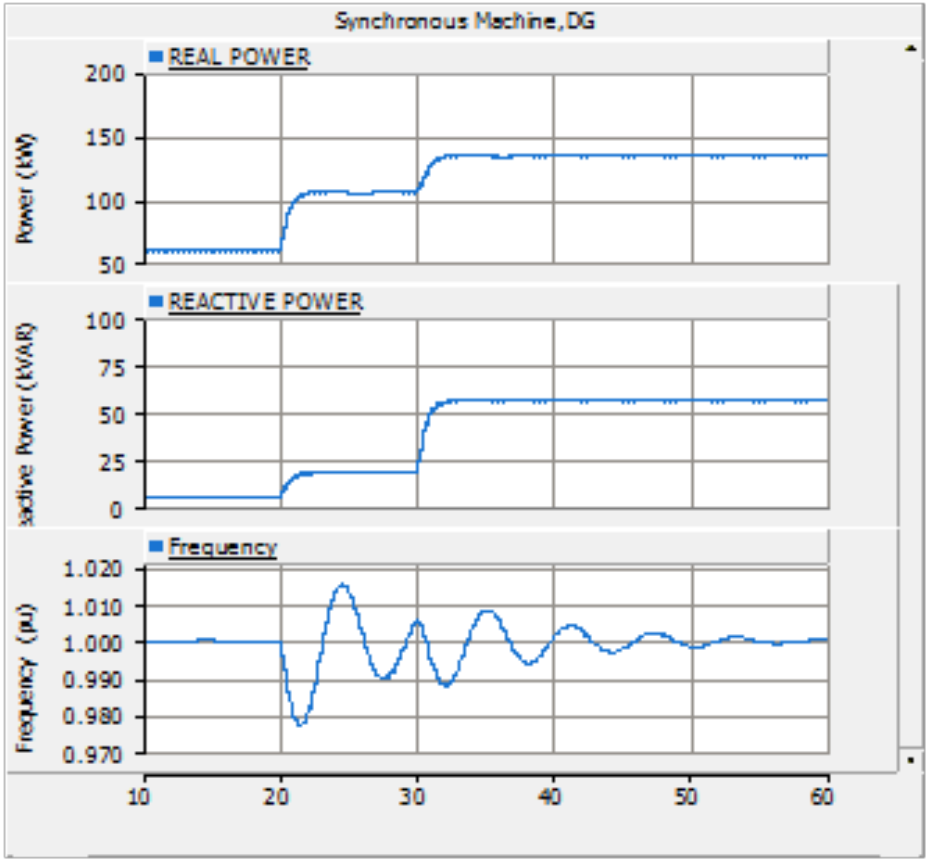


$$E_s = k_f \, I_f \, \omega_m$$

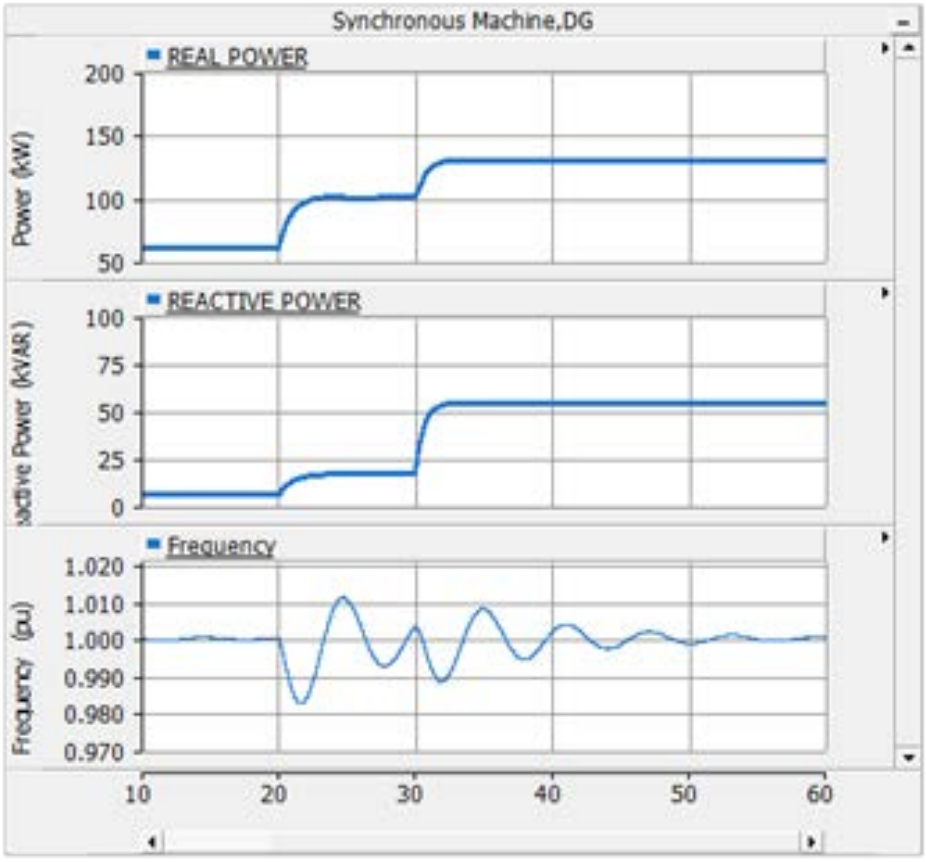
$$RPM = \frac{120 \, f_e}{poles}$$

Fig. 13. Simplified equivalent circuit and the corresponding phasor diagrams for resistive and inductive loads

Power Contribution from Diesel Genset



River generator contributes a constant output power of 40 kW.



