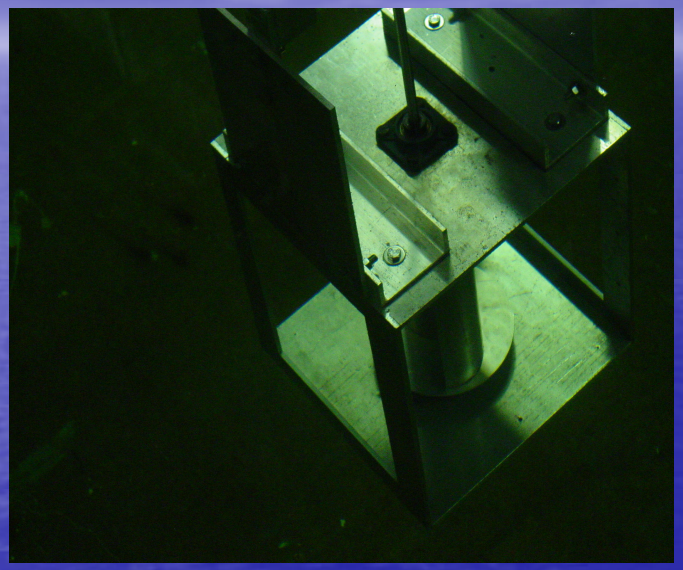
A Micro Seafloor Marine Current Energy Conversion System



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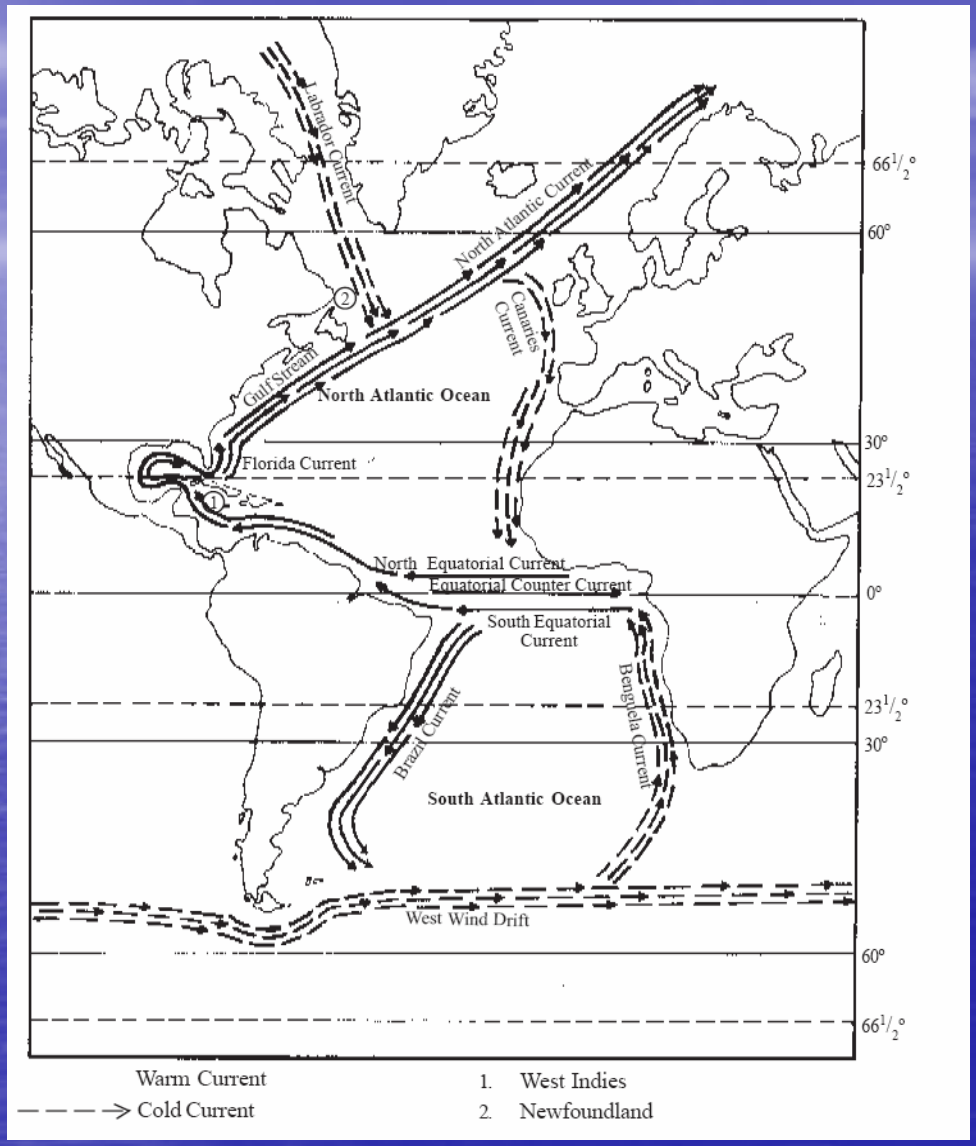
Memorial
University of Newfoundland

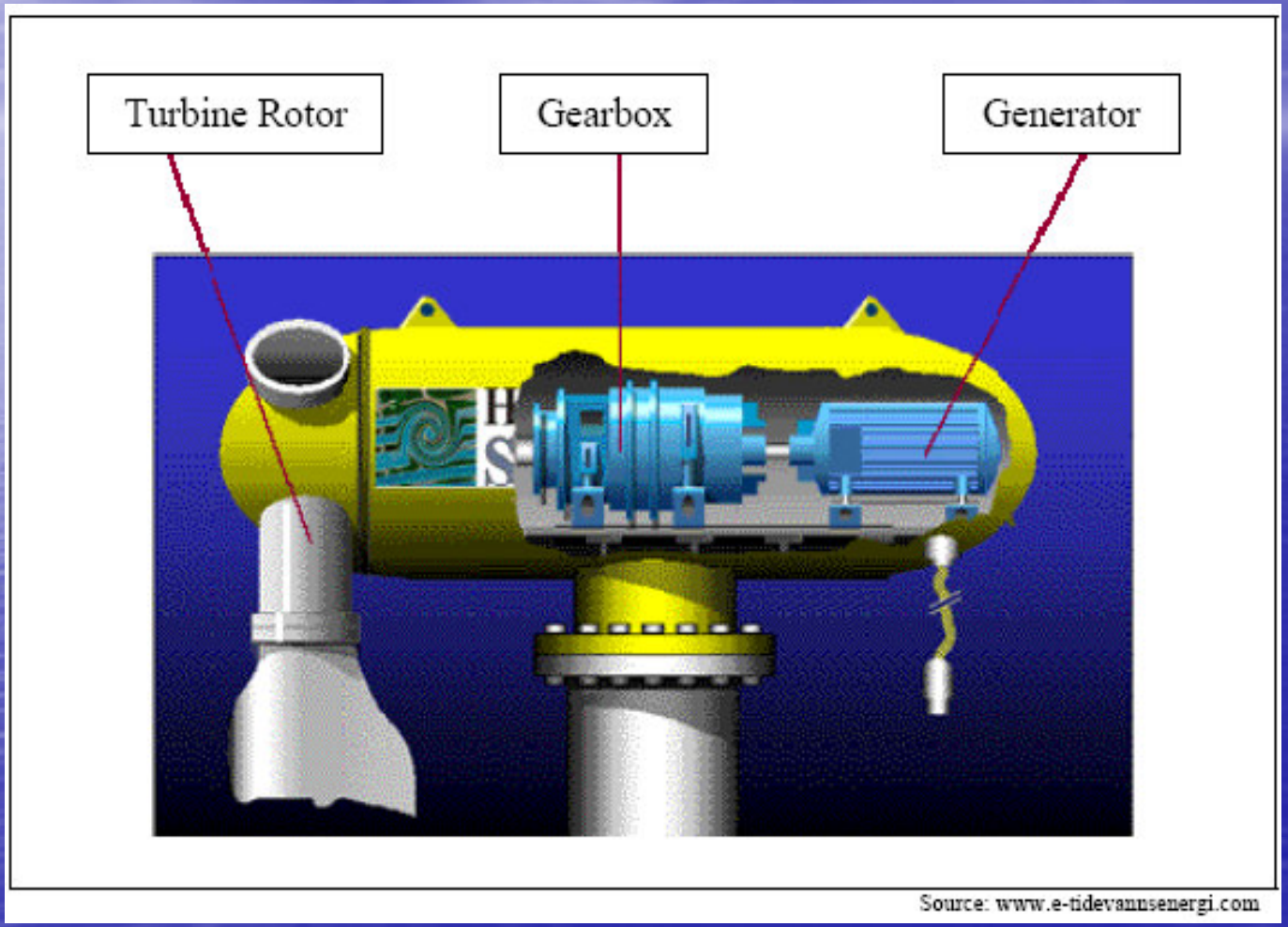
Presentation Outline

- Background
- Marine Energy Systems
- Savonius Turbine
- Scaling Laws
- Energy Conversion System
- Conclusion

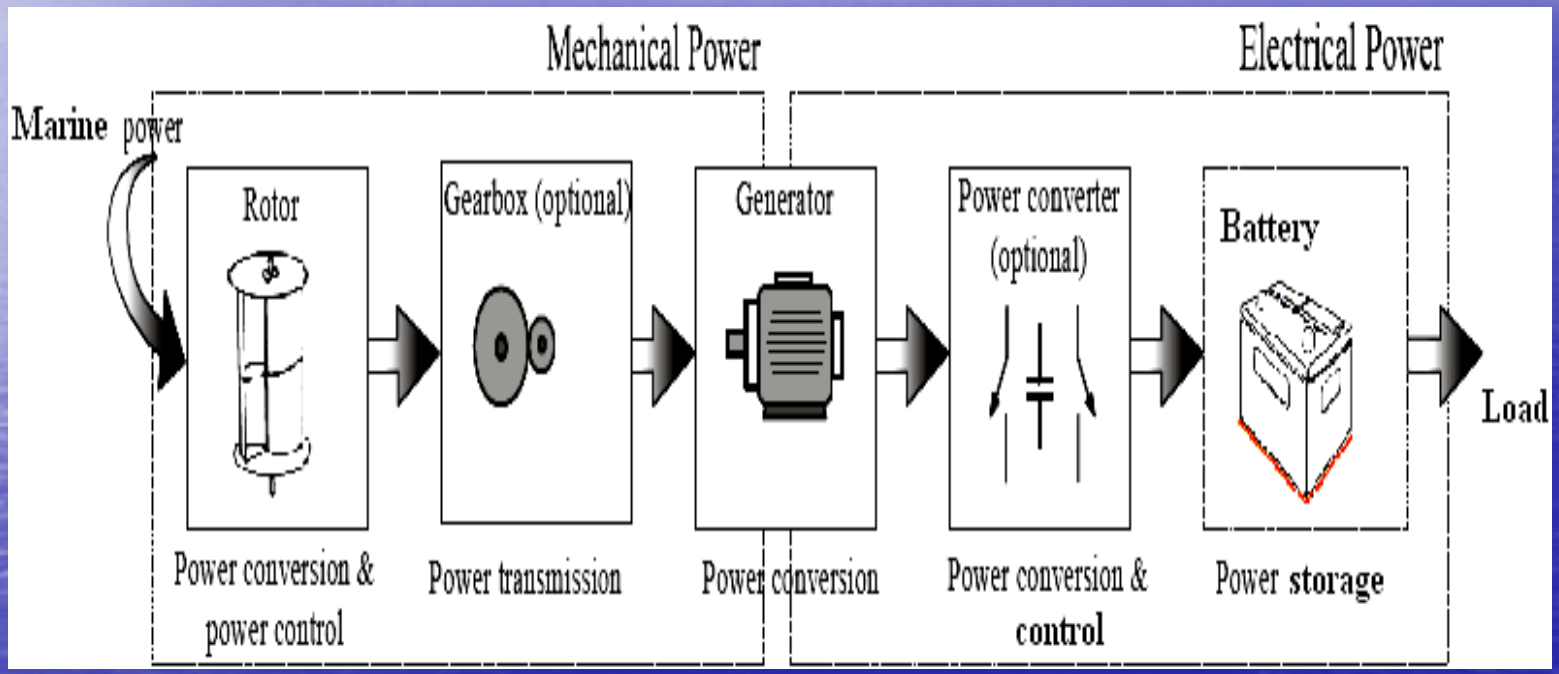

Labrador Current
North Atlantic Current
Canaries Current
Gulf Stream
North Atlantic Ocean
Florida Current
North Equatorial Current
Equatorial Counter Current
South Equatorial Current
Brazil Current
Benguela Current
South Atlantic Ocean
West Wind Drift
66 1/2°
60°
30°
23 1/2°
0°
23 1/2°
30°
60°
66 1/2°
Warm Current
Cold Current
1. West Indies
2. Newfoundland

