OUTRIGHT POWER SIMULATOR

USER MANUAL

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Glossary and Main Concepts used in this manual

FLISR – Fault Location Isolation and System restoration
FCI – Fault Current Indicator
HMI – Human Machine Interface
I/O – Input/Output(s)
IP – Internet Protocol
CB – Circuit Breaker
TS - Tie Switch
PLC – Programmable Logic Controller
RTU – Remote Telemetry Unit
SCADA – Supervisory Control and Data Acquisition
DMS – Distribution Management System
OMS – Outage Management System
Feeder Protection relays
Centralized solution
Distributed solution
Grid reconfiguration
Restoration path
Self-healing
Radial topology
Open Loop topology
Meshed topology
Source
Destination
T-node, Branch node
End node
Constraints
Components
Agents

Revisions

Rev#	Date	Changes
1.0	7/30/2020	First release
1.1		
1.2		
1.3		

Product List

Outright Power offers three products for covering FLISR requirements.

Simulator helps understanding how the designed grid performs from FLISR point of view

Advisor is an application to be embedded into an on-line platform (RTU, IED or DMS) with the purpose of guiding the grid operator into the FLISR manual process.

Real Time is an application to be embedded into an on-line platform (RTU, IED or DMS) with the purpose performing FLISR in a fully automatic way.

Outright Power Simulator

Introduction

The big problem

Medium voltage power distribution grids built in radial topologies do not allow transferring loads among separate circuits, and the available options for restoring power are using reclosers, emergency generators or batteries.

However, it is frequently required transferring loads to other circuits as fast as possible, so radial topologies are not helpful.

The traditional solution for this problem has been using the well-known open-loop topology.

But *as* the grid goes through expansions usually it evolves to meshed type, and the complexity for operating the grid may increase beyond expectations.

Meshed type grids consist of many circuits, some of them interconnected with each other through load break switches in open position (Tie Switches) so that loads may be transferred from one circuit to another through a process called “Grid reconfiguration”. Meshed grids do not allow two or more substation circuit breakers being connected at any time.

For finding the proper location of those Tie Switches, Distribution engineers work with load-flow and short-circuit applications, so that load current and short circuit limits are not exceeded.

If the grid topology is simple, there is no need for further studies involving grid operation.

But if the meshed grid is large, then “Grid reconfiguration” problem comes into stage.

In its simplest way it may be stated as follows:

Given a meshed-type power distribution grid, remove a feeder from the grid and then try to restore power downstream that feeder by closing an adequate Tie Switch.

The following conditions apply when performing grid reconfiguration:

- **Meshed-type topology must be kept at any moment during the reconfiguration process.**
- **No two or more substation circuit breakers should be interconnected at any time.**
- **No feeders should become overloaded**
- **Feeder voltage profile should be kept within tolerances**

If the removal of the feeder is due to a faulty condition, the process is then called Fault Location, Isolation and System Restoration, or FLISR. Grids supervised by FLISR algorithm are also known as Self-Healing Grids.

Now, writing a FLISR algorithm for reconfiguring the whole grid based on path searching is impossible due to the large number of iterations required. It would take too much time.

So, vendors are offering different mechanism for solving FLISR problem,

These solutions are, however, limited.

Some comments on complexity and present solutions

Is FLISR problem so difficult to solve?

When the first cellular systems came to life more than 30 years ago, vendors had to work out the problem of a downed microwave link, problem named “Network Restoration”.

The task of Network Restoration is to provide an alternate path between two points when the original path became disrupted by a fault. It has been satisfactory solved not only when a microwave link is down, but also when one or both cellular phones are moving, and the microwave links are being dynamically modified.

Having proved so successful, that technology got somehow modified and transferred to the Electrical world, but the result was not completely satisfactory. Although both technologies have similar objective, there are differences with significant impact.

Just to describe one, when a microwave link in communication networks fails, that link is quickly identified and removed from network.

In power distribution grids, when there is a short circuit, the faulty component must be localized, a challenge by itself, and then isolated from the grid. Identification of faulty components is not automatic as in comm networks. If the isolation cannot be performed for any reason (could be communication or device failure) the automatic self-healing process stops. As the algorithm is not tracing any path, just looking for another circuit for powering up the resulting isolated area, the self-healing process must stop when isolation fails.

Note that this solution is centralized: it runs either on Control Centers or Substations.

As said before, finding the paths over the whole grid to solve the grid reconfiguration problem will take too much time for the algorithm’s brute force. It is defined as time exponential with base 2, or 2^n where “n” is a parameter reflecting the size of the meshed grid, for instance a combination of sources and T-nodes. This means that the time required for solving grid reconfiguration grows exponentially with that parameter. This characteristic discouraged vendors from exploring path search strategies.

Given the limitations of the first algorithm, some other solutions were offered in the marketplace, possibly the most promoted has been the one based on “Agents” or “Teams”.

Again, this idea is imported from other fields, mainly the social, economic, or biological networks.

It assumes that the behavior of a system is the result of the behavior of its components (“agents”).

For a power distribution grid, each agent may be defined as a set including few nodes, some incoming and outgoing feeders, and at least one load break switch.

