Power Supply Options for a Naval Railgun

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Abstract—Large railguns require powerful power supply units. At the French-German Research Institute of Saint-Louis (ISL) most experimental railguns are driven by power supply units based on capacitors. Recent investigations at ISL explore the possibility to use coil based systems to increase the energy density of the power supply. In this study an electrical circuit simulation is used to investigate the difference for railgun operation in between a capacitor and a coil based power supply with respect to current amplitude behavior and projectile velocity. For this a scenario of a 25 MJ muzzle energy railgun is simulated with two different power supply options, replacing capacitors by coils and using a range of circuit resistances. The resistance determines to a large part the losses of the system and defines therefore the efficiency of the launch and the size of the power supply. The interpretation of the results of the performed simulations leads to the conclusion that the capacitor based system "naturally" produces a favorable current pulse trace with respect to launching a mechanical delicate payload. Further simulations show that the disadvantage of the inductor based supply can be mitigated by increasing the power supply unit subdivision into smaller units.

I. INTRODUCTION

Railguns are able to convert electrical energy into kinetic energy at the gigawatt power level [1]. Recent progress in railgun research allows to reach muzzle energies in excess of those being achieved by currently installed naval deck guns. Since several years, efforts in the US to further develop such a gun and to mature the technology to a useable, naval system have made tremendous progress. In [2] and [3] parameters of the investigated gun system and possible application scenarios are described. In the wake of this progress, the French-German Research Institute (ISL) started to investigate a shipboard long-range artillery scenario. Within this research effort, it was demonstrated in the laboratory that velocities above 3 km/s are achievable [1]. Further on, a preliminary launch package design was developed and tested to show that hypervelocity projectiles can be launched using railguns [4]. In the long-range artillery scenario, the projectile is launched under a steep firing angle to reach the distant target on a ballistic trajectory. Due to a muzzle velocity above 2000 m/s such a projectile can cover target distances far above 100 km. In [5] a 25 MJ muzzle energy railgun was investigated. Using a 6.4 m long barrel and a 4 MA current allows to launch a mass of 8 kg to 2500 m/s. Not answered was the question how a pulsed power supply (PPS) could look like for the envisioned system. Two possible choices are a capacitor or an inductor based system. The incentive to use an inductor based system is the higher energy density, possibly resulting in a reduced footprint of such a PPS. In experiments reported by [8] it was shown than an energy density gain of more than 10 can be realized with coils compared to high-end capacitors. Using an electrical simulation code, the effects of the two different PPS systems on the railgun launch performance are investigated.

II. GENERAL CONSIDERATIONS FOR THE PPS

A railgun uses electric current to drive the armature through the acceleration volume. A military payload might be sensitive to changes in acceleration and therefore it is of importance to aim for a constant current amplitude during the launch. The launch of a heavy projectile requires the conversion of electrical energy of the order of 100 MJ or more. Such an amount of energy is usually not stored in a single cell, instead the PPS is subdivided into several smaller, identical units. To generate a close to constant current amplitude shape these units are triggered following a time sequence. One possibility to trigger the release of a unit is to monitor the current amplitude and activate a subsequent unit whenever the current falls below a certain value. This approach requires a measurement of the total current and its interpretation. Usually applied in railgun experiments is another possibility: magnetic field sensors are placed along the barrel length and the passage of the armature is used to trigger one of the PPS units. At the same time the signal from the magnetic field sensors can be used to calculate the velocity of the armature. To obtain the velocity information during launch is essential, as it allows to reduce muzzle velocity dispersion by slightly modifying the trigger instants during launch [9]. A natural way to place these sensors is to do so by a fixed distance in between two sensors. Why this equidistant spacing makes sense can be understood by investigating the required electrical power and energy for the acceleration. When the armature traverses a certain length of an ideal railgun (meaning no losses), the PPS has to supply energy to build up the magnetic field (\(\Delta E_{\text{mag}}\)) behind the armature and to increase the kinetic energy (\(\Delta E_{\text{kin}}\)) of the armature. For the ideal railgun \(\Delta E = \Delta E_{\text{mag}} + \Delta E_{\text{kin}}\), with both components being of the same magnitude. The energy that is stored in a PPS unit will be exhausted after supplying the driving electric power for a certain time. Assuming that the amount of energy being stored in a PPS unit is just \(\Delta E\) it follows that

\[
\Delta E = P \cdot \Delta t
\]  

