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# Effect(S) of Nominal-T Configuration on Transmission Line

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## ABSTRACT

This research work focused on the effect of disturbances on transmission line. Osogbo to Akure 132kV transmission line is chosen as a case study which falls under medium line classification. Hence nominal-T network was considered in our analysis. In order to achieve this set objective, transmission line data were obtained from the station. The network was modeled and used to generate a signal flow graph which was further used in generating the system transfer function. The transfer function was tested with the line constants extracted from the data obtained to examine the effect and nature of the disturbances. A code was written and run with Linear Time Invariant (LTI) tool in MATLAB environment. The result revealed that there is always an occurrence of disturbance (voltage) at the receiving end. The system responses were recorded for both normal and disturbance states. It was discovered that the effect of the disturbance (although transient) was oscillatory in nature, which causes the power signal to swell and shrink very rapidly.

**Keywords:** Transmission line, nominal-T, model, system response, disturbance, MATLAB.

## INTRODUCTION

Electricity plays a major role in the economic growth and development of any country. Transmission line equally plays a very vital role in Electric Power System (EPS). It serves the purpose of transferring electric energy from the generating station to the distributing system, which ultimately supplies the load. It also serves the purpose of interconnecting utility, for the aim of power transfer within regions. In this wise, it is imperative to see that this fractional part of EPS, is always maintained. It is also a must to know the time it will take the system to return to steady state when disturbance occurs as a result of switching action of inductive or capacitive load such as motor or capacitor bank or lightning when rain falls. Disturbance, as the case may be represents an unwanted signal that affects the optimal performance of system. Here, we are considering transmission line as a system.

This research work is aim at studying the side effect of disturbances on transmission line and the likely cause of these disturbances. The word disturbance is an unwanted signal that affects the system's output and its optimal performance. With transmission line in question, lightning during rainfall, switching action of inductive or capacitive load proves a threat; these activities can lead to the tripping-off of line. This leads to series of occurrence ranging from system failure or collapse, loss of data or corruption of data, to physical damage of equipment. With this, impulse and step input signals were used in the analysis of this research work. [1] confirmed that some disturbances that reflect on transmission line or power system include interruptions, sag / under voltage, swell / overvoltage (Ferranti effect), waveform distortion, voltage fluctuation, frequency variation and transients.

## METHODOLOGY

The methodology employed in this research work involved dealing with the modeling of the network, thereafter constructing a signal flow graph which was used to obtain the system transfer function. This is done by considering the Laplace transform of the line constants (resistance, inductance and capacitance). The second aspect deal with analyzing the responses obtained from the written codes in MATLAB environment, by using impulse and step input signals as obtained in control system engineering.

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## MODELING OF A NOMINAL-T NETWORK

Osogbo to Akure 132kV transmission line was used as a case study for the research. The distance involved falls under medium line classification of transmission line. Hence in analyzing, the capacitance effect must be put into consideration. In this wise, the capacitance is assumed to be lumped or distributed along the line, and this method of considering capacitance in this manner is known as localized capacitance method [2] which is further classified into three categories, based on the manner in which the effect of capacitance is put into consideration. These are: End Condenser configuration, Nominal-π configuration and Nominal-T configuration.

In nominal-T configuration, the line capacitance is lumped or placed at the middle of the line. This kind of configuration allows full charging current to flow through half of the line.

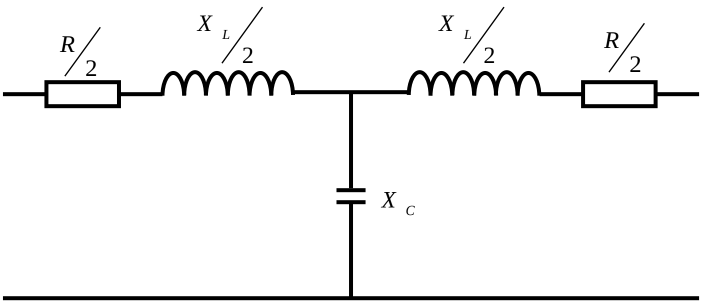



**Figure1**. *Nominal-T Network*

Nominal-T network of transmission line (Figure 1) was transformed to block diagram. Each block represents a single component or group of components which was characterized by a transfer function expression. In this diagram it was discovered that there was present of disturbances at the receiving end of the line, and these disturbances reflect as voltage. The block was then transformed into signal flow graph to obtain the transfer function of the system, with the aid of mason’s gain formula. Figure 2 and 3 represent the block diagram and signal flow graph of nominal-T configuration of transmission line respectively. **D** represents the disturbance at the receiving end of the line, which reflects in form of voltage.

