CWC Generator

Christian Brown, Naomi Echo, Alonso Garcia, Javan Jake, Kaitlyn Redman

NAU NORTHERN ARIZONA UNIVERSITY

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

- **Measurements:** Voltage (V), Rotational Speed (ω)
- **Calculation:** Kv rating
- **Equipment:** Arduino Uno, 3-phase rectifier, voltage divider, infrared sensor, dynamometer

Procedure

1. Mount generator to the dynamometer
    - To measure rotational speed
2. Connect generator phases to DAQ system
    - To measure voltage
3. Power dynamometer and increase speed quasi-statically, collecting data at each step
4. Stop system at max speed and export data for analysis

Expected Results

- Linear relationship of ω vs V
    - Slope of ω vs V = Kv
- ➉ Kv = 117 – 150 RPM/V
- ➉ V = 38 – 48 V
- ➉ ω = 5700 RPM (max)

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

Detailed Testing Plan

Experiment 2 & 3

What is being tested

1. **Measurements:** Voltage (V), Current (A), Rotational Speed(ω), Torque (τ)
2. **Calculations:** Mechanical Power (P_m), Electrical Power (P_e)
3. **Equipment:** Arduino Uno, 3-phase rectifier, voltage divider, infrared sensor, dynamometer, torque transducer, current sensor, programmable load

Procedure

1. Mount generator to the dynamometer
    - To measure rotational speed and torque
2. Connect generator phases to DAQ system
    - To measure voltage and current
3. Set programmable load to constant load value
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

- Non-linear relationship of ω vs V

❿ V = 38 – 48 V
❿ A = 2.4 - 24 A
❿ ω = 5700 RPM (max)
❿ $P_e = 1{,}150 \text{ W} \lesssim P_m$

