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POWER CORPORATION

Improved High Performance Flywheels

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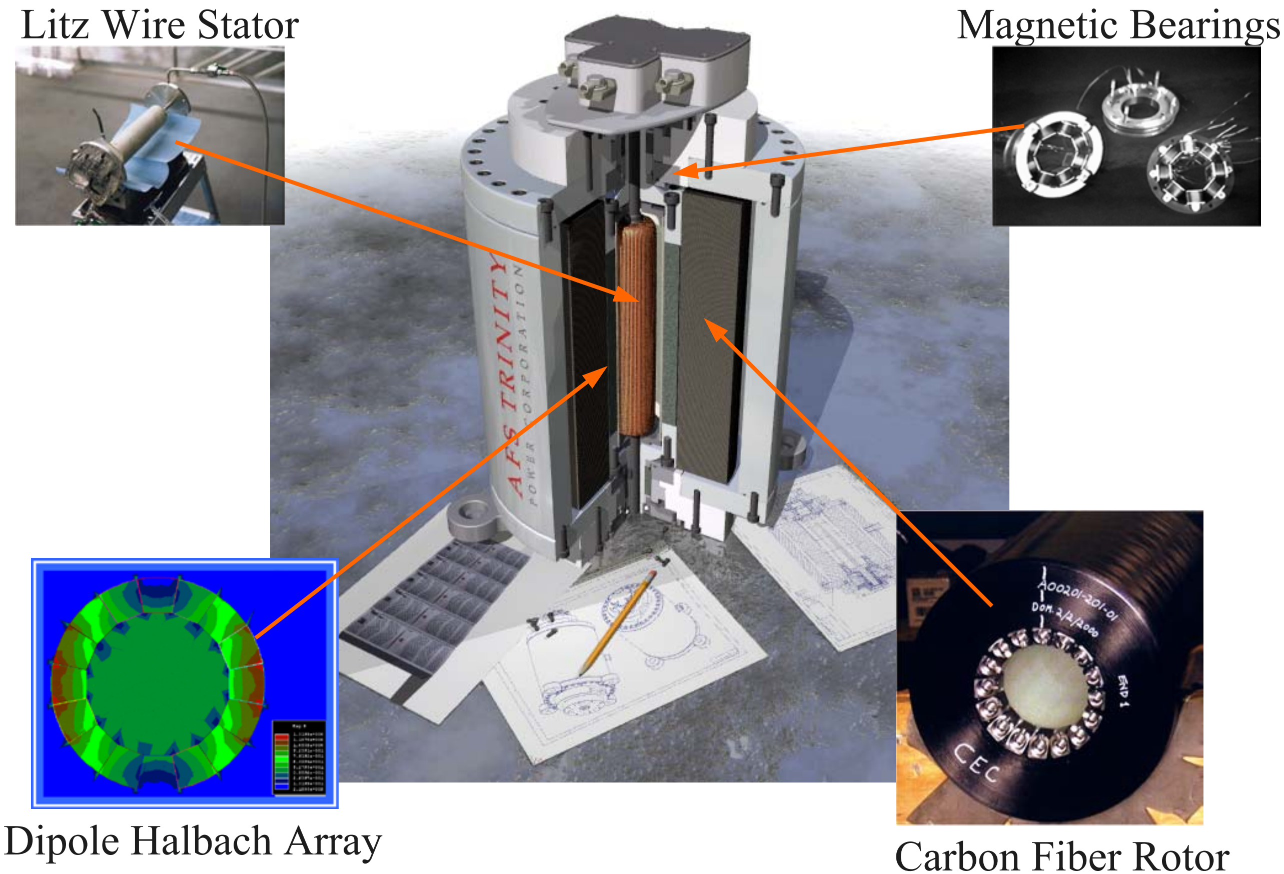
Topics

- Flywheel Power System Overview
- Objectives of the DOE/Sandia project
- Status of the project

M3 FPS (Flywheel Power System)

Flywheel Motor-Generator

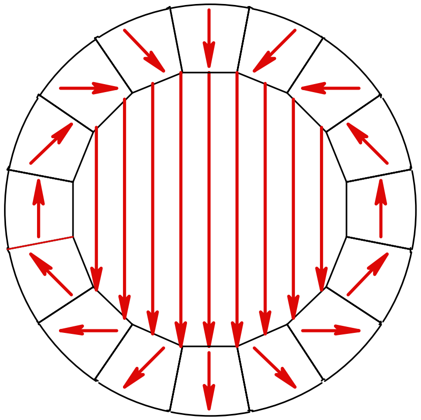


AFST Core FPS Architecture

- Carbon fiber rotor - more energy, less expensive than steel.
- Halbach Array motor-generator - no hysteresis, high power density.
- Mechanical or magnetic bearings depending on application.
- Power electronics and control are key to integration.
- Initial design point advocated by numerous interested end users.
  – Diverse applications: ridethrough, trackside, hybrids, military
  – Segregated application space on the basis of discharge time

