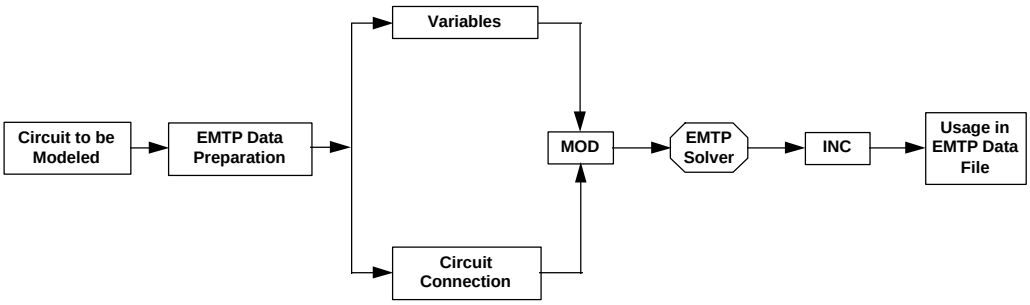
Introduction to EMTP Data Modules

- Overview of EMTP Data Module (EDM) Development:
  - Creating a data module
  - Data module usage
  - Examples



EMTP Data Module Workshop *Slide 1*

An EMTP Data Module (EDM) is an input data format which is accepted by the EMTP preprocessor to form a regular data case file. A module is similar to a procedure or subroutine in a programming language. The user calls the module, passes a number of parameters, and the module returns the proper EMTP data.

In many cases input modules can help users greatly reduce the amount of work required to develop EMTP data cases. In addition, modules help to build cases with better organization and readability.

EMTP Data Modules - When and Why?

- In general, a user should have already developed the equivalent model in an EMTP data case, and then wish to convert the data into a reusable data module.
- If a component/model is only going to be used once, the user will need to determine the usefulness of converting it into a module.
- A significant advantage of module usage is that they can be shared by a group, with one person responsible for development / maintenance and the others having access to the model.

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EMTP Data Modules - Overview

- Grouping of Input Data (/ Cards)
  - Grouping of Data Logically, Rather than by Rules
- Argument Substitution
  - Character Strings (Bus Names), Numbers
- Transportability and Reliability
- Ease of Use
  - $INCLUDE Special Request Card

Rule Book: 19.1

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Grouping of Input Data

- Grouping of EMTP data is accomplished using "/" cards:
  - Method allows data to be grouped logically, rather than with the traditional EMTP structure:

```
Miscellaneous Data Cards
Branch Data
BLANK End of Branch Data
Switch Data
Blank End of Switch Data
etc.
```

  - Allows large complex data sets (i.e. PWM inverter/motor) to be divided into smaller more manageable groups of data.
  - Six levels of nesting are allowed in data modules.

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Argument Substitution

- Data modules provide the facility to substitute variables (arguments), rather that simply inserting a portion of data into the larger data case.
- Concept is similar to programming procedures or functions.

```
Function Root (iRoot, value)
Dim iRoot as Integer
Dim value as Real
   Root = value^iRoot
End Function
```

- Arguments may be strings or numeric quantities.

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Transportability/Reliability & Ease of Use

- Each data module resides in a separate data file - once development and testing is completed it requires no maintenance.
- Possibility of unknown errors is reduced.
- Modules can be reused in the same data case.
- Modules can be reused in different studies.
- Modules are easily incorporated using “$INCLUDE” cards.

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EDM Preamble / Declaration

- A module may have three types of declarations, 'ARG', 'NUM', and 'DUM'.
  - 'ARG' argument
  - 'NUM' numeric constants
  - 'DUM' internal or dummy variables

```
ARG TERML,                                          -   ; NODES
ZERORE, ZEROINDUCTAN, POSIRE, POSIINDUCTAN,         -   ; SEQUENCE IMP.
AMPLITUDES, TSTARTTIME, TSTOPTIMES, RDAMP1              ; V, TSTART, TSTOP
C
NUM                                                 -   ;
ZERORE, ZEROINDUCTAN, POSIRE, POSIINDUCTAN,         -   ; SEQUENCE IMP.
AMPLITUDES, TSTARTTIME, TSTOPTIMES, RDAMP1              ; V, TSTART, TSTOP
C
DUM INTERA, INTERB, INTERC                              ; INTERNAL SOURCE
```

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The type 'ARG' stands for argument and is used to pass all external variables (numeric or character string). to the module. The variable type 'ARG' does not justify. Rather, it replaces the pattern as specified in the argument list (a variable may be padded with blanks by using the character '#'.

The type 'NUM' is a subset of type 'ARG', and informs the program to expect a numeric string rather than an alphanumeric string. These variables replace numeric fields in the EMTP data file. When specifying a numeric variable, the user must refer to the actual EMTP data. This is required because the numeric string must be the same length as the numeric field. If the field width is ten characters long, then the variable representing that field must also be ten characters long ('_' may be used to embed blank characters). In the usage of the module ($INCLUDE), if the user specifies a numeric string that is shorter than the specified field width the program will automatically right justify the quantity.

EDM Preamble - Special Characters

- Special characters:

'-'	continuation character
';'	indicate rest of line is comment
'#'	indicate imbedded blanks
'_'	indicate imbedded blanks in numeric field
'?','@'	one character substitution in column 80

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External Variables - Type ARG

- Type ‘ARG’ stands for argument and is used to pass all external variables to the module.
- All external variables (numeric or character string) must be declared as type ‘ARG’.
- Variable type ‘ARG’ does not justify. It replaces a pattern as given in the argument list.
- A variable can be padded with blanks using the special character ‘#’.

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EDM Guidelines - Node Name Creation

- Single bus and three-phase node name examples:

```
BUS01A - generates a name of:   BUS01A
                                .....^

BUS##A - generates a name of:   BUS  A
                                .....^
```

```
C <---Nodes--><---Refer--><-ohms<---mH<---uF
C <-Bus1<-Bus2<-Bus3<-Bus4<----R<----L<----C
  FAULTA                  0.001
  FAULTB                  0.001
  FAULTC                  0.001
C .....^.....^.....^.....^.....^.....^.....^
```

```
C <---Nodes--><---Refer--><-ohms<---mH<---uF
C <-Bus1<-Bus2<-Bus3<-Bus4<----R<----L<----C
  BUS01A                  0.001
  BUS01B                  0.001
  BUS01C                  0.001
C .....^.....^.....^.....^.....^.....^.....^
```

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Numeric Variables - Type NUM

- Type ‘NUM’ is a subset of type ‘ARG’ and informs the program to expect a numeric string instead of an alphanumeric string.
- These variables replace numeric fields in the EMTP data.
- Users must refer to the actual EMTP rules - specify the width of the variable as the full width of the numeric field.
- Users may use the special character ‘_’ to imbed blanks in the field.
- In the “$INCLUDE” statement, users may specify a numeric string that is less than the variable width - If this occurs the quantity is right justified.

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EDM Guidelines - Numeric Quantities

- For example: RDAMP1 refers to a resistor from nodes BUS01 to BUS02

```
C <---Nodes--><---Refer--><-Ohms<---mH<---uF
C Bus1->Bus2->Bus3->Bus4-><----R<----L<----C
  BUS01ABUS02A             RDAMP1
C .....^.....^.....^.....^.....^.....^.....^
```

- When the module is used: ‘230KV’, ‘SEND1’, and ‘200.00’ are used

```
C <---Nodes--><---Refer--><-Ohms<---mH<---uF
C Bus1->Bus2->Bus3->Bus4-><----R<----L<----C
  230KVASEND1A             200.00
C .....^.....^.....^.....^.....^.....^.....^
```

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Dummy Variables - Type DUM

- Type 'DUM' refers to internal variables of a module.
- Variables of type 'DUM' must have a six character width and should begin with an alphanumeric character.
- An internal variable is replaced with a unique name created by the program.
- The program currently has 6000 dummy variables available.

Seed Key	First Name	Last Name
DUM	DUM000	DUM999
DMU	DMU000	DMU999
MDU	MDU000	MDU999
MUD	MUD000	MUD999
UMD	UMD000	UMD999
UDM	UDM000	UDM999

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The type 'DUM' refers to internal variables (dummy) of a module. Variables of type 'DUM' must have a six character width and should begin with an alphanumeric character. An internal variable is replaced with a unique name created by the program. The name is composed by adding a number 000 to 999 to the term DUM. For example, the first dummy variable would be named 'DUM000' and the thousandth dummy variable would be 'DUM999'.

EDM Body

- The input formats and rules that need to be followed while building a MOD file are very similar to those while developing a regular EMTP data file.
- A major difference between a MOD file and a regular input file is that in the MOD file general character strings are used to replace all the determined node names and numerical values specified in the regular input file.
- In addition, all of the used character strings need to be declared as proper types.

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EDM Body - Data Sorting

- Data sorting - "/" cards:

/BRANCH	indicate branch data
/SWITCH	indicate switch data
/SOURCE	indicate source data
/TACS	indicate TACS data
/OUTPUT	indicate output data
/PLOT	indicate plot data
/REQUEST	indicate special request card
/STATISTICS	indicate statistics request cards
/END MODULE	indicate end of a data module

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EDM Body - '$' Request Cards

- '$' cards request the program to:

  [1] Read another input file

  [2] Set file attributes, such as directory

  [3] Modify the contents of card images using argument list

  [4] Change the 'seed key' of internal variables

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Special request cards:

$INCLUDE	read another input file
$SUFFIX	define file type (i.e. .INC)
$PREFIX	define file path (i.e. C:\EMTP\MODULE)
$DUMMY	defined dummy variable name
$EOF	indicates end of file

Note: avoid using BLANK ENDS and $DUMMY in a module

EDM Guidelines - Converting MOD to INC

- Process for Creating Modules:

  [1] Write Module File (*.MOD)

  [2] Convert to Include File (*.INC)

```
MODULE
D:\EMTPFILE\WORKBOOK\VOLUME2\3PHEQUIV.MOD
D:\EMTPFILE\WORKBOOK\VOLUME2\3PHEQUIV.INC
STOP
```

  [3] Use Module via $INCLUDE Request Card

```
$PREFIX, D:\EMTPFILE\WORKBOOK\VOLUME2\
$SUFFIX, .INC
```

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In general, the second and third lines give the paths leading to the places where MOD and INC files are stored. The MODULE command can be repeated as many times as necessary in a batch-mode execution.

After running the above MAKEMOD.DAT case, the EMTP generates the corresponding INC file. This file keeps all the circuit connections as specified in the MOD file, and the EMTP also generates connection codes for the EMTP internal matrix. The user does not need to pay attention to such codes (however, do not change anything in the INC file, all changes to the module should be made to the MOD file and then recompiled).

Module Usage

- $INCLUDE
  - Intructs program to read another input file:

```
$INCUDE   filename  argument, argument, argument, - ; comment
          argument, argument                        ; comment
```

- $PREFIX / $SUFFIX
  - Informs the program of common file attributes (path, extension):

```
$PREFIX  prefix name
$SUFFIX  suffix name
```

- BLANK Cards

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An input module is easily inserted into a data case as an include file. The user needs to use an '$INCLUDE' statement with proper number of parameters. The lines:

$PREFIX C:\ETK\MODULE\INCFILE\

$SUFFIX .INC

provide information regarding the path and file extension for the include files. An alternate format would be to include the entire path name in the '$INCLUDE' statement. For example, if the file name 'DATAMOD1' was called using the '$INCLUDE' statement the following path/file string would be passed to the EMTP.

$INCLUDE DATAMOD1

C:\ETK\MODULE\INCFILE\DATAMOD1.INC

Module Usage - Blank Cards

- Blank cards are required to terminate an EMTP data classes.
- Standard blank cards may not be used within modules and data files using modules.
- The keywork “BLANK ENDS” is used at the end of the data file.

```
BLANK ENDS TACS
BLANK ENDS BRANCH
BLANK ENDS SWITCH
BLANK ENDS SOURCE
BLANK ENDS OUTPUT
BLANK ENDS PLOT
BEGIN NEW DATA CASE
BLANK END OF ALL DATA CASES
```

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EDM Guidelines - Some General Rules

- There are several important rules to follow when creating modules. They include:

  [1] Each data block must start with the proper '/' card

  [2] A '$' card can be part of a data block

  [3] If an '$INCLUDE' card is embedded in a data block then it must be followed with the proper '/' card

  [4] The first eleven (11) characters of a line in a module must not be 'BLANK ENDS'. This pattern is a keyword and is used at the end of the EMTP data file.

  [5] The body of a module must end with a '/ENDMODULE' card, followed by a '$EOF' card.

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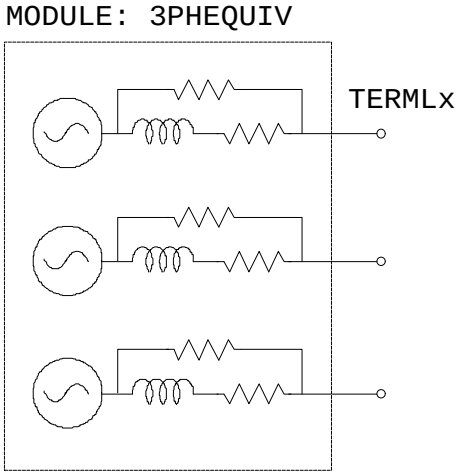
Module Example #1 - 3PHEQUIV

- Three-phase source equivalent - **3PHEQUIV**



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The module, 3PHEQUIV, is used to create a three-phase equivalent source representation. The source impedance is obtained by using positive and zero sequence impedance in a mutually coupled R-L model (type 51, 52, 53...), in parallel with a damping resistor (simple RLC). The voltage is obtained using a sinusoidal voltage source (Type 14).

Module 3PHEQUIV - Argument List

Argument	Description	Type	Length
TERML	Output terminal name 5 characters + (A)(B)(C)	ARG	5
ZERORE	Zero sequence source resistance (Ω)	NUM	6
ZEROINDUCTAN	Zero sequence source inductance (mH)	NUM	12
POSIRE	Positive sequence source resistance (Ω)	NUM	6
POSIINDUCTAN	Positive sequence source inductance (mH)	NUM	12
AMPLITUDES	Voltage source (peak voltage, phase-to-ground)	NUM	10
TSTARTTIME	Start time (sec), -1.0 for steady-state	NUM	10
TSTOPTIMES	Stop time (sec), 9999. for entire simulation	NUM	10
RDAMP1	Parallel damping resistor (Ω)	NUM	6
COM	Comment	N/A	N/A
INTERA(B)(C)	Internal nodes for voltage source connection	DUM	6

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Module 3PHEQUIV - .MOD File

```
ARG TERML,                                          -   ; ELECTRIC NODES
ZERORE, ZEROINDUCTAN, POSIRE, POSIINDUCTAN,         -   ; SEQUENCE IMP.
AMPLITUDES, TSTARTTIME, TSTOPTIMES, RDAMP1              ; V, TSTART, TSTOP
C
NUM                                                 -   ;
ZERORE, ZEROINDUCTAN, POSIRE, POSIINDUCTAN,         -   ; SEQUENCE IMP.
AMPLITUDES, TSTARTTIME, TSTOPTIMES, RDAMP1              ; V, TSTART, TSTOP
C
DUM INTERA, INTERB, INTERC                              ; INTERNAL SOURCE CONN.
C
/BRANCH
C <---Nodes--><---Refer--><-Ohms<---------mH
C <-Bus1<-Bus2<-Bus3<-Bus4<----R<----------L
51TERMLAINTERA            ZEROREZEROINDUCTAN
C .....^.....^.....^.....^.....^...........^  Zero Sequence
52TERMLBINTERB            POSIREPOSIINDUCTAN
C .....^.....^xxxxxxxxxxxx.....^...........^  Positive Sequence
53TERMLCINTERC
C .....^.....^xxxxxxxxxxxx.....^...........^
C
C <---Nodes--><---Refer--><-Ohms<---mH<---uF<-------------------------------Out
C Bus1->Bus2->Bus3->Bus4->><----R<----L<----C                                V
  TERMLAINTERA            RDAMP1
  TERMLBINTERB            RDAMP1
  TERMLCINTERC            RDAMP1
C .....^.....^.....^.....^.....^.....^.....^xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx^
C
/SOURCE
C <--Bus<I<-----Ampl<-----Freq<----Phase<-------A1<------T1><---Tstart<----Tstop
14INTERA 1AMPLITUDES      60.0       0.0                  TSTARTTIMETSTOPTIMES
14INTERB 1AMPLITUDES      60.0    -120.0                  TSTARTTIMETSTOPTIMES
14INTERC 1AMPLITUDES      60.0     120.0                  TSTARTTIMETSTOPTIMES
C .....^.^.........^.........^.........^.........^........^.........^.........^
/ENDMODULE
$EOF
```

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A module (.MOD) file is then converted into an include (.INC) file using the EMTP solver and the following structure (MAKEMOD.DAT):

```
MODULE
C:\ETK\MODULE\MODFILE\3PHEQUIV.MOD
C:\ETK\MODULE\INCFILE\3PHEQUIV.INC
STOP
```

Module 3PHEQUIV - .INC File

```
KEND    7   32   44   14    7   32   44   14    7   14    7   32   14    7   32
       14    7   32   14   20   70   80    8   20   70   80    8   20   70   80
        8
KTEX    1    0    0    1    1    0    0    1    1    1    1    0    1    1    0
        1    1    0    1    0    0    0    1    0    0    0    1    0    0    0
        1
C EMTP Data Module: 3PHEQUIV
C
C Description: Three-Phase Equivalent Source
C
C Created: 5/2/94 (TEG/LT)  Last Updated: 5/2/94 (TEG)
C
C Usage: 3PHEQUIV TERML, R0, L0, R1, L1, VPEAK, TSTART, TSTOP, RDAMP1 ; COM
C
/BRANCH
C <---Nodes--><---Refer--><-Ohms<---------mH
C <-Bus1<-Bus2<-Bus3<-Bus4<----R<----------L
51TERMLAINTERA          ZERROREZEROINDUCTAN
C .....^.....^.....^.....^.....^...........^  Zero Sequence
52TERMLBINTERB          POSIREPOSIINDUCTAN
C .....^.....^xxxxxxxxxxxx.....^...........^  Positive Sequence
53TERMLCINTERC
C .....^.....^xxxxxxxxxxxx.....^...........^
C
C <---Nodes--><---Refer--><-Ohms<---mH<---uF<-------------------------------Out
C Bus1->Bus2->Bus3->Bus4-><----R<----L<----C                                 V
  TERMLAINTERA           RDAMP1
  TERMLBINTERB           RDAMP1
  TERMLCINTERC           RDAMP1
C .....^.....^.....^.....^.....^.....^.....^xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx^
C
/SOURCE
C <--Bus<I<-----Ampl<-----Freq<----Phase<-------A1<------T1><---Tstart<----Tstop
14INTERA 1AMPLITUDES      60.0      0.0                    TSTARTTIMETSTOPTIMES
14INTERB 1AMPLITUDES      60.0   -120.0                    TSTARTTIMETSTOPTIMES
14INTERC 1AMPLITUDES      60.0    120.0                    TSTARTTIMETSTOPTIMES
C .....^.^.........^.........^.........^.........^........^.........^.........^
/ENDMODULE
$EOF **** END OF FILE ****
DATE AND TIME OF MODULE CONVERSION:    05/02/94  15.57.08
NUMBER OF ARGUMENTS DECLARED IN THIS MODULE:     9
NUMBER OF DUMMY VARIABLES DECLARED IN THIS MODULE:     3
```

