Application of MATLAB/Simulink for 1 Dimensional Multi-physics Analysis

Contents

2020. 6. 18

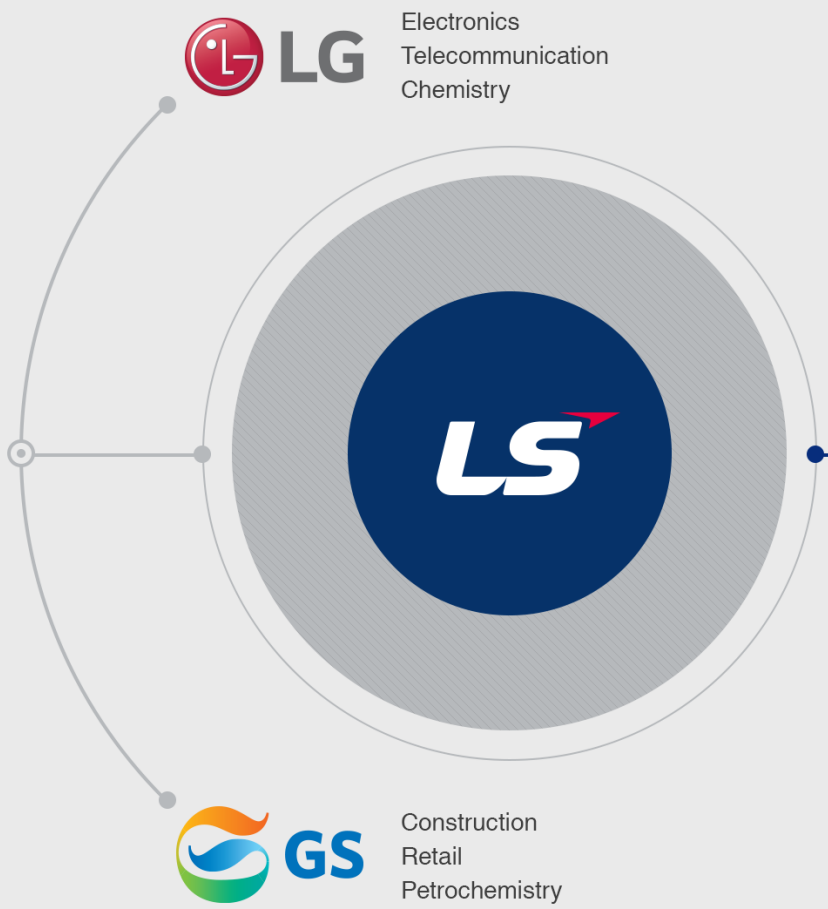
LS Electric, Electrotechnology R&D Center

HyunWoo Joo

LS ELECTRIC

FUTURING SMART ENERGY

LS Group is a conglomerate based in South Korea. It spun off from LG Group in 2003.
LS is leading in the field of electric power, automation, machinery, materials and energy.



LS Group

EMPLOYEES	12,700
AFFILIATES	48
SALES	22.9 B USD
TOTAL ASSET	22.6 B USD

LS ELECTRIC

EMPLOYEES	3,500
SALES	1.9 B USD
OPERATION INCOME	150 M USD

* Financial figures in 2019

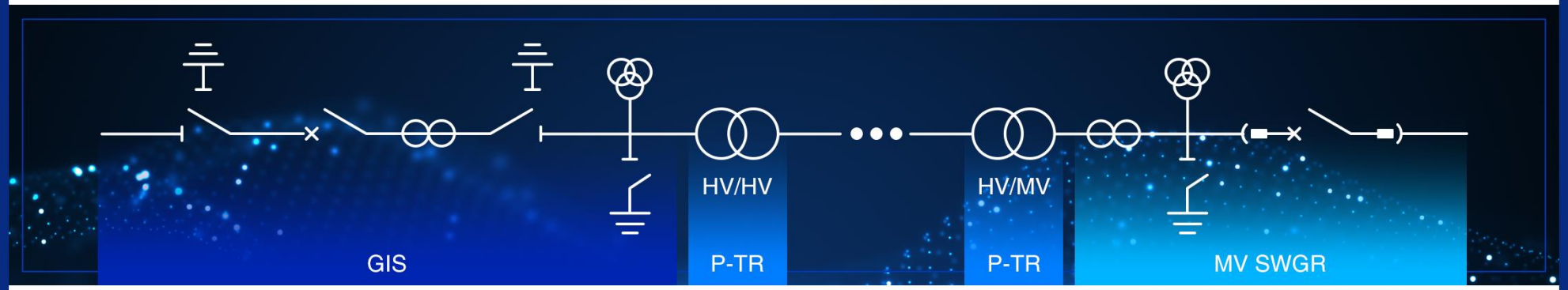
FUTURING SMART ENERGY

LS ELECTRIC

SMART ENERGY SOLUTION

Power Solution | Systems | HV S/S System

LS ELECTRIC manufacture the PDPS which constantly monitors the functions and performances of major power facilities including GIS and HV TR of HV power systems.

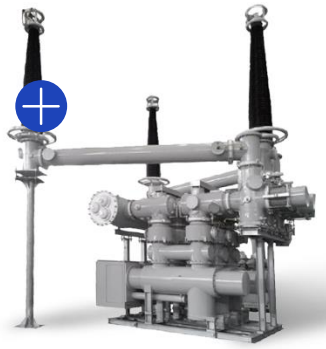


Management S/W Platform

- SCADA system (PQMS, PDPS, SAS, ECMS)
- Integrated on-line diagnosis system
- Substation Automation Sys.

Gas Insulated Switchgear

- Up to 420kV / 63kA / 6300A
- IEC 62271-200



HV Power Transformer

- Up to 550kV 800MVA
- IEC 60076, ANSI/IEEE C57
- Special purpose : Scott connection, Electric furnace, Shunt reactor, HVDC converter transformer

MV Switchgear (MCSG)

- Up to 36kV / 50kA / 5000A
- IEC 62271-200, ANSI/IEEE C37

Gas Insulated Switchgear (GIS)

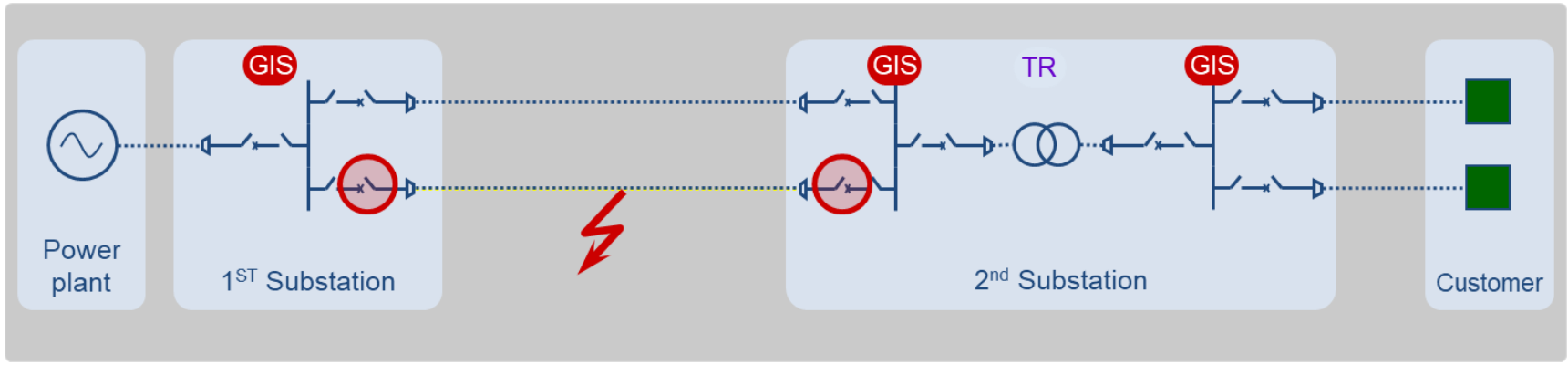
• **Gas insulated switchgear**

A compact, multicomponent device, enclosed in a grounded metallic case in which the basic insulating medium is SF_6 gas and which typically includes buses, switches, circuit breakers, and other related devices.