The original version of this solution works like this:

As soon as any agent detects lack of voltage, it opens all its load break switch(es). So, in case of short circuit on some feeder, the substation circuit breaker trips, and therefore all connected agents open their load break switches as well.

Once all agents have opened their switches the algorithm closes the substation circuit breaker and the reverse way begins. Each agent seeing voltage in its incoming feeder will close its load break switch until some agent closes into the fault, tripping for a second time the substation circuit breaker. At this moment, the algorithm will know the location of the fault, and the entire process will start all over again, but this time knowing where the fault is. The fault may be then isolated and the load downstream the fault is transferred to another circuit.

Note that this solution is field-distributed: each Agent or Team is running its own algorithm.

Further versions of this solution prevent the occurrence of closing into a fault.

There are also other solutions like DMS (Distribution Management Systems) including OMS applications (Outage Management Systems) for managing power outages. They may or not include self-healing algorithms.

The surprising correct solution

None of the algorithms presently offered in the marketplace can cover all FLISR requirements. And the reason for this situation is the inherent mathematical complexity.
What is Mathematical complexity?
Finding a node in a grid (for example any circuit breaker) is not difficult.
Finding a path between two nodes is not difficult either, and it is also possible adding constraints like the “shortest’, or the “cheapest” or the “highest priority” path for example.
Now, finding all paths in a whole grid for performing “Grid Reconfiguration”, with the conditions defined above:

- **Meshed-type topology must be kept at any moment during the reconfiguration process.**
- **No two or more substation circuit breakers should be interconnected at any time.**
- **No feeders should become overloaded**
- **If possible, feeder voltage profile should be kept within tolerances**

proved to be *Hard* to find for medium to large grids.
Hard is the term mathematicians use for saying that the number of iterations the algorithm must go through when traversing the whole grid is very large due to nested loops. No computer will be able to solve this problem in a reasonable time.

So, the main question is: if instead of searching paths all over the grid, the algorithm would be looking for paths just for the faulted feeder?

If in addition when searching the paths, the algorithm looks for open-loop rings, the traditional topology very well known by grid operators all over the world, using the following *constraints*:

- **start at the tripped substation circuit breaker,**
- **cross the faulted component(s),**
- **cross only one Tie Switch, and**
- **end at any other circuit breaker.**

then this solution solves grid reconfiguration problem, and mathematical complexity is skipped with important consequences:

- **This solution proved to be effective, Grid operators, completely familiar with open-loop topologies, are back on the loop.**
- **The algorithm will never leave automatic mode in case of device or communication failure, looking for the next switch to open for isolating the fault, either upstream or downstream until all options are exhausted.**
- **The FCIs, the weakest link in the fault location sequence, will have now a way to check their operation versus a completely independent source: the data from Feeder Protection relays (Distance-to-fault).**

More information may be found on our website www.outrightpwr.com

What is Outright Power Simulator

Outright Power Simulator is a patented application designed to create and simulate medium voltage power distribution grids for evaluating their self-healing FLISR behavior.
This application is intended for distribution, planning and operation engineers with the purpose of checking the FLISR process.

Outright Power Simulator solves the gap between theory and practice. Engineers and grid operators are no longer out of the loop.

Any number of components may be configured for simulating a large variety of meshed power grids, involving overhead lines as well as underground feeders.

Outright Power Simulator involves two components:

- **Graphical interface**

It allows configuring the grid in a graphical way by inserting all required elements in the diagram board:

- ✓ Circuit breakers,
- ✓ Feeders and nodes,
- ✓ Load break switches,
- ✓ Fault current indicators.

- **Topological engine**

Trip the selected circuit breaker, and two consecutive processes will take place.

- ✓ Fault Location.
  - Faulted components are shown in red
  - Isolated nodes are shown in yellow
  - All possible restoration paths are shown in light blue, Selected path is shown in dark blue.
  - Distance to fault based on FCIs information is displayed on screen.
  - FCI's Distance-to-Fault data may be confronted with data from corresponding Feeder Protection relay.

- ✓ Isolate and Restore
  - Load Break switches and circuit breakers are operated in the proper sequence.
  - Results are shown in a pop-up screen.

These are the simple steps to check FLISR process using Outright Power Simulator:

Configure the grid

Graphically configure the Power Distribution grid in the board screen. Include Substation Circuit breakers, Nodes, Feeders, Load Break Switches and FCIs in a simple and fast way.

Define the Fault

Choose a component devised to become faulty and modify the condition of involved FCIs accordingly.

Trip the Circuit Breaker

Trip the corresponding Substation circuit breaker. Fault Location process will take place.
The faulted area is shown in the screen and
the distance-to-fault based on FCI metric is also shown,
All possible paths are depicted. The application chooses the one with highest load margin. Other criteria may be easily implemented as well.

Isolate and Restore

Finally operate “Isolate and Restore”.
Fault is isolated whenever possible and power downstream the fault is restored.

Getting Started

Installing the Simulator

Obtain the Simulator_Setup_Vx.xx.exe file from Outright Power Inc representative, or download from the Outright Power website at this link:

It is important to install the latest version of this software. This will change as new features are added to the Simulator, and as this user manual is updated. The most recent software, documentation, and files will be available for download from Outright Power website. It can be installed just about any Windows OS, as far back as XP.

