CWC Generator

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Design Requirements Summary

Table 1: Customer Requirements

Customer Requirements		Description
CR1	Low Voltage	Client set safety standard
CR2	Small Size	Intended for a small-scale wind turbine
CR3	High Power	To perform well in the CWC
CR4	Under Budget	Limited to funds and donations
CR5	Adaptable Kv and Power	For future guideline changes and improvements, tip speed ratio and power curve required
CR6	Up to CWC Design Standards	Eligible to be used in competition
CR7	3 Phase AC Generator	Standard efficient small scale generator design
CR8	Tip Speed Ratio of 7 m/s	Efficient ratio for small scale wind turbines

Table 2: Engineering Requirements

Engineering Requirements		Description	Units
ER1	Maximum 48 Volts	CWC safety guidelines	V
ER2	45 cm Rotor Diameter	CWC guidelines of turbines	cm
ER3	Low Cogging Torque	Higher Efficiency at lower wind speeds	Nm
ER4	Low Kv Rating	Below 150 is desired for our design, this increases with voltage	N/A
ER5	High Power Output	Based on maximum wind speed	W
ER6	Number of Coils	Determined by stator geometry and fill ratio	N/A
ER7	Diameter of Coil	The gauge to be used in coil	cm
ER8	Cut Out Speed	Based on peak RPM that generates 48 V	m/s
ER9	Cut In Speed	CWC guidelines and higher efficiency	m/s
ER10	RPM	Range based on tip speed ratio	RPM
ER11	Current	From power calculations	A
ER12	Generator Torque	Power and RPM from Kv rating	Nm
ER13	Stator Skew	Based on calculation of range	N/A
ER14	Small Scale	Diameter, thickness, etc	cm

Top Level Testing Summary

Table 3: Testing Summary

Experiment #	What is Tested	Relevant DRs	Equipment Needed
1	No load dynamometer sweep	CR1, CR5, ER1, ER3, ER4	All Experiments will use the following: 1. Generator 2. Dynamometer 3. Other Things connected to the Dynamometer
2	Constant resistance dynamometer sweep	CR1, CR3, CR5, ER1, ER3, ER4	
3	Constant current dynamometer sweep	CR1, CR3, CR5, ER1, ER3, ER4	

Detailed Testing Plan

Experiment 1

What is being tested

- Determine how output voltage changes with rotational speed
- Use voltage–speed relationship to calculate Kv rating
- Measure resistive torque (internal friction + magnetic effects)
- Equipment: Arduino Uno, 3-phase rectifier + voltage divider, IR speed sensor, torque transducer, multimeter, dynamometer