One of the basic functions of GIS is protection, which is interruption of short-circuit and overload fault currents while maintaining service to unaffected circuits. GIS also provides isolation of circuits from power supplies

- **Compact design**
  - Space saving compact design minimize footprint and gas amount
  - Easy handling and maintenance by Modular Design
- **High Reliability & Safety**
  - Rigorously verify the reliability of product using testing facilities in PT&T (Test Lab.)
  - Improves reliability by design verification with advanced analytical CAE Tools
- **Manufacturing System**
  - Clean system manages prevention of Particle entrapment and control quality
  - Flexible manufacturing system enables short delivery and different needs response

• **Function of GIS**



Fault ➔ Fault Detecting ➔ Opening Contact ➔ Eliminating Arc ➔ Isolation of Circuit ➔ Prevent Accidents

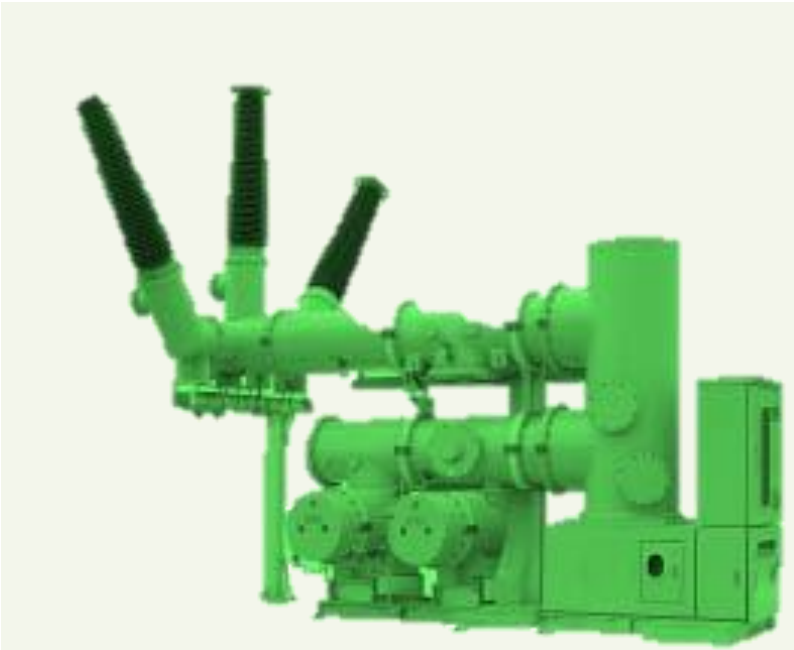
GIS Product Line-up

25.8/36kV | 72.5kV | 145kV | 170kV | 245kV | 362kV | 420kV

Rated voltage [kV]	25.8/36	72.5	145	170	245	362	420
Rated Current [A]	-3150	2000	~3150	1250~4000	~3150	4000~6300	4000
Rated Breaking Current [kA]	~40	20/31.5	40	50	40/50	50/63	50
Rated Making Current [kA]	~100	50/79	100/104	130	130	130/164	125
Power Frequency Voltage [kV]	70	140	275	325	460	520	650
LIWL [kV]	~170	325	650	750	1050	1175	1425

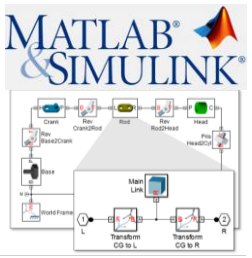
Project Overview

- SF6 Gas
- Conventional design process
- Test experience → easy to improve



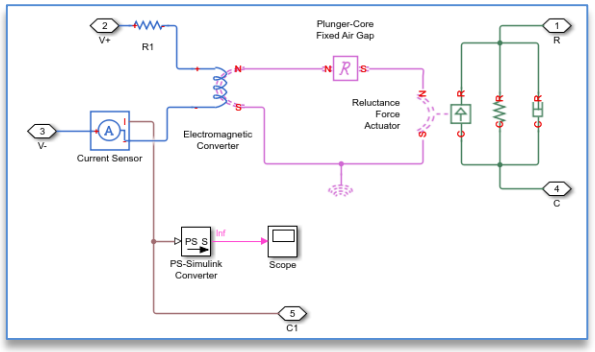
- Eco-friendly gas
- New design concept & process
- Difficult to estimate performance

- ➢ *Need for concept study in the beginning stage of design*
- ➢ *Optimal design between mechanism and chambers in GIS*
- ➢ *Reduction of trial & error and calculation time by 2D/3D analysis*

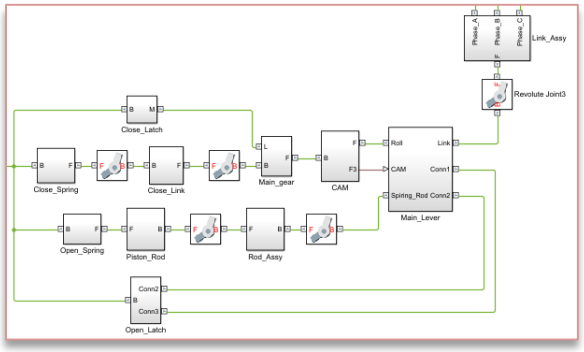


Overall 1D Analysis Model

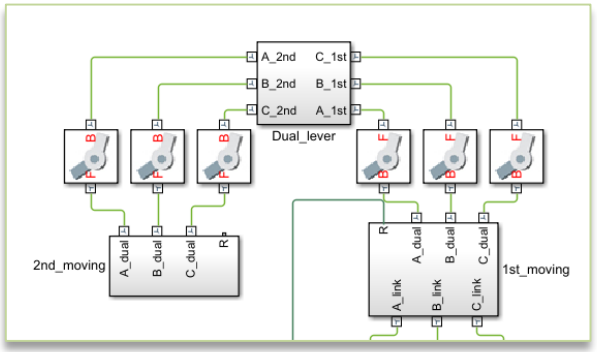
- Trip Coil
- Mechanism
- Dual Motion
- Contact Separation
- Arc Extinction



