

Frequency Dependent Q matrix: FDQ m-phase



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1 Theoretical background

The FDQ (Frequency Dependent Q matrix) underground cable model takes into account the frequency dependence of the cable parameters as well as the frequency dependence of the modal transformation matrix (\mathbf{T}_i or \mathbf{Q}). This model was specifically developed to model single-core direct-buried multiphase cables. To create data for this model it is necessary to approximate with rational functions the characteristic admittance Y_c and the propagation function $A = e^{-\gamma \ell}$ for each mode of the cable, as well as the modal transformation matrix \mathbf{Q} in the frequency domain. The “Cable Data” device is used to create the model data.

The details of the model can be found in [1].

The theoretical background on the distributed parameter line model can be found in the Help section of the “CP m-phase” device.

2 Available versions

There is only a multiphase version of this device. It is not allowed to change phases. Some options in the Drawing tab of this device can result in broken connections that the user might need to repair manually. It is assumed that such options are selected before making final connections to the cable. The Drawing tab allows using 3-phase pins when the device has 3 phases.

3 Parameters

The data for this device can be obtained from the “Cable Data” device in the lines.clf library. Related details are available in the Help section of the “Cable Data” device. An example of usage is given in Cable_Data\tcase2.ecf under the EMTPWorks directory Examples.

The **Number of phases** allows selecting the number of wires for this device. This number must be equal to the one found from the model data files specified below. If the model data files are generated by the “Cable Data” device then the number of phases will be set automatically after clicking OK.

The section for **Time-domain model data from Cable Data** is for naming the model Cable data file for the time-domain solution model. The selection assumes time-domain model data file format obtained from the Cable Data device. For details on the format of this file, see the Cable Data help section.

The **Frequency-domain model data from Cable Data** allows specifying separate models for the frequency domain computations in steady-state or frequency scan options of EMTP. The first option "Use model in steady-state solution (Exact-PI model)" allows selecting the Exact-PI circuit file for the steady-state-only solution. If not checked, EMTP will use the time-domain model data for calculating the steady-state solution. If the steady-state solution is followed by a time-domain solution, EMTP will automatically revert to the time-model file for performing steady-state initialization.

The second option "Use this model in frequency scan solution (Exact-PI model)" allows requesting the Exact-PI model data file for the frequency scan solution. If not checked, EMTP will use the time-domain model data for finding the cable frequency scan model.

The Exact-PI option allows calculating the pi-section model of the cable with representation of frequency variation in cable parameters. There are no approximations, since the pi-section is available for each frequency of the selected range.

Since this device needs data files to work, it provides an option for managing the locations of the data files: **Save data file names using relative path**. This option allows EMTP to use a relative path for the selected data files. It works only for files located in the same directory as the design or in a directory below the design file. Using relative path simplifies the maintenance of designs with model data files. It also simplifies the task of using this design on other computers.

3.1 Generic rules

The model data file format must be the one given in the "Cable Data" device. There is no extra testing for wrong data or numerically unstable cases.

It is not allowed to delete any pins or change pin attributes. The drawing of "FDQ m-phase" is continuously updated according to the selected number of wires and selected options in the "Drawing" tab.

4 Netlist format

Example of data:

```

FDQ;FDQ1;6;6;s36,s37,s38,s39,s40,s41,
3,1,0,1,1,
TCASE2_rv.pun,
TCASE2pi_rv.pun,
0
0
0

```

Field	Description
FDQ	Part name
FDQ1	Instance name, any name.
6	Total number of pins
6	Number of pins given in this data section
s36, s37,s38	Signal names connected to k-pins, any names
s39,s40,s41	Signal names connected to m-pins, any names
3	Number of phases
1	Use exact-pi file for steady state-study: -1 for no, 1 for yes
0	Use exact-pi file for frequency scan study: 0 for no, 1 for yes
1	Use relative path when 1
1	Units for trapped charge value
TCASE2_rv.pun	Name for the data file for time-domain study, any name
TCASE2pi_rv.pun	Name for the Exact-PI data file for frequency scan or steady-state study, any name
Trapped charge	Trapped charge as many lines as wires

Comma separated data is saved into the ParamsA attributes. The rest of the data is saved into the ModelData attribute

5 Steady-state model

The steady-state solution can be calculated from the time-domain data or from the Exact-PI circuits. The time-domain model data file is the one used for initialization.

The user can also request a steady-state only solution and use the Exact-PI model. The needed design steady-state frequencies must be available in the generated Exact-PI model file.

6 Initial conditions

Automatic initial conditions are found from the harmonic steady-state solution. The cable is initialized for quickly achieving steady-state conditions in time-domain at simulation startup.

The user can enter manual initial conditions for each wire. This represents trapped charge on the cable. If the cable is energized in steady-state then the user should not also provide trapped charge data.

7 Frequency Scan model

The frequency scan model is the same as the steady-state model. The ultimate precision is obtained using the Exact-PI model data file. In this case the frequency range chosen in the "Simulation Options" (for the frequency scan range) must be in accordance with the frequency of the Exact-PI data file generated by "Cable Data". An error message will stop the program if a frequency range mismatch occurs.

8 Time-domain model

The time-domain representation is explained in [1].

In some non-common cases, the Cable Data calculation function does not obtain a complex transformation matrix, a real matrix \mathbf{Q} is then found. The FDQ device does not accept such a real matrix in the current release of EMTP. For such cases it is recommended to use the Wideband "WB m-phase" model. The "WB m-phase" works for cables and lines.

9 References

- [1] L. Marti: "Simulation of transients in underground cables with frequency-dependent modal transformation matrices". IEEE Transactions in Power Delivery, Volume 3, Issue: 3, July 1988, pp. 1099 -1110