

MINICURSO DE PSCAD

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- 6 Exportando Dados
- 7 Automação de Simulações
- 8 Criação de Componentes e Bibliotecas

Visão Geral do PSCAD e do Curso

Objetivo

- Aprender a montar simulações de sistemas elétricos no PSCAD
- Aprender a extrair resultados
- Possivelmente, aprender o funcionamento de alguns circuitos básicos.

O que é o PSCAD

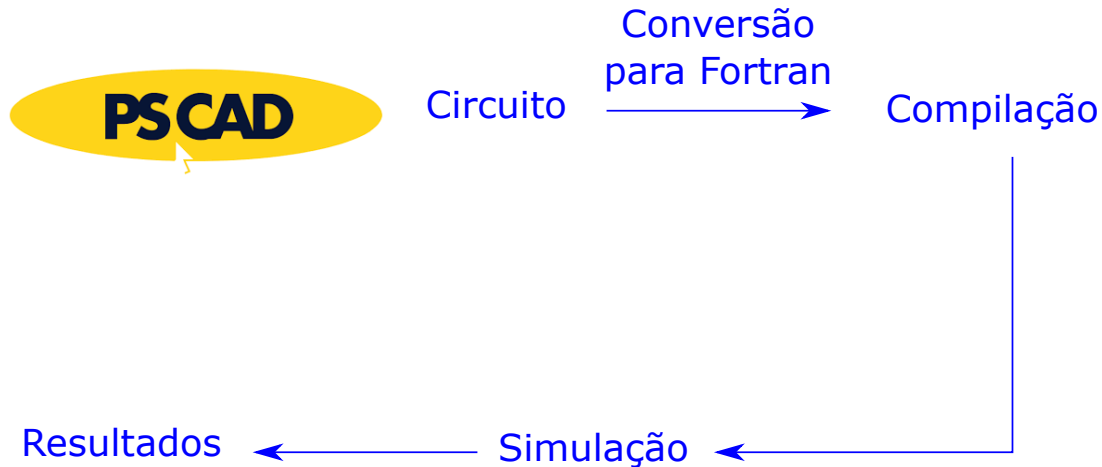
- O PSCAD (*Power Systems Computer Aided Design*) é uma interface gráfica para simulação no EMTDC
- o EMTDC é um programa utilizado para simulação de transitórios eletromagnéticos.

Para que serve o PSCAD

- Simulação de sistemas de potência: transitórios eletromagnéticos
 - Redes de distribuição e transmissão
 - Máquinas Elétricas
 - Sistemas de controle de fontes de energia

- Simulação de sistemas envolvendo eletrônica de potência.
 - Grid-connected/Grid-Forming Converters
 - HVDCs (*High Voltage Direct Current*)
 - FACTS (*flexible alternating current transmission system*)
 - Sistemas de controle

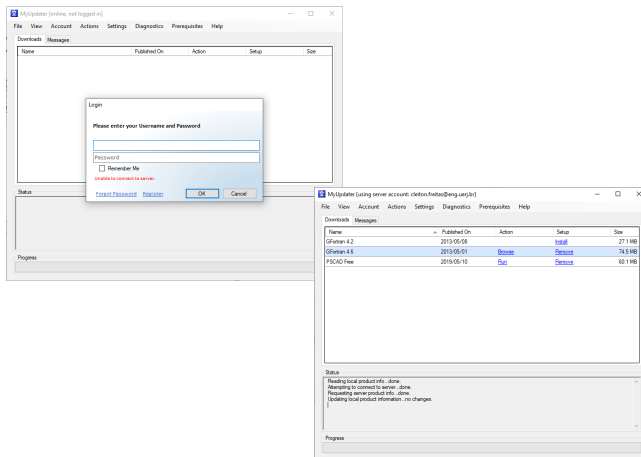
Ideia Geral do PSCAD



Primeiros Passos no PSCAD

PSCAD: Versão Gratuita

apenas um teste



PSCAD: Versão Gratuita

The screenshot displays the PSCAD Free software interface. The top menu bar includes Home, Project, View, Tools, Utilities, and a Return Certificate (Free Edition) button. The toolbar contains various icons for file operations (Cut, Copy, Paste, Delete), simulation (Clean, Build, Build Modified, Run, Stop, Pause, Skip, Step, Snapshot, Slow), and editing (Plot Step, Save Scenario, Delete Scenario, View Scenario, Active Scenario, Back, Forward, Up, Undo, Redo, Select, Wire Mode, Zoom In, Zoom Out, Zoom Extent, Zoom Rectangle). The main workspace is titled 'master:Main() Start Page' and features a 'Go To MyCentre' button. The 'Start Page' is divided into three columns: 'Updates', 'News', and 'Videos'. The 'Updates' column lists two updates: 'PSCAD v4.6.3 Update 5' (dated 10/21/2020) and 'PSCAD v4.6.3 Update 4' (dated 08/05/2020). The 'News' column includes 'New PSCAD Webinar Series' (dated 05/27/2020), 'COVID-19 Update' (dated 03/25/2020), and 'Support for the older Intel Fortran compilers and GFortran compilers - PSCAD v5.0' (dated 02/19/2020). The 'Videos' column shows a video titled 'Blackbox features - PSCAD Version 5' (dated 08/26/2020). The bottom status bar indicates 'Build Messages', 'Runtime Messages', 'Component Wizard', and 'Search'.

Welcome to PSCAD!

Updates

PSCAD v4.6.3 Update 5
10/21/2020 07:12:03 PM

PSCAD v4.6.3 Update 5 is now available for eligible users. Recent updates provided by some anti-virus programs had triggered the blocking of PSCAD compile time and runtime batch files, as they contained multiple period '.' characters. These filenames have been changed to include only a single period, thereby resolving the blocking issue. We have also included some improved licensing error logging.

For more details about this update, please contact sales@pscads.com.

PSCAD v4.6.3 Update 4
08/05/2020 02:15:51 PM

We are pleased to announce the release of PSCAD v4.6.3 Update 4 which supports TLS 1.2, includes an updated Master Library 4.6.3.2, and supports improved lock-based and certificate licensing.

All Professional v4.6.3 and Educational Edition licenses are eligible for this update. Those with active maintenance can obtain the download via MyCentre. If it is not automatically available in your MyCentre account, please contact your workgroup administrator, or sales@pscads.com.

For more details about this update, please click [here](#).

New Transformer Models for PSCAD
02/11/2020 09:07:43 PM

Various transformer and auto-transformer

News

New PSCAD Webinar Series
05/27/2020 08:29:42 PM

We are happy to announce we are hosting another Webinar Series!

For topics, dates and details visit our website [here](#).

We hope you can join us!

COVID-19 Update
03/25/2020 03:06:58 PM

The health and safety of our employees and customers remains our top priority. Until further notice, PSCAD will operate as a virtual company and all employees will be working from home or a safe remote location. We are focused on remaining available for our clients, and will continue to operate with the same timeliness that our customers and colleagues expect from us. Please stay safe and healthy.

Support for the older Intel Fortran compilers and GFortran compilers - PSCAD v5.0
02/19/2020 09:02:40 PM

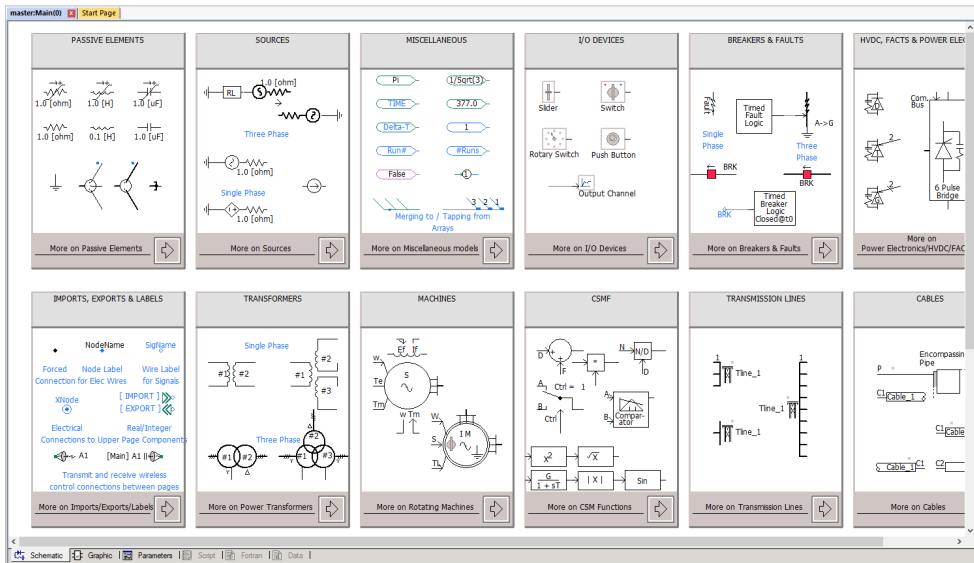
Support for the Intel Fortran compilers earlier than 12.0, and GFortran 4.2.1 has been removed as of PSCAD v5.0. If you will be using PSCAD v5.0, compiling may be performed using either the free Fortran compilers that come bundled with PSCAD (GFortran v4.6 and GFortran v8.1), or by using the professional edition of Intel Fortran compiler (versions 12 through 19).

