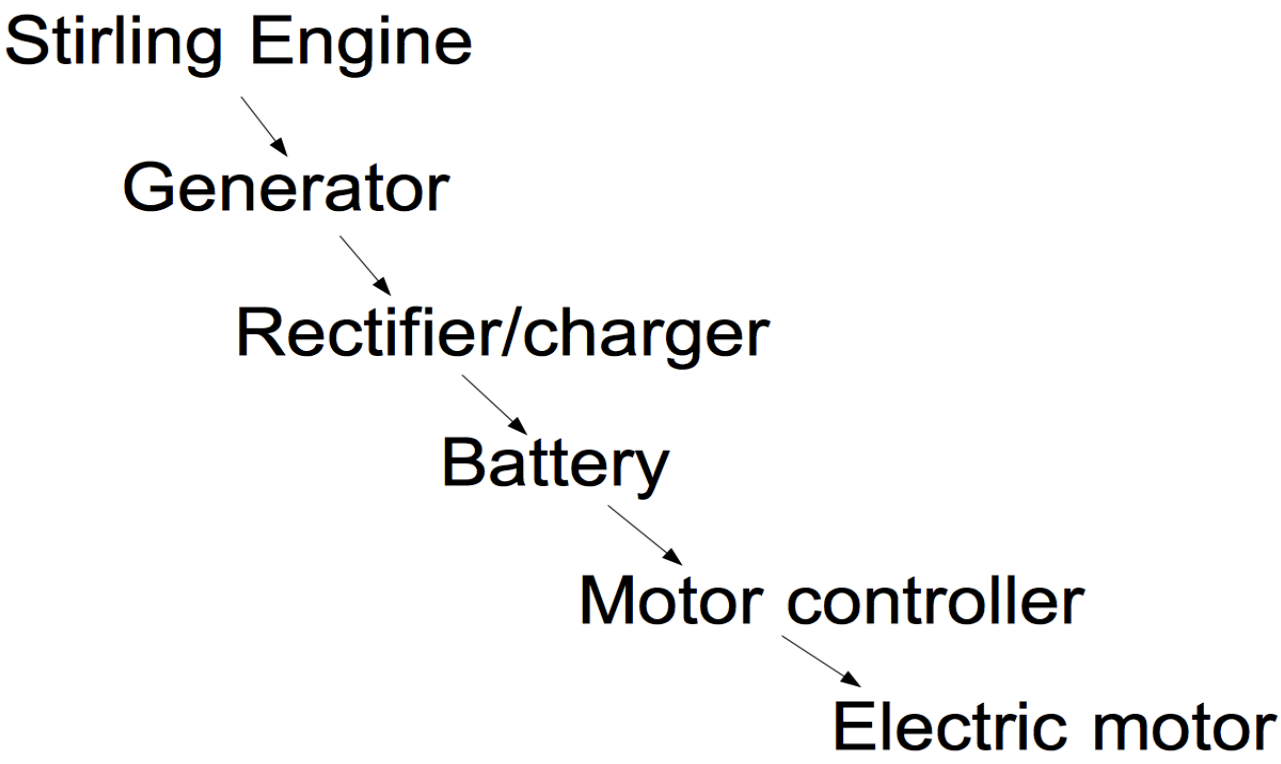
Hybrid Stirling-Electric for boats (and other applications)

