Introduction to The Next Generation of Distribution Analysis Tools

Summer course D3

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Universidad de los Andes
Bogotá, Colombia
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Electric Power Research Institute - EPRI

Together...Shaping the Future of Electricity

Advancing safe, reliable, affordable, and environmentally responsible electricity for society through global collaboration, thought leadership, and science and technology innovation

Areas of focus

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The instructor

Davis Montenegro, *Member, IEEE*

Davis Montenegro-Martinez serves as Engineer/Scientist III at the Electric Power Research Institute (EPRI) in the areas of power system modeling, analysis and high performance computing. He received his B.Sc. degree in electronics engineering from Universidad Santo Tomás, Bogotá, Colombia (2004); he is M.Sc. in electrical engineering from Universidad de los Andes, Bogotá , Colombia (2012). He received his Ph.D. in electrical engineering from Universidad de los Andes (2015), and a Ph.D. in electrical engineering from the University Grenoble-Alpes, France (2015).

Before joining EPRI, Davis served for 10 years as a lecturer for Universidad Santo Tomas in Colombia, during this time he was also technology consultant in the areas of industrial automation, software and electronic hardware design focused in the electric power industry, specifically in monitoring and control for meter calibration laboratories. His expertise in parallel computing techniques is being used at EPRI for incorporating multi-core processing to power system analysis methods such as QSTS, reducing the computational time required to perform these analysis using standard computing architectures.

Dr. Montenegro is also a member of the International Council on Large Electric Systems CIGRE, he was awarded with the IEEE 2016 I&CPS Ralph H. Lee Department Prize Paper Award at the 2017 I&CPS Technical Conference Awards luncheon in Niagara Falls, ON, Canada, for the paper titled "Energy Storage Modeling for Distribution Planning." He was also awarded an IEEE recognition in 2017 for notable services and contributions towards the advancement of IEEE and the engineering professions chairing of IM09 (Instrumentation and Measurements) Society Chapter, Colombian Section 2015–2017.

Application Programming Interfaces (API)

Application Programming Interfaces (API)

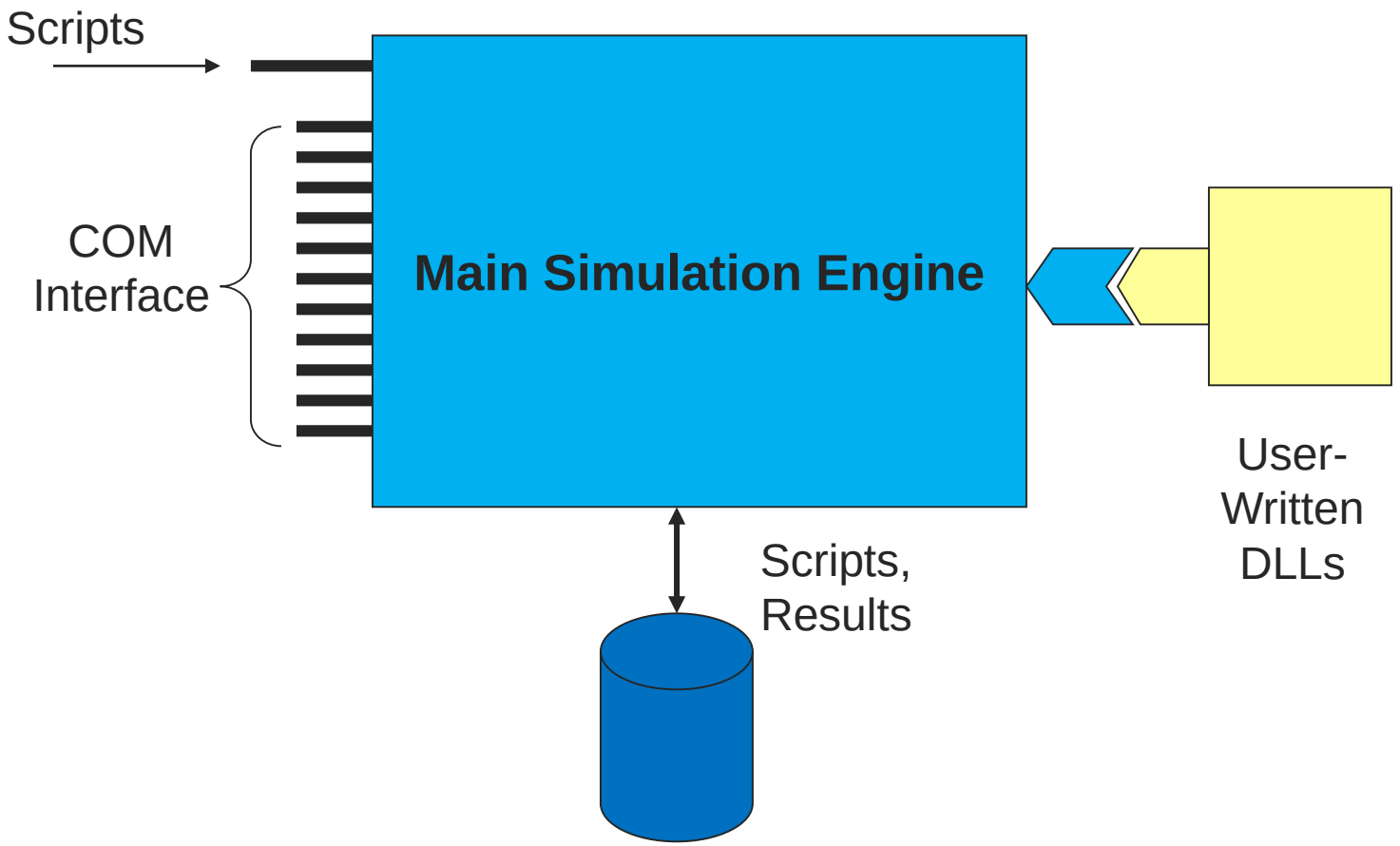
- Why You Might Want to Write Some Code …
  - There is no looping in the DSS scripting language
  - To implement an algorithm not in OpenDSS
    - For optimizing device siting …
      - Generators
      - Capacitors
      - Reclosers
    - To automate some repetitive analysis task
  - To develop a new device model or control
    - Using the COM interface
    - Writing a Dynamic-Linked Library (DLL)

Application Programming Interfaces (API)

- Why You Might Want to Write Some Code …
  - COM Interface
    - Microsoft standard: Windows only
    - Well-supported in MS Office, Python, Matlab, etc.
  - DirectDLL Interface
    - Standard function call library
  - Use a separate program to generate DSS scripting code
    - Run with standalone EXE
    - Create a file with DSS commands
    - Redirect to it

Application Programming Interfaces (API)

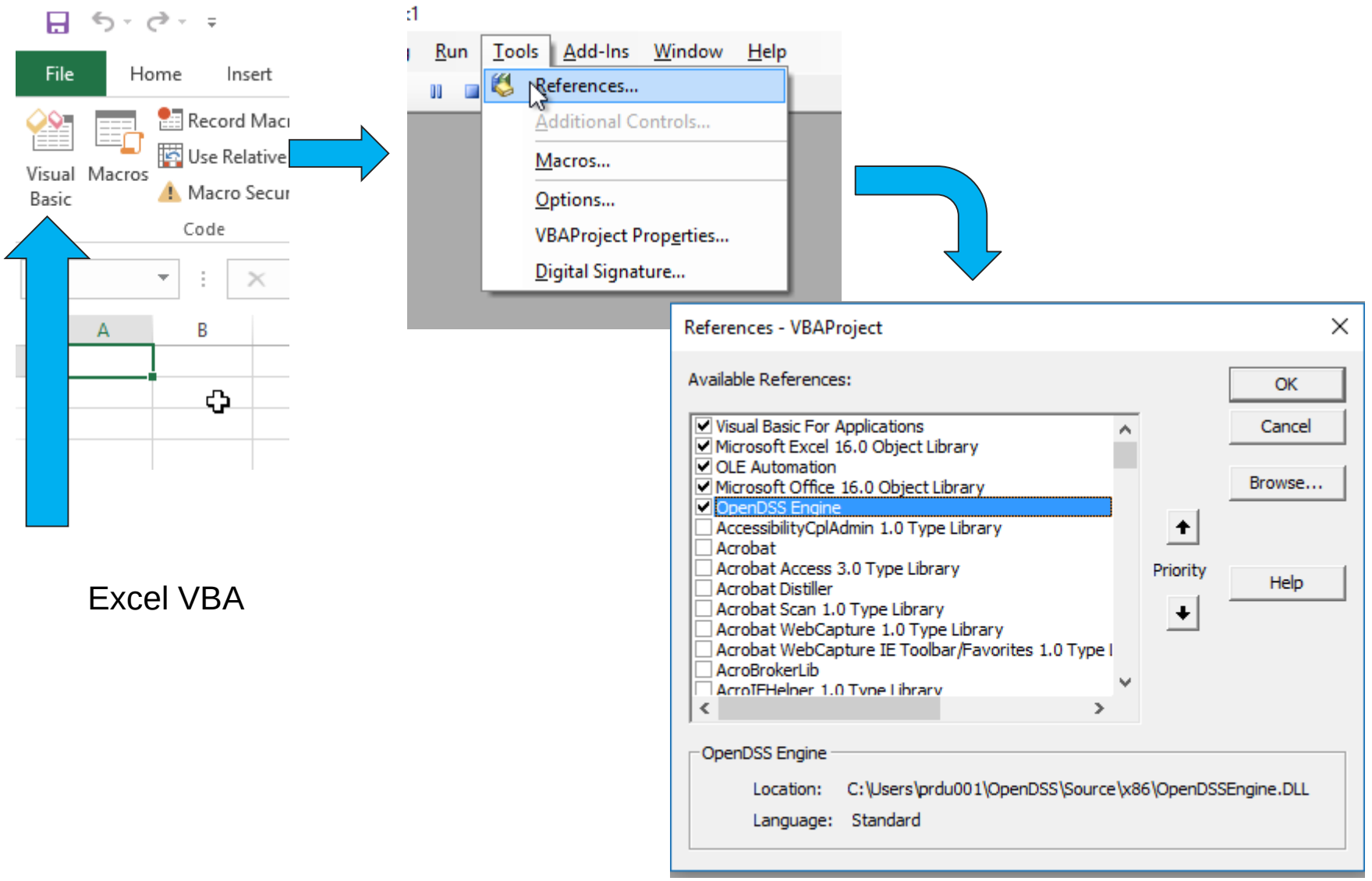
- Why You Might Want to Write Some Code …