Halbach Array

- ➢ Internal magnetic field uniform to 1% within bore.
- ➢ External field cancellation.
- ➢ Permanent magnet segments built into bore of rotor.
- ➢ No iron - eliminates hysteresis.
- ➢ No saturation limit.
- ➢ Very high fields (>4 kilogauss).
- ➢ Very high power density.



Demonstrated Performance Attributes

• Power symmetry	Charge rate = discharge rate
• Duty factor	50% at full power, 4 x 15s cycle: dwell-charge-dwell-discharge
• Efficiency	1-way efficiency is 95% at 110kW Round trip efficiency is ≈ 90%
• Losses	Very low on-rotor loss (<25W) Balance of system losses ≈ 500W
• Cycle performance	Demonstrated >40,000 w/o degradation Design >> 10^6 Cycle-to-cycle repeatability is perfect

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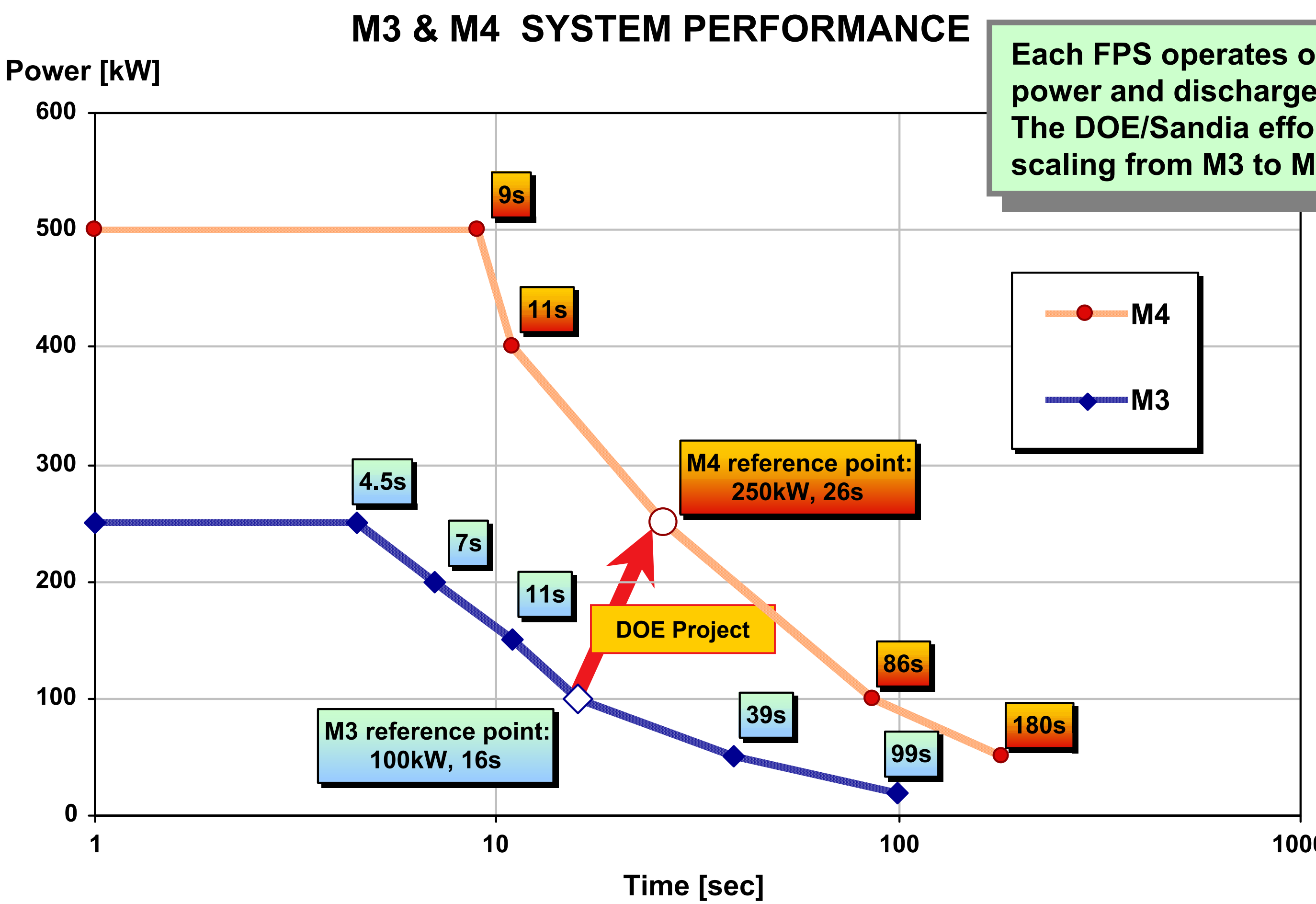
Objectives of the DOE/Sandia Project

