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Experiment-6

Aim

Study of Surge Impedance Loading of a transmission Line

Simulink Blocks Required

1. AC voltage source, 1 phase, 50 Hz, 326.598 kV peak
2. Current, power and voltage measurement blocks
3. RMS calculation blocks
4. Display units
5. Pi section transmission line (R=0.037 Ohms/km, L=0.97347 mH/km, C=0.11984 nF/km, total length=300 km, 6 sections of 50 km each, rated line to line voltage is 400 kV, per phase rating is 230.94 kV)
6. R element representing a purely resistive load
7. Powergui block

Software Used

MATLAB 2018a

Theory

Surge Impedance is the characteristic impedance of a lossless transmission line. It is also called Natural Impedance because this impedance has nothing to do with load impedance. Since line is assumed to be lossless, this means that series resistance and shunt conductance is negligible i.e. zero for power lines.

This means that, Series Resistance R = 0 and Shunt Conductance G =

As Characteristic Impedance Zc = z/y

where z is series impedance per unit length per phase and y is shunt admittance per unit length per phase.

z = R +jwL

y = G + jwC

For lossless line, z= jwL and y = jwC

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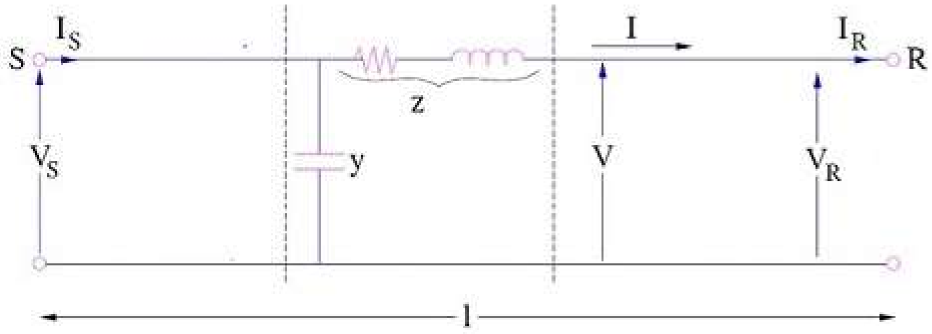
Hence according to definition,

Surge Impedance = Zs = Zc = √(jwL/jwC)

= √(L/C)

Surge Impedance Loading SIL

A transmission line terminated with load equal to surge impedance of line is called surge impedance loading SIL.



Let us a look at the voltage profile along the line for surge impedance loading condition. We know that voltage at any point is given as

V = [(Vr +ZcIr)/2]eμx + [(Vr-ZcIr)/2]e-μx

Where Zc is characteristic impedance. Since line is assumed lossless therefore characteristic impedance and surge impedance will be equal i.e. Zc = Zs. Also, line is terminated with surge impedance therefore Vr = ZsIr

V = [(Vr +ZsIr)/2]eμx + [(Vr-ZsIr)/2]e-μx = ZsIr eμx

Since μ = √yz = μ = √(j2w2LC) = jw√LC

V = ZsIr ejwx√LC

Assuming wx√LC = ϴ

V = ZsIr ejϴ = ZsIr ∠ϴ

The above expression of voltage shows that, for surge impedance loading the voltage profile along the line is uniform or flat. This means sending end voltage and receiving end voltages are same for surge impedance loading.

Thus SIL can also be defined as,

Surge Impedance Loading is the connected load in transmission line for which reactive power generated is equal to reactive power consumed i.e. the flow of reactive power is zero. There is an exact balance between reactive power generation and consumption. Mind that reactive power is generated here by shunt capacitance and being consumed by series inductance of line.

From the above definition of SIL, we can have a second method to calculate Surge Impedance Zs.

Reactive Power Generated = Reactive Power Consumed

V2wC = I2wL

(V/I) = √(L/C)

Zs = √(L/C)

PROCEDURE:

1. Build the SIMULINK model as shown in Fig.1.
2. Set the voltage of sending end (in the AC voltage source) to required level, i.e., 326.598 kV peak.
3. Run the simulation by applying load. In different simulation runs, keep on changing the load in suitable steps until the KW of the sending end increases to a certain limit, remains constant and then decreases.
4. Note down the value of maximum KW rating or loading. This value gives the SIL of the line.
5. Remove the load.
6. Build the SIMULINK model given in Fig.2. Note the receiving end is open circuited using a voltage measurement block. To find SIL, run the simulation and note down sending end voltage (Voc) and current (Ioc).
7. Build the SIMULINK model given in Fig.3. Note the receiving end is short circuited using a current measurement block. Run the simulation and note down sending end voltage (Vsc) and current (Isc).
8. Find impedance in open circuit and short circuit condition