Configure the grid

1.
Open the Simulator, create a new file, and save it with the name Demo.
Edit mode should be chequed.

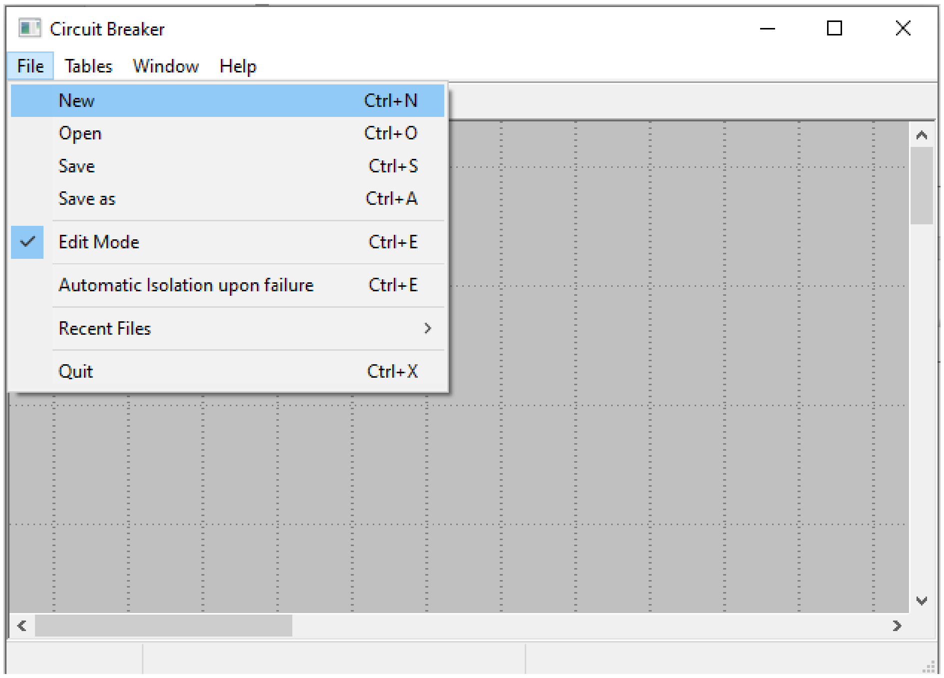

Figure 1

2.
Select a point on the grid, right click the mouse and “Add a Circuit Breaker node here”
It is possible entering settings for circuit breakers:

- Maximum load
- Current load
- Node number

Save the file after entering any setting.

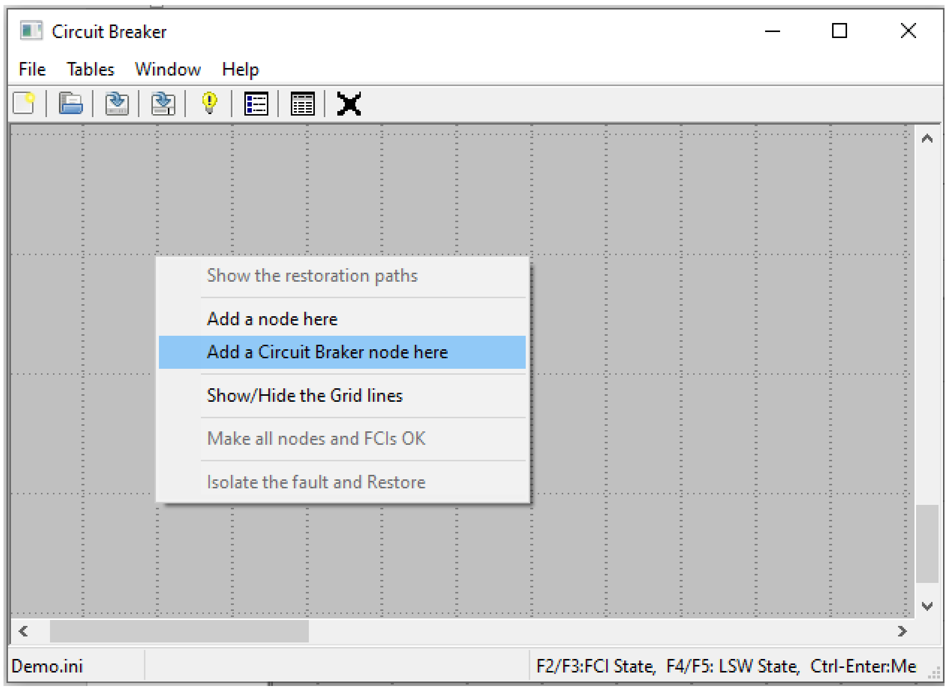

Figure 2

3.
Similarly, by choosing the option “Add a node here” create the grid as shown in Figure 4.
Connect the circuit breakers and nodes with feeders following the direction left to right and top to bottom.