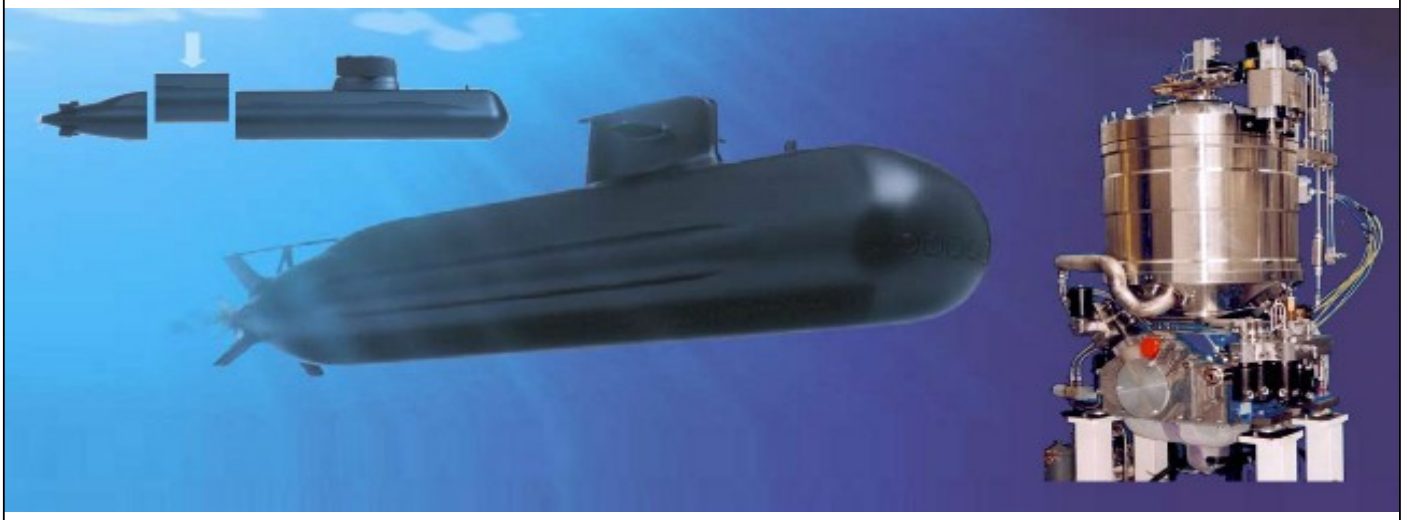
Alex Zivanovic

Stirling Engine Society Discussion Day

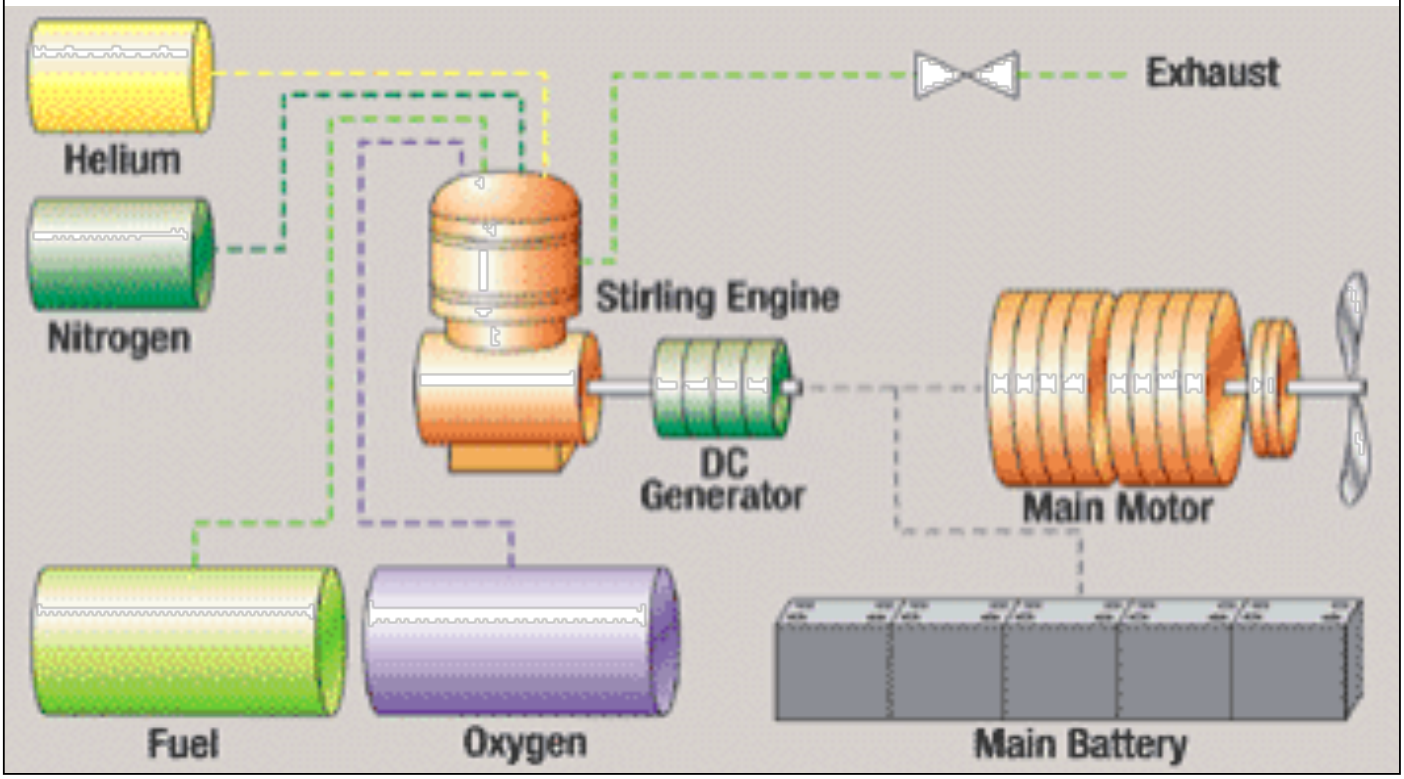
Oxford, 1 March 2014



Submarines in the Swedish Navy use a Kockums Stirling-electric hybrid system



Kockums submarine system



Advantages

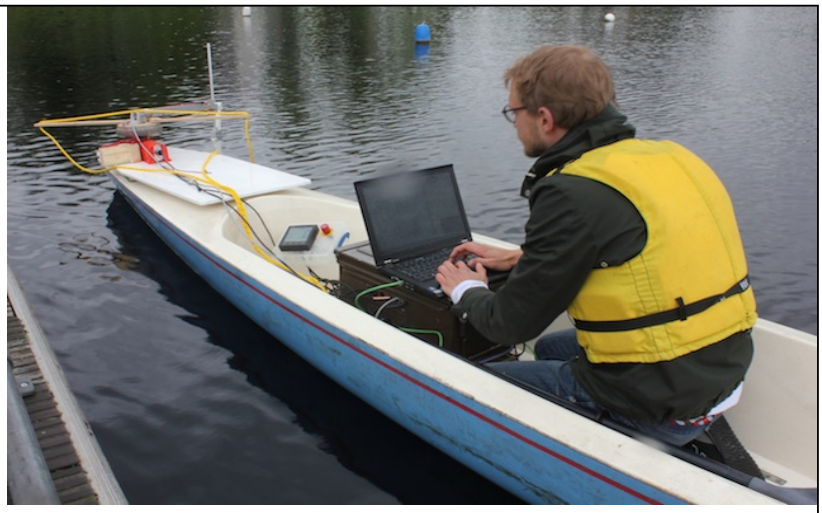
- Stirling engines are at their best when running at a constant speed with a constant load
- Charging a battery provides a constant load
- The stored energy in the battery allow bursts of higher power when necessary

Advantages

- Electric motors are easy to control (speed and direction)
- Propeller separate from stirling engine (easier installation)
- Can think of the Stirling Engine as a “range extender” for the electric system
- Or the battery as a way of “smoothing” the power from the engine