$$P_m = T\omega$$

$$P_e = VI$$

Detailed Testing Plan

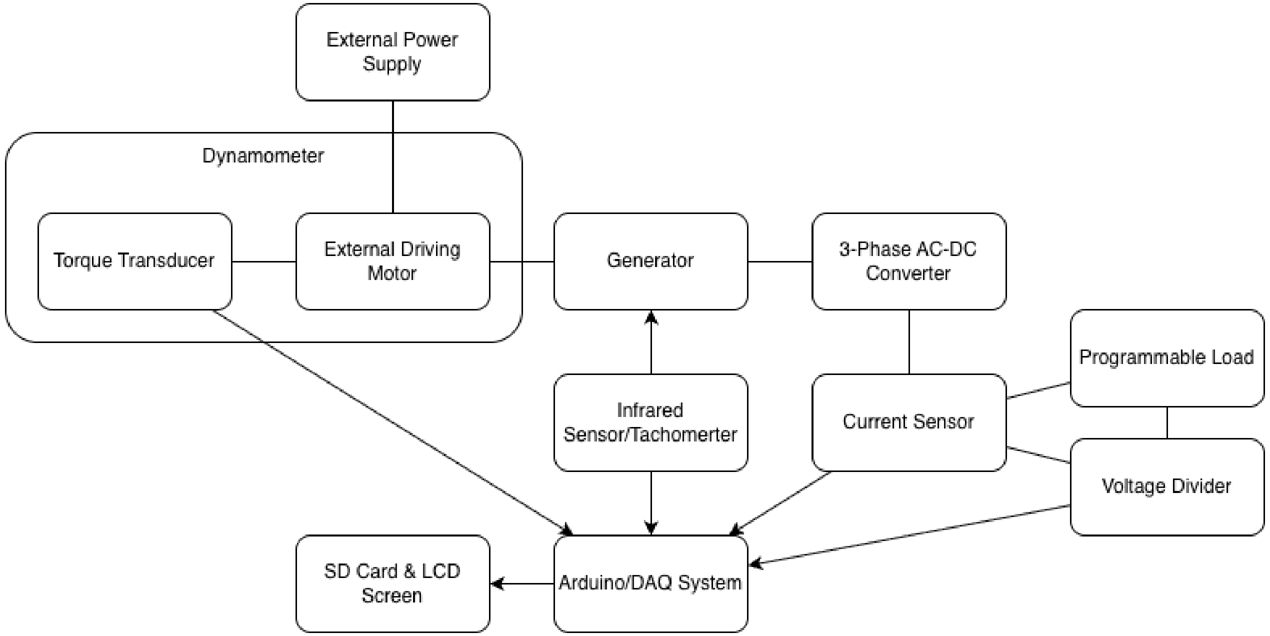


Figure 1: Schematic of testing apparatus

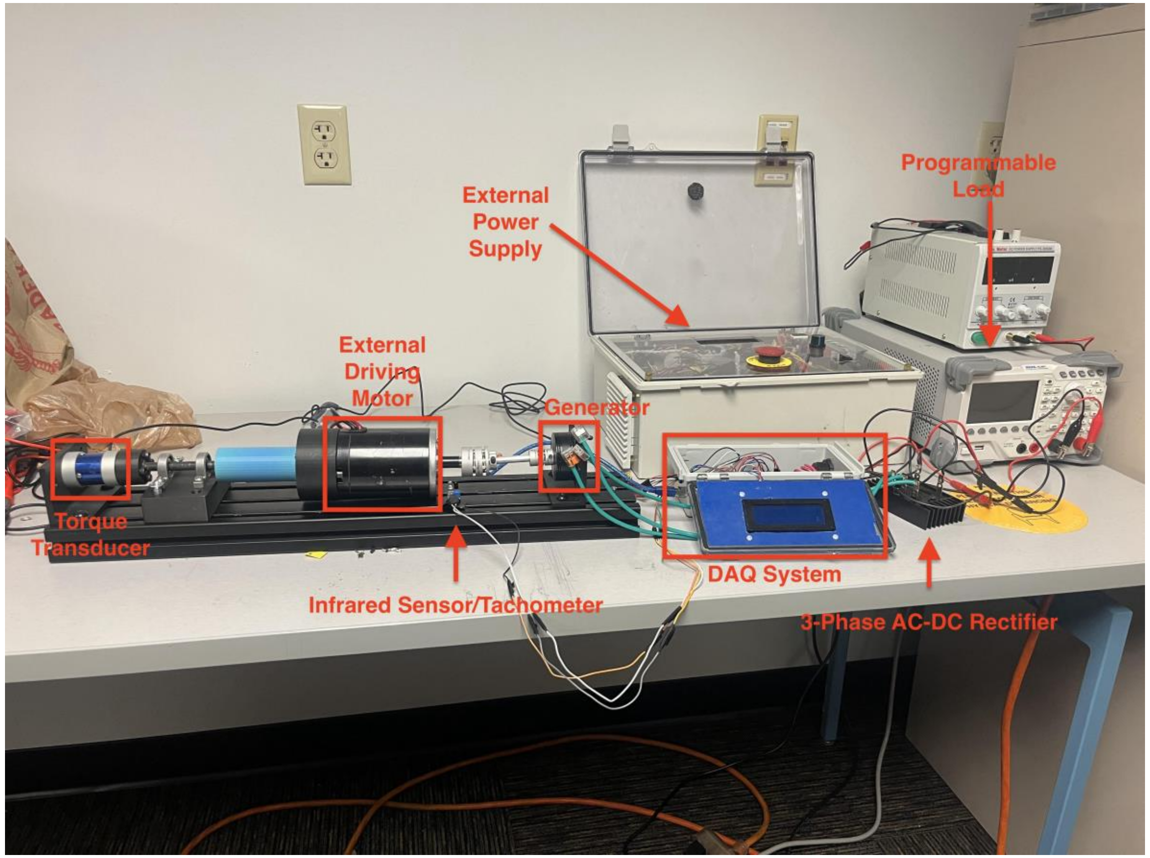
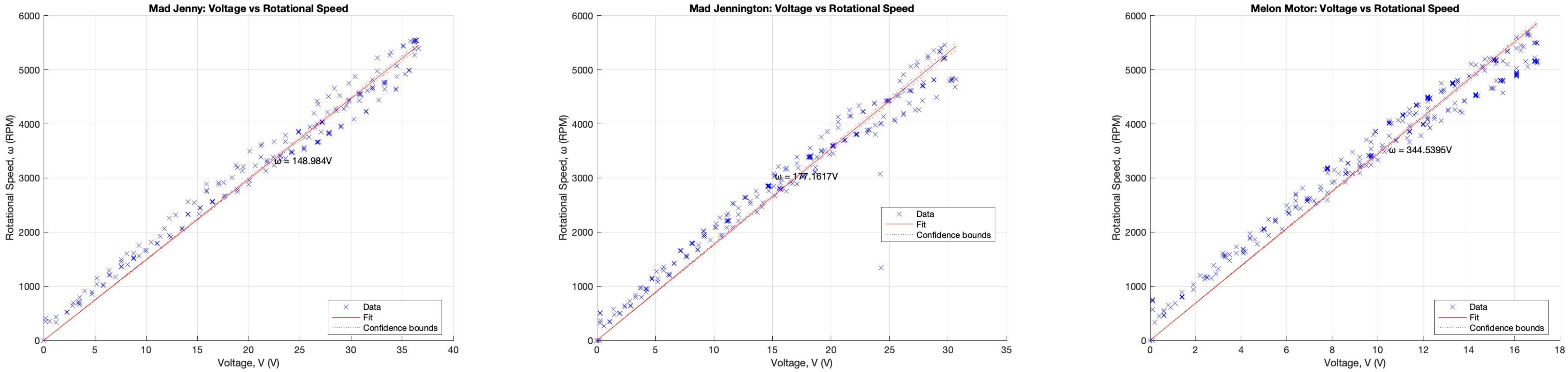


