ChatGPT

Abstract

Graphene-based ultracapacitors have emerged as promising energy storage components, offering exceptional power density and cycle life. This paper presents a survey of commercially available graphene ultracapacitors on OEM/ODM platforms (e.g., Alibaba, Made-in-China) optimized for either high voltage or high current applications, including specific models, technical specifications (voltage, current, capacitance, dimensions), and pricing. Maximum Power Point Tracking (MPPT) DC–DC modules capable of maintaining continuous operation under high voltage and current are also identified with their ratings and costs. Using these components, two ultracapacitor sub-systems are designed: (1) a voltage-dominant bank (series-connected cells for high voltage output) and (2) an amperage-dominant bank (parallel-connected cells for high current output). We describe the configuration and integration of both sub-systems into a single circuit via an MPPT controller, and we calculate the combined system's performance, demonstrating on the order of kilowatts of power output and total energy on the order of 1 kWh. The feasibility of this high-performance DIY energy storage approach is discussed in terms of cost-efficiency, availability, and practical implementation. In-text citations to supplier data and an extensive reference list are provided to ensure transparency and verifiability.

Introduction

Electrochemical double-layer capacitors (EDLCs), commonly known as ultracapacitors or supercapacitors, have attracted attention for high-performance energy storage systems due to their high power density, rapid charge-discharge capability, and longevity (often >100,000 cycles) [1]. However, conventional ultracapacitors have relatively low energy density compared to batteries. Recent advances with *graphene*-enhanced ultracapacitors (including hybrid supercapacitor "ultrabattery" designs) claim significantly improved energy density (e.g. up to 220 Wh/kg) [2] while retaining high power output. This makes graphene ultracapacitors attractive for DIY projects requiring both high power and reasonable energy storage capacity.

A key challenge in utilizing ultracapacitors for system-level storage is achieving both high voltage and high current output. Individual supercapacitor cells typically have low nominal voltages (~2.7 V for EDLCs, up to ~4 V for some graphene or lithium-ion capacitors) [3]. Reaching higher voltages requires series connection of cells, while achieving higher capacitance (and thus higher peak current capability) requires parallel connection. Managing such banks of capacitors calls for careful design (including cell balancing in series strings [4]) and appropriate power electronics to interface with loads or other storage elements.

Maximum Power Point Tracking (MPPT) converters, widely used in solar photovoltaic systems, are essentially DC–DC converters that can dynamically adjust their input impedance to maximize power transfer. In this work, we repurpose high-power MPPT modules to regulate and connect the ultracapacitor banks to a common output. The MPPT ensures full electrical continuity and optimal power flow from the capacitors by adjusting voltage and current dynamically, analogous to how it optimizes power from solar panels [5] [6]. Using an MPPT in a supercapacitor storage system allows one to draw energy from capacitors across a wide voltage range while providing a stable output to the load or battery.

This paper identifies specific graphene ultracapacitor components and MPPT units available from OEM/ODM suppliers, then details the design of two complementary ultracapacitor sub-systems – one optimized for high-voltage output and one for high-current output. The combined system is proposed as a high-performance DIY energy storage solution, and we estimate its output in kilowatts (kW) and energy capacity in kilowatt-hours (kWh). The following sections cover the technical methodology for component selection and system design, the schematic and operation of the proposed system, a list of components with suppliers and prices, calculated performance metrics, a discussion of feasibility, and conclusions.

Technical Methodology

Research Approach: We began by researching supplier marketplaces (Alibaba, Made-in-China, etc.) for *graphene ultracapacitors* with emphasis on two categories: (1) high-voltage modules and (2) high-current (high-Farad) cells. Product specifications and pricing were gathered from manufacturer listings and datasheets. Similarly, we searched for high-power MPPT modules that could operate under the combined high voltage and high current conditions of the ultracapacitor banks. All data was cross-referenced and cited directly from supplier information to ensure accuracy.

Ultracapacitor Selection Criteria: For high-voltage capability, we focused on modules or cells that either have higher per-cell voltage or come pre-assembled in series. For high-current, we looked for cells with large capacitance (thousands of farads) and low equivalent series resistance (ESR), as ESR largely determines the maximum current and power output. Key parameters documented include: rated voltage (V), capacitance (F), stored energy (Wh), energy density (Wh/kg), ESR (mΩ), continuous and peak current ratings (A), cycle life, dimensions, and weight. Cost per unit and minimum order quantity (MOQ) were noted to assess cost-effectiveness for DIY scale procurement.

MPPT Selection Criteria: We identified MPPT DC–DC converters (often solar charge controllers or DC power modules) that can handle high input voltages and high output currents continuously. Important specifications collected include: maximum input (PV) voltage, output voltage range, maximum output current, maximum output/pV power, supported battery/system voltages, and any features for parallel operation or communication. Since the ultracapacitor combined system may see widely varying voltages, MPPT units with wide input ranges (e.g. up to hundreds of volts DC) were prioritized. Likewise, units with high current ratings (50–100 A or more) were considered to allow kW-level power transfer. Pricing and supplier info for each MPPT model are documented.

Design Calculations: We formulated the design of two sub-systems – one series-heavy and one parallel-heavy. Using the gathered specs, we calculated how to configure each: number of cells in series to meet a target voltage, number of parallel strings to meet capacitance and current targets. Classical capacitor network formulas were used: capacitors in series have an effective capacitance of $C_{\text{series}} = \frac{1}{\sum(1/C_i)}$ and divide the applied voltage, whereas in parallel capacitances add directly $C_{\text{parallel}} = \sum C_i$ (assuming identical voltage across parallels) [7] [8]. The energy storage of each bank is estimated using $E = \frac{1}{2} C_{\text{bank}} V_{\text{max}}^2$, where V_{max} is the maximum charged voltage of that bank. This energy is then converted to kWh (1 Wh = 3600 J) for easier system-level comparisons. We also calculate nominal power output as $P = V_{\text{nom}} I_{\text{max}}$ for each bank, where I_{max} may be limited by the bank's ESR or by the MPPT's current limit. When combining through an MPPT (which itself has limits), the overall output power is constrained by the lesser of the source capability and the converter capability.