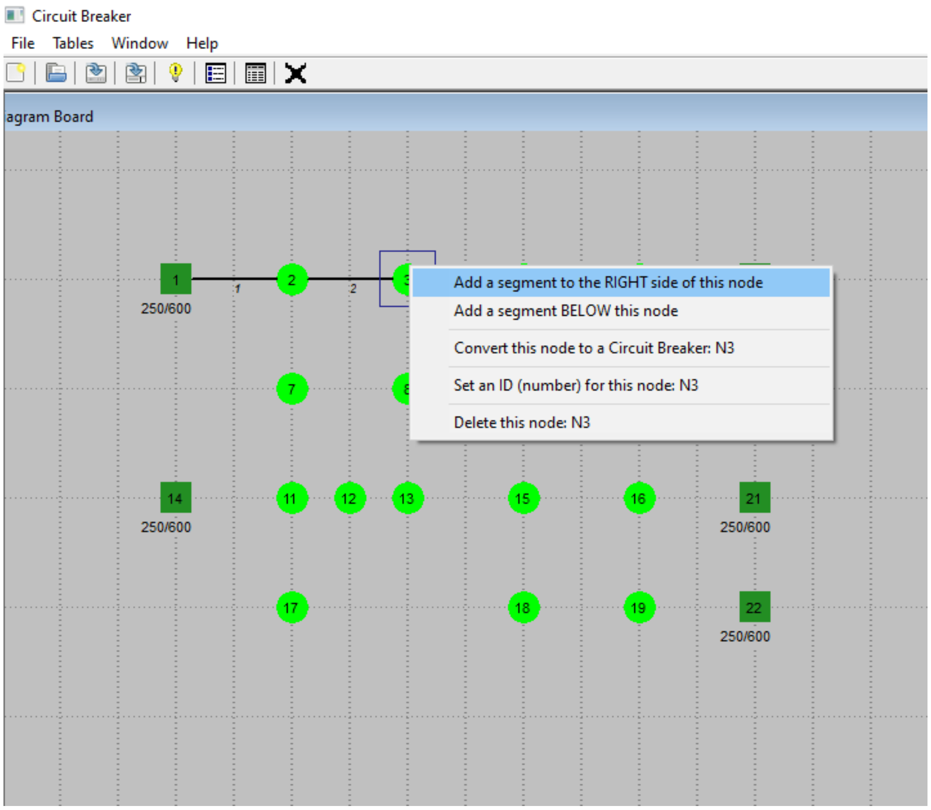

Figure 3

Grid should look like this:

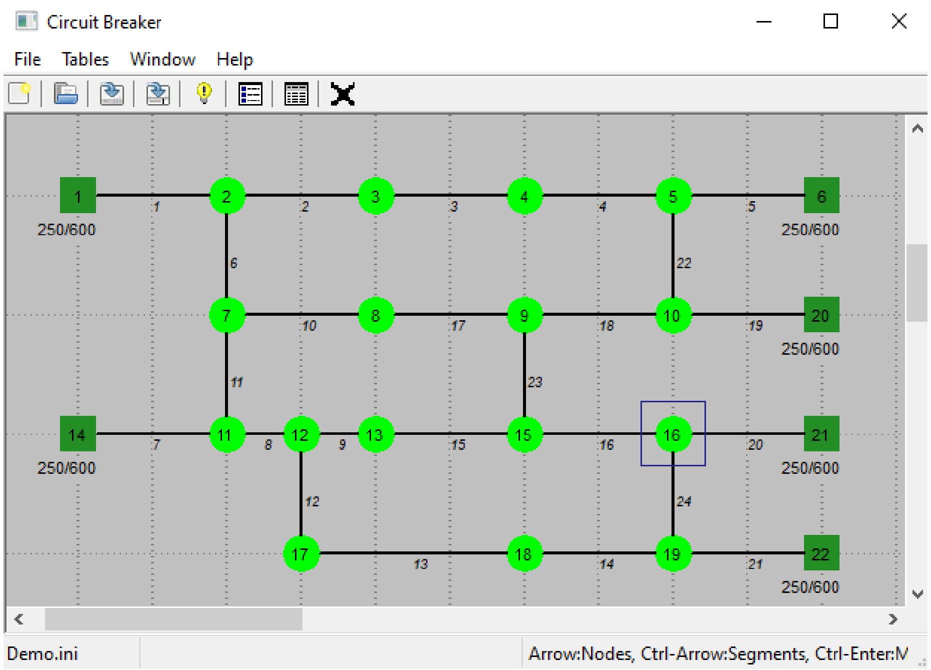

Figure 4

4.
There are 5 different options for feeder configuration.
Select any feeder for adding Load Switches and FCIs.
Note that

- Origin is the extreme of the segment at left or top
- End is the extreme of the feeder at right or bottom
- Length is given in meters

