ELG3311: EXPERIMENT 2
Simulation of a Transformer Performance

Objective

Using Matlab simulation toolbox (SIMULINK), design a model to simulate the performance of a single-phase transformer under different loads.

Goals

- Train the student with the concept of simulation
- Train the student in using SIMULINK toolbox.

Background information and preparation:

Efficiency and Voltage regulation are some characteristics of a transformer that vary with the load (its magnitude and its power factor). The characteristic Vs = fct(load) is also important to know how far down may drop the transformer's output voltage with a given load. Note that in this experiment, only the effect of load magnitude is tested

Review the transformer equivalent circuit and try to derive the equations for Is, Vs, Ip, η, %Reg with the assumption that you know – the primary input voltage Vp – copper impedance Zw – iron impedance Zi – and a load ZL. Read the appendix to understand the concepts and explore Matlab SIMULINK toolbox.

Simulation design scheme

We provide 2 inputs (Primary voltage and load) to a transformer and we plot the underlined characteristics (see Figure 1).

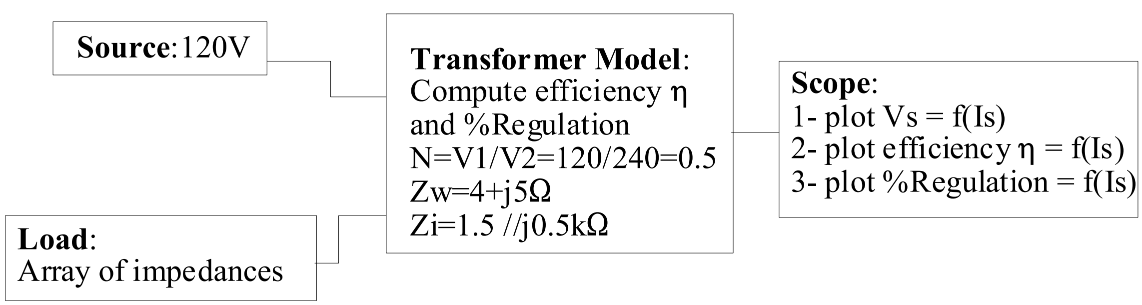


Figure 1: A Transformer simulation scheme

Procedure:

Goal: Reproduce 4 simulink models given in Appendix D.

1- Run matlab 6 and configure your workspace: example current directory to your working directory.

2- Use the menu File->New->Model to get a simulink model blank window.
3- Use the menu View -> Library Browser to get a window for the library of different blocks. Note: all the blocks that we need for this project will be found under “Simulink” branch.
4- To use a block, click on it in the Library Window (LW) and drag it to you Model Window (MW). Likely, get all the other blocks you need.
5- Right-click a block to configure its values our parameters.
Note on multiplex data bus: the data access syntax is u[*] where * is the order of the data multiplexed on the bus. See figure 2. Use that syntax to define formulas in Fcn blocks.

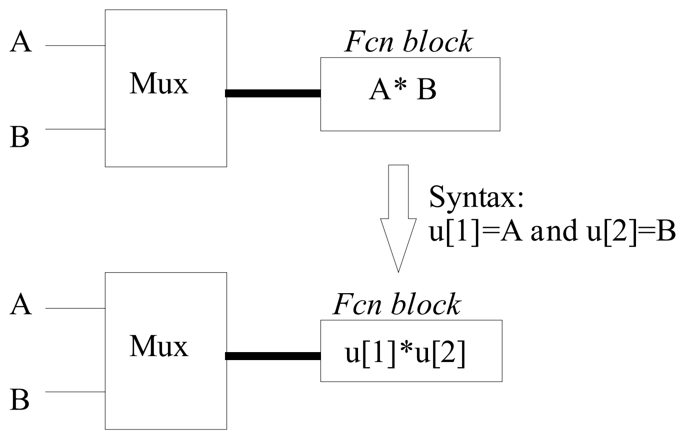


Figure 2: Syntax for data access on a data bus

6- Build the models and subsystems as shown in the figures 3 in appendix D
7- When finished constructing the models, configure the simulation parameters for the main model as follow: Stop time = 100.0. Leave all others parameters as default. Use the menu Simulation -> Simulation Parameters for this.
8- Run your simulation. Use the menu Simulation -> Simulation Start. If you get some errors, read carefully the errors messages and then debug. Use matlab “help button or popup menu” on blocks to get information about them.
9- If you model is successfully run (no error window popped up), use the script Ploter.m in Appendix C to plot the results.
10- Show your results to an assistant (TA).

