



# **Genetic Optimization for Pulsed Power System Configuration**

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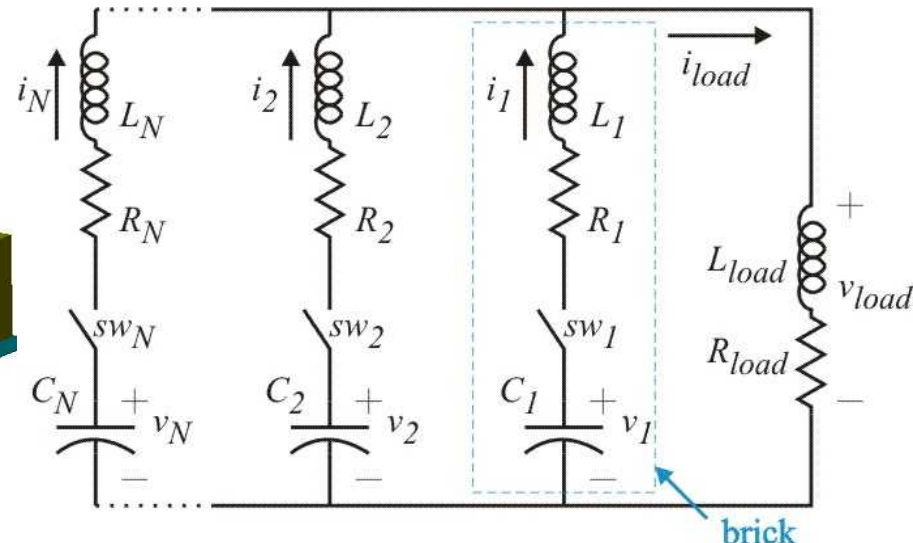
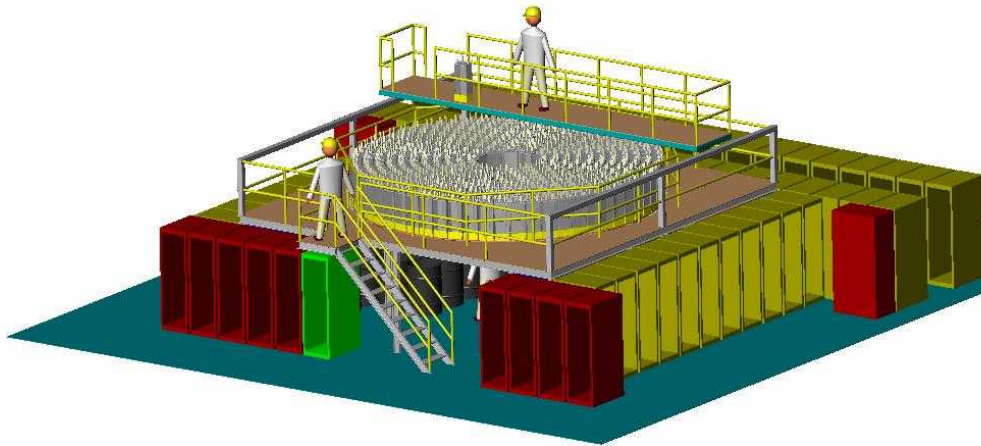
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# Manual Optimization of Complex Systems can be Extremely Challenging & Time Consuming

## Conceptual pulsed power system for load current shaping

- Programmable
  - Trigger points
  - Charge voltage
- Variables interact
  - Trigger time, charge voltage
- Multiple frequencies may be present
- Bricks connected early in time load bricks that connect later