Renewable Energy Systems

	Renewable resource	Low capital cost	Low running cost	Minimal environmental impact	Predictable	Minimal visual impact	Modular
Fossil	✗	✓	✗	✗	✓	✗	✗
Nuclear	✗	✓	✗	✗	✓	✗	✗
Wind	✓	✗	✓	✓	✗	✗	✓
Solar	✓	✗	✓	✓	✗	✗	✓
Hydro	✓	✓	✓	✗	✓	✗	✗
Wave	✓	✗	✓	✓	✗	✓	✓
Marine Current	✓	✗	✓	✓	✓	✓	✓



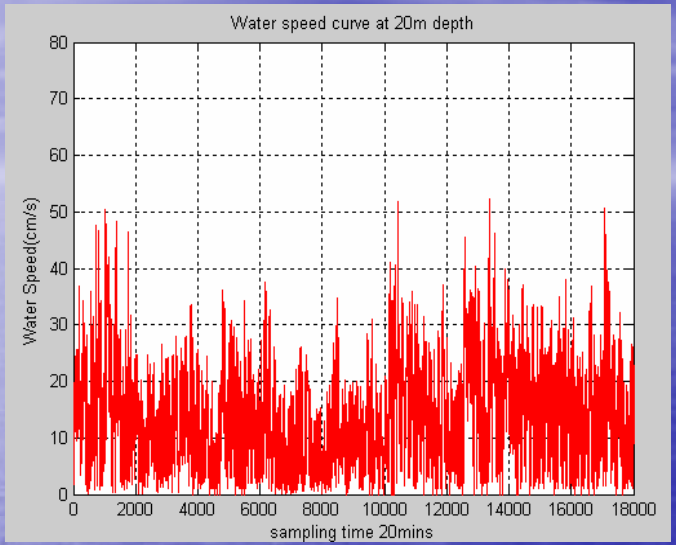
Source: www.e-tidevannsenergi.com

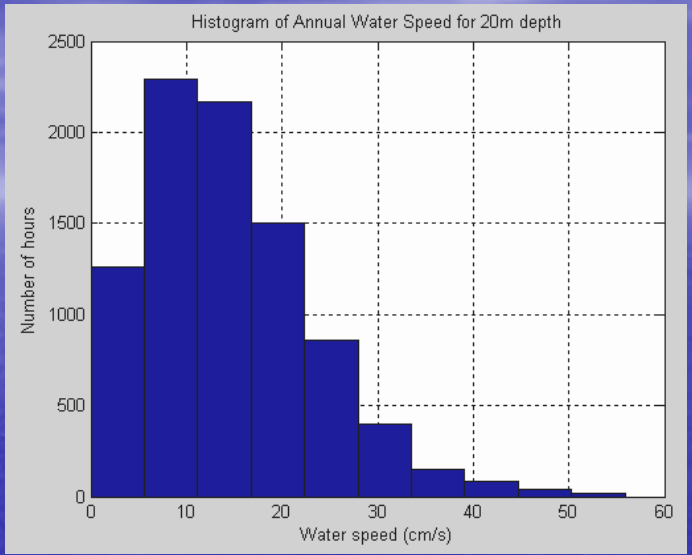

Mechanical Power
Electrical Power
Marine power
Rotor
Gearbox (optional)
Generator
Power converter
(optional)
Battery
Load
Power conversion &
power control
Power transmission
Power conversion
Power conversion &
control
Power storage

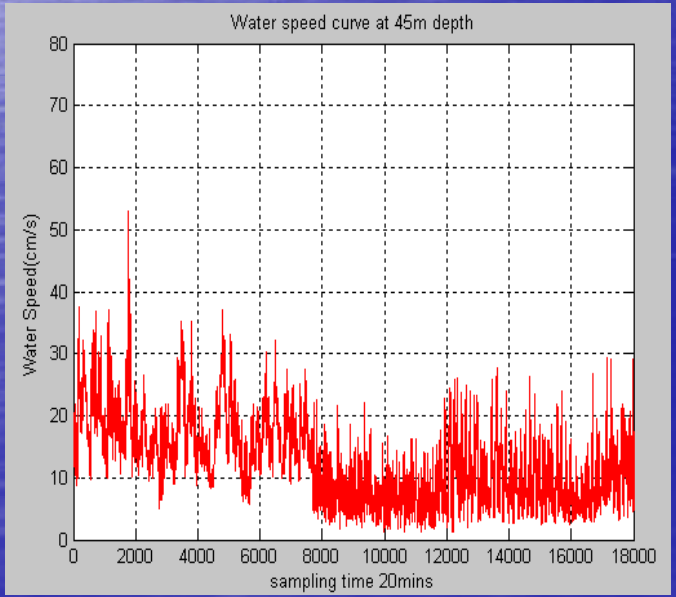
Thesis Objectives

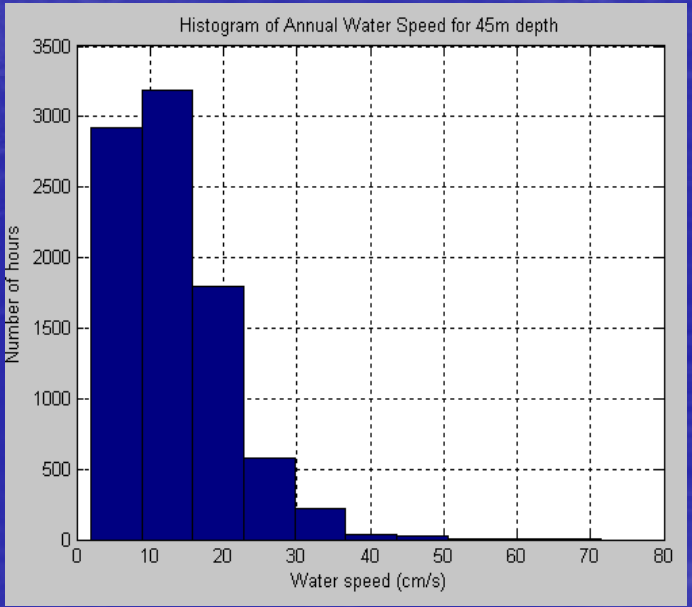
- Design and development of an efficient turbine
- System sizing based on seafloor marine current data
- Design and development of energy storage system
- System testing in deep-sea conditions

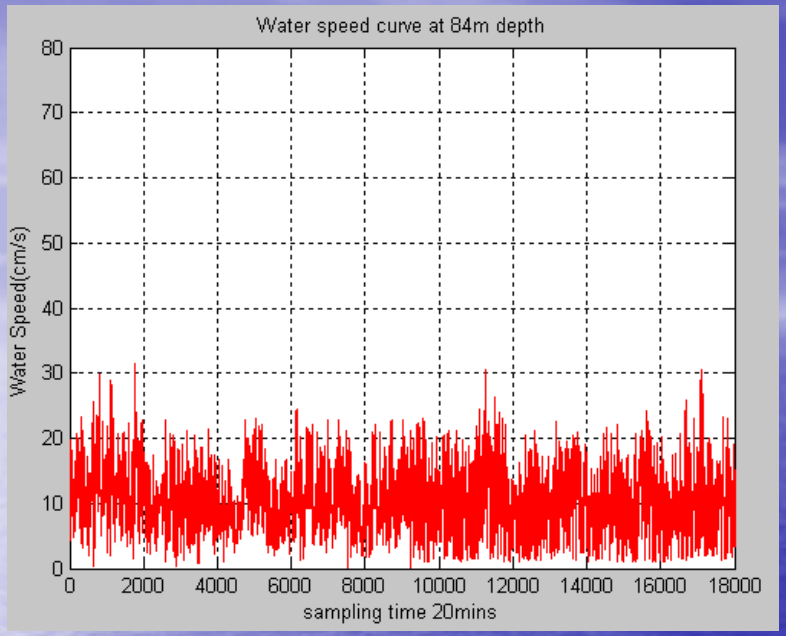
Study of Atlantic Ocean Current

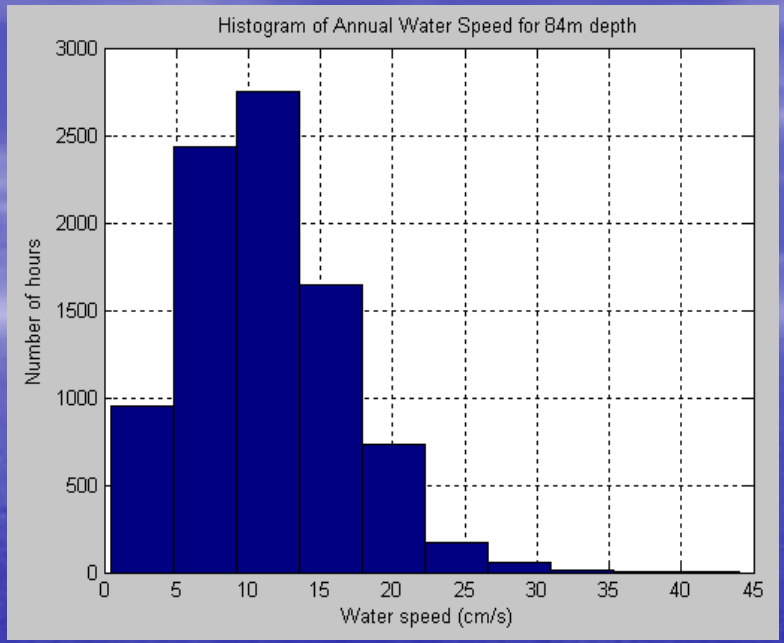


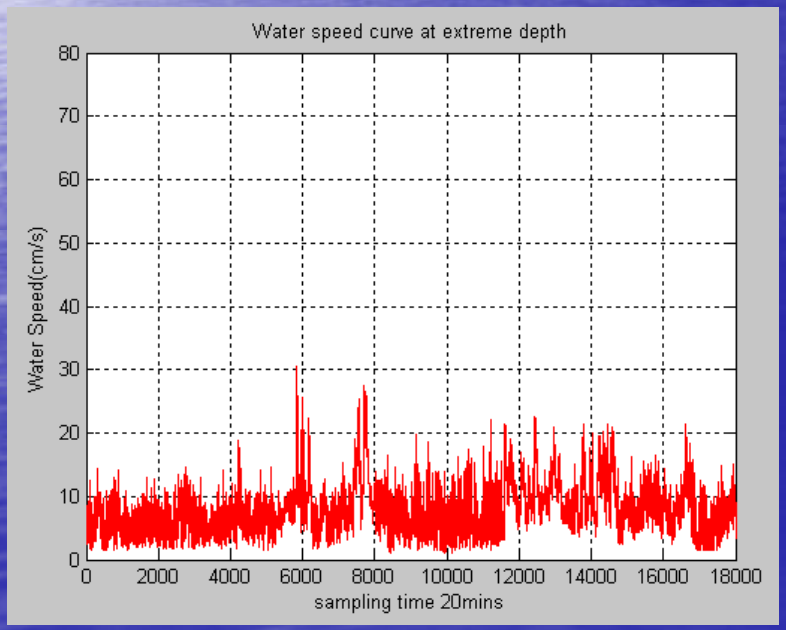


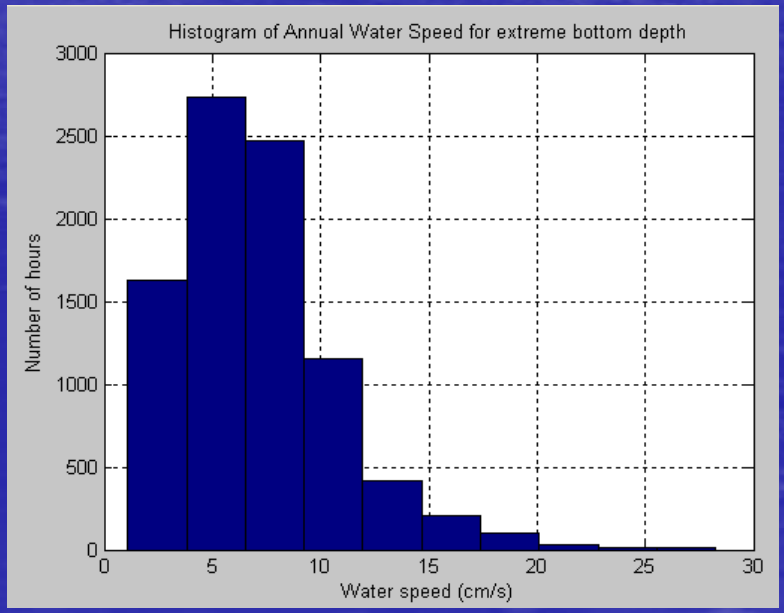





Water speed curve at 84m depth
Water Speed(cm/s)
sampling time 20mins
0
10
20
30
40
50
60
70
80
0
2000
4000
6000
8000
10000
12000
14000
16000
18000