If your project calls any libraries or objects, these must be pre-compiled using the same compiler as your project.

Videos

Blackbox features - PSCAD Version 5
08/26/2020 04:09:31 PM

PSCAD: Biblioteca Master



PSCAD: Biblioteca Master

master:Main(0):Passive(0) Start Page

RLC Branch Components
Series or Parallel Combinations or RLC are Automatically Collapsed.

Series RLC Tuned Filter

High Pass RLC Filter

Band Pass RLC Filter
 $F = 300.0 \text{ [Hz]}$

C-Type Filter

Runtime Configurable Passive Branch

Frequency Dependent Network Equivalent
FDNE1
1
2
3
Frequency Dependent Network Equivalent

Variable RLC Components
(Allows entry of numbers (like 1.0) or Variable Names (ABC)...)

- 1.0 [ohm]
- 1.0 [H]
- 1.0 [uF]

Single/Three Phase L-G Fixed Load
P+Q

Single Phase L-L Fixed Load

3 phase loads
(Resistive, Inductive and Capacitive)

- 1.0 [MW]
- 1.0 [MVAR]
- 1.0 [MVAR]

PASSIVE ELEMENTS

- 1.0 [ohm]
- 1.0 [H]
- 1.0 [uF]
- 1.0 [ohm]
- 0.1 [H]
- 1.0 [uF]

Transposition wires

Wires

Bus

3 phase short

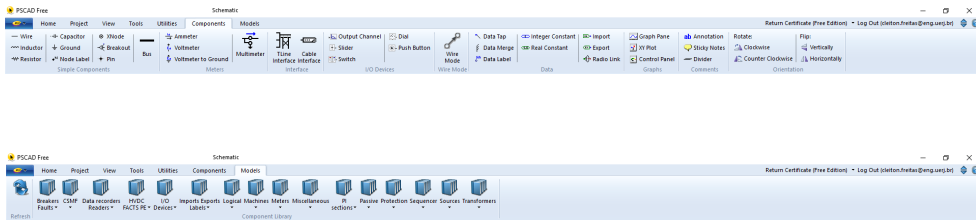
Spark Gap

More on Passive Elements

Schematic | Graphic | Parameters | Script | Fortran | Data

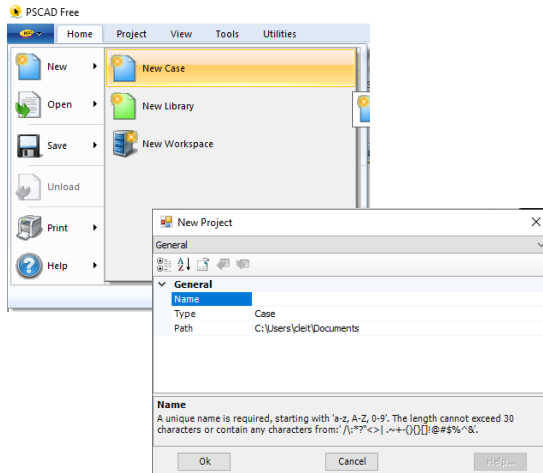
PSCAD: Biblioteca Master

Quando um projeto está aberto, também podemos acessar os componentes através dos seguintes menus.



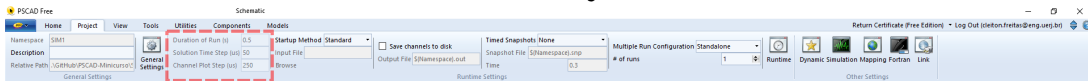
Criando uma Simulação: *New Case*

- *New Case*: Cria uma nova simulação
- *Name*: Nome do arquivo de simulação
- *Path*: Lugar onde salvar a simulação



Criando uma Simulação: Parâmetros do Projeto

Menu *Project*



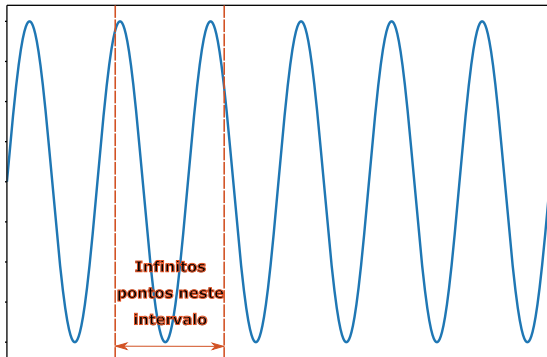
- *Duration of Run*: Tempo total de simulação
- *Time Step*: Intervalo de tempo entre os cálculos
- *Plot Step*: Intervalo de amostragem usado nos gráficos

Importância do Time Step

Mundo Real:

- O mundo é contínuo
- Existe um número **INFINITO** de instantes em um intervalo de tempo

$$y(t) = \sin(120\pi t)$$

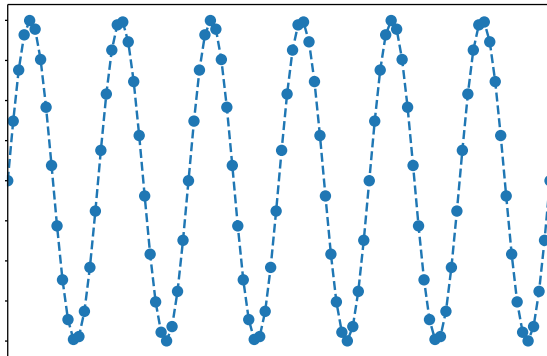


Importância do Time Step

Simulação Digital:

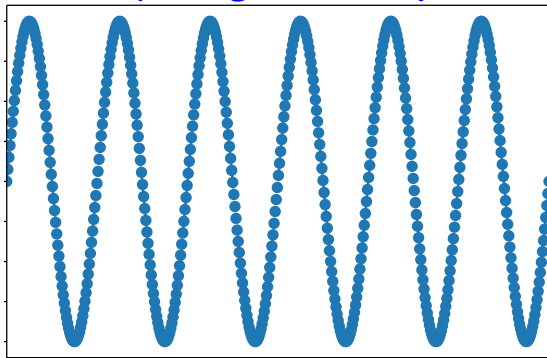
- O mundo é discreto
- Existe um número **FINITO** de instantes em um intervalo de tempo

$$y[kT_s] = \sin(120\pi kT_s)$$

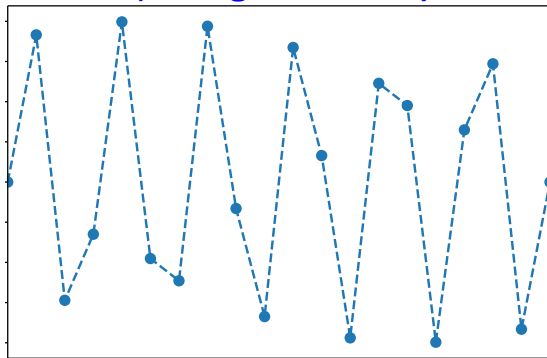


Importância do Time Step: ainda a senoide

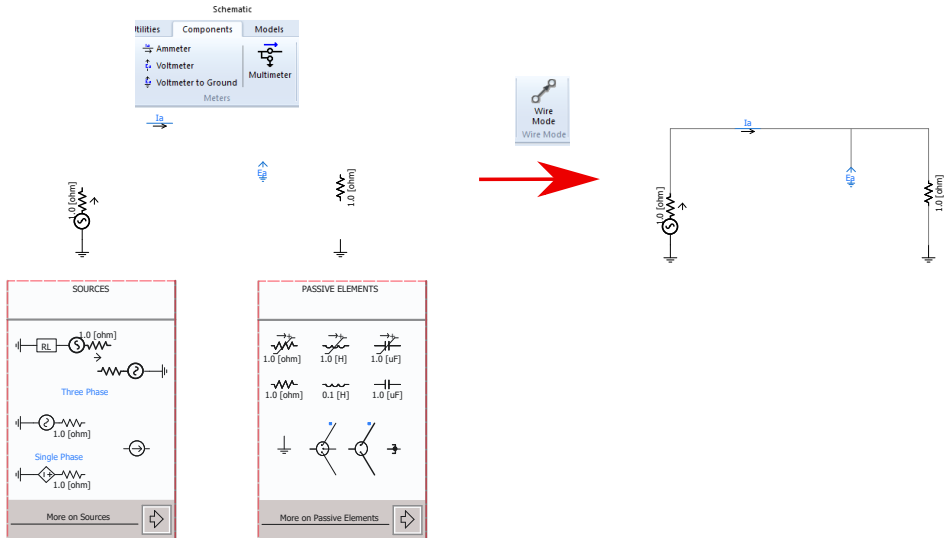
Simulação Digital: Muito preciso



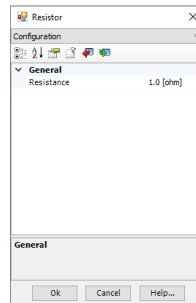
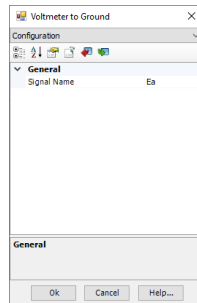
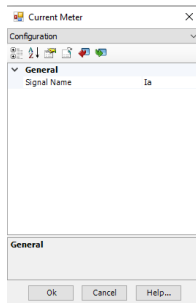
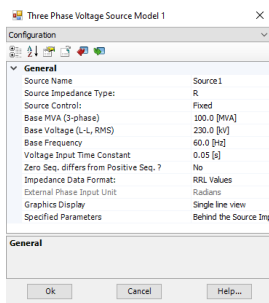
Simulação Digital: Pouco preciso