Application Programming Interfaces (API)

- COM interface

- There are many interfaces supplied by the COM server
- There is one registered *In-Process COM* interface:
  - ***OpenDSSEngine.DSS***
    - The DSS interface is the one your program instantiates
    - The DSS interface then creates all the others.
    - This is for simplicity for users who are not necessarily familiar with COM programming



Excel VBA

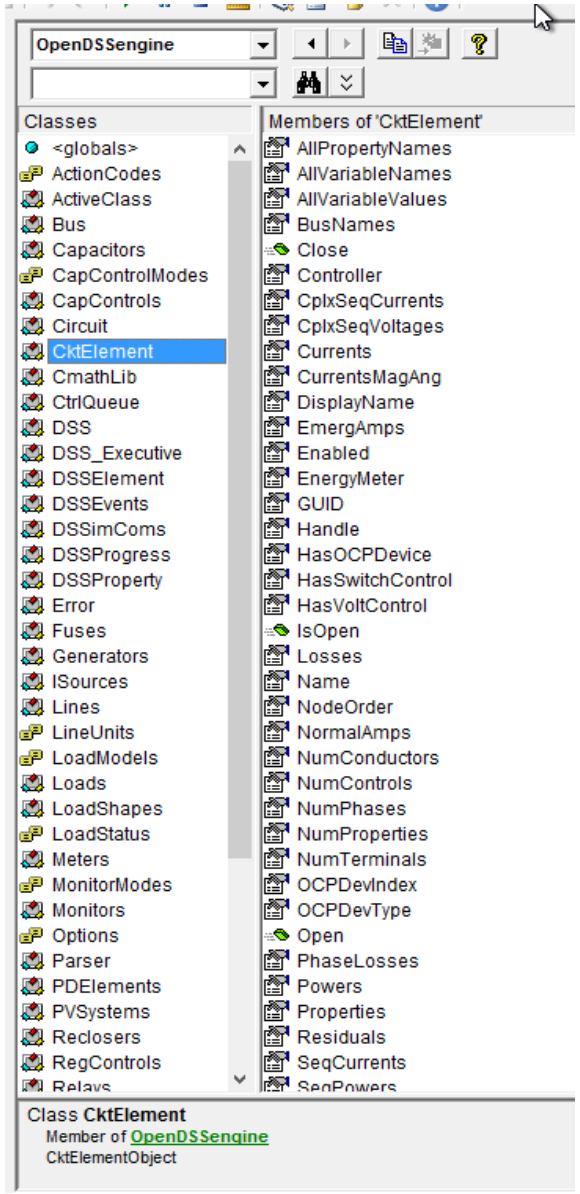
Application Programming Interfaces (API)

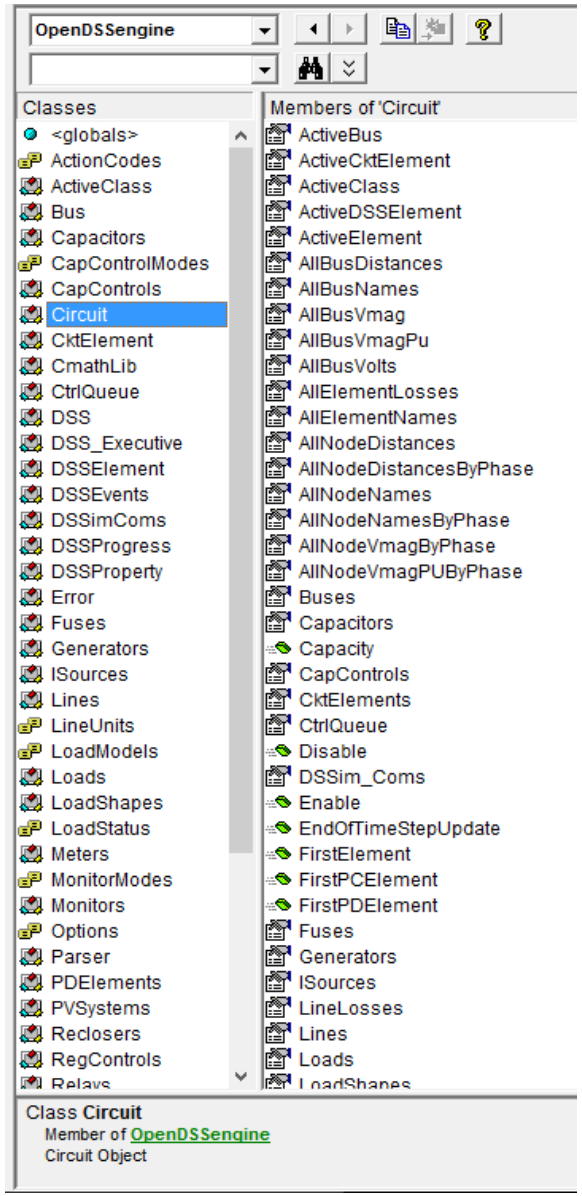
- COM interface
  - The interfaces generally act on the **ACTIVE object**
    - Active circuit,
    - Active circuit element,
    - Active bus, etc.
  - The interfaces generally point to the active object
    - To work with another object, change the active object
      - There are methods for selecting objects
      - You may also use script commands

Application Programming Interfaces (API)

- COM interface

The Object Browser in MS Office VBA is a good way to learn what is available through the OpenDSS COM Interface





Application Programming Interfaces (API)

- COM interface
  - Excel VBA
  - VB.net
  - C#
  - C/C++
  - Delphi, Free Pascal
  - MATLAB
  - Python
  - Java
  - LabView
  - R
  - Fortran (for DLLs, with DirectDLL)
  - Julia (with DirectDLL)

Application Programming Interfaces (API)

- COM interface

  Examples of accessing the COM server in various languages

  - In MATLAB:
    - `DSSobj = actxserver('OpenDSSEngine.DSS');`
  - In Excel VBA: (Early binding)
    - ```
      Public DSSobj As OpenDSSEngine.DSS
      Set DSSobj = New OpenDSSEngine.DSS
      ```
  - In Delphi
    - `{Import Type Library}`
    - `DSSObj := coDSS.Create;`
  - In PYTHON:
    - `self.engine = win32com.client.Dispatch("OpenDSSEngine.DSS")`
      ```

Application Programming Interfaces (API)

- Direct DLL interface
  - Your programming language does not support COM
    - In a non-Windows environment such as Apache server
  - Your programming language does not support early bindings in COM and you want to speed things up
    - MATLAB
    - See “COM Speed Comparison.pdf” in the Doc folder
  - If your programming language supports early binding in COM, continue to use the COM interface
    - The properties implemented in this library are the same implemented in the COM interface; Just accessed differently

Application Programming Interfaces (API)

- Direct DLL interface

BUSI	0x00a4a9f0	0x0064a9f0	124 (0x7c)	OpenDSSDirect.dll	C:\Users\prdu001\OpenDSS\Source\x64\OpenDSSDirect.dll	Exported Function
BUSS	0x00a4b220	0x0064b220	122 (0x7a)	OpenDSSDirect.dll	C:\Users\prdu001\OpenDSS\Source\x64\OpenDSSDirect.dll	Exported Function
BUSV	0x00a4b340	0x0064b340	121 (0x79)	OpenDSSDirect.dll	C:\Users\prdu001\OpenDSS\Source\x64\OpenDSSDirect.dll	Exported Function
CapacitorsF	0x00a5c160	0x0065c160	86 (0x56)	OpenDSSDirect.dll	C:\Users\prdu001\OpenDSS\Source\x64\OpenDSSDirect.dll	Exported Function
CapacitorsI	0x00a5bd40	0x0065bd40	87 (0x57)	OpenDSSDirect.dll	C:\Users\prdu001\OpenDSS\Source\x64\OpenDSSDirect.dll	Exported Function
CapacitorsS	0x00a5c330	0x0065c330	85 (0x55)	OpenDSSDirect.dll	C:\Users\prdu001\OpenDSS\Source\x64\OpenDSSDirect.dll	Exported Function
CapacitorsV	0x00a5c5e0	0x0065c5e0	84 (0x54)	OpenDSSDirect.dll	C:\Users\prdu001\OpenDSS\Source\x64\OpenDSSDirect.dll	Exported Function
CapControlsF	0x00a5f270	0x0065f270	74 (0x4a)	OpenDSSDirect.dll	C:\Users\prdu001\OpenDSS\Source\x64\OpenDSSDirect.dll	Exported Function
CapControlsI	0x00a5ee40	0x0065ee40	75 (0x4b)	OpenDSSDirect.dll	C:\Users\prdu001\OpenDSS\Source\x64\OpenDSSDirect.dll	Exported Function
CapControlsS	0x00a5f920	0x0065f920	73 (0x49)	OpenDSSDirect.dll	C:\Users\prdu001\OpenDSS\Source\x64\OpenDSSDirect.dll	Exported Function
CapControlsV	0x00a5fdc0	0x0065fdc0	72 (0x48)	OpenDSSDirect.dll	C:\Users\prdu001\OpenDSS\Source\x64\OpenDSSDirect.dll	Exported Function
CircuitF	0x00a47390	0x00647390	127 (0x7f)	OpenDSSDirect.dll	C:\Users\prdu001\OpenDSS\Source\x64\OpenDSSDirect.dll	Exported Function
CircuitI	0x00a46e30	0x00646e30	128 (0x80)	OpenDSSDirect.dll	C:\Users\prdu001\OpenDSS\Source\x64\OpenDSSDirect.dll	Exported Function
CircuitS	0x00a47440	0x00647440	126 (0x7e)	OpenDSSDirect.dll	C:\Users\prdu001\OpenDSS\Source\x64\OpenDSSDirect.dll	Exported Function
CircuitV	0x00a47ab0	0x00647ab0	125 (0x7d)	OpenDSSDirect.dll	C:\Users\prdu001\OpenDSS\Source\x64\OpenDSSDirect.dll	Exported Function
CktElementF	0x00a428a0	0x006428a0	133 (0x85)	OpenDSSDirect.dll	C:\Users\prdu001\OpenDSS\Source\x64\OpenDSSDirect.dll	Exported Function
CktElementI	0x00a42320	0x00642320	134 (0x86)	OpenDSSDirect.dll	C:\Users\prdu001\OpenDSS\Source\x64\OpenDSSDirect.dll	Exported Function
CktElementS	0x00a42b20	0x00642b20	132 (0x84)	OpenDSSDirect.dll	C:\Users\prdu001\OpenDSS\Source\x64\OpenDSSDirect.dll	Exported Function
CktElementV	0x00a430e0	0x006430e0	131 (0x83)	OpenDSSDirect.dll	C:\Users\prdu001\OpenDSS\Source\x64\OpenDSSDirect.dll	Exported Function
….						

https://sourceforge.net/p/electricdss/code/HEAD/tree/trunk/Version8/Distrib/Doc/OpenDSS_Direct_DLL.pdf

Dynamics simulation

Dynamics simulation

- Dynamics simulation mode
  - Dynamics mode is used for
    - Fault current calculations including Generator contributions
      - Single time-step solution
    - Machine transients
    - Inverter transients
  - Typical time step: 0.2 – 1 ms
    - Depends on time constants in model
  - A converged power flow is required to initialize the model.