Procedure

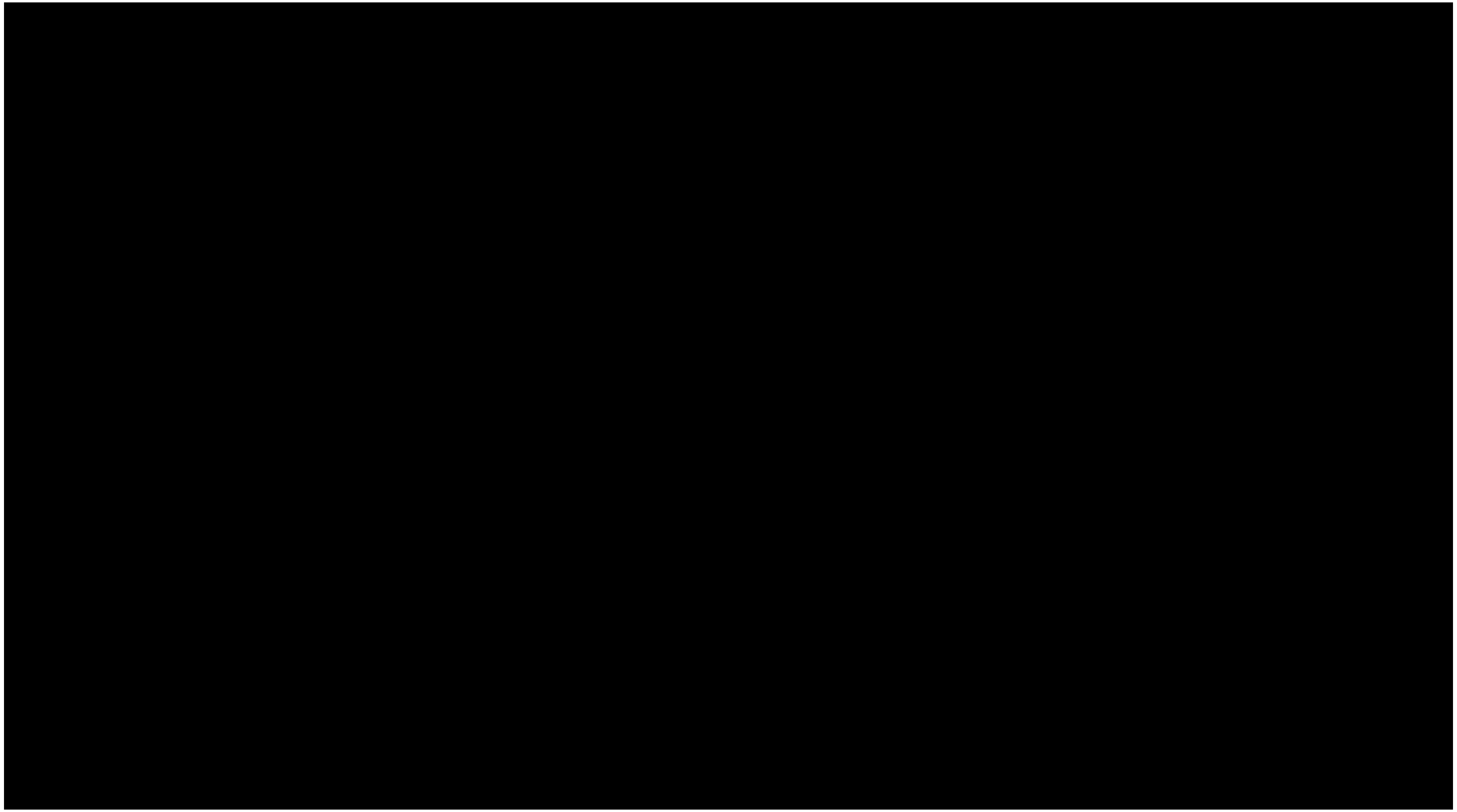
1. Mount generator and couple shaft to the dynamometer
2. Connect generator → rectifier → voltage divider → DAQ system
3. Integrate sensors with DAQ system:
    1. IR sensor → speed
    2. Torque transducer → torque
    3. Voltage divider → voltage
4. Power dynamometer and increase speed quasi-statically, collecting data at each step
5. Stop system at max speed and export data for analysis

Expected Results – What we will obtain

- Linear relationship between voltage and rotational speed
- Slope of V vs. RPM = Kv value
- Expected range: 117–150 RPM/V
- Approx. 38–48 V at max 5700 RPM
- Torque data used to calculate resistive torque required to begin rotation

$$Kv = \frac{\omega}{V}$$

Detailed Testing Plan



Detailed Testing Plan

Experiment 2 & 3

What is being tested

Determine: Kv rating, peak voltage, resistive torque, electrical & mechanical power

Verifies design requirements: low Kv, max voltage, low resistive torque, high power output

Equipment: external motor, torque transducer, IR speed sensor, Hall-effect current sensor, AC-DC rectifier, voltage divider, DAQ system

Procedure – How the test is performed

1. Mount generator and connect shaft to dynamometer
2. Connect generator → rectifier → voltage divider → DAQ system
3. Integrate sensors:
4. Torque transducer (torque)
5. IR sensor (speed)
6. Current sensor (current)
7. Power dynamometer and sweep speed quasi-statically, recording data at each step
8. Stop test at maximum throttle and process data