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Module 3PHEQUIV - Usage

```
BEGIN NEW DATA CASE
$PREFIX, C:\DOC\MODULE\INCFILE\
$SUFFIX, .INC
C
C <------------------------------------------------Misc Data-----------------
C
C ----Dt<---Tmax<---Xopt<---Copt
  50E-06 100.E-3
C .....^.......^.......^.......^
C -Iprnt<--Iplot<-Idoubl<-Kssout<-Maxout<---Ipun<-Memsav<---Icat<-Nenerg
    5001       3       1       1       1       0       0       2       0
C .....^.......^.......^.......^.......^.......^.......^.......^.......^
C
C <------------------------------------------------Circuit Data--------------
C
C Source Equivalent
C 2000 kVA, 6% Transformer, 480 V secondary (assume positive and zero seq equal)
C
C Usage: 3PHEQUIV TERML, R0, L0, R1, L1, VPEAK, -
C                TSTART, TSTOP, RDAMP1 ; COM
C
$INCLUDE 3PHEQUIV 480VB, 0.001, 0.018, 0.001, 0.018, 391.92, -
                   -1.0, 9999.9, 10.0
C
C <------------------------------------------------Nodal Output--------------
C
/OUTPUT
C
C BUS-->BUS-->BUS-->
  480VBA480VBB480VBC
C .....^.....^.....^
BLANK ENDS BRANCH
BLANK ENDS SWITCH
BLANK ENDS SOURCE
BLANK ENDS OUTPUT
BLANK ENDS PLOT
BLANK ENDS CASE
```

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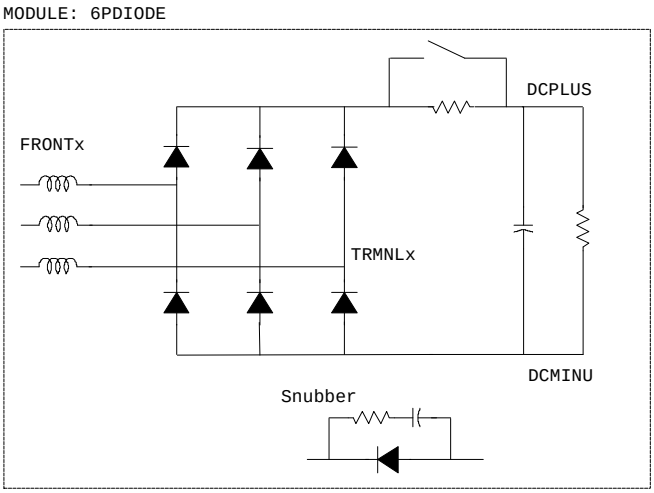
Module Example #2 - 6PDIODE

- Three-phase, six-pulse diode bridge - **6PDIODE**



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Module 6PDIODE - Argument List

Argument	Description	Type	Length
FRONT	Input terminal name 5 characters + (A)(B)(C)	ARG	5
TERML	Load side of reactor name 5 characters + (A)(B)(C)	ARG	5
DCPLUS	Positive side of dc bus	ARG	6
DCMINU	Negative side of dc bus	ARG	6
CHOKEL	Choke inductance (mH)	NUM	6
SNUBBR	Snubber resistance (Ω)	NUM	6
SNUBBC	Snubber capacitance (μF)	NUM	6
STARTR	starting resistor (Ω)	NUM	6
RSHORTTIME	Shorting switch closing time (sec)	NUM	10
DCBUSC	dc bus capacitance (μF)	NUM	6
DCBUSR	dc bus resistance (Ω)	NUM	6
?	Output request (current)	NUM	1
@	Output request (voltage)	NUM	1
RECPOS RECNEG SHRTBK	Internal nodes for bridge connections	DUM	6
DIOD1A, DIOD1C DIOD2A, DIOD2C DIOD3A, DIOD3C DIOD4A, DIOD4C DIOD5A, DIOD5C DIOD6A, DIOD6C	Internal nodes for diode connections	DUM	6

Module 6PDIODE - .MOD File

```
C EMTP Data Module: 6PDIODE
C
C Description: Six Pulse Diode Bridge Rectifier (capacitor smmothing, resistive load)
C
C Created: 5/5/94 (TEG/LT)  Last Updated: 5/5/94 (TEG)
C
C Usage: 6PDIODE FRONT,  TRMNL,  DCPLUS, DCMINU,                          -; NODES
C                CHOKEL, SNUBBR, SNUBBC, STARTR, RSHORTIME,               -; PARA
                 DCBUSC, DCBUSR, ?, @                                      ; PARA
C
ARG                                                                 - ; ARGUMENTS
FRONT, TRMNL, DCPLUS, DCMNUS,                                       - ; NODES
CHOKEL, SNUBBR, SNUBBC, STARTR,RSHORTTIME,                          - ; AC PARAMETERS
DCBUSC, DCBUSR, ?, @                                                  ; OUTPUT REQ
C
NUM                                                                 - ; NUMERICAL
CHOKEL, SNUBBR, SNUBBC, STARTR,RSHORTTIME,DCBUSC,DCBUSR               ; PARAMETERS
C
DUM                                                                 - ; DUM
RECPOS, RECNEG, SHRTBK,                                             - ; DUM1
DIOD1C, DIOD2C, DIOD3C, DIOD4C, DIOD5C, DIOD6C,                     - ; DUM2
DIOD1A, DIOD2A, DIOD3A, DIOD4A, DIOD5A, DIOD6A                        ; DUM2
C
/BRANCH
C
C AC Choke Inductance
C
C <---Nodes--><---Refer--><-Ohms<---mH<---uF<--------------------------------Out
C Bus1->Bus2->Bus3->Bus4->><----R<----L<----C
  FRONTATRMNLA            1.0E-5CHOKEL                                       1
  FRONTBTRMNLB            1.0E-5CHOKEL                                       ?
  FRONTCTRMNLC            1.0E-5CHOKEL                                       ?
C .....^.....^.....^.....^.....^.....^.....^xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx^
C
C Diode Snubber Circuits
C
C <---Nodes--><---Refer--><-Ohms<---mH<---uF<--------------------------------Out
C Bus1->Bus2->Bus3->Bus4->><----R<----L<----C
  TRMNLARECPOS            SNUBBR      SNUBBC
  TRMNLBRECPOS            SNUBBR      SNUBBC
  TRMNLCRECPOS            SNUBBR      SNUBBC
  TRMNLARECNEG            SNUBBR      SNUBBC
  TRMNLBRECNEG            SNUBBR      SNUBBC
  TRMNLCRECNEG            SNUBBR      SNUBBC
C .....^.....^.....^.....^.....^.....^.....^xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx^
C
C <-------- Connection to positive and negative dc bus
C
C <---Nodes--><---Refer--><-Ohms<---mH<---uF<--------------------------------Out
C Bus1->Bus2->Bus3->Bus4->><----R<----L<----C
  DIOD1CRECPOS            1.0E-5
  DIOD3CRECPOS            1.0E-5
  DIOD5CRECPOS            1.0E-5
  RECNEGDIOD4A            1.0E-5
  RECNEGDIOD6A            1.0E-5
  RECNEGDIOD2A            1.0E-5
C .....^.....^.....^.....^.....^.....^.....^xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx^
C
```

Module 6PDIODE - .MOD File Continued

```
C <-------- Connection to power system (diode front-end)
C
C <---Nodes--><---Refer--><-Ohms<---mH<---uF<-------------------------------Out
C Bus1->Bus2->Bus3->Bus4-><----R<----L<----C
  TRMNLADIOD1A            1.0E-5
  TRMNLBDIOD3A            1.0E-5
  TRMNLCDIOD5A            1.0E-5
  DIOD4CTRMNLA            1.0E-5
  DIOD6CTRMNLB            1.0E-5
  DIOD2CTRMNLC            1.0E-5
C .....^.....^.....^.....^.....^.....^.....^xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx^
C
C <-------- Phase-to-Phase Voltage Sampling
C
C <---Nodes--><---Refer--><-Ohms<---mH<---uF<-------------------------------Out
C Bus1->Bus2->Bus3->Bus4-><----R<----L<----C
  TRMNLATRMNLB            1.0E08                                            2
  TRMNLBTRMNLC            1.0E08                                            @
  TRMNLCTRMNLA            1.0E08                                            @
C .....^.....^.....^.....^.....^.....^.....^xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx^
C
C <-------- Starting Resistor
C
C <---Nodes--><---Refer--><-Ohms<---mH<---uF<-------------------------------Out
C Bus1->Bus2->Bus3->Bus4-><----R<----L<----C
  RECPOSSHRTBK            STARTR                                            ?
C .....^.....^.....^.....^.....^.....^.....^xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx^
C
/SWITCH
C
C <-------- Starting Resistor Short Switch
C
C BUS-->BUS--><---TCLOSE<----TOPEN<-------IE<----FLASH<--REQUEST<-----TARGET<--O
  RECPOSSHRTBKRSHORTTIME     9999.                                           ?
C .....^.....^.........^.........^.........^.........^.........^...........^...^
C
/BRANCH
C
C <-------- dc Bus Components
C
C <---Nodes--><---Refer--><-Ohms<---mH<---uF<-------------------------------Out
C Bus1->Bus2->Bus3->Bus4-><----R<----L<----C
  SHRTBKDCPLUS            1.0E-5                                            ?
  DCMNUSDCPLUS            DCBUSR
  DCPLUSDCMNUS                        DCBUSC                                2
  RECPOS                              1.0000
  RECNEG                              1.0000
  RECNEGDCMNUS            1.0E-5
C .....^.....^.....^.....^.....^.....^.....^xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx^
/SWITCH
C
C <-------- Diodes (front-end)
C BUS-->BUS--><------Vig<----Ihold<-------td<---------CLOSEDSame<Grid<Op/Cl<xxOO
11DIOD1ADIOD1C                0.1                                             ?
11DIOD3ADIOD3C                0.1                                             ?
11DIOD5ADIOD5C                0.1                                             ?
11DIOD4ADIOD4C                0.1                                             ?
11DIOD6ADIOD6C                0.1                                             ?
11DIOD2ADIOD2C                0.1                                             ?
C .....^.....^.........^.........^.........^.........^.........^...........^...^
/ENDMODULE
$EOF
```

Module 6PDIODE - .INC File

```
KARD    1    1    1    1    3    3    3    4    4    4    4    5    5    5    5
        6    6    6    6    7    7    7    7    8    8    8    8    9    9    9
        9   10   10   10   10   11   11   11   11   12   12   13   13   14   14
       15   15   16   16   17   17   18   18   19   19   20   20   21   21   22
       22   23   23   24   24   25   25   25   26   26   26   27   27   27   27
       29   29   29   29   31   31   31   32   32   32   33   33   33   34   35
       36   36   38   38   38   39   39   39   40   40   40   41   41   41   42
       42   42   43   43   43
KARG   10   11   12   13    1    2    5    1    2    5   12    1    2    5   12
        2    6    7  -15    2    6    7  -15    2    6    7  -15    2    6    7
      -14    2    6    7  -14    2    6    7  -14  -15  -12  -15  -10  -15   -8
      -14   -3  -14   -1  -14   -5    2   -6    2   -4    2   -2    2   -9    2
       -7    2  -11    2    2    2    2   13    2    2   13    8   12  -15  -13
        9   12  -15  -13    3   12  -13    3    4   11    3    4   10  -15  -14
        4  -14   12  -12   -6   12  -10   -4   12   -8   -2   12   -9   -3   12
       -7   -1   12  -11   -5
KBEG   18   26   34   37    3    9   33    3    9   33   80    3    9   33   80
        3   27   39    9    3   27   39    9    3   27   39    9    3   27   39
        9    3   27   39    9    3   27   39    9    9    3    9    3    9    3
        3    9    3    9    3    9    3    9    3    9    3    9    9    3    9
        3    9    3    3    9    3    9   80    3    9   80   27   80    3    9
       15   80    3    9    9   80    3    9    3   27    3    9   39    3    3
        9    3   80    9    3   80    9    3   80    9    3   80    9    3   80
        9    3   80    9    3
KEND   23   31   34   37    7   13   38    7   13   38   80    7   13   38   80
        7   32   44   14    7   32   44   14    7   32   44   14    7   32   44
       14    7   32   44   14    7   32   44   14   14    8   14    8   14    8
        8   14    8   14    8   14    7   14    7   14    7   14   13    8   13
        8   13    8    7   13    7   13   80    7   13   80   32   80    8   14
       24   80    8   14   14   80    8   14    8   32    8   14   44    8    8
       14    8   80   14    8   80   14    8   80   14    8   80   14    8   80
       14    8   80   14    8
KTEX    0    0    1    1    1    1    0    1    1    0    1    1    1    0    1
        1    0    0    1    1    0    0    1    1    0    0    1    1    0    0
        1    1    0    0    1    1    0    0    1    1    1    1    1    1    1
        1    1    1    1    1    1    1    1    1    1    1    1    1    1    1
        1    1    1    1    1    1    1    1    1    1    1    0    1    1    1
        0    1    1    1    1    1    1    1    1    0    1    1    0    1    1
        1    1    1    1    1    1    1    1    1    1    1    1    1    1    1
        1    1    1    1    1
C EMTP Data Module: 6PDIODE
C
C Description: Six Pulse Diode Bridge (front-end only)
C
C Created: 5/5/94 (TEG/LT)  Last Updated: 5/5/94 (TEG)
C
C Usage: 6PDIODE FRONT,  TRMNL,  DCPLUS, DCMINU,                          -; N
C                CHOKEL, SNUBBR, SNUBBC, STARTR, RSHORTIME,               -; P
                 DCBUSC, DCBUSR, ?, @                                      ; P
C
C
C
/BRANCH
C
C AC Choke Inductance
C
C <---Nodes--><---Refer--><-Ohms<---mH<---uF<-------------------------------Out
C Bus1->Bus2->Bus3->Bus4-><----R<----L<----C
  FRONTATRMNLA            1.0E-5CHOKEL                                      1
  FRONTBTRMNLB            1.0E-5CHOKEL                                      ?
  FRONTCTRMNLC            1.0E-5CHOKEL                                      ?
C .....^.....^.....^.....^.....^.....^.....^xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx^
```

Module 6PDIODE - .INC File Continued

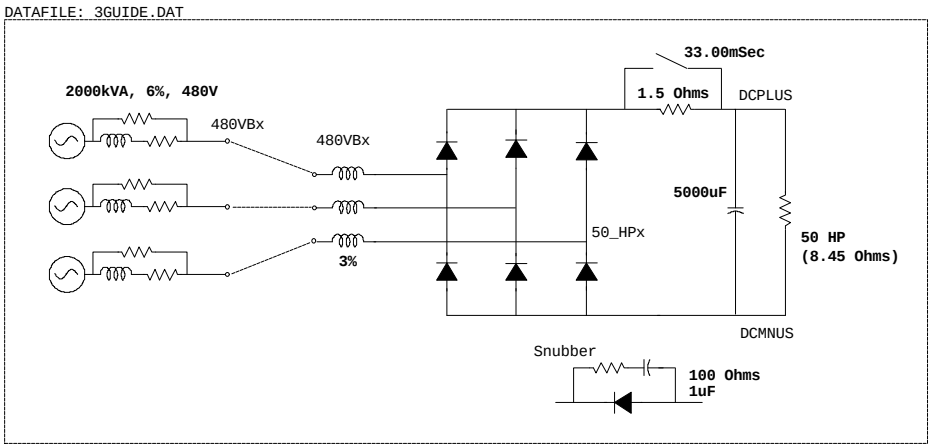
```
C Diode Snubber Circuits
C
C <---Nodes--><---Refer--><-Ohms<---mH<---uF<-------------------------------Out
C Bus1->Bus2->Bus3->Bus4-><----R<----L<----C
  TRMNLARECPOS            SNUBBR      SNUBBC
  TRMNLBRECPOS            SNUBBR      SNUBBC
  TRMNLCRECPOS            SNUBBR      SNUBBC
  TRMNLARECNEG            SNUBBR      SNUBBC
  TRMNLBRECNEG            SNUBBR      SNUBBC
  TRMNLCRECNEG            SNUBBR      SNUBBC
C .....^.....^.....^.....^.....^.....^.....^xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx^
C
C <-------- Connection to positive and negative dc bus
C
C <---Nodes--><---Refer--><-Ohms<---mH<---uF<-------------------------------Out
C Bus1->Bus2->Bus3->Bus4-><----R<----L<----C
  DIOD1CRECPOS            1.0E-5
  DIOD3CRECPOS            1.0E-5
  DIOD5CRECPOS            1.0E-5
  RECNEGDIOD4A            1.0E-5
  RECNEGDIOD6A            1.0E-5
  RECNEGDIOD2A            1.0E-5
C .....^.....^.....^.....^.....^.....^.....^xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx^
C
C <-------- Connection to power system (diode front-end)
C
C <---Nodes--><---Refer--><-Ohms<---mH<---uF<-------------------------------Out
C Bus1->Bus2->Bus3->Bus4-><----R<----L<----C
  TRMNLADIOD1A            1.0E-5
  TRMNLBDIOD3A            1.0E-5
  TRMNLCDIOD5A            1.0E-5
  DIOD4CTRMNLA            1.0E-5
  DIOD6CTRMNLB            1.0E-5
  DIOD2CTRMNLC            1.0E-5
C .....^.....^.....^.....^.....^.....^.....^xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx^
C
C <-------- Phase-to-Phase Voltage Sampling
C
C <---Nodes--><---Refer--><-Ohms<---mH<---uF<-------------------------------Out
C Bus1->Bus2->Bus3->Bus4-><----R<----L<----C
  TRMNLATRMNLB            1.0E08                                            2
  TRMNLBTRMNLC            1.0E08                                            @
  TRMNLCTRMNLA            1.0E08                                            @
C .....^.....^.....^.....^.....^.....^.....^xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx^
C
C <-------- Starting Resistor
C
C <---Nodes--><---Refer--><-Ohms<---mH<---uF<-------------------------------Out
C Bus1->Bus2->Bus3->Bus4-><----R<----L<----C
  RECPOSSHRTBK            STARTR                                            ?
C .....^.....^.....^.....^.....^.....^.....^xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx^
C
/SWITCH
C
C <-------- Starting Resistor Short Switch
C
C BUS-->BUS--><---TCLOSE<----TOPEN<-------IE<----FLASH<--REQUEST<-----TARGET<--O
  RECPOSSHRTBKRSHORTTIME     9999.                                           ?
C .....^.....^.........^.........^.........^.........^.........^...........^...^
C
/BRANCH
C
C
C
```