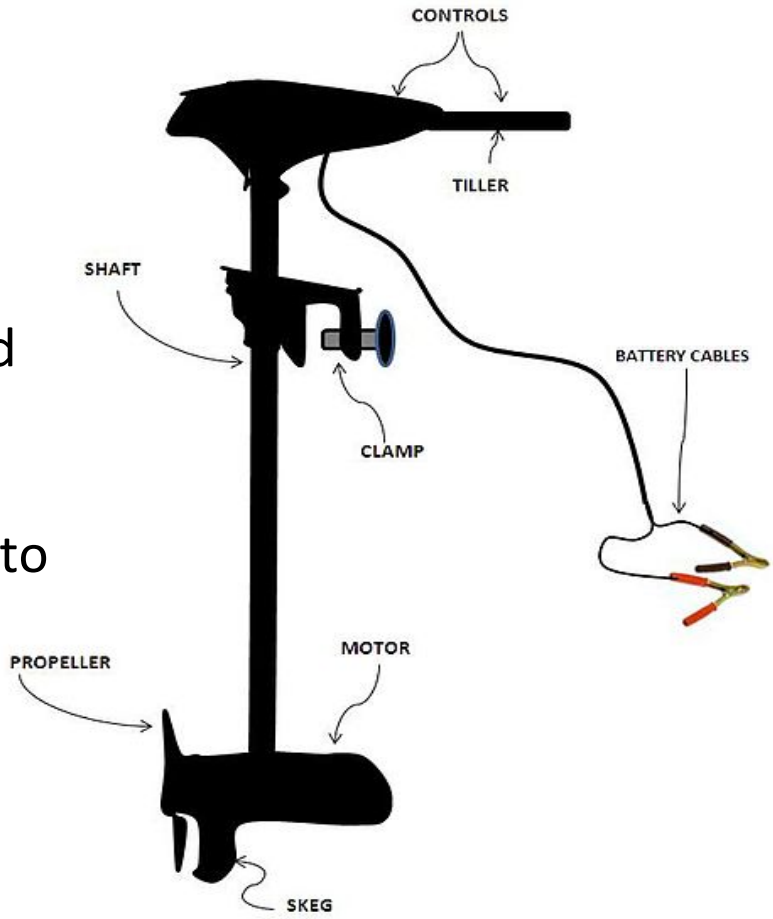
Allows experimentation with propulsion systems other than propellers (flapping foils, etc)

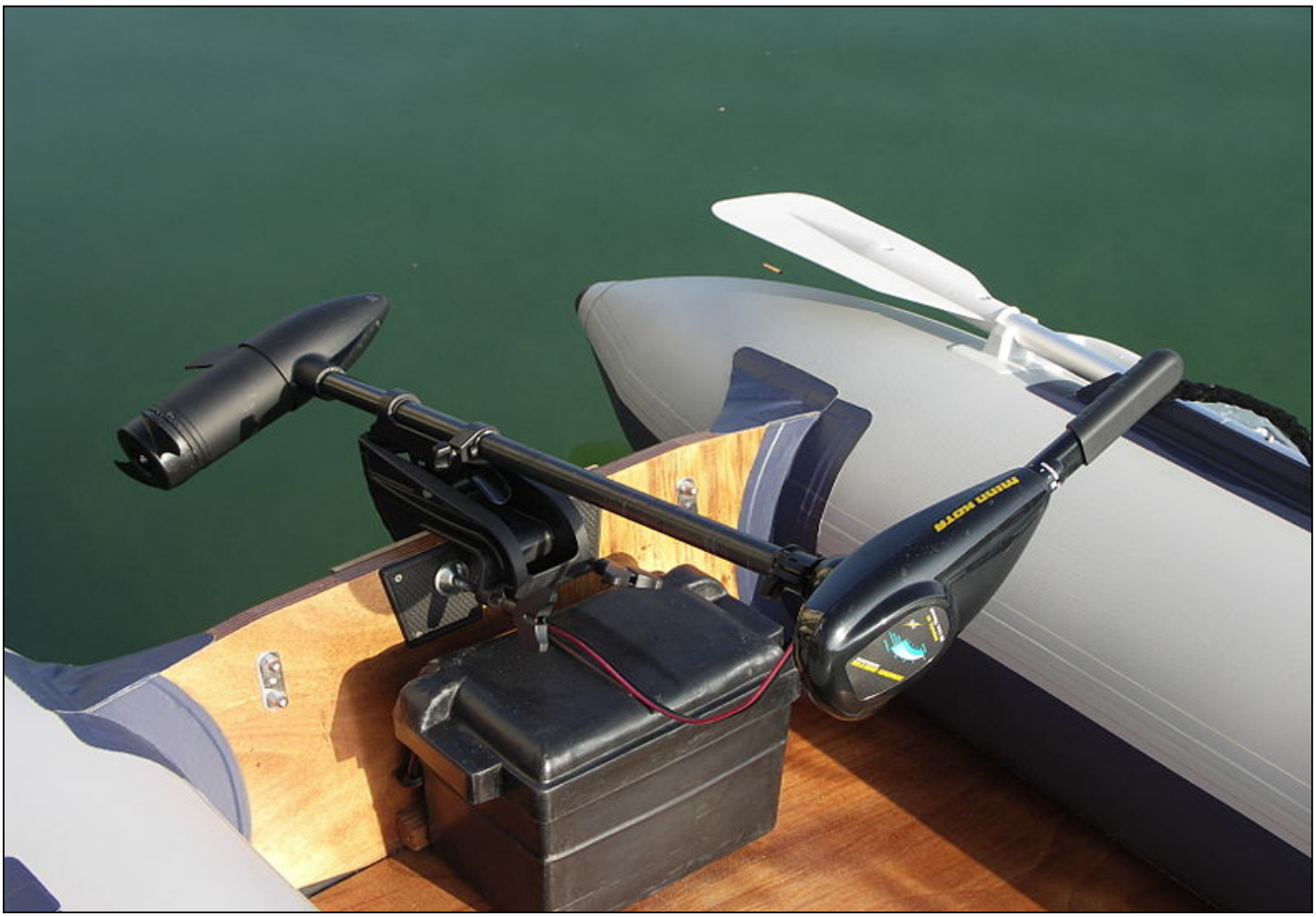
(pictures of the boat I am planning to use with the Stirling system)



Electric trolling motors

- Relatively cheap (motor + battery cost me £120 second-hand on eBay)
- Easy to install (clamps to transom)