# Over Coming these Challenges has started on a Scaled System

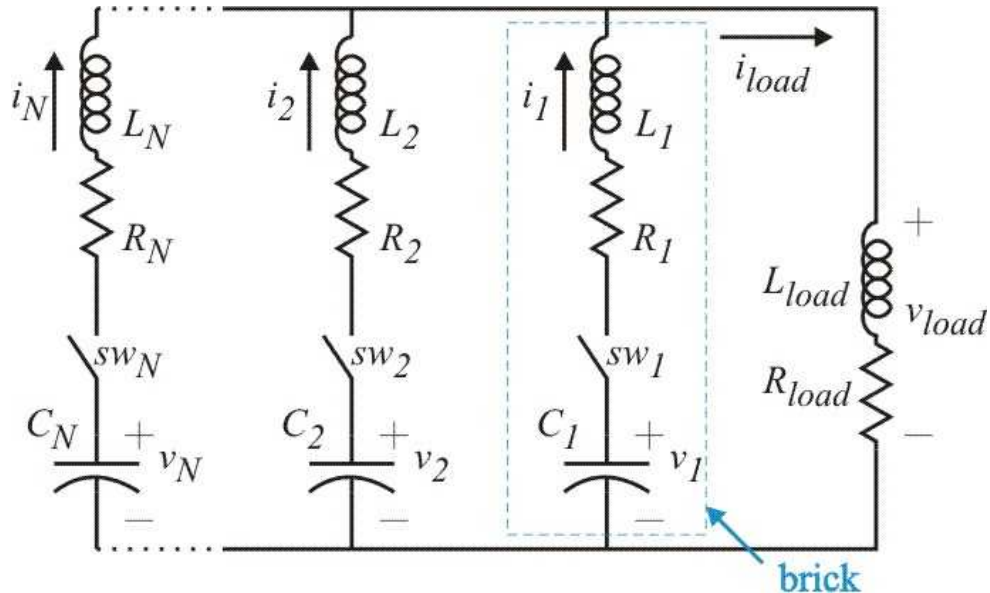
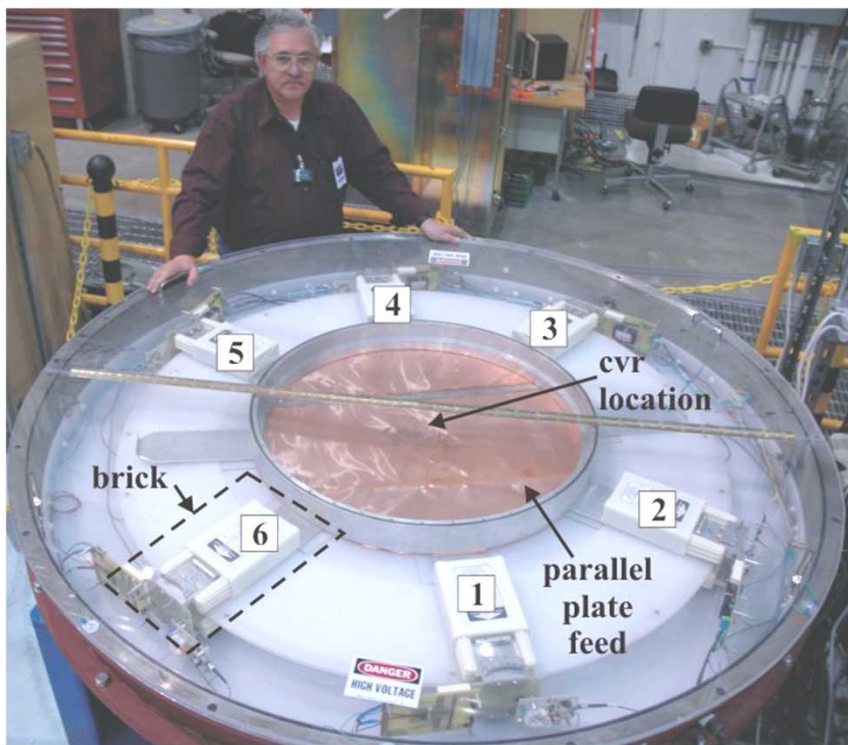
## 6 Brick current adder

Independently programmable trigger points

Independently programmable charge voltages

Parallel plate feed to the load

CVR as the load



# Genetic Optimizations are Powerful

- **Powerful**

- Large numbers of parameters
- Discontinuous information
- Derivative not required
- Measured and simulated data
- User defined fitness function
- Escapes local minimums