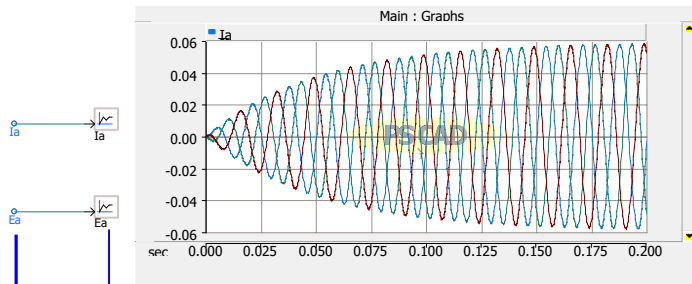
Criando uma Simulação: Continuando



Criando uma Simulação: Configuração dos componentes



Criando uma Simulação: Gráficos



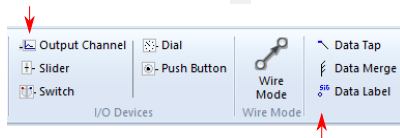
Output Chanel

Data Label

Grafico:
- Botão direito no
output channel

-Graph/meters/controls

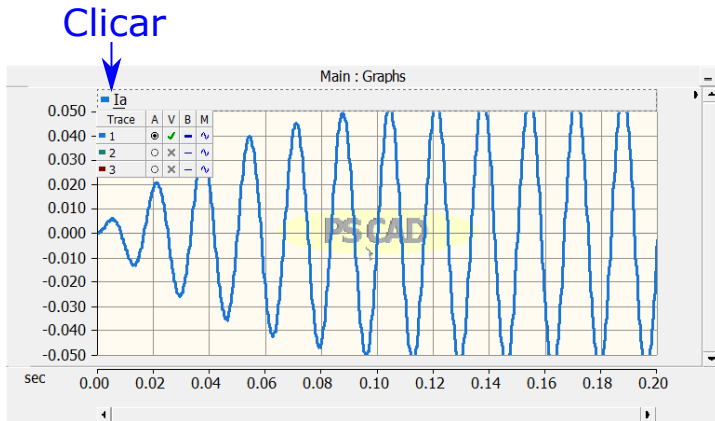
- add overlay graph
with signal



Visualização de Resultados: Alguns Detalhes

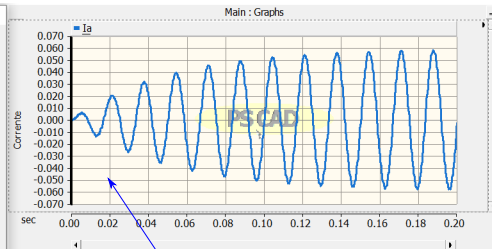
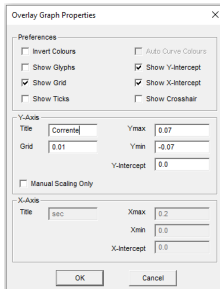
Ajustes nos Gráficos: Curvas

- É possível selecionar qual curva mostrar
- É possível selecionar aumentar a espessura da curva



Ajustes nos Gráficos: Escala

- Propriedades do gráfico
- Permite ajustar a escala
- Permite alterar a grade



Clicar com o direito

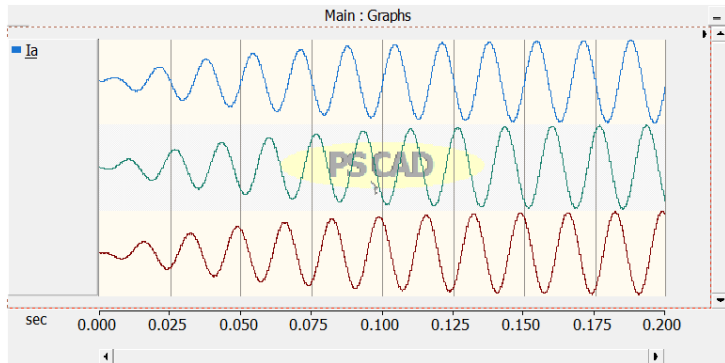
Ajustes nos Gráficos: Atalhos

Depois de clicar no gráfico:

- **E** - Ajusta a escala do tempo
- **Y** - Ajusta a escala y do gráfico para melhor visualização
- **B** - Ajusta a escala y do gráfico de acordo com a configuração do output channel
- **M** - Habilita dois cursores

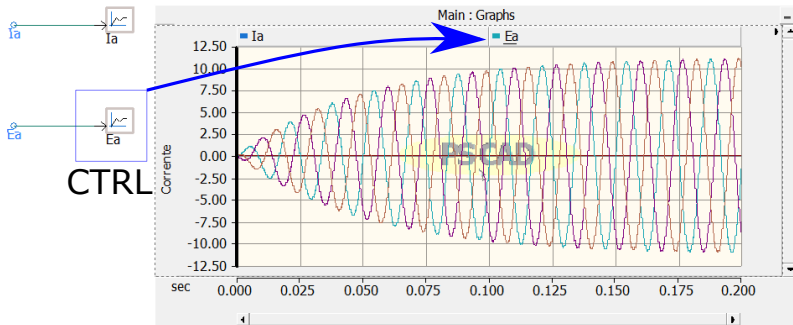
Ajustes nos Gráficos: Polygrphs

- Propriedades do gráfico
- Permite ajustar a escala
- Permite alterar a grade

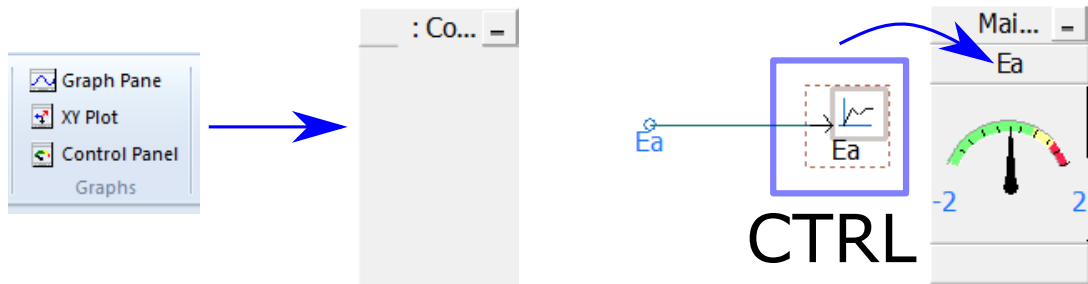


Ajustes nos Gráficos: adicionando curvas ao gráfico

- Selecione o *output channel*
- Precione a tecla *CTRL*
- Arraste em direção a um gráfico existente

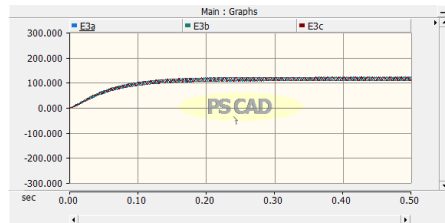
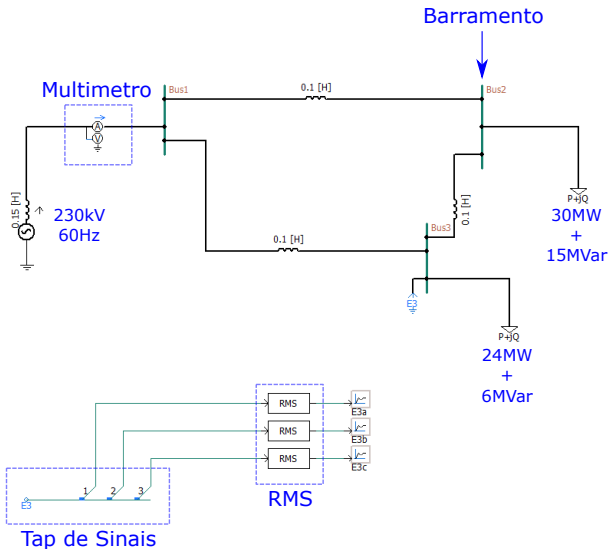


Ajustes nos Gráficos: Painéis de Controle

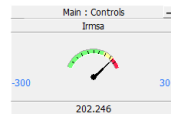


Circuitos Simples para Aprender Usar Outros Blocos

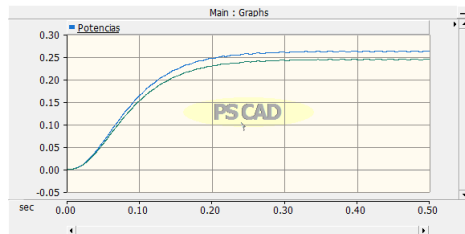
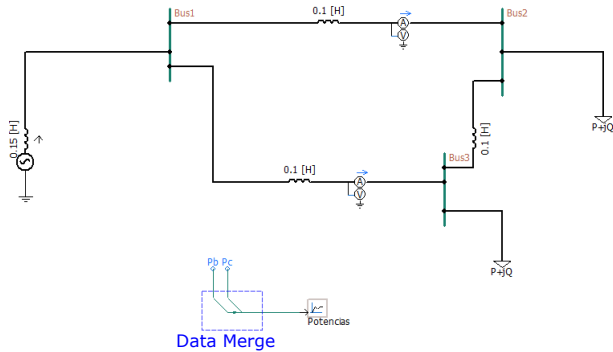
Circuito 2A