River generator contribution: 40 kW for t < 20 s, and 70 kW t > 20 s

Real and reactive power output and the corresponding frequency of the synchronous generator driven by the diesel generator connected to the grid

Voltage Regulation—Field Excitation—Synchronous Generator

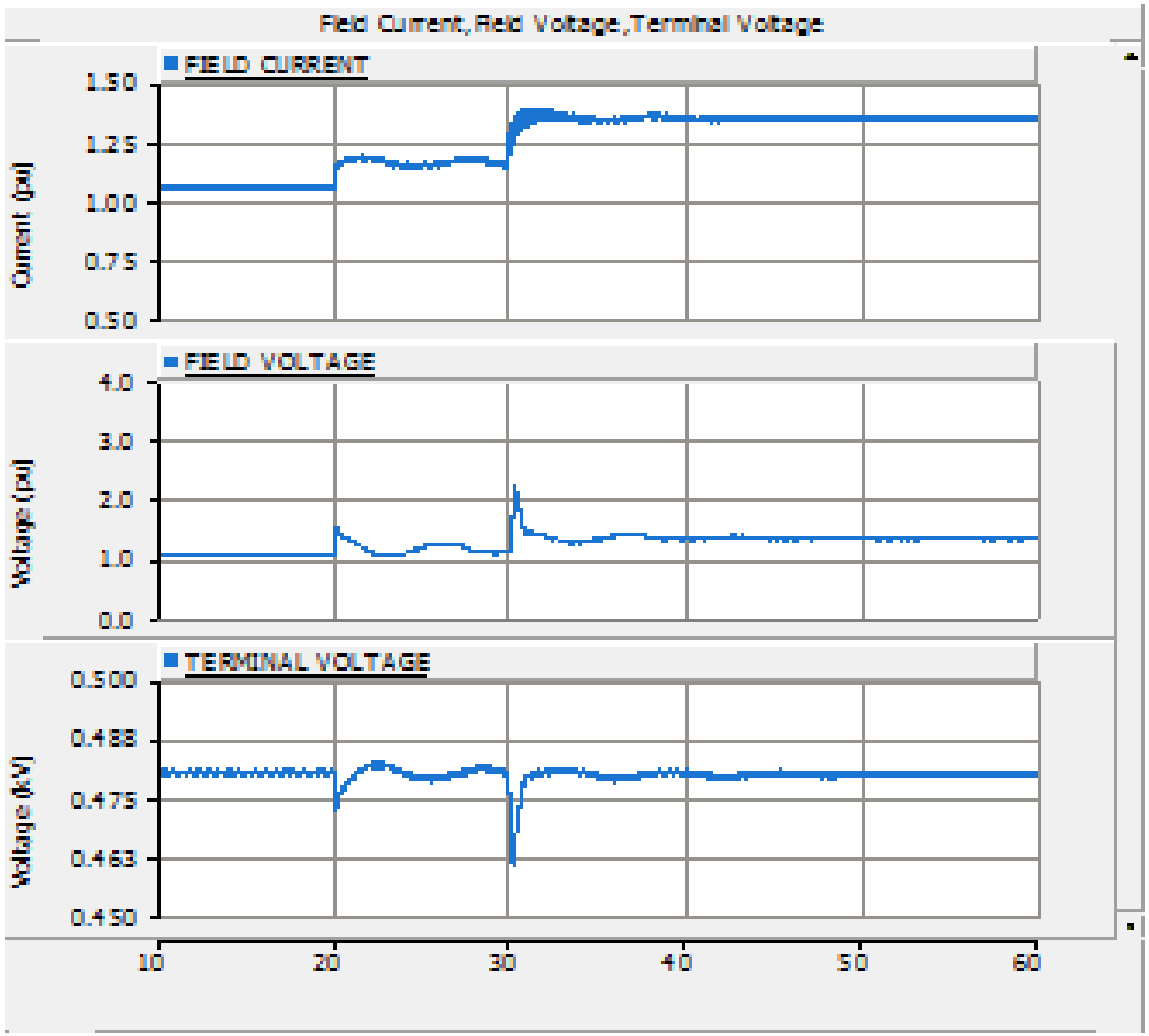


Fig. 16. Field current, field voltage of the exciter, and terminal voltage of the diesel generator

Conclusions

- This paper describes the deployment of a river generator installed in a small system. The turbine dynamics of a river generator, electrical generator, and power converter were modeled in detail. Thus, various simulations can be exercised, and the impact of different control algorithms, failures of power switches, and corresponding impacts can be examined.

- In this paper, the river generator is connected to a small isolated grid, and the power system network is supplied by a diesel generator. The frequency and the voltage regulation are represented by the governor and the exciter dynamic models. Similarly, the variations in load (size and type) are presented to observe the impact of the size of the resistive loads and the reactive loads.

- The river generator is normally controlled to generate maximum energy from the water flow; however, the real and reactive power can be modulated to provide ancillary services to the grid.