Minn Kota Maxxum 40 motor

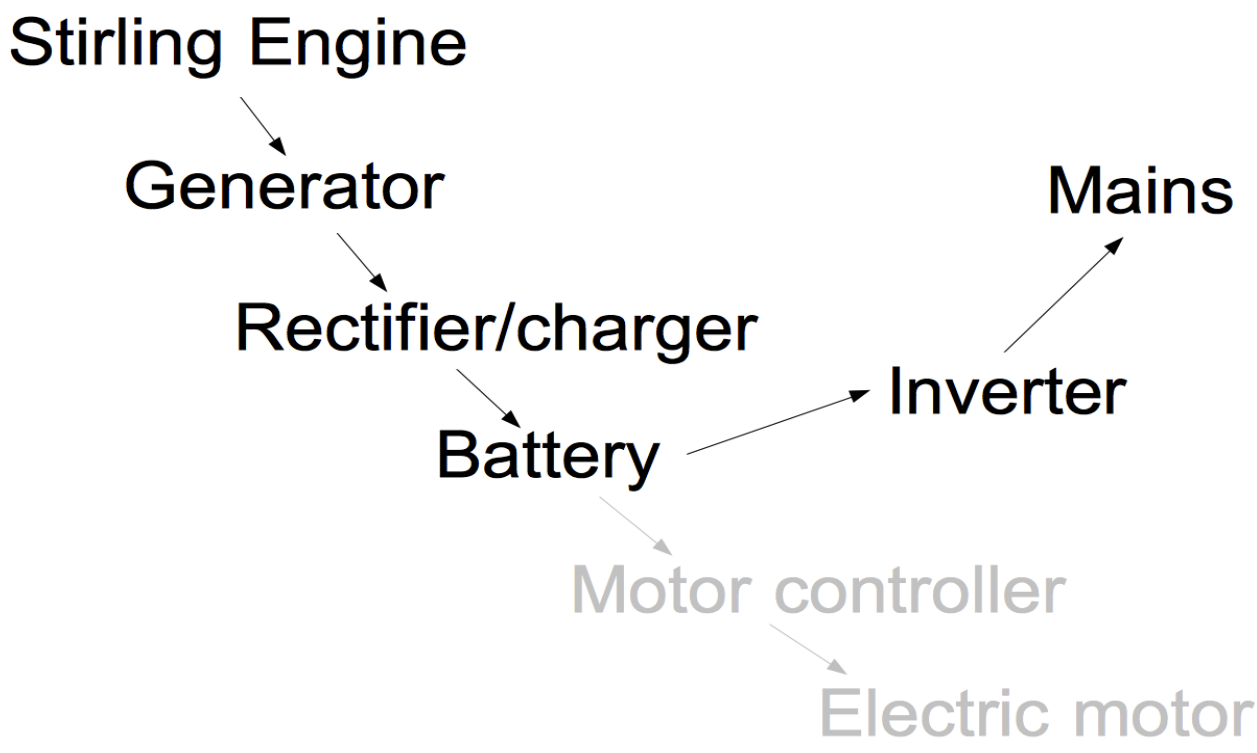
40 lbs maximum thrust

Output marked on handle	Measured Power	Approx run time with 85AH lead acid battery
10%	6 W	180 hours
25%	23 W	47 hours
50%	98 W	10.5 hours
75%	220 W	4.25 hours
100%	322 W	2.65 hours

I'm waiting for the weather to improve to see how fast my boat is at these settings

Other applications

- Not just boats…
  - Car, buggy
  - Bicycle, tricycle
  - Train (5” or $7^{1/4}$”gauge would be fun)



Disadvantages

- Efficiency Losses (we have so little power to start with…)
- Increased system complexity
- Battery replacement necessary (but less frequently than a pure electric system because the battery is not deep cycled), or could use super capacitors
- Stirling engine and Generator need to be well matched

Generator

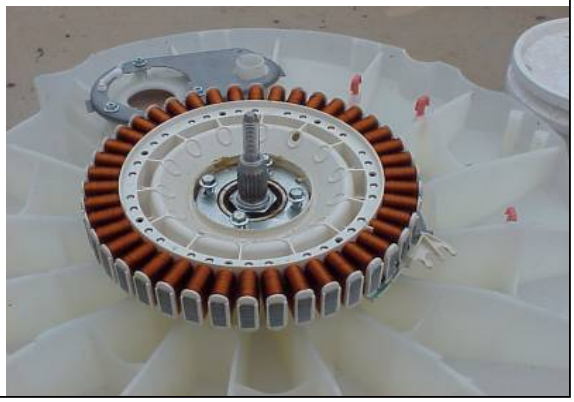
- Most generators work best at 1000s RPM
- Stirling engines in the Society are 100s RPM
- Could use gears or pulleys but there's an alternative…

Rewiring washing machine direct drive motors

- Direct Drive Motor drives washing machine drum directly (no pulleys or belts)
- Most on the internet are made by a company called *Fisher & Paykel*, based in New Zealand
- Equivalent available in UK is by LG

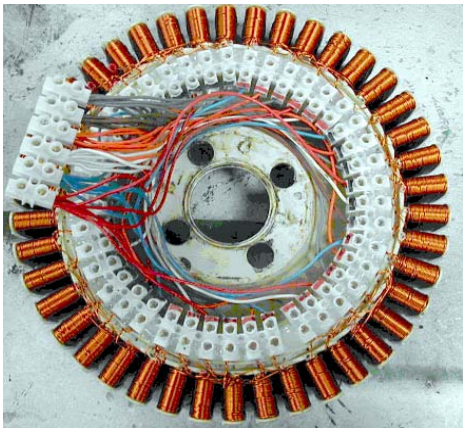
Rewiring washing machine direct drive motors

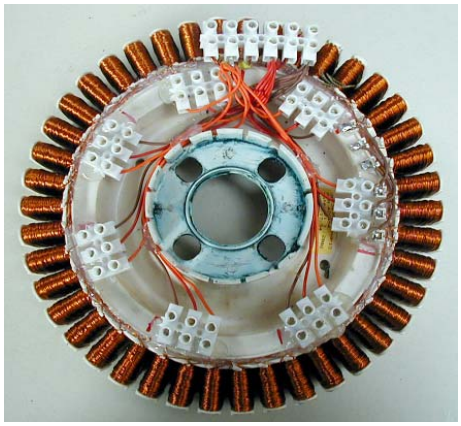
- 3 phase permanent magnet motor
- 42 or 36 poles
- Easily rewired