During a launch the required power increases, therefore the above power \(P\) is the average power during the short time interval \(\Delta t\). The same holds for the velocity, within the time \(\Delta t\), the velocity increases, but an average velocity \(v\) can be used to replace the time period by

\[
\Delta t = \frac{\Delta x}{v}
\]
With this equation one gets for the energy
\[ \Delta E = P \cdot \frac{\Delta x}{v} \]  \hspace{1cm} (3)

As power is force times velocity, the equation can be rewritten as
\[ \frac{\Delta E}{\Delta x} = F \]  \hspace{1cm} (4)

This last equation can be interpreted in this way: If the force \( F \) is constant, the railgun will consume the same amount of energy per barrel distance increment, regardless of the armature velocity. As it is one of the design goals to achieve a constant force and therefore acceleration of the armature, the PPS units trigger points have to be spaced by a constant distance. This “step-size” has to be adapted to the energy content of a PPS unit. This insight is used as a guiding principle for the simulations being presented in this paper.

III. SYSTEM RESISTANCE

In a railgun weapon system, all energy that is lost in the resistive part of the system can not be used for acceleration of the launch package. Therefore the system resistance has to be reduced as much as possible. Especially for a multi-shot system the joule effect generates heat loads which need to be removed from the weapon system at the cost of additional required energy, thus further reducing the overall efficiency. The energy lost is the power spent during the acceleration time. The following line of thought follows a discussion in [6]. The power \( P_{\text{joule}} \), that is converted into heat in the system due to the system resistance \( R \), is
\[ P_{\text{joule}} = R_s \cdot i^2 \]  \hspace{1cm} (5)

In this equation, the system resistance includes all resistances (from capacitors, coils, switches, cables, connectors, rail resistance,... ) and changes during the acceleration period. At the same time the power that is required to sustain the kinetic acceleration process is force times velocity, or
\[ P_{\text{kin}} = \frac{1}{2} L' \dot{i}^2 v \]  \hspace{1cm} (6)

The same amount of power is required for the build-up of the magnetic field, thus the power related to the acceleration can be written as
\[ P_{\text{acc}} = L' \dot{i}^2 v \]  \hspace{1cm} (7)

The required power needed by the railgun during launch is \( P = P_{\text{acc}} + P_{\text{joule}} \) and leads to the relation that the fraction of the usable power for acceleration (conversion efficiency) is
\[ \frac{P_{\text{acc}}}{P} = \frac{P_{\text{acc}}}{P_{\text{acc}} + P_{\text{joule}}} = \frac{1}{1 + \frac{R_s L}{L'}} \]  \hspace{1cm} (8)

If one is interested in the fraction of power that is converted into kinetic energy, the formula [8] is to be rewritten as
\[ \frac{P_{\text{kin}}}{P} = \frac{P_{\text{kin}}}{P_{\text{acc}} + P_{\text{joule}}} = \frac{1}{2 + \frac{2R_s}{L'v}} \]  \hspace{1cm} (9)

This last two equations show the interesting behavior of a railgun: The efficiency is a function of the velocity and increases with the velocity. They also show, that for a given railgun, it is of utmost importance to reduce the resistance as much as possible. This is of course stating the obvious: For a machine that consumes megaamperes the resistive losses become prohibitive if not the resistance is minimized. In figure [1] the equation [9] is evaluated for two different constant system resistances and an inductance gradient of 0.5 \( \mu \)H/m. For a launch in the long range artillery scenario, the armature is accelerated from stand-still to a velocity of 2500 m/s. The implicit assumption is a constant amplitude current pulse and no additional losses due to friction. For every velocity the efficiency to convert the electrical power of the PPS into kinetic energy of the projectile is shown in this figure for a system resistance of 0.1 m\( \Omega \) and 1 m\( \Omega \). This efficiency is a strong function of the velocity and the system resistance. In the case of a DC current pulse, the acceleration is constant and the launch efficiency is the arithmetic average of each of these curves. These efficiencies are denoted in the figure by \( \eta \). For a launcher with the above mentioned inductance gradient a system resistance of 1 m\( \Omega \) results in an efficiency of 18\% and at 0.1 m\( \Omega \) it reaches 39\%. It has to be mentioned that the system resistances used here are not the same as the resistances in the simulation described later in this paper. There the mentioned resistance is the resistance of one rack including the connection to the railgun. As several racks are feeding the railgun in parallel, the overall resistance is smaller than the used rack resistance. Real world efficiencies (and also those in the simulation described later) will deviate from these calculated ones for several reasons: The performance when using a real railgun degrades as mechanical friction and eddy currents occur, but the magnetic energy stored in the inductance of the rails can be converted (at least partly) into kinetic energy before shot-out by a drop in current amplitude, thus increasing the efficiency. For the later effect, the barrel needs to extend beyond the length at which all PPS units are exhausted.