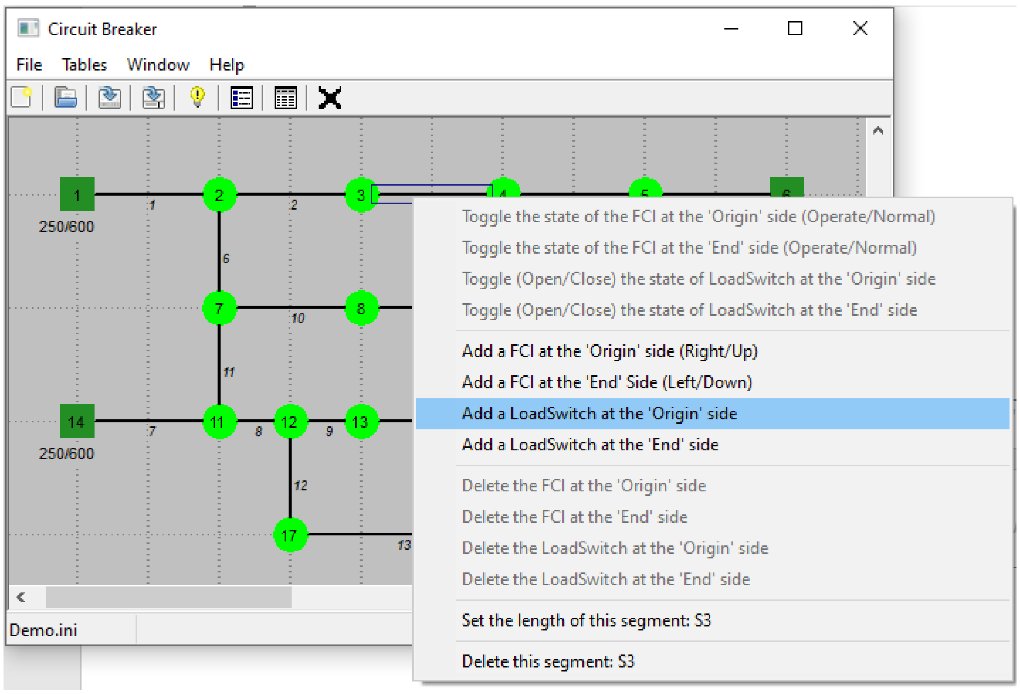

Figure 5

5.
Then toggle the position of Load Break switches according to the Normal Switch configuration defined for the grid:

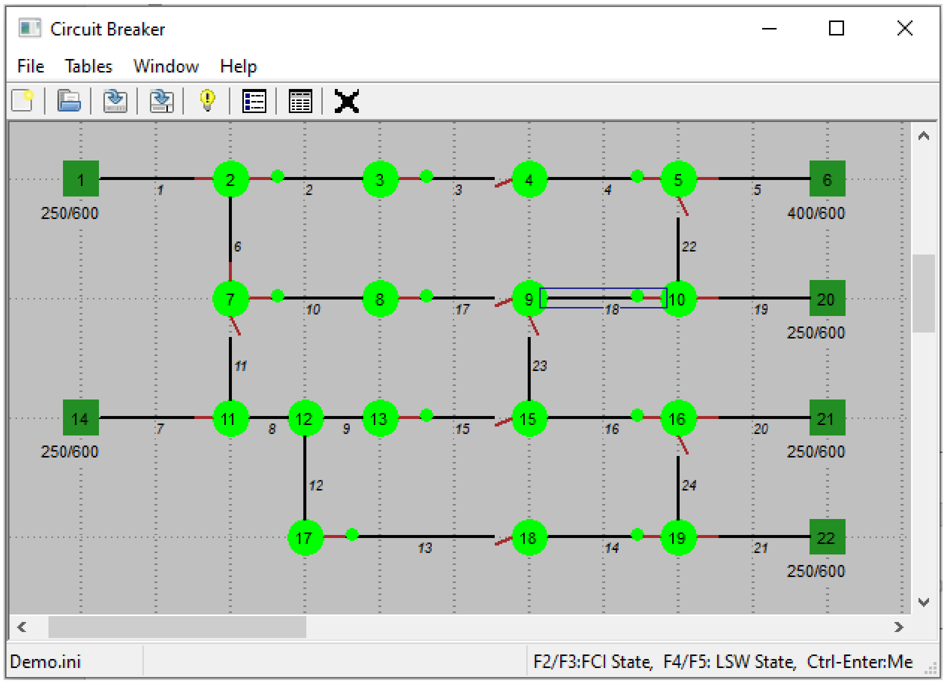

Figure 6

Define the fault

1.
Toggle the status of any desired FCI and Save the file.

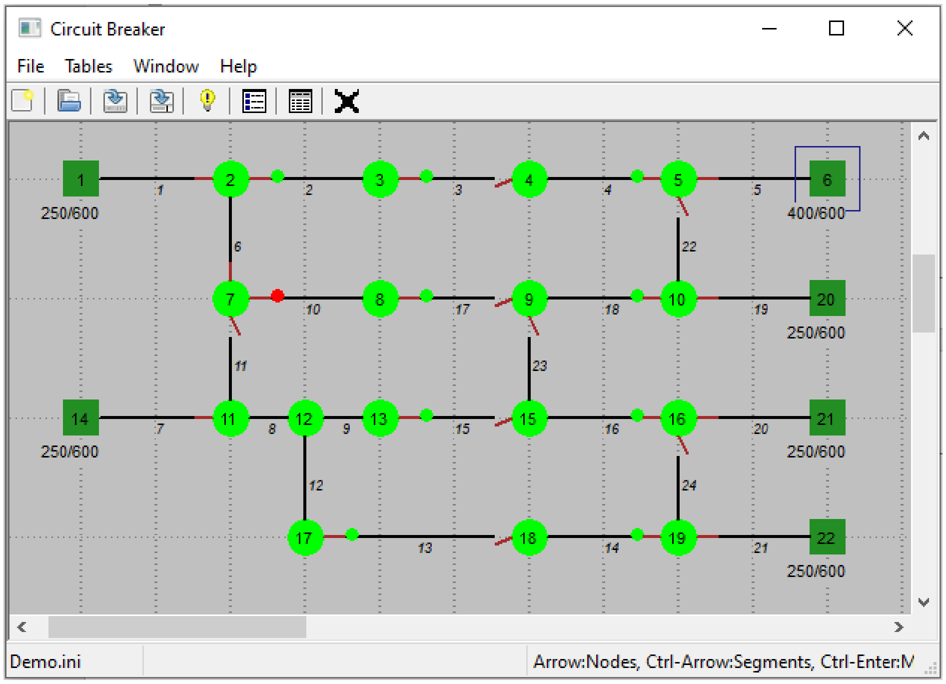

Figure 7

Trip the Circuit Breaker

1.
Uncheck the condition Edit Mode
Automatic Isolation upon failure also should be unchecked for now

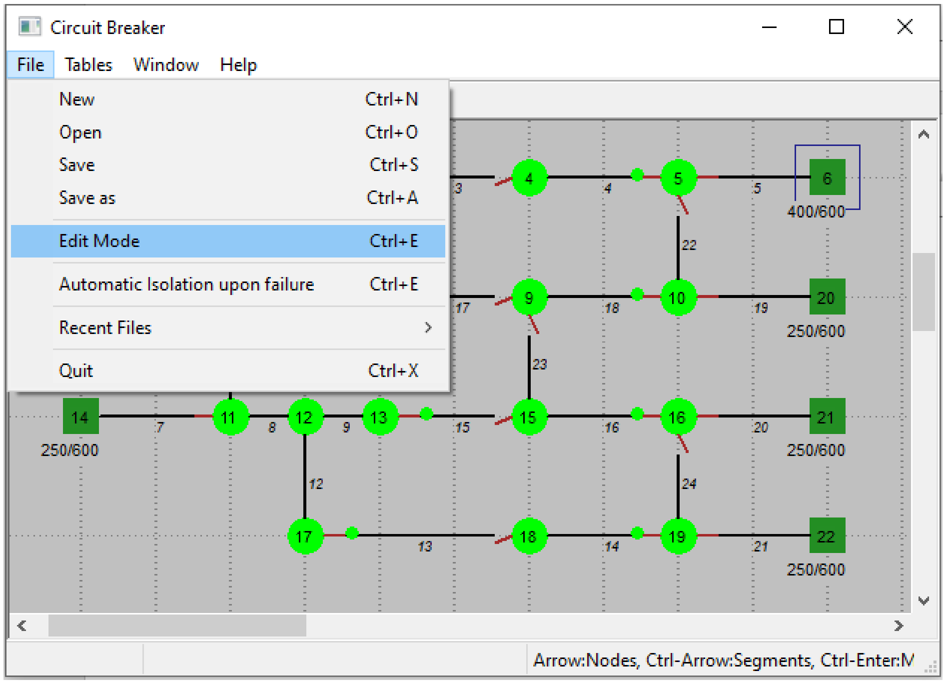

Figure 8

2.
Select node 1, right click the mouse and "*Toggle the state of this node*".