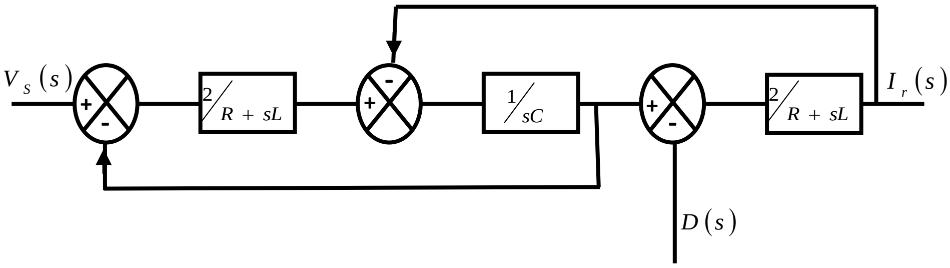



**Figure2.** *Model of Nominal-T Network*

The analysis of the network was carried out by substituting the line constants extracted from the line data obtained from Akure 132kV Station under peak, off-peak hours and raining period. The reading obtained for the respective conditions were then analyzed.

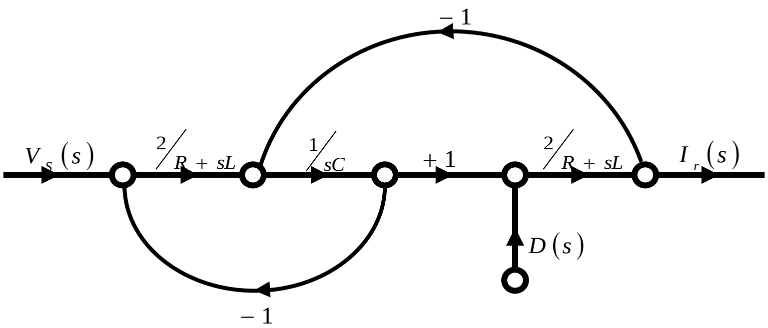



**Figure3.** *Signal flow representation of Nominal-T Network*

Accuracy of a system is ensured when the steady state error of the system is at minimum and when the system takes a shorter time to return to its original state when disturbance occurs. The outcomes of all this analyses were stated clearly under result. From the transmission line data obtained, the extracted data for Osogbo to Akure 132kV Station are stated in Table 1.

**Table1.** *Osogbo to Akure SC 132kV data*

| | | |
|---|---|---|
| Conductor | | |
| Thermal rating (Amps) | 306 | |
| Size ($mm^2$) | 100 | |
| Type | HYENA | |
| Length (km) | 93 | |
| Surge impedance (ohms) | 417 | |
| Line impedance | $Z_1$ | $Z_0$ |
| Resistance, R (ohms) | 0.0261322 | 0.259551 |
| Inductive reactance, $X_L$ (ohms) | 0.2298441 | 0.74233 |
| Susceptance | $B_1$ | $B_0$ |
| | 0.04 | 0.02 |

From the data, the line constants were extracted using the following formulae

$$Z_1 = (r + jx_L)L \tag{1}$$

Where,

$$X_L = 2\pi fL \quad and \quad Y = \sqrt{B^2 + G^2}$$

$Z_1$ = line impedance in ohms

r = line resistance in ohms/km

$x_L$ = Inductive reactance in ohms/km

$X_L$ = Inductive reactance of the line

w = Angular frequency in radian/sec.

f = System frequency in Hz

Y = Shunt admittance of the line in Siemen

B = Susceptance due to the presence of line capacitance.

G = Conductance in mho

Line resistance, inductance and capacitance values were calculated as 2.34Ω, 69.98mH and 11841.13μF respectively. These line constants were substituted into the transfer function obtained from Figure 2, which was transformed into signal flow graph equation shown in equation 2.

$$I_r(s) = \frac{4V_s(s)}{0.0046\, s^3 + 0.17\, s^2 + 0.27\, s + 9.72} + \frac{2D(s)}{0.00000064\, s^2 + 0.00031\, s + 4} \tag{2}$$

Where,

$V_s$ represents sending end voltage

D represents disturbance

s represents complex frequency variable.

$I_r$ represents receiving end current.