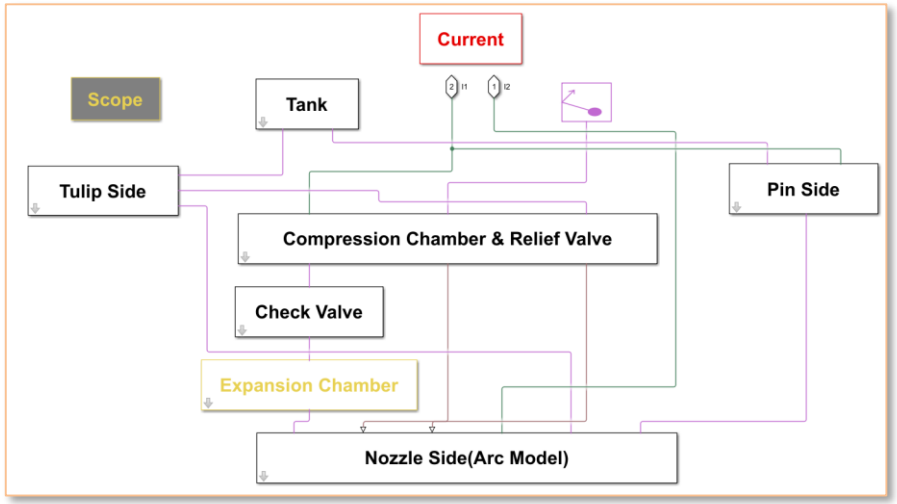
<Trip Coil>



<Mechanism & Link Assembly>



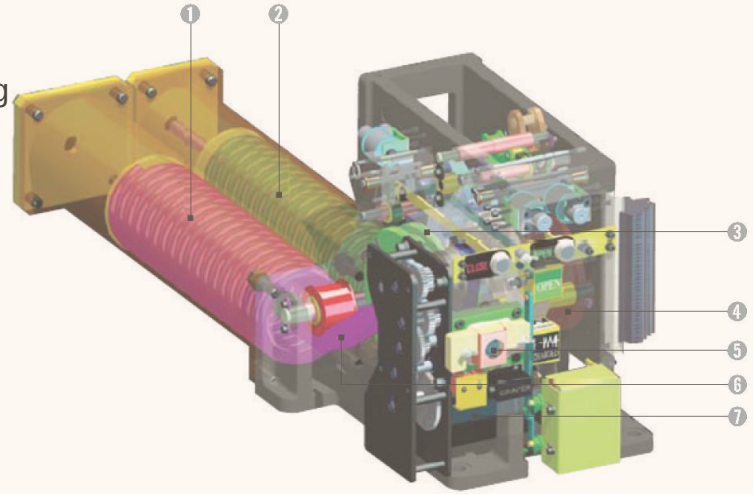
<Dual Motion>

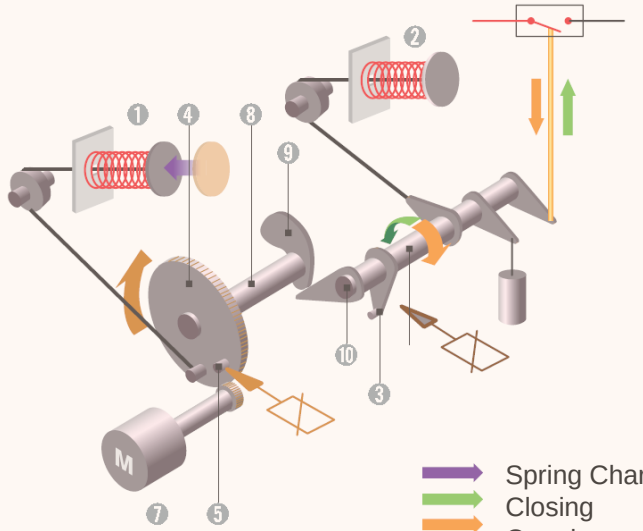


<CB Interrupter>

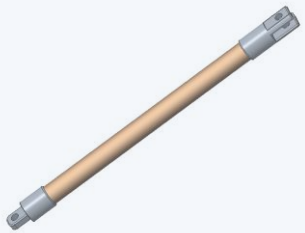
Mechanism Model

❶ Closing spring
❷ Trip spring
❸ Fly wheel
❹ Trip latch
❺ Closing latch
❻ Closing chain
❼ Motor

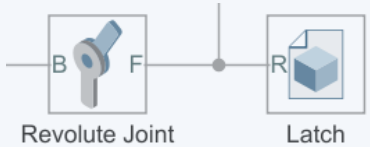


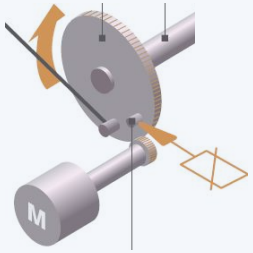


<Spring>

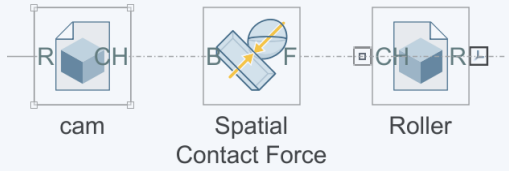


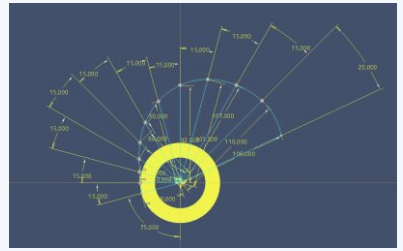
<Body>





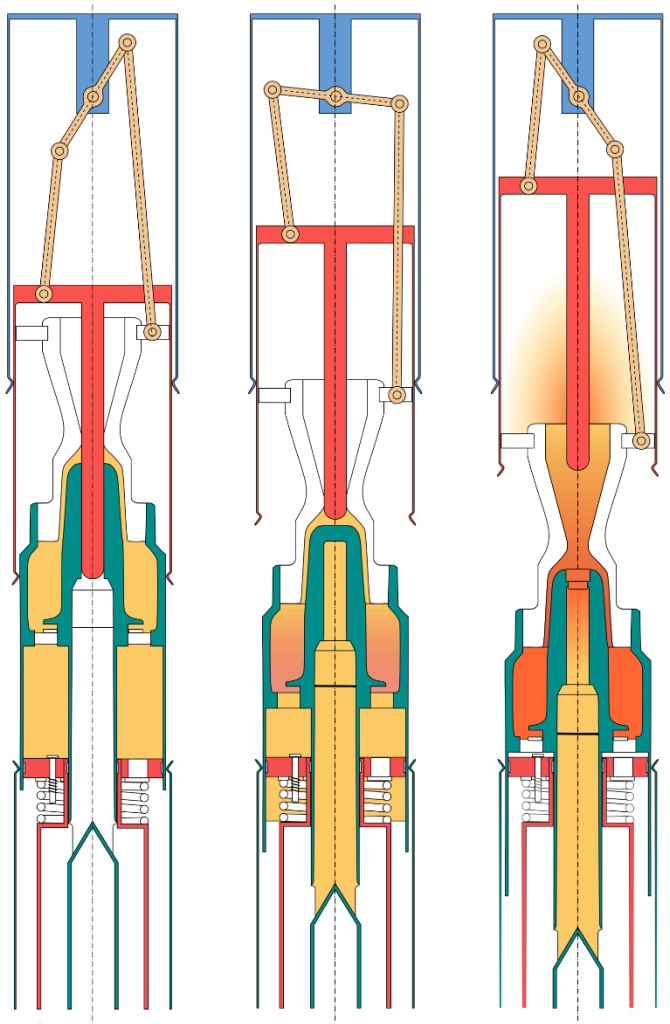
<Latch>



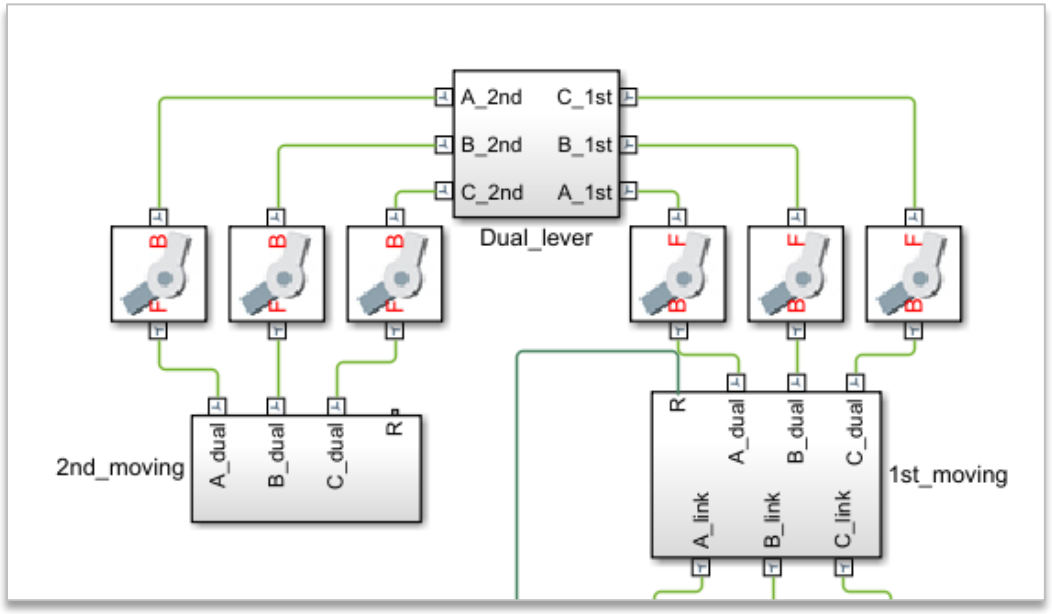


<CAM>

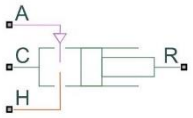
Dual Motion & Chamber Model



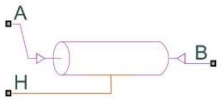
<Closed> <Opening> <Open>



<Dual Motion>



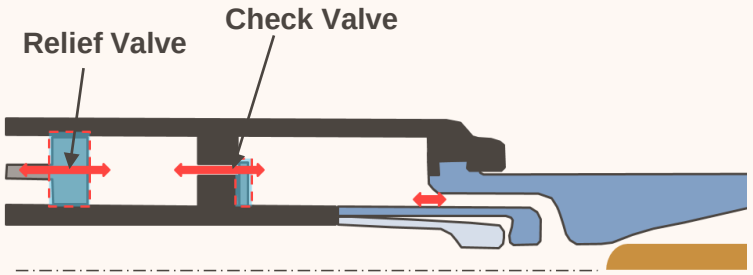
<Compression Chamber>
(Variable Volume ΔV_1)

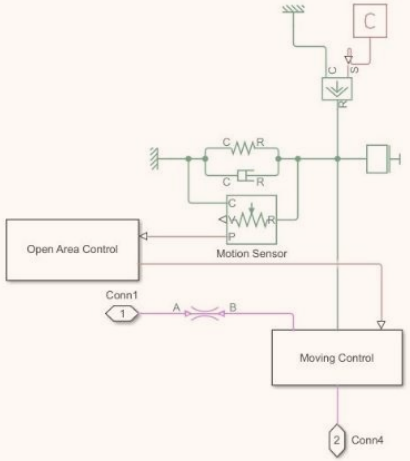


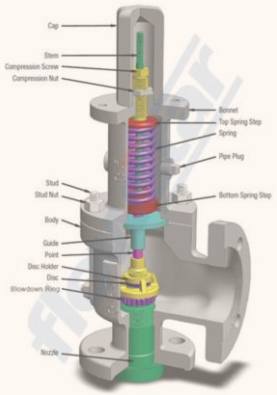
<Back flow channel>
(Fixed Volume V_2)