Dynamics simulation

- Dynamics simulation mode – basic algorithm

```
Increment_time;

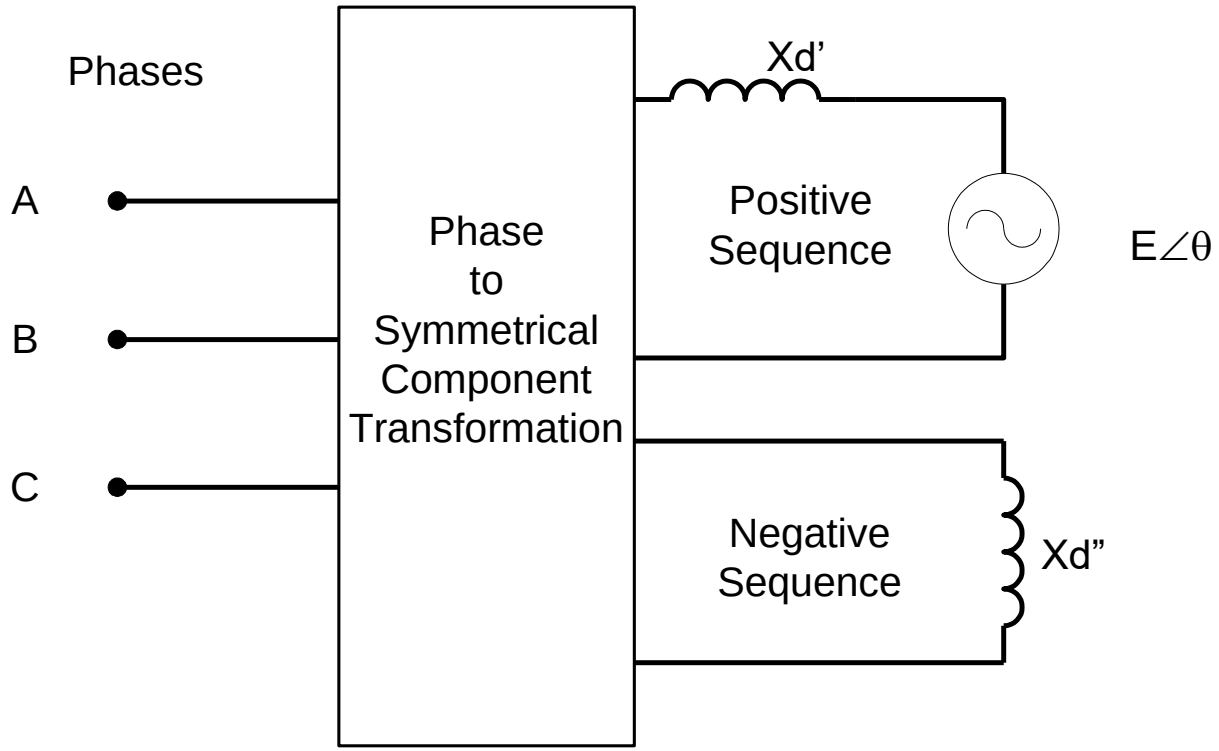
        {Predictor}
            IterationFlag := 0;
            IntegratePCStates;
            SolveSnap;

        {Corrector}
            IterationFlag := 1;
            IntegratePCStates;
            SolveSnap;
```

Dynamics simulation

- Dynamics simulation mode – use
  - Initialize state variables in all PC Elements
    - For example, in a Generator object currently:
      - Compute voltage, E_1, behind *Xd' and* Initialize the phase angle, θ, to match power flow (approximately)
  - Set derivatives of the state variables to zero
    - For the Generator: Speed (relative to synch frequency), Angle
  - Set controlmode=time
    - When running in time steps of a few seconds or less, controls that depend on the control queue for instructions on delayed actions will be automatically sequenced when the solution time reaches the designated time for an action to occur.

3-Phase Generator Model in Dynamics Mode



Differential Equations for Default Generator (1-Mass)

Derivative Calculation:

$$\frac{dv}{dt} = \frac{Pshaft - Pterm - Dv}{M}$$

$$\frac{d\theta}{dt} = v$$

Integration

Trapezoidal integration formula for θ, for example:

$$\theta_{n+1} = \theta_n + \frac{\Delta t}{2}\left[\left.\frac{d\theta}{dt}\right|_n + \left.\frac{d\theta}{dt}\right|_{n+1}\right]$$

Dynamics simulation

- Dynamics simulation mode – use

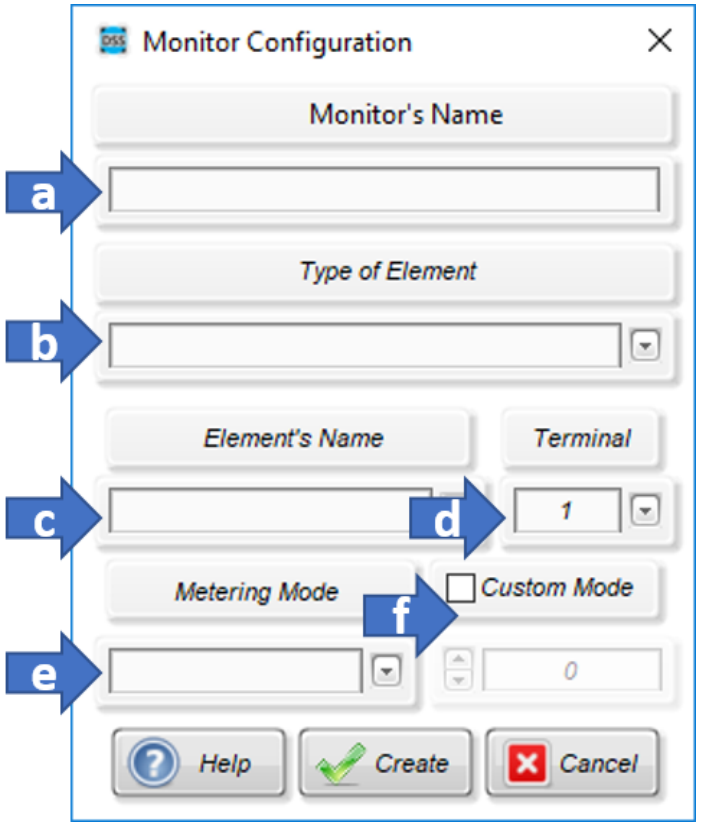
Let’s run an example

Visualizing data

Monitors and meters in OpenDSS-G

Monitors and meters in OpenDSS-G

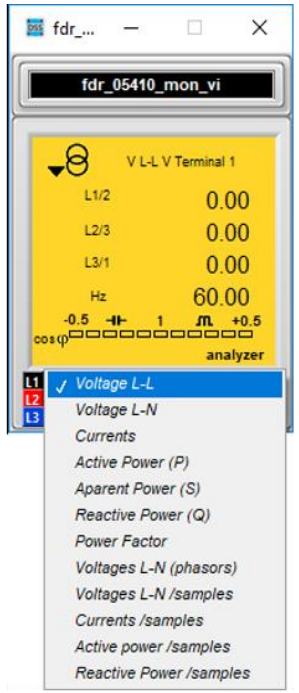
- Monitors



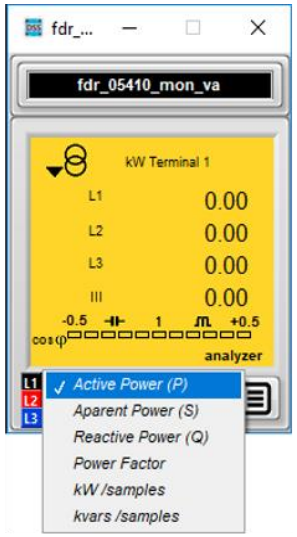
Monitors and meters in OpenDSS-G

- Monitors

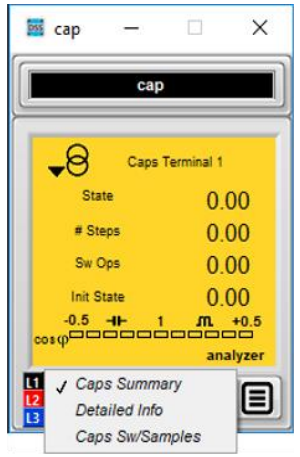
(a)



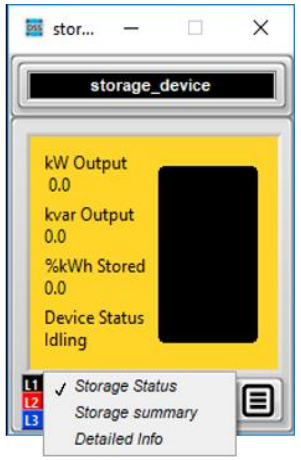
(b)



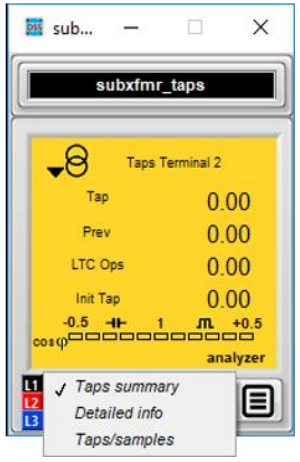
(c)