Graphical information shown includes:

- **Faulted elements (nodes and segments) in red**
- **Isolated nodes in yellow**
- **Energized nodes in green**
- **Distance-to-fault based on FCI shown in the bottom banner.**
  This range may be compared with data from Feeder protection relay

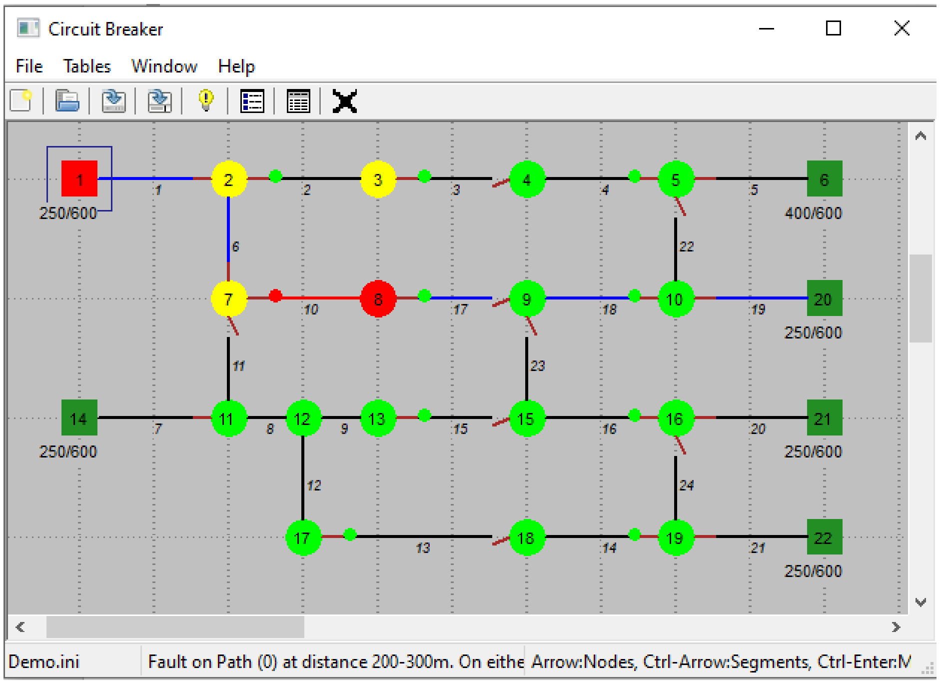

Figure 9

Isolate and Restore

1.
Right Click in a clear area of the board and select the option "*Isolate the fault and restore*"
Fault will be isolated, and power downstream the fault restored.
Pop up window will show the sequence of operations.