Configuring stators

- The stators can be reconnected in numerous configurations including series/parallel (left) and parallel (right)

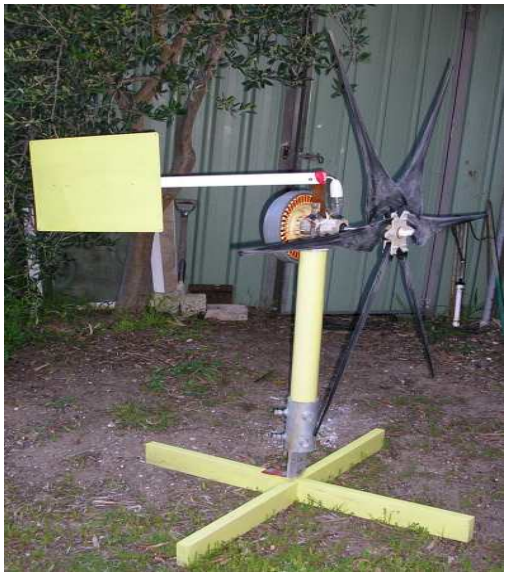




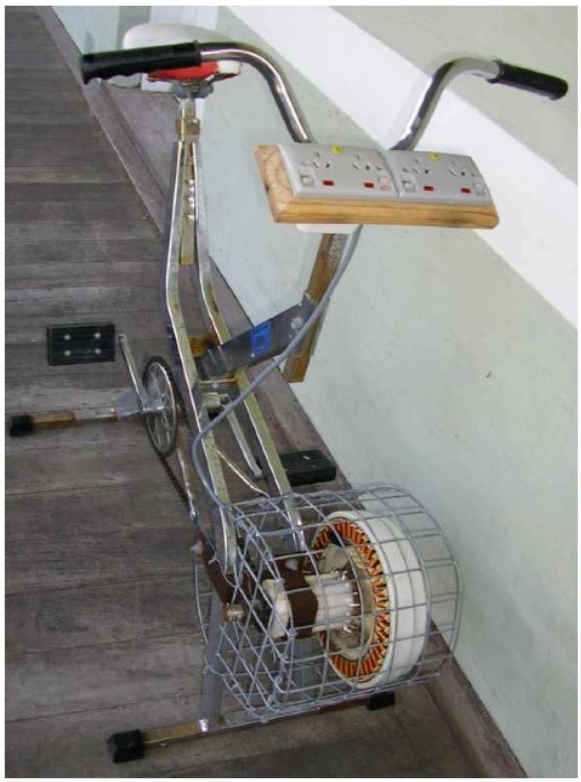
Fisher and Paykel washing machine motors for electricity generation

Applications:

- Wind generators
- Microhydroelectric generators
- Exercise bike generator
- Motor driven generator
- Scalelectric set generator
- Electric motor drive