APPENDIX A: Derived Formulas for a Transformer

These formulas (Equ#1-4) are to be used in Fcn block to compute some values. Don't forget the syntax u[*] to refer to the appropriate variable.

Known parameters

$$Zw = 5 + 5i\Omega; \quad Zi = 1500 + 500i\Omega$$

$$ZL = \text{var}\,iable = 200 \rightarrow 80\Omega \text{ } by \text{ } steps \text{ } of \text{ } 10\Omega$$

$$N = ratio = 0.5; \quad Vp = 120V$$

Secondary current

$$Is = \frac{Vs}{ZL} \qquad Equ\#1$$

Secondary voltage

$$Vp = Zw * \frac{Is}{N} + N * Vs \Rightarrow Vs = \frac{Vp}{\frac{Zw}{N * ZL} + N} \qquad Equ\#2$$

Efficiency

$$Ip = Ie + \frac{Is}{N}; \quad Ie = \frac{Vp}{Zi} \Rightarrow \eta = \frac{\mathrm{Re}\{Vs * Is^*\}}{\mathrm{Re}\{Vp * Ip^*\}} * 100 \approx \frac{\frac{Vs^2}{ZL}}{\frac{Vp^2}{Zi} + \frac{Vs * Vp}{N * ZL}} * 100 \qquad Equ\#3$$

Voltage regulation

$$\%\,\mathrm{Re}\,g = \left(1 - \frac{N * Vs}{Vp}\right) * 100 \qquad Equ\#4$$

Note:

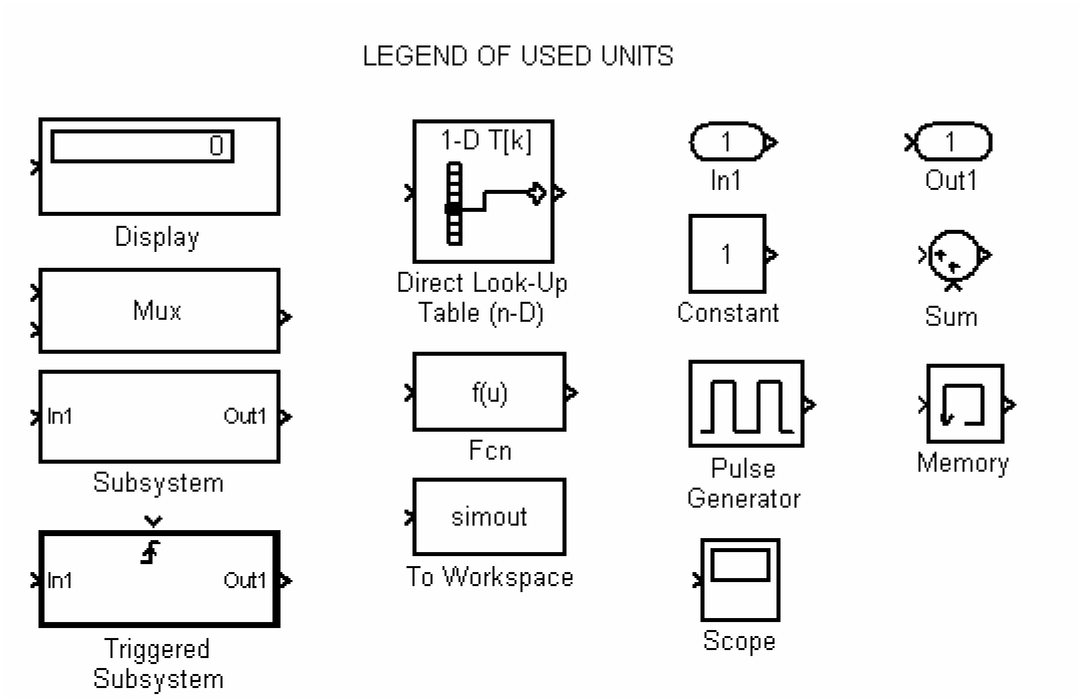
1- The 2nd formula for the efficiency is an approximation because it does the ratio of apparent powers rather than active powers. This is because, including the working of complex values should increase the complexity of this experiment. You may try it for fun for yourself.

