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Simulating the 5 kW New Energy Current Energy Converter in a Turbulent Environment

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Abstract

Microgrids have many factors, such as energy resource variability, to consider when adding a new source of power. While large grids can balance out fluctuations, microgrids typically require energy storage to handle these fluctuations in demand or availability. Current Energy Converters (CEC) naturally fluctuate with the ocean or river current. These fluctuations can vary day to day with rain fall or glacier melt but are considered more predictable than wind or solar. For microgrids, these fluctuations may represent a higher proportion of the energy mix, their relative contributions must be understood and properly taken into consideration. Power curves from CEC manufacturers don't typically provide enough information to predict how a CEC will perform in turbulence or transitional flows. Being able to predict power generation in a range of flow conditions is critical to properly model a CEC integrated into a microgrid. A University of Alaska Fairbanks (UAF)-owned New Energy 5kW CEC has been tested over several seasons at UAF's Tanana River Test Site (TRTS) while high resolution velocity measurements were being collected upstream of the CEC via an Acoustic Doppler Current Profiler (ADCP). This field data is being used to develop a model of the CEC to better predict how it performs under mean and turbulent flow fluctuations. The resulting Simulink model can be used in microgrid modeling for evaluating integration of a CEC device.

Keywords: Current Energy Converters, Power Systems Modeling; Microgrids

1. Introduction

There are over 200 islanded remote communities in Alaska ranging in population from a few dozen to a few thousand [1]. These communities depend on fuel shipments via barge or plane to sustain their electricity usage, resulting in high energy prices, in some cases over $1/kWh [1]. Many of these communities are located near a hydrokinetic resource [3,4]. However, since the microgrids are islanded, fluctuation from a natural water resource can greatly impact the microgrid.

The Alaska Center for Energy and Power has established a Current Energy Converter (CEC) test site in the Tanana River near Nenana, Alaska [4]. The Tanana River Test Site (TRTS) is set up to deploy CECs with a variable resistance or power load bank. This set up is meant to collect power output data from CECs at known conditions which might not be optimized for maximum power output. This set up is meant to test all possible power output situations and see how the CEC will perform. This study will focus on modeling the New Energy CEC at the TRTS so it can be validated with field data.

Nomenclature

ω_r	CEC rotor rotation
ω_g	CEC generator rotation
TSR	Tip speed ratio
v	river velocity
r	CEC radius
K	CEC specific constant
u	gear ratio
i	DC current
V	DC voltage

2. Model

The Simulink model is made to represent the New Energy 5kW CEC shown in the wiring diagram in Fig 1. The CEC produces wild AC that is fed into a rectifier with a DC load bank. During testing the load bank is set to a range of constant resistances. The CR1000X data logger shown in Fig.1 is used to record RPMs, and DC current and voltage. The AC transducer in Fig. 1 is measuring AC voltage and current. For this Simulink model the main objective will be getting the DC voltage and current measurements to closely resemble the measured values at the TRTS.

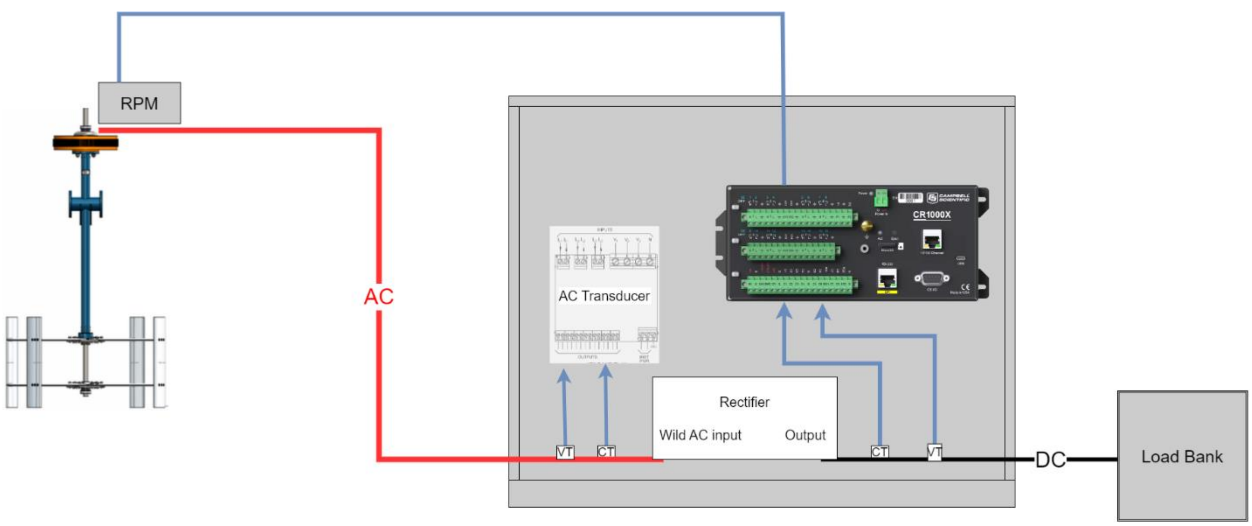

Fig. 1. Wiring diagram of the New Energy 5kw CEC at the Tanana River Test Site including all instruments connected to the CR1000X and the AC transducer.