Microhydroelectric generator



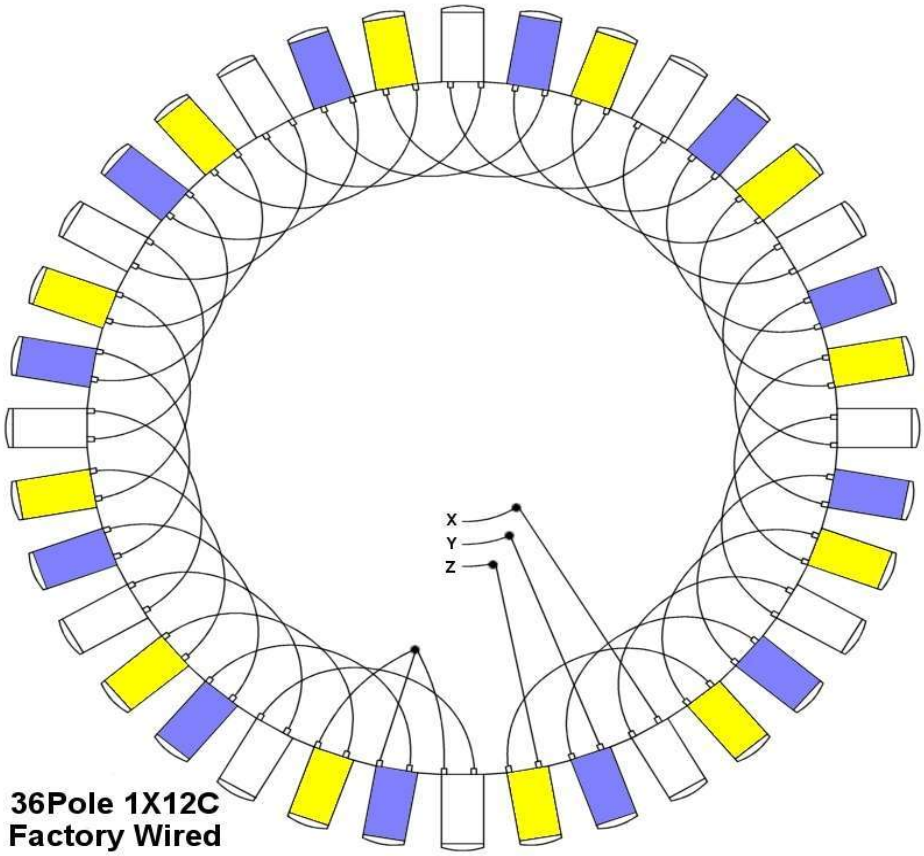
Scalelectric set generator

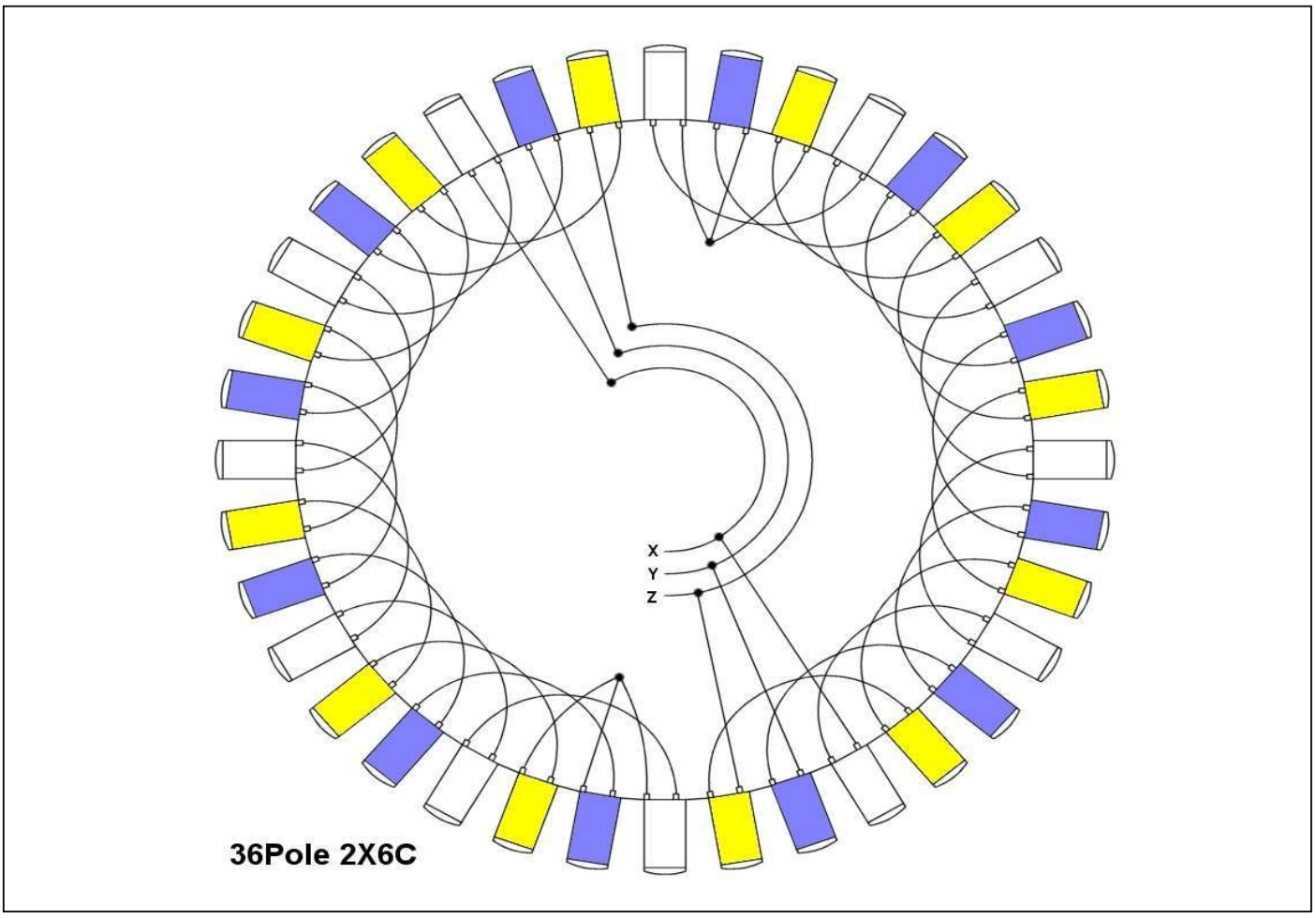
Rewiring

- Produces 3 phase AC
- At full speed:
  - 400 volts unloaded
  - up to 4 amps loaded
- not a very usable range for charging batteries, and very dangerous to work with