Histogram of Annual Water Speed for 84m depth
Number of hours
Water speed (cm/s)
0
500
1000
1500
2000
2500
3000
0
5
10
15
20
25
30
35
40
45

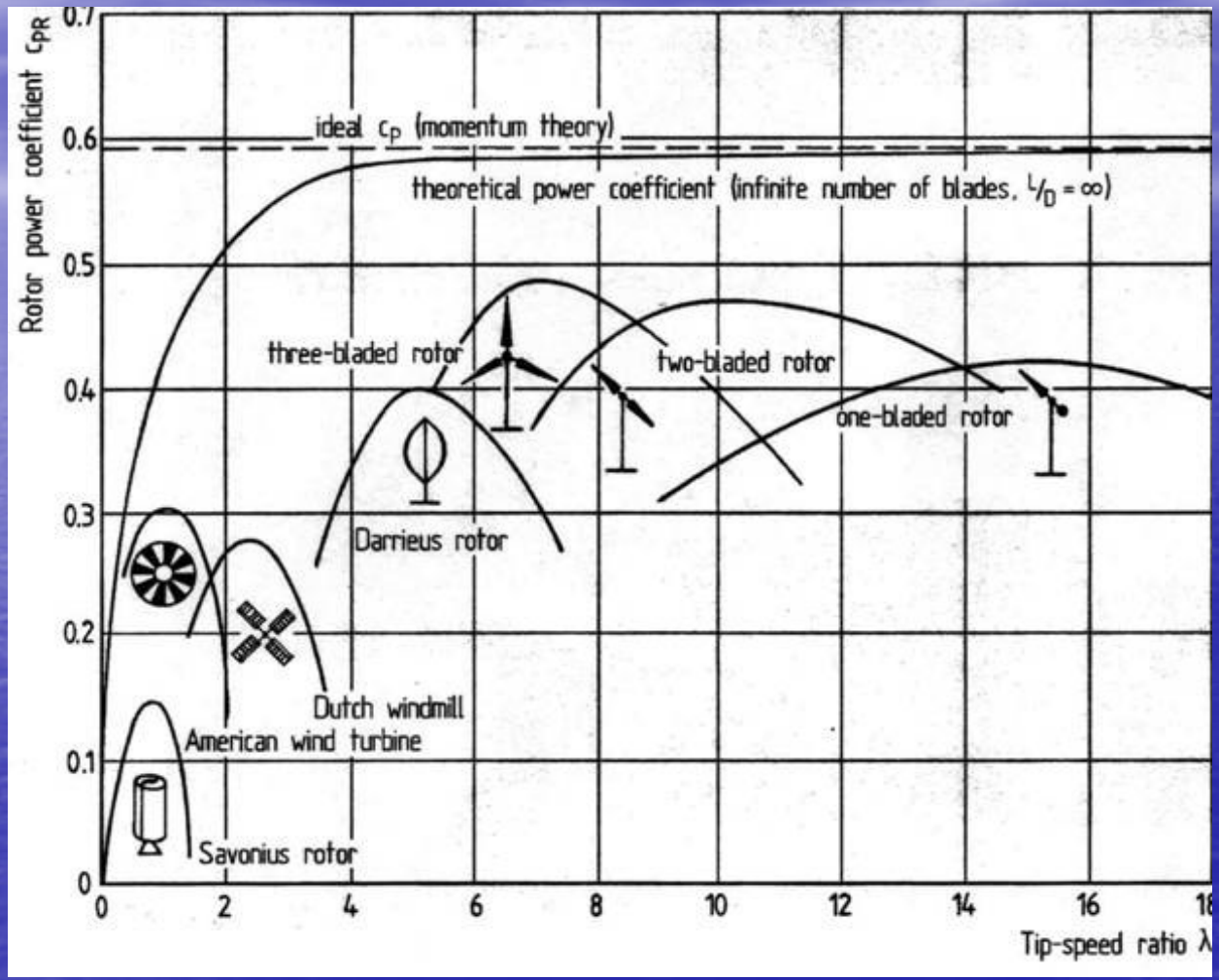

Water speed curve at extreme depth
Water Speed(cm/s)
sampling time 20mins
0
10
20
30
40
50
60
70
80
0
2000
4000
6000
8000
10000
12000
14000
16000
18000


Histogram of Annual Water Speed for extreme bottom depth
Number of hours
Water speed (cm/s)
0
500
1000
1500
2000
2500
3000
0
5
10
15
20
25
30

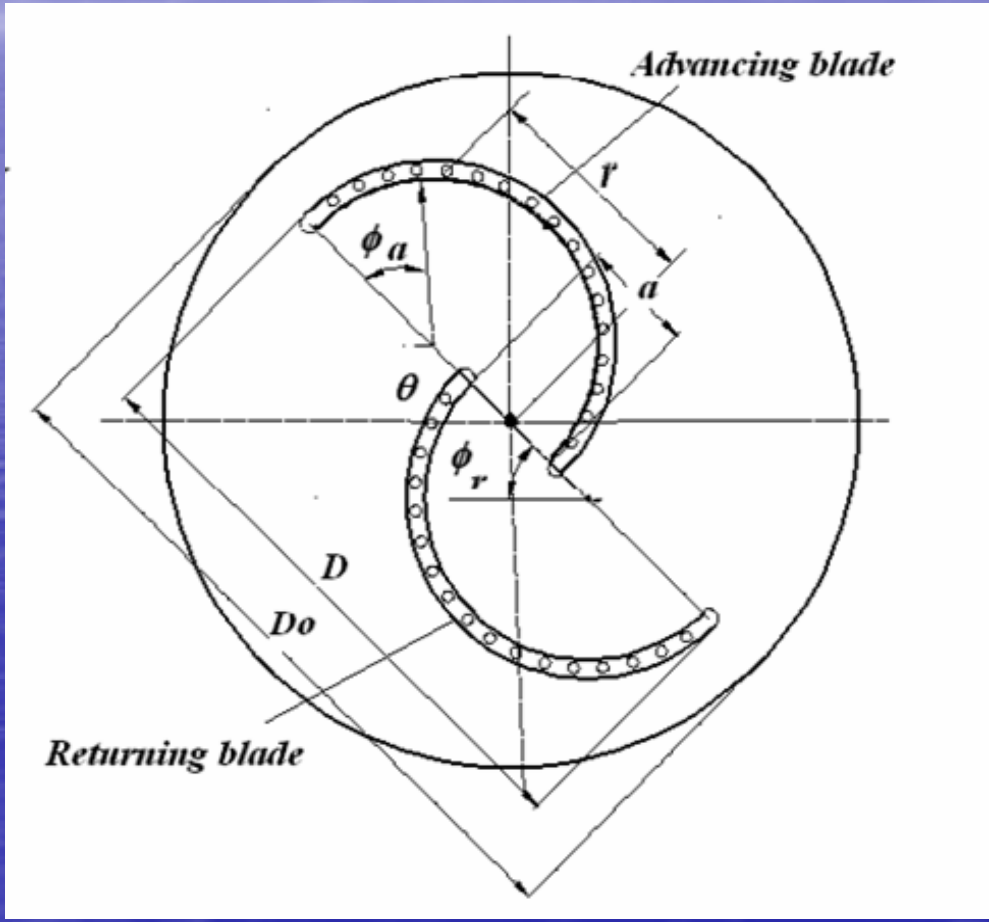
Annual Energy Estimation

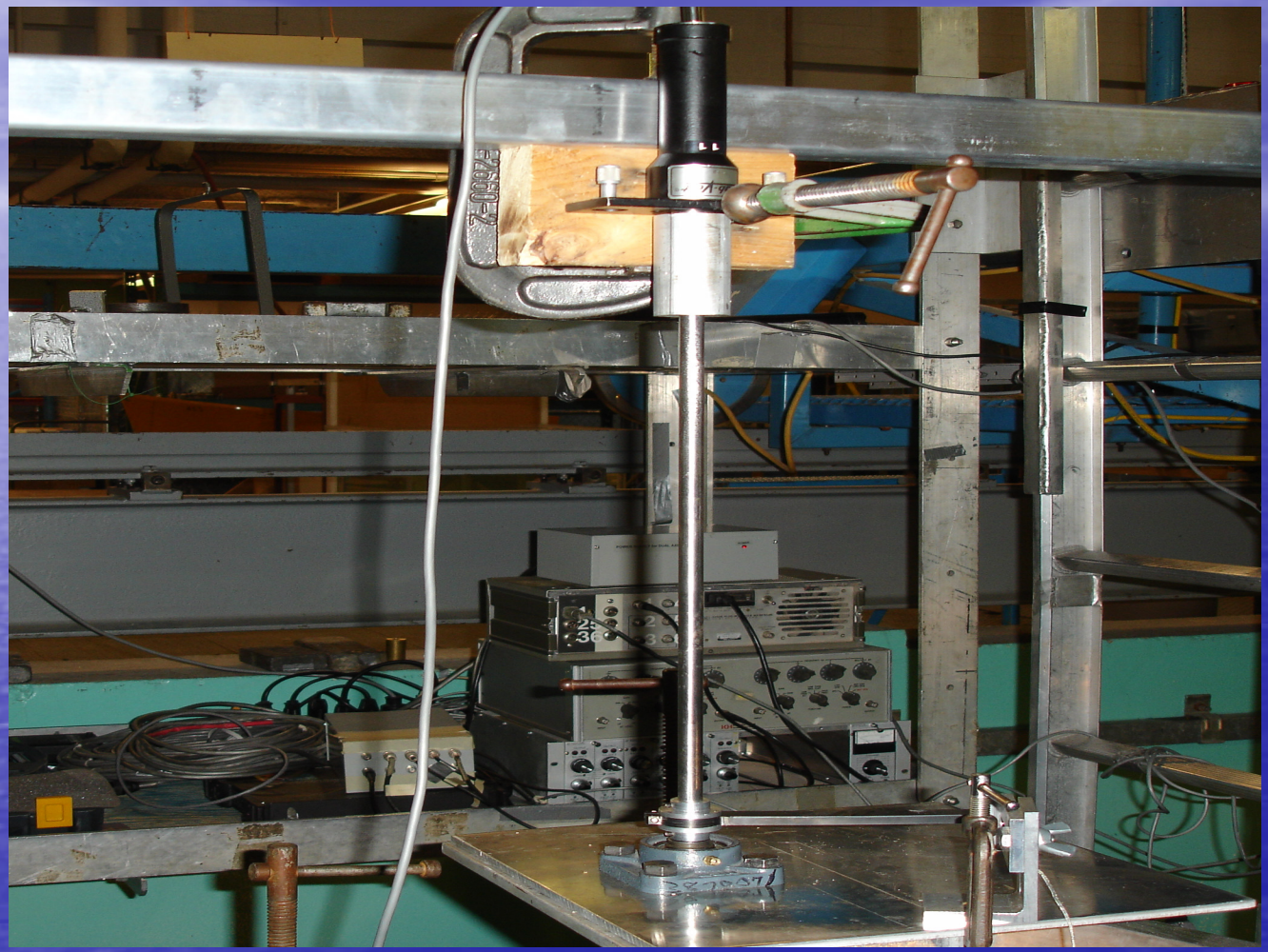
Depth (m)	Average Flow Speed (cm/s)	Maximum available power density (W/m^2)	Extractable Power with a turbine (W/m^2)	Maximum available energy density in a year (Whr/m^2)	Extractable energy density in a year (Whr/m^2)
20	14.6070	1.5583	0.2337	152195.0	23169.0
45	13.2005	1.1501	0.1725	44045.0	5954.0
84	11.2233	0.7069	0.1060	109590.0	15906.0
Near Bottom	7.0555	0.1756	0.0263	98465.0	14268.0