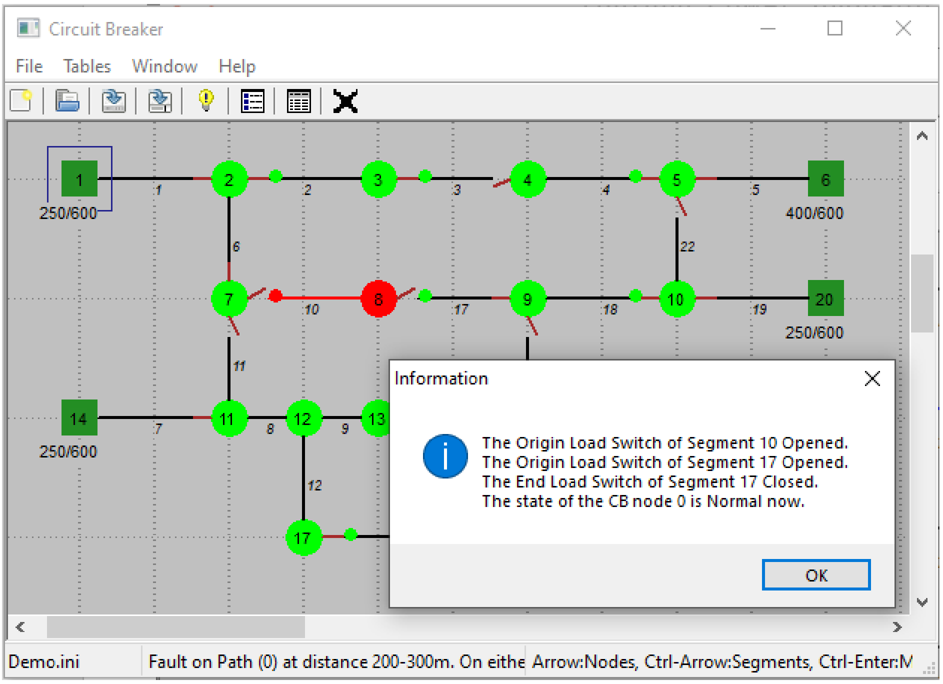

Figure 10

Example with two restoration paths

1.
For this example, Simulator will have to choose between two different paths for performing FLISR. Present criterion is evaluating the load margin each circuit breaker is holding, being each one originally configured with 600A maximum load and 250A current load.

To modify these parameters right click on the circuit breaker symbol and follow the commands shown. Enter 500 Amps for current load at circuit breaker 1 (Node 1)

After clicking OK, save, close and reopen the file for the new value to be applicable.

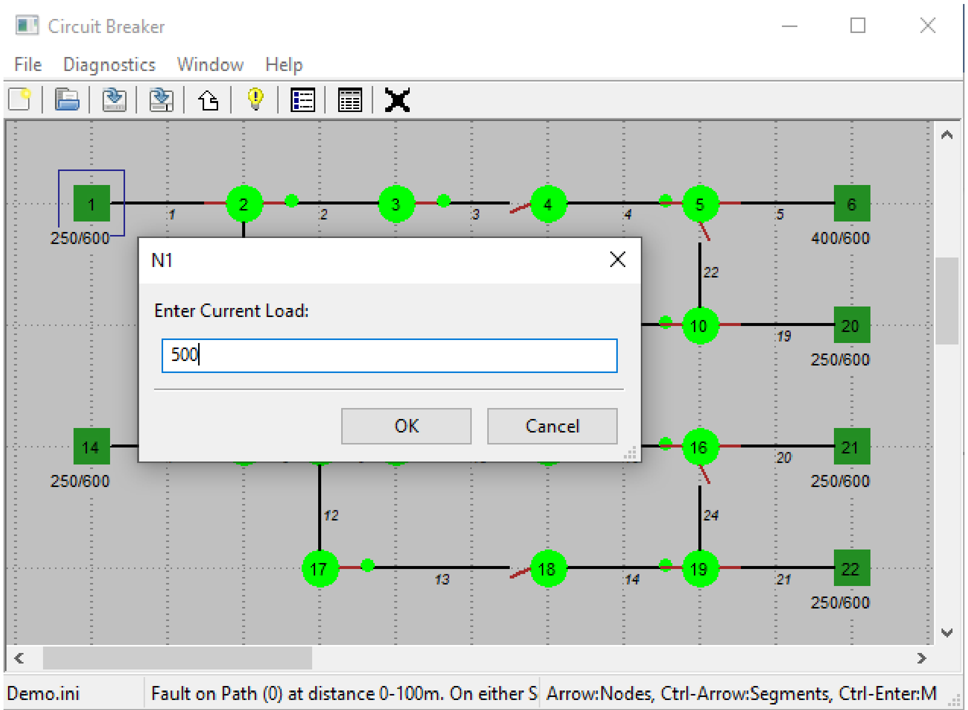

Figure 11

2.
In this case, two restoration paths are found. The application will select the path based on load margin available at each circuit breaker and operate on it. Other criteria for selecting the path are possible to implement.
Selected path is shown in dark blue.