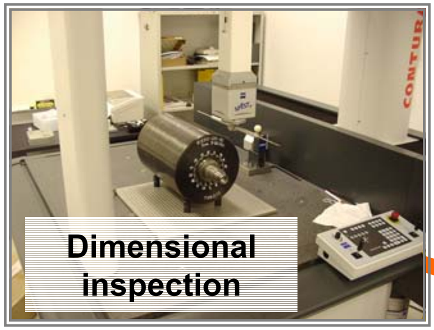
- The DOE/Sandia project is part of a larger program to scale the existing system to larger size
  - Present size: 100kW, 15 seconds
  - Objective: 250kW, 25 seconds
- The DOE/Sandia effort is conducted in partnership with the California Energy Commission (CEC).
  - CEC participation: System development and integration, Scale-up to 2 kWh
  - Sandia/DOE participation: Rotor scale-up cost share to CEC and internal funds
- DOE/Sandia program goals: develop and prove composite rotor innovations that will permit scaling of the rotor from M3 size to M4 size
  - Modify design, materials, manufacturing process
  - Build test pieces at present M3 scale - test pieces are flywheel rotors
  - Prove innovations through burst testing flywheel rotors

FPS Operating Range and the DOE/Sandia Project



Each FPS operates over a range of power and discharge time.
The DOE/Sandia effort will facilitate scaling from M3 to M4 capability.