Module 6PDIODE - .INC File Continued

```
C
C <-------- dc Bus Components
C
C <---Nodes--><---Refer--><-Ohms<---mH<---uF<--------------------------------Out
C Bus1->Bus2->Bus3->Bus4->><----R<----L<----C
  SHRTBKDCPLUS            1.0E-5                                              ?
  DCMNUSDCPLUS            DCBUSR
  DCPLUSDCMNUS                        DCBUSC                                  2
  RECPOS                              1.0000
  RECNEG                              1.0000
  RECNEGDCMNUS            1.0E-5
C .....^.....^.....^.....^.....^.....^.....^xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx^
C
/SWITCH
C
C <-------- Diodes (front-end)
C BUS-->BUS--><------Vig<----Ihold<-------td<---------CLOSEDSame<Grid<Op/Cl<xxOO
11DIOD1ADIOD1C                0.1                                             ?
11DIOD3ADIOD3C                0.1                                             ?
11DIOD5ADIOD5C                0.1                                             ?
11DIOD4ADIOD4C                0.1                                             ?
11DIOD6ADIOD6C                0.1                                             ?
11DIOD2ADIOD2C                0.1                                             ?
C .....^.....^.........^.........^.........^.........^.........^...........^...^
/ENDMODULE
$EOF **** END OF FILE ****
DATE AND TIME OF MODULE CONVERSION:    05/04/94  11.58.18
NUMBER OF ARGUMENTS DECLARED IN THIS MODULE:    13
NUMBER OF DUMMY VARIABLES DECLARED IN THIS MODULE:    15
                     **USER-SUPPLIED HEADER CARDS FOLLOW**
ARG                                                                 - ; ARGUMENTS
FRONT, TRMNL, DCPLUS, DCMNUS,                                       - ; NODES
CHOKEL, SNUBBR, SNUBBC, STARTR,RSHORTTIME,                          - ; AC PARAME
DCBUSC, DCBUSR, ?, @                                                  ; OUTPUT RE
NUM                                                                 - ; NUMERICAL
CHOKEL, SNUBBR, SNUBBC, STARTR,RSHORTTIME,DCBUSC,DCBUSR               ; PARAMETER
DUM                                                                 - ; DUM
RECPOS, RECNEG, SHRTBK,                                             - ; DUM1
DIOD1C, DIOD2C, DIOD3C, DIOD4C, DIOD5C, DIOD6C,                     - ; DUM2
DIOD1A, DIOD2A, DIOD3A, DIOD4A, DIOD5A, DIOD6A                        ; DUM2
IOD4A, DIOD5A, DIOD6A                       ; DUM2
```

System Example #1

- System example illustrating usage of modules 3PHEQUIV and 6PDIODE:



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Module 3PHEQUIV - Argument List

Argument	Description	Type	Length	Value
TERML	Output terminal name 5 characters + (A)(B)(C)	ARG	5	480VB
ZERORE	Zero sequence source resistance (Ω)	NUM	6	0.001
ZEROINDUCTAN	Zero sequence source inductance (mH)	NUM	12	0.018
POSIRE	Positive sequence source resistance (Ω)	NUM	6	0.001
POSIINDUCTAN	Positive sequence source inductance (mH)	NUM	12	0.018
AMPLITUDES	Voltage source (peak voltage, phase-to-ground)	NUM	10	391.92
TSTARTTIME	Start time (sec), -1.0 for steady-state	NUM	10	-1.0
TSTOPTIMES	Stop time (sec), 9999. for entire simulation	NUM	10	9999.9
RDAMP1	Parallel damping resistor (Ω)	NUM	6	10
COM	Comment	N/A	N/A	None
INTERA(B)(C)	Internal nodes for voltage source connection	DUM	6	N/A

Module 6PDIODE - Argument List

Argument	Description	Type	Length	Value
FRONT	Input terminal name 5 characters + (A)(B)(C)	ARG	5	480VB
TERML	Load side of reactor name 5 characters + (A)(B)(C)	ARG	5	50_HP
DCPLUS	Positive side of dc bus	ARG	6	DCPLUS
DCMINU	Negative side of dc bus	ARG	6	DCMNUS
CHOKEL	Choke inductance (mH)	NUM	6	0.3667
SNUBBR	Snubber resistance (Ω)	NUM	6	100.0
SNUBBC	Snubber capacitance (μF)	NUM	6	1.0
STARTR	Starting resistor (Ω)	NUM	6	1.500
RSHORTTIME	Shorting switch closing time (sec)	NUM	10	33.00E-03
DCBUSC	dc bus capacitance (μF)	NUM	6	1000
DCBUSR	dc bus resistance (Ω)	NUM	6	8.45
?	Output request (current)	NUM	1	0
@	Output request (voltage)	NUM	1	0
RECPOS RECNEG SHRTBK	Internal nodes for bridge connections	DUM	6	N/A
DIOD1A, DIOD1C DIOD2A, DIOD2C DIOD3A, DIOD3C DIOD4A, DIOD4C DIOD5A, DIOD5C DIOD6A, DIOD6C	Internal nodes for diode connections	DUM	6	N/A

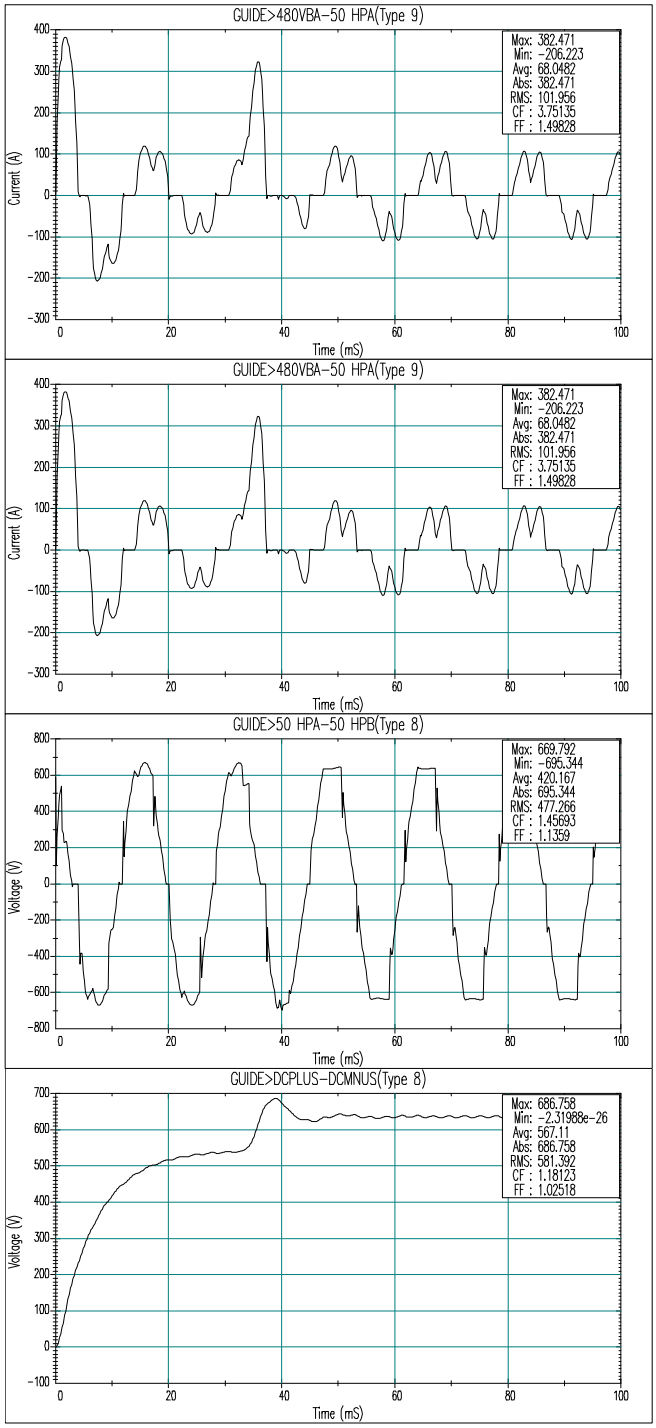
Data Case - GUIDE.DAT

```
C  ######################################################################
C
C       Title:  Three-Phase Six-Pulse Diode Bridge
C               (Using Module Files)
C
C          By:  Thomas Grebe - Electrotek Concepts, Inc.
C        Date:  May, 1994
C
C        Case:  Example for EMTP Data Module Guide
C
C   Conditions:  2000 KVA, 6%, 480 V Source
C               50 HP Drive, 3% Choke
C
C     Remarks:
C
C  ######################################################################
C
BEGIN NEW DATA CASE
$PREFIX, C:\DOC\MODULE\INCFILE\
$SUFFIX, .INC
C
C <------------------------------------------------Misc Data-----------------
C
C ----Dt<---Tmax<---Xopt<---Copt
  50E-06 100.E-3
C .....^.......^.......^.......^
C -Iprnt<--Iplot<-Idoubl<-Kssout<-Maxout<---Ipun<-Memsav<---Icat<-Nenerg
    5001       3       1       1       1       0       0       2       0
C .....^.......^.......^.......^.......^.......^.......^.......^.......^
C
C <-----------------------------------------------Circuit Data--------------
C Source Equivalent
C 2000 kVA, 6% Transformer, 480 V secondary (assume positive and zero seq equal)
C
C Usage: 3PHEQUIV TERML, R0, L0, R1, L1, VPEAK, -
C                 TSTART, TSTOP, RDAMP1 ; COM
C
$INCLUDE 3PHEQUIV 480VB, 0.001, 0.018, 0.001, 0.018, 391.92, -
                   -1.0, 9999.9, 10.0
C
C Six-Pulse Diode Bridge
C 50 HP, 3% Choke, Snubber = 100 Ohms & 1.0uF
C
C Usage: 6PDIODE FRONT,  TRMNL,  DCPLUS, DCMINU,                            -; NODES
C                 CHOKEL, SNUBBR, SNUBBC, STARTR, RSHORTIME,                -; PARA
C                 DCBUSC, DCBUSR, ?, @                                      -; PARA
C
$INCLUDE 6PDIODE  480VB, 50_HP, DCPLUS, DCMNUS, -
                  0.3667, 100.0, 1.0, 1.500, 33.00E-3, -
                  5000.0, 8.45, 0, 0
C
C <-----------------------------------------------Nodal Output--------------
/OUTPUT
C BUS-->BUS-->BUS-->
  480VBA480VBB480VBC
C .....^.....^.....^
BLANK ENDS BRANCH
BLANK ENDS SWITCH
BLANK ENDS SOURCE
BLANK ENDS OUTPUT
BLANK ENDS PLOT
BLANK ENDS CASE
```

Network Connectivity - GUIDE.DAT

```
FROM BUS NAME 1 NAMES OF ALL ADJACENT BUSSES
 -------------+------------------------------------------------------------
        480VBA1DUM003*DUM003*50 HPA*
        DUM0031480VBA*480VBA*
        480VBB1DUM002*DUM002*50 HPB*
        DUM0021480VBB*480VBB*
        480VBC1DUM001*DUM001*50 HPC*
        DUM0011480VBC*480VBC*
        50 HPA1480VBA*50 HPB*50 HPC*DUM018*DUM017*DUM009*DUM012*
        50 HPB1480VBB*50 HPA*50 HPC*DUM018*DUM017*DUM007*DUM010*
        50 HPC1480VBC*50 HPA*50 HPB*DUM018*DUM017*DUM005*DUM014*
        DUM0181TERRA *50 HPA*50 HPB*50 HPC*DUM015*DUM013*DUM011*DUM016*DUM016*
        DUM0171TERRA *50 HPA*50 HPB*50 HPC*DUM006*DUM004*DUM008*DCMNUS*
        DUM0151DUM018*DUM009*
        DUM0131DUM018*DUM007*
        DUM0111DUM018*DUM005*
        DUM0061DUM017*DUM012*
        DUM0041DUM017*DUM010*
        DUM0081DUM017*DUM014*
        DUM009150 HPA*DUM015*
        DUM007150 HPB*DUM013*
        DUM005150 HPC*DUM011*
        DUM012150 HPA*DUM006*
        DUM010150 HPB*DUM004*
        DUM014150 HPC*DUM008*
        DUM0161DUM018*DUM018*DCPLUS*
        DCPLUS1DUM016*DCMNUS*DCMNUS*
        DCMNUS1DUM017*DCPLUS*DCPLUS*
        TERRA 1DUM018*DUM017*
 -------------+------------------------------------------------------------
```

Sample Resutls for Case GUIDE.DAT



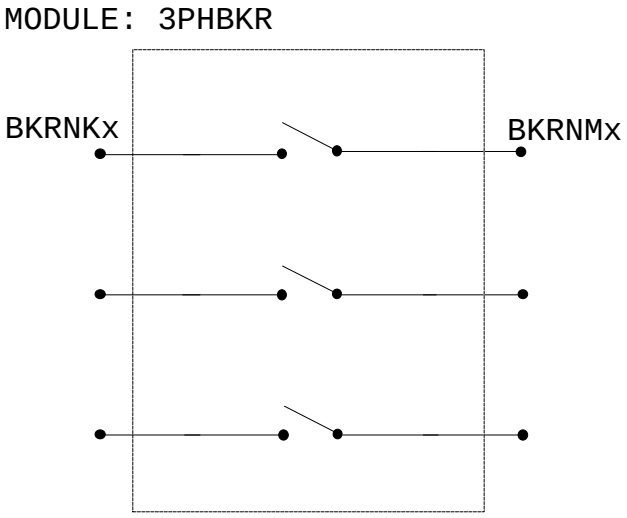
MODULE: 3PHBKR

Description: **Three-Phase Time Controlled Circuit Breaker**

Usage:

```
$INCLUDE 3PHBKR BKRNK, BKRNM, CLOSINGTMA, -
          OPENINGTMA, CLOSINGTMB, OPENINGTMB, -
          CLOSINGTMC, OPENINGTMC, STRAYC, ? ; COM
```

Diagram:



Example:

```
$INCLUDE 3PHBKR BUS01, CAP01, 66.66E-03, 9999.9, -
         70.00E-03, 9999.9, 68.00E-03, 9999.9, -
         0.0001, 1
```

Parameter List:

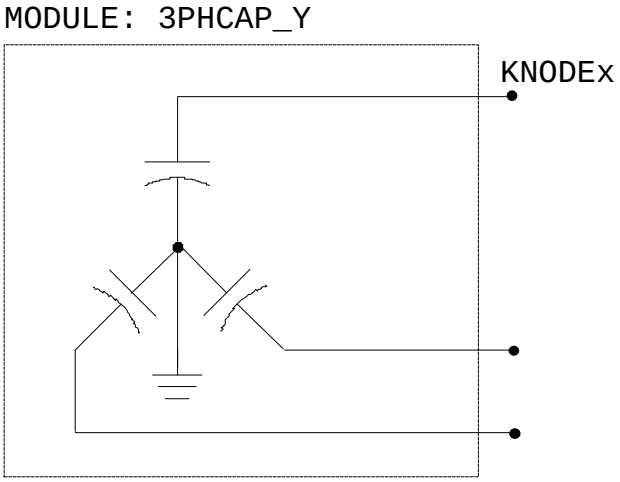
Argument	Description	Type	Length
BKRNK	From terminal name 5 characters + (A)(B)(C)	ARG	5
BKRNM	From terminal name 5 characters + (A)(B)(C)	ARG	5
CLOSINGTMA	Phase A closing time (sec), -1.0 for steady-state	NUM	10
OPENINGTMA	Phase A opening time (sec), -1.0 for steady-state	NUM	10
CLOSINGTMB	Phase B closing time (sec), -1.0 for steady-state	NUM	10
OPENINGTMB	Phase B opening time (sec), -1.0 for steady-state	NUM	10
CLOSINGTMB	Phase B closing time (sec), -1.0 for steady-state	NUM	10
OPENINGTMB	Phase B opening time (sec), -1.0 for steady-state	NUM	10
STRAYC	Parallel damping resistor (Ω)	NUM	6
?	Output request (1: current, 2: branch voltage)	ARG	1

MODULE: 3PHCAP_Y

Description: **Three-phase Wye-Grounded Capacitor Bank**

Usage: `$INCLUDE 3PHCAP_Y KNODE, CPHASE, ? ; COM`

Diagram:



Parameter List:

Argument	Description	Type	Length
KNODE	Capacitor terminal name 5 characters + (A)(B)(C)	ARG	5
CPHASE	Capacitor value - wye connected (μF)	NUM	6
?	Output request (1: current, 2: branch voltage)	NUM	1
COM	Comment	N/A	N/A

Example:

```
$INCLUDE 3PHCAP_Y CAP01, 4.42, 0
```

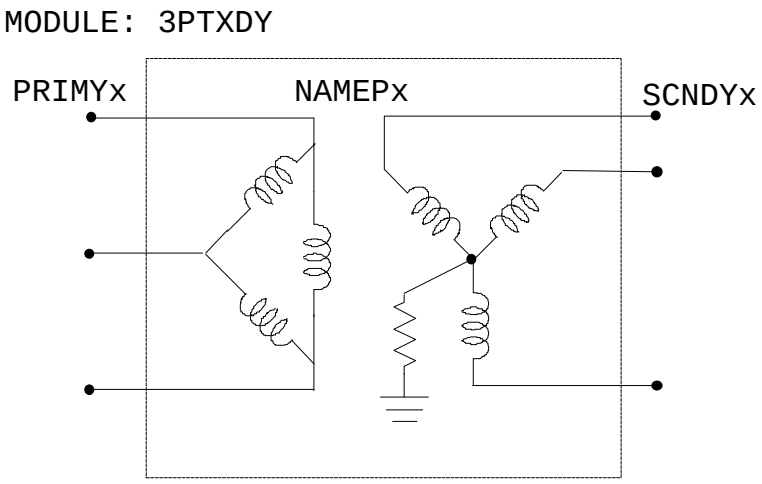
MODULE: 3PHTXDY

Description: **Three-Phase Delta/Wye Transformer**

Usage:

```
$INCLUDE 3PHTXDY PRIMY, SCNDY, NAMEP, RESHGH, -
         INDHGH, VLTHGH, RESLOW, INDLOW, VLTLOW, -
         GNDRES, ? ; COM
```

Diagram:



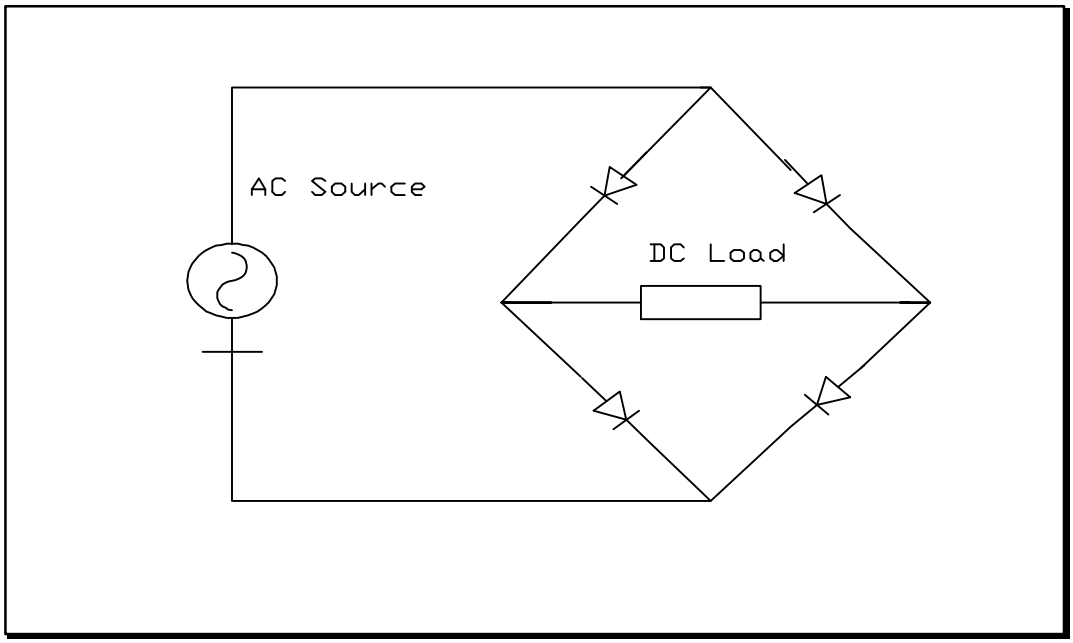
Example:

```
$INCLUDE 3PHTXDY BUS01, 13BUS, XFMR1, 79.35, 2104.8, -
         230.0, 0.087, 2.31, 7.62, 0.001, 0
```

Parameter List:

Argument	Description	Type	Length
PRIMY	Primary terminal name 5 characters + (A)(B)(C)	ARG	5
SCNDY	Secondary terminal name 5 characters + (A)(B)(C)	ARG	5
NAMEP	Transformer name 5 characters + (A)(B)(C)	ARG	5
RESHGH	High-side resistance (Ω)	NUM	6
INDHGH	High-side inductance (mH)	NUM	6
VLTHGH	High-side voltage (kV)	NUM	6
RESLOW	Low-side resistance (Ω)	NUM	6
INDLOW	Low-side inductance (mH)	NUM	6
VLTLOW	Low-side voltage (kV)	NUM	6
GNDRES	Grounding resistance (Ω)	NUM	6
?	Output request (ground) (1: current, 2: branch voltage)	NUM	1
COM	Comment	N/A	N/A

Single Phase Power Supply Module



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Single Phase Power Supply Module - cont

```
C ************************************************************************
C                      Power Electronics Applications:
C                       A Single-Phase Power Supply
C                             ETK-LM062994LT
C EX1.dat
$PREFIX C:\ETK\MODULE\INCFILE\
$SUFFIX .INC
BEGIN NEW DATA CASE
C ----Dt<---Tmax<---Xopt<---Copt
46.3E-06 0.10000
C -Iprnt<--Iplot<-Idoubl<-Kssout<-Maxout<---Ipun<-Memsav<---Icat<-Nenerg
   5001       1       0       0       1       0       0       2       0
C ************************************************************************
C
C 13.8kV, 3-phase Voltage Source:
C
C               BUS-1, R0    L0     R1    L1     RD  Vphpk  Tstart,Tstop ;  COM.
$INCLUDE 3PHRDS  V7697, .0033,0.4959,.0066,0.3364,20.,11268.,-1.0,  9999  ;
C
C A 50 kVA 2% single phase pole top transformer:
C
C NCLUDE 1PHXFMS  XFMHVA, XFMHVX, XFMLVA, XFMLVX                - ;
C                 Rh,     Lh,     Vh,     Rl,     Ll,     Vl      ;
$INCLUDE 1PHXFMS  V7697A, V7697X, TX120A, TX120X,                 - ;
                  5.0778, 33.673, 7967.4, 0.0576, 0.3819, 120.00   ;  parameters
C
C Transformer grounding
C
$INCLUDE 1PHRLC   V7697X, ______, 0.001, 0.005, 0.0,  0            ;  grounding
$INCLUDE 1PHRLC   TX120X, ______, 0.001, 0.005, 0.0,  0            ;  grounding
```

EMTP Data Module Workshop *Slide 45*

Single Phase Power Supply Module - cont

```
C
C Residential subdivision over head wire into HOUSE#1
C
$INCLUDE 1PHRLC   TX120A, HOUS1A, 0.015, 0.008, 0.0,  1  ; 100' over-head
$INCLUDE 1PHRLC   TX120X, HOUS1X, 0.015, 0.008, 0.0,  1  ; 100' over-head
C
C LINEAR LOADS in HOUSE1
C
C 100 W motor load: pf=0.8, eff=.9,
C (120^2)*0.8*0.9/100=103.68@36.87 = 82.944+jw*165.08 mH
C
$INCLUDE 1PHRLC HOUS1A, HOUS1X, 82.944, 165.08, 0.00,  1 ; 100 W motor
C
C 150 W Regular load: (120^2/150=96.0ohms) in HOUS1A
C
$INCLUDE 1PHRLC HOUS1A, HOUS1X, 96.00, 0.00,    0.00,  1 ; 150 W lights
C
C 250 W Non-linear loads in HOUSE1
C
C                FRONTM, FRONTN, DCPLUS, DCMNUS,                 - ;  CON. NODES
C                CHOKER, CHOKEL, SNUBBR, SNUBBC, STARTR, SHRT,   - ;  NUM.
C                DCBUSC, LOADSR, LOADSL, LOADPR, LOADPL, ?, @      ;  PARA.
$INCLUDE 1PHDB   HOUS1A, HOUS1X, H1DC1P, H1DC1N,                 - ; NODES
                 0.0100, 2.7500, 100.0,  0.150,   5.0,    .025,  - ; PARA.
                 100.0,  1.0E06, 1.0E06, 57.60,   0.0,   1, 2      ; PARA.
C
/OUTPUT
  V7697A      TX120A      HOUS1A      HOUS1X
/PLOT
$INCLUDE ENDRUN
```

EMTP Data Module Workshop *Slide 46*

Single Phase Power Supply Module - cont

```
C ************************************************************************
C *             A Single Phase Diode Bridge Rectifier Module
C *                          lt122293
C NCLUED 1DIOCNVT FRONTN, FRONTM, DCPLUS, DCMNUS,                    - ; NODES
C                 CHOKEL, SNUBBR, SNUBBC, STARTR, RSHORTTIME,        - ; NUM.
C                 DCBUSC, LOADSR, LOADSL, LOADPR, LOADPL,     ?,  @    ; PARA.
C ************************************************************************
ARG                                                                  - ; ARGUMENTS
FRONTM, FRONTN, DCPLUS, DCMNUS,                                      - ; CON.
NODES
CHOKER, CHOKEL, SNUBBR, SNUBBC, STARTR, RSHORTTIME,                  - ; NUM.
DCBUSC, LOADSR, LOADSL, LOADPR, LOADPL, ?, @                           ; PARA.
NUM                                                                  - ; NUMERICAL
CHOKER, CHOKEL, SNUBBR, SNUBBC, STARTR, RSHORTTIME,                  - ; NUM.
DCBUSC, LOADSR, LOADSL, LOADPR, LOADPL                                 ; PARA.
DUM                                                                  - ; DUM
DIOD1A, DIOD1C, DIOD2A, DIOD2C, DIOD3A, DIOD3C, DIOD4A, DIOD4C,      - ; DUM1
TRMNLM, TRMNLN, SHRTBK, RECPOS, RECNEG                                 ; DUM2
/BRANCH
C AC Choke Inductance
C <-Bus1<-Bus2<-Bus3<-Bus4<----R<----L<----C                                V
  FRONTMTRMNLM            CHOKERCHOKEL                                     1
  FRONTNTRMNLN            CHOKERCHOKEL
C Diode Snubber Circuits
C <-Bus1<-Bus2<-Bus3<-Bus4<----R<----L<----C                                V
  TRMNLMRECPOS            SNUBBR      SNUBBC
  TRMNLMRECNEG            SNUBBR      SNUBBC
  RECPOSTRMNLN            SNUBBR      SNUBBC
  RECNEGTRMNLN            SNUBBR      SNUBBC
```

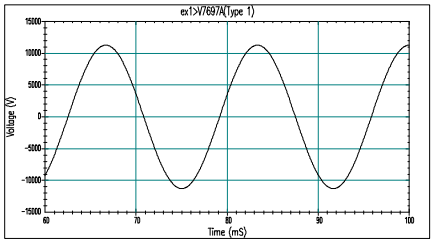
EMTP Data Module Workshop *Slide 47*

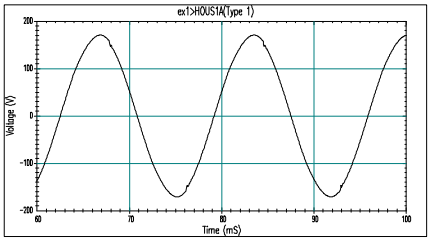
Single Phase Power Supply Module - cont

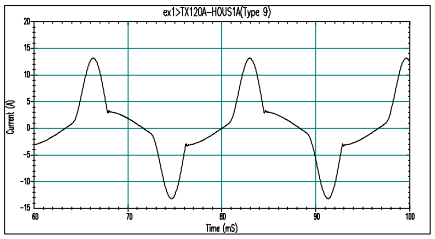
```
C <-------- Connection to power system (diode front-end)
  TRMNLMDIOD1A            1.0E-5
  DIOD1CRECPOS            1.0E-5
  TRMNLMDIOD3C            1.0E-5
  DIOD3ARECNEG            1.0E-5
  RECPOSDIOD4C            1.0E-5
  DIOD4ATRMNLN            1.0E-5
  RECNEGDIOD2A            1.0E-5
  DIOD2CTRMNLN            1.0E-5
C <-------- Starting Resistor
  RECPOSSHRTBK            STARTR
C <-------- dc Bus
  RECPOS                  1.0E06
  SHRTBKDCPLUS            1.0E-5
  DCPLUSDCMNUS            LOADSRLOADSL
  DCPLUSDCMNUS                        DCBUSC                                  2
  DCPLUSDCMNUS            LOADPRLOADPL
  RECNEGDCMNUS            1.0E-5
  RECNEG                  1.0E06
/SWITCH
C <-------- Starting Resistor Short Switch
C BUS-->BUS-->&lt;---TCLOSE<----TOPEN<-------IE<----FLASH<--REQUEST<-----TARGET<--O
  RECPOSSHRTBKRSHORTTIME      9999
C <-------- Diodes (front-end)
C <BUS-><BUS-><-----Vig><---Ihold><-------td<---------CLOSEDSame<Grid<Op/Cl<xxOO
11DIOD1ADIOD1C       0.0       0.0                                             ?
11DIOD2ADIOD2C       0.0       0.0
11DIOD3ADIOD3C       0.0       0.0                                             @
11DIOD4ADIOD4C       0.0       0.0
/ENDMODULE
$EOF
```

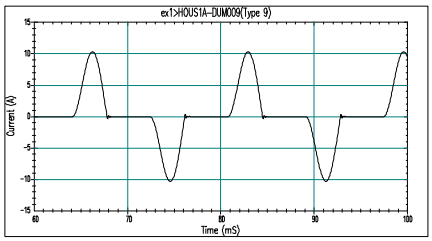
EMTP Data Module Workshop *Slide 48*

Single Phase Power Supply Module - cont





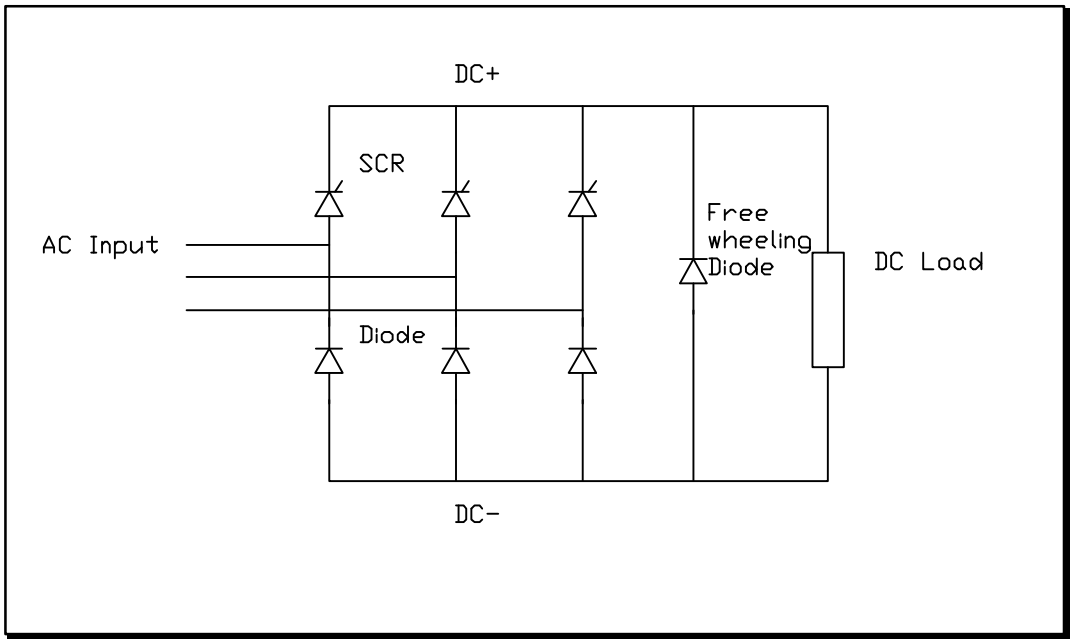




Suggested Excises:
1) Rerun the case and using TOP to get current harmonics
2) Rerun with 10% ac choke to see how it affects the current harmonics
3) Rerun the case with a different time step size.

EMTP Data Module Workshop *Slide 49*

Semiconverter Module



EMTP Data Module Workshop *Slide 50*

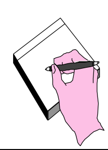
Semiconverter Module - cont

```
C ************************************************************************
C                     Power Electronics Applications:
C               Semi-controlled three-phase bridge rectifier
C                           ETK-LM042893LT
C EX2.dat
$PREFIX C:\ETK\MODULE\INCFILE\
$SUFFIX .INC
BEGIN NEW DATA CASE
C ----Dt<---Tmax<---Xopt<---Copt
46.30E-6 0.08300
C -Iprnt<--Iplot<-Idoubl<-Kssout<-Maxout<---Ipun<-Memsav<---Icat<-Nenerg
  150000       1       0       0       0      -1       0       1       0
C 1st  ><change>< 2nd  ><change>< 3rd  ><change>< 4th  ><change>< 5th  ><change>
  250000       1
C ************************************************************************
TACS HYBRID
/TACS
C       Firing delay in Radian
98ALPHAD  =100.
98ALPHAR  =ALPHAD*PI/180.
33ALPHAD
C ^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^
C 480 ac voltage source 1000kVA, 6.5 %, SC=15 MVA
C               BUS-1, R0    L0      R1    L1     RD  Vphpk  Tstart,Tstop ; COM.
$INCLUDE 3PHRDS  SOURC, .0004, .06, .0008, .0407, 20., 392., -.0825, 9999 ;
C
C               BUS-1, R,      L,     C,     ?, @     ; COM. RLC bank
$INCLUDE 3PHWYEG SOURC, 1.0E06, 0.0,   0.0,   0, 0     ; V REF.
C
C               BUS1,  BUS2,  Tcls,   Topen,Ie,  ?, @ ; 3-phase breaker
$INCLUDE 3PHBRK  SOURC, TY480, -1.000, 9999, 0.0, 1, 1 ; measuring
C ^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^
```


Semiconverter Module - cont

```
C       Power transformer (delta/wye with nuetral grounded), and
C       Stray Capacitance for PE switching (opertimized dampping)
C                 BUS-1,  R,    L,   C,     ?, @         ; COM. RLC bank
$INCLUDE 3PHWYEG  SOURC,  18.0, 0.0, 0.556, 0, 0         ; Stray C and damping
C
C                 BUS1,   BUS2,   NEUTRL, NAMES,       - ; CONNECTION BUS
C                 Rh,     Lh,     Vh,                  - ; primary winding
C                 Rl,     Ll,     Vl,     Rg             ; secondary winding
$INCLUDE 3DYXFM1S TY480,  CNVRT,  TXMRNT, CNVTX,       - ;
                  0.0138, 0.3667, 480.,                - ; 480 V DELTA SIDE
                  0.0046, 0.1222, 277.00, 10.E-6         ; 480 V WYE-g SIDE
$INCLUDE 3PHWYEG  CNVRT, 18.0, 0.0, 0.556, 0, 0          ; Stray C and damping
C ^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^
C 3-Phase Semiconverter (SCR) Module
C NCLUED 3PSCR1 FRONT, TRMNL, DCPLUS,DCMNUS,REFVN, ALPHAA,                 - ;
NODES
C               REFSFT,CHOKEL,SNUBBR,SNUBBL,SNUBBC,STARTR,RSHORTIME,REACTR,- ;
C               STRAYR,STRAYC,?,@                                            ;
PARA.
C USAGE:
$INCLUDE 3PSCR2 CNVRT, BRDGP, DCPLUS,DCMNUS,SOURC, ALPHAR,                 - ;
NODES
                30.0,  0.0,   100.,  0.0,   5.0,   0.050, -.05,     .0001, - ;
PARA1.
                10.,   1.0,   1,1                                            ;
PARA2.
$INCLUDE 1PHRLC DCPLUS,DCMNUS, 1.5,  10.,  0.0, 1  ; DC bus load
C ^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^
/OUTPUT
C Bus1->Bus2->Bus3->Bus4->Bus5->Bus6->Bus7->
  SOURCASOURCBSOURCCCNVRTACNVRTBCNVRTC
C ^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^
/PLOT
$INCLUDE ENDRUNTC
```