System Integration: We propose a topology where the high-voltage bank and high-current bank are both connected to a common DC bus via an MPPT-based converter. In practice, this could be achieved with one bank directly on the bus and the other interfaced via a bidirectional MPPT converter, or using two MPPT converters into a common output (e.g., a battery or DC link). For simplicity, we assume one primary MPPT handles the power flow such that it draws from the two banks sequentially or in parallel as needed. The MPPT's control algorithm would be set to keep the capacitor banks within safe voltage ranges (never over-discharge them to zero or over-charge beyond limits) while delivering power to the load. We discuss this control conceptually rather than delving into specific control schemes, as our focus is on component feasibility and overall performance estimates.

Using these methods, we derive a representative design and run numerical examples for output power and energy. All calculated results are presented in the **Calculations and Output Estimates** section, with assumptions clearly stated.

System Design and Schematic Description

Overview: The proposed system consists of two ultracapacitor sub-banks – one optimized for high voltage (Series Bank) and one optimized for high current (Parallel Bank) – which are combined via an MPPT power converter to supply a common output. Figure 1 (conceptual, described in text) illustrates the configuration. The Series Bank uses multiple graphene ultracapacitor cells in series to achieve a high output voltage, at the expense of lower equivalent capacitance. The Parallel Bank uses multiple cells in parallel (and minimal series count) to achieve very high capacitance and current capability, but at a lower voltage. The MPPT converter interfaces these banks to the load, ensuring that each bank operates near its optimum voltage/current range and that the load sees a stable voltage.

Series (High-Voltage) Sub-System: The voltage-dominant bank is constructed by connecting *N* ultracapacitor cells in series. In our design, we select graphene ultracapacitor pouch cells rated around 4.2 V each (these are hybrid LIC-type "ultrabattery" cells) [3]. By connecting, for example, *N = 12* cells in series, the bank's maximum voltage is ~50.4 V (4.2 V × 12). This high-voltage string yields a comparatively lower total capacitance: if each cell is 21,000 F, the series string has $C_{\text{series}} \approx 21{,}000\ \text{F}/12 = 1,750\ \text{F}$. To increase capacitance and share current, multiple such series strings could be paralleled; however, in the pure high-voltage bank we prioritize voltage over capacitance, so we consider a single string first. The series bank includes a passive or active balancing circuit across cells (as is standard for supercapacitor modules [9] [10]) to prevent over-voltage on any cell. The high-voltage bank is designed to provide a high output voltage with moderate capacitance – ideal for applications where a higher voltage is needed to drive a load (or charge a higher-voltage battery) but extreme currents are not continuously required from this section alone.

Example Series Bank Specifications: Using 12× GH 4.2 V ultracapacitor cells (21,000 F each) yields ~50 V max and ~1750 F. The stored energy at full charge is $E_{series} = \frac{1}{2}(1750\ \text{F})(50.4\ \text{V})^2 \approx 0.62\ \text{kWh}$. The internal resistance of each cell is ~2 mΩ, so 12 in series gives ~24 mΩ total [11]. The series bank can support significant current; e.g., if each cell can do 200 A continuous [12], the series string can also carry 200 A (limited by the weakest link). 200 A at ~50 V corresponds to 10 kW of power, though in practice thermal considerations may derate continuous current. The physical footprint of this bank would be roughly 12 times a single cell (each cell ~220×128×7.5 mm) [13], possibly stacked with insulation – yielding a compact module shape.

Parallel (High-Current) Sub-System: The current-dominant bank is built by connecting *M* ultracapacitor cells in parallel (and using the minimum series count needed for the application). In our design, we use the same type of graphene ultracapacitor cells but configure them to maximize capacitance. For example, we might use only *n = 4* cells in series (for ~16.8 V max) per string, and then connect *m = 3* of these strings in parallel. This results in a parallel bank of 12 cells total (4S3P configuration). The bank's voltage is ~16.8 V max (suitable for stepping up via DC–DC), and the capacitance is tripled compared to a single 4-cell string. If one 4-cell string is 21,000 F/4 = 5250 F, three in parallel give ~15,750 F at 16.8 V. The parallel bank thus has extremely high capacitance and low ESR. The high capacitance directly translates to high charge storage and the ability to supply large surge currents with minimal voltage drop. This bank is intended to source or sink large currents (for acceleration, surge power, etc.) at a lower voltage. The MPPT converter will boost this lower voltage to the desired system voltage when delivering power from the parallel bank.

Because the parallel bank uses fewer series cells, each cell operates over a larger voltage swing fraction (e.g. 0–4.2 V for 4 in series vs. 0–4.2 in 12 series would be a smaller fraction of total). This bank also requires cell balancing for the series elements (4 in each string), but managing 4-cell strings is simpler. With multiple strings in parallel, a proper design will ensure current sharing (nearly identical cell characteristics and lengths of interconnects, or using small series resistances to equalize currents).

Example Parallel Bank Specifications: Using the same 21,000 F, 4.2 V cells in a 4S3P arrangement yields ~16.8 V and ~15,750 F. The stored energy if fully charged is $E_{parallel} = \frac{1}{2}(15,750\ \mathrm{F})(16.8\ \mathrm{V})^2 \approx 0.62\ \mathrm{kWh}$ (roughly equal to the series bank since the total number of cells and their energy content is the same in this example). The effective ESR is one-third of a single string's ESR, because three strings in parallel: each string ~8 mΩ (4×2 mΩ in series), and 3 in parallel gives ~2.7 mΩ. Such low ESR means the voltage drop under load is very small; the parallel bank can sustain extremely high currents. With each cell rated ~200 A continuous, each 4-cell string can do 200 A; three in parallel can supply ~600 A continuous. At ~16 V, 600 A corresponds to ~9.6 kW. Short bursts (a few seconds) could be even higher (e.g., >1000 A or >15 kW) given the low ESR, limited by cell heating and connector ratings. The physical size of this bank is similar total volume to the series bank (12 cells total), but arranged differently (3 stacks of 4 series cells each).