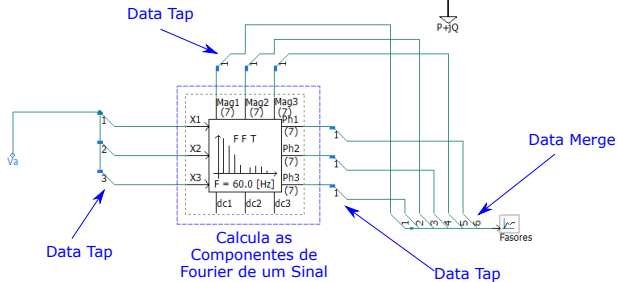
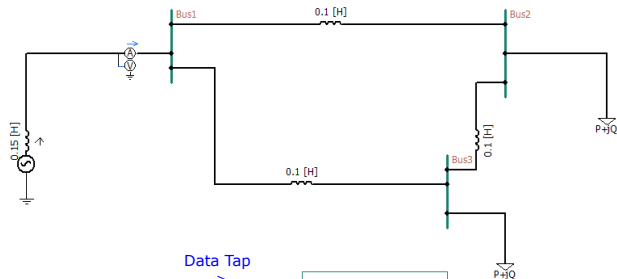
Imisa → Irmisa



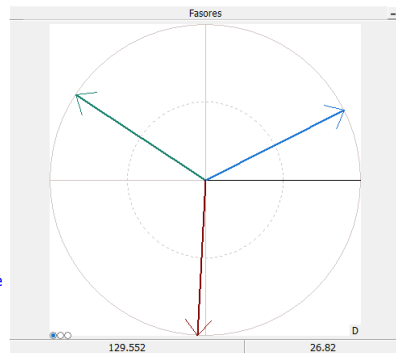
Circuito 2B



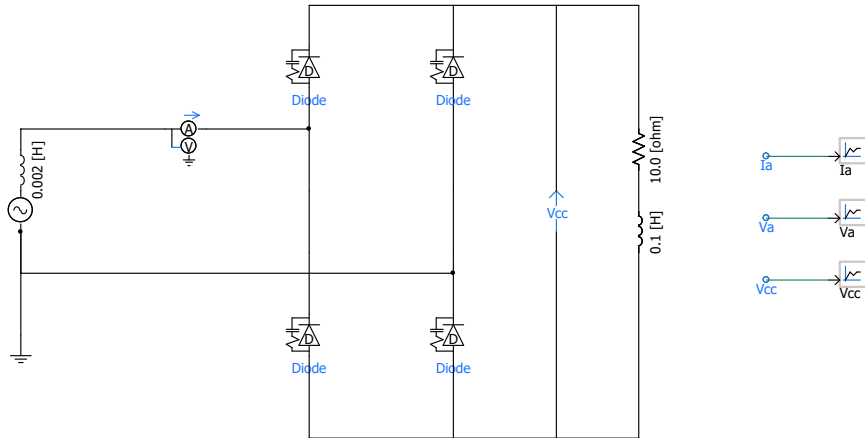
Circuito 2C



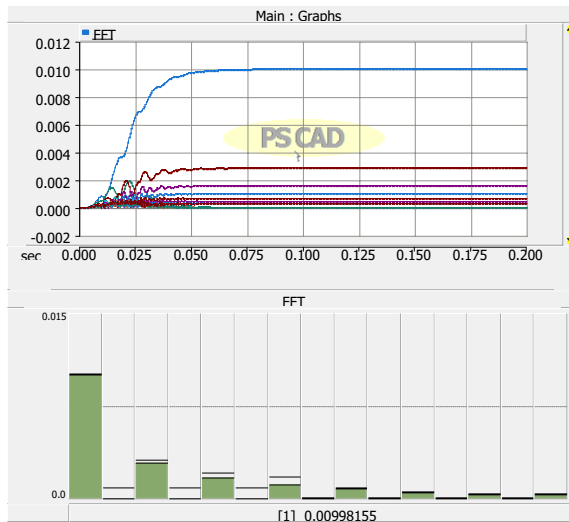
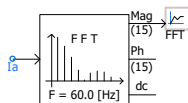
Em Grpahs/Meters/Controls:
Add PhasorMeter



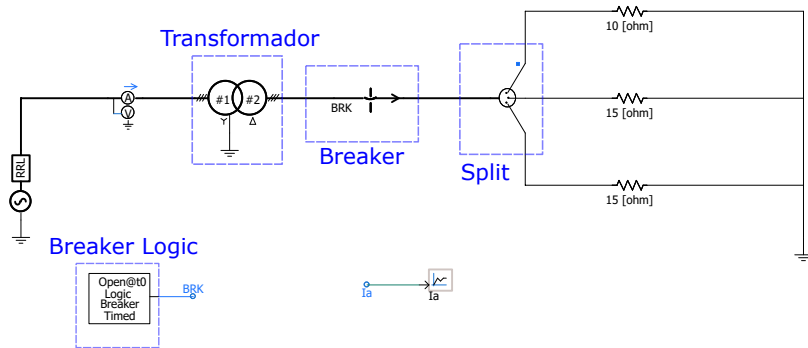
Circuito 2D: Nosso primeiro circuito monofásico



Circuito 2D: FFT

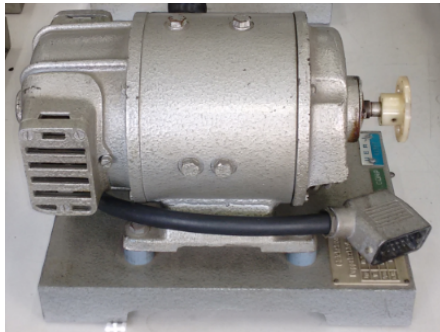


Circuito 2E: Transformadores e etc

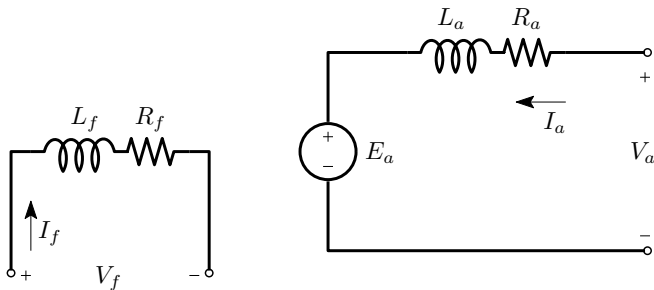


Circuito 2F: Máquinas CC

Máquina

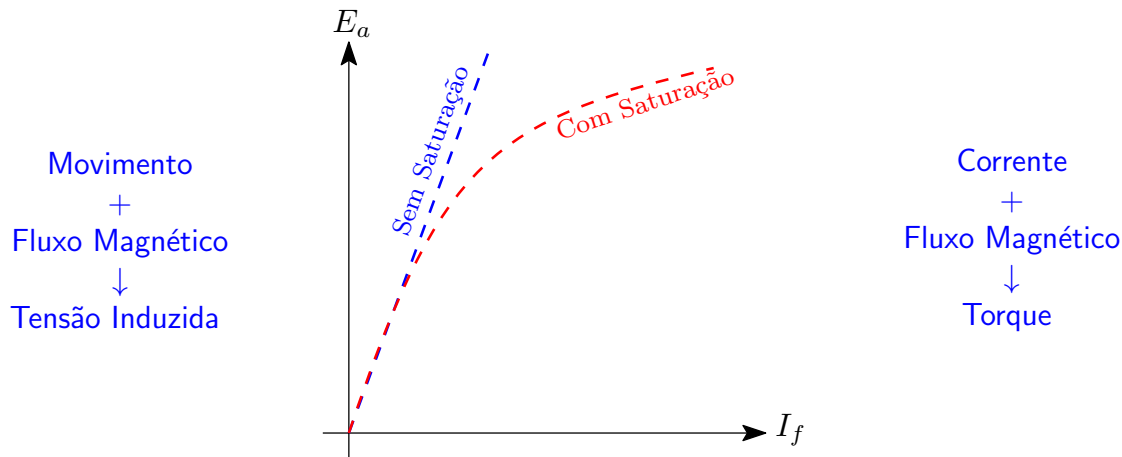


Modelo Matemático¹



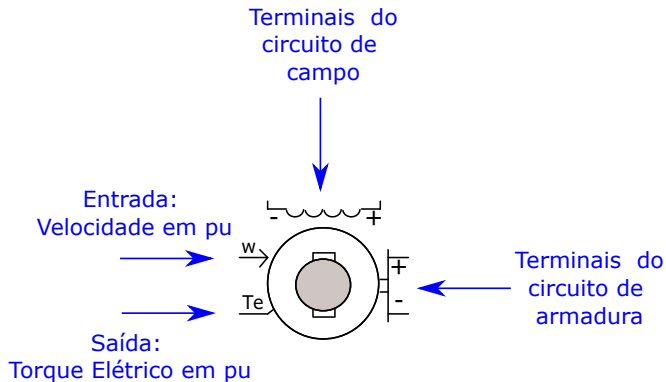
¹Stephen J. Chapman, Fundamentos das Máquinas Elétricas. 5ed. Capítulos 7 e 8.