- **Based on nature**

- Mating, Mutation, Elitism

- **Biological Equivalents**

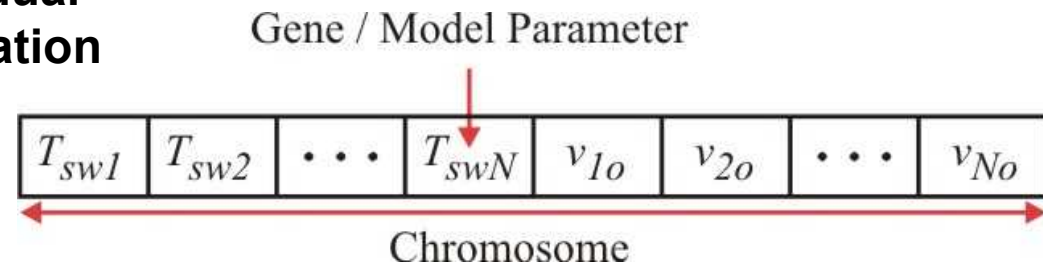
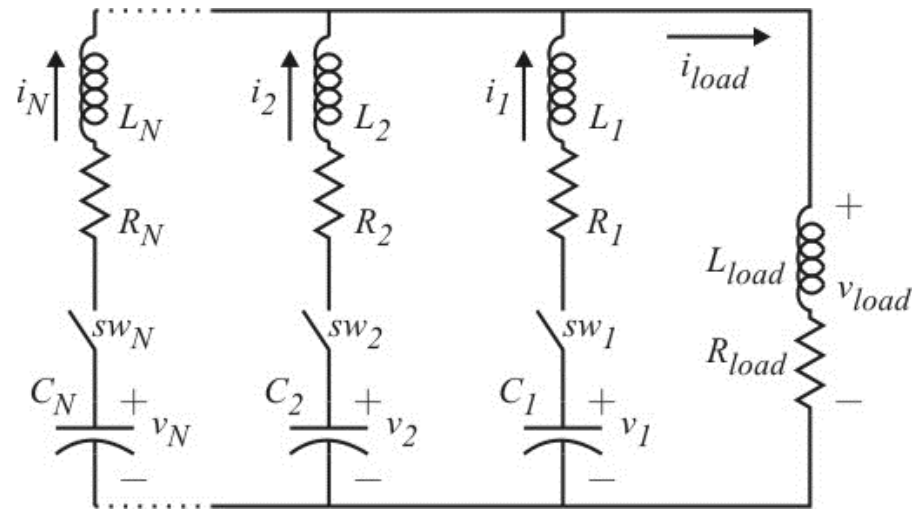
- Model parameter → Genes
- Set of parameters → individual
- Set of models → population

- **Figure of Merit**

- Assigned to each individual

- **GOSET**

- Program for implementing the search



# System Characterization was Based on Measured and Simulated Data

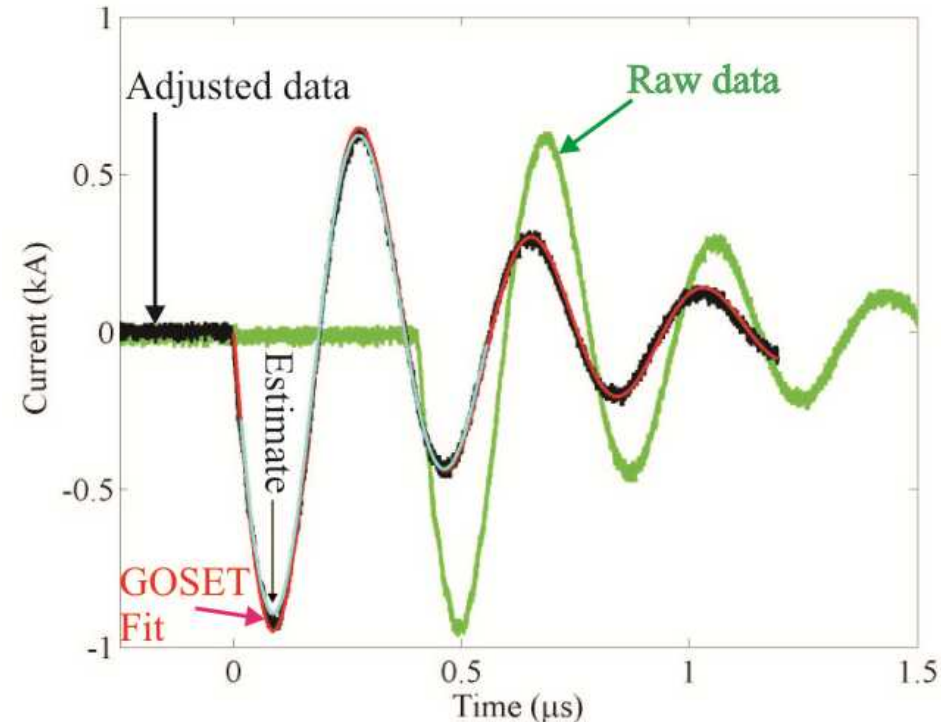
- Multiple configurations tested
- Damped sinusoidal load currents

$$i = i_0 e^{-\alpha t} \sin(\varpi_d t)$$

- Estimated parameters define search space
- Genetic optimization refines parameter estimates based on fitness function

$$fitness = \left( 1 + \sum_{t=t_1}^{t_2} (i - i_m)^2 \right)^{-1}$$

- Equation parameters converted to circuit parameters
- Least squares fit used to solve for best circuit parameters