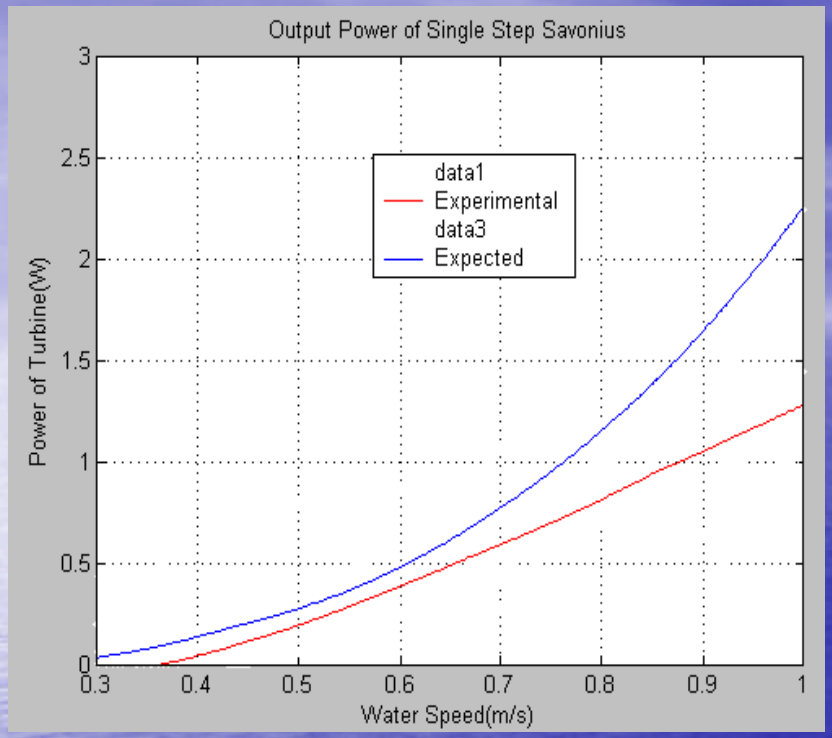
State of the Art Systems

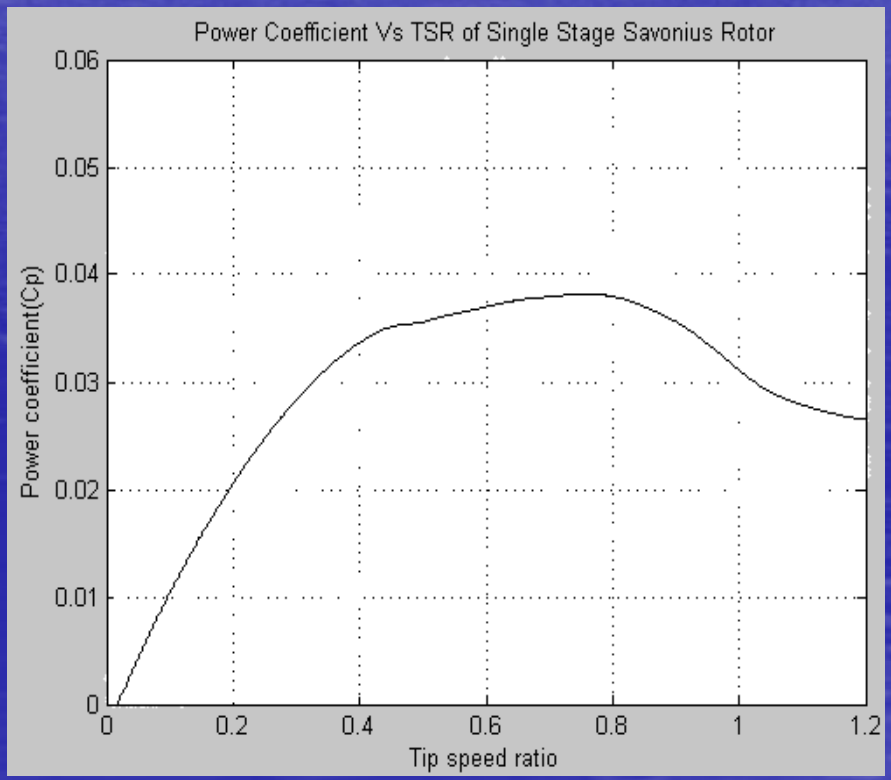

Rotor power coefficient c_{PR}
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
ideal c_P (momentum theory)
theoretical power coefficient (infinite number of blades, $l/D = \infty$)
three-bladed rotor
two-bladed rotor
one-bladed rotor
Darrieus rotor
Dutch windmill
American wind turbine
Savonius rotor
0
2
4
6
8
10
12
14
16
Tip-speed ratio λ

