Interim Report

CoP results using capacitors

Introduction:

This interim report addresses some additional experimentation whereby the receiving battery, conventionally used in previous Coefficient of Performance (CoP) tests, is replaced with a bank of capacitors.

In the regular CoP testing protocol, the flyback generator is supplied by a power supply, instead of the regular 'run' battery, in order to provide consistency and flexibility of the supply voltage. The pulses are directed to the 'receiving' battery without the battery swapping system enabled. The purpose of replacing the receiving battery with a bank of capacitors was to see if the same energy gains are observed and as a way of indicating the significance of the battery chemistry in the energy harvesting process.

If similar CoP values are derived, then that suggests that the pulses are initiating energetic processes that are independent of the battery electrochemistry through some form of direct polarisation. If on the other hand, the CoP results are significantly less than one, then that would indicate that in some way the electrochemistry is fundamental to the energy harvesting process and the associated energy pathways. While this would not provide any detailed information on the mechanisms and pathways involved, it would allow certain options to be placed to one side and certain other alternatives to be explored as plausible mechanisms for the harvesting phenomenon.

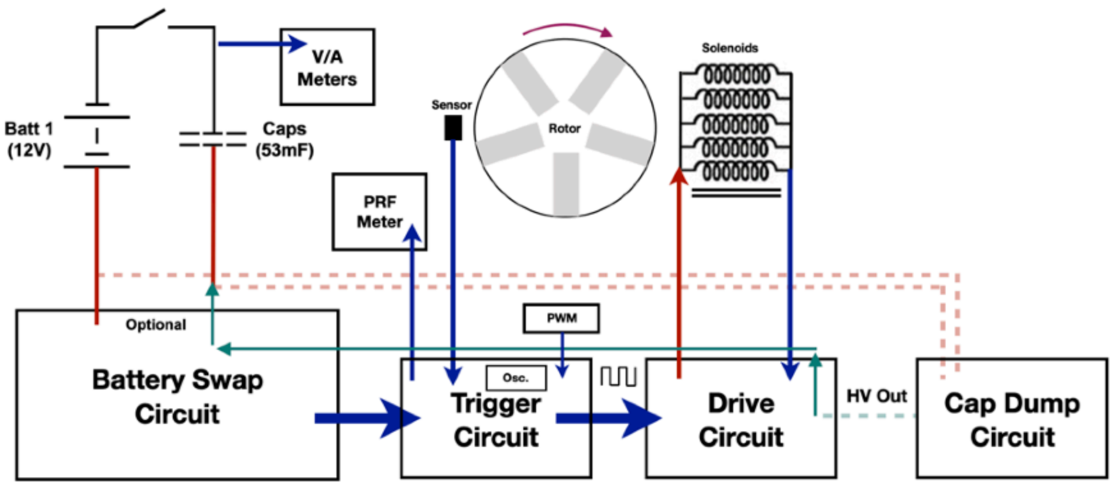

Fig 1: Functional diagram using capacitors in place of 'receiving' battery

Initially, the prospect of using super capacitors offered certain advantages to a regular Lead Acid or Lithium's Iron Phosphate battery in that a capacitor can have its energy content reduced to zero with a measured discharge. In contrast, a battery would be damaged by draining it to that extent and, if done repeatedly, would be unlikely to perform reliably in the future if at all. However, the disadvantage is that with the typical nominal voltage of a 500F super capacitor being only 2.7V, this presented a series of challenges that would make achieving consistent and accurate measurements difficult to achieve. This was so even when multiple units were grouped together in series to make a higher voltage, lower capacitance module. For several reasons an alternative approach needed to be found.

Firstly, the flyback generator requires a common ground connection for both the supply and the receiving battery and for the pulses to enter the battery. When replacing the receiving battery with a capacitor bank with a low voltage, the power supply would automatically try to raise the capacitor voltage to the supply voltage which resulted in a slow but significant charging of the capacitors. Attempts to create a circuit with a separate and isolated ground reference for the receiving battery interfered with the pulse creation process and effectively disabled the unit. The common ground was determined to be an essential feature of the device for successful operation.

