App Note 507 - Charging Large Load Capacitors

Introduction

TDK-Lambda's ALE series Capacitor Charging Power Supplies, are specifically designed to rapidly and efficiently charge capacitors in pulsed discharge loads such as lasers and modulators. These supplies operate as constant current sources which makes them ideal for operating with the variable load impedance of a charging capacitor. This application note aims to highlight the advantages of the ALE series supplies, and some useful precautions when charging large high energy storage capacitors.

Load Fault Condition

ALE power supplies are rated to run in repetitive circuits that often operate with tens or hundreds of charge/discharge cycles per second. In this case capacitor charge times are short and the power supply reaches the programmed output voltage typically within a few milliseconds or tens of milliseconds.

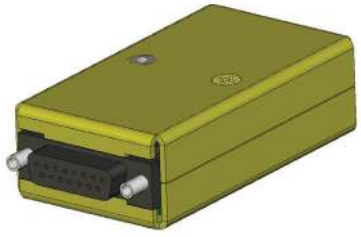
When supplies are used to charge large loads over a few seconds or longer, the power supply will indicate a Load Fault or Overload condition. Load Fault is a simple timer circuit within the supply designed to protect it and the load, in the event of an external short or latching condition. The supply output shuts down ('off' state) and indicates a Load Fault if the output voltage does not reach the programmed voltage after charging for 500ms. Following 500ms in the 'off' state, the load fault indication clears and the supply automatically begins recharging the load(1). This 500ms on, 500ms off cycle continues until the programmed output voltage is reached, leading to a staircase like charge voltage waveform.

Operating the power supply in this mode will not cause any damage to the unit, but it is not the fastest way to charge the load since the supply is only operating at 50% duty cycle.

Long Charge Adapter

To realize the fastest charge time from any ALE supply charging large energy storage capacitors, a programming module is available that optimizes the output current profile of the supply. Using this module results in significantly improved charge times compared with conventional HVDC power supplies with identical power ratings, or capacitor charging supplies operated in the Load Fault mode.

The ALE Long Charge Adapter (or LCA) is a simple module that plugs into the power supply remote control interface and modifies its output current to automatically minimize charge time for large loads. A sketch of the LCA is shown below.



With the LCA installed the Load Fault circuit is effectively defeated, allowing the supply to continuously deliver its full rated charge current while the output voltage is less than 50% of rated, and linearly reduces output current to half its rated value at 100% of rated voltage.

The LCA module requires no modification to the normal control circuits and operates in both remote and local mode.

Calculating load charge time with an LCA equipped power supply involves a charge simulation spreadsheet that can be obtained from our web site, or by contacting the factory. The simulation requires the load circuit information to be defined (Capacitance, Charge Voltage, Supply Rated Voltage), and allows the user to try different power supply combinations for optimum circuit operation.

Example

The following example demonstrates a standard 30kW, 26kV HVDC power supply, and a capacitor charging supply with and without the LCA, charging a 7000µF load capacitor to 24kV.

Conventional HVDC supply

A conventional HVDC power supply with a 30kW, 26kV rating has an output current rating of 1.15A (30kW/26kV). The time to charge 7000µF to 24kV is given by;

$$T_c = C \times V / I = 7000 \times 10^{-6} \times 24 \times 10^{3} / 1.15 = 146 \text{seconds}$$

Capacitor Charging Supply without LCA

The ALE model 303 is a 30kW rated capacitor charging supply with a peak output current of 2.88A at 26kV. The average charging current is half this value (1.44A) when the supply operates in load fault mode. The charge time is given by;

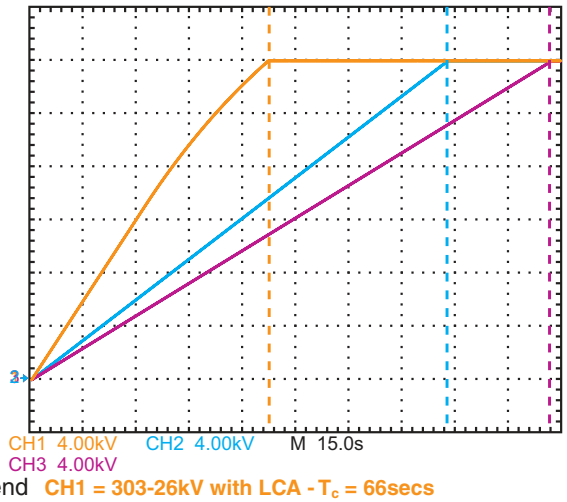
$$T_c = C \times V / I = 7000 \times 10^{-6} \times 24 \times 10^{3} / 1.44 = 117 \text{seconds}$$

Capacitor Charging Supply with LCA

Using the same model ALE 303 supply, and the Long Charge Adapter, the time to charge the load to 24kV is;

$$T_c = 66 \text{seconds (using simulation spreadsheet)}$$

The graph below shows the charge waveforms for each case of the example above.