Proving New Rotor Design and Process Improvements



Burst Testing

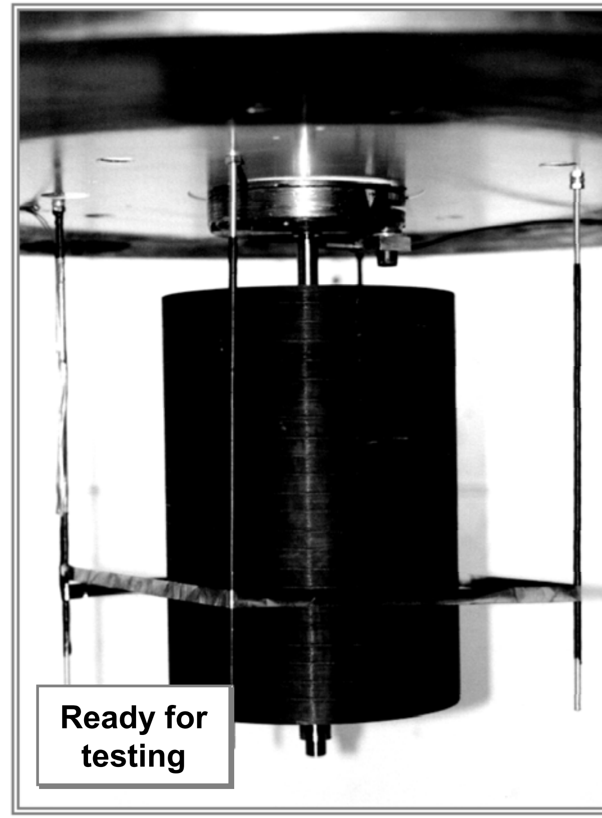
Process Control

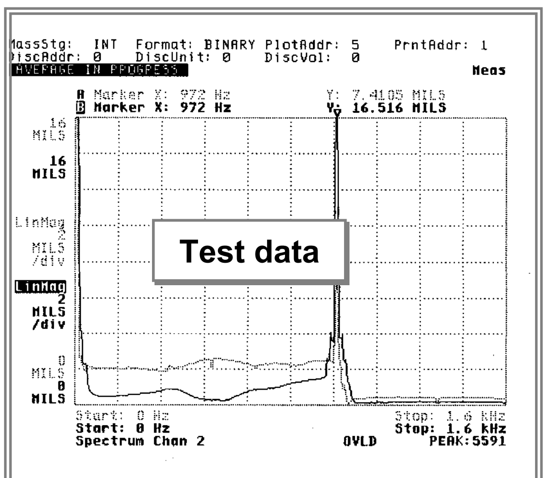
		M3AM Rotor S/N A10301-201-04 - Rotor built for P5											
Group #	Comments	End to Machine	Runout at min speed			Runout maximum				Lead End X-Bar		Torque End X-Bar	
			RPM	B%	A%	RPM	B%	RPM	A%	Balance (gr-in)	Angle	Balance (gr-in)	Angle
1	9/10/02 - initial balance check	Lead								28.700	209	39.625	204
2	6/01/02 - final balance check: built as P5B1	Lead								0.165	39	0.15	324
3	6/01/02 - final balance check: P5B1, turned end to end	Torque								0.422	322	0.172	79
FRACAS 22	high vac. Chip in O-ring groove												
P5B1	implied RO. (100%=2.4mil)	0.0024		0.0002	0.0006								
A-init-run	start of first run, accelerating		9900	7%	25%	23k+	22%	19k+	33%				
A-init-run	end of first run, decelerating		6180	8%	13%								
A-cyc-618	Last data for build		2940	14%	37%	32k-	20%	29k-	56%				
	implied unbalance (x gm-in/%)	4.69		65.7	173.5								
FRACAS 24	DC caps failed												
4	7/24/02 - initial balance for P5B2	Lead								10.25	235	12.00	242
5	7/24/02 - final balance for P5B2	Lead								0.162	231	0.222	332
6	7/24/02 - final balance for P5B2, rotor turned end to end	Torque									79	0.251	96
P5B2	implied RO. (100%=2.4mil)	0.0024											
A-T1-020805	start of first run, accelerating		6000										
A-T1-020805	end of first run, decelerating		3000										
A-T5, B-T5	Last data for build												
FRACAS 28	Runout display questionable	19-Aug											
FRACAS 29	Stator shorted and failed	26-Aug											
7	8/28/02 - initial balance for P5B3	Lead									234	7.22	182
8	8/28/02 - final balance for P5B3	Lead								0.433	136	0.387	148
9	8/28/02 - final balance for P5B3, rotor turned end to end	Torque								0.461	222	0.195	225
P5B3	implied RO. (100%=2.4mil)	0.0024		0.0002	0.0006								
020830_recal	start of first run, accelerating		3000	9%	24%								
020830_recal	end of first run, decelerating		3000	4%	28%	25k-	21%	25k-	42%				
021018 T23	Last data for build (10/18/02)		3000	32%	69%	25k-	37%	25k-	81%				

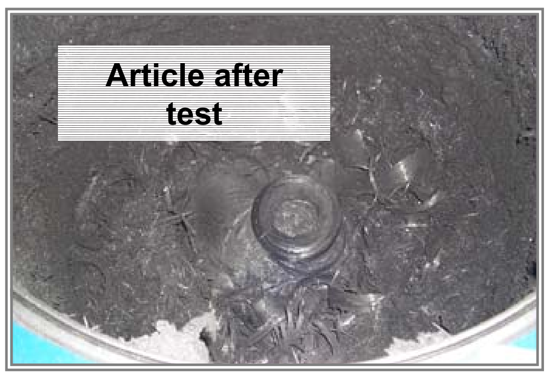
Successful burst test results are an essential aspect of rotor development.

Safety is Fundamental Requirement

- Safety is the paramount design requirement
- AFST has extensive experience proving rotor design margin through testing
  - Control design and manufacturing process
  - Repeatable performance varying lots and vendors
  - Burst tests, life tests
- All design or process innovations must meet same high standard
  - Prove design through statistically significant number of tests







The goal of the program is to prove the new design in a series of burst tests.

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Status

- Project history
  - Timeline: underway for 5 months
  - Initial activity: design modifications involving material and process changes
  - First articles of new design were found unsatisfactory during post-manufacturing inspection
  - Further investigation identified root cause as process related
- Present state
  - An experiment to isolate process variable is underway (multiple test pieces)
  - Ongoing activity stretches project timeline
  - Present process development conducted at company and vendor expense
- Projections
  - Pending results of process experiments, will resume production of test articles in 1/03
  - Followed by spin testing of 3 rotors over 10 week period

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We anticipate that the project will attain its original goals