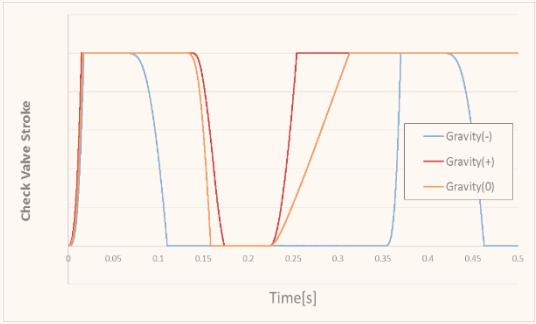
<Tank>
(Fixed Volume V_3)

Valves & ODP

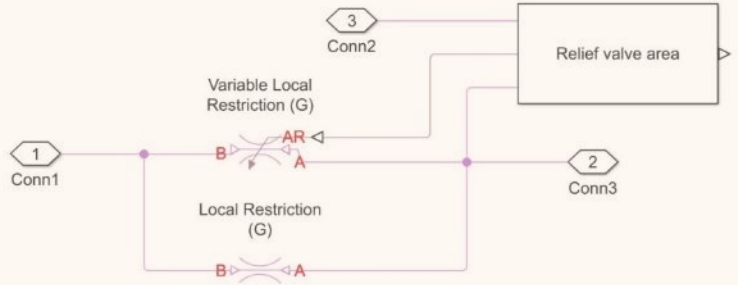


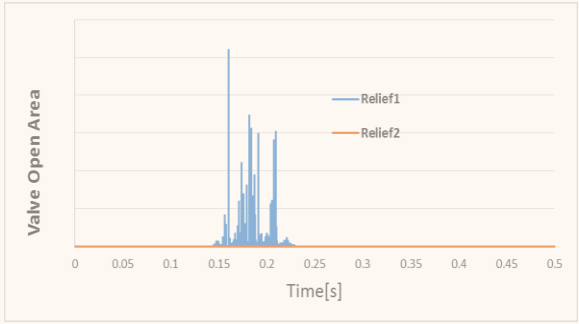




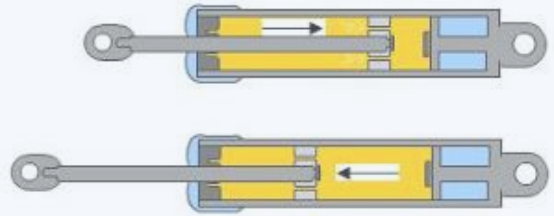


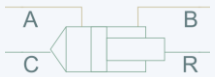
<Check Valve>





<Relief Valve>

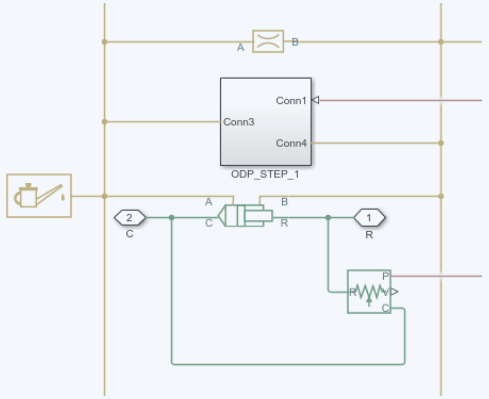




Double-Acting
Hydraulic Cylinder

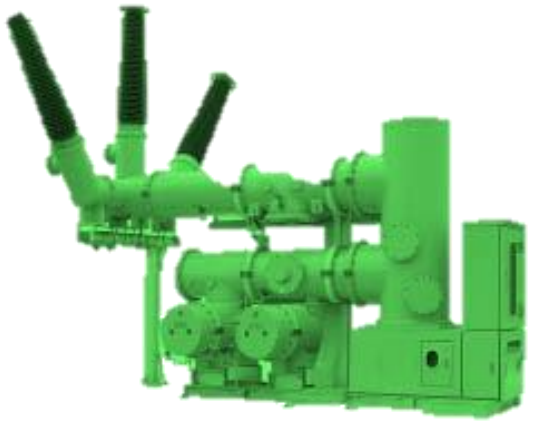
Variable Area
Hydraulic Orifice

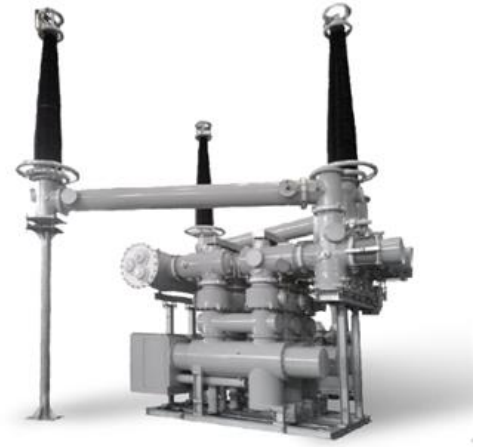
Fixed Orifice

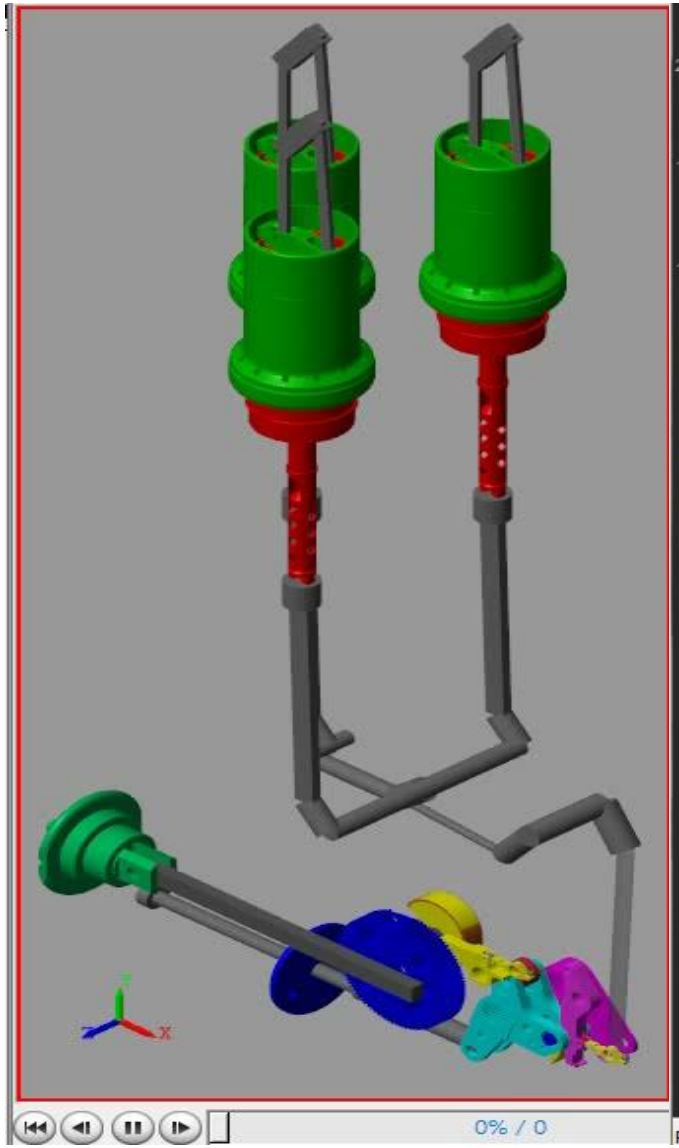


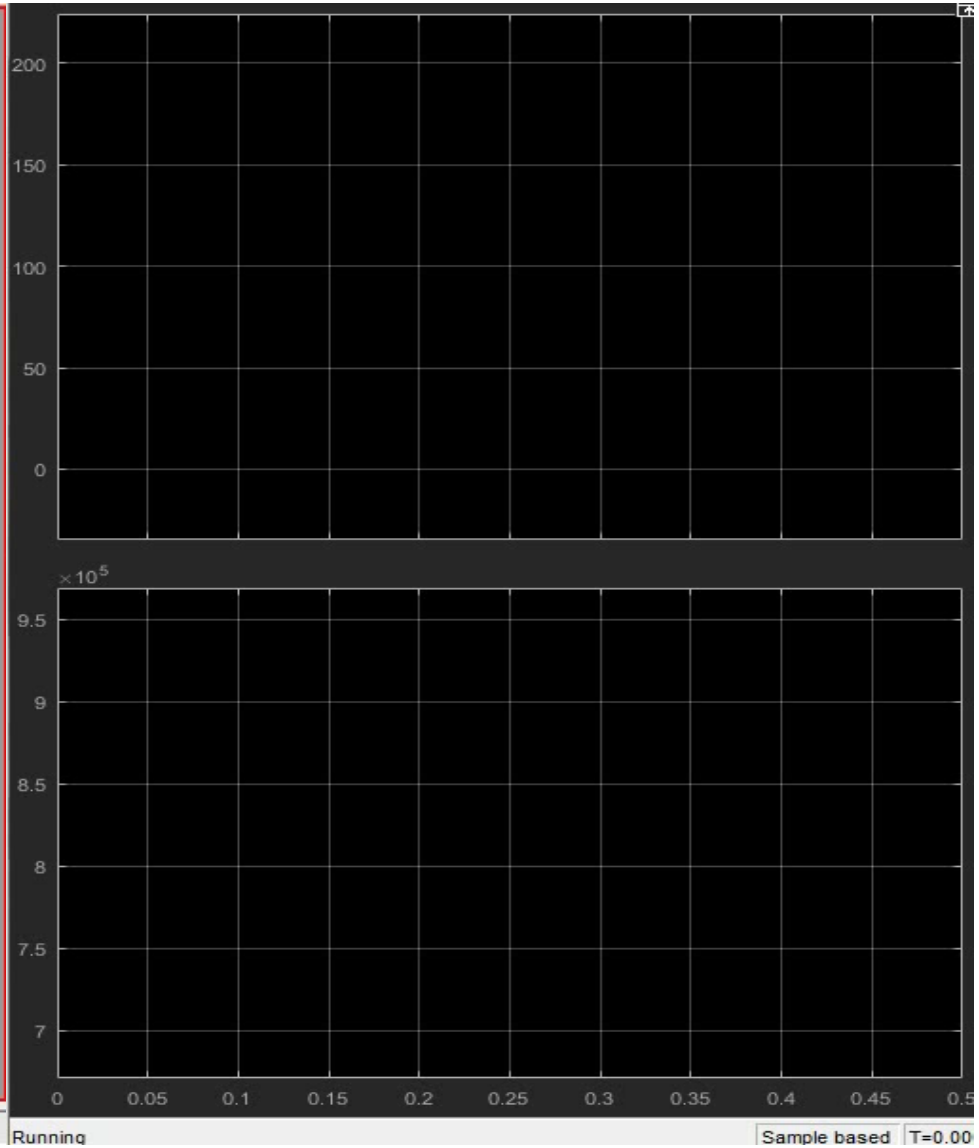
<ODP Block>

No Load Simulation (Stroke & Pressure)