EMTP Data Module Workshop *Slide 52*



Semiconverter Module - cont

```
C ************************************************************************
C *                    3-Phase Semiconverter (SCR) Module
C INCLUED 3PSCR2   FRONT,TRMNL,DCPLUS,DCMNUS,REFVN,ALPHAA,
- ; NODES
C                  FDELAY,CHOKEL,SNUBBR,SNUBBL,SNUBBC,STARTR,RSHORTIME,REACTR,
- ;
C                  STRAYR,STRAYC,?,@
; PARA.
C Using a smaller connection stub line resistance 1.0e-6 instead of 1.0e-5
C USING Vf=0.3 Ih=0.1
C ************************************************************************
ARG                                                          - ; ARGUMENTS
FRONT,TRMNL,DCPLUS,DCMNUS,REFVN,ALPHAA,                      - ; CON. NODES
FDELAY,CHOKEL,SNUBBR,SNUBBL,SNUBBC,STARTR,RSHORTTIME,REACTR, - ; PARAMETERS
STRAYR,STRAYC,?, @                                             ; OUTPUT
REQ.
NUM                                                          - ; NUMERICAL
FDELAY,CHOKEL,SNUBBR,SNUBBL,SNUBBC,STARTR,RSHORTTIME,REACTR, - ; PARAMETERS
STRAYR,STRAYC                                                  ; STRAY R
AND C
DUM                                                          - ; DUM
VARIABLE
PULSE1, PULSE2, PULSE3, PULSE4, PULSE5, PULSE6,              - ; DUM1
PULSE7, PULSE8, PULSE9, CNTRL1, CNTRL2, CNTRL3,              - ; DUM2
THYT1A, THYT2A, THYT3A, DIOD1A, DIOD2A, DIOD3A,              - ; DUM3
THYT1C, THYT2C, THYT3C, DIOD1C, DIOD2C, DIOD3C,              - ; DUM4
RECPOS, RECNEG, SHRTBK, TDELAY, REFSFT, VANRMS                 ; DUM5
C C
C  -------------------------FIRING CONTROL-------------------------
/TACS
90REFVNA
90REFVNB
90REFVNC
98VANRMS66+REFVNA                              60.000
```

EMTP Data Module Workshop *Slide 53*

Semiconverter Module - cont

```
C <---------Ref. signal for firing angles in step with line-line voltage
98PULSE1  =(REFVNA .GT. REFVNC)
98PULSE2  =(REFVNB .GT. REFVNA)
98PULSE3  =(REFVNC .GT. REFVNB)
C C DEVICE 53 USING NAMED DELAY "REFSFT" TO ADJUST REFERENCE POINT
98REFSFT  =FDELAY*PI/(180.*377.)
98PULSE453+PULSE1                                  0.0         0.0085REFSFT
98PULSE553+PULSE2                                  0.0         0.0085REFSFT
98PULSE653+PULSE3                                  0.0         0.0085REFSFT
C C DEVICE 53 USING NAMED DELAY "TDELAY" TO CONTROL FIRING ANGLE
98TDELAY  =ALPHAA/377.
98PULSE753+PULSE4                                  0.0         0.0085TDELAY
98PULSE853+PULSE5                                  0.0         0.0085TDELAY
98PULSE953+PULSE6                                  0.0         0.0085TDELAY
98CNTRL1  =((PULSE7*PULSE4) .GT. ZERO  )
98CNTRL2  =((PULSE8*PULSE5) .GT. ZERO  )
98CNTRL3  =((PULSE9*PULSE6) .GT. ZERO  )
C  TACS output requests
33PULSE1PULSE4PULSE7CNTRL1CNTRL2CNTRL3
33VANRMS
/BRANCH
C AC Choke Inductance
C <-Bus1<-Bus2<-Bus3<-Bus4<----R<----L<----C                                  V
  FRONTATRMNLA            1.0E-6CHOKEL                                        1
  FRONTBTRMNLB            1.0E-6CHOKEL                                        @
  FRONTCTRMNLC            1.0E-6CHOKEL                                        @
C Diode Snubber Circuits
C <-Bus1<-Bus2<-Bus3<-Bus4<----R<----L<----C                                  V
  THYT1ATHYT1C          SNUBBRSNUBBLSNUBBC
  THYT2ATHYT2C          SNUBBRSNUBBLSNUBBC
  THYT3ATHYT3C          SNUBBRSNUBBLSNUBBC
  DIOD1ADIOD1C          SNUBBRSNUBBLSNUBBC
  DIOD2ADIOD2C          SNUBBRSNUBBLSNUBBC
  DIOD3ADIOD3C          SNUBBRSNUBBLSNUBBC
```

EMTP Data Module Workshop *Slide 54*

Semiconverter Module - cont

```
C <-------- Connection to positive and negative dc bus
C <-Bus1<-Bus2<-Bus3<-Bus4<----R<----L<----C                                V
  THYT1CRECPOS            1.0E-6
  THYT2CRECPOS            1.0E-6
  THYT3CRECPOS            1.0E-6
  THYT1CRECPOS                  0.0001
  THYT2CRECPOS                  0.0001
  THYT3CRECPOS                  0.0001
C C
  RECNEGDIOD2A            1.0E-6
  RECNEGDIOD3A            1.0E-6
  RECNEGDIOD1A            1.0E-6
  RECNEGDIOD2A                  0.0001
  RECNEGDIOD3A                  0.0001
  RECNEGDIOD1A                  0.0001
C <-------- Connection to power system (diode front-end)
C <-Bus1<-Bus2<-Bus3<-Bus4<----R<----L<----C                                V
  TRMNLATHYT1A            1.0E-6
  TRMNLBTHYT2A            1.0E-6
  TRMNLCTHYT3A            1.0E-6
  TRMNLATHYT1A                  0.0001
  TRMNLBTHYT2A                  0.0001
  TRMNLCTHYT3A                  0.0001
C C
  DIOD2CTRMNLA            1.0E-6
  DIOD3CTRMNLB            1.0E-6
  DIOD1CTRMNLC            1.0E-6
  DIOD2CTRMNLA                  0.0001
  DIOD3CTRMNLB                  0.0001
  DIOD1CTRMNLC                  0.0001
C <-------- Phase-to-Phase Voltage Sampling
C <-Bus1<-Bus2<-Bus3<-Bus4<----R<----L<----C                                V
  TRMNLATRMNLB            1.0E08                                            ?
  TRMNLBTRMNLC            1.0E08                                            @
  TRMNLCTRMNLA            1.0E08                                            @
```

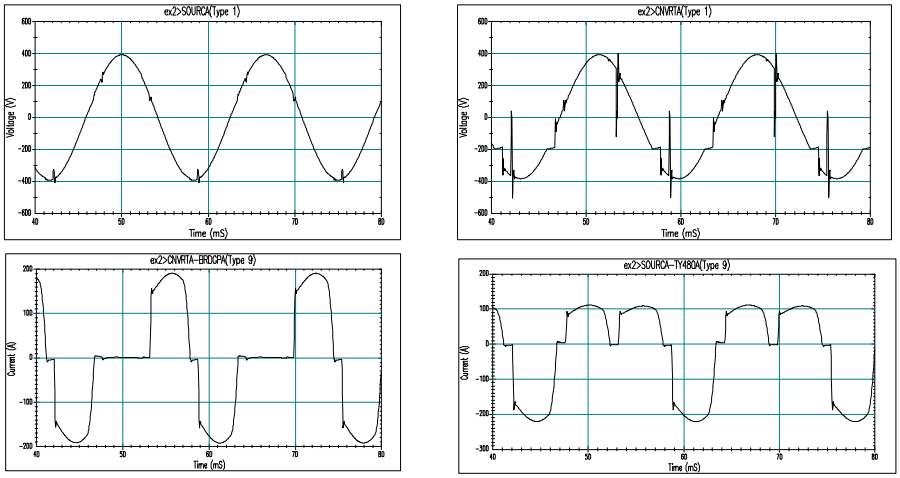
EMTP Data Module Workshop *Slide 55*

Semiconverter Module - cont

```
C <-------- Starting Resistor
C <-Bus1<-Bus2<-Bus3<-Bus4<----R<----L<----C                                V
  RECPOSSHRTBK            STARTR
/SWITCH
C <-------- Starting Resistor Short Switch
C BUS-->BUS--><---TCLOSE<----TOPEN<-------IE<----FLASH<--REQUEST<-----TARGET<--O
  RECPOSSHRTBKRSHORTTIME      9999                                          0
/BRANCH
C <-------- dc Bus
C <-Bus1<-Bus2<-Bus3<-Bus4<----R<----L<----C                                V
  SHRTBKDCPLUS            1.0E-6REACTR                                      0
?
  RECPOS                  STRAYR      STRAYC
  DCPLUSDCMNUS            1.0E08                                            2
  RECNEG                  STRAYR      STRAYC
  RECNEGDCMNUS            1.0E-6REACTR
/SWITCH
C <-------- Upper bridge SCRs and Low bridge diodes
C BUS-->BUS--><------Vig<----Ihold<-------td<---------CLOSEDSame<Grid>SIGNALxxOO
11THYT1ATHYT1C      0.3      0.1                                 CNTRL1         ?
11THYT2ATHYT2C      0.3      0.1                                 CNTRL2         @
11THYT3ATHYT3C      0.3      0.1                                 CNTRL3         @
11DIOD2ADIOD2C      0.3      0.1                                                @
11DIOD3ADIOD3C      0.3      0.1                                                @
11DIOD1ADIOD1C      0.3      0.1                                                ?
C <-------- Flywheel diode
C BUS-->BUS--><------Vig<----Ihold<-------td<---------CLOSEDSame<Grid>SIGNALxxOO
11RECNEGRECPOS      0.3      0.1                                                1
/ENDMODULE
$EOF
```

EMTP Data Module Workshop *Slide 56*

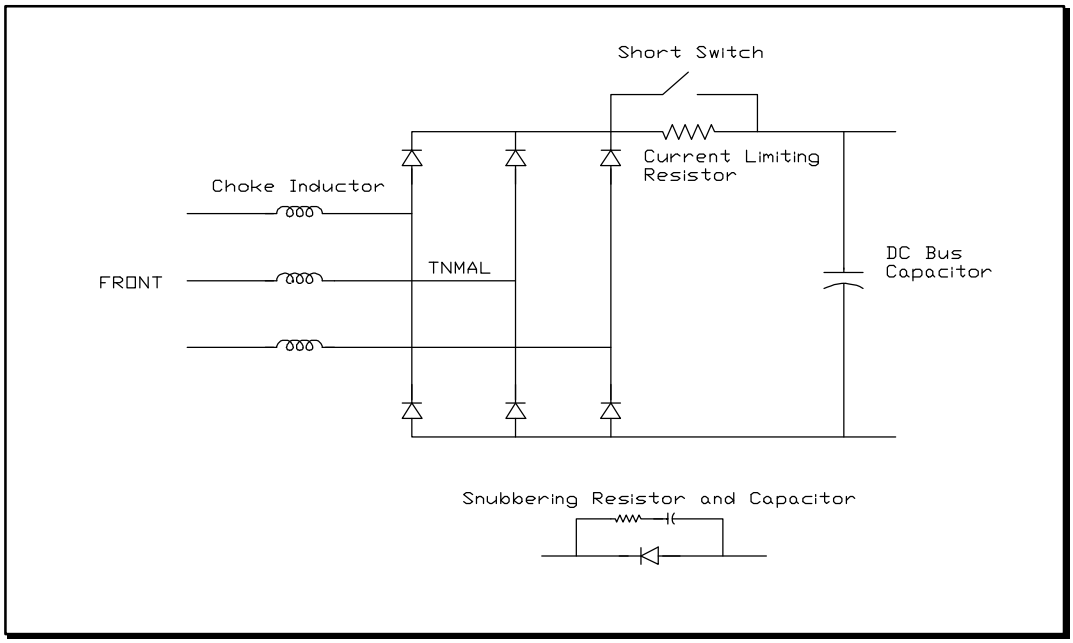
Semiconverter Module - cont



Suggested Excises:

1) Rerun the case and using TOP to get primary and secondary side current harmonics
2) Rerun the case with alpha=15 degrees, modify the case file to have Vll output
3) Rerun the case with alpha=60 degrees, comparing the voltage and current waveforms obtained with different firing delaying angles.

Six Pulse Diode Bridge Rectifier Module



EMTP Data Module Workshop *Slide 58*

Six Pulse Diode Bridge Rectifier - cont

```
C ************************************************************************
C *
C *           General Diode Bridge Rectifier Module (LT081193)
C *
C USAGE: INCLUED DIOCNVT FRONT,  TRMNL,  DCPLUS, DCMINU,            -; NODES
C *              CHOKEL, SNUBBR, SNUBBC, STARTR, RSHORTIME, DCBUSC   ; PARA.
C ************************************************************************
ARG                                                                 - ; ARGUMENTS
FRONT, TRMNL, DCPLUS, DCMNUS,                                       - ; CON. NODES
CHOKEL, SNUBBR, SNUBBC, STARTR,RSHORTTIME,DCBUSC,                   - ; PARAMETERS
?, @                                                                  ; OUTPUT REQ.
NUM                                                                 - ; NUMERICAL
CHOKEL, SNUBBR, SNUBBC, STARTR,RSHORTTIME,DCBUSC                     ; PARAMETERS
DUM                                                                 - ; DUM
RECPOS, RECNEG, SHRTBK,                                             - ; DUM1
DIOD1C, DIOD2C, DIOD3C, DIOD4C, DIOD5C, DIOD6C,                     - ; DUM2
DIOD1A, DIOD2A, DIOD3A, DIOD4A, DIOD5A, DIOD6A                       ; DUM2
/BRANCH
C AC Choke Inductance
C <-Bus1<-Bus2<-Bus3<-Bus4<----R<----L<----C                                V
  FRONTATRMNLA            1.0E-5CHOKEL                                      1
  FRONTBTRMNLB            1.0E-5CHOKEL                                      ?
  FRONTCTRMNLC            1.0E-5CHOKEL                                      ?
C Diode Snubber Circuits
C <-Bus1<-Bus2<-Bus3<-Bus4<----R<----L<----C                                V
  TRMNLARECPOS            SNUBBR      SNUBBC
  TRMNLBRECPOS            SNUBBR      SNUBBC
  TRMNLCRECPOS            SNUBBR      SNUBBC
C <-Bus1<-Bus2<-Bus3<-Bus4<----R<----L<----C                                V
  TRMNLARECNEG            SNUBBR      SNUBBC
  TRMNLBRECNEG            SNUBBR      SNUBBC
  TRMNLCRECNEG            SNUBBR      SNUBBC
C <-------- Connection to positive and negative dc bus
C <-Bus1<-Bus2<-Bus3<-Bus4<----R<----L<----C                                V
  DIOD1CRECPOS            1.0E-5
  DIOD3CRECPOS            1.0E-5
  DIOD5CRECPOS            1.0E-5
  RECNEGDIOD4A            1.0E-5
  RECNEGDIOD6A            1.0E-5
  RECNEGDIOD2A            1.0E-5
```

EMTP Data Module Workshop *Slide 59*

Six Pulse Diode Bridge Rectifier - cont

```
C <-------- Connection to power system (diode front-end)
C <-Bus1<-Bus2<-Bus3<-Bus4<----R<----L<----C                                V
  TRMNLADIOD1A            1.0E-5
  TRMNLBDIOD3A            1.0E-5
  TRMNLCDIOD5A            1.0E-5
  DIOD4CTRMNLA            1.0E-5
  DIOD6CTRMNLB            1.0E-5
  DIOD2CTRMNLC            1.0E-5

C <-------- Phase-to-Phase Voltage Sampling
C <-Bus1<-Bus2<-Bus3<-Bus4<----R<----L<----C                                V
  TRMNLATRMNLB            1.0E08                                           2
  TRMNLBTRMNLC            1.0E08                                           @
  TRMNLCTRMNLA            1.0E08                                           @
C <-------- Starting Resistor
C <-Bus1<-Bus2<-Bus3<-Bus4<----R<----L<----C                                V
  RECPOSSHRTBK            STARTR                                           ?
/SWITCH
C <-------- Starting Resistor Short Switch
C BUS-->BUS-->&lt;---TCLOSE<----TOPEN<-------IE<----FLASH<--REQUEST<-----TARGET<--O
  RECPOSSHRTBKRSHORTTIME      9999                                         ?
/BRANCH
C <-------- dc Bus
C <-Bus1<-Bus2<-Bus3<-Bus4<----R<----L<----C                                V
  SHRTBKDCPLUS            1.0E-5                                           ?
  DCMNUSDCPLUS            10000.
  DCPLUSDCMNUS                      DCBUSC                                 2
  RECPOS                            1.0000
  RECNEG                            1.0000
  RECNEGDCMNUS            1.0E-5
/SWITCH
C <-------- Diodes (front-end)
C BUS-->BUS-->&lt;------Vig<----Ihold<-------td<---------CLOSEDSame<Grid<Op/Cl<xxOO
11DIOD1ADIOD1C               0.1                                           3
11DIOD3ADIOD3C               0.1                                           ?
11DIOD5ADIOD5C               0.1                                           ?
11DIOD4ADIOD4C               0.1                                           ?
11DIOD6ADIOD6C               0.1                                           ?
11DIOD2ADIOD2C               0.1                                           ?
/ENDMODULE
$EOF
```

EMTP Data Module Workshop *Slide 60*

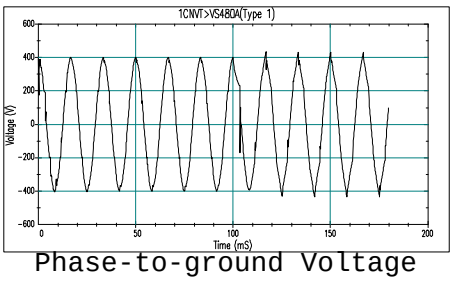
Six Pulse Diode Bridge Rectifier - cont

Input file listing:

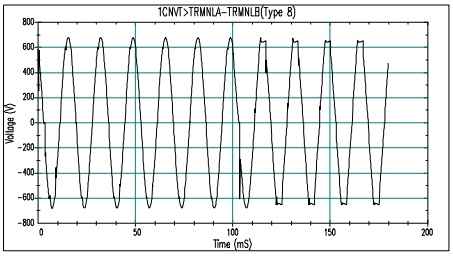
```
C ************************************************************************
C                  EMTP INPUT MODULE USING ILLUSTRATION CASE
BEGIN NEW DATA CASE
C ----Dt<---Tmax<---Xopt<---Copt
 50.E-060.180000
C -Iprnt<--Iplot<-Idoubl<-Kssout<-Maxout<---Ipun<-Memsav<---Icat<-Nenerg
    5001       3       1       3       1       0       0       2       0
$PREFIX C:\ETK\MODULE\INCFILE\
$SUFFIX .INC
C ************************************************************************
C
C       480 Voltage Source
C                BUS-1, R0      L0      R1      L1      RD     Vphpk
C                Tstart,Tstop
$INCLUDE 3PHRDS  VS480, 0.0004, 0.0600, 0.0008, 0.04070 20.00, 392.0, - ;
                 -1.0,  9999                                          ; SOURCE
C
C       Switch between Source and 150kW DC Drive
C                 BUS-1, BUS-2, Tclose, Topen, Imarg  ?, @
$INCLUDE 3PHBRK   VS480, DRIVE, -1.000, 9999,  0.0,   1, 1 ; CURRENT SOURCE REF.
C
C       Diode Converter
C                BUS-1,  PWCNT,  DC+     DC-
C                CHOKEL, SNUBR,  SNUBC,  Rcharg, Tshort, DCCAP,  ?, @
$INCLUDE DIOCNVT DRIVE,  TRMNL,  DCPLUS, DCMNUS,                     - ; NODES
                 0.001,  10.0,   10.0,   0.50,   0.10,   22500., 0, 0  ; PARA.
/BRANCH
C <BUS1><BUS2>            <RES ><IND ><CAP >                                  O
  DCPLUSDCMNUS            2.8000
/OUTPUT
  VS480A
/PLOT
$INCLUDE ENDRUN
```