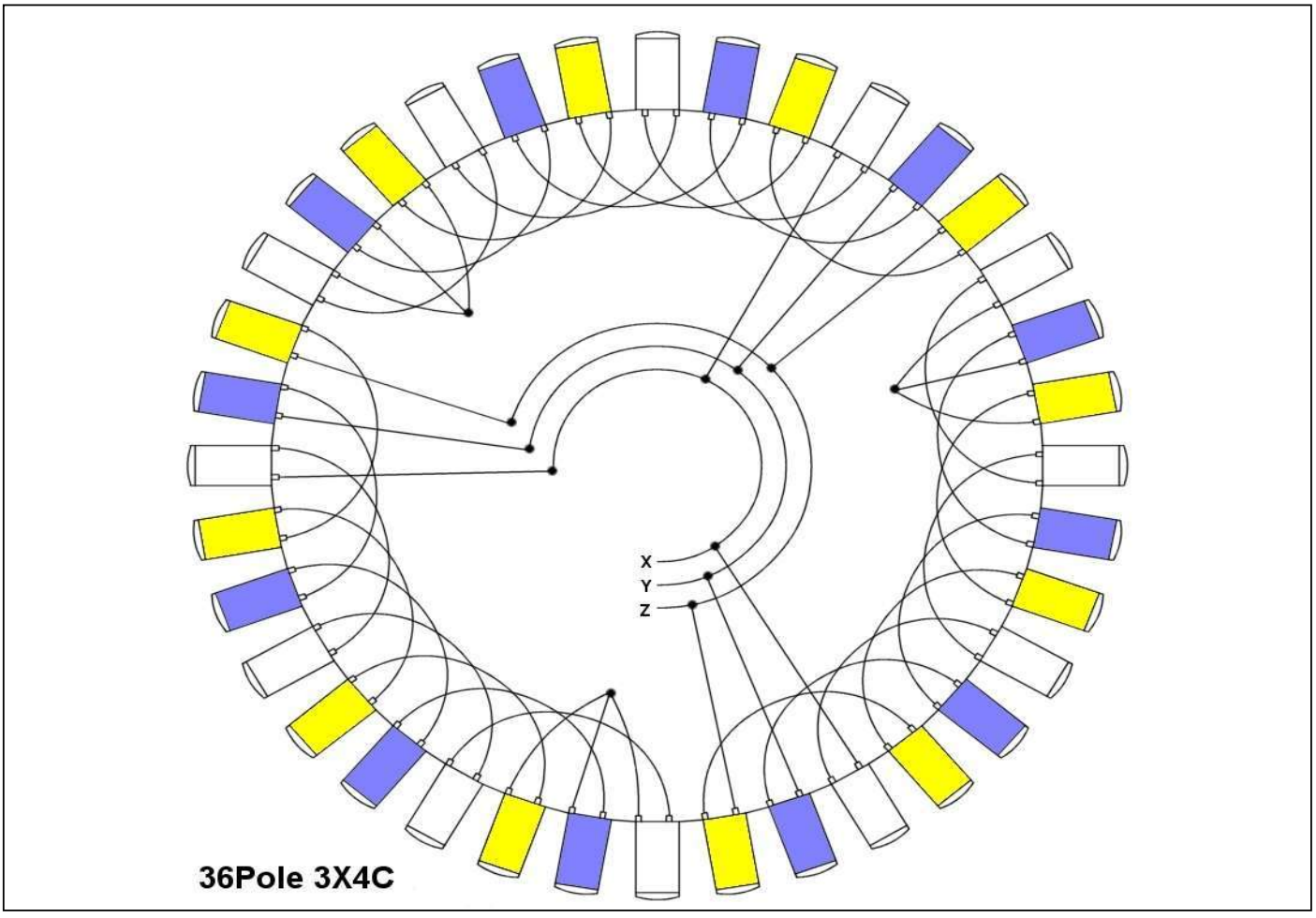
Rewiring

- String of 12 coils, 3 phases = 36 coils
- Rewire into shorter strings to get battery charging voltage (e.g. 14V) at a particular RPM
- Then connect these strings in parallel to increase the current to match the power output of the Stirling Engine