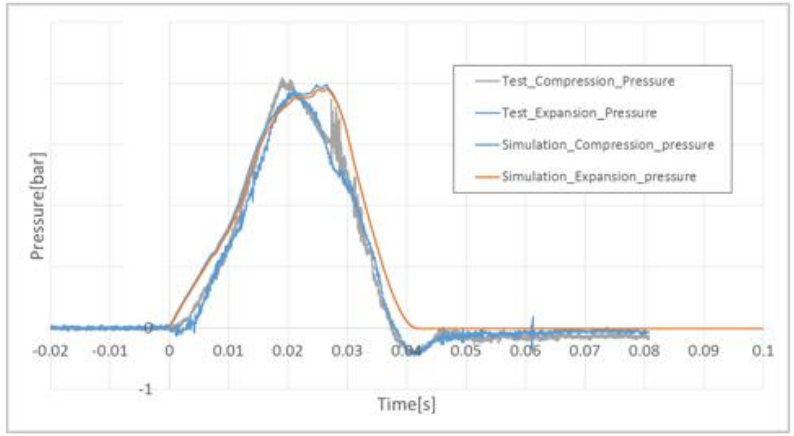




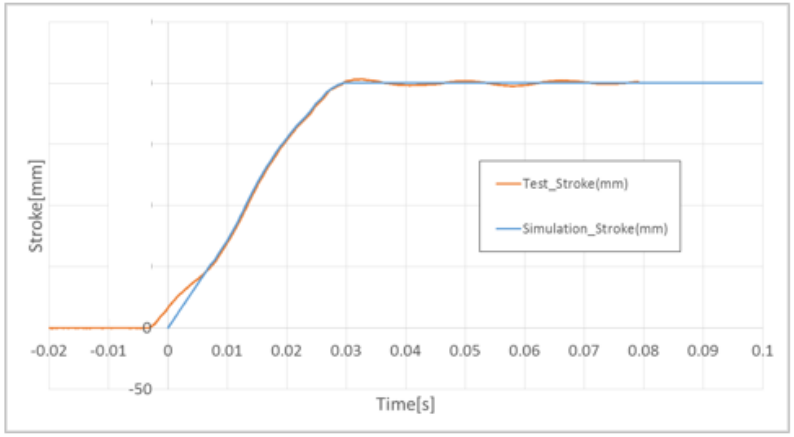


No Load Simulation Results

• Comparisons with experimental results

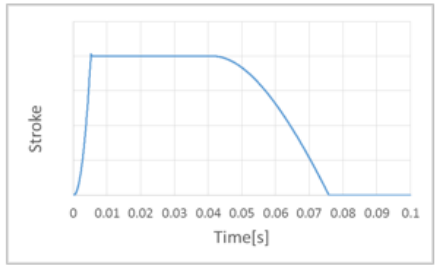


Expansion and Compression Pressure [bar]

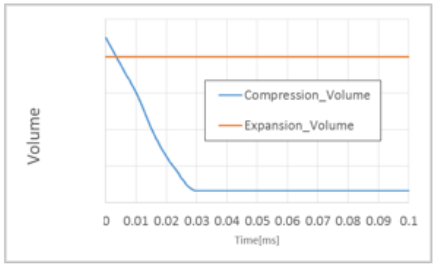


Stroke [mm]

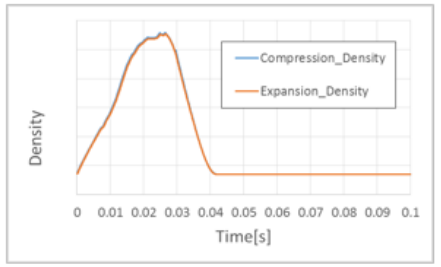
• 1D Results (Strokes, Temperature & Pressures)



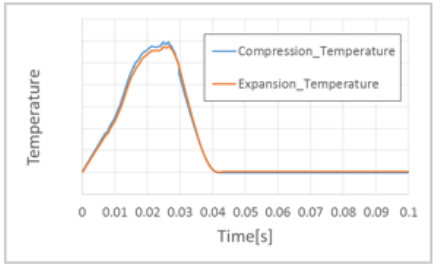
Check Valve Stroke [mm]



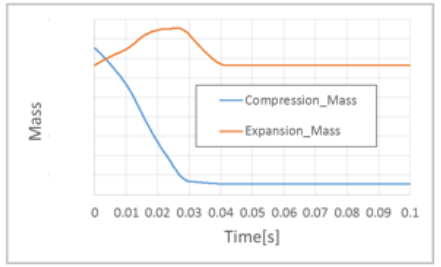
Expansion and Compression Volume[mm³]



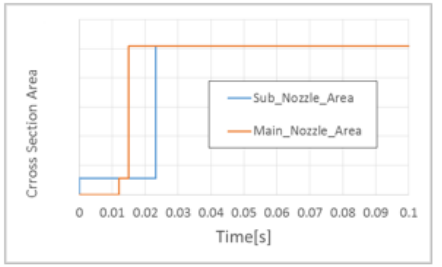
Expansion and Compression Density[kg/m³]



Expansion and Compression Temperature[K]

