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WHITE PAPER: TRIGGERING OF LARGE PULSED POWER SYSTEMS.

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Large pulsed power systems utilized for particle accelerators, radiation effects testing, and simulating the effect of nearby or direct lightning strikes, are most often comprised of highly energetic Marx generators to create the high voltages and currents required by these applications. Because many of the laboratories operating these sources need reliable, repeatable results, the triggering of these systems can present a significant challenge in the design and operation of these machines.

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STANDARD 3-STAGE TRIGGERING (OEM)

Many of the large pulsed power systems employed by the DOE and other research institutions are decades old and utilize triggering components that are reaching the end of their service life. A typical triggering scheme for such a system is shown in Figure 1.

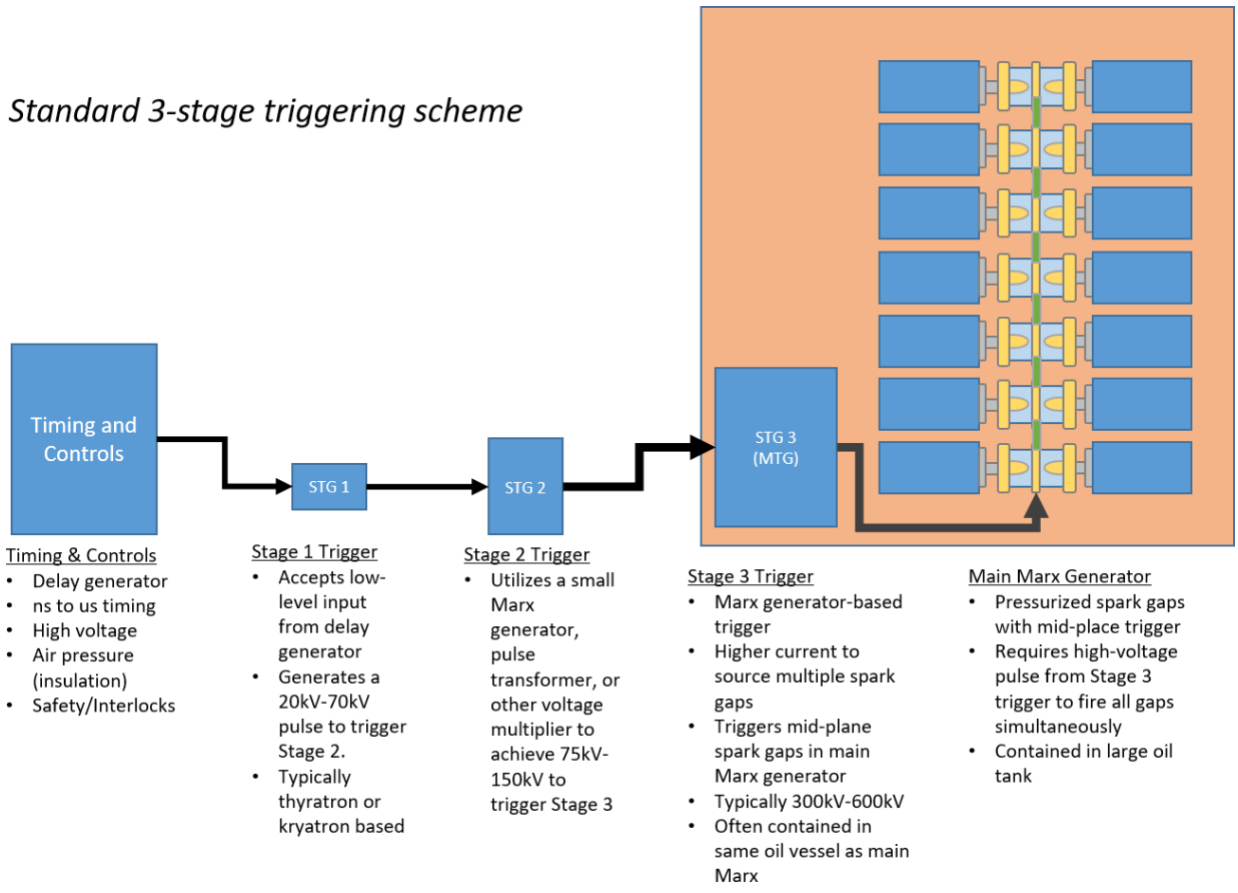

Figure 1 Standard 3-stage triggering scheme for large pulsed power systems

A low voltage timing signal is sent to a stage 1 trigger that utilizes a switch such as a thyratron or kryatron to generate a higher-voltage pulse (20kV-70kV). This pulse is then multiplied in "Stage 2" by either a Marx generator, pulse transformer or other voltage multiplication/pulse-compression technique. Lastly, the resultant pulse in stage 2 is used to trigger a Stage 3 Marx generator (a.k.a. Marx Trigger Generator or MTG) typically contained in the same oil tank as the main Marx generator. This stage 3 Marx provides 300kV-600kV to the mid-plane trigger electrode on either the first few, or all stages of the Main Marx generator.

While this 3-stage triggering topology has been used successfully for many decades, a number of issues are causing the operators of these pulsed power facilities to look for alternative triggering methods. A summary of these issues is listed below:

- Difficult to source stage-1 trigger components, such as the kryatron switch
- Unavailable components because of defunct manufacturers – e.g. EG&G, Pacific-Atlantic Electronics etc…
- Multiple components reaching the end of their service life
- High timing jitter due to the combined jitter of the 3 stages
- Difficult to service stage 3 Marx trigger components because of oil-immersion
- Long down-times in repair because of components that have long lead-times and that are located in places that are difficult to service

APELC 2-STAGE TRIGGERING SCHEME

APELC has proposed and implemented a 2-stage triggering scheme that addresses each of the above issues in the following ways:

- Stage 1 trigger utilizing readily available COTS components
- Reduction of total components by triggering a single Marx Trigger Generator with a 20kV pulse from the Stage 1 trigger (TTR-RR)
- Low system jitter because of the reduction of trigger stages and implementation of wave-erection principles in the design of the MG12-1C-150NF
- Extremely easy to maintain/low-downtime system with the use of quick-disconnects on charge, trigger and insulating air connections.
- Extremely easy to maintain/low-downtime system with the use of APELC's modular spark gap rail
- Low cost of replacement because of the reduced number of components
- Stage 1 trigger can accept optical or TTL timing inputs, making for ease of integration with existing controls

The APELC 2-stage triggering scheme shown in Figure 2 utilizes the APELC TTR-RR Trigger generator to supply a ~20kV fast (~10ns rise-time) trigger pulse to the first stage of the APELC MG12-1C-150NF Marx generator. When charged to 50kV, the MG12-1C-150NF can provide up to a 600kV pulse to trigger the mid-plane gaps of main Marx generator. The TTR-RR trigger generator is shown in Figure 3 and the MG12-1C-150NF is shown in Figure 4.