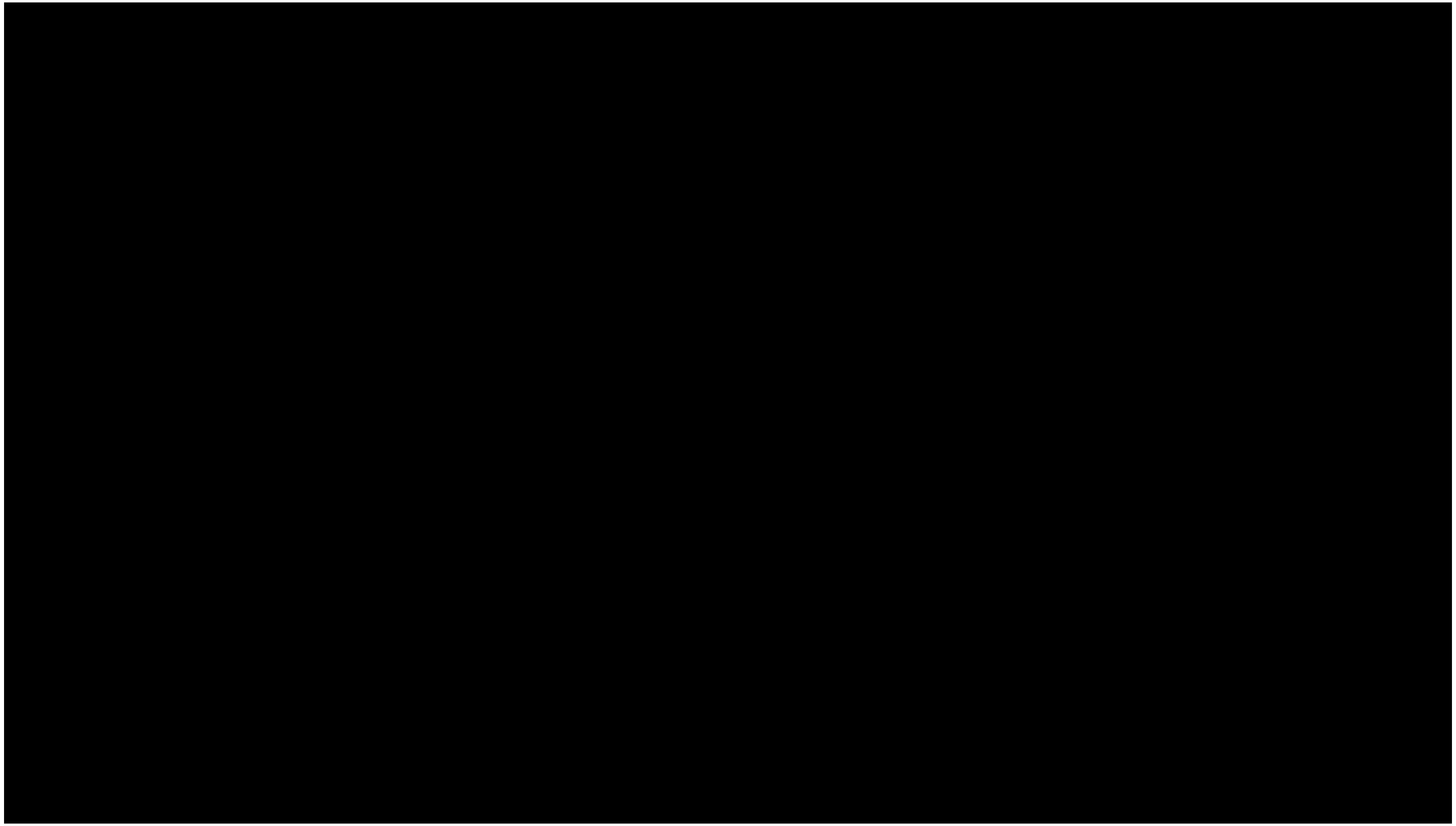
Expected Results – What we will obtain

- Nonlinear voltage vs. speed curve → determines Kv rating
- Resistive torque determined from torque required before rotation
- Mechanical power = torque × rotational speed
- Electrical power = voltage × current