Combined System via MPPT: The two sub-systems are integrated through an MPPT power converter to act as a single unified storage system. In one possible configuration, the high-voltage bank could be connected directly to a DC bus (e.g., a ~48 V system bus), and the high-current bank is connected via a bidirectional MPPT DC–DC converter that boosts its ~16 V up to the bus voltage when discharging and possibly bucks from the bus to recharge the lower-voltage bank when needed. In another configuration, both banks feed a dedicated MPPT that treats the combination akin to dual PV arrays – for instance, the MPPT could draw from the higher-voltage bank until its voltage drops to a set threshold, then start drawing from the lower-voltage bank (boosting it) to continue delivering power. The exact control would depend on the MPPT capabilities (most off-the-shelf units are single-input, so a custom controller or use of two controllers might be required for truly simultaneous sourcing). For conceptual analysis, we assume the MPPT can manage input from both sources (either sequentially or in parallel through appropriate power electronics).

The MPPT is configured to maintain output at the desired load voltage (which could be charging a battery or powering an inverter). It continuously monitors the input side and adjusts duty cycle to draw maximum power without collapsing the source voltage below safe limits. For the high-voltage bank, this might mean drawing it down from 50 V toward a minimum (perhaps 28 V as specified in some modules [10]) before stopping. For the parallel bank, the MPPT in boost mode would draw it down from 16.8 V to some lower limit. Throughout, the MPPT ensures the current drawn is within its rating and the capacitors' capability, effectively blending the strengths of both banks. The result is a system that behaves as a single storage source with higher effective voltage range and sustained current output than either bank alone.

In summary, the Series Bank provides a higher voltage reservoir which the MPPT can tap into directly, while the Parallel Bank provides a "current reservoir" that the MPPT can boost from when high power is needed. This complementary design allows the combined system to maintain both high voltage and high current output as required by the load, with the MPPT orchestrating energy flow for optimal performance.

Component List with Suppliers and Pricing

Ultracapacitors (Graphene EDLC/Hybrid):

- **GH 4.2 V 21,000 F Graphene Ultracapacitor Cell (Pouch type)** – Rated at 4.2 V max, 21,000 F capacitance. Stored energy ~75 Wh per cell (manufacturer claims ~220 Wh/kg energy density) [2]. Dimensions ~220 × 128 × 7.5 mm, weight ~350 g each [13]. Internal resistance ~2 mΩ, supporting fast charge/discharge (continuous up to ~200 A) [11] [12]. Price is approximately **\$30 per cell** at low quantities (min. order 6 pcs) [14], with volume pricing down to \$30 or below for 10k+ orders. This cell is a "graphene ultrabattery" pouch offered by Dongguan City Gonghe (GH) and similar suppliers. *(Supplier:* Alibaba – GH Electronics, Model 4.2V21000F)*.

- **YKY 4.2 V 21,000 F Graphene Supercapacitor (Similar to above)** – Another supplier's offering (Shenzhen Yukun, YKY brand) with comparable specs: 21,000 F, 4.2 V, fast charge/discharge, ESR ~2 mΩ, cycle life >40,000 cycles. It lists standard charge current 30 A (≈0.5C), max charge 100 A, and max continuous discharge 200 A (≈20C) [15] [12]. Unit weight ~340 g. Pricing about **\$36–\$40 each** for 1–99 pcs (dropping to \$36 at 1000+ pcs) [16]. *(Supplier:* Alibaba – Shenzhen Yukun Tech, Model 4.2V21000F "punch" ultracapacitor)*.

- **Graphene "Ultrabattery" 16 V Module, 200 F** – A pre-packaged module containing series-connected graphene supercapacitor cells. Rated 16 V, 200 F with very low ESR ~2.5 mΩ [17]. Often built by combining 4× 4.2 V cells in series. Example: GH offers a 16 V 200 F module (model GHT16V200FL) with operating temp –20~60 °C and >20,000 cycle life [18]. Approximate pricing is **\$120–\$160 per module** (lower end for bulk orders ≥10k) [19] [20]. These modules simplify series assembly for higher voltage, including internal balancing. *(Supplier:* Alibaba – GH Electronics)*.

- **High-Capacitance EDLC Cells (for high current)** – Traditional cylindrical supercapacitors (2.7–3.0 V) can be used in parallel to boost current capability. For example, 2.7 V 3400 F cells (Ø60 mm ultracapacitors often cloned from Maxwell) are available at around **\$5–\$12 each** [21]. These have very low ESR (<1 mΩ) and can deliver pulses of hundreds to thousands of amps (common in automotive starter modules). Another example: 2.7 V 5000 F graphene-enhanced supercap cells, priced about **\$8.50–\$14.50** in volume (100+ pcs) [22]. Such cells (~3 Wh each) could be integrated in parallel with the graphene cells to further increase peak power (though in our design, the graphene cells themselves have comparable power capability).

- **High-Voltage Supercapacitor Modules (48 V)** – For reference or larger scale designs, ready-made high-voltage supercap banks exist. Dongguan GH lists a **48 V, 2100 Wh (2.1 kWh) graphene**

supercapacitor pack, 5000 F total capacitance, priced around **\$1680 per set** [23]. Similarly, Shanghai GTCAP offers a **48 V 5000 F (1 kWh) graphene supercap module** with built-in management, at **\$1500+ for single units** (pricing drops to \$920 at 1000+ units) [24]. These modules achieve ~55 Wh/kg and come with integrated balancing and safety circuitry [25]. While such modules are beyond typical DIY budgets, they indicate the commercial availability of high-energy ultracapacitor systems.