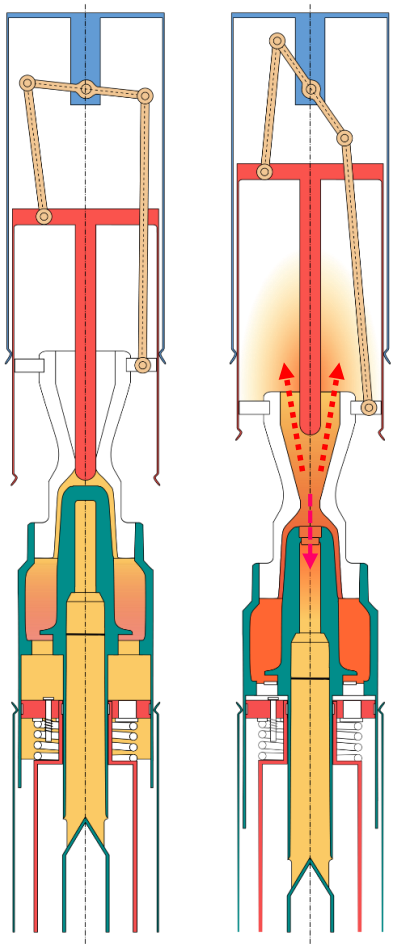


Expansion and Compression Mass[kg]

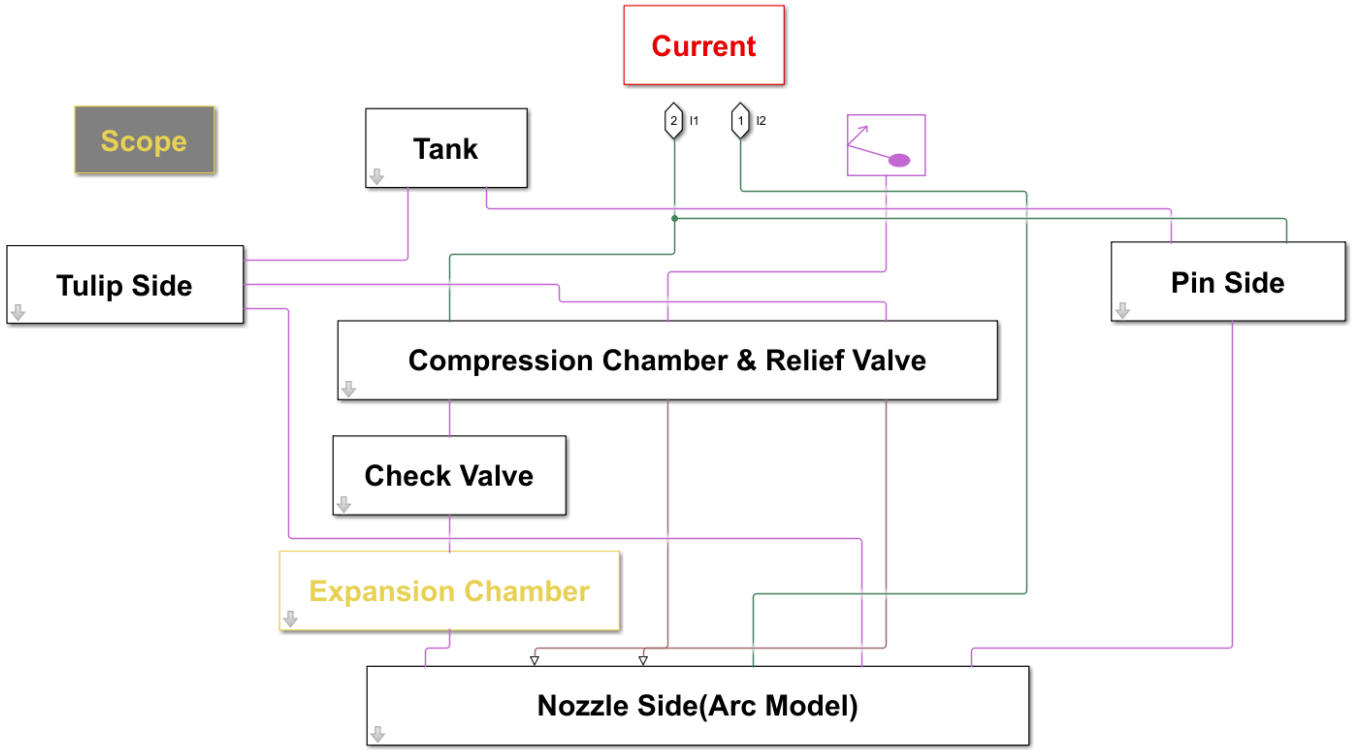


Sub and main nozzle Cross-Section Area(mm²)

Arc Extinction (Load Analysis)

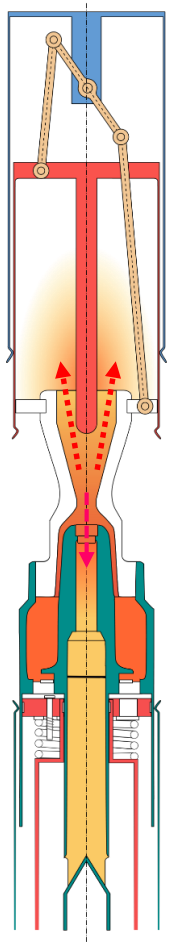


<Opening> <Arc Extinction>

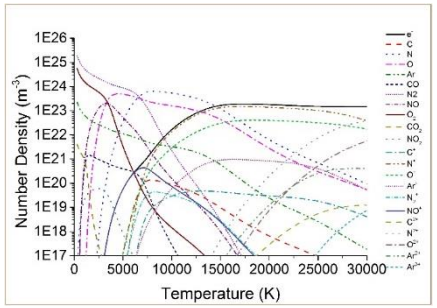


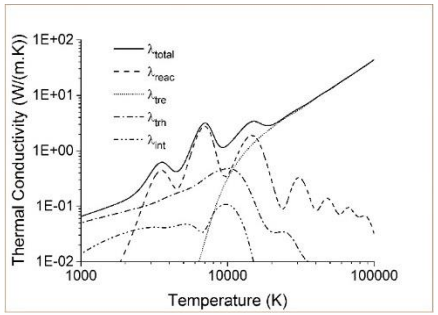
Fault Current ➔ Opening Contact ➔ Compression Chamber ➔ Expansion Chamber ➔ Arc Analysis & Gas Properties ➔ Pin & Tulip (Cooling Chamber) ➔ Tank

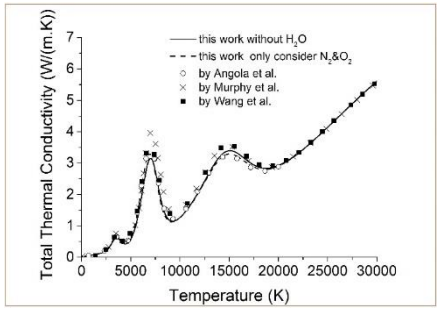
Arc Modeling



<Arc Extinction>



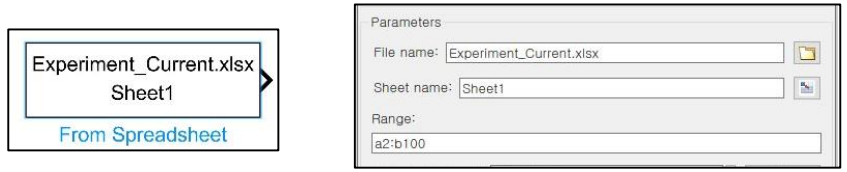




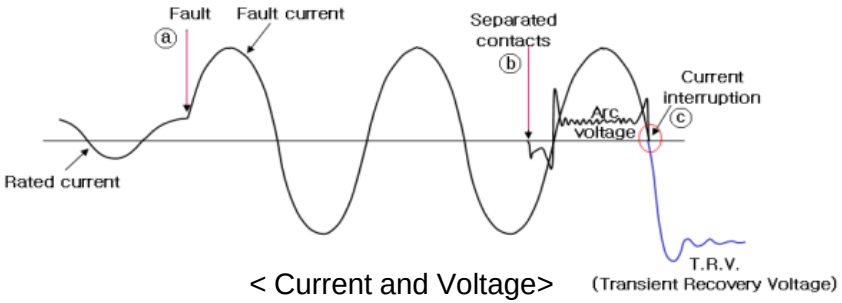
<Gas Properties>

Items	Definition
Arc Plasma	Thermodynamic quantities of Arc Plasma
Arc Model	Arc voltage and Arc Energy
Radiation Model	Amount of energy released by radiation and absorbed by nozzle material
Ablation Model	Ablated mass distribution
Arc Heating Coefficient	Amount of energy transferred to each chamber
Cooling Model	Amount of energy removed from cooling and dissociation
Electric Current Model	Electrical current for three phase