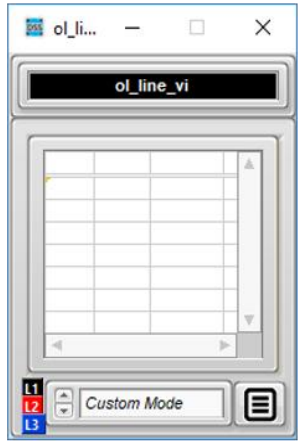
(d)



(e)

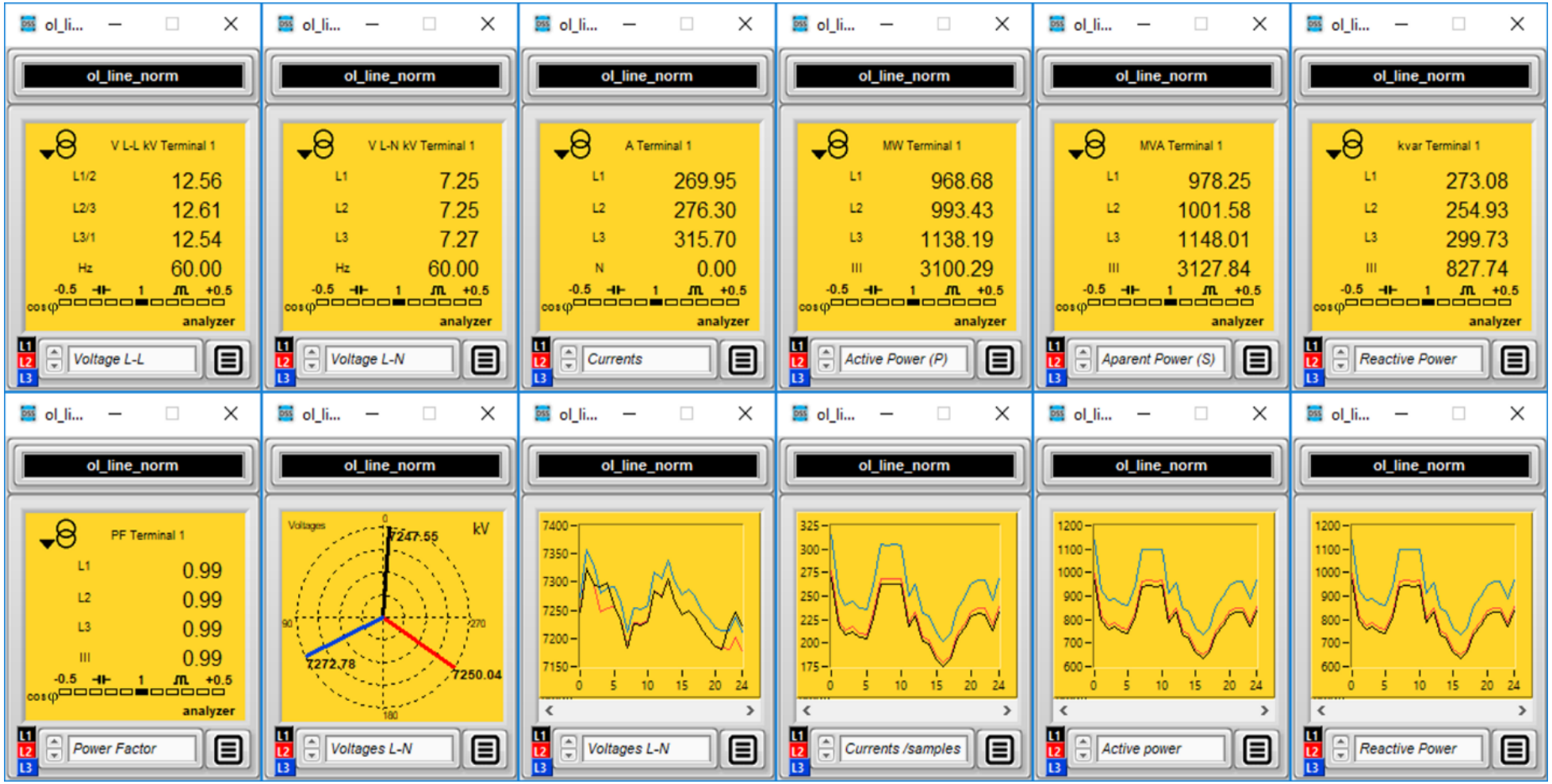


(f)