	R (mΩ)	L (nH)	C (nF)
Brick	754	181.4	18.4
Load	84	15.5	



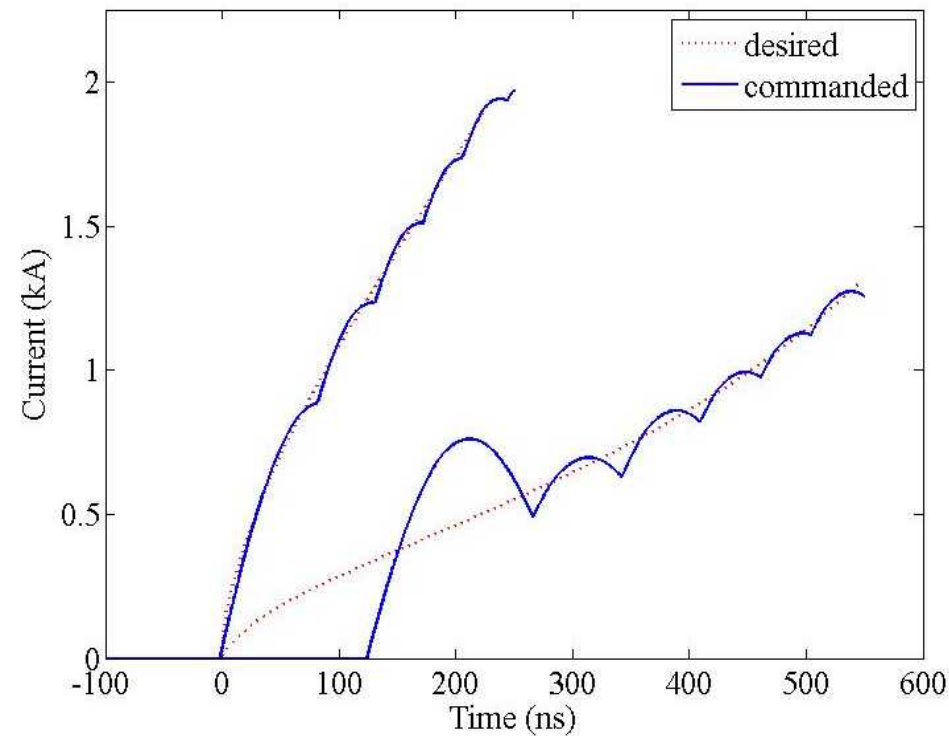
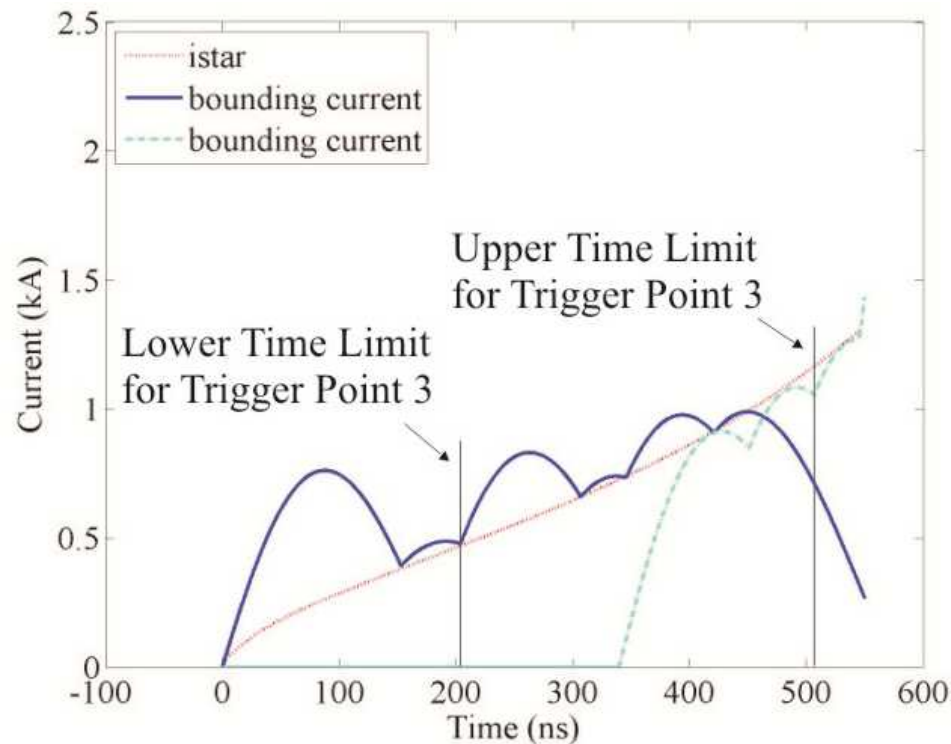
# Trigger Times and Charge Voltages Determined by Genetic Optimization