![Fig. 1. Power conversion efficiency for a L'=0.5 \mu H/m railgun at different system resistances.](image)
IV. Capacitor based PPS

A capacitor based PPS unit (here called rack) is composed of a capacitor, a switch, a pulse-forming coil, a crow-bar diode and a resistance. A slightly simplified electrical circuit diagram of such a rack is shown in figure 2. In this investigation, the inductance of the pulse-forming coil contains all the inductances of the circuit including the cables connecting the rack to the railgun. The same holds for the resistance. The minor simplification of this circuit diagram is that it neglects the slight change in total circuit inductance and resistance when the capacitor is exhausted and the crow-bar diode becomes active. For practical purposes this small effect can be ignored without effect on the resulting pulse height and shape. The peak amplitude that is delivered by such a rack is calculated by using the equation:

\[ I_{\text{peak}} = U_0 \cdot \sqrt{\frac{C}{L}} \]  

(10)

By a careful selection of the capacitance and inductance the peak current amplitude of one rack can be adjusted. For an individual rack, not only the current amplitude, but also the rise time of the current pulse is of importance. This value is calculated by

\[ t_{\text{peak}} = \frac{\pi}{2} \cdot \sqrt{L/C} \]  

(11)

and dependent on the two parameters inductance and capacitance, as well. As explained in the previous section, to be able to allow for a close to constant acceleration of the launch package, it is not sufficient to use only one rack as PPS. Instead the current output of several racks are superimposed by triggering the current release of the individual racks in a sequence governed by the passage of the armature through the barrel.

By triggering the current release of the individual racks in a sequence governed by the passage of the armature through the barrel. To investigate the strong dependence of the launch performance on the resistance as discussed in section III, three cases are considered. The system performance was simulated using the value of the resistance R in figure 2 of 0.1 mΩ, 0.5 mΩ and 1 mΩ. For each resistance the capacitance and inductance of the rack and the trigger positions are modified to allow for an approximate equivalent acceleration to the final velocity of 2500 m/s (25 MJ muzzle energy). The values for the resistance and inductance as used in the simulation are listed in table I. The different positions of the armature to trigger the corresponding rack are listed in table II. These positions are determined to ensure a mostly flat current pulse shape. The results for the three simulated cases are shown in figure 3. A plateau of about 4.5 MA of current during most of the acceleration time is needed for the acceleration of the armature. The dynamical nature of the circuit (increasing inductance and resistance) during the launch makes an exact replication of the current pulse shape difficult for each of the three investigated cases. Therefore the optimization was stopped as soon as the final goal of 25 MJ of muzzle energy was reached for each case and the current peak amplitude did not exceed 4.5 MA for too long of a time. Due to the increasing resistance the energy stored increased from 53 MJ (0.1 mΩ) to 63 MJ (0.5 mΩ) and finally to 75 MJ (1 mΩ). This translates to a launch efficiency of 47%, 40% and 33%, respectively. The efficiencies are larger than the values in figure I, as firstly, several racks do contribute to the current at the same time. During this period, the rack resistances R are parallel, resulting in a smaller system resistance. Secondly, the current pulse is not a DC pulse, instead the falling amplitude at the end of the acceleration process leads to a conversion of the rail magnetic field into kinetic energy.

V. Electric Circuit Simulation with Capacitor based PPS

The simulation code using the NGSPICE [7] program which is routinely used to evaluate the railguns at ISL was modified to simulate the proposed simple breech feed railgun with a 6.4 m long barrel. The inductance gradient L’ is an input and was set to 0.5 µH/m. For the rails, copper material with a resistivity of 17 nΩm was used. The resistance gradient R’ is calculated using the resistivity and the cross-section of the rails. To account for the higher resistance due to the skin effect a factor of 2 was used to increase the calculated rail resistance. With a width of 90 mm and a rail height of 60 mm and including the factor for the skin effect a value of R’ of 6.3 µΩ/m is used. This value evaluates for an average resistance contribution from the rails of approx. 0.04 mΩ for the 6.4 m long barrel. Friction was taken into account by reducing the acceleration force by 10%. Except for the inductance gradient, all assumptions of the relevant parameters are chosen to be conservative. The starting position of the armature is located three times the caliber (0.27 m) down the barrel. This distance to the breech ensures that the armature experiences the full strength of the magnetic field. The total energy is distributed across 10 racks, which are individually connected to the breech of the railgun. Three racks are triggered to ramp up the current at launch start, the remaining 7 racks are triggered subsequently with the passage of the armature through the barrel. To account for the higher resistance due to the skin effect a factor of 2 was used to increase the calculated