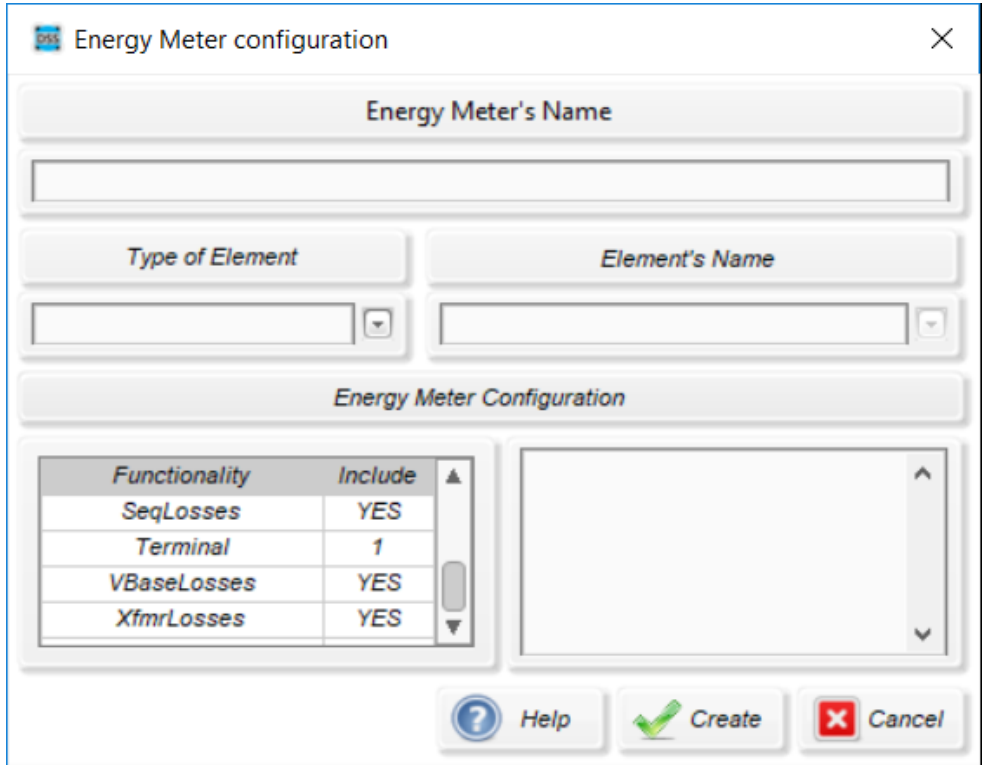
Monitors and meters in OpenDSS-G

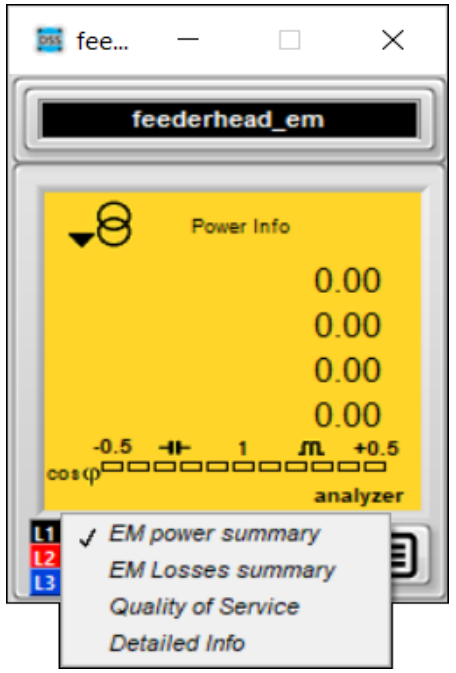
- Monitors

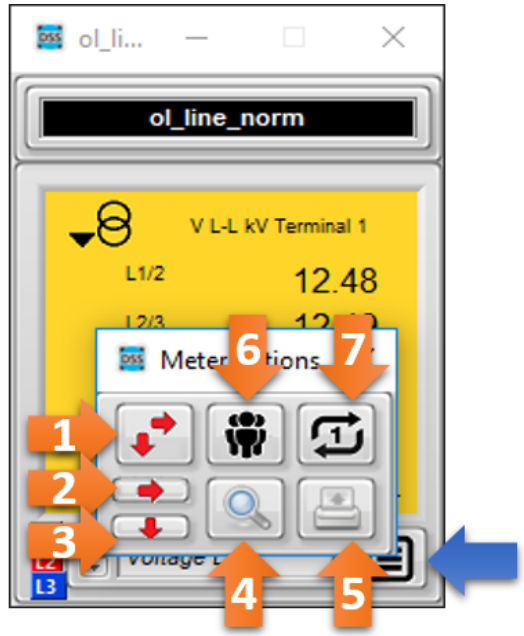


Monitors and meters in OpenDSS-G

- Energy meters

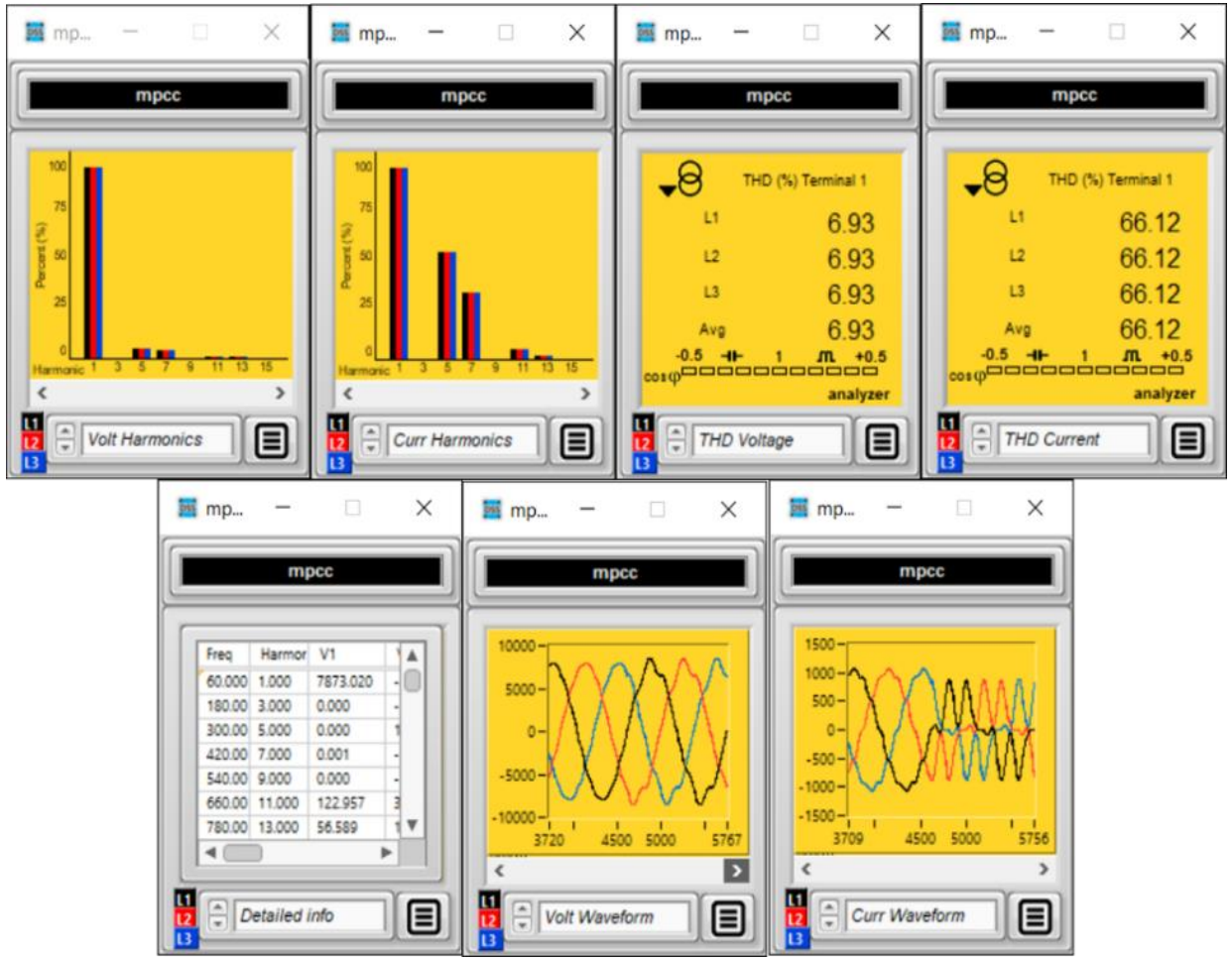






Monitors and meters in OpenDSS-G

- Special mode (Harmonics)



Monitors and meters in OpenDSS-G

Let’s run an example

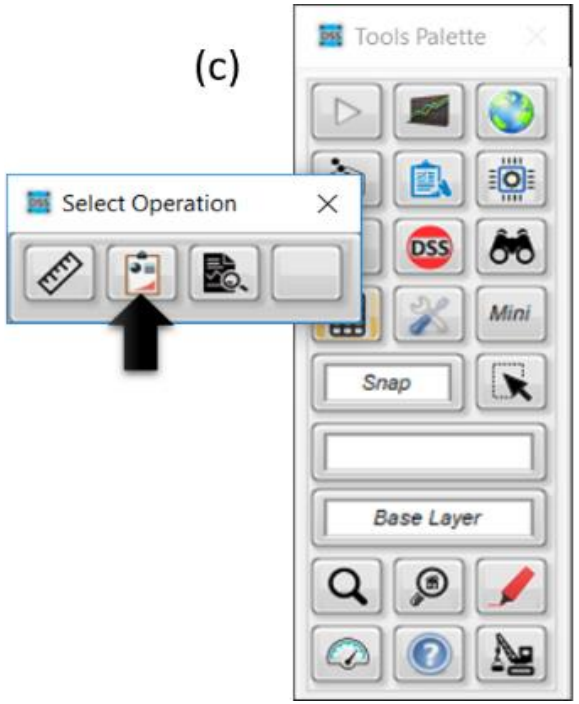
Model statistics

- Getting information about the model

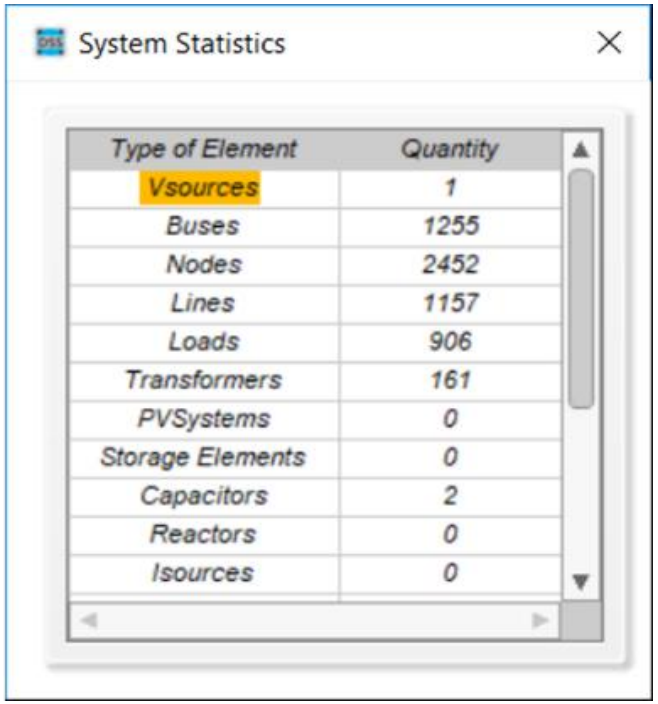
(a)

(b)

(c)



(d)



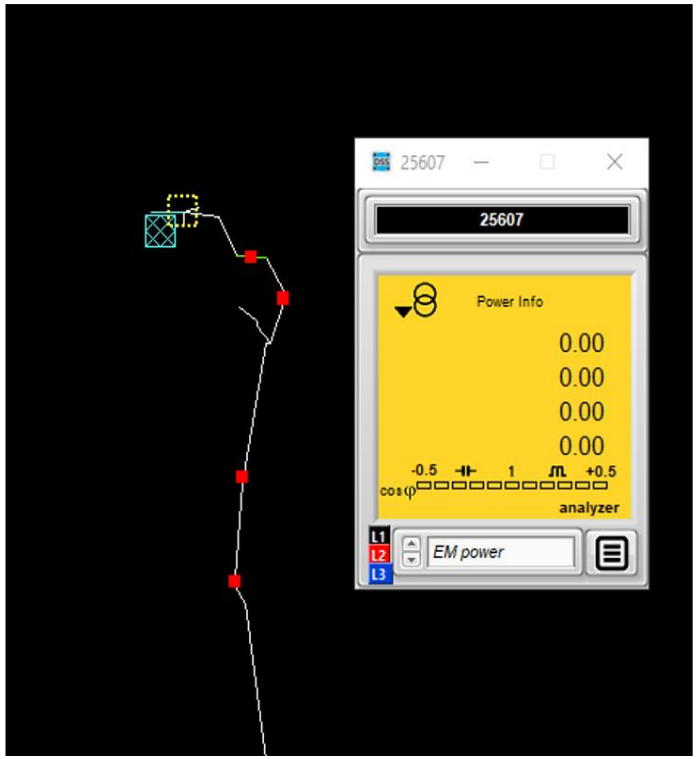
Finding elements within the model

- Getting information about the elements within model

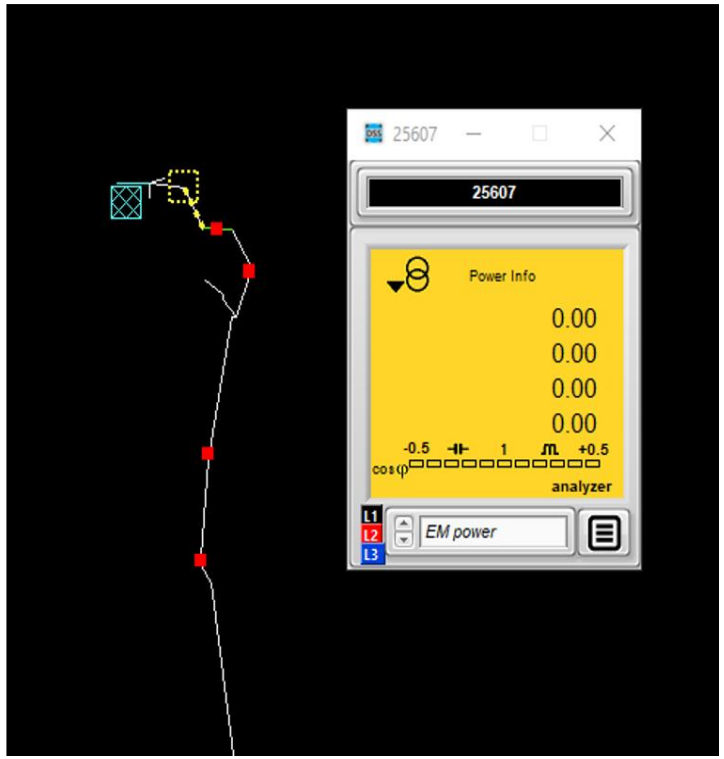
(a)

(b)

(a)