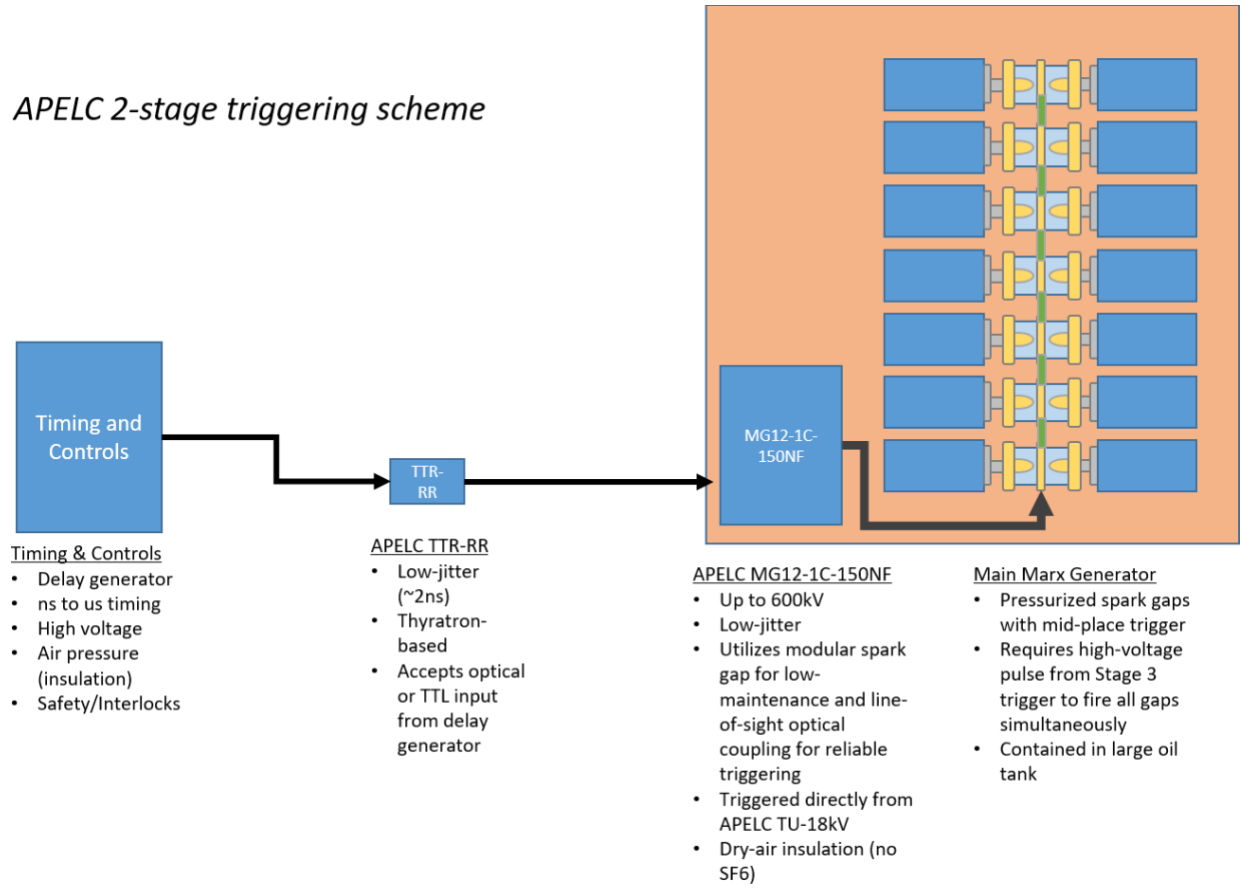

Figure 2 APELC 2-stage triggering scheme

The MG12-1C-150NF can either be self-contained in its own oil tank as shown in Figure 4, or can be placed into the Main Marx generator oil tank with the MG12's bulkhead at the top of the tank for easy access. The MG12 also has a built-in dummy load and CVR that can be removed during normal operation and put in when a calibrated output waveform into a known load is needed for verification of Marx performance.

Figure 3 APELC TTR-RR Trigger generator

Figure 4 APELC MG12-1C-150NF

APELC MG15-3C-940PF TRIGGER SCHEME

The APELC MG15-3C-940PF Marx generator shown in Figure 5 is perhaps our most mature and well-documented Marx. The MG15-3C-940PF can also deliver up to 600KV into an open circuit, but is a lower energy pulse (33J) in comparison to the MG12-1C-150NF. In some instances it may be possible to use the MG15-3C-940PF to trigger mid-plane gaps directly, or the MG15 can be terminated into a single 50 Ohm cable to trigger Stage 3 MTG's. A dual output option is also available to allow for simultaneous triggering of 2 Stage 3 MTGs (Figure 7). The MG15-3C-940PF has an extremely low-jitter when used with the APELC TTR-RR trigger (~2ns RMS) as shown in Figure 6 and has been life-time tested up to 250,000 shots before requiring maintenance.

Figure 5 APELC MG15-3C-940PF Marx Generator shown with dual-output configuration and coaxial dummy loads

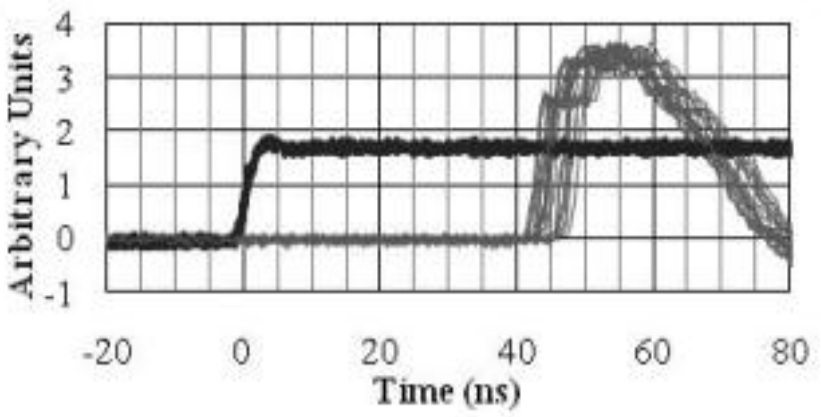

Figure 6 Overlay of 21 MG15-3C-940PF output pulses referenced to the fire command signal from a delay generator (RMS jitter <2ns)