Secondly the computerised battery analyser (CBA) circuitry would interpret the low capacitor voltage during a discharge as a small capacity battery and so restrict the discharge current to 5mA. This rendered the time taken to measure a discharge inordinately long and liable to error on account of the noted self-discharge behaviour. The charged super capacitors were observed to drop their voltage at a rate of about 40mV/s, even when disconnected from all other circuitry, and which would made stable and accurate measurements of voltages achieved after charging, and serving as the reference voltage for discharging, difficult to achieve.

An effective work around was devised by using the bank of capacitors that formed part of the capacitive discharge unit that was tested early on in the project. This comprised a set of four 15 mF, 80V capacitors grouped in parallel so as to construct a 60mF, 80V capacitor bank and with an actual measured capacitance of 53mF.

The higher operating voltage would avoid the problems with the CBA and involved voltage measurements in the 12-60V range, and so in between the effect of the common ground on the capacitors' voltages and the maximum possible value. Making measurements starting around 12V, and less than the nominal 80V breakdown value, would provide for sufficient data even though charging would occur over a much shorter time period than when using super capacitors. The times used however, of the order of 40-60s, were long enough to make accurate measurements of the charging time for calculation of the energy supplied to the generator and the functional circuit is shown in Fig 1.

An additional benefit of using the smaller bank of capacitors is that its value was readily measured with a regular capacitance meter, whereas all such equipment failed to give a reading for the super capacitors.

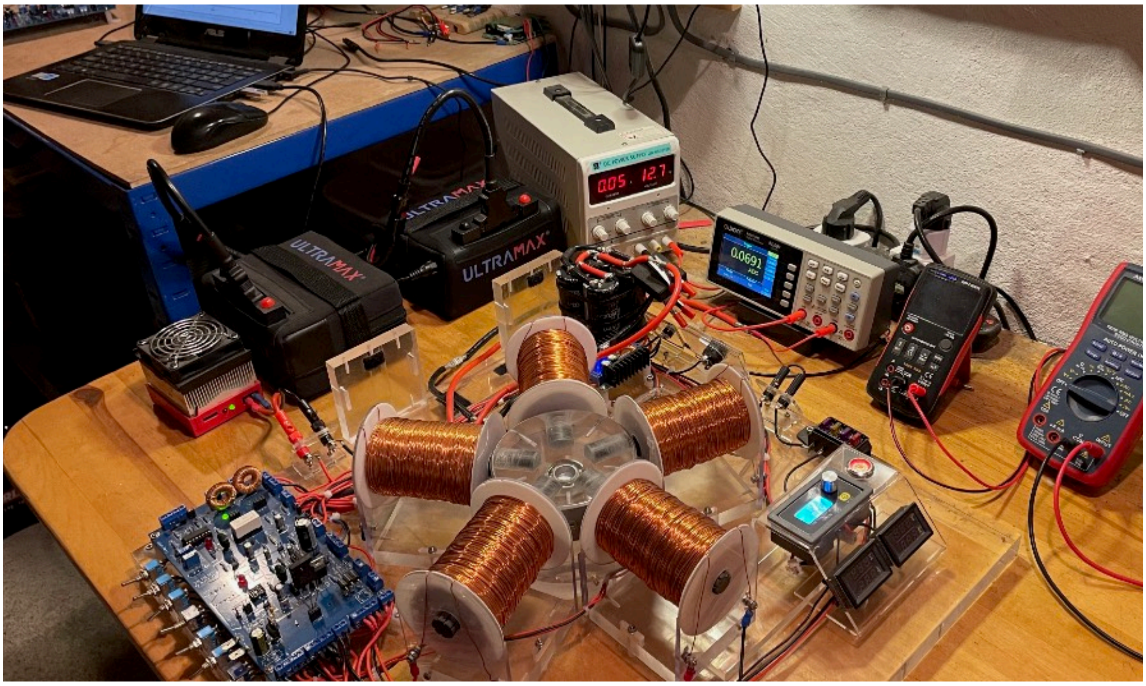

Fig 2: Measurement Setup

The experimental setup was as shown in Fig 2 with the capacitor bank replacing the ‘receiving’ battery. The pulses used were 1.7kV generated with an IGBT active device at 50Hz, and which resulted in a suitable rate of voltage rise during the pulse charging.