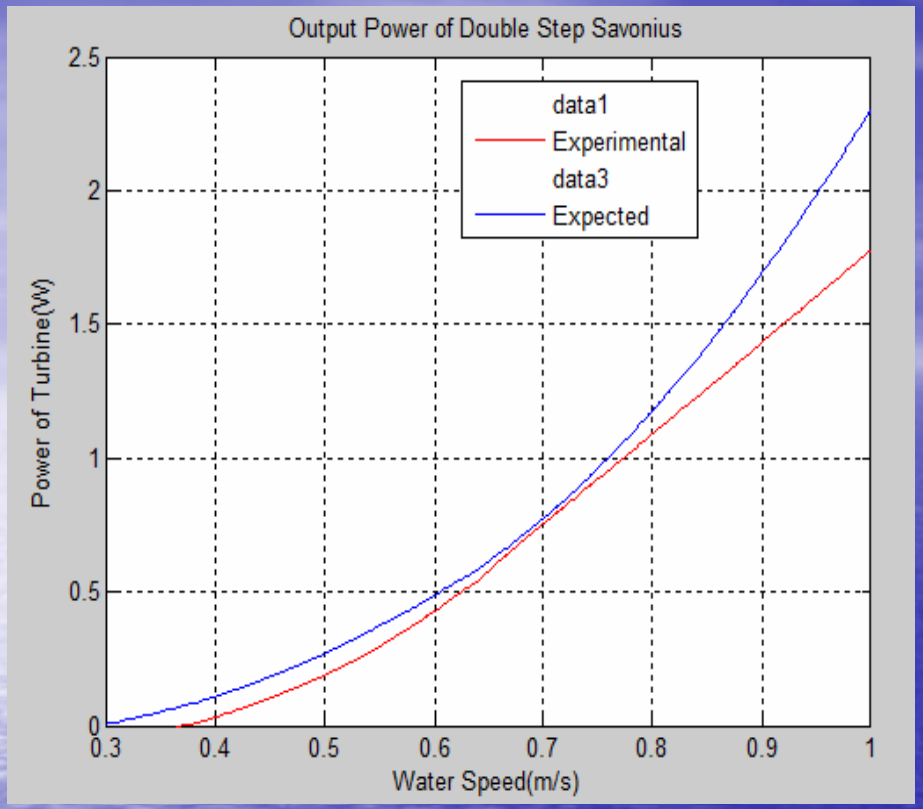
Savonius Rotor

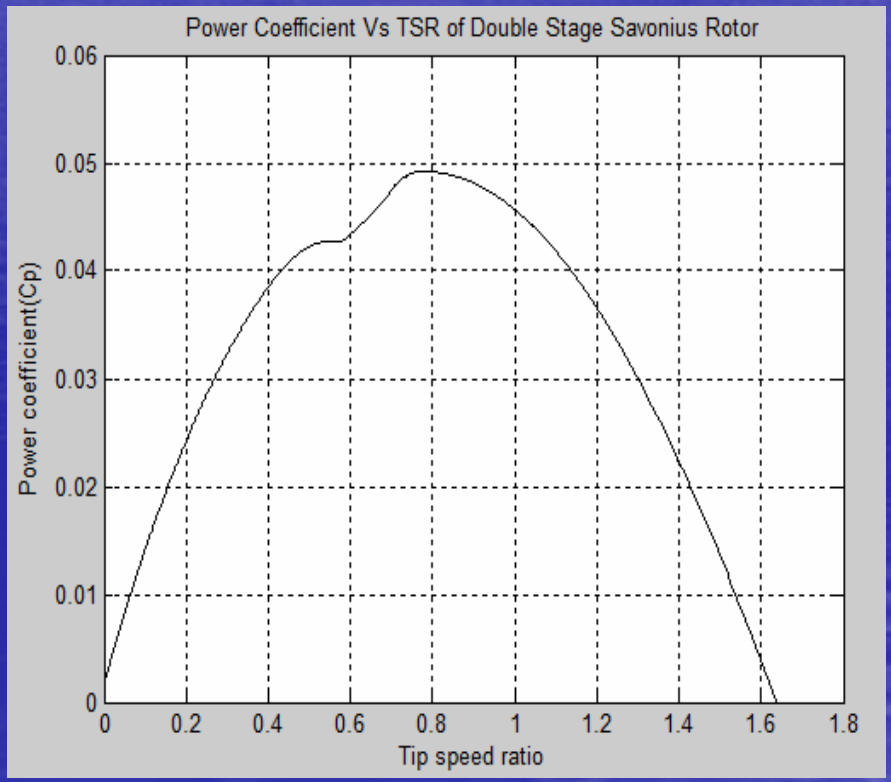


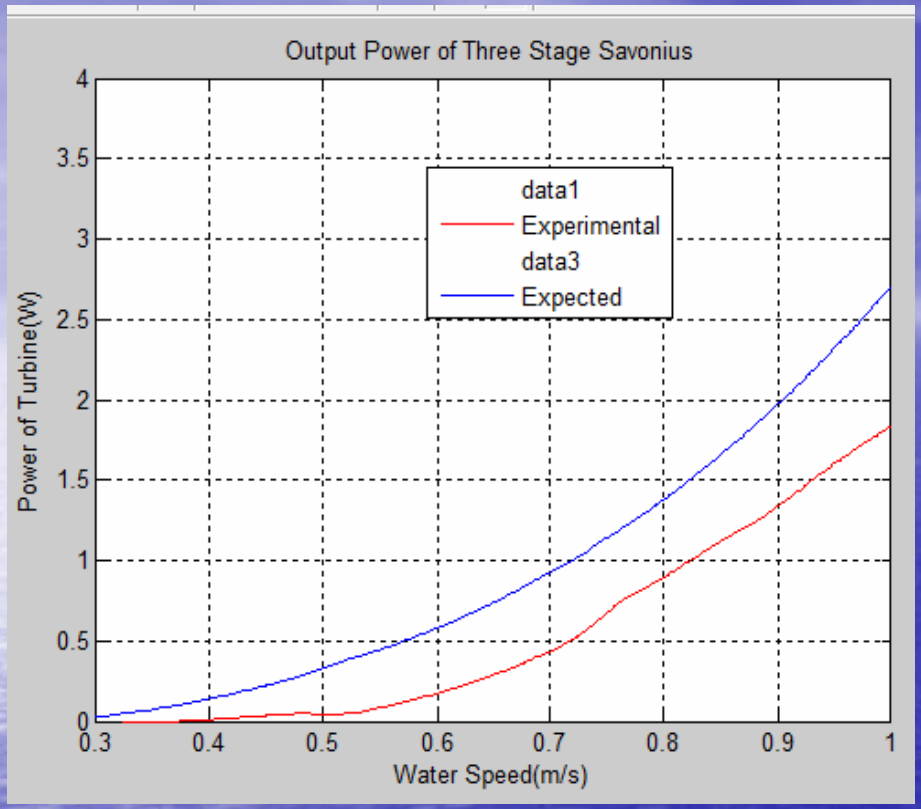


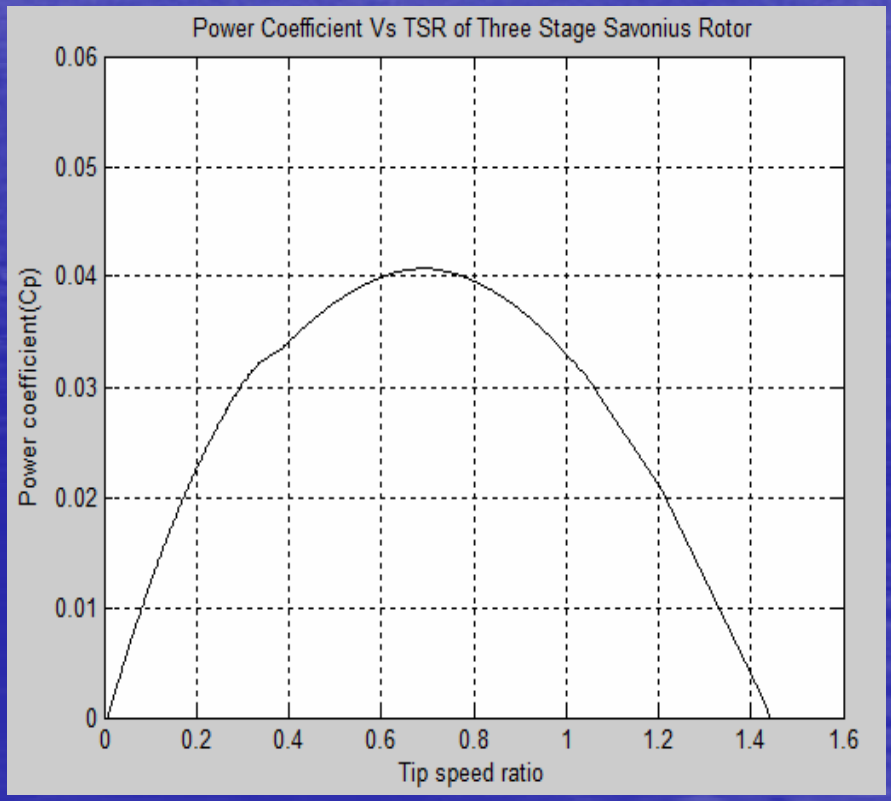

Output Power of Single Step Savonius
Power of Turbine(W)
Water Speed(m/s)
data1
Experimental
data3
Expected
0
0.5
1
1.5
2
2.5
3
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1


Power Coefficient Vs TSR of Single Stage Savonius Rotor
Power coefficient(Cp)
Tip speed ratio
0
0.01
0.02
0.03
0.04
0.05
0.06
0
0.2
0.4
0.6
0.8
1
1.2


Output Power of Double Step Savonius
data1
Experimental
data3
Expected
Power of Turbine(W)
Water Speed(m/s)
2.5
2
1.5
1
0.5
0
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1

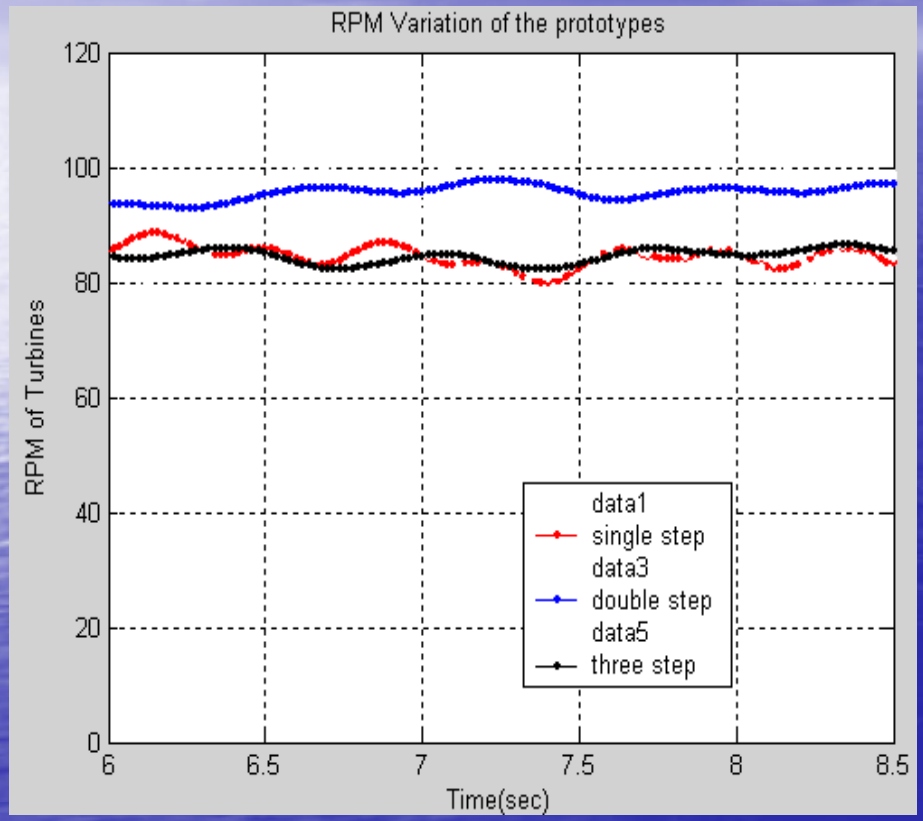

Power Coefficient Vs TSR of Double Stage Savonius Rotor
Power coefficient(Cp)
Tip speed ratio
0.06
0.05
0.04
0.03
0.02
0.01
0
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8

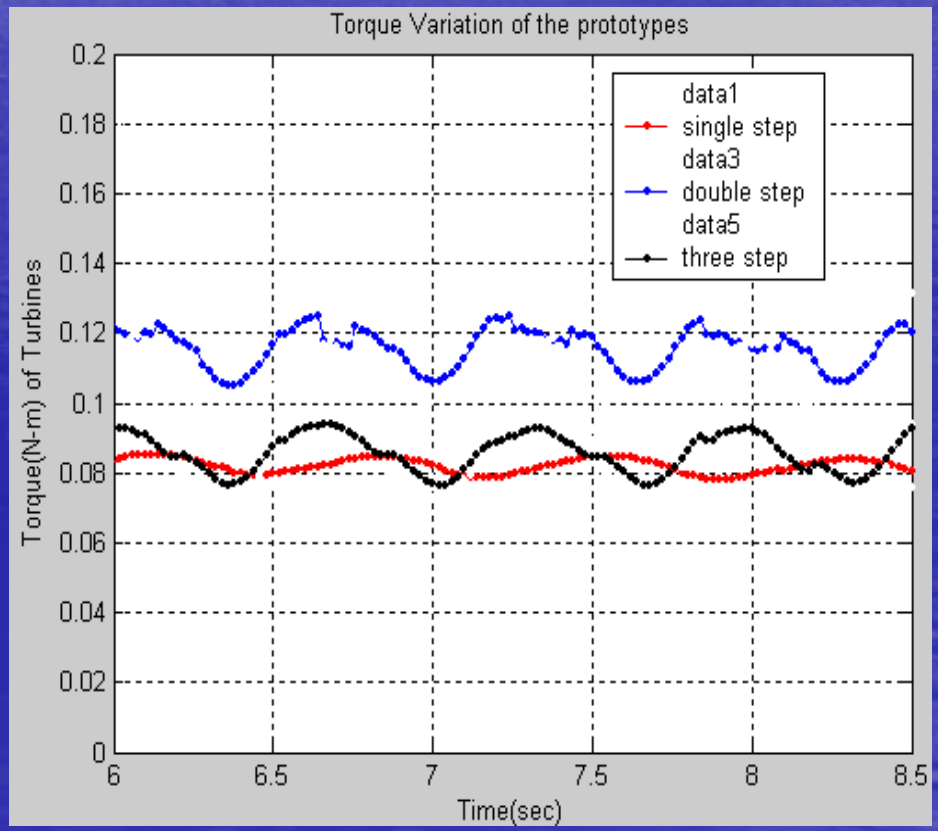

Output Power of Three Stage Savonius
Power of Turbine(W)
Water Speed(m/s)
data1
Experimental
data3
Expected
0
0.5
1
1.5
2
2.5
3
3.5
4
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1


Power Coefficient Vs TSR of Three Stage Savonius Rotor
Power coefficient(Cp)
Tip speed ratio
0
0.01
0.02
0.03
0.04
0.05
0.06
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6