2- The expression of the voltage regulation is different from the one in the textbook because in this experiment, V-primary is constant while V-secondary varies with the load. The scenario is opposite in the case of the textbook where V-primary is supposed to increase to maintain V-secondary constant when the load increases.

APPENDIX B: used blocks legend

The following instructions are examples of links that lead to simulink blocks or modules used to design the models in this experiment.

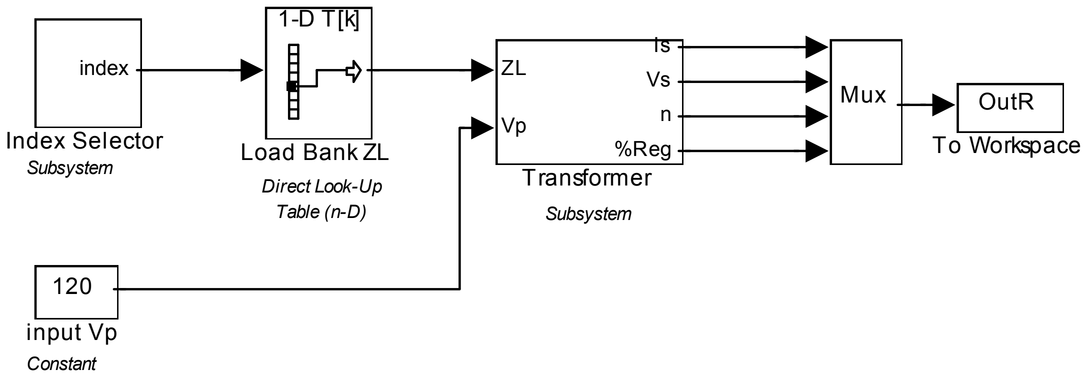
Block's mnemonic	Library links
Mux	Simulink -> Signal routing
Constant, In1, Pulse Generator, Trigger	Simulink -> Source
To Workspace	Simulink -> Sinks
Sum, Abs	Simulink -> Math Operations
Memory	Simulink -> Discrete
Triggered Subsystem	Simulink -> Ports & Subsystem
Fcn	Simulink -> User-Defined Functions
Direct Look-up Table	Simulink ->Look-up Tables



APPENDIX C: Ploter.m script

```
% Matlab M-file to plot the simulation outputs.

% It plots the %Regulation and Efficiency vs apparent load

%Plot Vs
subplot(3,1,1);  plot(OutR(:,1), OutR(:,2));
xlabel('Load current [A]');
ylabel('[V]');
title('Output Voltage');

%Plot Efficiency
subplot(3,1,2);  plot(OutR(:,1), OutR(:,3));
xlabel('Load current [A]');
ylabel('n[%]');
title('Efficiency');

%Plot %Regulation
subplot(3,1,3);  plot(OutR(:,1), OutR(:,4));
xlabel('Load current [A]');
ylabel('%Reg[%]');
title('%Regulation');
```

APPENDIX D: Sample of the models to design



TRANSFORMER SIMULATOR

This module can be seeing as 4 blocs:

