Energy Bank Capacitor Applications

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Introduction

High Power capacitors can be identified as storage volume. A tank will storage water drop, capacitors will storage electrical charge (electrons).

Everybody knows what is a dam or flood barrier or a toilet flush, Energy Storage Capacitor will act as dam or toilet flush

The principle of working is a “long” charge time and a “short” discharge time in order to generate a short pulse with peak current

Short pulse with peak current will produce a high power pulse able to create :
- high magnetic field in inductances
- or magnetic field in magnets
- or an ionization in a lamp
- or a plasma in the material
- or EM pulse lightning
- or High Frequency tubes

Applications are multiples but some of them are well identified as :
- particles accelerators in Research Labs
- EM guns for Military applications
- Fusion Laser for Military applications
- High Magnetic field for Research (Medical)
- Marx Generator for Military applications and Electrical Labs
- EM cylinders
- Electrical Forming
- Klystrons and other High Power electronic tubes

Some others classical applications DC banks filtering in storage High Energy application are met for Transport&Distribution of Energy (Flexible AC Transmission System, STAtic COMpensator, Unified Power Flow Controller).

More and more, banks of capacitors are used as Energy storage banks in order to deliver energy during several 100ms. Contrary to batteries and supercapacitors, power capacitors have no limitation in term of discharge time.

These High Energy applications request not only few elementary capacitors but lot of capacitors mechanical mounted and electrical connected on mechanical frames.

II.1. Energy

Power range means several kV and “High” capacitance in order to generate “High” energy from 100kJ up to several MJ per equipment. The max elementary capacitance is about 125kJ per unit.

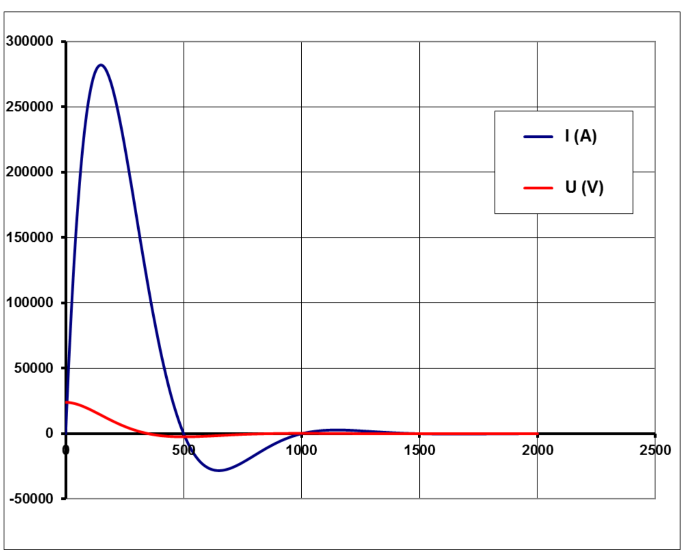
We remember that :
Energy = ½ CV^2 (with E in Joule, C in F and V in Volt).

II.2. Peak Current (discharge voltage)

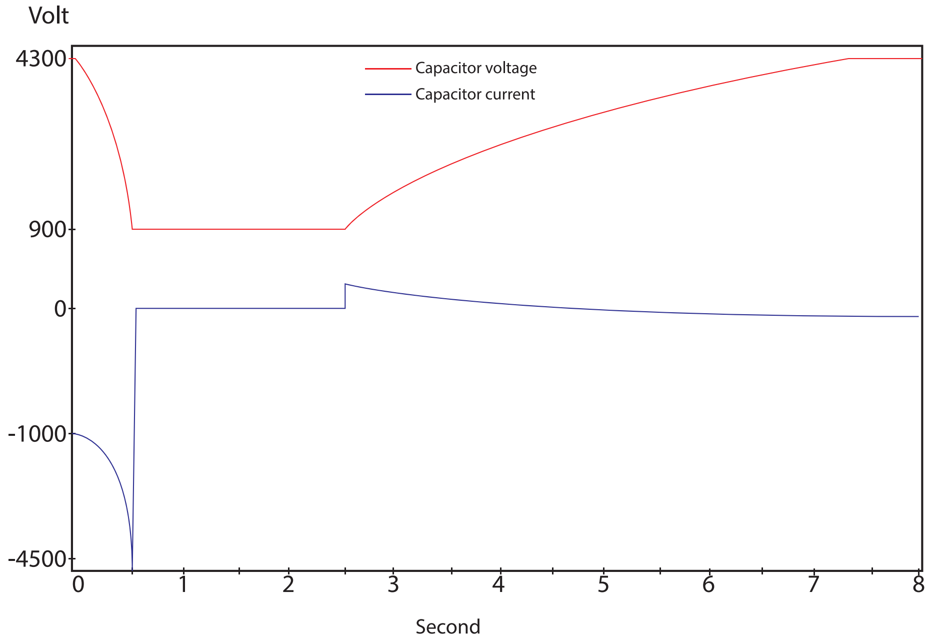
If Peak Current is proportional to capacitance, current depends also of ratio between voltage and time of discharge. Depending of applications, Peak Current can shift from few kA up to several MA.