Comparison of Prototypes

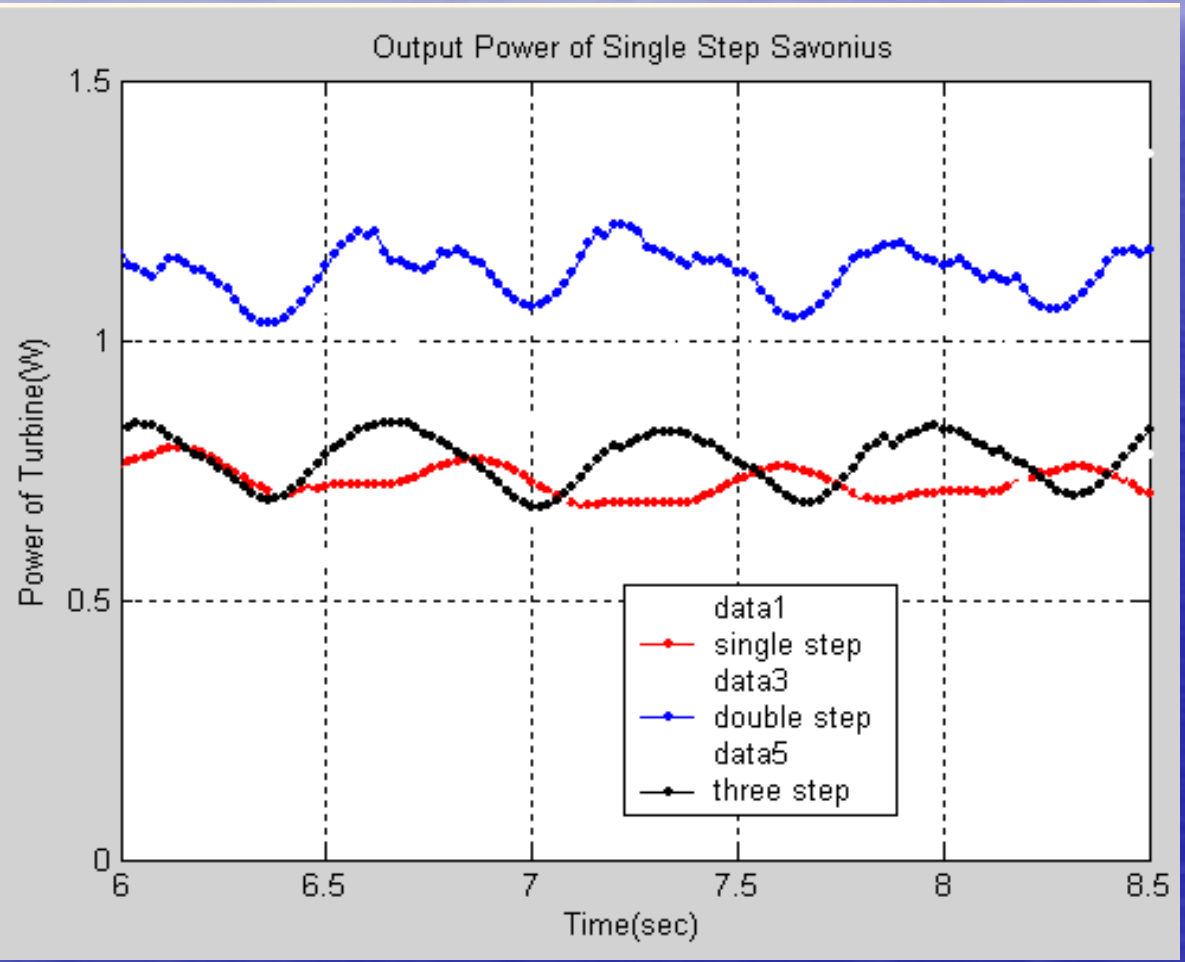
At water current of 0.8 m/s





Comparison of Prototypes

At water current of 0.8m/s



Dimensional Analysis

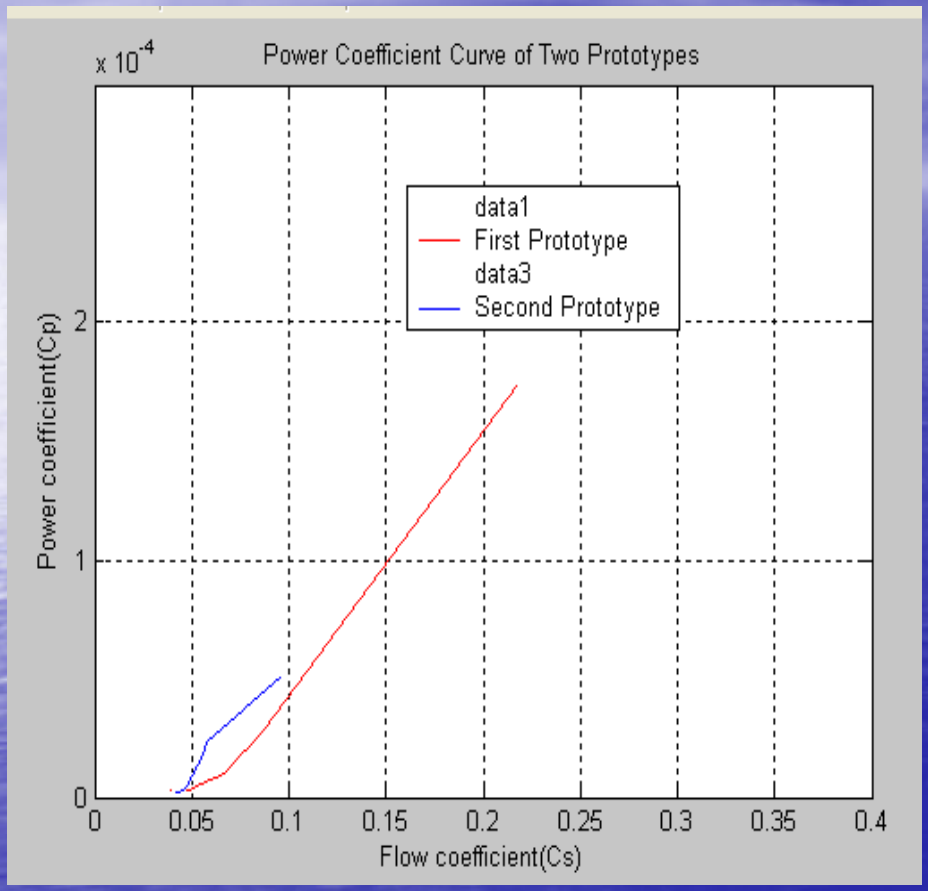
$$C_P = \frac{P}{\rho D^5 N^3}$$

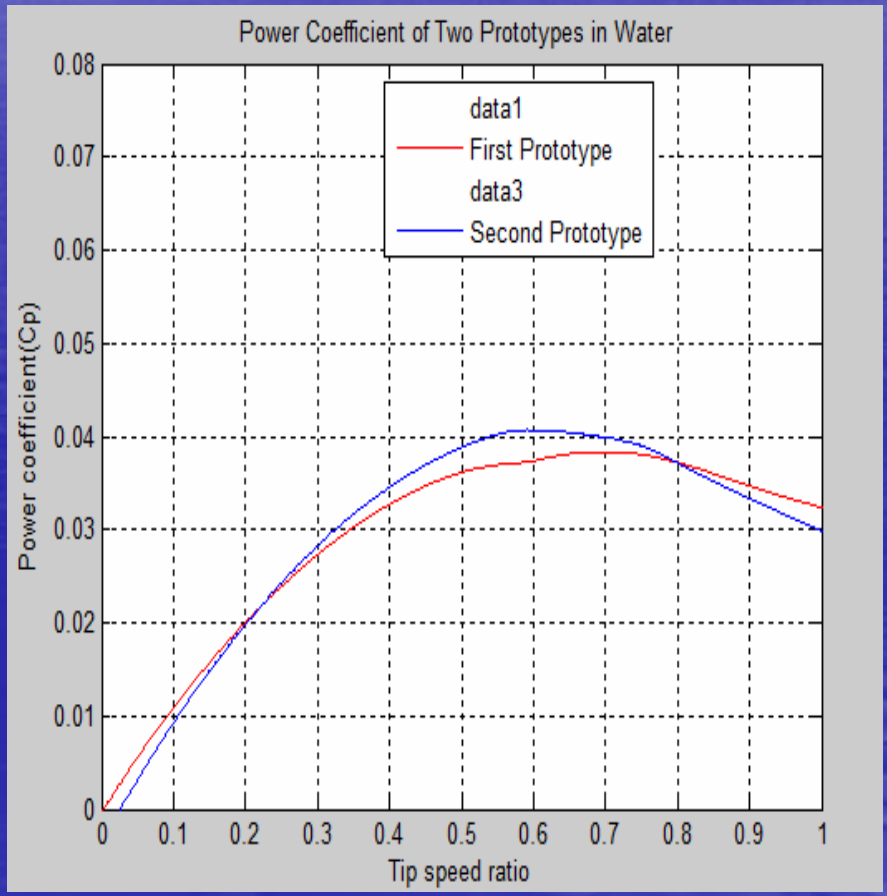
$$C_P = \frac{P}{\frac{1}{2}\rho A V^3}$$

$$C_Q = \frac{V}{ND}$$

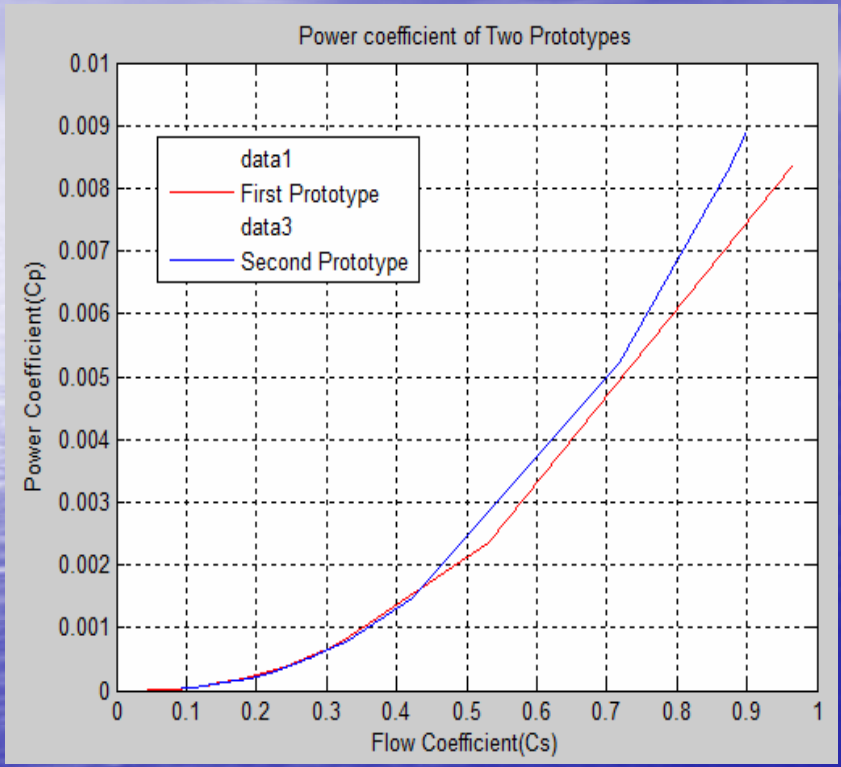
$$\lambda = \frac{U}{V} = \frac{\omega R}{V}$$