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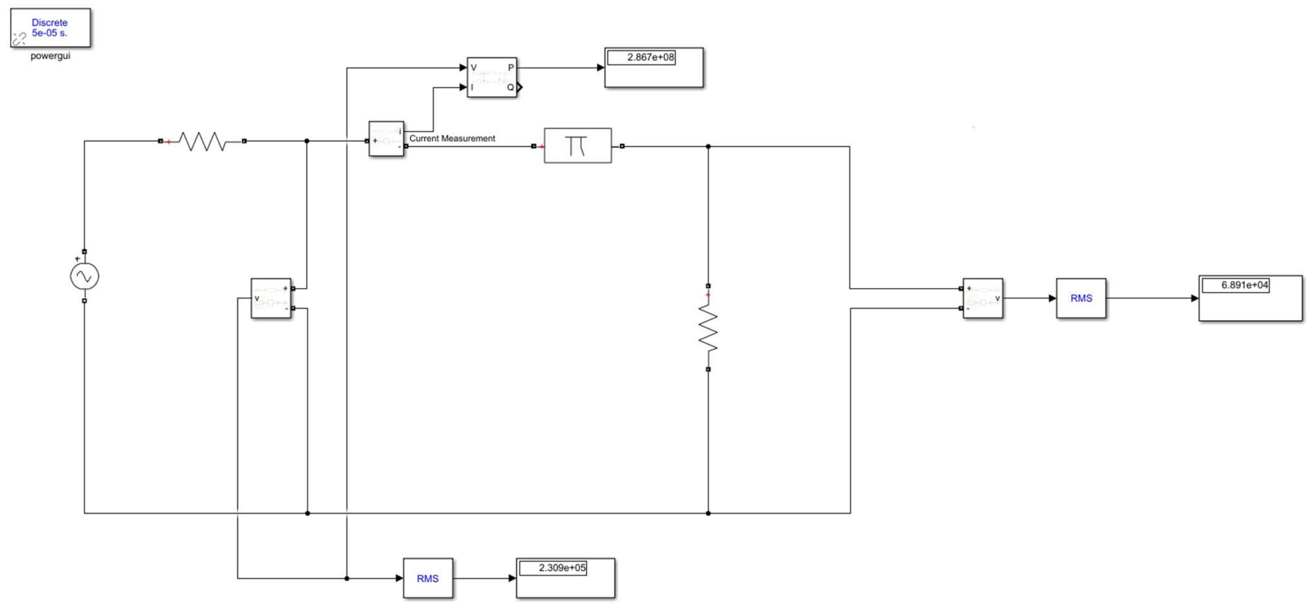
Circuit Diagram

1. Finding the surge impedance loading



Observation Table

S.No	Load (ohm)	Vs (KV)	Vr (KV)	Load Power (KW)
1	5	230.9	7.3	167400
2	10	230.9	36.01	228200
3	20	230.9	58.08	267900
4	30	230.9	78.12	297200
5	40	230.9	95.94	316900
6	50	230.9	118.05	331400
7	60	230.9	125.2	333000
8	65	230.9	128.9	333000
9	68	230.9	131.2	333000
10	69	230.9	134.7	333000
11	70	230.9	142.1	331000