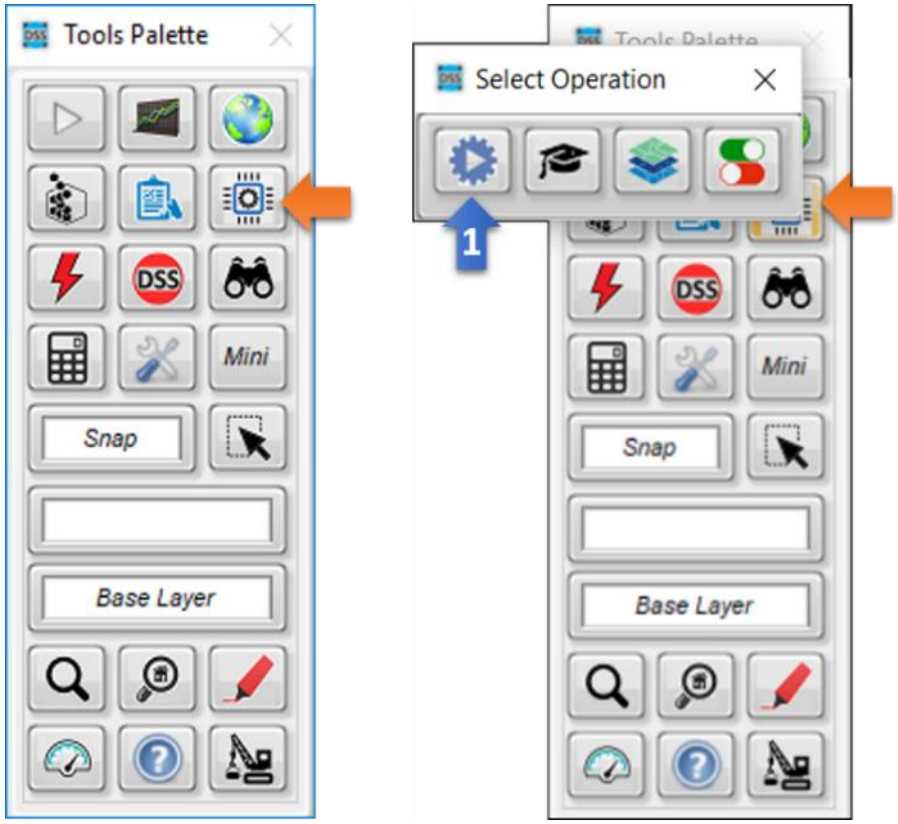


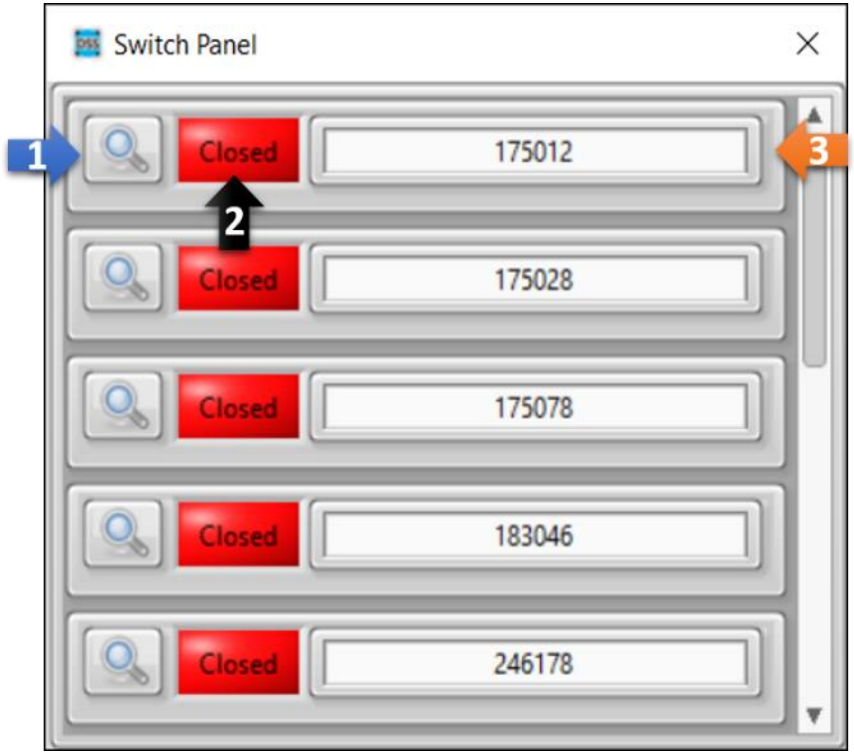
(b)