MPPT Power Modules:

- **EPEVER Tracer10420AN (100 A MPPT Solar Controller)** – A high-quality MPPT charger widely used in solar setups, repurposed here for ultracapacitor control. Supports 12/24/36/48 V battery systems, with a maximum PV (input) open-circuit voltage of 200 V [26]. Rated output is 100 A, allowing up to ~5 kW into a 48 V battery (100 A × ~50 V). Conversion efficiency ~98% and tracking efficiency ≥99% [27]. Typically includes LCD and communication options. Price ranges **\$150–\$300** depending on supplier and quantity [28] (around \$200 each for small orders). This unit can handle high input voltages and high output current, making it suitable for linking a ~50 V capacitor bank to a 48 V system or stepping down from higher series strings. *(Supplier:* Alibaba via Ningbo Cinco or Huizhou Epever, min. order 2 pcs)*.

- **JNGE High-Voltage MPPT (JN-HV series, 100 A)** – An MPPT charge controller by Anhui JNGE Power designed for *high system voltages*. It supports nominal battery voltages up to 360 V DC and PV input up to 880 V DC [29]. Models are available in 50 A, 80 A, 100 A versions. For instance, the 100 A model can interface a PV (or capacitor) array up to 60 kW (880 V, 68 A PV input approx.) and charge a high-voltage battery at 100 A [30] [31]. It features configurable battery chemistry settings (Gel, AGM, Li-ion, etc.) [32] and optional monitoring (WiFi/GPRS). Such a unit could manage a series ultracapacitor bank at ~300–600 V if needed. The price is around **\$455 per unit** (1 pc MOQ) [33]. While this capability is beyond what our 50 V/16 V banks require, it demonstrates the availability of MPPT converters for very high voltage systems (and could be useful if one wanted to stack many capacitors in series for higher bus voltages).

- **Generic 60–100 A MPPT Boost/Buck Modules:** There are also simpler, cost-effective MPPT modules for lower voltage applications. For example, a "Smart 100 A Solar Charge Controller" with high input (up to ~100 V) is listed at **\$15–\$42** [34], though such low-cost units often have unverified performance and may not truly handle 100 A continuously. Another example is a **50 A/100 A MPPT (High-Voltage 192–384 V input)** listed at **\$455** [35] – likely the same JNGE model via a distributor. For our design, a robust choice is the EPEVER or an equivalent well-reviewed 100 A unit in the \$150–\$300 range which balances cost and reliability [28]. If the design output is a 48 V system, a 100 A MPPT effectively limits continuous output to ~4.8 kW. Those seeking higher continuous power may consider parallel MPPT units or higher-current models (some suppliers offer 200 A MPPTs, or one could use a DC–DC converter like an inverter's DC stage).

Other Components: In addition to the main capacitors and MPPT, a complete system would include: heavy-gauge bus bars or wiring and fuse/breaker for the high current paths, a balancing circuit or BMS for each capacitor string (some modules include this internally [9]), cooling arrangements if necessary (fans or heat sinks on the MPPT or on capacitors if running near their continuous limits), and an enclosure for safety. These are standard electrical components and can be sourced from electronics suppliers. While not explicitly listed with prices (as they vary widely), they should be factored into the project budget. For instance, passive balancing resistors or active balancer boards for supercapacitors (up to 16S) are commonly available for \$10–\$50. High-current DC contactors or relays (e.g., 100 A+) may cost \$30–\$100. Such details go beyond the scope of supplier "models," but are critical for a safe DIY build.

Table 1 summarizes the key components with their specs and costs as identified.

Table 1: Key Components for the Ultracapacitor Energy Storage System

Component	Key Specifications	Approx. Price (USD)	Source (Ref)
GH Graphene Ultracap Cell	4.2 V, 21,000 F (75 Wh). 220 Wh/kg, ESR ~2 mΩ, 200 A cont.	\$30 @ MOQ 6 (down to \$30)	Alibaba (Gonghe) [36] [14]
YKY Graphene Ultracap Cell	4.2 V, 21,000 F. ESR 2 mΩ, 200 A cont, 300×175×60 mm, 340 g	\$36 @1–99 (to \ $36 @1000)	Alibaba (Yukun) [11] [16]
Graphene 16 V Module	16 V, 200 F. 4-series internal, ESR 2.5 mΩ, –20~60 °C	\$160 @2 pcs (to \$120 bulk)	Alibaba (Gonghe) [37] [38]
EDLC Supercap Cell	2.7 V, 3400–5000 F. ESR ~0.3–0.5 mΩ (typical), cyl. can	\$5–\$15 each (small qty)	Alibaba (various) [21] [22]
48 V/5000 F Module	48 V (max 48.6), 5000 F, ~1 kWh, 55 Wh/kg, 18 kg, ESR <20 mΩ	\$1500 @1 (to \ $920 bulk)	Made-in-China (GTCAP) [24] [25]
EPEVER 100 A MPPT	12–48 V out, 200 V in, 100 A, ~5 kW, eff. >98%, LCD/comm	\$150–\$300 (typ. \$200)	Alibaba (Epever/ Cinco) [28]
JNGE HV 100 A MPPT	up to 360 V out, 880 V in, 100 A, 60 kW PV, 26 kg unit	\$455 each @1	Alibaba (JNGE) [29] [33]
Generic 100 A MPPT	e.g. 96 V in, 60 A/80 A/100 A out (12–48 V) – budget version	\$40 (claim)	Alibaba (generic) [39]

Note: Prices are indicative and subject to change; they do not include shipping or import fees. MOQ = Minimum Order Quantity for listed price. "Generic 100 A MPPT" refers to low-cost units with unverified specs – caution is advised with these.

Calculations and Output Estimates

Using the design described, we can estimate the performance of the combined ultracapacitor system in terms of total energy storage and power output. We base our calculations on the example where each sub-bank uses 12 graphene ultracapacitor cells (either in series or in the 4S3P configuration), as outlined earlier.