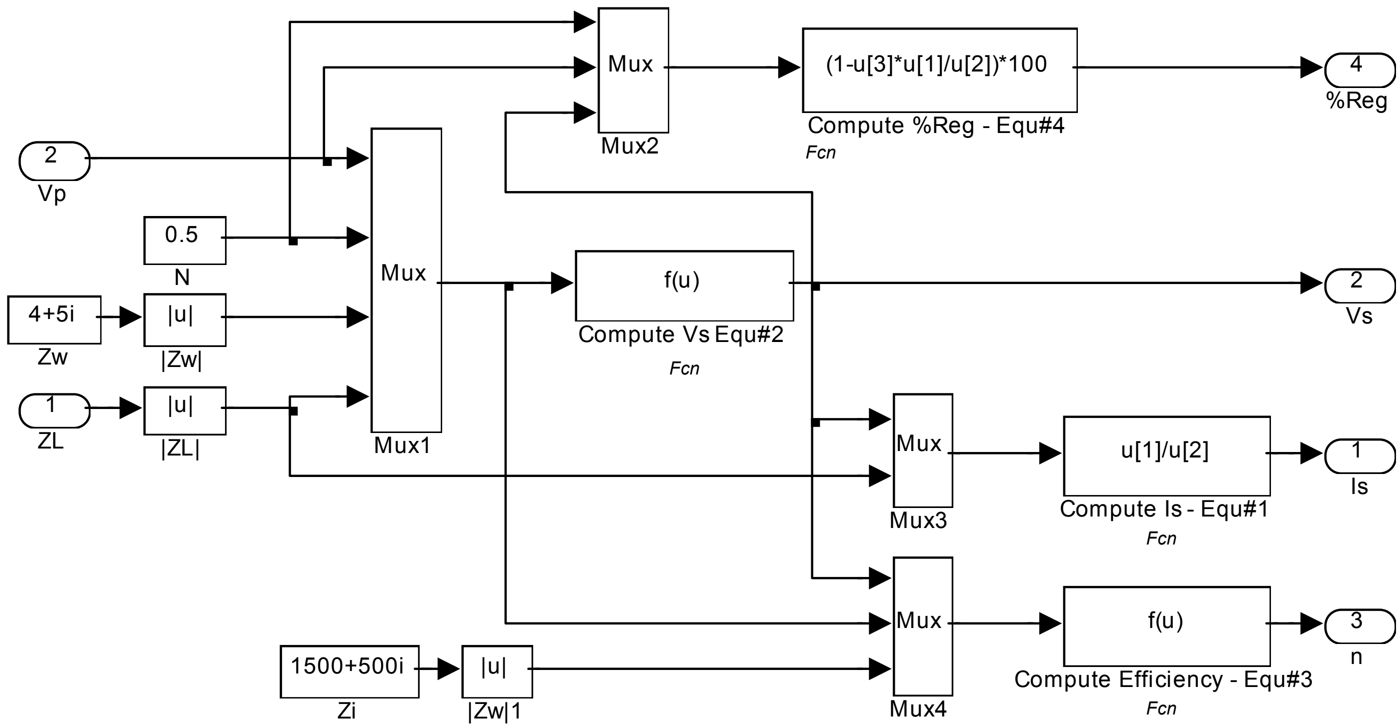
1- A bank of Loads ZL arranged in a column vector;

2- A load ZL selector. It simply provides an index i to select a corresponding ZL(i)

3- A Tranformer model. It takes in a Load ZL (or ZL(i)) and a Primary source voltage Vp
 and outputs:
 Is: secondary current
 Vs: secondary voltage
 n: Efficiency
 %Reg: Voltage Regulation

4- A result collector. It creates a matrix variable 'OutR' in matlab workspace whose columns are in order Is, Vs, n, %Reg. It's rows contains the match results for each ZL (or ZL(i)). OutR can be plot from Matlab workspace using Ploter.m script.

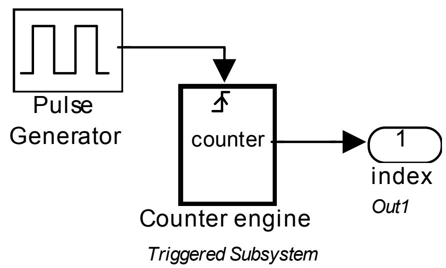
Figure 3.1: Transformer simulator



TRANSFORMER MODEL
Caracteristics: Zw = 4+5i;   Zi = 1500+500i;   N = 0.5;   Vp = to be input
Derived formulas: see Appendix.
Outputs:

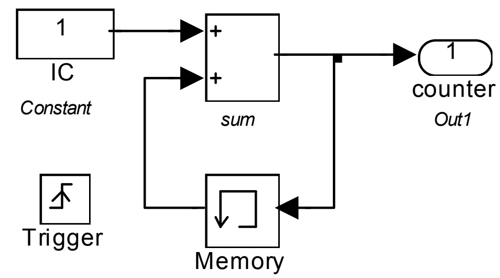
- Is: secondary current
- Vs: secondary voltage
- n: Efficiency
- %Reg: Voltage Regulation

Figure 3.2: Transformer Model Subsystem



SELECTOR
This module generate at its output, an integer sequence 1, 2, 3, ...

Figure 3.3: Index Selector Subsystem



A counter System that outputs 1,2... on front edge of the triger.

Figure 3.4: Counter Triggered Subsystem

Note: Start with a triggered sub-system and then add the memory and the sum box.