Interacting with the model

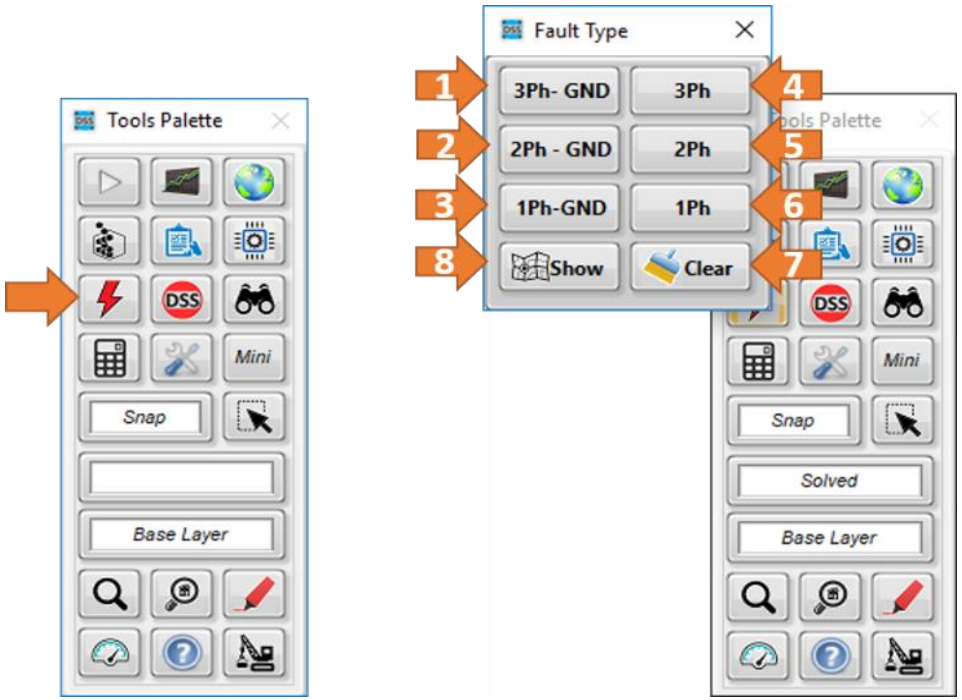
- Close/open switching elements

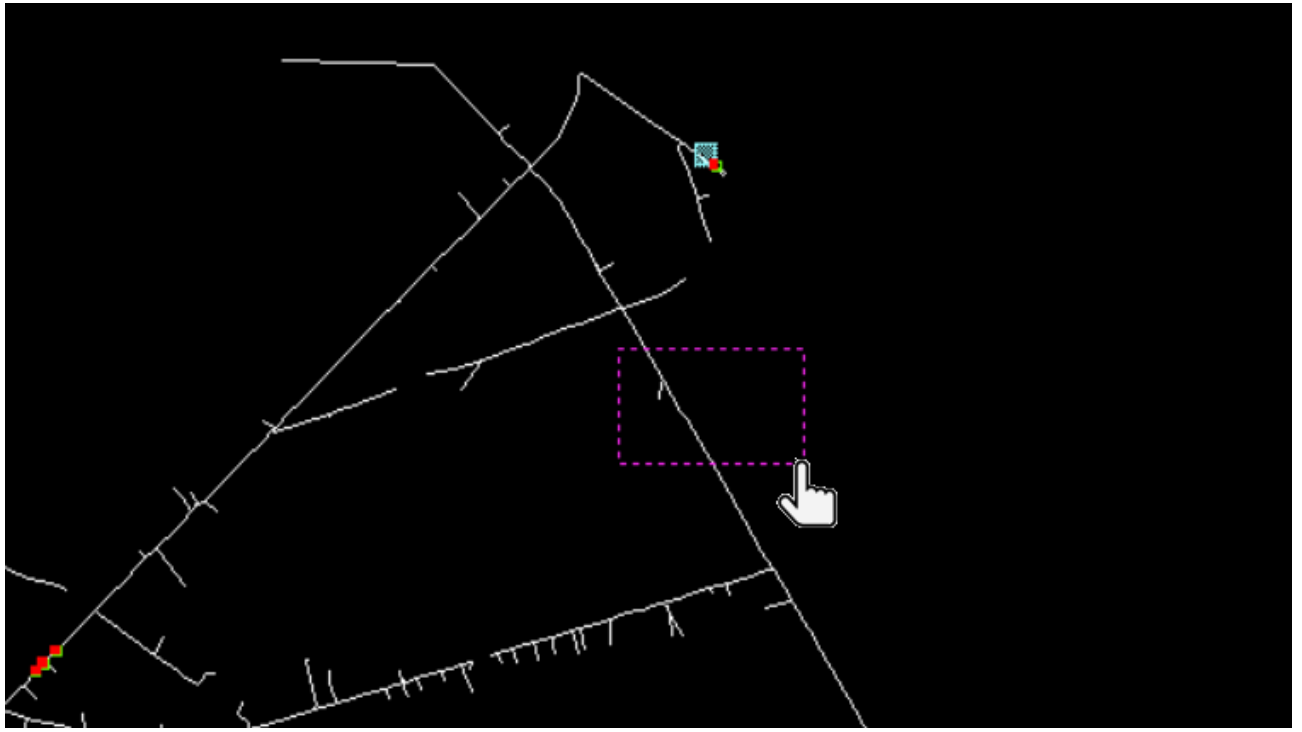




Interacting with the model

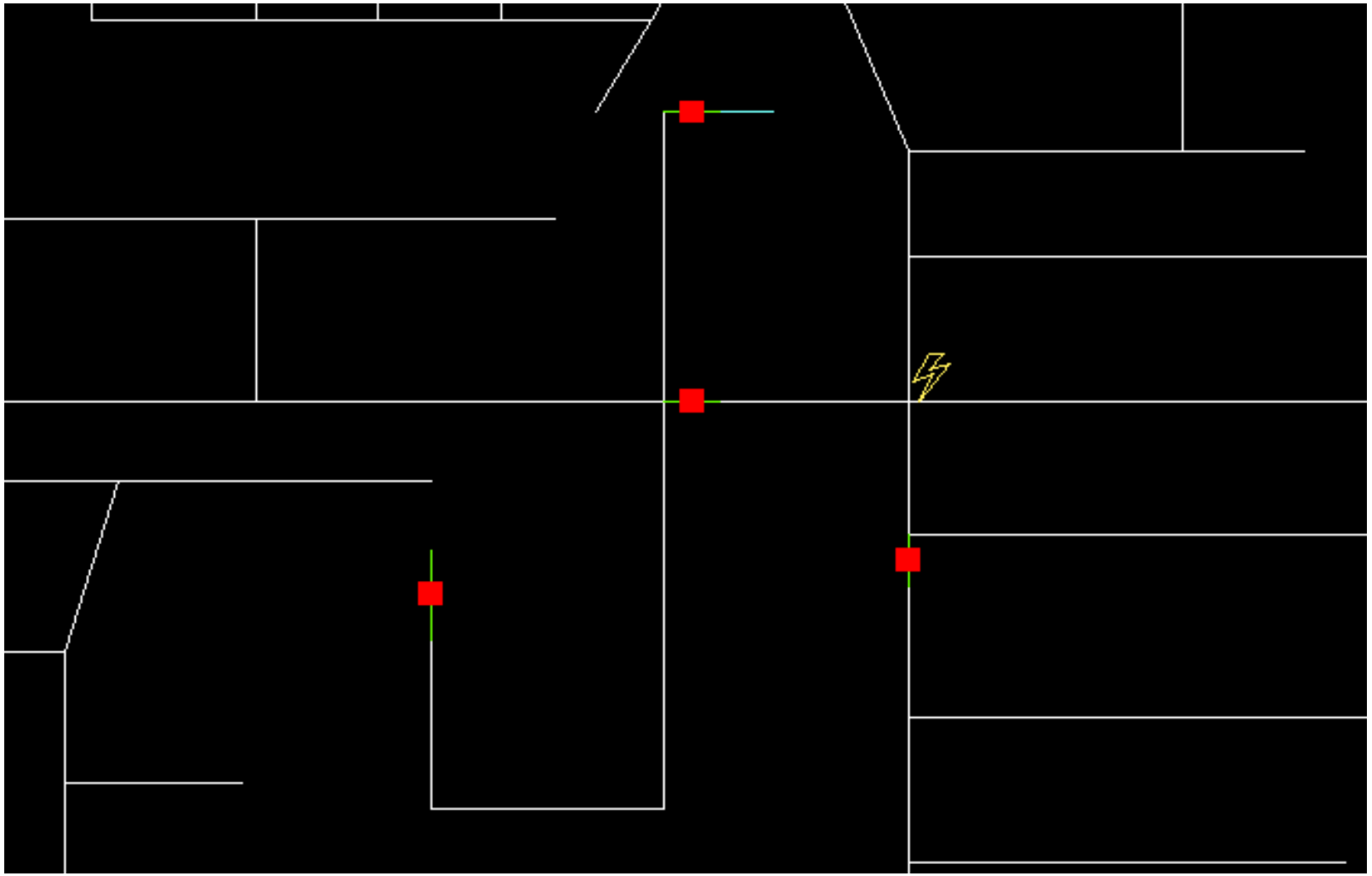
- Adding faults





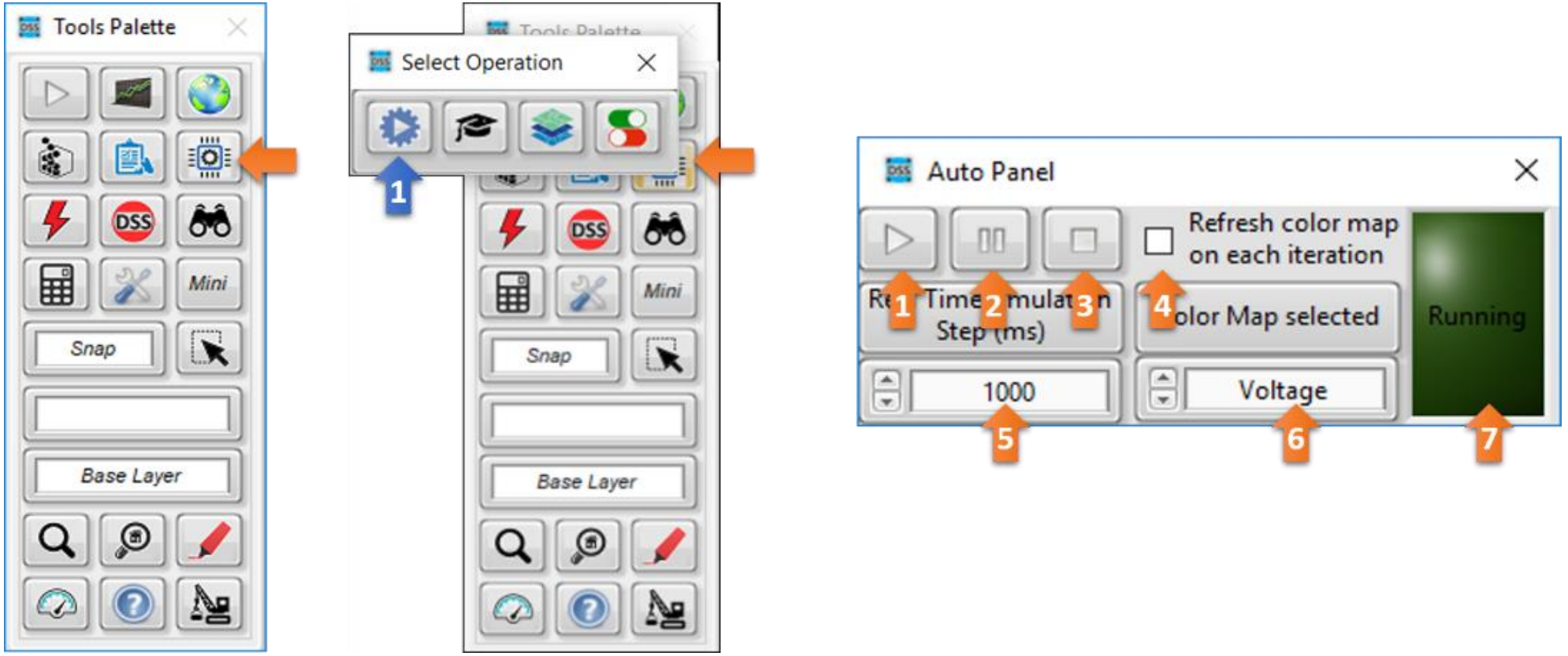
Interacting with the model

- Adding faults



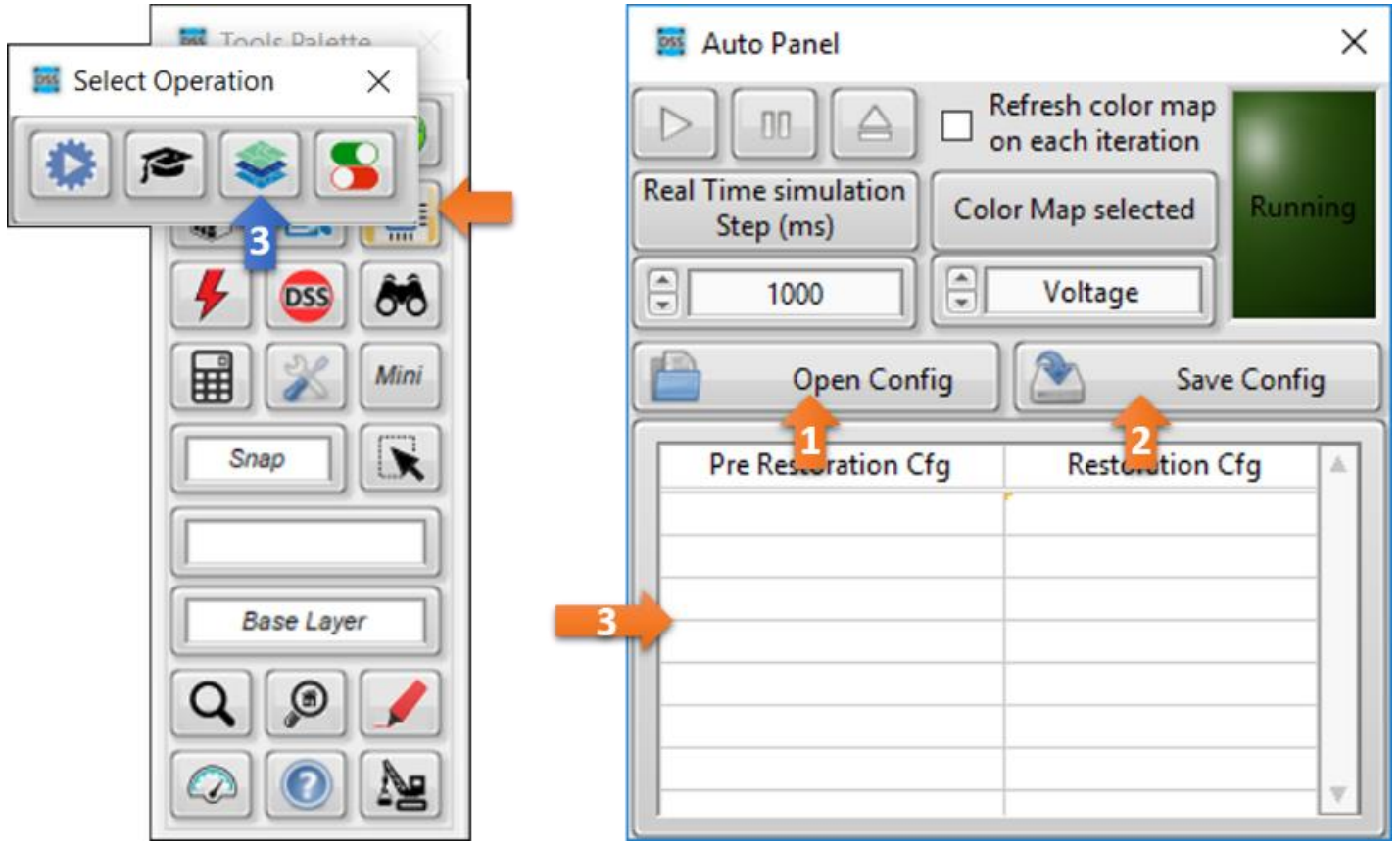
Real-Time simulation

- Real-Time simulation module



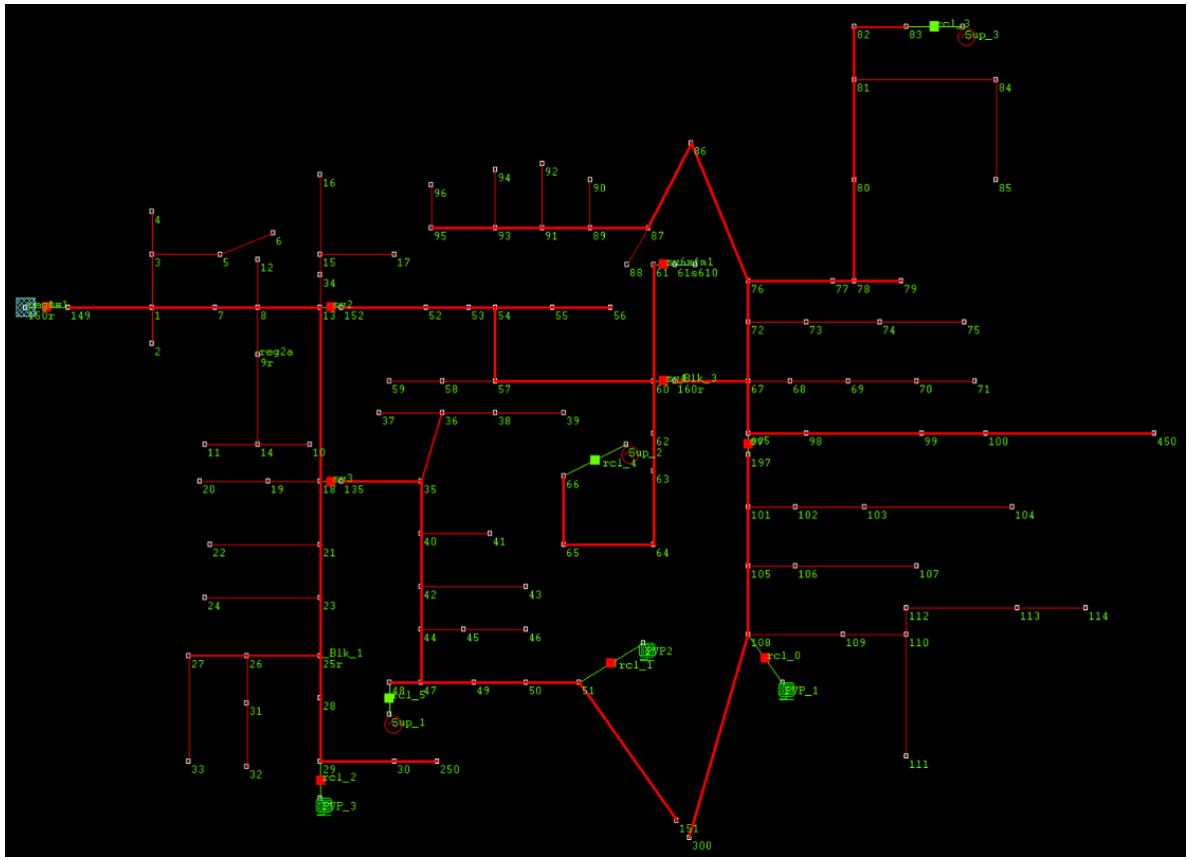
Real-Time simulation

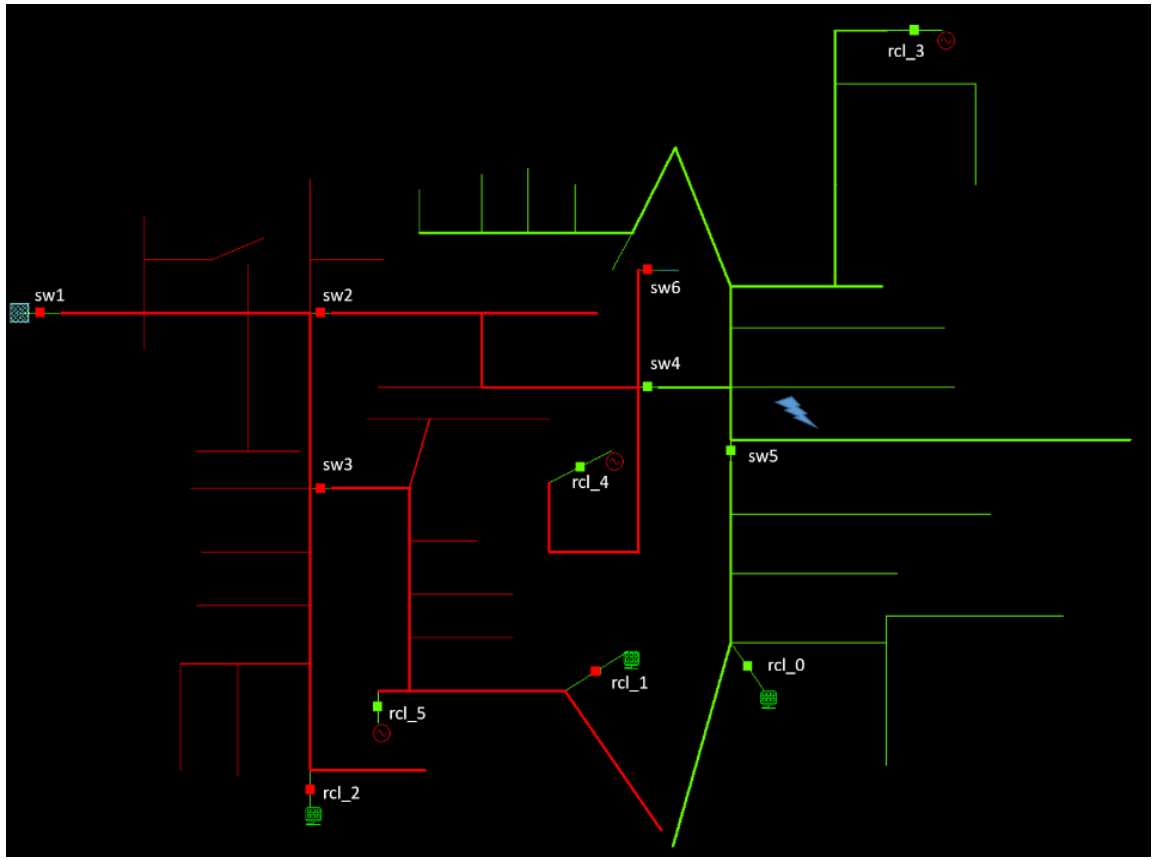
- FLISR (Fault Location, Isolation and Service Restoration) simulation module



Real-Time simulation

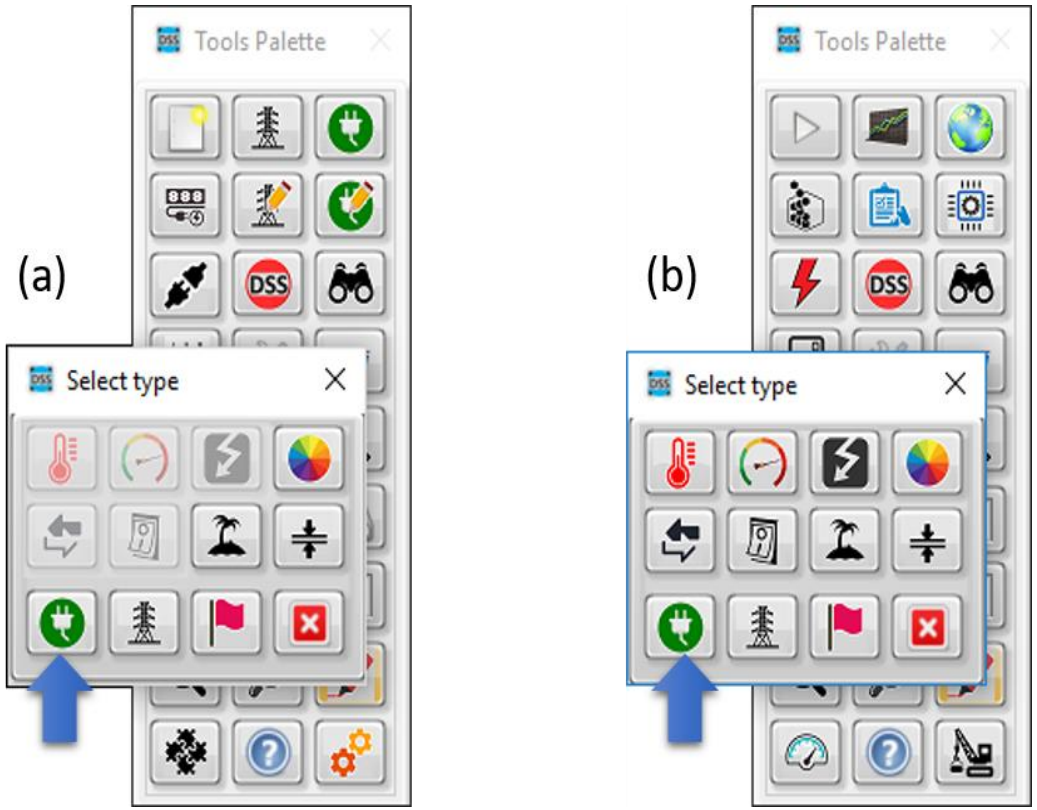
- FLISR (Fault Location, Isolation and Service Restoration) simulation module





Visualizing elements within the model

- The elements palette



Co-Simulating with OpenDSS-G

- The TCP-IP server

OpenDSS-G has a TCP/IP server integrated for co-simulation with other platforms. The document that describes the protocol and uses can be downloaded from https://sourceforge.net/projects/dssimpc/files/Documents/DSTCP-Comm.pdf/download.

Co-simulation examples for MATLAB and NI LabVIEW can be found at https://sourceforge.net/p/dssimpc/code/HEAD/tree/trunk/Distribution/Examples/.

Co-Simulation with OpenDSS-G

Let’s run an example

Today's challenge

Today's challenge

Given the system at
https://sourceforge.net/p/dssimpc/code/HEAD/tree/trunk/Distribution/Examples/Ckt_7_Storage/

Automate a process to evaluate the valid alternatives (technically) to solve the issues in the feeder during three years. The whole analysis cannot take more than 5 min. The alternatives can combine to provide a complete solution during the three years.

Together...Shaping the Future of Electricity