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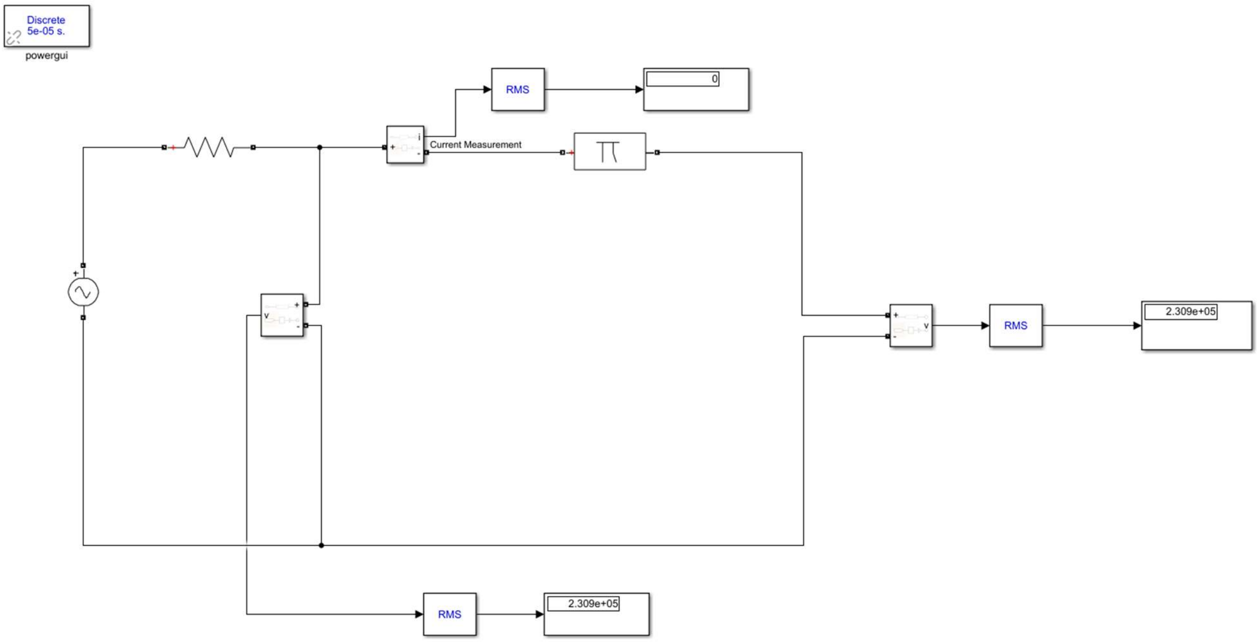
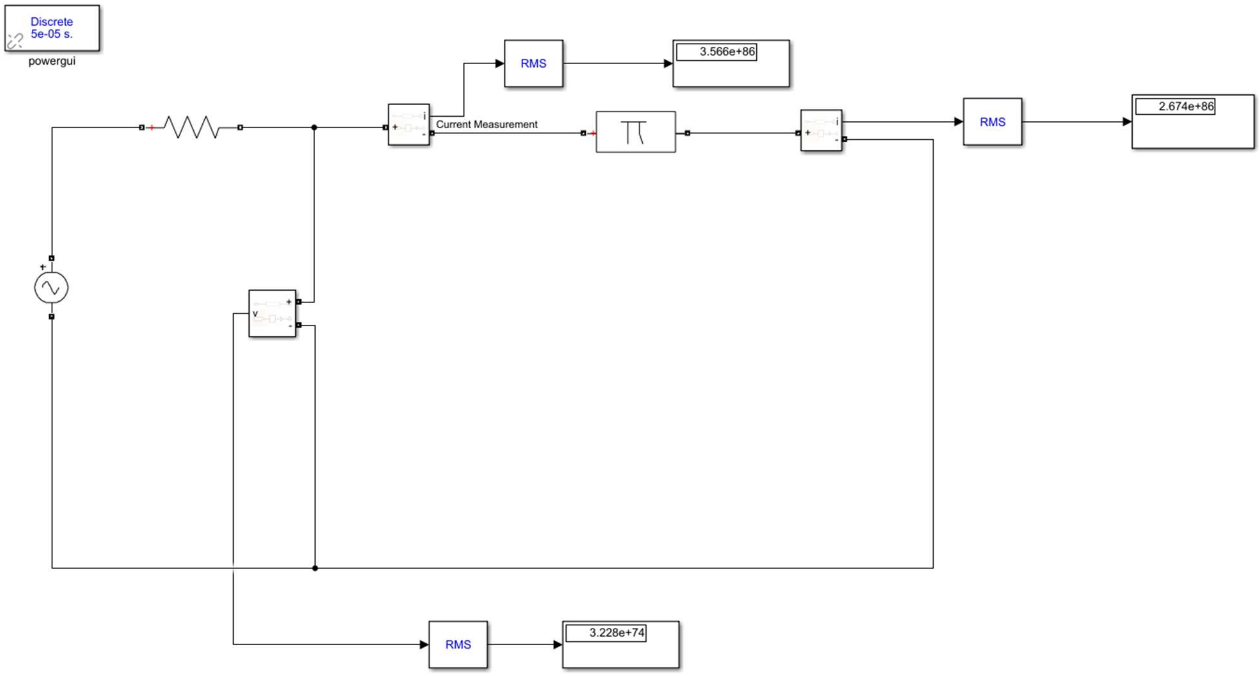
2. Open circuit measurements



3. Short Circuit Measurements



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Observation Table

	SENDING END		RECEIVING END	
	Vs (KV)	Is (A)	Vr (KV)	Ir (A)
OPEN	230.9	0.00015	230.9	0
SHORT	322.8 x 10^{69}	3.566 x 10^{86}	0	2.674 x 10^{86}

Calculations

$$Z_{OC} = \frac{V_{OC}}{I_{OC}} = \frac{230900}{0.00015} = 1.539 \times 10^{9}\ \Omega$$

$$Z_{SC} = \frac{V_{SC}}{I_{SC}} = \frac{3.228 \times 10^{74}}{3.566\ x\ 10^{86}} = 9.0776 \times 10^{-13}\ \Omega$$

Core or Natural Impedance,

$$Z_c\ or\ Z_n = \sqrt{Z_{OC} Z_{SC}} = \sqrt{1.539 \times 10^{9}\ \times 9.0776 \times 10^{-13}}$$

$$Z_c\ or\ Z_n = 0.037377\Omega$$

Surge Impedance Loading,

$$P = \frac{V^2}{Z_C} = \frac{129600\ \times 129600}{0.037377} = 4.493 \times 10^{8}\ KW$$

Result

Surge Impedance of line = 68Ω

Surge Impedance Loading (SIL) of line = 4.493 x 10^8 KW