Circuito 2F: Mais Sobre o Modelo da Máquina



Circuito 2F: Máquinas CC no PSCAD

- Representa apenas as equações elétricas
- A dinâmica mecânica é deixada de lado



Circuito 2F: Modelando a Dinâmica Mecânica

Lei de Newton dos sistemas rotacionais: Convertendo para pu:

$$J \frac{d\omega_m}{dt} = T_e - T_m$$

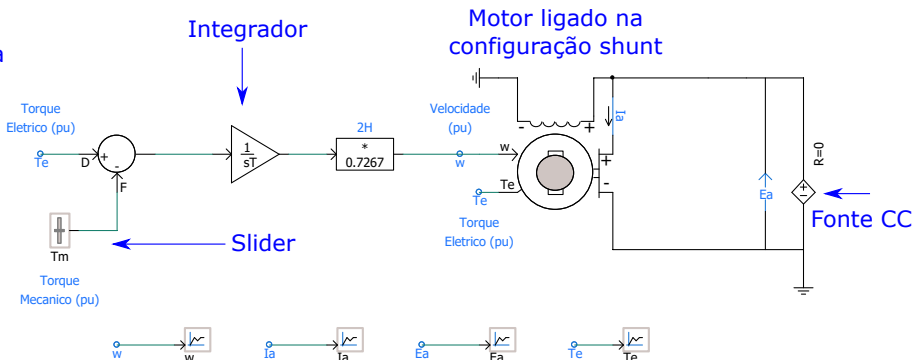
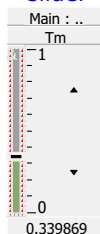
$$2H \frac{d\omega_{m,pu}}{dt} = T_{e,pu} - T_{m,pu}$$

$$H = \frac{J}{2} \frac{\omega_{nominal}}{P_{nominal}}$$

- T_e - Torque eletromagnético (calculado pelo modelo da máquina)
- T_m - Torque mecânico
- ω_m - Velocidade mecânica

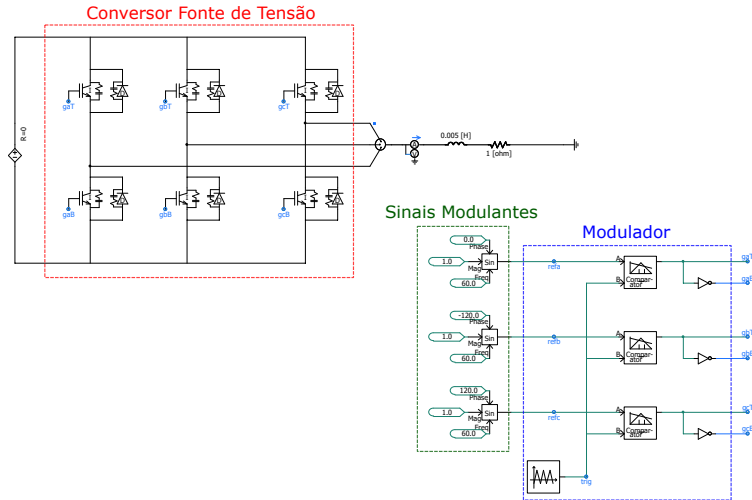
Circuito 2F: Circuito

Painel para
controlar o
slider

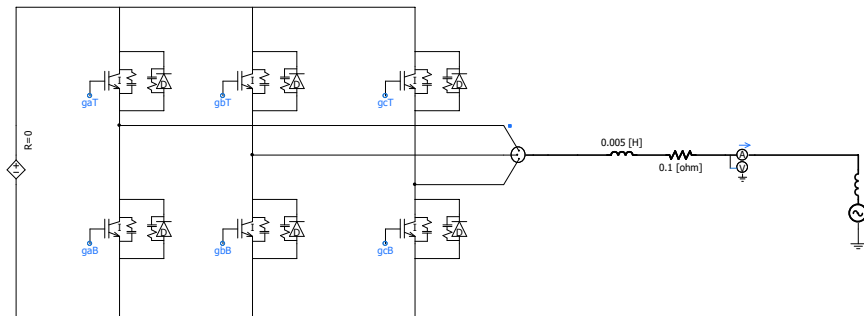


Mais Simulações

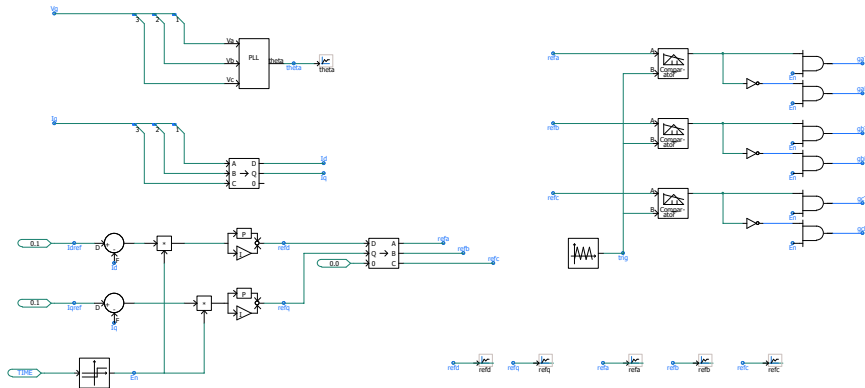
Circuito A: Inversor *Stand alone*



Circuito B: Inversor Conectado a Rede



Circuito B: Inversor Conectado a Rede - Controle

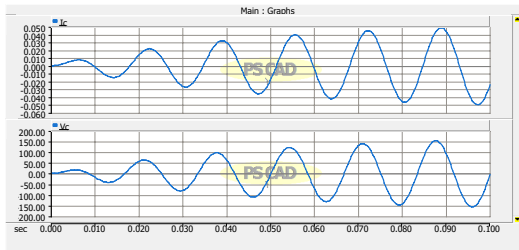


Exportando Dados

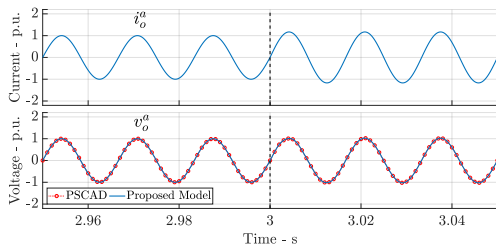
Porque Exportar Dados?

Motivo 1: Para produzir gráficos com melhor qualidade

PSCAD



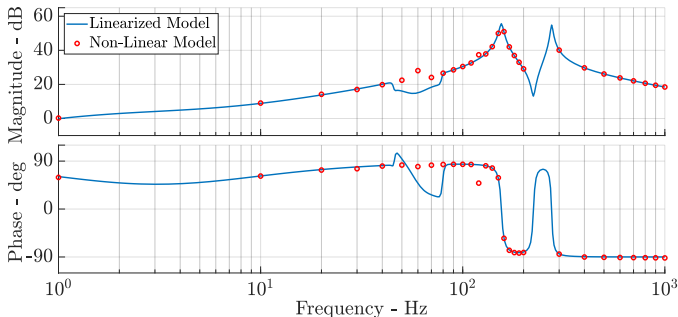
MATLAB/OCTAVE/matplotlib/etc



Porque Exportar Dados?

Motivo 2: Para produzir gráficos de variáveis/funções indiretamente obtidas

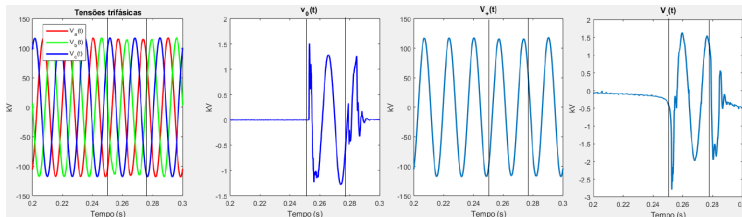
Diagrama de bode



Porque Exportar Dados?