Energy Capacity (kWh): Each 4.2 V, 21,000 F graphene cell holds about 75 Wh when charged to 4.2 V [40]. With 12 cells, the *total* stored energy is roughly $12 \times 75 = 900\ \mathrm{Wh}$ if all were utilized fully. In our Series Bank (12 in series), because all cells discharge together from 50.4 V down to some lower cutoff (say 0 V ideally, but practically one would not go below ~2.5 V per cell to avoid steep voltage drop-off), the usable energy might be slightly less – but for an upper estimate we'll take the full 900 Wh. The Parallel Bank with 12 cells (4S3P) also stores ~900 Wh in total. However, note that if both banks are used in one system, they are not simply additive in energy unless both can be fully discharged into the load. In our combined design, the MPPT would draw from one bank and then the other. In principle, if the control is arranged to sequentially use both banks' energy, the total available energy is the sum. Thus, ~0.9 kWh from the series bank + ~0.9 kWh from the parallel bank = **~1.8 kWh** theoretical. In practice, overlapping operating ranges or reserves might reduce this a bit. To be conservative, we estimate on the order of **1–1.5 kWh** usable energy for the combined system. This aligns with using each bank from its max voltage down to maybe half voltage (since MPPT might stop drawing when voltage gets too low to be efficient), yielding about half the energy each. For instance, discharging each bank from 100% to 50% voltage releases 75% of stored energy (since $E \propto V^2$), so that would be ~0.7 kWh per bank, ~1.4 kWh total usable.

Voltage Ranges: The Series Bank operates ~50 V down to a minimum (which could be set by MPPT – perhaps 25 V to avoid diminishing returns). The Parallel Bank operates ~16.8 V down to maybe ~8 V before the MPPT can no longer efficiently boost it (typical boost converters might need input >~1/3 of output). If our output bus is 48 V, the parallel bank at 8 V is a 6:1 boost ratio to 48 V, which is feasible but with some efficiency loss. So we might use 12 V as a cutoff (4 V per cell average, ~50% SOC) for better efficiency. These cutoffs mean not all energy is extracted, consistent with the usable ~1.4 kWh noted above.

Power Output (kW): The peak power capability of the ultracapacitors is extremely high due to low ESR. For a rough estimate, at full charge the Series Bank (50 V, ESR ~24 mΩ) could theoretically supply a short-circuit current $I_{sc} \approx V/ESR = 50/0.024 \approx 2083\ A$. That is obviously not a usable steady current, but it indicates a peak discharge on the order of >2000 A for a very brief pulse, equating to ~100 kW (!) momentarily. More practically, the cell's own 200 A continuous rating is a safer limit. 200 A at ~50 V gives **10 kW** continuous from the series bank [12] . The Parallel Bank, with ESR ~2.7 mΩ, at ~16 V full charge could deliver $I_{sc} \approx 16/0.0027 \approx 5925\ A$ peak (again theoretical). Its continuous composite rating (3 strings × 200 A each) is ~600 A, which at ~16 V is **9.6 kW** continuous. If boosted to 48 V by an ideal converter, that 9.6 kW remains 9.6 kW (minus converter losses). So each sub-system alone could supply on the order of 10 kW continuously (and far more for sub-second bursts, e.g. thousands of amps for a second until voltage sags).

However, the actual delivered power will be limited by the MPPT converter and the load's demand. If we choose the EPEVER 100 A MPPT for a 48 V system, its maximum output is ~4.8 kW (100 A × 48 V). It cannot pass more current than 100 A into the load, so even if the capacitors can supply 200–600 A, the MPPT bottleneck is 100 A. Thus, **nominal continuous output is about 4–5 kW** with that converter. We could oversize the converter (e.g. two MPPTs in parallel, or a custom DC/DC) to utilize more of the cap capability. For example, a 200 A converter at 48 V would allow ~9.6 kW, matching one bank's continuous potential. The JNGE high-voltage MPPT, if used with a high-voltage series string directly, could output 100 A into a high-voltage battery – e.g., 100 A at 300 V is 30 kW. But in our scenario, we are likely interfacing to a ~48 V system for DIY scale, so we consider ~5 kW a reasonable continuous output goal.

Combined (Simultaneous) Operation: If both banks could somehow discharge simultaneously into the load (e.g., if we had two converters feeding the same bus), the power could be additive. In an ideal scenario with no converter limit, the system might deliver ~10 kW from each bank = ~20 kW total for a short time. This would quickly drop the capacitor voltages, but it shows the immense power density available – one could, for instance, deliver 15–20 kW for perhaps a few minutes until 1–1.5 kWh is expended. For instance, 1.5 kWh at 20 kW would last 0.075 h (4.5 minutes). At a more modest 5 kW draw, 1.5 kWh lasts ~0.3 h

(18 minutes). At 1 kW, it could run ~1.5 h. These figures illustrate the classic trade-off of ultracapacitors: huge power, modest energy.

We can also compute examples of energy delivered at different rates. Using the relationship $E = \frac{1}{2}CV^2$: for the series bank (C_eq ~1750 F, V from 50 V down to 25 V), the usable energy is $0.5 * 1750 * (50^2 - 25^2) = 0.5 * 1750 * (2500 - 625) = 0.5 * 1750 * 1875 = 1.64e6\ J = 456\ Wh$. Similarly for the parallel bank (C_eq ~15750 F, V 16.8 to 8.4), $E = 0.5 * 15750 * (282 - 70.6) = 0.5 * 15750 * 211.4 = 1.66e6\ J = 461\ Wh$. Sum ~917 Wh. If drawn over 1 hour, that's ~0.917 kW average. Over 0.5 h, ~1.83 kW average. Over 10 min (0.167 h), ~5.5 kW average. These rough calculations align with the idea that the system could output on the order of several kW for on the order of tens of minutes. A higher-power burst (e.g. 10 kW) can be sustained for only ~5–6 minutes with ~0.9 kWh.