Equation 2 represents the starting point of the analysis. The equation revealed the two effects on the system and these effects were analyzed using the conditions mentioned earlier on. The analysis was considered for normal state of the system and the effect of disturbance on the system as well. Lastly, the combinations of these effects were considered. For the two effects, equation 2 was segmented, the first one represents the normal condition and the second one represents the effect of disturbances as obtained from the network as shown in equation 3 and 4.

$$I_r(s) = \frac{4K_1}{\left(0.0046\ s^3 + 0.17\ s^2 + 0.27\ s + 9.72\right)} \tag{3}$$

$$I_r(s) = \frac{2K_2}{\left(0.0000064\ s^2 + 0.00031\ s + 4\right)} \tag{4}$$

Where,

$K_1$ represents impulse input signal and step input signal (Vs)

$K_2$ represents impulse input signal and step input signal (D)

Since the disturbance $K_2$ is in form of voltage, a value was chosen to multiply the receiving end voltage so that $K_2$ becomes equation 5.

$$K_2 = n * V_r \tag{5}$$

Where,

n represents an arbitrary value assumed.

*Details of peak hour reading is as follows;*

Receiving end current ($I_R$):-860A

Receiving end power ($P_R$):-43MW

Receiving end power factor ($PF_R$):-0.93 lagging

Receiving end voltage ($V_R$):-114kV

System frequency (F):-50Hz

*And that of off-peak are;*

Receiving end current ($I_R$):- 391A

Receiving end power ($P_R$):-45.5MW

Receiving end power factor ($PF_R$):-0.93 lagging

Receiving end voltage ($V_R$):-125kV

System frequency (F):-50Hz

*When rain falls the data obtained are;*

Receiving end current ($I_R$):-493A

Receiving end power ($P_R$):-40.85MW

Receiving end power factor ($PF_R$):-0.98 lagging

Receiving end voltage ($V_R$):-128kV

System frequency (F):-50Hz

The MATLAB codes used to exhibit the nature of the disturbance discovered from the network modelled and that of the normal state is as shown below.

For impulse input consideration to show the nature of disturbances

```
    %program to show the nature of disturbance effects for nominal-T, when
    %the arbitrary entity n is varied.
 num=228000; den= [0.0000064 0.00031 4];
sys1=tf (num, den);
num1=912000; den1= [0.0000064 0.00031 4];
sys2=tf (num1, den1);
num2=684000; den2= [0.0000064 0.00031 4];
```

```
sys3=tf (num2, den2);
subplot
impulse (sys1,’g’, sys2,'-b', sys3,'k'), grid
legend ('sys1-response when n=1','sys2-response when n=2','sys3-response when n=3')
title ('impulse response for disturbance effect, when n is varied')
```

*For normal state*

```
num=124400; den= [0.0046 0.17 0.27 9.72];
sys=tf (num, den);
impulse (sys), grid
legend ('response for normal state of the system');
title ('impulse response of the system at normal state')
```

For step input consideration to show the nature of disturbances

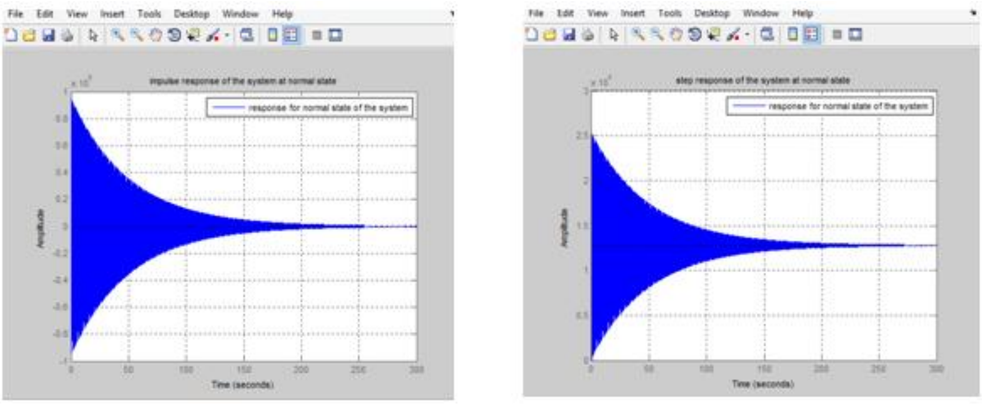
```
        %program to show the nature of disturbance effects for nominal-T, when
        %the arbitrary entity n is varied.
num=228000; den= [0.0000064 0.00031 4];
sys1=tf (num, den);
num1=912000; den1= [0.0000064 0.00031 4];
sys2=tf (num1, den1);
num2=684000; den2= [0.0000064 0.00031 4];
sys3=tf (num2, den2);
subplot
step (sys1,’g’, sys2,'-b', sys3,'k'), grid
legend ('sys1-response when n=1','sys2-response when n=2','sys3-response when n=3')
title ('response for disturbance effect, when n is varied')
```