Experimental methodology:

The measurement process used was simpler than for the regular CoP measurements and involved the following stages:

1. Let the capacitor settle at around 12V, due to the common ground, switch off and measure the voltage with the CBA.

2. Start pulse charging alongside recording the run time, the current supplied, using automatic recording by the RDM unit, and the graphical voltage-time plot using the CBA’s Charge Monitor function.

3. At a suitable capacitor voltage, switch off and isolate the capacitors to limit any discharge.

4. Record the starting voltage using a separate meter from the CBA (to minimise the small discharging within the units circuitry while it is still connected but in idle mode.

5. Set up the discharge parameters on the CBA, connect the unit and run it in discharge mode until the set shut-off voltage is reached at typically 14V.

6. Record the energy discharged in Wh as well as the graphical plot and the supply current data from the RDM unit.

7. Record screen grabs of both stages.

8. Correct the energy supplied to the generator to account for the small intervening discharge prior to the main discharge stage (further explained below)

9. Calculate the energy supplied to the generator by the power supply, as per the CoP test process.

10. Calculate the energy discharged (retrieved) from the capacitors using the CBA discharge data and derive the CoP value

The correction referred to in step 8 relates to the fact that after pulse charging the bank of capacitors will discharge a small amount during the brief time it is still connected to the CBA before disconnection. If, for example, the capacitors dropped 7% of their voltage then the voltage range available in the discharge stage is correspondingly reduced. The calculated energy supplied to the generator was therefore reduced by the same proportion to accurately reflect the voltage available for discharge and the measured energy release.

The method using smaller capacitors circumvented the various issues around using super capacitors, and yet still provided a suitable means to observe the effect of the flyback pulses on a receiving system in the absence of any battery chemistry. The super capacitors will still have a valuable use in a control experiment, in that they will serve to absorb the HV pulses instead of their being directed to the receiving battery. This will provide a means to observe the behaviour of the battery under the conditions that represent a null hypothesis.

Results:

Once the methodology had been adjusted and practiced to allow for smooth test runs, then three tests were undertaken with different charging end voltages. These are shown in the following graphical plots and spreadsheet tables.