Summary of Expected Output: The nominal combined output of the system can be described as approximately **5 kW of power for ~15–20 minutes**, or about **1–1.5 kWh** of energy total. In peak scenarios, up to ~10–15 kW could be achieved for a few minutes (limited by converter or wiring if not by the caps). Conversely, at lower discharge rates (hundreds of watts to 1 kW), the system could run for an hour or more on a full charge. These performance levels, while lower in energy than typical chemical batteries, far exceed batteries in power capability and can be ideal for bridging power gaps or handling surge loads in a DIY setup.

It is also worth noting the rapid recharge ability: with sufficient charging current (say a 5 kW source), the entire 1.5 kWh could be recharged in ~20 minutes (since ultracaps can accept high currents until nearly full, unlike batteries that taper off). This makes the system attractive for applications like regenerative braking or cyclic UPS systems where frequent fast charge/discharge occurs.

All these estimates assume using the identified components under their rated conditions. Real-world performance will be influenced by factors like converter efficiency (typically 95–98% efficient, losing a bit of energy as heat), wiring losses, and heat dissipation during high current use. Nonetheless, the calculations show that a kilowatt-scale output with around a kilowatt-hour of storage is achievable with commercially available graphene ultracapacitors and MPPT converters.

Discussion of Feasibility

The proposed ultracapacitor-based storage system demonstrates a pathway to high power delivery in DIY energy projects, but it also highlights several practical considerations:

Cost Efficiency: Graphene ultracapacitors are still a relatively new product, but the prices from OEM suppliers are falling into a range that is competitive on a per-cycle basis. At roughly \$30 for a 75 Wh cell [14], the cost is \$0.40/Wh – much higher than lead-acid or Li-ion batteries in initial cost. However, given an ultracapacitor's extremely long cycle life (20,000 to 100,000 cycles) [41] [42], the lifetime cost per cycle can be very low. For instance, if a \$30 cell can cycle 20,000 times, that's \$0.0015 per cycle per cell. In applications with frequent deep cycles or high C-rate demands, ultracaps may actually be more cost-effective over the long term than batteries that would need replacement. That said, for one-time DIY builds, the upfront cost per kWh (~\$400 per kWh in our design, or higher if fewer cells) is a significant investment. We prioritized relatively cost-efficient units (e.g., pouch "ultrabatteries" instead of brand-name Maxwell modules) to keep the budget reasonable.

Availability and Shipping: The components identified are available via platforms like Alibaba and Made-in-China, meaning they are generally coming directly from Chinese manufacturers. Shipping large capacitors internationally is usually feasible (they are not classified as dangerous goods like lithium batteries, but their weight is substantial). For example, ordering a set of 12 graphene cells (total ~4 kg) is manageable; shipping costs and times (air vs sea) need to be considered. Many suppliers offer DHL/FEDEX air shipping for small quantities, albeit at a premium. The MPPT units are easier to ship and sometimes stocked by local or international retailers (EPEVER controllers, for instance, are often available on Amazon or eBay).

One should verify supplier credibility – we found at least one discussion casting doubt on the authenticity of "graphene ultracapacitors" meeting their claimed specs [43]. It is wise to order a sample first and test the capacitance and energy density. The cited specs (220 Wh/kg for a graphene ultracap) are remarkably high – close to lithium-ion battery levels [2]. If true, this represents a breakthrough; if exaggerated, the actual performance might be lower. The DIYsolar forum suspected some graphene ultracap cells might actually be a type of lithium-ion capacitor or hybrid that behaves partly like a battery [43]. Even if so, the device can still be useful, but its internal chemistry might require observing certain precautions (for example, LICs have a higher nominal voltage around 3.8 V and should not be over-discharged too far).

Technical Feasibility: From an electrical standpoint, building the two sub-banks is straightforward. Series connecting capacitors to 50 V is common (commercial modules do up to 48 V or higher with balancing). Paralleling capacitors is also standard to increase capacity. The key is ensuring proper balancing of series cells – passive resistors or active balancing ICs can dissipate differences. Given the large cell capacitance, even a small leakage or imbalance current could lead to voltage drift, so a balancing circuit is mandatory for safe long-term operation [9]. The MPPT controller must be configured correctly: essentially, it would treat the ultracap banks as a power source. If using a solar MPPT, one might set a "solar panel" input that is actually the capacitor bank. The MPPT will try to operate at the maximum power point – for a solar panel, that's a voltage-current sweet spot. For a capacitor, the concept is different: the MPPT would likely just draw as much current as allowed until the capacitor voltage falls to a minimum threshold. We may need to "trick" the MPPT or use a programmable DC–DC that can be set to draw down to a certain input voltage. Some MPPT units allow setting a minimum PV voltage or have a constant current mode which could be useful here. The continuity of the circuit is maintained as long as the MPPT remains connected; quality MPPTs use synchronous rectification (no series diodes that disconnect at low current) so the circuit stays closed throughout operation.

Safety: Ultracapacitors can deliver extremely high currents, so safety mechanisms are crucial. Fast-acting fuses or DC circuit breakers should be in place to disconnect the banks in case of a short. The banks should be enclosed to prevent accidental shorts (a wrench dropped across a 50 V supercap bank could result in a severe arc flash). Thermal monitoring might be wise; if a cell is over-stressed, it could overheat. The graphene cells are advertised as safe (non-combustible) [42], which is a major advantage over batteries – no risk of fire or explosion under normal failure modes. Nonetheless, any high current system needs careful assembly (tight connections, no loose wires).

Performance and Use Cases: The combined system as designed would excel in roles where short, intense bursts of power are needed, along with moderate energy storage. For example, it could serve as a buffer for an off-grid solar power system: the ultracaps could handle surge loads (like pump or motor startups requiring 5–10 kW for a few seconds) which a battery might struggle with, and also absorb quick charge from solar peaks. The MPPT could mediate between the caps and a battery bank, prolonging battery life by smoothing out transients. Another use is in electric vehicles or carts: a supercap bank could assist the main battery during acceleration and regenerate during braking. Our design's ~50 V level is in the safe low-voltage range (<60 V DC) which is good for DIY (higher voltages require more caution and insulation). With ~1.5 kWh, an EV boost application is limited (e.g., an extra ~10 kW for a few minutes), but it could noticeably improve performance when paired with a battery.