### Table I

| R   | E_{peak} | C   | L    | t_{peak} | I_{max} |
|-----|----------|-----|------|----------|---------|
| 0.1 mΩ | 5.3 MJ   | 22 mF | 4 µH  | 0.47 ms  | 1.63 MA |
| 0.5 mΩ | 6.3 MJ   | 26 mF | 4.6 µH | 0.54 ms  | 1.65 MA |
| 1 mΩ   | 7.5 MJ   | 31 mF | 5 µH  | 0.62 ms  | 1.73 MA |

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![Fig. 2. Schematic representation of a capacitor based PPS-rack.](image-url)
VI. INDUCTOR BASED PPS

In a capacitor based PPS as shown in figure 2, the energy stored in a capacitor is transferred to the pulse forming coil L and finally to the railgun. In an inductively driven PPS, the coil does directly feed the railgun. In a coil the energy content is

\[ E_{\text{ind}} = \frac{1}{2} L I^2 \] (12)

When using the values for the inductance L and the current \( I_{\text{max}} \) from the table and the equation one realizes that these compute just to the energy content of a rack (5.3 MJ, 6.3 MJ and 7.5 MJ). Therefore a straight forward replacement of the capacitor based rack is to rearrange the circuit according to the schematic from figure 4 and use the pulse-forming coil of the capacitor based rack as storage inductance. This allows a one-to-one comparison of a railgun driven by rather similar capacitor or inductor based PPS racks. Actually, when one does not want to change the number of racks, there are no degrees of freedom available to deviate much from the inductance value. The current amplitude is determined by the required acceleration of the projectile and bound by the current carrying limit of the rails, and the total required energy by the efficiency of the launch, which is dominated by the system resistance. For the racks from figure 4 it is assumed that the switch S is closed and the coil L is charged with the corresponding current at the beginning of the launch process.

The charging system and its efficiency is not considered in this investigation. The current is stored loss-free in the coil and the release of the energy is triggered by the opening of the switch S. The discharge into the railgun is via the diode D and the resistance R. The purpose of the diode D is to disallow current from other racks to enter the circuit. This prevents a recharging of a discharged coil from racks that are triggered later during the launch process. When triggering a rack, the charged inductance is switched to the railgun, which represents a variable and growing inductance. This reduces the amplitude of the current from the storage coil and explains the smaller increments in current amplitude per switched rack as the acceleration time progresses.

A. Simulation Results for Inductor Based PPS

For the simulation of the launcher performance, the simulation as described in section was modified by replacing the capacitor based rack with the inductor based rack in the SPICE circuit. After this, the cases for the system resistance of 0.1 mΩ, 0.5 mΩ and 1 mΩ were simulated. The results are shown in figure 5. Inspecting the velocities of the projectile reveals, that the reached velocities are of up to 5% lower than the target velocity of 2500 m/s. Inspecting the current trace, it becomes apparent, that the current amplitude variation is not as smooth as in the simulation using capacitor based racks. The triggering of a charged inductor equipped rack leads to a pronounced jump in the current amplitude. With the increase in the railgun inductance during the launch process, the current variation becomes smaller as the ratio total inductance to rack inductance becomes larger, but stays still significant. In addition the maximum current amplitudes are above 5 MA, higher than in the capacitor based simulations. The launch efficiencies are 45%, 36% and 33%. The relatively strong variation of the current amplitude (peak-to-valley) of up to 1.4 MA is a clear disadvantage for this solution as this behavior translates to strong changes in the acceleration during the launch and thus to a hard mechanical load for the launch package. As the current has to flow through the inductor-switch circuit at the time interval from charging of the coil up to the release of the rack energy, a real coil based PPS will suffer drastic losses during this time period. An effect that is neglected in this analysis, instead it is assumed that the charging can take place infinitely quick just before the rack is triggered.

| R | Rack | 1 | 2 | 3 | 4 | 5 |
|---|-----|---|---|---|---|---|
| 0.1 mΩ | 0.27 m | 0.27 m | 0.27 m | 0.72 m | 0.99 m |
| 0.5 mΩ | 0.27 m | 0.27 m | 0.27 m | 0.52 m | 0.99 m |
| 1 mΩ | 0.27 m | 0.27 m | 0.27 m | 0.47 m | 0.99 m |

TABLE II

Positions to trigger the corresponding capacitor rack during the passage of the armature through the barrel.