$$P_m = T\omega$$

$$P_e = VI$$

Detailed Testing Plan



Results – Kv Curves

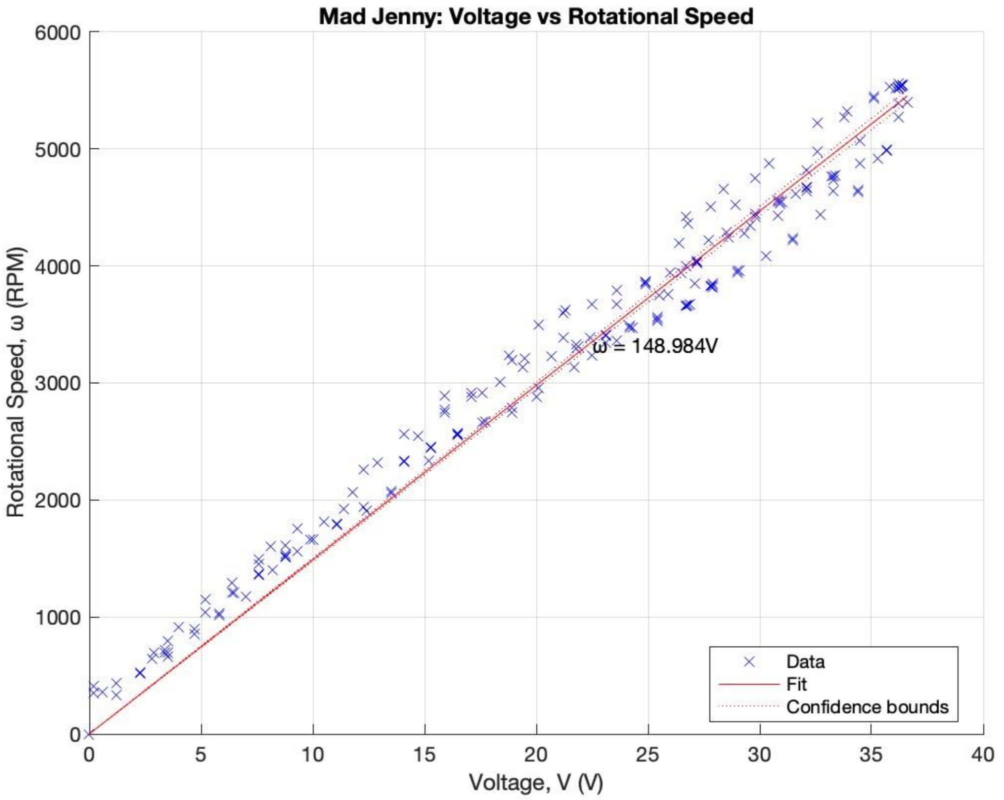


Figure 1: Mad Jenny Kv Curve

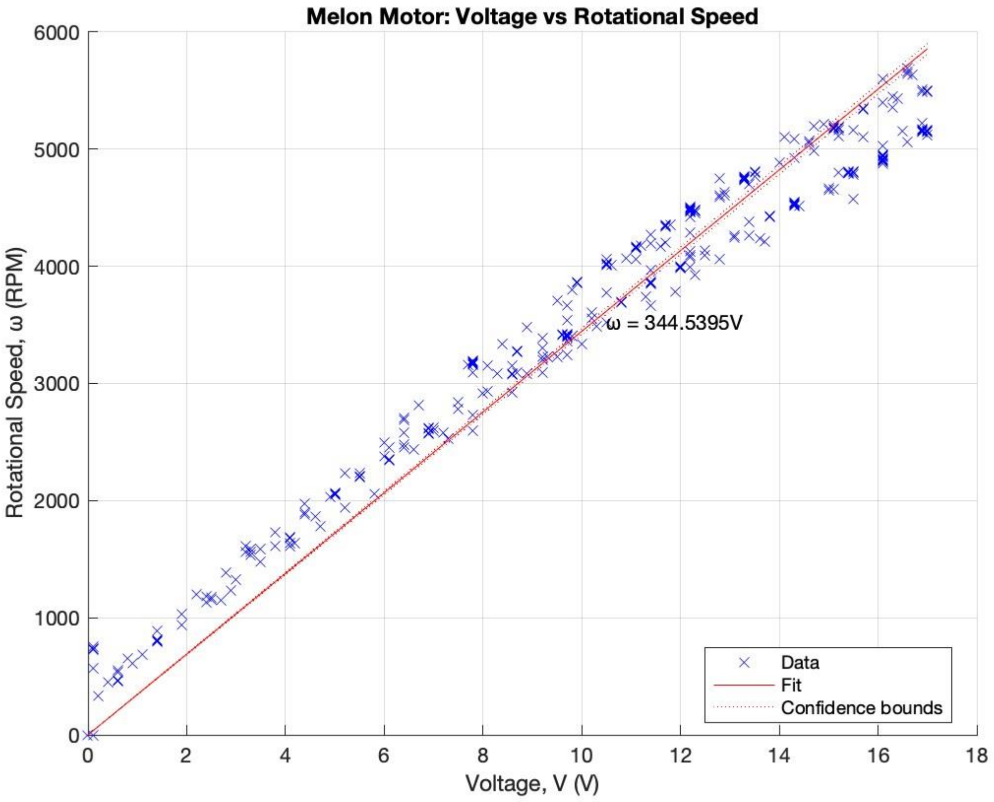


Figure 2: Melon Motor Kv Curve

Results – Constant Resistance Power Curves

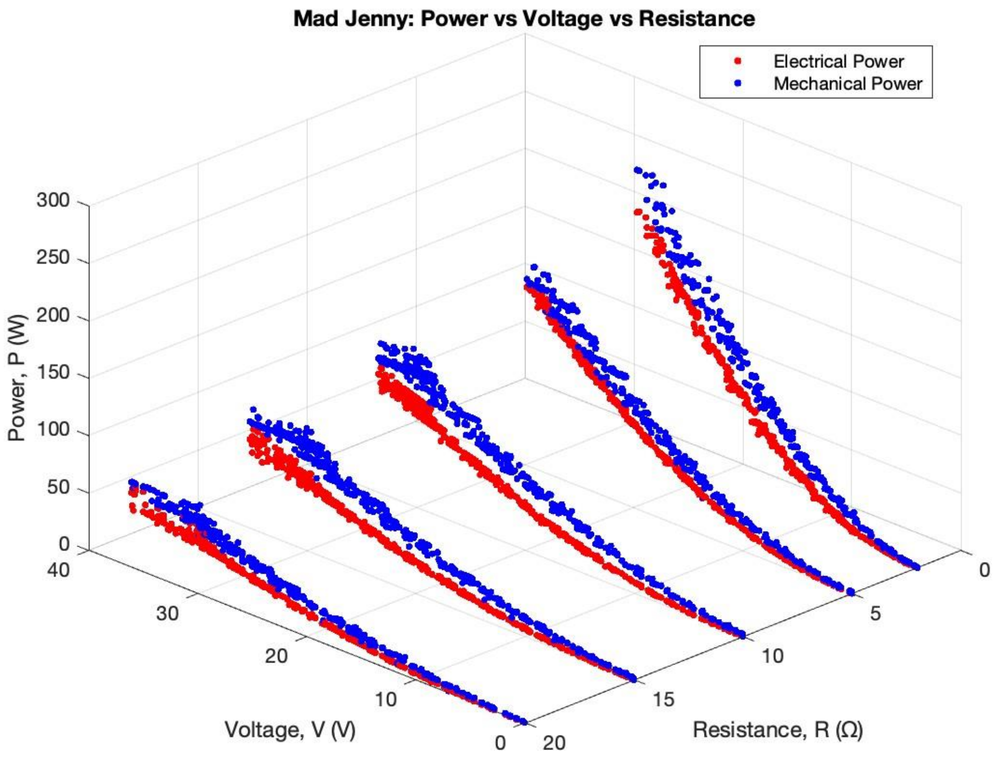


Figure 3: Mad Jenny Power Curve with Constant Resistance

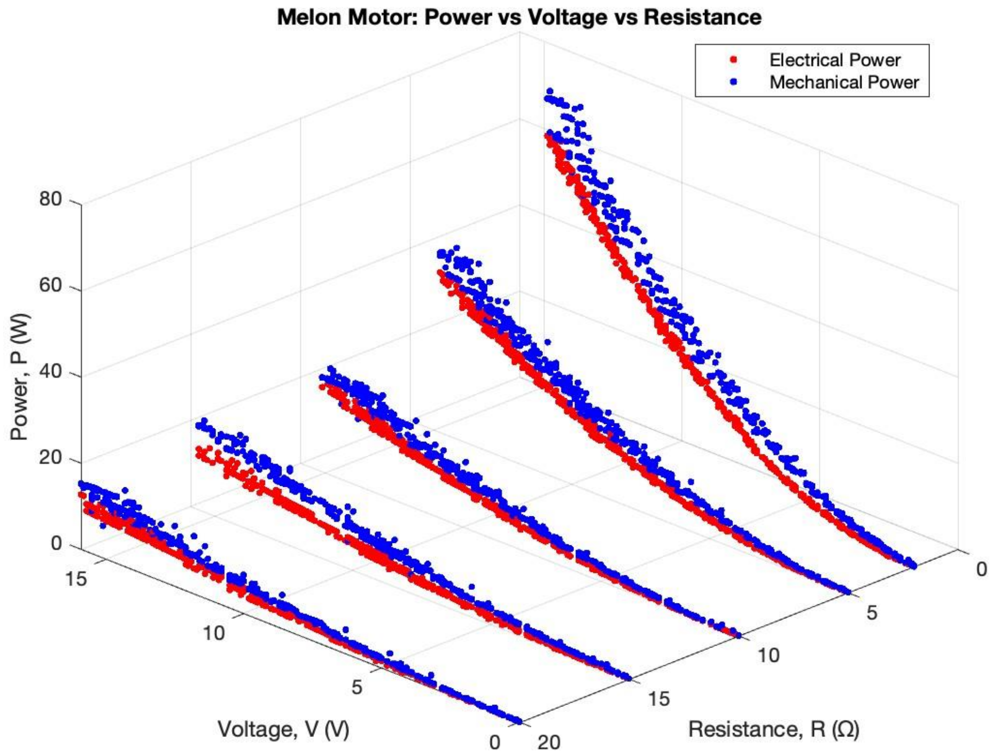


Figure 4: Melon Motor Power Curve with Constant Resistance

Results – Constant Current Power Curves

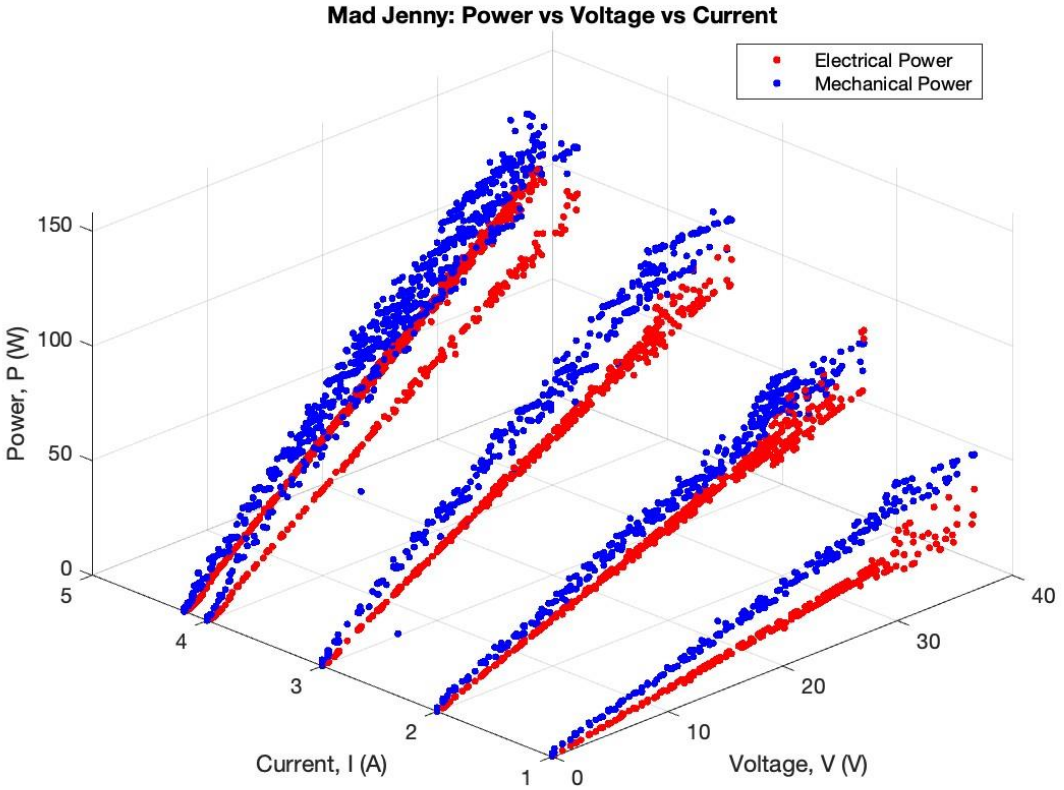