- Charge voltages are limited
  - By switch performance
    - Jitter and Self break voltage
- Trigger times are limited
  - By charge voltage and wave shape

## Fitness Function

$$fitness = \left( 1 + 10^{-3} \sum_{t=t_1}^{t_2} (i - i_m)^2 \right)^{-1}$$

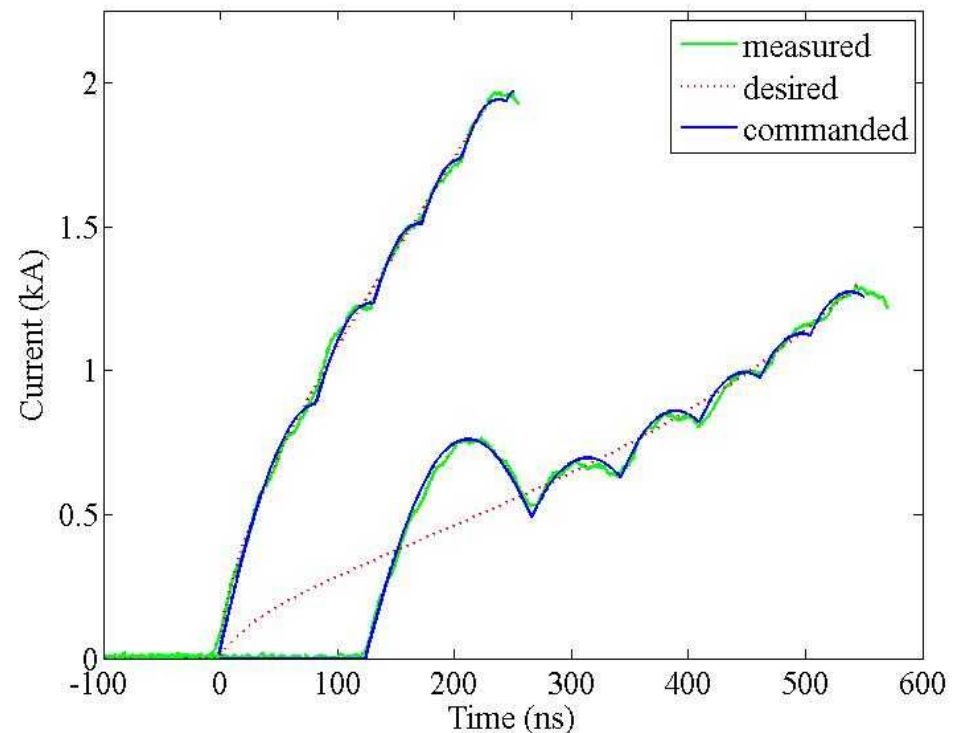
## Resulting waveforms



# Simulations Match the Measured Load Currents

- Switch performance significantly impacts measured results
- Characterizing switch delay and jitter versus voltage is critical

Brick	200ns Waveform		500ns Waveform	
	Trigger time (ns)	Charge Voltage (kV)	Trigger time (ns)	Charge Voltage (kV)
1	206	3.60	124	3.00
2	82	3.04	461	3.02
3	-2	3.50	266	3.60
4	172	3.60	409	3.12
5	131	3.54	504	3.00
6	244	3.00	342	3.26



# Conclusion:

## More Complex Pulsed Power Systems will Require new Tools

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- **Genetic optimization is powerful**
  - Large degrees of complexity
  - Discontinuous systems
- **Characterization and optimization are complex**
  - Equations and models for system characterization
  - Simulations for system optimization
- **More complex systems are in the future**
  - Flexibility increases complexity
    - Multiple trigger points
    - Independent charge voltages