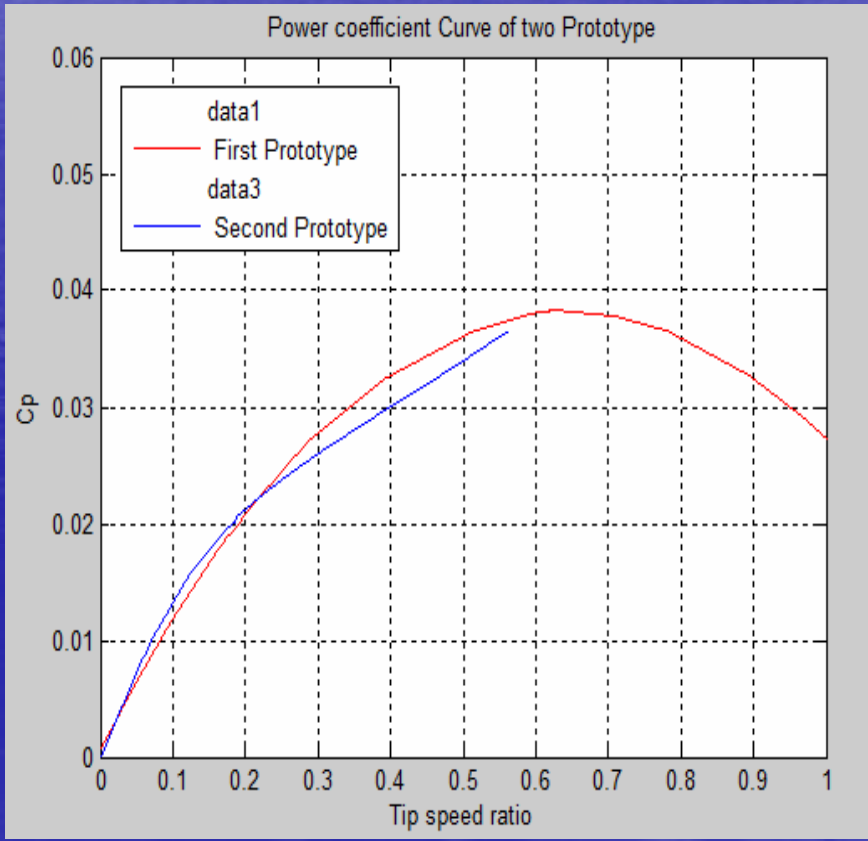
Wave Tank Result



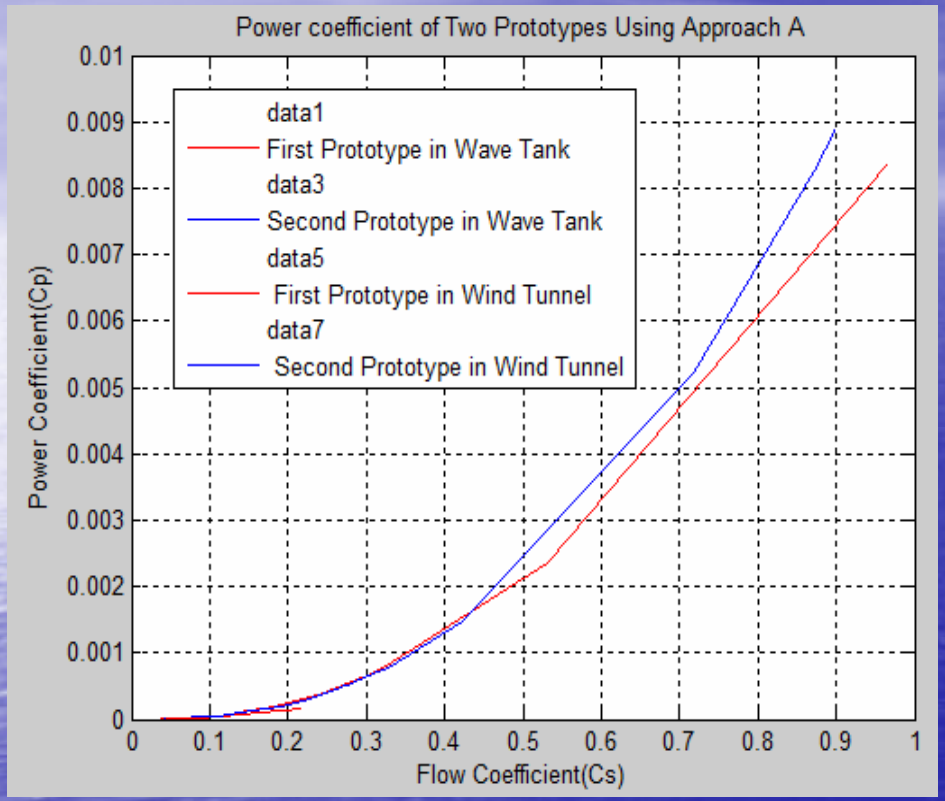


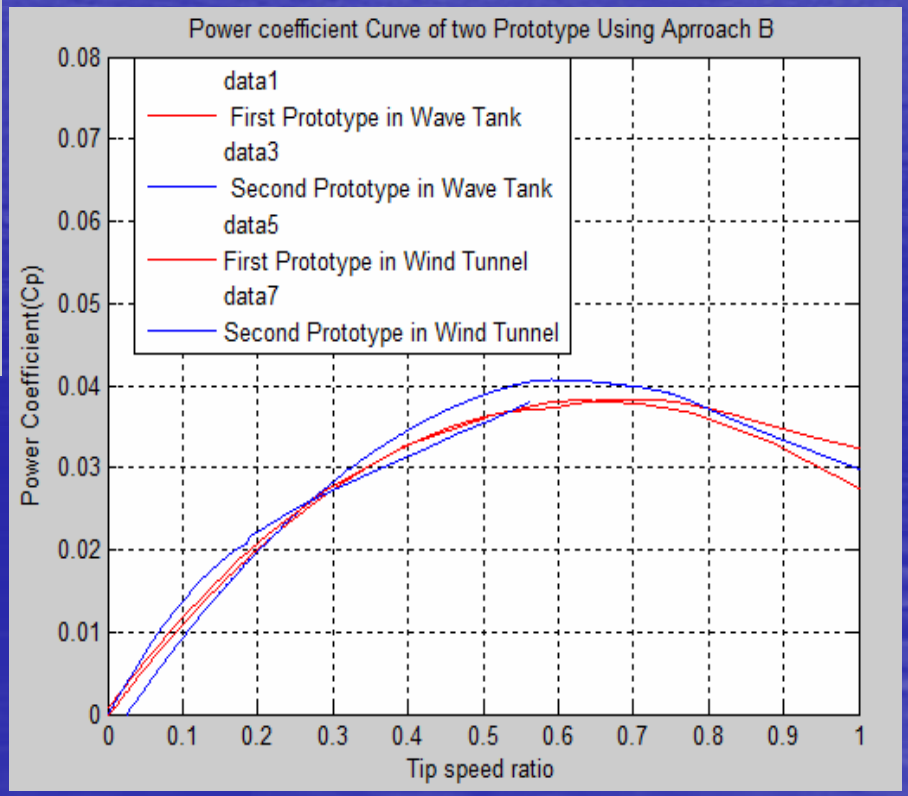
Wind Tunnel Result



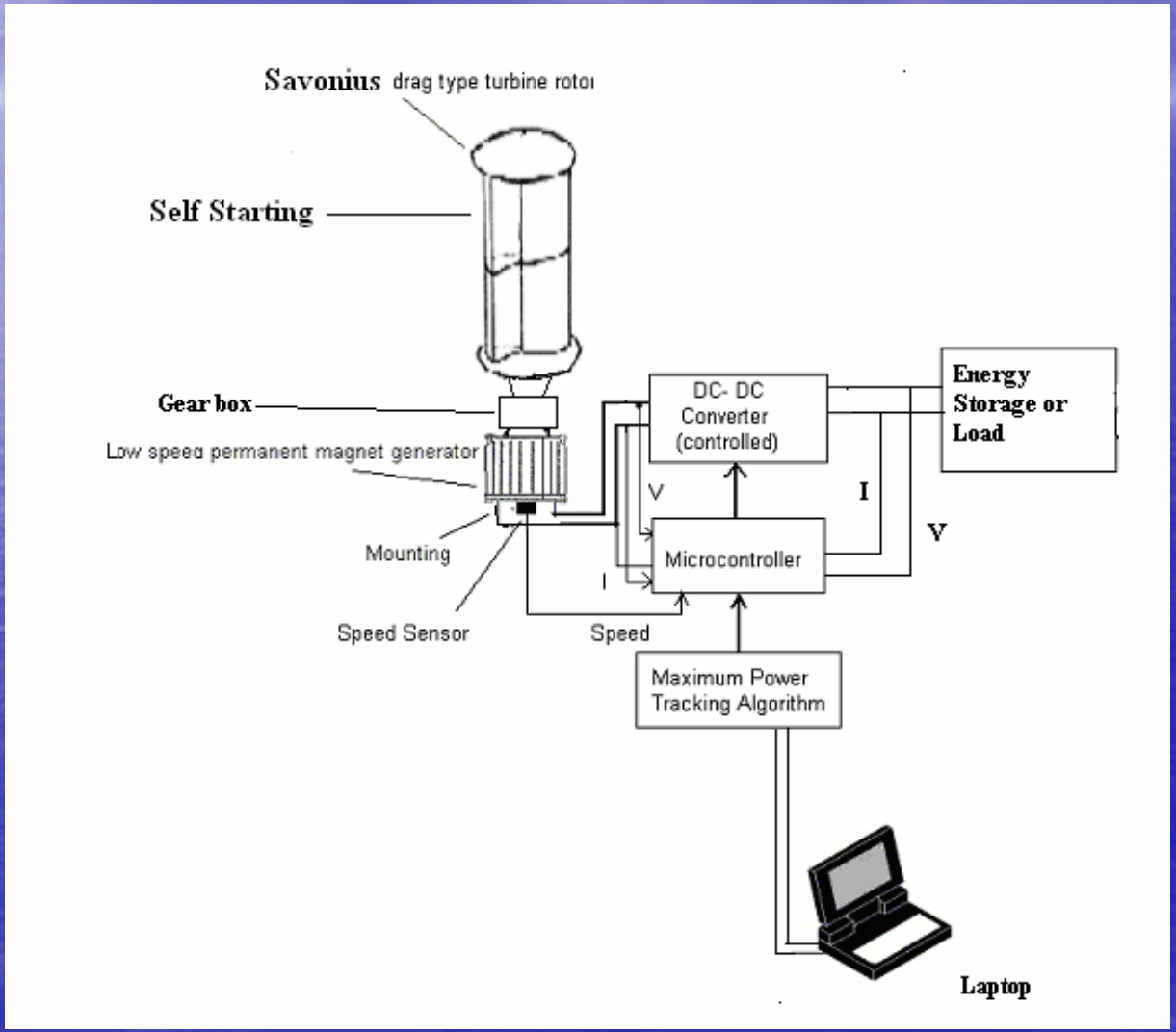


Wave Tank and Wind Tunnel Comparison

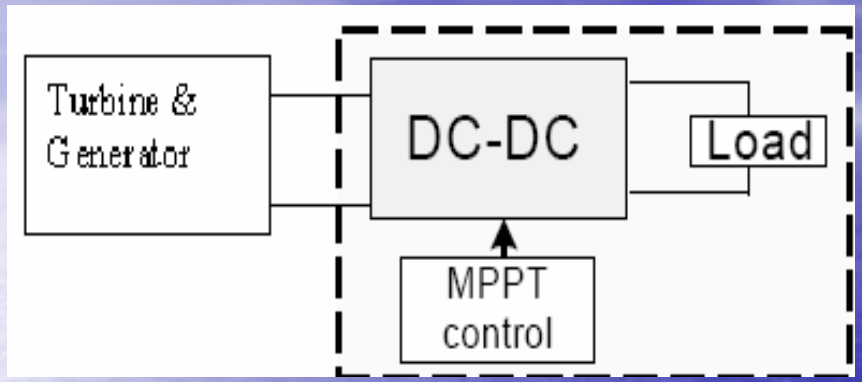




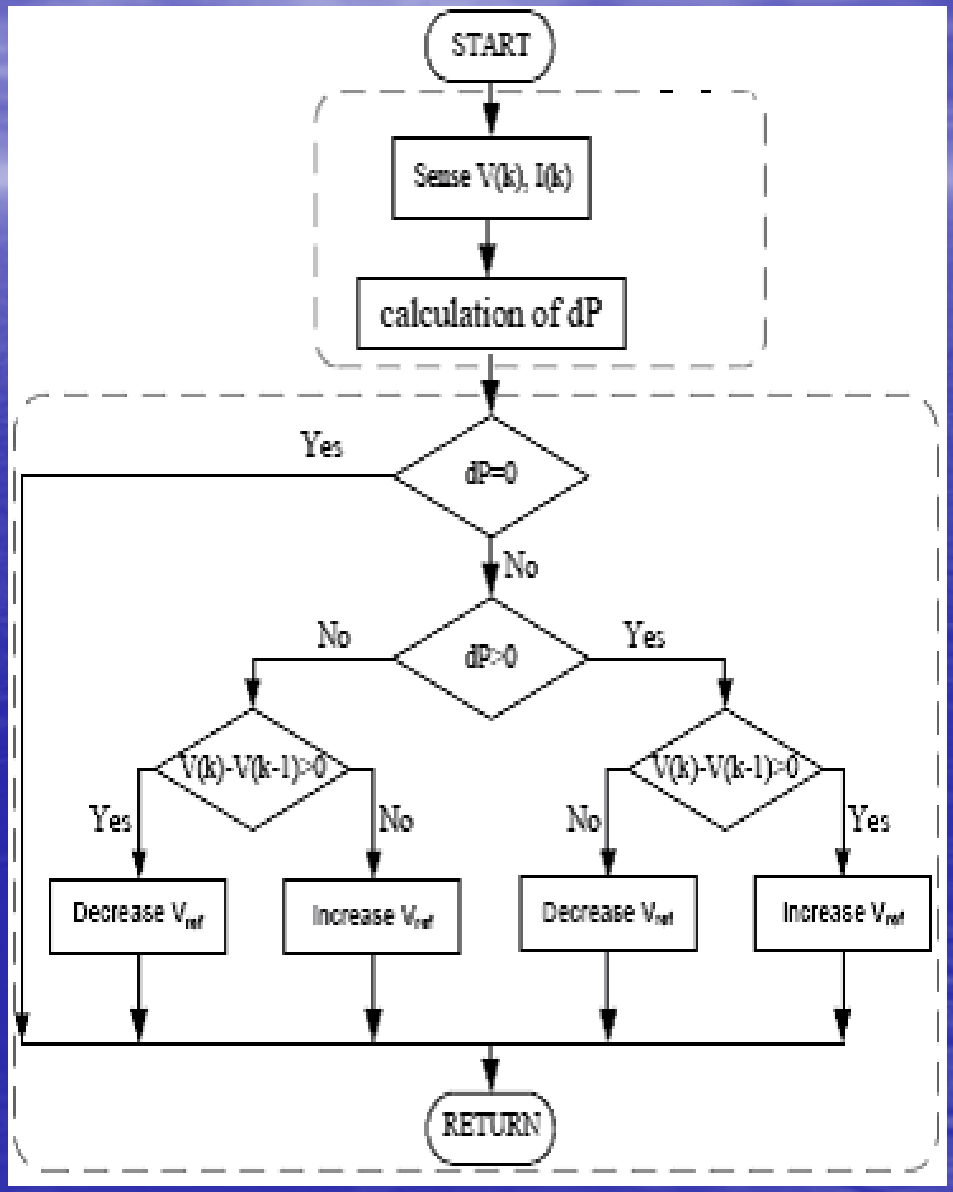
Energy Conversion System



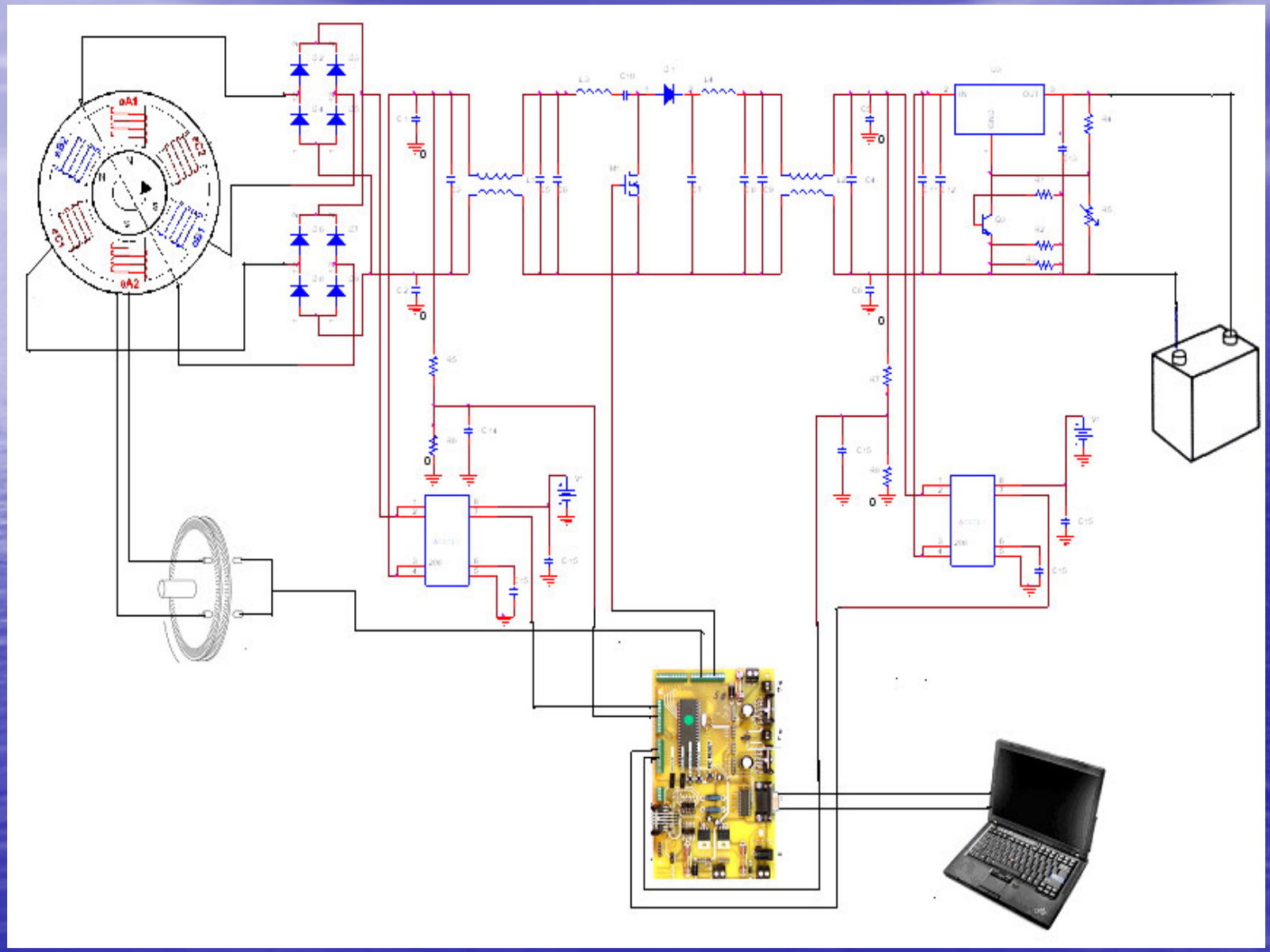
MPPT Algorithm

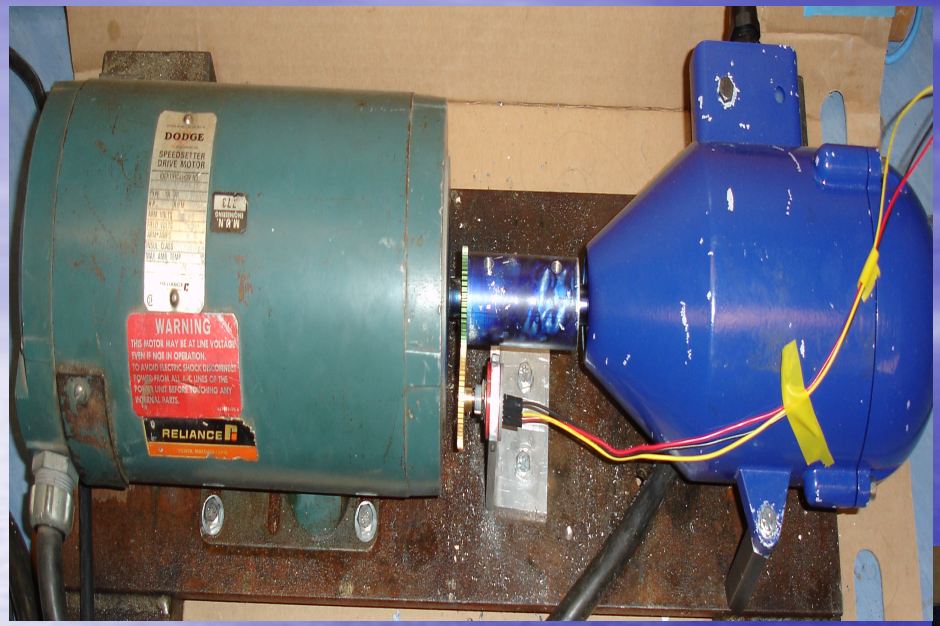


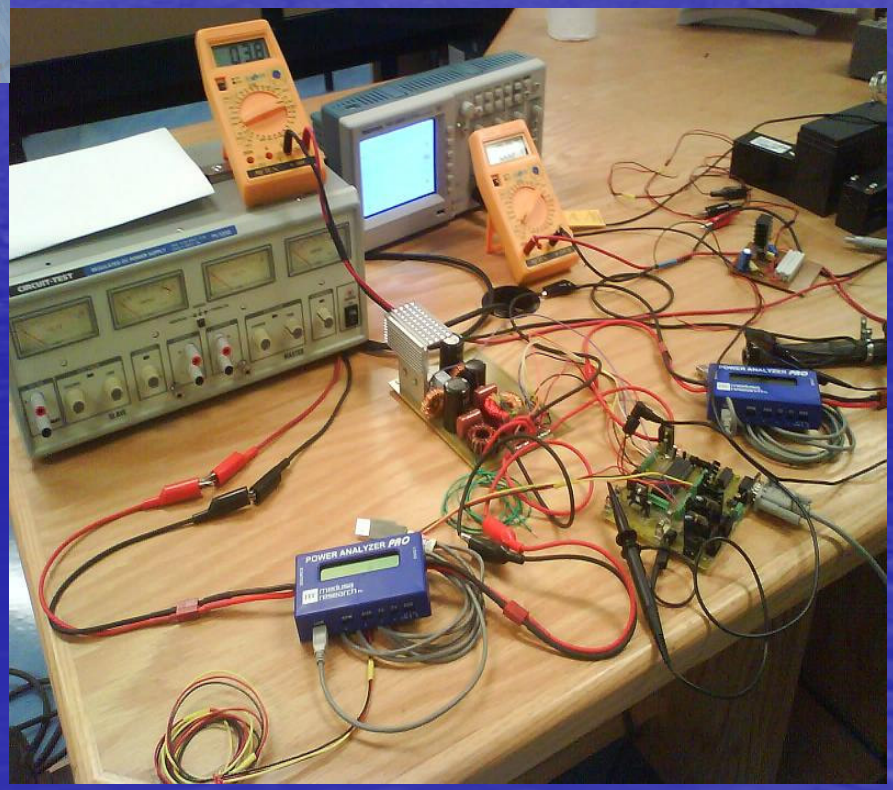
Case	dP	dV	Action
1	<0	<0	+
2	<0	>0	-
3	>0	<0	-
4	>0	>0	+



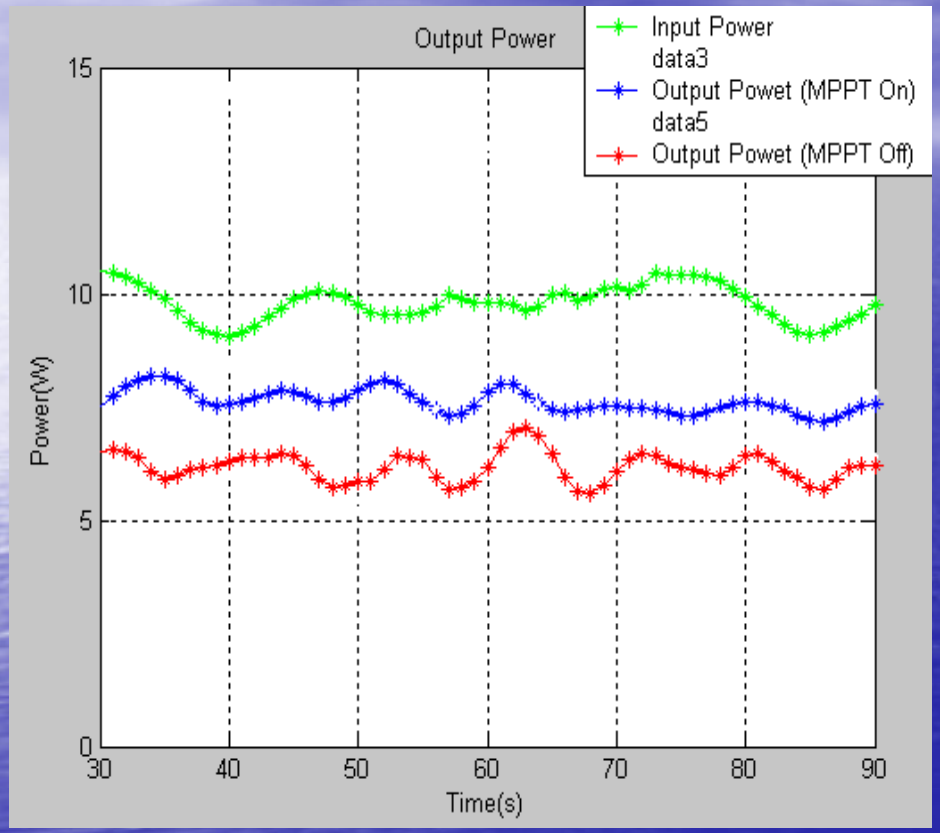
Energy Conversion System Setup

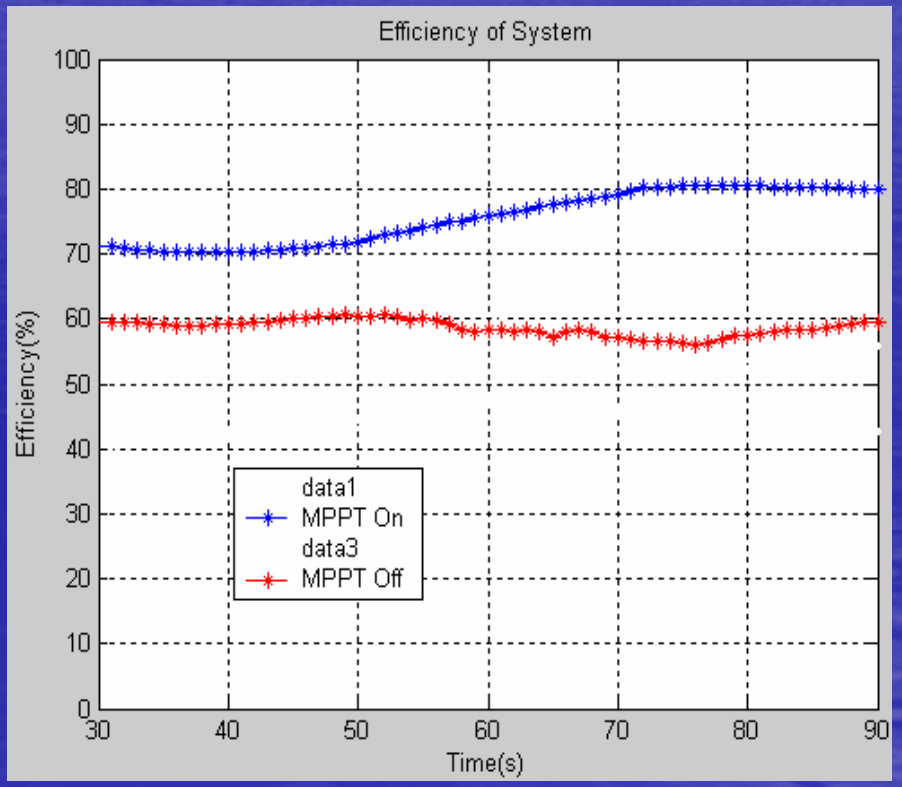



DODGE
SPEEDSETTER
DRIVE MOTOR
WARNING
RELIANCE


POWER ANALYZER PRO

Experimental Result





Thesis Contribution

Conclusion

Future Work

Acknowledgements

Supervisors

Dr.M.Tariq Iqbal

Dr.Michael Hinchey

Others

Dr.Vlastimil Masek

Paul Bishop

Brian Pretty

Publications

- *'Sea-Floor Power Generation System', presented at 17th IEEE NECEC Conference, November 8, 2007, St. Johns, NL.*
- *'Submerged Water Current Turbine', going to be presented at Ocean'08 MTS/IEEE Quebec Conference.*
- *'Performance of Savonius Rotor as Water Current Turbine' submitted in Journal of Ocean Technology.*
- *'Scaling Laws of Water Current Turbine' submitted in Journal of Ocean Engineering.*

THANK YOU

???