Figure 5: Mad Jenny Power Curve with Constant Current

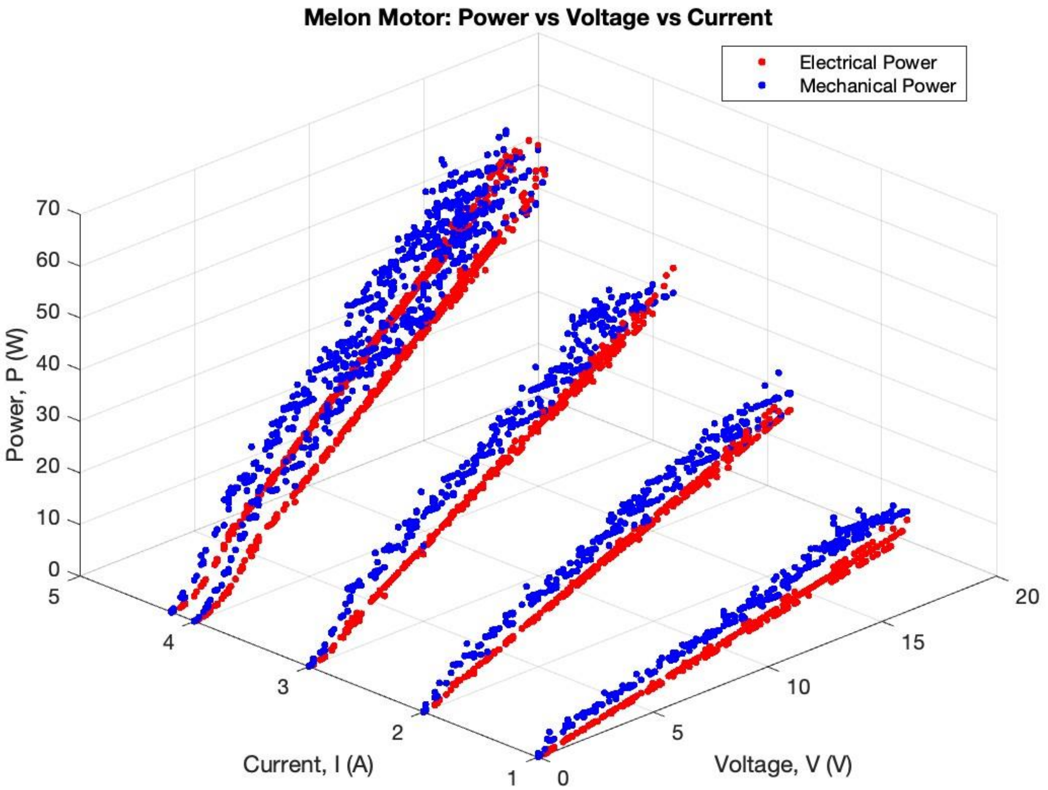


Figure 6: Melon Motor Power Curve with Constant Resistance

Specification Sheet Preparation

Table 4: Customer Requirements

Customer Requirements		CR met?	Client Acceptable?
CR1	Low Voltage	Y	Y
CR2	Small Size	Y	Y
CR3	High Power	N	
CR4	Under Budget	Y	Y
CR5	Adaptable	Y	
CR6	Up to CWC Design Standards	Y	Y
CR7	3 Phase AC Generator	Y	Y
CR8	Tip Speed Ratio of 7 m/s		

Specification Sheet Preparation

Table 5: Engineering Requirements