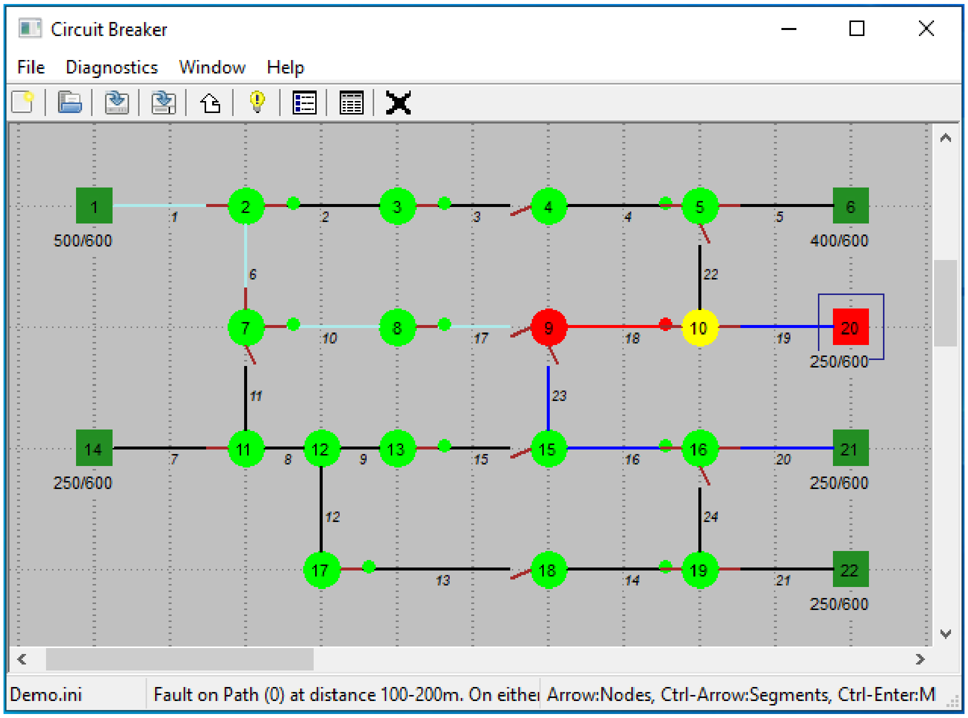

Figure 12

2.
As before, right Click in an empty area of the board and select the option "*Isolate the fault and restore*"
Fault will be isolated, and power downstream the fault restored.
Pop up window will show the sequence of operations.

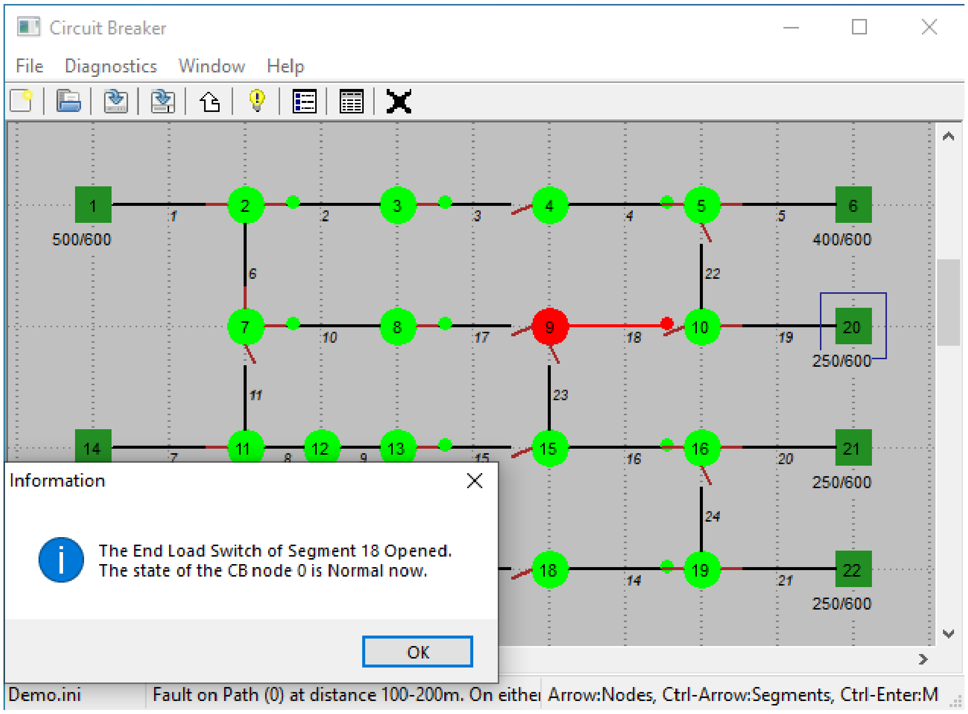

Figure 13

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