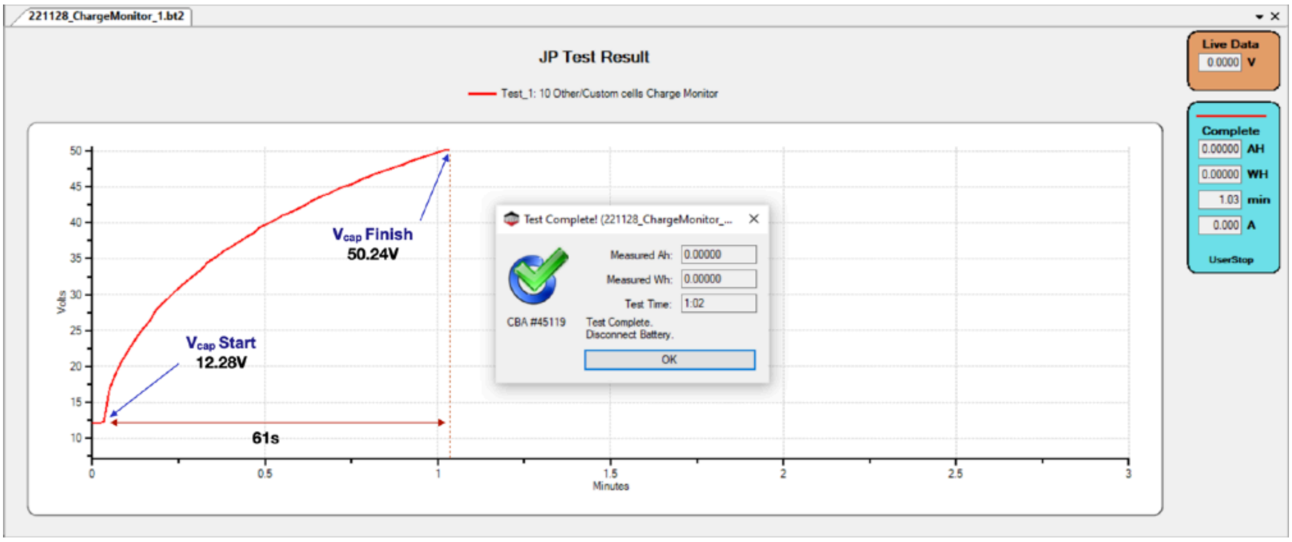

Fig 3: Pulse charging of the capacitors

Figure 3 shows the live charting plot, with its characteristic exponential form, as the pulses were applied to the bank of capacitors. Table 1 presents the numerical charging data for the three test runs and Table 2 the energy supply data.

	Data - Exp 8: Super-capacitor charging							
	Blue - data input	***Red - Auto Fill/Calculations***						
	Capacitor (53mF): Charging							
Test No.	**Cap. (F)**	**HV (kV)**	**PRF (Hz)**	**Start Voltage [1] (V_i)**	**End Voltage [2] (V_i)**	**dV1 (V) [3]**	**CBA Test ID**	**Screengrab File**
1	0.053	1.7	50	12.28	50.24	37.96	*281122_Charge Monitor_1-1.bt2*	*281122-Charge Monitor End 1*
2	0.053	1.7	50	11.99	40.65	28.66	*281122_Charge Monitor_1-2.bt2*	*281122-Charge Monitor End 2*
3	0.053	1.7	50	11.87	30.91	19.04	*281122_Charge Monitor_1-3.bt2*	*281122-Charge Monitor End 3*
Notes	*[1] The voltage start point for pulse charging and which is not zero due to the effect of the common ground wiring that applies the supply voltage to the reading*							
Notes	*[2] The voltage end point arbitrarily decided and less than the maximum specification rating of 80V*							
Notes	*[3] The voltage range over the charging period. Used with the discharge voltage range (dV2) to calculate the energy supplied correction*							

	(PSU) - Supply									
Test No.	**Supply V (V) [1]**	**Coil V (V) [1]**	**Circuit V (V)**	**Circuit Current (A) [2]**	**Circuit Power (W)**	**I_{av} (A) [3]**	**Run Time (s) [4]**	**$E_{(Supplied)}$ (J) [5]**	**$E_{(Supplied)}$ (J) [6]**	**RDM Imaging/Export File**
1	13.12	12.36	12.35	0.098	1.29	0.26	59	194	174	*281122-Current Table 1*
2	13.20	12.44	12.42	0.098	1.29	0.25	30	96	88	*281122-Current Table 2*
3	13.20	12.44	12.42	0.098	1.29	0.29	14	52	46	*281122-Current Table 3*
Notes	*[1] No Load value [2] Current to circuit excluding coils (MOSFET/IGBT off)*									
Notes	*[3] Total circuit current including coils. Derived from Mean of RDM data set*									
Notes	*[4] Time taken for capacitor to reach chosen voltage*									
Notes	*[5] Total energy to circuit and coils calculated using their respective voltages ((Coil V x (Total I - Circuit I) x Time) + (Circuit Power x Time)*									
Notes	*[6] Energy supplied to generator with a correction applied for the same voltage range as that discharged ($E_{supplied}$ x (dV2/dV1))*									