We remember that :
Ipeak = C $\Delta V / \Delta t$ (with Ipeak in Amps, C in F, V in Volt and t in second)

An example for energy bank C=10x300µF/24kV



II.3. Voltage Ripple



The energy bank will discharge itself partially about 80% during 500ms. This discharge can be repeat several times per day or few times per month.

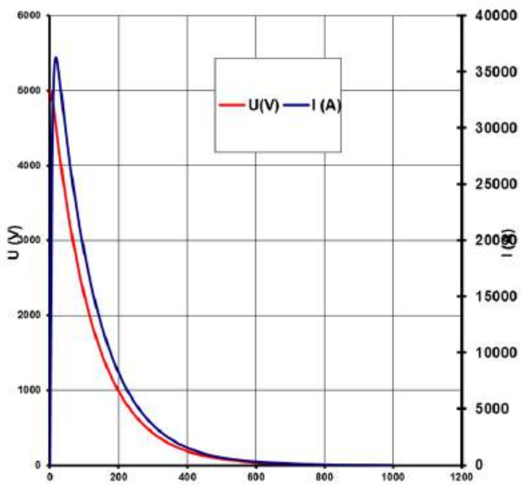
The target is to present energy storage available in case of switching or short time disruption.

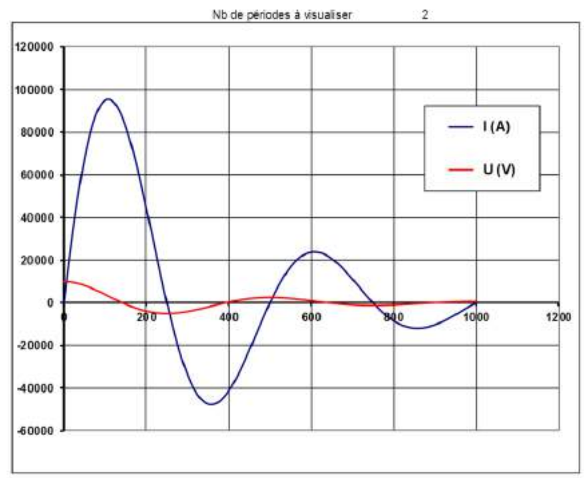
In this case batteries or supercapacitors cannot provide this energy during this time, electrolytic caps cannot be used due to high voltage and high energy and security of working.

II.4. Pulse Current

II.4.1. Principle

Capacitor (C) charge or discharge is first order mode, exponential law in serial resistance (R). If in the circuit we add an inductance (L), at minimum there is always inductance due to serial inductance of cap and inductance of connections, the charge and discharge mode will be second order with sine waves of current and voltage.

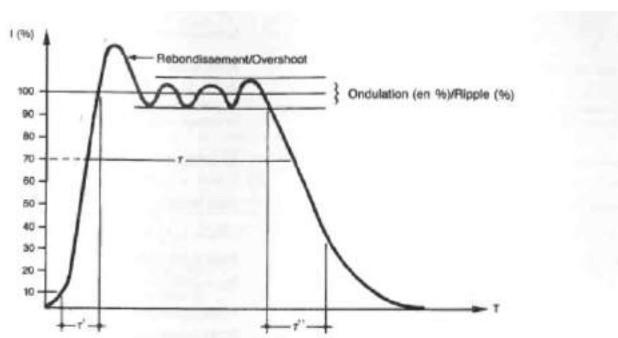


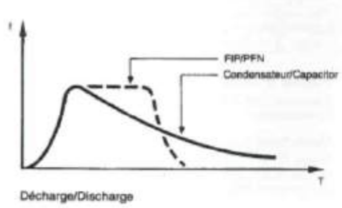


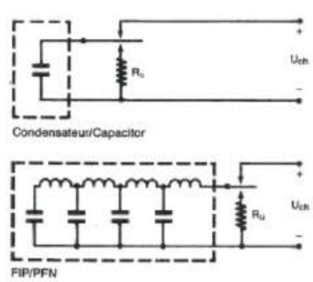
A R, L, C circuit can generate only sine waves pulse but sometimes, the load request square pulses, it's the case of magnetron, klystron or magnets.

In this case it's necessary to use a PFN (Pulse Forming Network).

II.4.2. Pulse Forming Network







A PFN, is realized with L, C cells, same as delay line, but the PFN is charge and discharged in its entrance on its characteristic impedance in order to generate a square calibrated pulse without reversal. Square pulse have specific characteristics as : rise time, fall time, overshoot, ripple, ramp that TPC control with cells characteristics. TPC is a the only one company to design and to manufacture PFN.