![Simulation results](image)

Fig. 3. Simulation results for the capacitor based racks.

![Schematic representation](image)

Fig. 4. Schematic representation of an inductor based PPS-rack.
In the above simulation using inductor based racks with the same energy content as its capacitor based counterpart it was shown that the current amplitude shows strong variations during the launch. The sawtooth pattern results in an acceleration profile that can be disadvantageous for delicate payloads (as for example a hypervelocity projectile with moveable fins). One obvious idea to reduce the current variations is to increase the number of racks by reducing the stored energy content per rack. To investigate the effect of smaller, but more energy portions being fed to the railgun, the simulation was repeated using 20 and 40 racks. To first order, one could think of simply varying the inductance value of the storage coil by a factor corresponding to the ratio of the number of racks (i.e. using 2 µH instead of 4 µH when using 20 instead of 10 racks) and keeping the maximum current at the same value. But as this simple scaling changes the ratio of the rack to railgun inductance, the current amplitude in the railgun changes, too. Instead three parameters (inductance, current amplitude and number of initially triggered racks) were varied to achieve a current amplitude of the same height for all three cases at the starting time of the acceleration. The chosen parameters for the racks are shown in table III. As the inductance of the racks is reduced, it is required to increase the number of racks that are triggered at acceleration start. As this number can not be varied arbitrarily (racks can not be divided) the maximum current and the inductance were adopted using a trial-and-error method until the same initial current amplitude was achieved in the three cases. The results of these simulations are shown in figure 6. The velocity traces show the same behavior and within a small margin the end-velocity is the same for all the cases. Investigating the three current traces, one can deduce that in fact the peak-to-valley amplitude of the sawtooth pattern becomes smaller when the total energy is distributed to more individual racks. To get a quantitative handle on this behavior, the arithmetic mean current value and the standard deviation was calculated for every point in time of the simulation. The standard deviation gives an information how far the data points vary from the mean value. Here we compare the relative standard deviation of the current at the time when all racks have been fired (in the figure 6 the time when the current starts to drop rapidly at approx. 3.3 ms). The values are 8%, 5.5% and 3.5% for the simulation with 10, 20 and 40 racks, respectively. This result clearly shows that it is possible to drastically reduce the current (and acceleration) ripple in a coil based PPS driven railgun by using many small racks.

### Table III

| N_racks | E_rack | L     | I_max | N_racks_initial |
|---------|--------|-------|-------|-----------------|
| 10      | 5.3 MJ | 4 µH  | 1.63 MA | 5               |
| 20      | 2.65 MJ | 3.14 µH | 1.3 MA | 4               |
| 40      | 1.33 MJ | 1.57 µH | 1.3 MA | 5               |

**B. Increasing Rack Segmentation**

In the above simulation using inductor based racks with the same energy content as its capacitor based counterpart it was shown that the current amplitude shows strong variations during the launch. The sawtooth pattern results in an acceleration profile that can be disadvantageous for delicate payloads (as for example a hypervelocity projectile with moveable fins). One obvious idea to reduce the current variations is to increase the number of racks by reducing the stored energy content per rack. To investigate the effect of smaller, but more energy portions being fed to the railgun, the simulation was repeated using 20 and 40 racks. To first order, one could think of simply varying the inductance value of the storage coil by a factor corresponding to the ratio of the number of racks (i.e. using 2 µH instead of 4 µH when using 20 instead of 10 racks) and keeping the maximum current at the same value. But as this simple scaling changes the ratio of the rack to railgun inductance, the current amplitude in the railgun changes, too. Instead three parameters (inductance, current amplitude and number of initially triggered racks) were varied to achieve a current amplitude of the same height for all three cases at the starting time of the acceleration. The chosen parameters for the racks are shown in table III. As the inductance of the racks is reduced, it is required to increase the number of racks that are triggered at acceleration start. As this number can not be varied arbitrarily (racks can not be divided) the maximum current and the inductance were adopted using a trial-and-error method until the same initial current amplitude was achieved in the three cases. The results of these simulations are shown in figure 6. The velocity traces show the same behavior and within a small margin the end-velocity is the same for all the cases. Investigating the three current traces, one can deduce that in fact the peak-to-valley amplitude of the sawtooth pattern becomes smaller when the total energy is distributed to more individual racks. To get a quantitative handle on this behavior, the arithmetic mean current value and
energy is of the same value as the kinetic energy of the projectile. In a practical railgun the current has usually already started to decay and therefore the rail magnetic field energy is at least partly converted into kinetic energy, thus improving the launch efficiency. The inductances in the PPS itself transfer the stored energy to the railgun. They are discharged by this energy transfer and by the system resistance. In figure 8 the distribution of the energy being stored in these two inductances during the launch period are shown. Initially three racks are fired simultaneously and the energy is intermittently stored in the rack coils (in figure 8 the three traces showing the energy being stored in the coils of the racks are marked by "E_{ind, PPS}", those for the rails by "E_{ind, Rails}"). As the armature progresses along the rails, the rail inductance becomes more important and more racks are fired. During this process the triggered racks are depleted from energy and more energy is stored in the rail magnetic field. The energy is being transferred from the PPS coils to kinetic energy of the projectile, magnetic energy of the rails and ohmic heat. The release points for the subsequently fired racks are close to equally spatially spaced. The explanation for the increase in the energy being stored in the active rack coils is the following: As the projectile velocity increases, the projectile passes the distance in between two subsequent trigger points faster than the charging/discharging time for a rack can transfer the energy. After 4 ms, the racks have all fired and the current through the railgun is driven fully by the decaying magnetic field of the inductances. At shot-out there is approx. 5 MJ of energy left in the PPS coils and between 16 MJ to 18 MJ still stored in the rail magnetic field.