Load Simulation Results



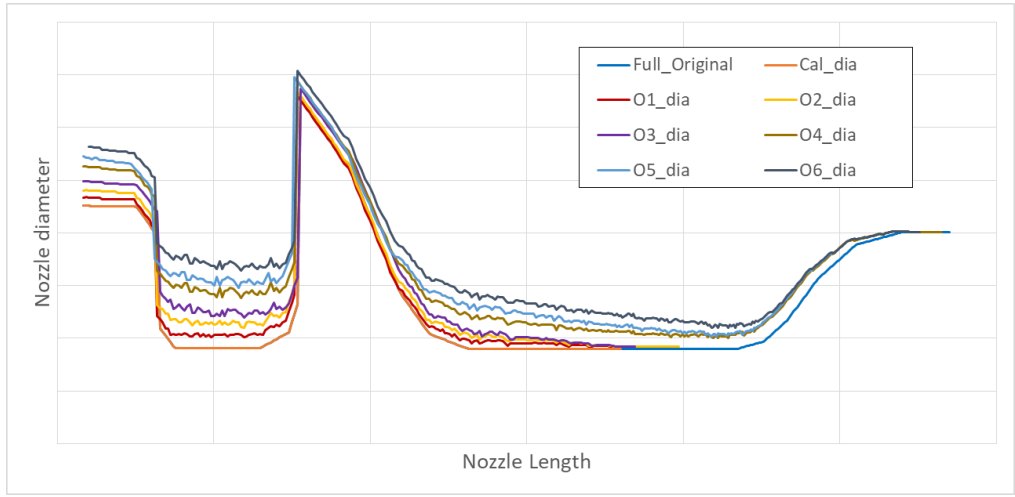
< Element Block >



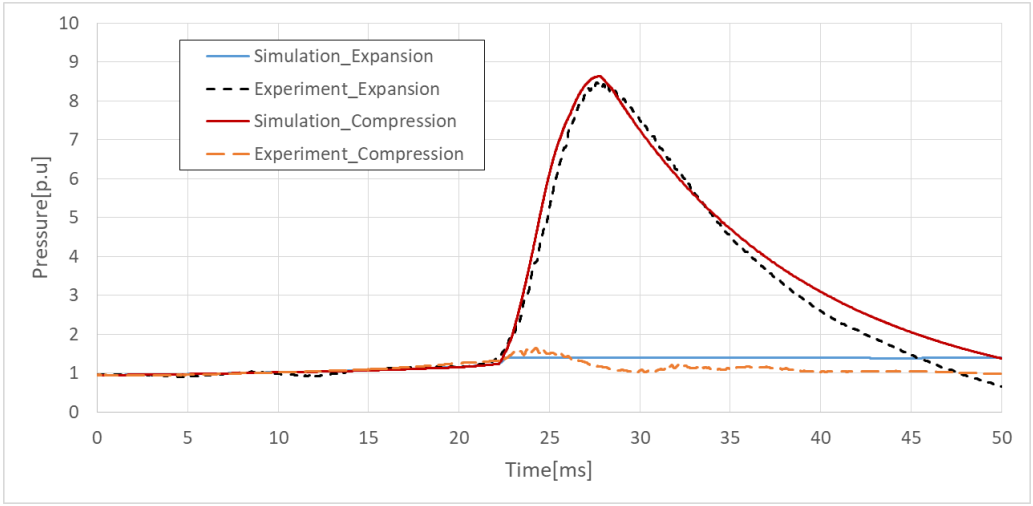
< Current and Voltage>

Sequence	Arcing Time	Current (Duty)
Cal	10ms	20%
O1	12.7ms	90%
O2	11.6ms	90%
O3	10.4ms	100%
O4	22.9ms	90%
O5	15.9ms	90%
O6	19.9ms	90%

< Test Input current>

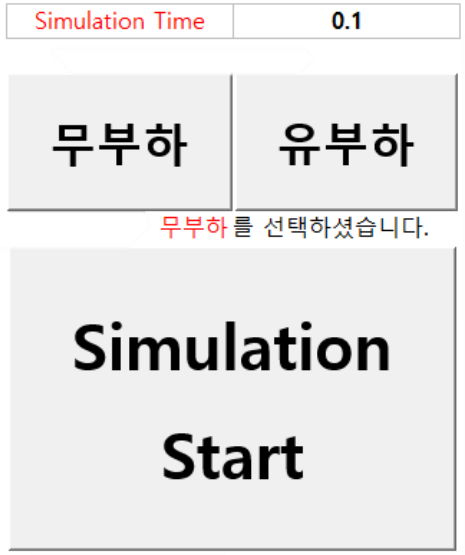


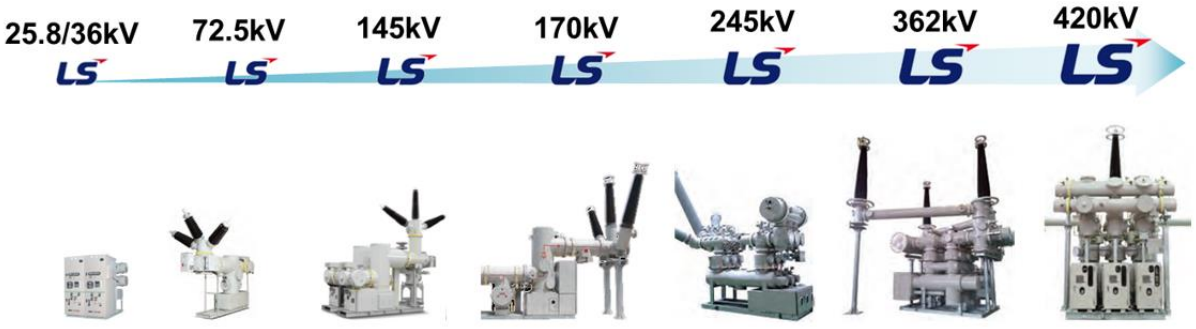
< Change of Nozzle Diameter with successive test>

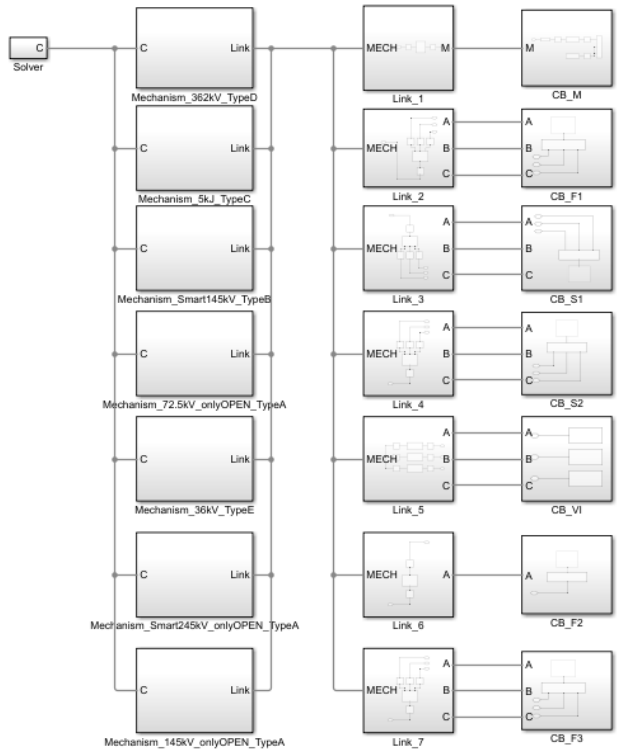


< O3 Pressure>

1D Simulation for GIS Products



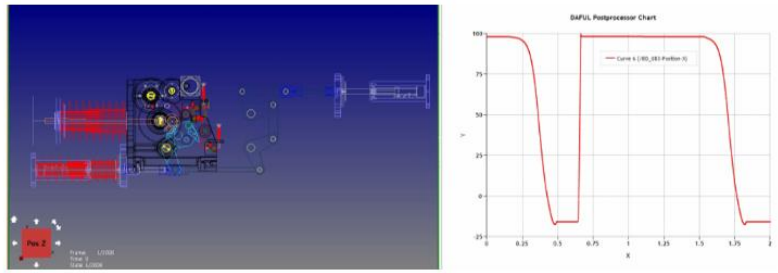




Conclusion

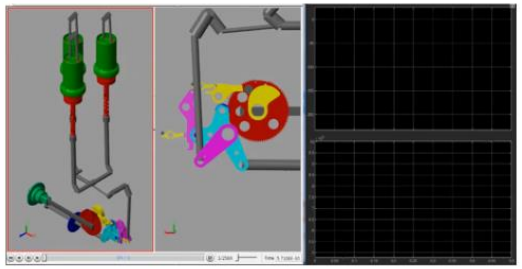
[R&D Speed-Up]