*For normal state*

```
num=124400; den= [0.0046 0.17 0.27 9.72];
sys=tf (num, den);
step (sys), grid
legend ('response for normal state of the system');
title ('step response of the system at normal state')
```

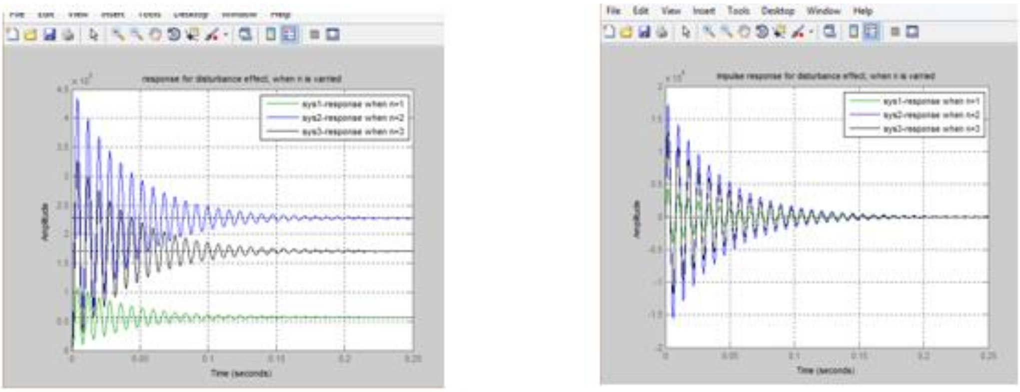
## ANALYSIS OF RESULTS

The analysis of the network modeled was carried out in MATLAB environment and the following results were obtained.




**(a)** Step response **(b)** Impulse response

**Figure5.** *The nature of the responses obtained for normal states.*



**(a)** Step response **(b)** Impulse response

**Figure4.** *The nature of the responses obtained for disturbance state of the system, when n is varied*

From the responses shown above, it was discovered that the nature of the disturbance that reflects at the receiving end of the T-network modeled was transient in nature. The transient disturbances that occur in power system have been classified into Impulsive and Oscillatory [1]. These classifications have to do with the nature and shape of the waveform obtained. Referring to figure 4, it is obvious that the nature of the transient disturbance is oscillatory. Oscillatory transients can be defined as an abrupt change in the steady-state condition of a signal's current, voltage or both at the positive and negative limit, which is oscillatory at the system natural frequency [3]. With this, since the modeled network analyzed, presented the disturbance in form of voltage, hence it can be concluded that the oscillatory transient was as a result of a sudden change in the steady state condition of the signal's voltage, which is oscillating at the system frequency.

It can also be inferred from figure 4, that as n is being varied another disturbance surface, which is known as overvoltage or swelling or Ferranti effect [1]. This was as a result of rise in the receiving end voltage of the line. Also an oscillatory transient occurs because the load resists the change being made as a result of switching action. This transient usually decay to zero within a cycle, it also leads to the swelling and rapid shrinking of the power signal alternatively. This transient can also emanate from actions like turning off inductive or capacitive load such as motor or capacitor bank.

Figure 5 shows that the normal state is steady in operation because when simulated with step and impulse signals it was detected that there was not distortion in the nature of the response obtained. Also the responses only take a few second to return to steady state, when displaced in normal operation as a result of disturbances. But the disturbance state shows a distorted response when simulated with the two input signals and this shows that the system is prone to occurrence like tripping off, which makes the system to become unsteady at that very state.

## CONCLUSION

With the results obtained from this simulation work, it can be concluded that the nature of the disturbance that reflected at the receiving end of any T configuration is transient and oscillatory in nature. The research revealed that likely cause of this occurrence on T configuration is mainly switching actions such as turning off inductive or capacitive load. Lastly, it was also discovered that when the receiving end voltage is high, it leads to swelling and shrinking of power signal alternatively that can cause trip off on the line.

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