Table 2: Supply data during generator operation

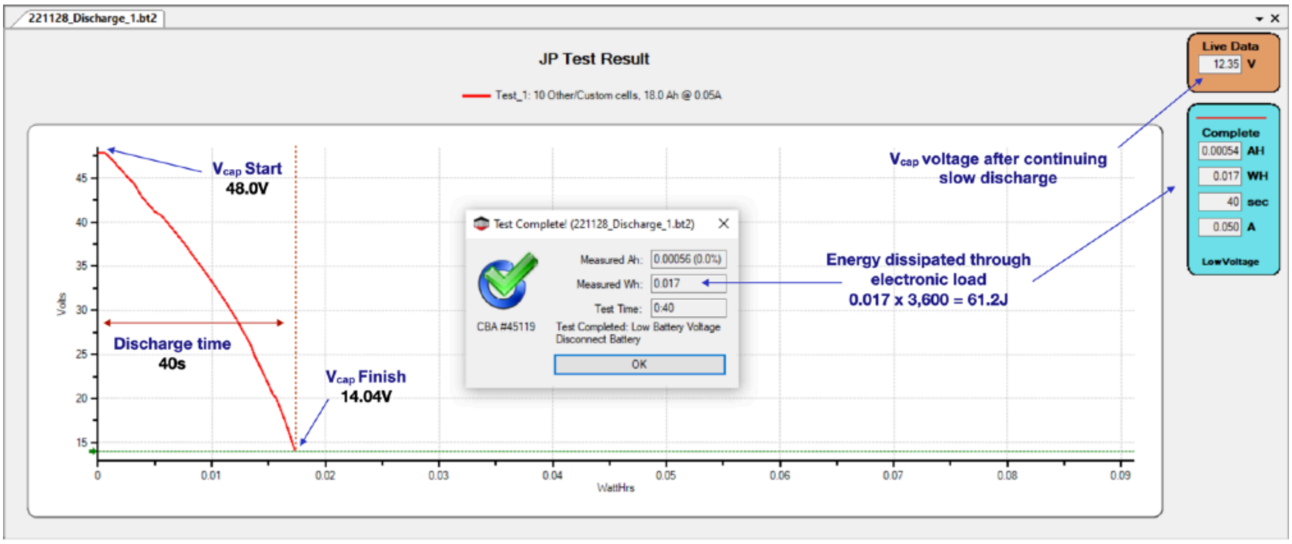

Fig 4: Discharge of the capacitors with a measured energy release

After charging and isolating the capacitors, to prevent unwanted discharge, the CBA was used to undergo a measured discharge and this resulted in the plot in Fig 4 and with the assembled data for discharge presented in Table 3.

	Capacitor (53mF): Discharging							
Test No.	**Start Volt (V_i) [1]**	**Final Volt (V_f) [2]**	**dV2 (V) [3]**	**dV2/dV1 [4]**	**E Discharge (Wh)**	**E Discharge (J)**	**CBA Test ID**	**Screengrab Files**
1	48.00	14.04	33.96	0.89	0.017	61.20	*281122_Discharge_1-1.bt2*	*281122-Discharge End 1*
2	39.92	13.53	26.39	0.92	0.012	43.20	*281122_Discharge_1-2.bt2*	*281122-Discharge End 2*
3	30.58	13.71	16.87	0.89	0.006	21.60	*281122_Discharge_1-3.bt3*	*281122-Discharge End 3*
Notes	*[1] Voltage at start of CBA discharge function*							
Notes	*[2] Voltage at auto-shut off of CBA discharge function*							
Notes	*[3] (Start - Finish) voltage range*							
Notes	*[4] Ratio of discharging voltage range (dV2) to the charging voltage range (dV1). Used as a correction factor for the energy supplied to the generator*							

Table 3: Capacitor discharge data

The CBA automatically allocated a discharge current of 50mA which was a suitable value for the plot to be acquired in a reasonable time. This current was nevertheless adapted by the electronic load during the discharge process and which resulted in a different discharge curve than normally expected for a capacitor. Normally a capacitor, via discharge, will demonstrate an exponential voltage decay expressed by $V.e^{-t/RC}$. However, due to the CBA unit maintaining the discharge current at a level commensurate with the voltage being presented to it, this had the effect of modifying and inverting the shape of the discharge curve.

The derived CoP values, and their associated uncertainties, are presented in Table 4 along with the various statistical equations used to calculate them.