2D/3D Analysis



- Need for 3D model and Time-consuming calculation time
- Technical difficulty in coupled real-time simulation between dynamics and arc simulation

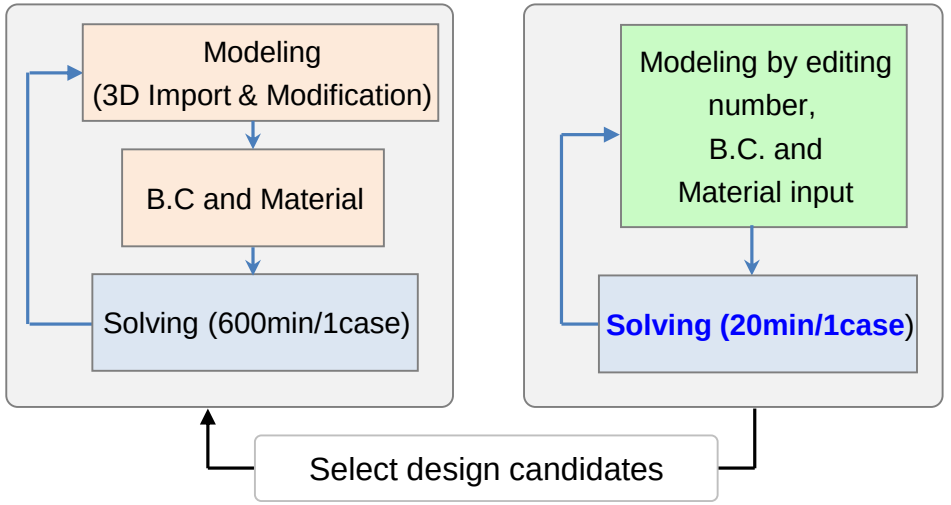
1D Analysis



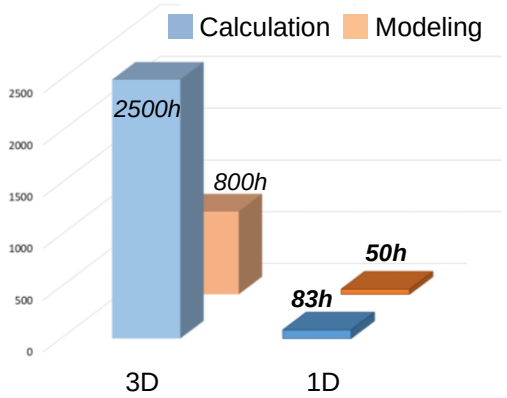
- Best solution for coupled real-time simulations

[Design parameter Optimization]

3D 1D analysis process



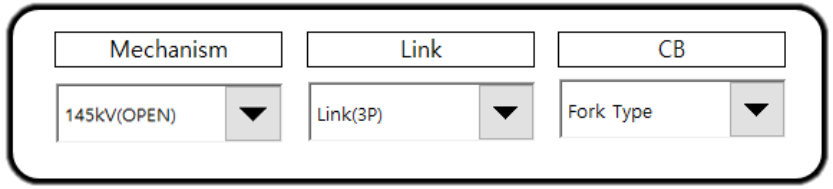
Calculation time comparison for 100 case Models

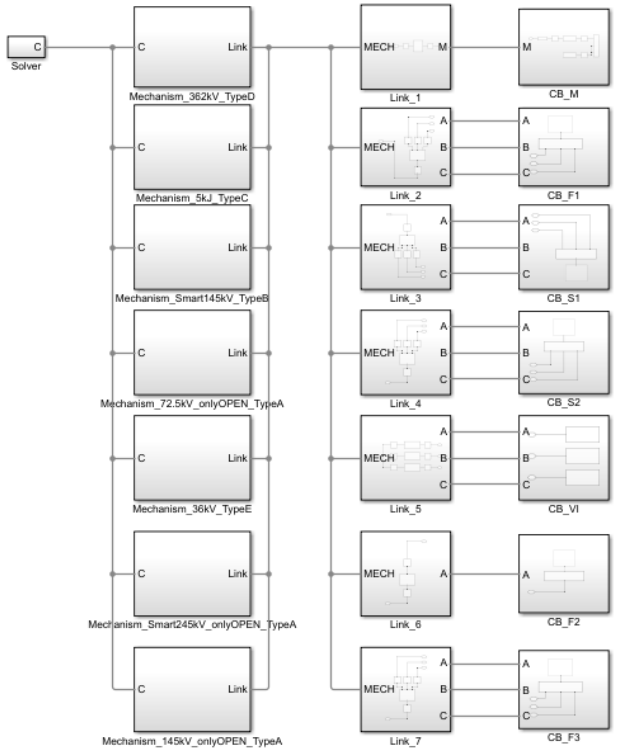


- Calculation time [H]
  : 93% reduction
- Modeling [H]
  : 94% reduction

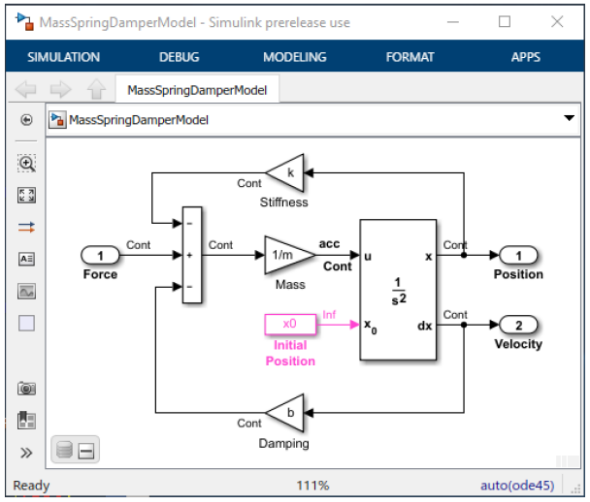
Future Plan

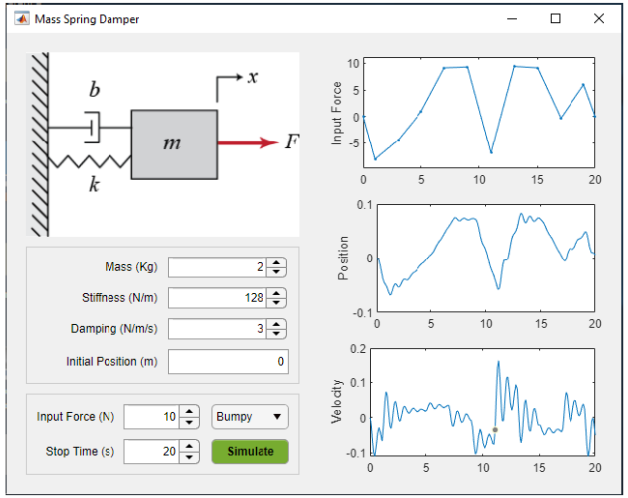
Excel based

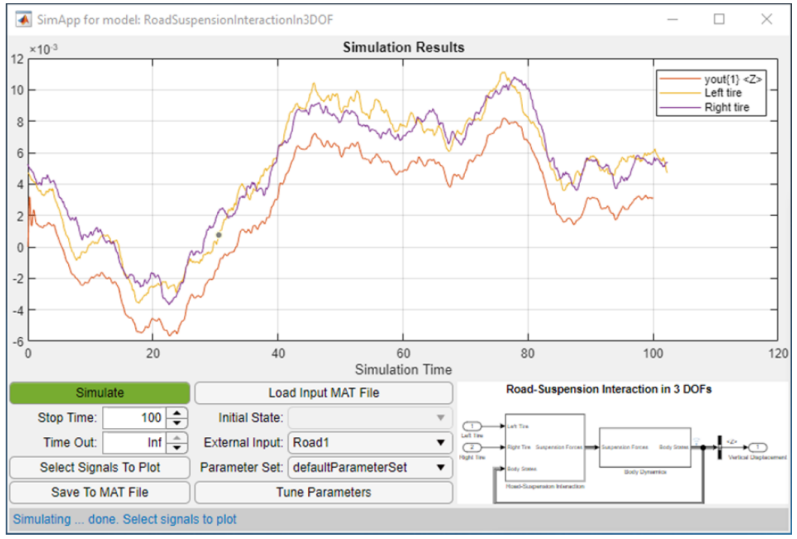




Simulink Compiler







LS ELECTRIC

Thank you for your attention

FUTURING SMART ENERGY