This wiring diagram is used to create a Simulink model shown in Fig2. The CEC's RPM, and DC voltage and current will be compared to the experimental data collected at the TRTS. The difference between the experimental DC current and voltage will be used to quantify the accuracy of the model. To improve accuracy of the model a variable tip speed ratio (TSR) was input into the model based of the results from the RPM sensor from the experimental data.

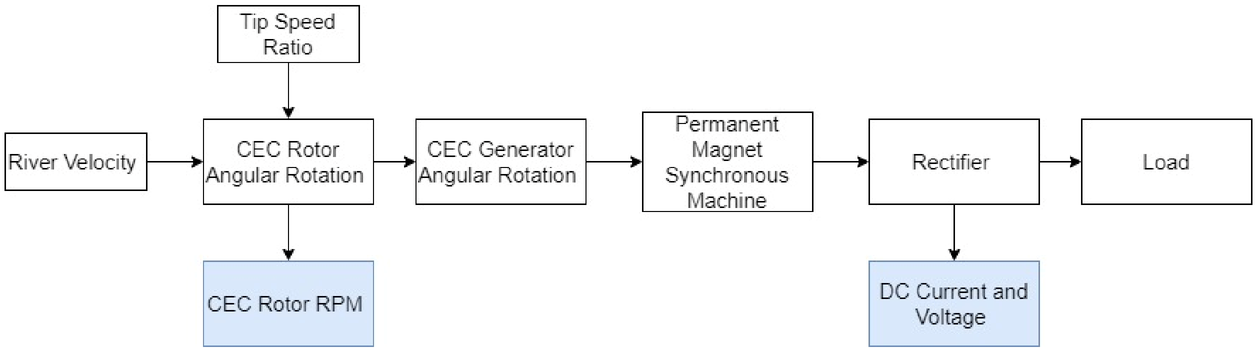

Fig. 2. Flow diagram of the model of the New Energy CEC that simulates the Tanana River Test Site Near Nenana Alaska. The light blue shaded boxes are outputs.

The mechanical portion of the Simulink model (CEC) is calculated with several equations. CEC rotor rotation is estimated using equation (1). The TSR is input based on the experimental data. This was compared to the ideal value based on the optimal values in the New Energy spec sheet [5] and calculated to be 2.4. The rotor radius is 0.75m. Figure 3 displays the resulting CEC rotor rotation in RPM using the variable TSR. The model results are identical to the experimental data.

$$\omega_r = \frac{TSR * v}{r} \tag{1}$$

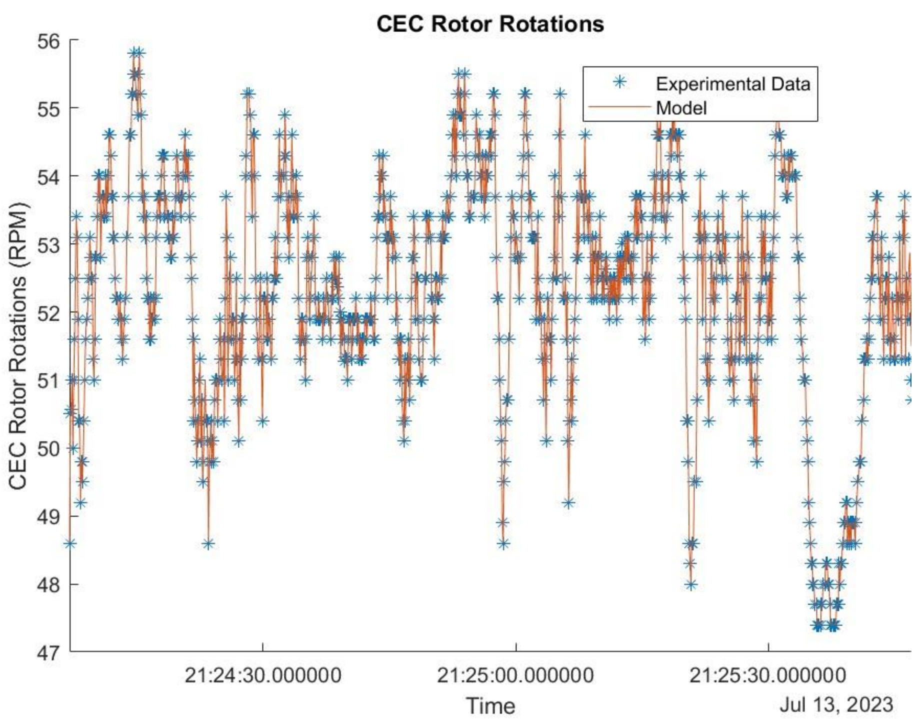

Fig. 3. CEC rotor RPM experimental vs modeled data.