B. Inductor Based PPS

In the inductor based PPS system, the discharge of the initially stored energy into the railgun is more direct. At triggering the coil of the PPS rack is connected to the railgun as resistive-inductive load. Discussing the discharge process shown in figure 9 qualitatively, the coil based system behaves overall as the capacitor based system. In the onset of the acceleration process only very little energy is being transferred into the inductance of the rails, but this changes rapidly with increasing launch time. The energy being stored in the coils of the activated (triggered) racks is first dominating, but becomes rapidly smaller once all racks had been triggered (after 3.2 ms to 3.8 ms depending on the resistance). But the energy traces show a strong dependence on the rack trigger process. Whenever a rack is triggered, the energy in the coils and rails changes rapidly and the traces develop a sawtooth like pattern. As such a behavior is not beneficial for the launch (acceleration of payload, forces acting on barrel,...) the importance of a small resistance R is again demonstrated by this figure. When comparing the traces of the simulation for the 1 mΩ and the 0.1 mΩ resistances it can be seen that a smaller resistance and the resulting lower storage inductance results in a smoother energy transfer process. In this simulations the energy being stored at shot-out in the PPS coils is in between 4 MJ to 5 MJ, while the rail magnetic field stores in between 12 MJ to 13 MJ. The rail magnetic field energy at shot-out is significantly smaller than in the capacity based system (by 4 MJ to 5 MJ) and can be explained by the fact, that in the capacitor based system there is an additional time to charge the pulse forming coils from the capacitor – a delay that is not existing in the inductor based system.

VIII. SUMMARY AND CONCLUSIONS

Railguns are an attractive choice for long range deck guns. The combination of large muzzle velocity with large muzzle energy allows to reach distances far in excess of conventional artillery guns. The main problem of such a weapon system is the lack of sufficiently small and lightweight electrical power supply capability on the platform. Therefore different technologies are investigated as intermediate energy storage and power source. The most mature solution are capacitor based PPSs. But capacitors have a large footprint and weight for a given energy content. A PPS based on inductors might
Fig. 9. Coi based PPS: Energy stored in the inductances of the PPS and the rails for the three simulated scenarios.

dramatically improve the energy density and is therefore an interesting alternative. In this investigation it was shown that the electrical behavior of an inductor based PPS differs from the capacitor based PPS. To first order, for a given PPS stored energy being split up into a number of identical racks, it is possible to accelerate a given projectile to the same velocity using capacitor or inductor based racks. When exchanging charged capacitors for charged coils, the efficiencies (kinetic energy divided by stored electrical energy in the PPS) are approximately the same. The current amplitude trace is smoother for capacitor based racks and therefore favorable compared to inductor based racks. For an inductor based PPS it is possible to reduce the disadvantageous current ripple by increasing the number of racks, by making them smaller with respect to the stored energy. When taking into account the charging of the rack and the hold time until discharge, capacitor based systems seem to be favorable, at least in the configuration investigated here. Due to the internal resistance of the storage inductor, inductor based racks can not be used to store energy for a time longer than a fraction of the launch time without incurring prohibitive losses.

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