Motivo 3: Para Processar Dados

Ex: Extração de componentes simétricas no domínio do tempo²

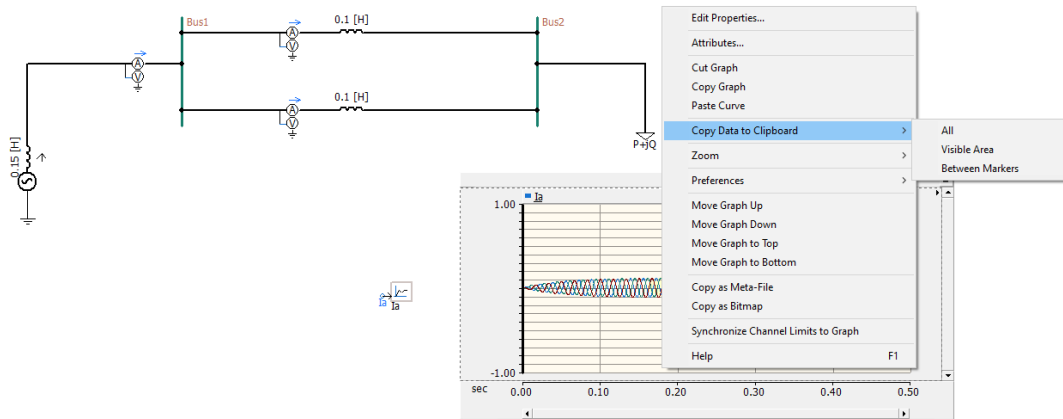


$$v_2(\omega t) = \frac{1}{3} \begin{pmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \end{pmatrix} \begin{pmatrix} g_\omega(t)v_a(\omega t) \\ g_\omega(t)v_b(\omega t) \\ g_\omega(t)v_c(\omega t) \end{pmatrix} + \frac{1}{3} \begin{pmatrix} 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{pmatrix} \begin{pmatrix} H\{g_\omega(t)v_a(\omega t)\} \\ H\{g_\omega(t)v_b(\omega t)\} \\ H\{g_\omega(t)v_c(\omega t)\} \end{pmatrix} \quad (12)$$

$$H\{s(t)\} = \frac{1}{\pi} \int_{-\infty}^{+\infty} \frac{s(\tau)}{\tau - t} d\tau$$

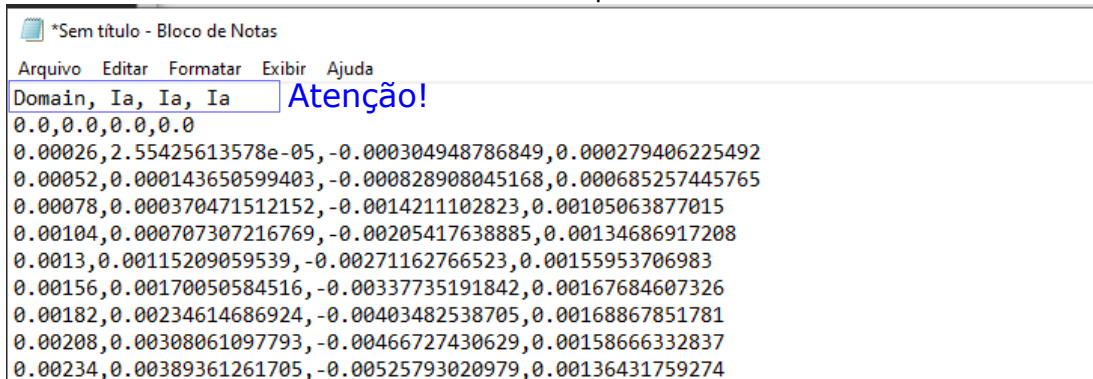
²Verônica Rodrigues Feijão, [Estudo de Localização de Falhas de Curta Duração para uma Rede de 14 Barras](#). Projeto de Graduação - UERJ, 2019.

Primeira Possibilidade: Serve para Pequenas Tarefas



Primeira Possibilidade: Serve para Pequenas Tarefas

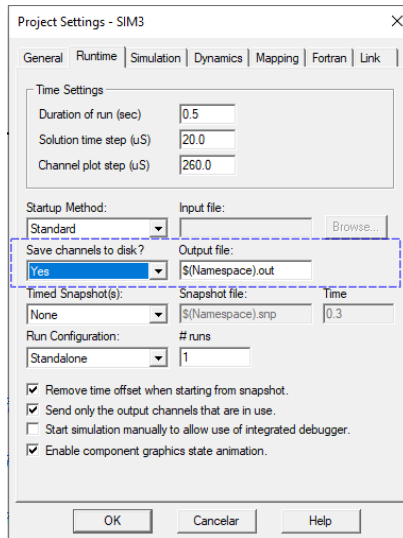
É só colar em um arquivo de texto:



```
*Sem título - Bloco de Notas
Arquivo  Editar  Formatar  Exibir  Ajuda
Domain, Ia, Ia, Ia
Atenção!
0.0,0.0,0.0,0.0
0.00026,2.55425613578e-05,-0.000304948786849,0.000279406225492
0.00052,0.000143650599403,-0.000828908045168,0.000685257445765
0.00078,0.000370471512152,-0.0014211102823,0.00105063877015
0.00104,0.000707307216769,-0.00205417638885,0.00134686917208
0.0013,0.00115209059539,-0.00271162766523,0.00155953706983
0.00156,0.00170050584516,-0.00337735191842,0.00167684607326
0.00182,0.00234614686924,-0.00403482538705,0.00168867851781
0.00208,0.00308061097793,-0.00466727430629,0.00158666332837
0.00234,0.00389361261705,-0.00525793020979,0.00136431759274
```

Segunda Possibilidade: Útil para Grandes Tarefas

- Podemos configurar a simulação para salvar os dados dos ioutput chanel
- Basta configurar a opção *save to disk*
- É gerado um arquivo com extensão *.map* contendo informações
- São gerados aquivos com extensão *.out* contendo os dados



Segunda Possibilidade: Útil para Grandes Tarefas

- Os arquivos *.out* e *.map* são dispostos na pasta de arquivos compilados da simulação
- Cada arquivo *.out* têm até 10 sinais, um por coluna
- A primeira coluna de todos os arquivos *.out* contém o vetor de domínio (Tempo ou Frequência)



Segunda Possibilidade: Útil para Grandes Tarefas

SIM3.map - Bloco de Notas

Arquivo Editar Formatar Exibir Ajuda

0 0

MAP: "Main.dta" !

1 9 1 2 3 4 5 6 7 8 9 /
0 0

!-----
! Recorder Channel Information
!-----

PGBList:

PGB(1)	Output	Desc="Ia:1"	Group="Main"	Max=2.0	Min=-2.0	Units=""
PGB(2)	Output	Desc="Ia:2"	Group="Main"	Max=2.0	Min=-2.0	Units=""
PGB(3)	Output	Desc="Ia:3"	Group="Main"	Max=2.0	Min=-2.0	Units=""
PGB(4)	Output	Desc="Ib:1"	Group="Main"	Max=2.0	Min=-2.0	Units=""
PGB(5)	Output	Desc="Ib:2"	Group="Main"	Max=2.0	Min=-2.0	Units=""
PGB(6)	Output	Desc="Ib:3"	Group="Main"	Max=2.0	Min=-2.0	Units=""
PGB(7)	Output	Desc="Ic:1"	Group="Main"	Max=0.010	Min=-0.010	Units=""
PGB(8)	Output	Desc="Ic:2"	Group="Main"	Max=0.010	Min=-0.010	Units=""
PGB(9)	Output	Desc="Ic:3"	Group="Main"	Max=0.010	Min=-0.010	Units=""
PGB(10)	Output	Desc="Va:1"	Group="Main"	Max=2.0	Min=-2.0	Units=""
PGB(11)	Output	Desc="Va:2"	Group="Main"	Max=2.0	Min=-2.0	Units=""
PGB(12)	Output	Desc="Va:3"	Group="Main"	Max=2.0	Min=-2.0	Units=""
PGB(13)	Output	Desc="Vb:1"	Group="Main"	Max=2.0	Min=-2.0	Units=""
PGB(14)	Output	Desc="Vb:2"	Group="Main"	Max=2.0	Min=-2.0	Units=""
PGB(15)	Output	Desc="Vb:3"	Group="Main"	Max=2.0	Min=-2.0	Units=""
PGB(16)	Output	Desc="Vc:1"	Group="Main"	Max=2.0	Min=-2.0	Units=""
PGB(17)	Output	Desc="Vc:2"	Group="Main"	Max=2.0	Min=-2.0	Units=""
PGB(18)	Output	Desc="Vc:3"	Group="Main"	Max=2.0	Min=-2.0	Units=""
PGB(19)	Output	Desc="Pa"	Group="Main"	Max=2.0	Min=-2.0	Units=""
PGB(20)	Output	Desc="Pb"	Group="Main"	Max=2.0	Min=-2.0	Units=""
PGB(21)	Output	Desc="Pc"	Group="Main"	Max=2.0	Min=-2.0	Units=""
PGB(22)	Output	Desc="Qa"	Group="Main"	Max=2.0	Min=-2.0	Units=""
PGB(23)	Output	Desc="Qb"	Group="Main"	Max=2.0	Min=-2.0	Units=""
PGB(24)	Output	Desc="Qc"	Group="Main"	Max=2.0	Min=-2.0	Units=""