Figure 2: Physical testing apparatus

Results/Data

Kv Curves



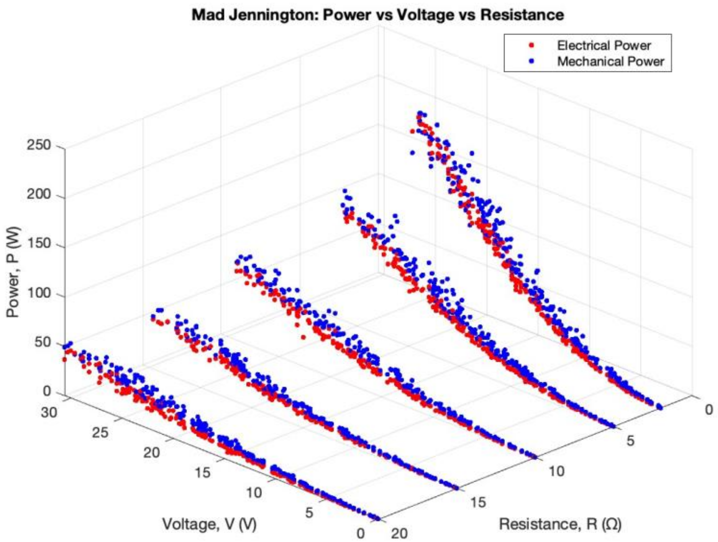
(a) Mad Jenny **(b)** Mad Jennington **(c)** Melon Motor