The CEC generator rotations is calculated using equation (2). The rotation from the rotor was then converted to rotation on the motor, equation (3), using the gear ratio of 16.62 printed on the New Energy CEC nameplate.

$$\omega_g = \omega_r * u \quad (2)$$

For overall comparison power is calculated using equation (4). The percent error is used to quantify the difference between the model and experimental results, equation (3).

$$Power = i * V \quad (3)$$

$$Error = \frac{|Experiment - model|}{Experiment} 100\% \quad (4)$$

The Permanent Magnet Synchronous Machine and Rectifier blocks are from the Simulink Simscape library. The Permanent Magnet Synchronous Machine built into the New Energy CEC had limited information on the nameplate so the generator specifications from a previous electrical model based on a TRTS deployment with similar generator size was used [6].

3. Results

The power of the experimental and modeled data at a constant load of 10 ohms is shown in Figure 4 for the duration of 100 seconds. The average percent error for this time window is 10.38%, listed in table (1).

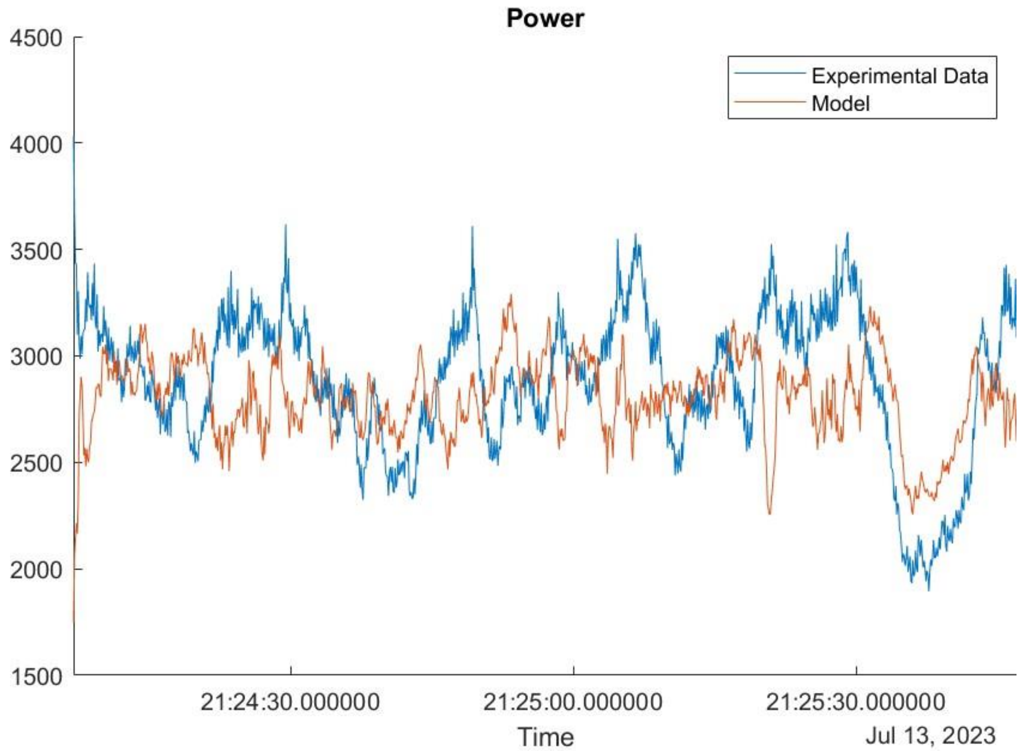

Fig. 4. CEC rotor RPM experimental vs modeled data.

Table 1. Percent error values listed for model simulated time window of 100 seconds.

	Average Error (%)
Power	10.38
Current	5.179
Voltage	5.397

4. Conclusion

This Simulink model is a starting point to model the variation of power production from a CEC. We hope to run further test on our generator to tailor the model to our specific generator. The results from this model can be used to verify and apply the mechanical rotation calculation to other power system models that are optimized for power usage. Being able to accurately model the power output of different CECs will be key to implementing them in remote communities.

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