EMTP Data Module Workshop *Slide 61*

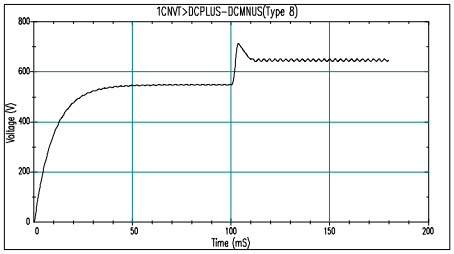
Six Pulse Diode Bridge Rectifier - cont



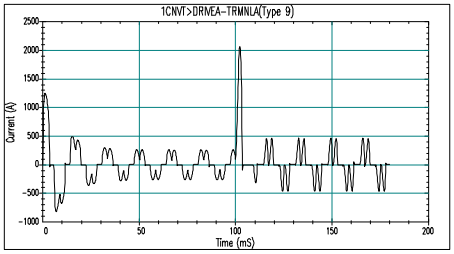
Phase-to-ground Voltage



Phase-to-phase Voltage



DC bus Voltage



AC Input Current

EMTP Data Module Workshop *Slide 62*

Six-Pulse SCR Bridge Module

```
C ************************************************************************
C *                   SIX-PULSE BRIDGE SCR MODULE
C INCLUED 6PSCR   FRONT,TRMNL,DCPLUS,DCMNUS,REFVN,ALPHAR,                      -; NODES
C                 FDELAY,CHOKEL,SNUBBR,SNUBBL,SNUBBC,STARTR,RSHORTIME,REACTR,?,@  ; PARA.
C ************************************************************************
ARG                                                                 - ; ARGUMENTS
FRONT,TRMNL,DCPLUS,DCMNUS,REFVN,ALPHAR,                             - ; CON. NODES
FDELAY,CHOKEL,SNUBBR,SNUBBL,SNUBBC,STARTR,RSHORTTIME,REACTR,        - ; PARAMETERS
?, @                                                                  ; OUTPUT REQ.
NUM                                                                 - ; NUMERICAL
FDELAY,CHOKEL,SNUBBR,SNUBBL,SNUBBC,STARTR,RSHORTTIME,REACTR           ; PARAMETERS
DUM                                                                 - ; DUM VARIABLE
PULSE1, PULSE2, PULSE3, PULSE4, PULSE5, PULSE6,                     - ; DUM1
CNTRL1, CNTRL2, CNTRL3, CNTRL4, CNTRL5, CNTRL6,                     - ; DUM2
THYT1A, THYT2A, THYT3A, THYT4A, THYT5A, THYT6A,                     - ; DUM3
THYT1C, THYT2C, THYT3C, THYT4C, THYT5C, THYT6C,                     - ; DUM3
RECPOS, RECNEG, SHRTBK, TDELAY, INIDLY, VACRMS,                     - ; DUM4
REFVAC, REFVBA, REFVCB, SIGNAC, SIGNBA, SIGNCB,                     - ; DUM5
SIGN01, SIGN03, SIGN05                                                ; DUM6
C C
C  -------------------------FIRING CONTROL-------------------------
/TACS
90REFVNA
90REFVNB
90REFVNC
88REFVAC  =REFVNA-REFVNC
88REFVBA  =REFVNB-REFVNA
88REFVCB  =REFVNC-REFVNB
98VACRMS66+REFVAC                               60.000
```

EMTP Data Module Workshop *Slide 63*

Six-Pulse SCR Bridge Module - cont

```
C <---------Ref. signal for firing angles in step with line-line voltage
C C         phase-lock-loop
C <OUT ><>I<IN1-> I<IN2-> I<IN3-> I<IN4-> I<IN5-> <--A-><--B-><--C-><--D-><--E->
98SIGNAC60+ZERO   +ZERO   +PLUS1                  0.0000            REFVAC
98SIGNBA60+ZERO   +ZERO   +PLUS1                  0.0000            REFVBA
98SIGNCB60+ZERO   +ZERO   +PLUS1                  0.0000            REFVCB
98SIGN01  =SIGNAC-SIGNBA
98SIGN03  =SIGNBA-SIGNCB
98SIGN05  =SIGNCB-SIGNAC
98PULSE1  =SIGN01 .GT. ZERO
98PULSE3  =SIGN03 .GT. ZERO
98PULSE5  =SIGN05 .GT. ZERO
98PULSE253+PULSE1                                 0.0   .002780.0167
98PULSE453+PULSE3                                 0.0   .002780.0167
98PULSE653+PULSE5                                 0.0   .002780.0167
C C DEVICE 53 USING NAMED DELAY TDELAY TO CONTROL FIRING ANGLE
98INIDLY  =RAD(FDELAY)
  TDELAY  +INIDLY +ALPHAR                         .00265
98CNTRL153+PULSE1                                 0.0         0.0167TDELAY
98CNTRL253+PULSE2                                 0.0         0.0167TDELAY
98CNTRL353+PULSE3                                 0.0         0.0167TDELAY
98CNTRL453+PULSE4                                 0.0         0.0167TDELAY
98CNTRL553+PULSE5                                 0.0         0.0167TDELAY
98CNTRL653+PULSE6                                 0.0         0.0167TDELAY
C  TACS output requests
33SIGNACSIGNBASIGNCB
33SIGN01SIGN03SIGN05
33PULSE1PULSE2PULSE3PULSE4PULSE5PULSE6
33INIDLYTDELAY
33CNTRL1CNTRL2CNTRL3CNTRL4CNTRL5CNTRL6
33VACRMS
```

EMTP Data Module Workshop *Slide 64*

Six-Pulse SCR Bridge Module - cont

```
/BRANCH
C AC Choke Inductance
C <-Bus1<-Bus2<-Bus3<-Bus4<----R<----L<----C                              V
  FRONTATRMNLA            1.0E-4CHOKEL                                    1
  FRONTBTRMNLB            1.0E-4CHOKEL                                    @
  FRONTCTRMNLC            1.0E-4CHOKEL                                    @
C Diode Snubber Circuits
C <-Bus1<-Bus2<-Bus3<-Bus4<----R<----L<----C                              V
  THYT1ATHYT1C            SNUBBRSNUBBLSNUBBC
  THYT2ATHYT2C            SNUBBRSNUBBLSNUBBC
  THYT3ATHYT3C            SNUBBRSNUBBLSNUBBC
  THYT4ATHYT4C            SNUBBRSNUBBLSNUBBC
  THYT5ATHYT5C            SNUBBRSNUBBLSNUBBC
  THYT6ATHYT6C            SNUBBRSNUBBLSNUBBC
C <-------- Connection to positive and negative dc bus
C <-Bus1<-Bus2<-Bus3<-Bus4<----R<----L<----C                              V
  THYT1CRECPOS            0.0001
  THYT3CRECPOS            0.0001
  THYT5CRECPOS            0.0001
  THYT1CRECPOS                  0.0001
  THYT3CRECPOS                  0.0001
  THYT5CRECPOS                  0.0001
C C
  RECNEGTHYT4A            0.0001
  RECNEGTHYT6A            0.0001
  RECNEGTHYT2A            0.0001
  RECNEGTHYT4A                  0.0001
  RECNEGTHYT6A                  0.0001
  RECNEGTHYT2A                  0.0001
C <-------- Connection to power system (diode front-end)
C <-Bus1<-Bus2<-Bus3<-Bus4<----R<----L<----C                              V
  TRMNLATHYT1A            0.0001
  TRMNLBTHYT3A            0.0001
  TRMNLCTHYT5A            0.0001
  TRMNLATHYT1A                  0.0001
  TRMNLBTHYT3A                  0.0001
  TRMNLCTHYT5A                  0.0001
C C
  THYT4CTRMNLA            0.0001
  THYT6CTRMNLB            0.0001
  THYT2CTRMNLC            0.0001
  THYT4CTRMNLA                  0.0001
  THYT6CTRMNLB                  0.0001
  THYT2CTRMNLC                  0.0001
C <-------- Phase-to-Phase Voltage Sampling
```

EMTP Data Module Workshop *Slide 65*

Six-Pulse SCR Bridge Module - cont

```
C <-------- Phase-to-Phase Voltage Sampling
C <-Bus1<-Bus2<-Bus3<-Bus4<----R<----L<----C                                V
  TRMNLATRMNLB            1.0E08                                           ?
  TRMNLBTRMNLC            1.0E08                                           @
  TRMNLCTRMNLA            1.0E08                                           @
C <-------- Starting Resistor
C <-Bus1<-Bus2<-Bus3<-Bus4<----R<----L<----C                                V
  RECPOSSHRTBK            STARTR                                           ?
/SWITCH
C <-------- Starting Resistor Short Switch
C BUS-->BUS--><---TCLOSE<----TOPEN<-------IE<----FLASH<--REQUEST<-----TARGET<--O
  RECPOSSHRTBKRSHORTTIME      9999                                         ?
/BRANCH
C <-------- dc Bus
C <-Bus1<-Bus2<-Bus3<-Bus4<----R<----L<----C                                V
  SHRTBKDCPLUS            0.0001REACTR                                     ?
?
  DCPLUSDCMNUS            1.0E05                                           2
  RECPOS                            1.0000
  RECPOSRECNEG            1.0E05                                           @
  RECNEG                            1.0000
  RECNEGDCMNUS            0.0001
/SWITCH
C <-------- Diodes (front-end)
C BUS-->BUS--><------Vig<----Ihold<-------td<---------CLOSEDSame<Grid>SIGNALxxOO
11THYT1ATHYT1C              0.1                              CNTRL1         ?
11THYT2ATHYT2C              0.1                              CNTRL2         ?
11THYT3ATHYT3C              0.1                              CNTRL3         @
11THYT4ATHYT4C              0.1                              CNTRL4         @
11THYT5ATHYT5C              0.1                              CNTRL5         @
11THYT6ATHYT6C              0.1                              CNTRL6         @
/ENDMODULE
$EOF
```

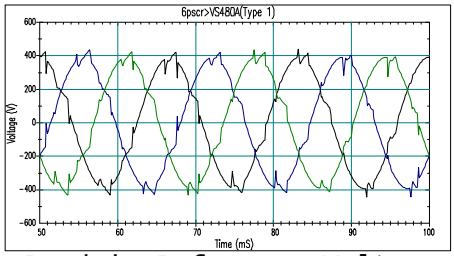
EMTP Data Module Workshop *Slide 66*

Six-Pulse SCR Bridge Module - cont

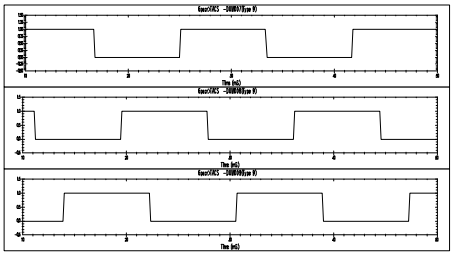
```
Six-pulse SCR bridge simulation input data file listing:
C ************************************************************************
C 6PSCR.DAT
C                  SIMULATION OF A SIX PULSE SCR OPERATION
BEGIN NEW DATA CASE
C ----Dt<---Tmax<---Xopt<---Copt
46.3E-060.150000
C -Iprnt<--Iplot<-Idoubl<-Kssout<-Maxout<---Ipun<-Memsav<---Icat<-Nenerg
    5001       3       1       3       1       0       0       2       0
$PREFIX C:\ETK\MODULE\INCFILE\
$SUFFIX .INC
TACS HYBRID
C ************************************************************************
/TACS
98ALPHAR  =(PI/2.)*SIN(8.7*TIMEX)
33ALPHAR
C       480 Voltage Source
C                BUS-1, R0      L0      R1      L1      RD     Vphpk
C                Tstart,Tstop
$INCLUDE 3PHRDS  VS480, 0.0004, 0.0600, 0.0008, 0.04070 20.00, 392.0,      - ;
                 -1.0,  9999                                          ; SOURCE
C
C       Switch between Source and 150kW DC Drive
C                BUS-1, BUS-2, Tclose, Topen, Imarg  ?, @
$INCLUDE 3PHBRK   VS480, DRIVE, -1.000, 9999,  0.0,   1, 1           ; MEASURING
C
C       6-Pulse SCR Converter
C                BUS-1,  PWCNT,  DC+,    DC-,    REFVN,  ALPHAR,           - ;
C                FDELAY,CHOKEL,SNUBR,SNUBL,SNUBC,Rcharg,Tshort,REACT,?,@     ;
$INCLUDE 6PSCR   DRIVE,  TRMNL,  DCPLUS, DCMNUS, VS480,  ALPHAR,         - ; NODES
                 0.0,   0.001, 10.0, 0.0,  10.0, 0.10,  0.05,  0.001,0,0   ; PARA.
/BRANCH
C The drive load is represented here by a lumped R.
C The capacitance is used for dc output voltage smoothing
C <BUS1><BUS2>            <RES ><IND ><CAP >                                  O
  DCPLUSDCMNUS                        22500.
  DCPLUSDCMNUS            2.8000
/OUTPUT
  VS480AVS480BVS480C
/PLOT
$INCLUDE ENDRUNTC
```

EMTP Data Module Workshop *Slide 67*

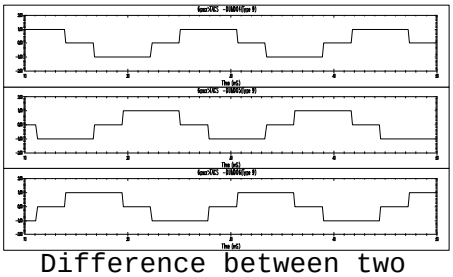
Six-Pulse SCR Bridge Module - cont



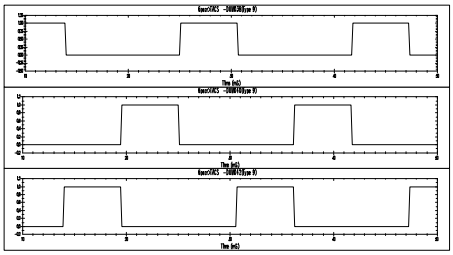
Read in Reference Voltage



Level Switch Output



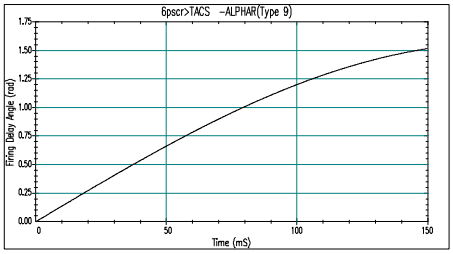
Difference between two Level Switch Output



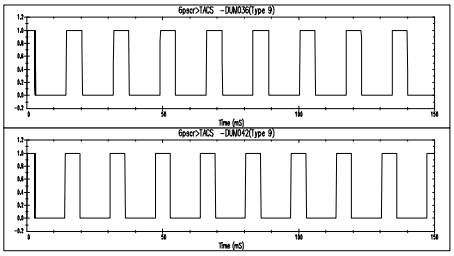
Firing Pulse Without Delaying

EMTP Data Module Workshop *Slide 68*

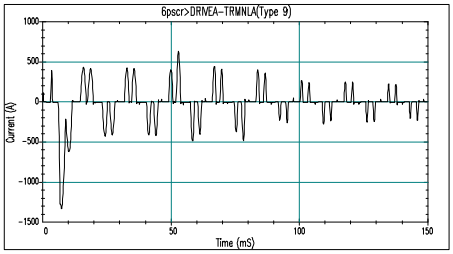
Six-Pulse SCR Bridge Module - cont



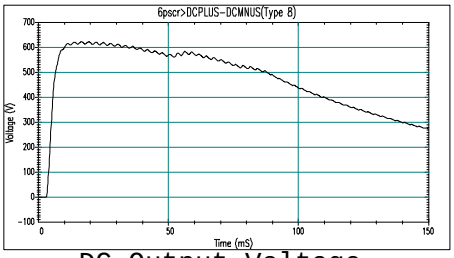
Firing Delaying Angle



Firing Signal with and without delaying



AC input Current



DC Output Voltage

EMTP Data Module Workshop *Slide 69*

Twelve-Pulse Converter Module

```
C ***************************************************************************
C                     Power Electronics Applications:
C                Six-pulse BConverter (Square Wave Converter)
C                              ETK-LM042893LT
C EX4.dat
$PREFIX C:\ETK\MODULE\INCFILE\
$SUFFIX .INC
BEGIN NEW DATA CASE
C ----Dt<---Tmax<---Xopt<---Copt
46.3E-06 0.100
C -Iprnt<--Iplot<-Idoubl<-Kssout<-Maxout<---Ipun<-Memsav<---Icat<-Nenerg
    5001       1       0       0       0       0       0       2       0
C ***************************************************************************
C
C 480V equivalent voltage source
C
$INCLUDE 3PHRDS SOURC 3.7E-6, 1.2E-4, 1.0E-5, 2.5E-4, 50., 391.9,-1.0, 9999  ;
C
C Stub line connection between the source and the formation transformer
C
C        Module   BUS-1, BUS-2, R,      L,   C,   ?, @
$INCLUDE 3PHRLCLN SOURC, HDELT, 0.0001, 0.0, 0.0, 1, 1  ;  Primary I-measuring
C
C Formation Delta/Delta/Wye tranformer
C
$INCLUDE 3DDYXFM1 HDELT, LDELT, LWYEG, NTRLPT, NAMEP,      - ;  NODES
                 .00045, 0.0270, 0.480,                    - ;  PARA1, Delta-H
                 .00045, 0.0270, 0.480,                    - ;  PARA2, Delta-L
                 .00015, 0.0090, 0.277, 10000.               ;  PARA3, Wye-L
C
C Stray cap. for controlling num. oscillation
C
```

EMTP Data Module Workshop *Slide 70*

Twelve-Pulse Converter Module - cont

```
$INCLUDE 3PHWYEG  LDELT, 0.001, 0.001, 2.00,   0,    0     ;  STRAY
$INCLUDE 3PHWYEG  LWYEG, 0.001, 0.001, 2.00,   0,    0     ;  STRAY
C
C Twelve-pulse converter
C
C        MODULE  LDELT,  LWYEG,  TRML1,  TRML2,  DCBUSP, DCBUSN,      - ;  btwn
FRONT and
C               CHOKEL, SNUBRR, SNUBRC, STARTR, TSHORT, DC_CAP, ?, @   ;  TRMNL
is an ac choke
$INCLUDE 12PCNVT LDELT,  LWYEG,  TRML1,  TRML2,  DCPLUS, DCMNUS,      - ;  NODES
                 0.001,  5.00,   15.0,   0.10,   0.01,   37500., 0, 0   ;  PARA.
/BRANCH
  DCPLUSDCMNUS            0.8398
/OUTPUT
  SOURCASOURCBSOURCC
  HDELTAHDELTBHDELTC
  LDELTALDELTBLDELTC
  LWYEGALWYEGBLWYEGC
/PLOT
$INCLUDE ENDRUN
```