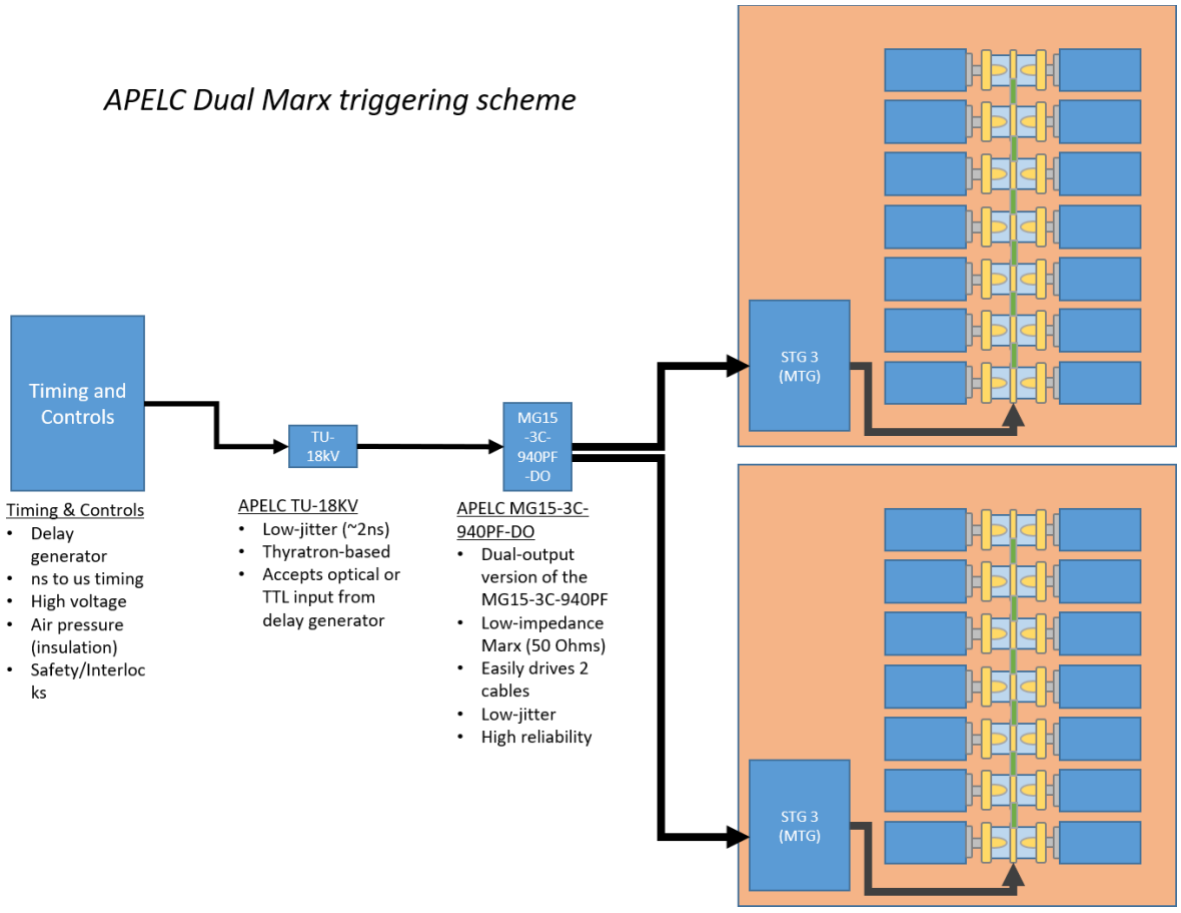

Figure 7 APELC MG15-3C-940PF with dual-output option for simultaneous trigger of 2 MTG's

More information on our Marx and trigger generators for pulsed power systems can be found on our website at www.apelc.com