Scalability: One can scale the energy by adding more cells in parallel strings (for the parallel bank) or more series modules in parallel (for the series bank). Doubling the number of cells would double energy (and cost) linearly. The power capability scales with how many parallel paths are added. In essence, the architecture is modular. One could also choose a higher base voltage – e.g., 100 V bank (by ~24 cells series) and a correspondingly higher output DC bus and MPPT. We presented 48–50 V as a convenient level matching many inverters and controllers. The JNGE MPPT shows that even 300–600 V capacitor banks are feasible with the right controller, which could yield multi-kW discharge without high currents (but then the series string gets long, requiring meticulous balancing).

Comparison to Batteries: It's worth discussing the niche this system fills relative to conventional batteries. At ~1–2 kWh capacity, it's equivalent to a small lithium battery (e.g., a 12 V 100 Ah $LiFePO_4$ has ~1.2 kWh). The ultracap system is far more expensive per kWh and physically larger/heavier than that $LiFePO_4$ battery. However, it can deliver an order of magnitude higher power (tens of kW vs a $LiFePO_4$ typically ~1–2 kW continuous, maybe 4–5 kW peak) and survive tens of thousands more cycles. For applications where high power and high cycle count are paramount (and cost is secondary), the ultracap approach is superior. For pure energy storage over long durations, chemical batteries are still more practical. A possible hybrid approach is to use both: the ultracap bank handles fast transients and the battery handles slower, longer discharges – this can prevent battery stress and extend its life [44].

Feasibility for DIY: As a DIY project, assembling this system requires intermediate to advanced electrical skills. The availability of components is there (thanks to OEM marketplaces), and the pricing, while not cheap, is within reach of dedicated hobbyists or researchers (a few thousand dollars for a one-off system). The main challenges are integrating the control electronics (MPPT setup) and ensuring safety/balance. Fortunately, MPPT solar controllers are designed to be user-friendly and have built-in protections, which we leverage. The fact that our design stays in SELV (Safety Extra Low Voltage) range (<60 V) means the risk of electric shock is reduced compared to high-voltage systems, focusing safety mainly on high current management.

In conclusion, the feasibility of a high-performance DIY ultracapacitor energy storage system is backed by the current market offerings of graphene supercapacitors and power electronics. The design meets the theoretical goals of high voltage and high current output, with the trade-off being cost and complexity. As graphene ultracapacitor technology matures and perhaps as prices drop further, such systems could become more commonplace in niche energy storage roles.

Conclusion

This paper presented an in-depth exploration of graphene-enhanced ultracapacitors and high-power MPPT converters for use in a DIY energy storage system. We identified specific commercially available components – from 4.2 V, 21,000 F graphene "ultrabattery" cells (capable of ~75 Wh each and high current output) [40] [12] to 100 A MPPT DC–DC modules [28] – and detailed their specifications and costs. Two complementary ultracapacitor sub-systems were designed: a series-connected bank optimized for high voltage (~50 V) and a parallel-connected bank optimized for high amperage (hundreds of amps). By interfacing both banks through an MPPT controller, we demonstrated a combined system that can deliver power on the order of several kilowatts with an energy capacity around 1–2 kWh. Calculations show that the system could, for example, supply ~5 kW for ~15 minutes (or lower power for longer, higher for shorter), which is impressive for an ultracapacitor-based solution.

The results highlight that such a system is technically feasible with off-the-shelf components. Graphene ultracapacitors, while more expensive per kWh than batteries, offer extraordinary cycle life and power density, making them attractive for high-performance scenarios. The MPPT modules commonly used in renewable energy can be repurposed to manage the discharge of ultracapacitor banks, maintaining continuous power flow and protecting the capacitors from excessive depletion. We also provided a component list with supplier information and pricing, showing the availability of these advanced components via OEM channels to hobbyists and engineers.

In discussing feasibility, we addressed the pros and cons: the system achieves a unique combination of high power and moderate energy, but at a monetary cost and with added complexity (balancing circuits, high-current safety). Use cases that benefit from instantaneous high power and rapid cycling – such as peak shaving, UPS systems, or hybrid EV power – stand to gain the most. Meanwhile, purely long-duration storage is better left to batteries in terms of cost-effectiveness.

Overall, the integration of high-voltage and high-current graphene ultracapacitor sub-systems into one MPPT-controlled circuit is a novel approach to DIY energy storage. It leverages the strengths of emerging supercapacitor technology and modern power electronics. As component technologies continue to improve (e.g., even higher energy density ultracaps or more affordable converters), we can expect the performance and cost balance of such systems to further improve. This work serves as a reference for those interested in building or understanding high-power capacitor banks, providing a foundation of real-world data and a blueprint-style design. Future experimentation could involve actually constructing the system and validating the performance against the estimates, as well as refining control strategies for managing dual-source ultracapacitor setups. The continued development of graphene and other nanomaterials in energy storage suggests that the gap between batteries and capacitors will continue to narrow, potentially leading to versatile hybrids that bring the best of both worlds to demanding applications.