III. TPC realizations

III.1. TPC Know How

TPC has more 47 years of experience in electrotechnic field, the usual values are kilo Volt x kilo Amps = Mega Watt. Size of such applications induce several m3 and several tons.

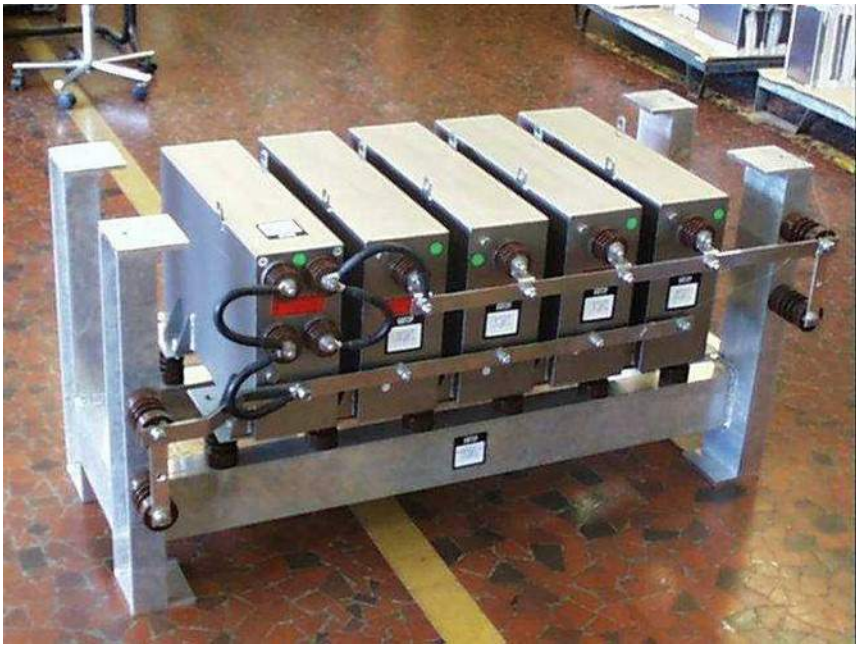
TPC Know How is to design such components meeting electrical and mechanical functions.

TPC is also able to design mechanical structure supporting capacitors, electrical insulation, connections and cabling.

III.2. DC filtering for industrial application

Depending of power application, when one reach several MW, several DC capacitors are connected in parallel.

III.2.1. Resonance filter for railways substations



C2943 : 2175µF +/- 2% - 6.2kV - 220kg

III.2.2. DC filter for power electronic tube

TFL 118 : 160µF +/- 10% - 32kV – 1250kg

L1296 : 500µs – 58kV – 1.5MW – 23000kg

III.4. DC Energy storage for 50/60Hz converter

C2961 : 74000µF +/- 5% – 4.2kV – 4500kg

Nota : Total bank per converter is 0.28F/4.2kV

III.5. DC Energy storage for Smooth filter for electromagnets (Synchrotron Power Supply)

C2953 : 400.000µF +/-5% - 1650 V – 1500kg

Nota : these cabinets have been designed and realized with additional control/command functions as :

- Thermal measurements
- Zero Voltage Testing
- Security system
- Programmable Logic Computer

III.6. DC Energy storage for Power System Booster for Magnets supply for Proton Synchrotron

C2955 : 64575µF +/- 2.5% - 5kVdc – 3450kg

Nota : the total bank is 0.25F / 5kVdc working in marine containers

III.7. Discharge Energy Bank for Electromagnetic gun (Military applications)

C2931 : 0.17F +/- 10% - 10.75kV – 29000kg

Customer's Specific Requirements

Company / Name / Email / Phone	Project / Quantity

Applications	DC Application		Discharge Application	
Total Capacitance (µF)				
Tolerance (%)				
Operating coltage (ripple included)				
Ripple voltage (peak to peak)				
Working frequency (Hz)				
Peak current				
RM S current				
M aximum current/duration				
Discharge				
Pulse duration @ 5%Ipeak (µs)				
Time to Ipeak (µs)				
Ringing Frequency (Hz)				
Reversal Voltage (%)				
Repetition rate				
Hold time @ full voltage (s)				
Fault peak current/nb shots				
Fault reversal voltage (%)				
Lifetime expectancy				
Maximum Inductance (nH)				
Test voltage between terminals (kV)				
Test voltage between shorted terminals and case (kV)				
Maximum surge voltage M SV (kV)				
M SV Duration / Frequency	second	/year		

Capacitors Integration					
Capacitors Dimensions (mm)			Operating Position	Terminals	
length	width	hight	vertical	Type	Number
			horizontal		

Bank Information					
Bank available volume (mm)			Insulation level (k V rm s)		
length	width	hight	form0V	fromg ground	

Thermal Characteristics		
Storage temperature (ºC)	Operating Temperature (ºC)	Cooling
min	min	Natural Convection
average	Average	Forced Air
max	max	

Remarks

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