Test No.	Receiving Capacitors - CoP & Uncertainties															
Test No.	HV (kV)	PRF (Hz)	$V_{(cap)}$ pk	δ_V V	δ_I A	δ_t s	$E_{(Supplied)}$ J	δ_{Es}	Δ_{Es} J	$E_{(Discharged)}$ J	δ_{Ed}	Δ_{Ed} J	CoP	δ_{CoP}	Δ_{CoP}	CoP $\pm$ Δ_{CoP}
1	1.7	50	50.2	7.62E-03	3.85E-02	1.69E-02	174	6.3E-02	1.09E+01	61	8.2E-02	5.00E+00	0.35	1.4E-01	0.05	0.35 ± 0.05
2	1.7	50	40.7	7.58E-03	4.00E-02	3.33E-02	88	8.1E-02	7.12E+00	43	1.2E-01	5.00E+00	0.49	2.0E-01	0.10	0.49 ± 0.10
3	1.7	50	30.9	7.58E-03	3.45E-02	7.14E-02	46	1.1E-01	5.18E+00	22	2.3E-01	5.00E+00	0.47	3.4E-01	0.16	0.47 ± 0.16
Equations	$E_{(Supplied)} = V_{(av)} . I_{(av)} . t$ J			$\delta_V = \Delta_V / V$, $\delta_I = \Delta_I / I$, $\delta_t = \Delta_t / t$				$\delta_{Es} = (\delta_V + \delta_I + \delta_t) = \Delta_{Es} / E_{(Supplied)}$			$\Delta_{Es} = (\delta_V + \delta_I + \delta_t) \times E_{(Supplied)}$ J					
Equations	$\delta_{Er} = \Delta_{Er} / E_{(Received)}$			CoP = $E_{(Discharged)} / E_{(Supplied)}$			$\delta_{CoP} = (\delta_{Ed} + \delta_{Es})$				$\delta_{CoP} = \Delta_{CoP} / CoP \therefore \Delta_{CoP} = \delta_{CoP} \times CoP$					

Table 4: CoP calculations and uncertainties

Conclusions and Discussion:

The CoP values shown in Table 4, being well below 1, are in effect the same as conventional measurements of efficiency. In other words, the efficiency in the conversion of energy from the supply source to the inductively generated pulses is of the order of 50% or less. This is to be expected due to the losses experienced inside the solenoids due to magnetic hysteresis and related causes, as well as heating losses in the circuit components. Indeed, part of the list of scheduled experiments was to use capacitors as a way to derive the generator efficiency, although in those it was planned to use $E = I/2\ CV^2$ as a simple way to calculate the energy held within the capacitors after charging. Some quick computations using this formula gave values that were generally similar to the values of energy released from the capacitors as determined by the electronic load. Small variations here are due to the fact that the capacitors started their pulse charging process from a standing voltage of about 12V instead of from zero volts.

It was noted that the CoP values were not consistent but rather a function of the peak capacitor voltage reached. This is taken to be due to the normal exponential charging profile and which is steepest at lower voltages and then levels off asymptotically, with a reducing gradient, towards the maximum voltage. With the energy supplied being a linear function of time, then charging the capacitor closer to its maximum possible voltage (80V) will have increasingly less effect and serve to increase the energy input denominator in the CoP calculation, and therefore reduce the resulting value.

More specifically, with $V = Q / C\ (1 - e^{-t/RC})$ or $V = V_{max}\ (1 - e^{-t/RC})$, and where C = 0.053F and RC is estimated to be 80s, then after I x RC time constant, the voltage should have risen by 63% of 80V = 50.6V. Given that there was a ‘standing voltage’ on the capacitor, due to the supply issues discussed earlier, then this would have taken it up to around 61V after 80s. However, as t proceeds, the rate of charging levels off as $e^{-t/RC}$ asymptotes at V_{max} and this reduces the measured CoP as described.

These results clearly indicate that there is no evidence of a process of energy gain taking place, from whatever source, that involves the effect of the voltage transients on the space-time metric itself, as has been considered. This clarifies the answer to the question regarding whether the HV transients are themselves able to trigger an energy influx from some source by virtue of their voltage gradient (dV/dt) alone and without the agency of other components, for example, chemical complexes and other structures and chemical fractions within the battery's electrochemistry.

Given these results, it enables the focus of attention to be placed in more fruitful areas such as 'dissipative structures', negentropic process, thermodynamic asymmetry, boundary conditions, metastable states and other possible reasons for Second Law violations.

Testing any hypotheses in these areas will require a different approach to that already undertaken to test the hypothesis regarding the presence or not of an energy harvesting phenomenon. Such testing would involve a detailed study of the electrochemical potentials, Gibbs free energy, enthalpy and entropy changes within the bulk of the system.

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9th December 2022