Legend **CH1 = 303-26kV with LCA - T_c = 66secs**
CH2 = 303-26kV w/o LCA - T_c = 117secs
CH3 = Conventional 30kW 26kV HVDC supply - T_c = 146secs.

The graph and data clearly shows that the ALE 303 supply equipped with the LCA, and with the same rating as a conventional 30kW DC supply, charges the 7000µF load to 24kV in less than half the time.

Note 1. If LP option is enabled, supply requires HV ON/OFF cycle to clear Load Fault.

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The faster charge time significantly reduces voltage stress on the load capacitor resulting in a longer operating life.

There are three different LCAs available, each for use with one of three product families. All LCAs function in an identical manner, but have different connector pin arrangements depending on the power supply family control interface.

Part 26922100 for models 500A, 102A, 152A, and 202A

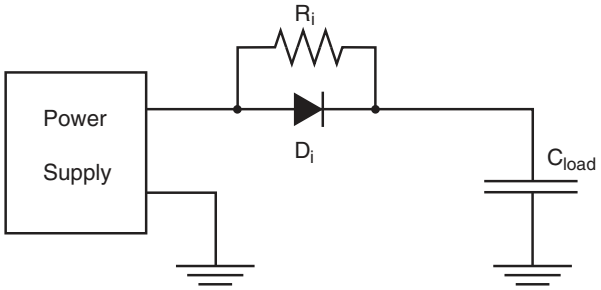
Part 26922200 for models 402, 802, XR802, and LC1202

Part 26922300 for models 203 and 303

The LCA can be purchased with the supply at the time of ordering, or as a spare part through our repair depot, contact the factory for current pricing.

Safety Precautions

When a capacitor charging power supply is used to charge a load circuit that contains greater that 1kiloJoule of stored energy, it is wise to add an external isolation network between the power supply and the load. The isolation circuit will prevent the load capacitor from discharging into the power supply in the event of a catastrophic failure in the output section of the supply. The power supply warranty may be voided if an isolation network is not installed. The sketch below shows the recommended isolation network.



Diode D_i isolates the power supply from the load and in the event of a catastrophic failure in the power supply output section will prevent rapid discharge of the energy in C_{load} through the supply, which could present a safety hazard. D_i should have a reverse voltage rating at least 1.5 times the rating of the power supply, and a forward current rating at least 2 times the power supply capability.

Resistor R_i is designed to dissipate the energy stored in C_{load} in the event of a power supply output failure. The value of R_i should be approximately 100Ω with an energy rating sufficient to dissipate all of the stored energy in C_{load}.

For additional isolation it is recommended that the power supply is disconnected from the load circuit using a high voltage relay or disconnect switch prior to load discharge.

For suggested protection circuit component manufacturers, see opposite.

High Voltage Diode manufacturers

Dean Technology, Inc.
Dallas, TX, Tel. 972-248-7691
Web: www.deantechnology.com, Email: info@hvca.com

Voltage Multipliers Inc
Visalia, CA.
Tel. 559-651-1402.
Web: www.voltagemultipliers.com

High Energy Resistors manufacturers

Kanthal Globar
Amherst, NY, Tel. 716-691-4010
Web: www.globar.com

HVR Advanced Power Components
Tonawanda, NY, Tel. 716-693-4700
Web: www.hvrapc.com

High Voltage Relay manufacturers

Ross Engineering Corporation
Campbell, CA, Tel. 800-654-3205
Web: www.rossengineeringcorp.com/hv_relays.htm

Tyco Electronics (Kilovac)
Tel. 800-253-4560
Web: relays.tycoelectronics.com/kilovac/

If you have any questions or comments regarding this or any of our Application Notes or products, please contact Andy Tydeman at the factory, we are here to help.

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