EMTP Data Module Workshop *Slide 71*

Twelve-Pulse Converter Module - cont

```
C ************************************************************************
C *
C *           General 12-pluse Diode Bridge Rectifier Module
C *
C USAGE: INCLUED CONVERT FRNT1,  FRNT2,  TRML1,  TRML2,  DCPLUS, DCMINU, -; NODES
C *              CHOKEL, SNUBBR, SNUBBC, STARTR, RSHORTIME, DCBUSC        ; PARA.
C ************************************************************************
ARG                                                                     - ;
ARGUMENTS
FRNT1, FRNT2, TRML1, TRML2, DCPLUS, DCMNUS,                             - ; CON.
NODES
CHOKEL, SNUBBR, SNUBBC, STARTR,RSHORTTIME,DCBUSC,                       - ;
PARAMETERS
?, @                                                                      ; OUTPUT
REQ.
NUM                                                                     - ;
NUMERICAL
CHOKEL, SNUBBR, SNUBBC, STARTR,RSHORTTIME,DCBUSC                          ;
PARAMETERS
DUM                                                                     - ; DUM
RECPOS, RECNEG, SHRTBK,                                                 - ; DUM1
DIO01C, DIO02C, DIO03C, DIO04C, DIO05C, DIO06C,                         - ; DUM2
DIO07C, DIO08C, DIO09C, DIO10C, DIO11C, DIO12C,                         - ; DUM2
DIO01A, DIO02A, DIO03A, DIO04A, DIO05A, DIO06A,                         - ; DUM2
DIO07A, DIO08A, DIO09A, DIO10A, DIO11A, DIO12A                            ; DUM2
/BRANCH
C AC Choke Inductance
C <-Bus1<-Bus2<-Bus3<-Bus4<----R<----L<----C                                V
  FRNT1ATRML1A            1.0E-4CHOKEL                                      1
  FRNT2ATRML2A            1.0E-4CHOKEL                                      1
  FRNT1BTRML1B            1.0E-4CHOKEL                                      ?
```

EMTP Data Module Workshop *Slide 72*

Twelve-Pulse Converter Module - cont

```
  FRNT1CTRML1C            1.0E-4CHOKEL                                  ?
  FRNT2CTRML2C            1.0E-4CHOKEL                                  ?
C Diode Snubber Circuits
C <-Bus1<-Bus2<-Bus3<-Bus4<----R<----L<----C                            V
  TRML1ARECPOS            SNUBBR      SNUBBC
  TRML2ARECPOS            SNUBBR      SNUBBC
  TRML1BRECPOS            SNUBBR      SNUBBC
  TRML2BRECPOS            SNUBBR      SNUBBC
  TRML1CRECPOS            SNUBBR      SNUBBC
  TRML2CRECPOS            SNUBBR      SNUBBC
C <-Bus1<-Bus2<-Bus3<-Bus4<----R<----L<----C                            V
  TRML1ARECNEG            SNUBBR      SNUBBC
  TRML2ARECNEG            SNUBBR      SNUBBC
  TRML1BRECNEG            SNUBBR      SNUBBC
  TRML2BRECNEG            SNUBBR      SNUBBC
  TRML1CRECNEG            SNUBBR      SNUBBC
  TRML2CRECNEG            SNUBBR      SNUBBC
C <-------- Connection to positive and negative dc bus
C <-Bus1<-Bus2<-Bus3<-Bus4<----R<----L<----C                            V
  DIO01CRECPOS            0.0010
  DIO03CRECPOS            0.0010
  DIO05CRECPOS            0.0010
  DIO07CRECPOS            0.0010
  DIO09CRECPOS            0.0010
  DIO11CRECPOS            0.0010
  DIO01CRECPOS                 0.0100
  DIO03CRECPOS                 0.0100
  DIO05CRECPOS                 0.0100
  DIO07CRECPOS                 0.0100
  DIO09CRECPOS                 0.0100
  DIO11CRECPOS                 0.0100
```

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Twelve-Pulse Converter Module - cont

```
RECNEGDIO10A           0.0010
  RECNEGDIO12A           0.0010
  RECNEGDIO02A           0.0010
  RECNEGDIO04A           0.0010
  RECNEGDIO06A           0.0010
  RECNEGDIO08A                 0.0100
  RECNEGDIO10A                 0.0100
  RECNEGDIO12A                 0.0100
  RECNEGDIO02A                 0.0100
  RECNEGDIO04A                 0.0100
  RECNEGDIO06A                 0.0100
C <-------- Connection to power system (diode FRNT1-end)
C <-Bus1<-Bus2<-Bus3<-Bus4<----R<----L<----C                                V
  TRML1ADIO01A           0.0010
  TRML2ADIO03A           0.0010
  TRML1BDIO05A           0.0010
  TRML2BDIO07A           0.0010
  TRML1CDIO09A           0.0010
  TRML2CDIO11A           0.0010
  TRML1ADIO01A                 0.0100
  TRML2ADIO03A                 0.0100
  TRML1BDIO05A                 0.0100
  TRML2BDIO07A                 0.0100
  TRML1CDIO09A                 0.0100
  TRML2CDIO11A                 0.0100
  DIO08CTRML1A           0.0010
  DIO10CTRML2A           0.0010
  DIO12CTRML1B           0.0010
  DIO02CTRML2B           0.0010
  DIO04CTRML1C           0.0010
  DIO06CTRML2C           0.0010
```

EMTP Data Module Workshop *Slide 74*

Twelve-Pulse Converter Module - cont

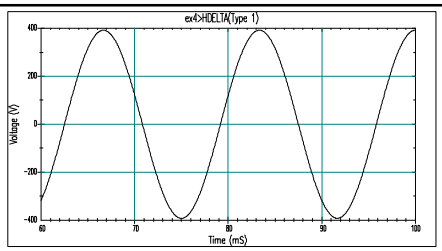
```
DIO10CTRML2A                0.0100
  DIO12CTRML1B                0.0100
  DIO02CTRML2B                0.0100
  DIO04CTRML1C                0.0100
  DIO06CTRML2C                0.0100
C <-------- Phase-to-Phase Voltage Sampling
C <-Bus1<-Bus2<-Bus3<-Bus4<----R<----L<----C                                V
  TRML1ATRML1B           1.0E08                                             2
  TRML2ATRML2B           1.0E08                                             2
  TRML1BTRML1C           1.0E08                                             @
  TRML2BTRML2C           1.0E08                                             @
  TRML1CTRML1A           1.0E08                                             @
  TRML2CTRML2A           1.0E08                                             @
C <-------- Starting Resistor
C <-Bus1<-Bus2<-Bus3<-Bus4<----R<----L<----C                                V
  RECPOSSHRTBK           STARTR                                             ?
/SWITCH
C <-------- Starting Resistor Short Switch
C BUS-->BUS--><---TCLOSE<----TOPEN<-------IE<----FLASH<--REQUEST<-----TARGET<--O
  RECPOSSHRTBKRSHORTTIME      9999                                          ?
/BRANCH
C <-------- dc Bus
C <-Bus1<-Bus2<-Bus3<-Bus4<----R<----L<----C                                V
  SHRTBKDCPLUS           0.00100.0100                                       ?
  DCMNUSDCPLUS           10000.
  DCPLUSDCMNUS                      DCBUSC                                   2
  RECPOS                            1.0000
  RECNEG                            1.0000
  RECNEGDCMNUS           0.00100.0100
```

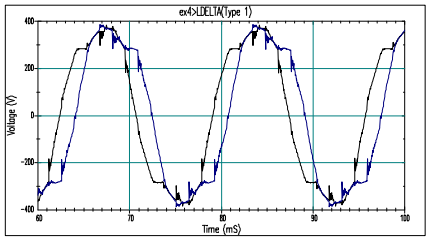

Twelve-Pulse Converter Module - cont

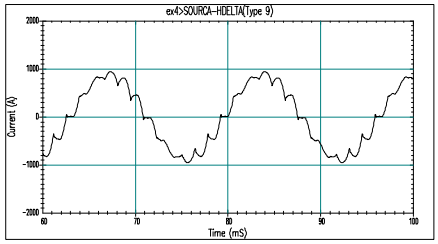
```
/SWITCH
C <-------- Diodes (FRNT1-end)
C BUS-->BUS--><------Vig<----Ihold<-------td<---------CLOSEDSame<Grid<Op/Cl<xxOO
11DIO01ADIO01C                0.1                                                ?
11DIO03ADIO03C                0.1                                                ?
11DIO05ADIO05C                0.1                                                ?
11DIO07ADIO07C                0.1                                                ?
11DIO09ADIO09C                0.1                                                ?
11DIO11ADIO11C                0.1                                                ?
C ------------------------------------------------------------------------------
11DIO08ADIO08C                0.1                                                @
11DIO10ADIO10C                0.1                                                @
11DIO12ADIO12C                0.1                                                @
11DIO02ADIO02C                0.1                                                @
11DIO04ADIO04C                0.1                                                @
11DIO06ADIO06C                0.1                                                @
C ------------------------------------------------------------------------------
/ENDMODULE
$EOF
```

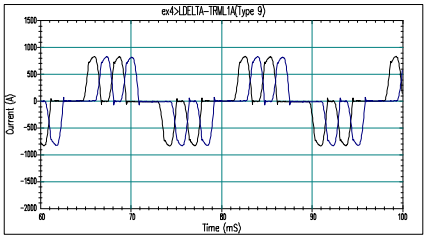
EMTP Data Module Workshop *Slide 76*

Twelve-Pulse Converter Module - cont









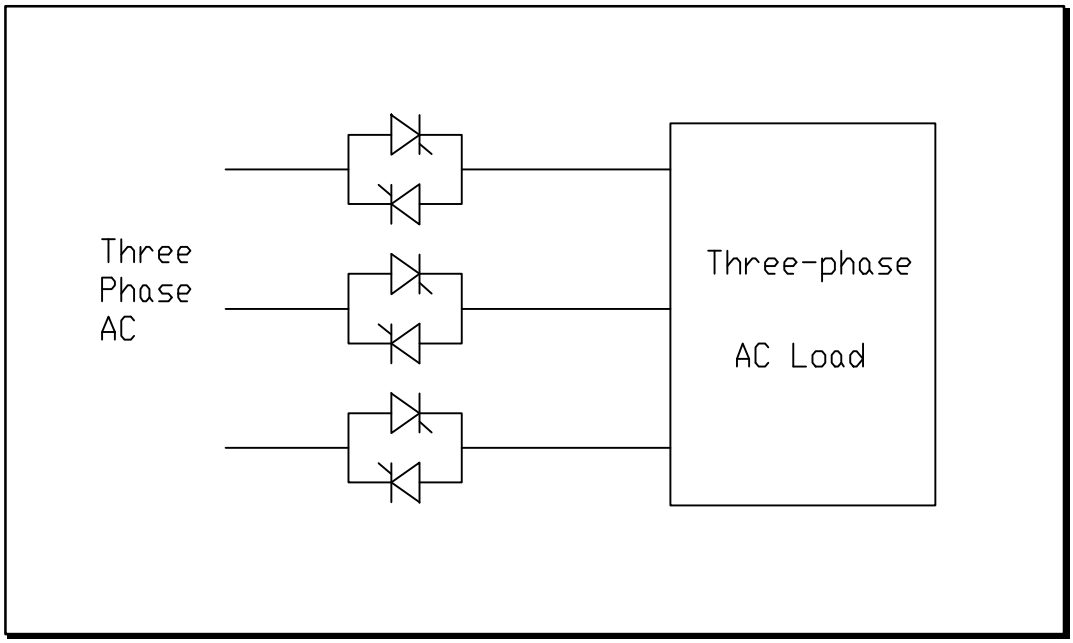
Suggested Excises:

1) Rerun the case and using TOP to get current harmonics for each 6-pulse converter and for the resultant 12-pulse converter

2) Rerun with different dc voltage smoothing capacitance.

EMTP Data Module Workshop *Slide 77*

Three-Phase ac Regulator Module



EMTP Data Module Workshop *Slide 78*

Three-Phase ac Regulator Module - cont

```
C ************************************************************************
C                     Power Electronics Applications:
C                Three-phase AC Regulator with Resistive Load
C                              ETK-LM062994LT
C EX5.dat
$PREFIX C:\ETK\MODULE\INCFILE\
$SUFFIX .INC
BEGIN NEW DATA CASE
C ----Dt<---Tmax<---Xopt<---Copt
46.3E-06 0.10000
C -Iprnt<--Iplot<-Idoubl<-Kssout<-Maxout<---Ipun<-Memsav<---Icat<-Nenerg
    5001       1       0       0       1       0       0       2       0
C ************************************************************************
TACS HYBRID
C
C 480V equivalent voltage source
C
C NCLUDE 3PHSOR VIBUS,ID,FREQ,AMPLA,AMPLB,AMPLC,ANGA, ANGB, ANGC, Tstt, Tstp ; COM
$INCLUDE 3PHSOR VS480,01,60.0,392., 392., 392., 0.0,  -120., 120., -1., 9999 ; 480
V Source
C
C Source impedance
C
C                BUS-1, BUS-2, R0      L0      R1      L1    ; COM.
$INCLUDE 3PHZ012  VS480, B480V, .0004, .0600, .0008, .0407    ; SOURCE IMPEDANCE
C
C Stray parameter for num. stable
C
C                       BUS-1, R,      L,    C,     ?, @     ; COM.
$INCLUDE 3PHWYEG        B480V, 1.000, .0000, 2.000, 0, 0     ; SOURCE GROUNDING
```


Three-Phase ac Regulator Module - cont

```
C
C Connection switch
C
C                 BUS-1, BUS-2, Tclose, Topen, Imarg  ?, @    ; COM
$INCLUDE 3PHBRK   B480V, TX480, -1.000, 9999,  0.0,   1, 1    ; Current measuring
C
C Supplying Transformer
C
C                 BUS-1,  BUS-2,  NUETRL, XFMID,
C                 Rp,     Lp,     Vp,
C                 Rs,     Ls,     Vs,     Rg,
$INCLUDE 3DYXFM1S TX480,  ACREG,  TXMRNT, CNVTX,       - ; 1000 kVA 4% DELTA/WYE
Iso. Tx
                  0.0028, 0.0367, 480.,                - ; 480 V DELTA SIDE
                  0.0009, 0.0122, 277.00, 10.E-6         ; 480 V WYE-G SIDE
C
C REFREQ - detected frequency
C
C NCLUDE FDMNT ID, REFVN, FDMNT, REFREQ  ;
; ARG0. NODES
$INCLUDE FDMNT 90, TX480, FDMNT, REFREQ  ; find fundamental of the signal
; ARG0. NODES
C
/TACS
C
C ALPHAD - Voltage control firing delay angle in DEG.(working range 0-150deg)
C          ATT. Vref. is taken from the primary which is 30 degree leading.
C          Therefore, the alpha=90 degrees actually gives a delay of 60 deg.
C
98ALPHAD  = 90.
C
```


Three-Phase ac Regulator Module - cont

```
C Three-phase ac regulator module
C
$INCLUDE 3PACREG ACREG, HEATR, FDMNT, ALPHAD, 250., 10., -1.0, 9999, 1, 2 ;
C
C Heater load of 50kW
C
$INCLUDE 3PHWYEG         HEATR, 4.608, 0.0,   0.000, 0, 0   ; 50 kW AT 480V
C ************************************************************************
/OUTPUT
  VS480A      VS480B      VS480C
  ACREGA      ACREGB      ACREGC
/PLOT
$INCLUDE ENDRUNTC
```

EMTP Data Module Workshop *Slide 81*

Three-Phase ac Regulator Module - cont

```
C ***************************************************************************
C           A THREE-PHASE FULL-WAVE AC REGULATOR (CONTROLLER) MODULE
C                              (LM070694lt)
C Usage:
C        3PACREG---module name
C                 INPUT---ac source connection node
C                        OUTPT---ac load connection nodee
C                               FDMNT---reference voltage obtained by calling
FDMNT module
C                                       ALPHAD---firing delay angle in deg.
ACOUT---drive ac output terminal
C NCLUDE 3PHACREG INPUT,  OUTPT,  FDMNT,  ALPHAD,            - ;
C                 RSNUBR, CSNUBR, TCLOSETIME,TOPENTIMES, ?, @   ; DECLARED as
NODES NAMEs
C                 RSNUBR---snubber R
C                        CSNUBR---snubber C
C                               TCLOSETIME---regulator switching closing time
C                                  TOPENTIMES---regulator switching
opening time
C                                                 ?, @---output request
C                                                      ;---commends line
C ***************************************************************************
ARG                                                          - ; ARGUMENTS
INPUT,  OUTPT,  FDMNT, ALPHAD,                               - ; ARG1
RSNUBR, CSNUBR, TCLOSETIME, TOPENTIMES, ?, @                   ; ARG2
NUM                                                          - ; NUMERICAL
RSNUBR, CSNUBR, TCLOSETIME, TOPENTIMES                         ; NUM1
DUM                                                          - ; DUM
TERMNA, TERMNB, TERMNC, INIDLY, TDELAY,                      - ; DUM1
CNTRL1, CNTRL3, CNTRL5, CNTRL4, CNTRL6, CNTRL2,              - ; DUM2
PULSE1, PULSE3, PULSE5, PULSE4, PULSE6, PULSE2,              - ; DUM3
TRNON1, TRNON3, TRNON5, TRNON4, TRNON6, TRNON2,              - ; DUM4
THYT1A, THYT2A, THYT3A, THYT4A, THYT5A, THYT6A,              - ; DUM5
THYT1C, THYT2C, THYT3C, THYT4C, THYT5C, THYT6C                 ; DUM6
```

EMTP Data Module Workshop *Slide 82*

Three-Phase ac Regulator Module - cont

```
/TACS
C  Firing pulse (in step with reference signal)
98CNTRL1  = 1.1*(FDMNTA .GT. ZERO)
98CNTRL3  = 1.3*(FDMNTB .GT. ZERO)
98CNTRL5  = 1.5*(FDMNTC .GT. ZERO)
98CNTRL4  = 1.4*(FDMNTA .LE. ZERO)
98CNTRL6  = 1.6*(FDMNTB .LE. ZERO)
98CNTRL2  = 1.2*(FDMNTC .LE. ZERO)
C  DEVICE 53 USING NAMED DELAY TDELAY TO CONTROL FIRING ANGLE
98INIDLY  = ALPHAD*PI/180.
  TDELAY  +INIDLY                                .00265
98PULSE153+CNTRL1                                0.0         0.0080TDELAY
98PULSE353+CNTRL3                                0.0         0.0080TDELAY
98PULSE553+CNTRL5                                0.0         0.0080TDELAY
98PULSE453+CNTRL4                                0.0         0.0080TDELAY
98PULSE653+CNTRL6                                0.0         0.0080TDELAY
98PULSE253+CNTRL2                                0.0         0.0080TDELAY
C  FIRING SIGNALS
98TRNON1  = 1.1*((CNTRL1.GT.ZERO).AND.(PULSE1.GT.ZERO))
98TRNON3  = 1.3*((CNTRL3.GT.ZERO).AND.(PULSE3.GT.ZERO))
98TRNON5  = 1.5*((CNTRL5.GT.ZERO).AND.(PULSE5.GT.ZERO))
98TRNON4  = 1.4*((CNTRL4.GT.ZERO).AND.(PULSE4.GT.ZERO))
98TRNON6  = 1.6*((CNTRL6.GT.ZERO).AND.(PULSE6.GT.ZERO))
98TRNON2  = 1.2*((CNTRL2.GT.ZERO).AND.(PULSE2.GT.ZERO))
C  TACS output requests
33TRNON1TRNON3TRNON5TRNON4TRNON6TRNON2
C ************************************************************************
/BRANCH
C <---------Connections to input  terminals
  TERMNATHYT1A           1.0E-4
  TERMNATHYT4C           1.0E-4
  TERMNBTHYT3A           1.0E-4
```