References

[1] Dongguan City Gonghe Electronics Co., Ltd., *“Professional Manufacturer ROHS Approved 4.2V21000F combined series super battery,”* Alibaba Product Listing, 2025. [Online]. Available: 36 14

[2] Dongguan City Gonghe Electronics Co., Ltd., *“16V 200F Ultra Super Capacitor Graphene new type superbattery,”* Alibaba Product Listing, 2025. [Online]. Available: 37 38

[3] Alibaba.com, *“High voltage ultracapacitor – Graphene Super Capacitor 4.2V 21000F Farad…,”* Alibaba search listing, 2025. [Online]. Available: 3

[4] Shenzhen Yukun Technology Co., Ltd., *“40000 times Long Cycle 4.2V 21000F Supercapacitor Battery for Solar Backup,”* Alibaba Product Listing, 2025. [Online]. Available: 11 12

[5] Alibaba.com, *"Boost Energy Efficiency with High-Capacity... Low ESR Supercapacitor Solutions,"* Alibaba search listing, 2025. [Online]. Available: 21 22

[6] Shanghai Green Tech Co., Ltd., *"GTCAP Graphene Super Capacitor Module 48V 5000F 1KWH,"* Made-in-China, 2025. [Online]. Available: 24 25

[7] EPEVER (Huizhou Yuebin Technology Co.), *"Tracer10420AN 100A MPPT Solar Charge Controller (100V–200V input, 48V output),"* Alibaba Top Ranking listing, 2025. [Online]. Available: 28

[8] Anhui JNGE Power Co., Ltd., *"High Voltage 50A 80A 100A 192V–384V MPPT Solar Charge Controller (JN-HV series),"* Alibaba Product Listing, 2025. [Online]. Available: 29 33

[9] Alibaba.com, *"High Voltage Ultracapacitor"* (Search results showing 48V 2100Wh module), Alibaba, 2025. [Online]. Available: 23

[10] DIY Solar Forum, *"Graphene Ultracapacitor now the same $/lifecycle as LiFePO4?"* Online Forum Discussion, 2024. [Online]. Available: 45

[11] Electronics-Tutorials.ws, *"Ultracapacitors as Energy Storage Devices,"* (explains series/parallel of ultracaps), 2021. [Online]. Available: 46

[12] Tecate Group, *"Ultracapacitor Technical Guide,"* Application Note (series connection and balancing), 2020. [Online]. Available: 47

(Additional supplier datasheets and academic references on ultracapacitor performance and MPPT theory can be inserted here as needed.)

---

1 21 22 Boost Energy Efficiency with High-Capacity low esr supercapacitor Solutions
https://www.alibaba.com/showroom/low-esr-supercapacitor.html

2 13 14 36 40 Professional Manufacturer Rohs Approved 4.2v21000f Combined Series Super Battery - Buy Ultra Capacitor Battery fast Charge Battery super Capacitor Battery 4.2v motor Starting combined Series Ultra Battery Product on Alibaba.com
https://www.alibaba.com/product-detail/Professional-Manufacturer-ROHS-Approved-4-2v21000f_1601486433754.html

3 High-Performance high voltage ultracapacitor for Reliable Circuit Stability
https://www.alibaba.com/showroom/high-voltage-ultracapacitor.html

4 46 Ultracapacitors As Energy Storage Devices - Electronics Tutorials
https://www.electronics-tutorials.ws/capacitor/ultracapacitors.html

5 6 Does an MPPT solar controller, turn excess voltage into Current ...
https://diysolarforum.com/threads/does-an-mppt-solar-controller-turn-excess-voltage-into-current-amps.33420/

7 Let's Learn About Super Capacitors! (A Practical Guide to Super ...
https://www.instructables.com/Lets-learn-about-Super-Capacitors-A-Practical-G/

8 The Forever Rechargeable VARIABLE Super Capacitor Battery
https://www.instructables.com/The-Forever-Rechargeable-VARIABLE-Super-Capacitor-/

9 10 24 25 42 GTCAP graphene super capacitor module 48V 5000f 1KWH - Graphene Super Capacitor and Super Capacitor Module
https://xiedenglang.en.made-in-china.com/product/GXxmetCoqhYE/China-GTCAP-graphene-super-capacitor-module-48V-5000f-1KWH.html

11 12 15 16 41 40000times Long Cycle Punch Farad Capacitor 21000f 4.2v Supercapacitor Battery For Solar Backup Power Bank - Buy Punch Super Capacitor energy Density Supercapacitor 4.2v21000f super Capacitor 4.2v Product on Alibaba.com
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https://www.alibaba.com/product-detail/16v-200F-Ultra-Super-Capacitor-Graphine_1601486221723.html

23 Company Overview - Dongguan City Gonghe Electronics Co., Ltd.
https://gongheenergy.en.alibaba.com/productgrouplist-820131170/High_power_Capacitor_Banks.html

26 28 Top Ranking - Alibaba.com
https://sale.alibaba.com/p/dviiav4th/index.html?wx_navbar_transparent=true&path=/p/dviiav4th/index.html&cardType=&cardId=&topOfferIds=60716510836&categoryIds=201268586&rankCpvId=10001277481&rankCountryId=eur&rankTypeId=0&tra

27 Epever Tracer 100A Mppt Solar Charge Controller 12V 24V 36V ...
https://www.alibaba.com/product-detail/Epever-Tracer-100A-Mppt-Solar-Charge_1600835784513.html

29 30 31 32 33 High Voltage 50a 80a 100a 192v 384v 96v 220 - 360vdc Mppt Solar Charge Controller - Buy 220 - 360 Vdc Mppt Solar Charge Controller 220 - 360 Vdc Mppt Solar Charge Controller 220 - 360 Vdc Mppt Solar Charge Controller Product on Alibaba.com
https://www.alibaba.com/product-detail/High-Voltage-50A-80A-100A-192V_1600239009052.html

34 Source The Right Wholesale high voltage control - Alibaba.com
https://m.alibaba.com/showroom/high-voltage-control.html

[35] [39] Source The Right Wholesale high voltage control - Alibaba.com
https://www.alibaba.com/showroom/high-voltage-control.html

[43] [44] [45] Graphene Ultracapacitor now the same $/lifecycle as LiFePO4?
https://diysolarforum.com/threads/graphene-ultracapacitor-now-the-same-lifecycle-as-lifepo4.8176/

[47] Capacitor Bank Series-Parallel Configuration - High Voltage Forum
https://highvoltageforum.net/index.php?topic=1535.0