Figure 3: Kv Curves

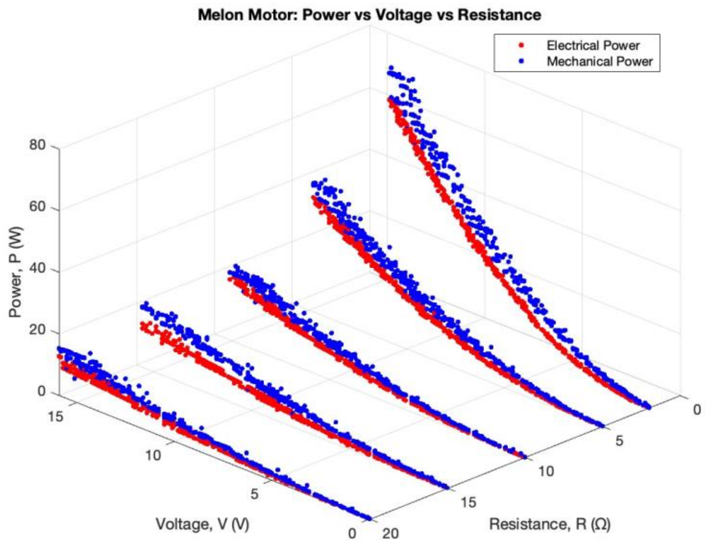
Results/Data

Constant Resistance Power Curves

(a) Mad Jenny



(b) Mad Jennington

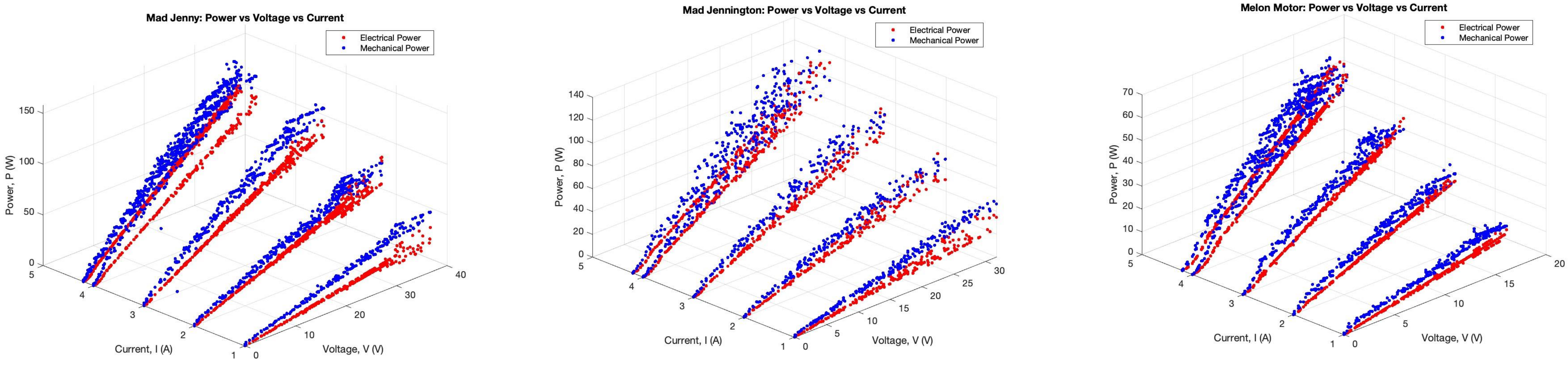


(c) Melon Motor

Figure 4: Constant Resistance Power Curves

Results/Data

Constant Current Power Curves



(a) Mad Jenny

(b) Mad Jennington

(c) Melon Motor

Figure 5: Constant Current Power Curves

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	Y
CR4	Under Budget	Y	Y
CR5	Adaptable	Y	Y
CR6	Up to CWC Design Standards	Y	Y
CR7	3 Phase AC Generator	Y	Y
CR8	Tip Speed Ratio of 7 m/s	Y	Y

Specification Sheet Completion

Table 5: Engineering Requirements Met

Engineering Requirements		Target	Tolerance	Measured/Calculate Value	ER Met?	Client Acceptable?
ER1	Maximum 48 Volts	48V	N/A	N/A	Y	Y
ER2	4.5 cm Rotor Diameter	4.5 cm	±0.5 cm	4.8 cm	Y	Y
ER3	Low Cogging Torque	N/A	N/A	N/A	Y	Y
ER4	Number of Coils	15	±2	13	Y	Y
ER5	Cut Out Speed	25 m/s	±1 m/s	25 m/s	Y	Y
ER6	Cut In Speed	3 m/s	±0.5 m/s	3 m/s	Y	Y
ER7	RPM	5500 rpm	±500 rpm	5040 rpm	Y	Y
ER8	Stator Skew	2 degrees	±1 degree	2	Y	Y
ER9	Small Scale	1.5 in Diameter	±0.5 in	1.9 in	Y	Y

Specification Sheet Completion

Table 6: Engineering Requirements Not Met

Engineering Requirements		Target	Tolerance	Measured/Calculate Value	ER Met?	Client Acceptable?
ER10	Low Kv Rating	150	±10	25,200	N	Y
ER11	High Power Output	100 kW	±50 kW	0 kW	N	Y
ER12	Diameter of Coil	23 AWG	N/A	22 AWG	N	Y
ER13	Current	23 A	±2 A	0 A	N	Y
ER14	Generator Torque	2 Nm	±0.5 Nm	0 Nm	N	Y

Caveat to no's - testing third generator and creating proper user manual for dyno are sufficient replacements. (Signed: Willy)

Potential Failures

Magnets

- Not alternating north and south
- Not spaced evenly apart

Lamination Stack

- Large air gap between layers

Recommendations- Magnets

- Ensure north and south sides are altered
- Use a 3D printed spacer to ensure even spacing

Recommendations- Lamination Stack

- Remake it with a vacuum chamber

Potential Failures

Coils

- Phases are shorting together
  - Flexing/rubbing together from the magnetic field
- Phases are shorting to lamination stack
  - Flexing/rubbing on stack
  - sharp corners not properly covered with epoxy
  - Coils are too tight
- The coils were not wound in the correct directions
  - multiple people winding

Possible Fixes - Coils

- Wind coils a bit looser to avoid over-tension
- Use phish paper instead of epoxy to cover lamination stack
- Use a clear diagram for winding to ensure correct winding directions

QFD

	House Of Quality		Technical Specifications (How): 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 6: QFD

Thank you
Any questions?

10.1 References

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