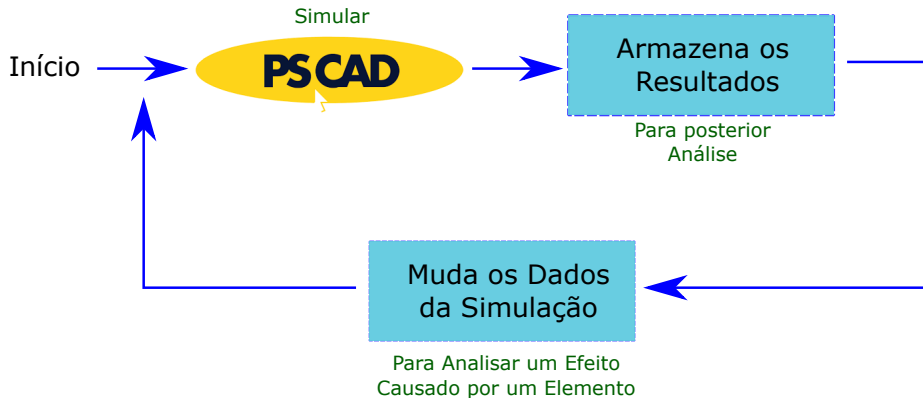
SIM3_01.out - Bloco de Notas

Arquivo Editar Formatar Exibir Ajuda

0.000000000000E-03	0.000000000000E-03	0.000000000000E-03	0.000000000000E-03
0.2600000000000000E-03	0.2542561357753E-04	-0.30494878684929E-03	0.27941
0.5200000000000000E-03	0.14365059940254E-03	-0.82890804516779E-03	0.6852
0.7800000000000000E-03	0.37047151215170E-03	-0.14211102823005E-02	0.1050
0.1040000000000000E-02	0.70730721676945E-03	-0.20541763888525E-02	0.1346
0.1300000000000000E-02	0.11520905953931E-02	-0.27116276652265E-02	0.1559
0.1560000000000000E-02	0.17005058451575E-02	-0.33773519184166E-02	0.1676
0.1820000000000000E-02	0.23461468692398E-02	-0.40348253870473E-02	0.1688
0.2080000000000000E-02	0.30806109779251E-02	-0.46672743062920E-02	0.1586
0.2340000000000000E-02	0.38936126170468E-02	-0.52579302097871E-02	0.1364
0.2600000000000000E-02	0.47731238361279E-02	-0.57902948875026E-02	0.1017
0.2860000000000000E-02	0.57055404355816E-02	-0.62484037334804E-02	0.5428
0.3120000000000000E-02	0.66758716942846E-02	-0.66170832109185E-02	-0.5878
0.3380000000000000E-02	0.76679512095828E-02	-0.68821989031839E-02	-0.7857
0.3640000000000000E-02	0.8646661046665E-02	-0.70308908011256E-02	-0.1633
0.3900000000000000E-02	0.96482016209595E-02	-0.70517926423351E-02	-0.2596
0.4160000000000000E-02	0.10600297913179E-01	-0.69352323168216E-02	-0.3665
0.4420000000000000E-02	0.11502515703874E-01	-0.66734105884810E-02	-0.4829
0.4680000000000000E-02	0.12336507334353E-01	-0.62605556503747E-02	-0.6075
0.4940000000000000E-02	0.13084289671375E-01	-0.56930513310058E-02	-0.7391
0.5200000000000000E-02	0.13728515294674E-01	-0.49695370949035E-02	-0.8758
0.5460000000000000E-02	0.14252738399712E-01	-0.40909783300176E-02	-0.1016
0.5720000000000000E-02	0.14641671902944E-01	-0.30607057825093E-02	-0.1158
0.5980000000000000E-02	0.14881432332584E-01	-0.18844233821527E-02	-0.1299
0.6240000000000000E-02	0.14959769225420E-01	-0.57018409416961E-03	-0.1438
0.6500000000000000E-02	0.14866275927883E-01	0.87166616871896E-03	-0.1573
0.6760000000000000E-02	0.14592578915390E-01	0.24285761416583E-02	-0.1702
0.7020000000000000E-02	0.14132502995292E-01	0.408059074835734E-02	-0.1821
0.7280000000000000E-02	0.13482210042817E-01	0.58270825210175E-02	-0.1930
0.7540000000000000E-02	0.12640309232715E-01	0.76337598749263E-02	-0.2027
0.7800000000000000E-02	0.11607937068382E-01	0.94860360305526E-02	-0.2109
0.8060000000000000E-02	0.10388805871060E-01	0.11362670578152E-01	-0.2175
0.8320000000000000E-02	0.89892197700512E-02	0.13241332545139E-01	-0.2223
0.8580000000000000E-02	0.74180576264351E-02	0.15098864963208E-01	-0.2251
0.8840000000000000E-02	0.56027337370243E-02	0.46161666666666E-01	0.3350

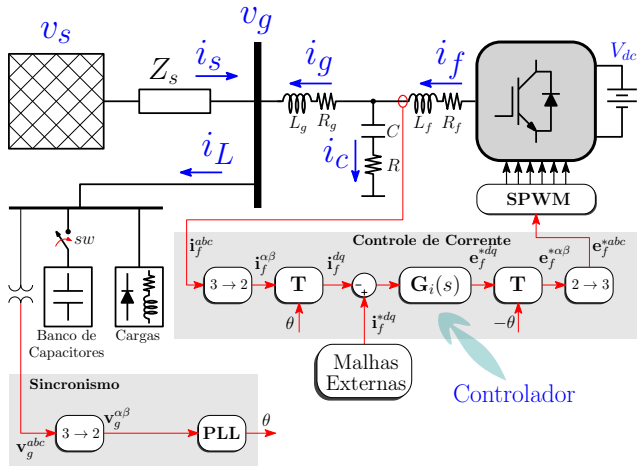
Automação de Simulações

O que significa automatizar simulações?



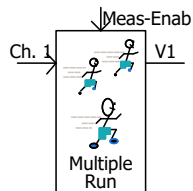
Por que automatizar simulações?

Motivo 1: Ajustar sistemas de controle

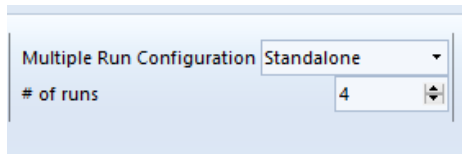


Como fazer?

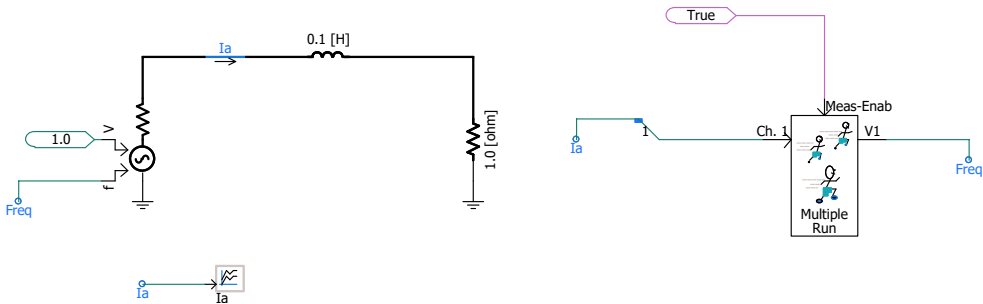
- Inserir/Configurar o bloco *Multiple run* localizado no grupo de *I/O Devices* na biblioteca Master.



- Configurar o projeto para *Multiple run*.

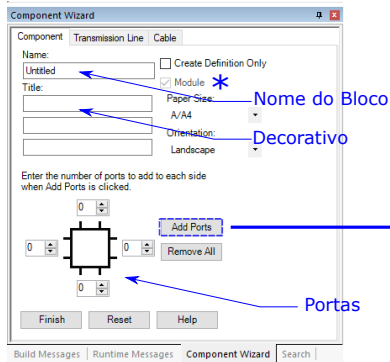


Circuito Exemplo

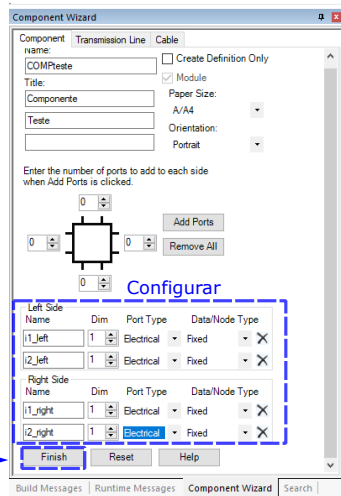


Criação de Componentes e Bibliotecas

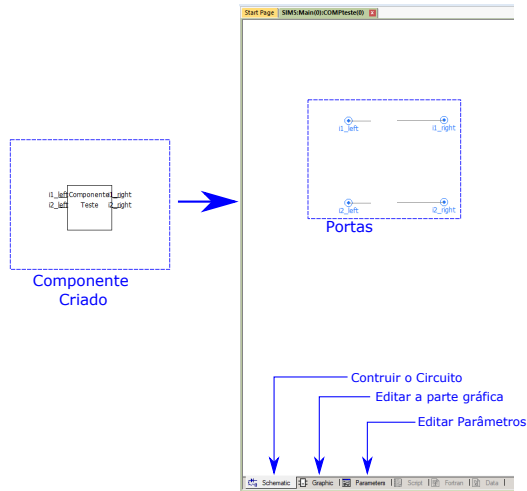
Encapsulando Circuitos: *Component Wizard*