EMTP Data Module Workshop *Slide 83*

Three-Phase ac Regulator Module - cont

```
TERMNBTHYT6C            1.0E-4
  TERMNCTHYT5A            1.0E-4
  TERMNCTHYT2C            1.0E-4
C <---------Connections to output terminals
  THYT1COUTPTA            1.0E-4
  THYT4AOUTPTA            1.0E-4
  THYT3COUTPTB            1.0E-4
  THYT6AOUTPTB            1.0E-4
  THYT5COUTPTC            1.0E-4
  THYT2AOUTPTC            1.0E-4
C <---------Thyristor snubbers
  TERMNAOUTPTA            RSNUBR      CSNUBR
  TERMNBOUTPTB            RSNUBR      CSNUBR
  TERMNCOUTPTC            RSNUBR      CSNUBR
C <-Input  Phase-to-Phase Voltage Sampling
C <-Bus1<-Bus2<-Bus3<-Bus4<----R<----L<----C                              V
  INPUTAINPUTB            1.0E06                                          2
  INPUTBINPUTC            1.0E06                                          @
  INPUTCINPUTA            1.0E06                                          @
C <-Output Phase-to-Phase Voltage Sampling
  OUTPTAOUTPTB            1.0E06                                          2
  OUTPTBOUTPTC            1.0E06                                          @
  OUTPTCOUTPTA            1.0E06                                          @
/SWITCH
C regulator switch for control and current measuring
C <BUS1><BUS2><--Tclose><-Topen--><-Imargin>                              O
  INPUTATERMNATCLOSETIMETOPENTIMES    0.                                  1
  INPUTBTERMNBTCLOSETIMETOPENTIMES    0.                                  ?
  INPUTCTERMNCTCLOSETIMETOPENTIMES    0.                                  ?
C Thyristor switching devices, USING TYPE-11 SWITCHES
```

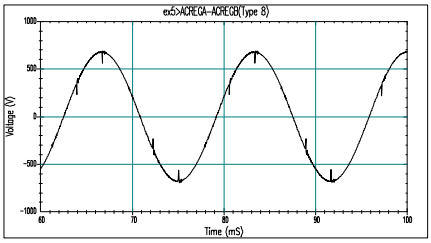
EMTP Data Module Workshop *Slide 84*

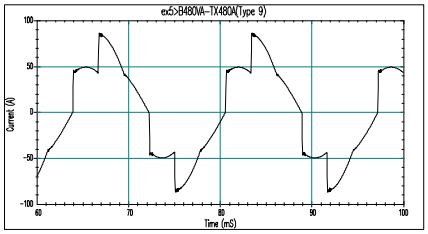
Three-Phase ac Regulator Module - cont

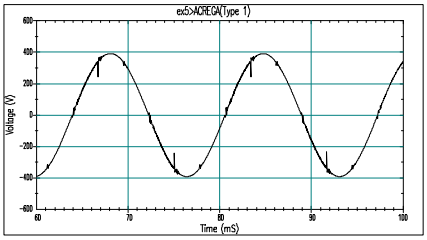
```
C <BUS1><BUS2><--Vig--><--Ihold-><--Tdion->xxxxxxxxxx<clsd>same<grid><O/C?>xxOO
11THYT1ATHYT1C                                                  TRNON1         1
11THYT3ATHYT3C                                                  TRNON3         ?
11THYT5ATHYT5C                                                  TRNON5         ?
11THYT4ATHYT4C                                                  TRNON4         1
11THYT6ATHYT6C                                                  TRNON6         ?
11THYT2ATHYT2C                                                  TRNON2         ?
/ENDMODULE
$EOF
```

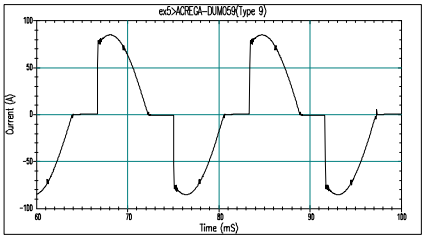
EMTP Data Module Workshop *Slide 85*

Three-Phase ac Regulator Module - cont







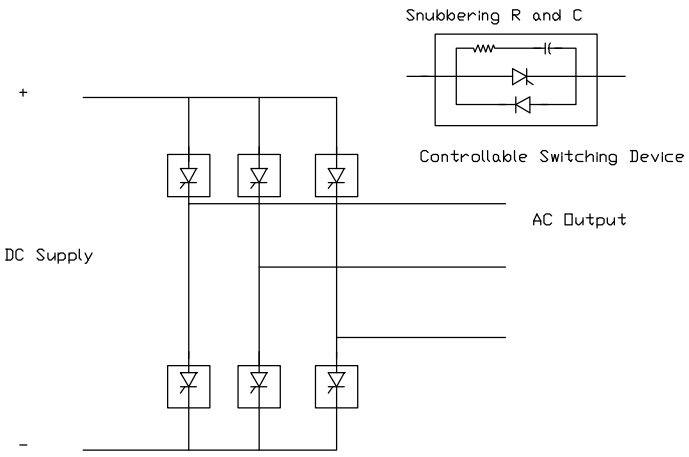


Suggested Excises:

1) Rerun the case and using TOP to get current harmonics
2) Rerun the case with different delaying angle.
3) Rerun the case with a R-L type load to see load current and voltage waveforms

EMTP Data Module Workshop *Slide 86*

PWM VSI Module



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PWM VSI Module - cont

GVSI.MOD file listing:

```
C ************************************************************************
C                    General pwm vsi module (#LT070493)
C NCLUDE GVSI   INVRT, ACBUS, DCPLUS,DCMNUS,INVRTN,REFVN, DELTAD,FRATIO,   - ; NODES
C               FDLDEG,CHOKEL,Rs,    Cs,    HLFRCH,Tshrt,                 - ;
C               HLFDCL,TWODCC,KFACTR,Tblock,?,     @                       ;
C ************************************************************************
ARG                                                                        - ;  ARGUMENTS
INVRT,  ACBUS,  DCPLUS, DCMNUS, INVRTN, REFVN,  DELTAD, FRATIO,            - ;  NODES
FDLDEG, CHOKEL, SNBRES, SNBCAP, HLFRCH, TRCSHORTED,                        - ;  NUMERICAL
PARA.
HLFDCL, TWODCC, KFACTR, TBLOCK, ?,      @                                    ;  CONT1.
NUM                                                                        - ;  NUMERICAL
VARIABLE
FDLDEG, CHOKEL, SNBRES, SNBCAP, HLFRCH, TRCSHORTED,                        - ;  CONT1.
HLFDCL, TWODCC, KFACTR, TBLOCK                                               ;  CONT2.
DUM                                                                        - ;  DUM
VARIABLE
SYSFRA, SYSFRB, SYSFRC, SYSFRQ, RFRMSA, RFRMSB, RFRMSC,                    - ;  DUM1
SINSIG, PULSES, SAWSIG, SAWSCL, INTSAW, CARRYT, DLYINT,                    - ;  DUM2
DCCOMP, CRYSIG, INDEXA, INDEXB, INDEXC, DDLDEG, TDLSEC,                    - ;  DUM3
PULSEA, PULSEB, PULSEC, CONTR1, CONTR3, CONTR5,                            - ;  DUM4
GTO1ON, GTO2ON, GTO3ON, GTO4ON, GTO5ON, GTO6ON,                            - ;  DUM5
DGTO1A, DGTO2A, DGTO3A, DGTO4A, DGTO5A, DGTO6A,                            - ;  DUM6
DGTO1C, DGTO2C, DGTO3C, DGTO4C, DGTO5C, DGTO6C,                            - ;  DUM7
DIOP1A, DIOP2A, DIOP3A, DIOP4A, DIOP5A, DIOP6A,                            - ;  DUM8
DIOP1C, DIOP2C, DIOP3C, DIOP4C, DIOP5C, DIOP6C,                            - ;  DUM9
INVPLS, INVMNS, SHRTBP, SHRTBN                                               ;  DUM12
C ************************************************************************
```

EMTP Data Module Workshop *Slide 88*

PWM VSI Module - cont

```
/TACS
C <--PWM firing signal generation
C read reference voltage signals
90REFVNA
90REFVNB
90REFVNC
C find reference frequency using device-50 (freq. meter)
C <OUTP>CD+<IN1 > +<IN2 > +<IN3 > +<IN4 > +<IN5 > <F(0)><MDF)>< C  >< D  ><  E >
98SYSFRA50+REFVNA                                  60.    10.
98SYSFRB50+REFVNB                                  60.    10.
98SYSFRC50+REFVNC                                  60.    10.
C  find average frequency over three-phase (try to avoid local disturbance)
98SYSFRQ  =(SYSFRA+SYSFRB+SYSFRC)/3.
C find rms using device-66 (rms meter)
98RFRMSA66+REFVNA                                  60.
98RFRMSB66+REFVNB                                  60.
98RFRMSC66+REFVNC                                  60.
C carry frequency sin wave generator
98SINSIG  =1.0*SIN(2*PI*SYSFRQ*FRATIO*TIMEX)
C carry frequency bi-direction pulse wave formation (the magnitude equal to +1 and -1)
98PULSES  =1.0*(SINSIG .GT. 0) - 1.0*(SINSIG .LE. 0)
C carry triangle generation(integrate PULSES over the time)
C <OUTP>CD+<IN1 > +<IN2 > +<IN3 > +<IN4 > +<IN5 > <GAIN><FLO ><FHI ><NLO ><NHI >
 1SAWSIG  +PULSES                                  1.0000
1.0
0.0       1.0
C carry triangle scale to higth = 2
98SAWSCL  = 4.*SYSFRQ*FRATIO*SAWSIG
C carry triangle dc off-set (rolling integration of SAWSCL over a carry period)
C <OUTP>CD+<IN1 > +<IN2 > +<IN3 > +<IN4 > +<IN5 > <GAIN><FLO ><FHI ><NLO ><NHI >
 1INTSAW  +SAWSCL                                  1.0000
1.0
0.0       1.0
98CARRYT  =1/(SYSFRQ*FRATIO)
98DLYINT53+INTSAW                                            0.0084CARRYT
C carry dc off-set
```

EMTP Data Module Workshop *Slide 89*

PWM VSI Module - cont

```
98DCCOMP  = (INTSAW-DLYINT)/CARRYT
C carry triangle after removing dc off-set
98CRYSIG  = SAWSCL-DCCOMP
C output level index
98INDEXA  = KFACTR*REFVNA/(SQRT(2)*RFRMSA)
98INDEXB  = KFACTR*REFVNB/(SQRT(2)*RFRMSB)
98INDEXC  = KFACTR*REFVNC/(SQRT(2)*RFRMSC)
C gto firing pulse generation
98PULSEA  = INDEXA .GT. CRYSIG
98PULSEB  = INDEXB .GT. CRYSIG
98PULSEC  = INDEXC .GT. CRYSIG
C cal. & add dynamic time delay to firing pulses
  DDLDEG  +DELTAD
88TDLSEC  =(FDLDEG+DDLDEG)/(360.*SYSFRQ)
98CONTR153+PULSEA                                          0.0084TDLSEC
98CONTR353+PULSEB                                          0.0084TDLSEC
98CONTR553+PULSEC                                          0.0084TDLSEC
C type-13 switch TACS control signals (IF O/C >0, CLOSE. IF O/C <=0, OPEN)
98GTO1ON  = 1.1*(CONTR1 .GT. 0.0)*(TIMEX .GT. TBLOCK)
98GTO3ON  = 1.3*(CONTR3 .GT. 0.0)*(TIMEX .GT. TBLOCK)
98GTO5ON  = 1.5*(CONTR5 .GT. 0.0)*(TIMEX .GT. TBLOCK)
98GTO4ON  = 1.4*(.NOT. CONTR1   )*(TIMEX .GT. TBLOCK)
98GTO6ON  = 1.6*(.NOT. CONTR3   )*(TIMEX .GT. TBLOCK)
98GTO2ON  = 1.2*(.NOT. CONTR5   )*(TIMEX .GT. TBLOCK)
C <--TACS output
C <BUS ><BUS ><BUS ><BUS ><BUS ><BUS ><BUS ><BUS ><BUS ><BUS ><BUS ><BUS ><BUS >
33SYSFRQ      RFRMSA      SINSIGPULSESSAWSIGSAWSCLINTSAWDLYINTDCCOMPCRYSIG
33INDEXAINDEXBINDEXC      GTO1ONGTO2ONGTO3ONGTO4ONGTO5ONGTO6ON
```


PWM VSI Module - cont

```
C <------------------------ VSI CIRCUIT CONNECTION ---------------------------->
/BRANCH
C <--AC choke
C <-Bus1<-Bus2<-Bus3<-Bus4<-R--><--L-><--C->                                   V
  INVRTAACBUSA            0.0010CHOKEL                                         1
  INVRTBACBUSB            0.0010CHOKEL                                         ?
  INVRTCACBUSC            0.0010CHOKEL                                         ?
C <--Upper bridge
C connection between inverter +pole and ac buses
C <Bus1><Bus2><Bus3><Bus4><--R-><--L-><--C->                                   V
  INVPLSDGTO1A            0.0010
  INVPLSDGTO3A            0.0010
  INVPLSDGTO5A            0.0010
C
  DGTO1CACBUSA            0.0010
  DGTO3CACBUSB            0.0010
  DGTO5CACBUSC            0.0010
C
  INVPLSDIOP1C            0.0010
  INVPLSDIOP3C            0.0010
  INVPLSDIOP5C            0.0010
C
  DIOP1AACBUSA            0.0010
  DIOP3AACBUSB            0.0010
  DIOP5AACBUSC            0.0010
C Lower bridge
C connection between ac buses and inverter +pole
C <Bus1><Bus2><Bus3><Bus4><--R-><--L-><--C->                                   V
  ACBUSADGTO4A            0.0010
  ACBUSBDGTO6A            0.0010
  ACBUSCDGTO2A            0.0010
```

EMTP Data Module Workshop *Slide 91*

PWM VSI Module - cont

```
C
  DGTO4CINVMNS            0.0010
  DGTO6CINVMNS            0.0010
  DGTO2CINVMNS            0.0010
C
  ACBUSADIOP4C            0.0010
  ACBUSBDIOP6C            0.0010
  ACBUSCDIOP2C            0.0010
C
  DIOP4AINVMNS            0.0010
  DIOP6AINVMNS            0.0010
  DIOP2AINVMNS            0.0010
C <--DIODE and GTO snubbers
C <-Bus1<-Bus2<-Bus3<-Bus4<----R<----L<----C                                V
  INVPLSACBUSA            SNBRES      SNBCAP                                3
  INVPLSACBUSB            SNBRES      SNBCAP
  INVPLSACBUSC            SNBRES      SNBCAP
C
  ACBUSAINVMNS            SNBRES      SNBCAP
  ACBUSBINVMNS            SNBRES      SNBCAP
  ACBUSCINVMNS            SNBRES      SNBCAP
C <--DC bus connections
C <-Bus1<-Bus2<-Bus3<-Bus4<----R<----L<----C                                V
  INVPLS                  1.0E05
  INVPLSSHRTBP            HLFRCH0.0001
  SHRTBPDCPLUS            0.0010HLFDCL                                      ?
  DCPLUSINVRTN                        TWODCC                                @
  DCPLUSDCMNUS            1.0E06                                            2
  DCMNUSINVRTN                        TWODCC                                @
  SHRTBNDCMNUS            0.0010HLFDCL                                      ?
  INVMNSSHRTBN            HLFRCH0.0001
  INVMNS                  1.0E05
```

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PWM VSI Module - cont

```
C <--AC line voltage measuring branches
  ACBUSAACBUSB            1.0E06                                              2
  ACBUSBACBUSC            1.0E06                                              @
  ACBUSCACBUSA            1.0E06                                              @
/SWITCH
C <-------- Starting Resistor Short Switch
C BUS-->BUS--><---TCLOSE<----TOPEN<-------IE<----FLASH<--REQUEST<-----TARGET<--O
  INVPLSSHRTBPTRCSHORTED      9999
  INVMNSSHRTBNTRCSHORTED      9999
C <--Inverter GTOs
C BUS-->BUS--><------------------------------------>CLOSEDSame<Grid><O/Cl>xxOO
13DGTO1ADGTO1C                                                        GTO1ON   3
13DGTO2ADGTO2C                                                        GTO2ON   ?
13DGTO3ADGTO3C                                                        GTO3ON   ?
13DGTO4ADGTO4C                                                        GTO4ON   ?
13DGTO5ADGTO5C                                                        GTO5ON   ?
13DGTO6ADGTO6C                                                        GTO6ON   ?
C <--Parallel reversal Diodes
11DIOP1ADIOP1C     1.    .1                                                     3
11DIOP2ADIOP2C     1.    .1                                                     ?
11DIOP3ADIOP3C     1.    .1                                                     ?
11DIOP4ADIOP4C     1.    .1                                                     ?
11DIOP5ADIOP5C     1.    .1                                                     ?
11DIOP6ADIOP6C     1.    .1                                                     ?
/ENDMODULE
$EOF
```

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PWM VSI Module - cont

Where,

INVRT - inverter connection bus name
ACBUS - Inverter bridge ac connection bus name
DCPLUS - dc positive connection bus name
DCMNUS - dc negative connection bus name
INVRTN - dc neutral point
REFVN - Node name which provides the firing angle reference line-to-ground voltage
DELTAD- input variable passing a dynamic phase delay angle(in degree)
FRATIO- input variable passing a ration of the PWM and reference frequencies
FDLDEG- Fixed delay angle in degree
CHOKEL- AC choke inductance connected between INVRT and ACBUS
Rs - Snubber resistance
Cs - Snubber capacitance
HLFRCH - A half of dc bus charging resistance
TSHRT - Time when the HLFRCH is shorted
HLFDCL - A half of dc circuit inductance (in mH)
TWODCC - Double of the dc capacitance (in uF)
KFACTR - Load (output) index
TBLOCK - blocking signal, when t<TBLOCK, the inverter is blocked.

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