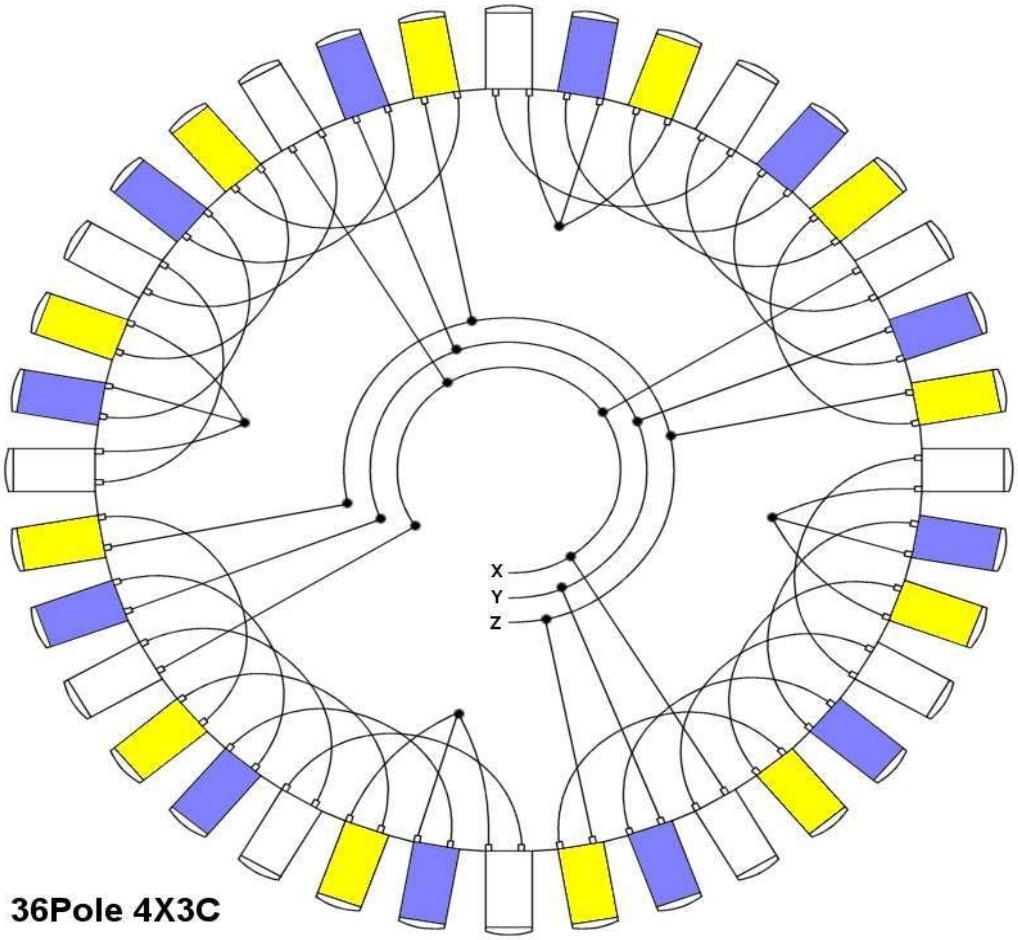




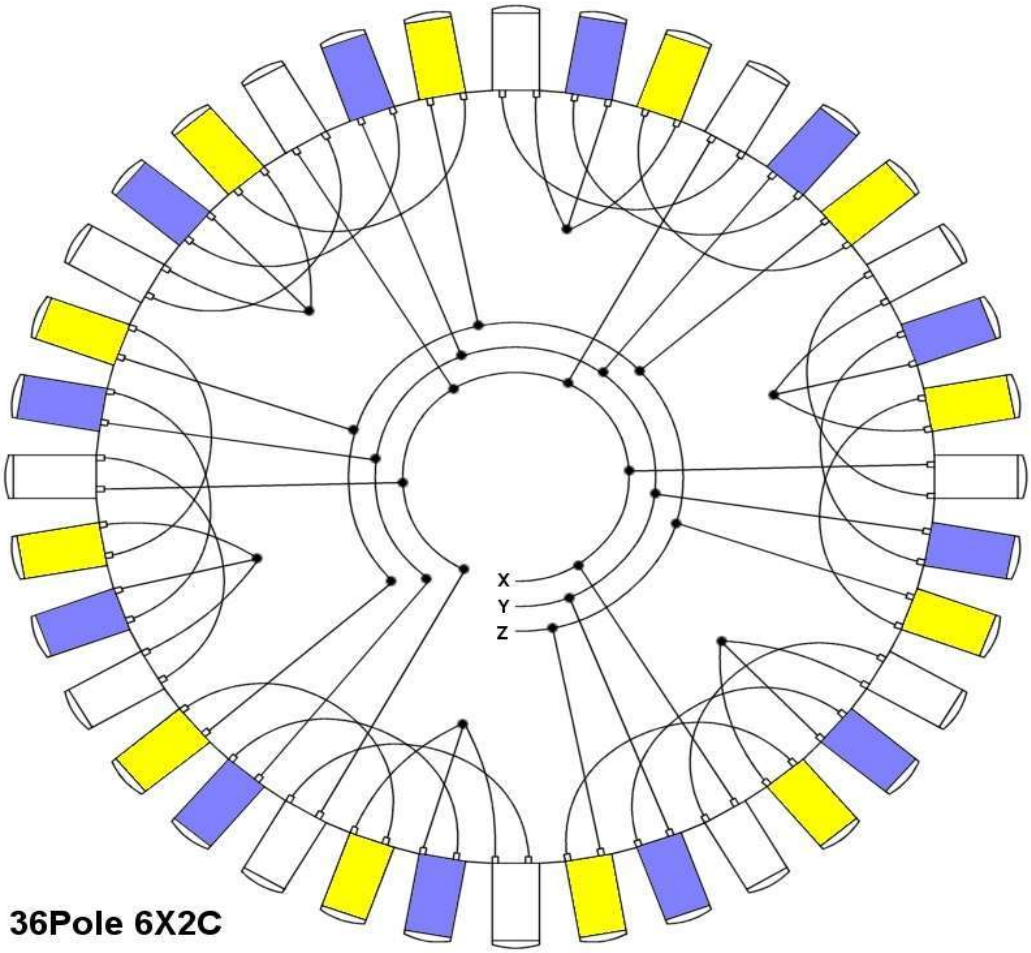
36Pole 2X6C



36Pole 3X4C



36Pole 4X3C

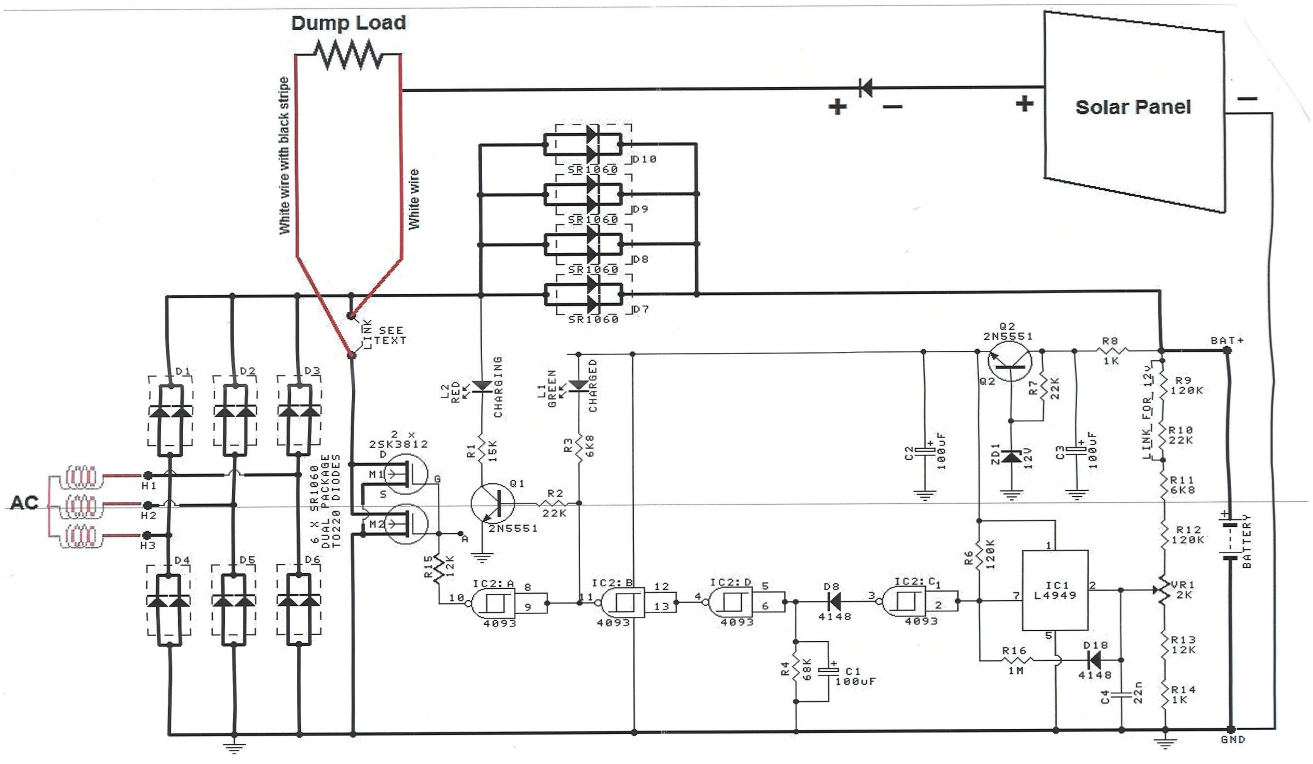


36Pole 6X2C

My development

- Bought a 36 pole LG motor (unused spare part)
- Modified it with quick connect electrical connectors to make it easy to rewire
- In process of making the shaft and stand
- Bought a 3-phase rectifier and battery charger unit
- Bought a dump load (12V car heater & light bulbs)
- Bought a lead-acid 85AH battery
- Bought a Minn Kota Maxxum 40 electric outboard

Rectifier/Charger (commercially available)



- Now I'd like to attach it to a Stirling Engine (in the 10 – 100 W range) and test it as a generator

Any offers?