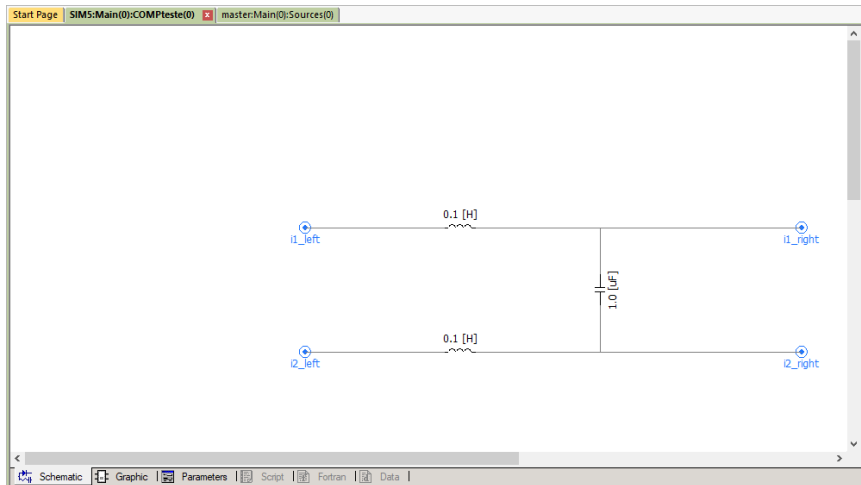
Depois de
Configuras
as Portas



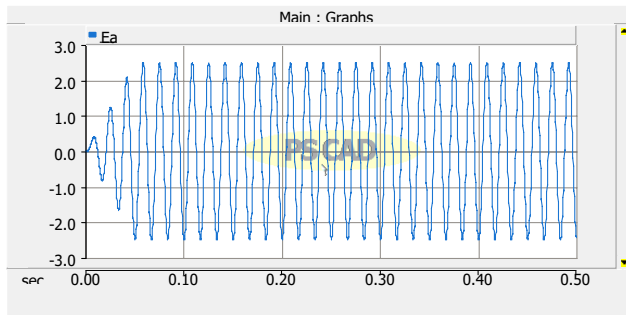
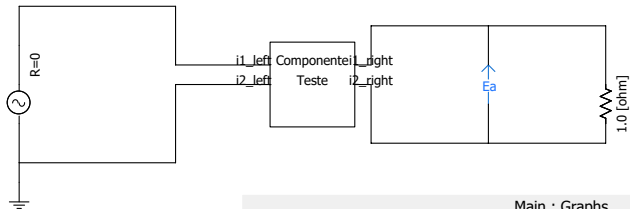
Encapsulando Circuitos: Resultado



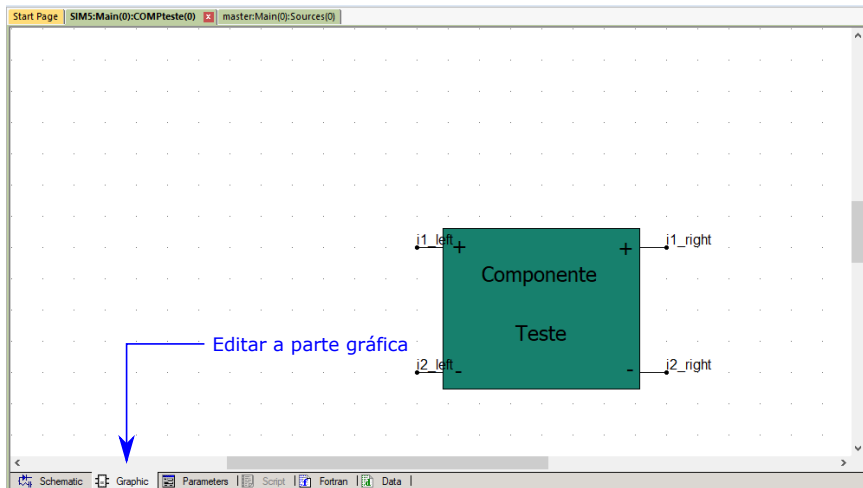
Encapsulando Circuitos: Montando o Esquemático



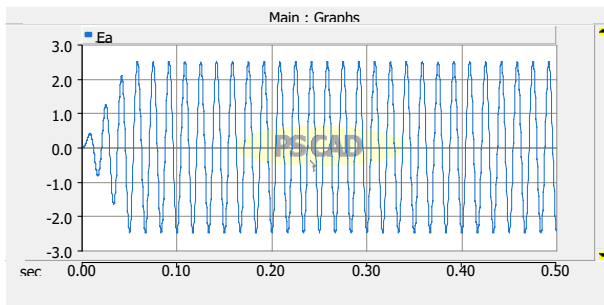
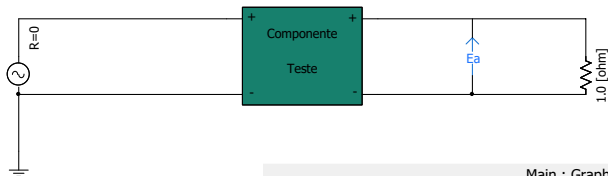
Encapsulando Circuitos: Testando



Encapsulando Circuitos: *Decorando o Bloco*

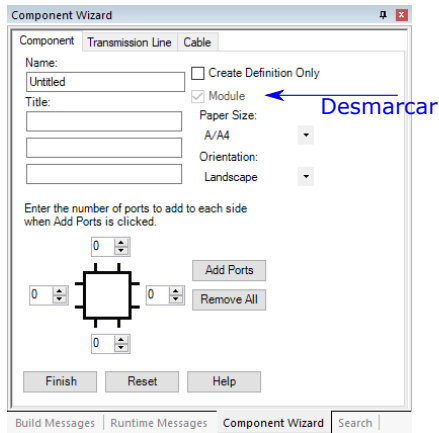


Encapsulando Circuitos: Testando, de novo



Programando componentes com FORTRAN

- Criar um bloco seguindo os passos anteriores
- Demarcar a opção *Module*
- Programar o bloco na aba script



Programando componentes com FORTRAN: Componente A

Componente que soma uma constante K a todos os elementos de um vetor. Ou seja:

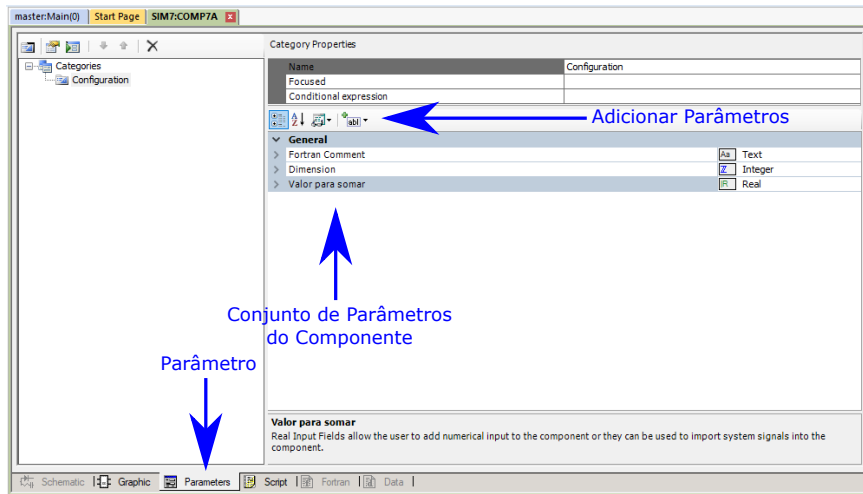
$$\mathbf{y}[n] = \mathbf{x}[n] + K$$

\mathbf{y} - Vetor com N posições (saída do bloco)

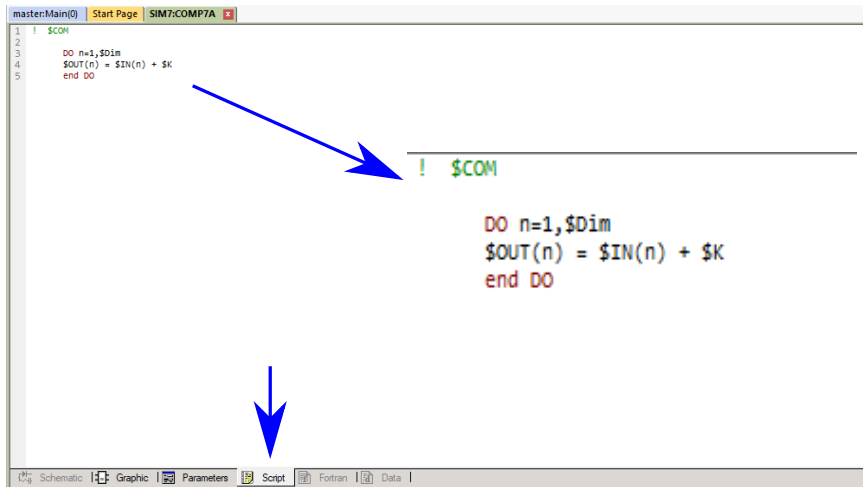
\mathbf{x} - Vetor com N posições (entrada do bloco)

K - Constante

Programando componentes com FORTRAN: Componente A



Programando componentes com FORTRAN: Componente A

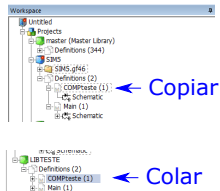


Programando componentes com FORTRAN: Componente B

```
master:Main(0):CSMF(0) | Start Page | S
1  ! $COM
2
3
4  IF ($IN > $Teste) THEN
5  $OUT = 5.23
6  ELSE
7  $OUT = -2.1
8  END IF|
```

Guardando componentes em uma Biblioteca

- Crie uma biblioteca
- No workspace, Copie a definição do componente do seu projeto
- Cole na seção de definições da biblioteca



Obrigado pela Atenção!

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