Engineering Requirements		Target	Tolerance	Measured/Calculate Value	ER Met?	Client Acceptable?
ER1	Maximum 48 Volts	48V	N/A	N/A	Y	Y
ER2	45 cm Rotor Diameter	45 cm	±5 cm			
ER3	Low Cogging Torque	N/A	N/A	N/A	Y	Y
ER4	Low Kv Rating	150	±10	25,200	N	
ER5	High Power Output	100 kW	±50 kW	0 kW	N	
ER6	Number of Coils	15	±2	13	Y	Y
ER7	Diameter of Coil	23 AWG	N/A	22 AWG	N	
ER8	Cut Out Speed	25 m/s	±1 m/s			
ER9	Cut In Speed	3 m/s	±0.5 m/s			
ER10	RPM	5600 rpm	±500 rpm	5040 rpm	N	
ER11	Current	23 A	±2 A	0 A	N	
ER12	Generator Torque	2 Nm	±0.5 Nm			
ER13	Stator Skew	2 degrees	±1 degree	2	Y	Y
ER14	Small Scale	1.18 in Diameter	±0.01			

QFD

House Of Quality			Maximum 48 Volts	45 cm Rotor Diameter	Low Cogging Torque [Nm]	Low Kv Rating	High Power Output [W]	Number of Coils	Wire Gauge	Cut Out Speed	Cut In Speed	RPM	Current	Generator Torque	Stator Skew	Small Scale	Competitive Assessment		
	Customer Requirements (What)	Importance	1	2	3	4	5	6	7	8	9	10	11	12	13	14	1	2	3
1	Low Voltage	100	9	3	9	9	9	9	9	9	9	9	9	3	3	1	1	9	3
2	Small Size	74	3	9	9	1	9	9	9	1	1	1	3	1	9	9	1	9	1
3	High Power	100	9	1	9	9	9	9	9	9	9	9	9	3	3	3	9	3	1
4	Under Budget	34	1	3	1	1	3	3	3	3	3	1	1	1	1	9	1	3	9
5	Adaptable Kv and Power	52	1	3	3	9	3	9	9	1	1	3	3	3	3	1	3	3	1
6	Up to CWC Standards	100	9	9	9	9	9	3	9	9	9	9	3	3	1	9	9	9	3
7	3 phase AC	48	3	3	3	3	1	9	3	1	1	3	9	3	3	3	3	9	9
8	70 m/s Tip Speed Ratio	62	3	9	1	3	3	1	1	9	9	9	1	3	1	9	9	9	9
		Target	48 V	45 cm	2 N-m	<150	100 kW	15 coils	23 AWG	25 m/s	3 m/s	5760-7200 RPM	23 A	2 Nm	2 degrees	1.18 in Diameter			
		Importance	38	40	44	44	46	52	52	42	42	44	38	20	24	44			

Figure 7: QFD

Thank you
Any questions?

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