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Advantage to Short Circuit Current of Calculation on Power System by the MVA Method

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Author's contribution

The sole author designed, analyzed and interpreted and prepared the manuscript.

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ABSTRACT

The short circuit current of the equipment must be carefully calculated. If it is not effective to isolate the fault point, while the system is abnormal. That will leads to prolonged fault time and the instability of power system. The calculation process is very so complicated that must to establish any capacity of equipment on system. This article will introduce method of the traditional algorithm beginning. Next, to establish the basic principles of simplified procedures such as the capacity of two parallel devices are considered as a series method (plus), but the capacity of two series devices are considered as a parallel method to calculate. Finally, to calculate the fault short-circuits current based on the actual equipment capacity on the power system. Another technique is to transform the structure of transmission line from ▵ to Y so that it easy to simplify for calculation. It is proved to be a simple and easy to understand what method for short circuit fault current of calculation. The method can provide accurate and effective calculation of system short circuit capacity and current at each equipment point, so that designer can make appropriate specifications in design and procurement to avoid wasteful investment.

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Keywords: Single - line diagram; per – unit system (P.U.); short circuit current; capacity.

1. INTRODUCTION

When any important equipment on the power system is added or replaced, the interrupted capacity value (or short circuit current) of the equipment must be carefully calculated. If the interrupted capacity value of the equipment is improper, it will either cause waste of equipment investment or be not effective to isolate the fault point, when the system is abnormal, which leads to both prolonged fault time (or expansion of the power outage area) and the instability of the power system. Calculating the equipment interruption capacity value will be related to the per-unit parameters of system of any equipment on the entire system. Therefore, the calculation process is very complicated such as the system p.u.(per-unit) standardizing, equipment's the impedance value, and the fault current value of each fault point. First of all, this article will use the traditional algorithm to unify the p.u. system and calculate the impedance value out of each device on the power system in single diagram, and then simplify to calculate the fault current value of each point of failure. Next, to establish the basic principles of simplified calculations which be proposed in this article. The capacity of two parallel devices are considered as a series method (plus), but the capacity of two series devices are considered as a parallel method to calculate. Finally, to calculate the fault short circuit current based on the actual equipment capacity on the power system. It is proved to be a simple and easy to understand what method for short circuit current of calculation.

2. LITERATURE REVIEW

2.1 Interrupting Capacity and Short-Circuit Calculation

The equipment of power system are designed to allow a limited amount of current to flow through; so that is done to prevent overheating of the equipment due to I^2R losses. The limitation on the current is largely due to the insulation or impedance of the load to which it is connected.

2.2 Short Circuit Definition

If the Insulation of impedance of the load is shorted, according to Ohm's law, an abnormally high current will flow through the circuit. This situation is called a short circuit. Depending on what the remaining insulation of the circuit, the short-circuit current could be up to 30 times as high as the normal current. Under at this abnormally high level, most equipment will likely be the fire of combustible components within or in the vicinity.

2.3 Short-Circuit Calculation

To avoid damage from excessive heat and the magnetic force created by a short circuit, all equipment connect to power system must have an interrupting rating or interrupting capacity, those capacity must equal to or greater than short circuit capacity of the system which is been limited.

The calculation of the short circuit capacity of a power system is very involved and complex. Conservatively, it can be as high as 20-30 times the normal full-load current of the system.

For example, if a power system is designed to carry a full-load current of 2000A, then the short-circuit capacity could be in the neighborhood of 20 * 2000 (40,000) A, or even 30 * 2000 (60,000) A. Computer programs are calculate a realistic level of short-circuit current. In its simplified form, the short-circuit current can be conservatively calculated by the following equations.

$$Isc = 100 \times \frac{I}{Zp + Zt} \quad (1)$$

Or

$$Isc = \frac{MVAs}{\sqrt{3} * (BuskV)} \quad (2)$$

Where

Isc = short-circuit current, A
E = voltage, V
Z = total impedance, ohms
I = full-load current of the transformer, A
Zp = impedance of the primary, %
Zt = impedance of the transformer, %

Conservatively, the impedance of the primary on a large utility substation or a network may be considered negligible (near zero); thus, a short circuit near the secondary side of the the transformer (or mains). For example, the short circuit current (Is) of a large system connected to a transformer rated with 5 percent impedance could be $100 \times \frac{I}{5}$ or 20I.

2.4 Interrupting Capacity

To prevent the system and equipment from being destroyed by heat, arcing, and fire caused by a short circuit, and transmission lines and cables must be protected by devices such as circuit breakers. All equipment or devices installed on the power system must also carry an interrupting capacity (Is_C) greater than the calculated short-circuit current.

2.5 Short Circuit Calculation Example

The full-load current of a building power distribution system is 1200 A. The building is served by a single transformer having 5 percent impedance. The utility power service supplying the transformer is from a nearby substation with practically unlimited power. Determine the available short circuit current at the main switchboard.

Solution:From equation (1)

$$I_{SC} = 100 \times \frac{I}{Zp + Zt} = 100 \times \frac{1200}{0+5} = 24{,}000 \text{ A}$$

(Impedance of the substation is considered to be near zero because the substation has an unlimited power supply).

2.6 Methods of Tradition

There are two methods of tradition for calculating the short circuit current of any equipment on the power system: the p.u. and the MVA method. The algorithmic steps are described in Table 1.

References [1,2] introduce what the basic definition and calculation method of short-circuit current. As for these references [3-9] are only as reference. The algorithm in [10] is the same as this paper but the difference of the implement method is implemented in MATLAB application software in this paper.

3. A SIMPLE METHODS

This paragraph is divided into two sections to describe such as calculation criteria and taking a realistic example on power system to calculate.

3.1 Calculation Criteria

When using this method, several principles must be followed, such as the following:

- Firstly, the capacity of circuit- short current of each equipment must to calculate so that is convenient to simplify.
- The capacity of two parallel devices are considered as a series method (plus or minus), but the capacity of two series devices are considered as a parallel method to calculate.
- Symbols explanations are Isc, Ic, MVAs, MVA. Where, Isc is system short circuit current, Ic is device short current. MVA_s is system short circuit capacity, MVA is device short capacity.
- The graphic explanation of equipment capacity conversion short circuit equipment capacity is shown Table 2.

3.2 Some Realistic Examples

Case 1: This section will use an example to solve the system's short circuit fault current by the MVA method. Consider the single line diagram of a simple power system shown in Fig. 1. System data of each device is shown in Table 3. Determine the fault current a balanced three-phase fault at primary side of F (#3 bus), as shown in Fig. 2,

and the calculation steps are as follows:

- Step 1. Calculate the short capacity of each device from the specifications in Table 3. As shown in Fig. 2.
- Step 2. In order to simplify calculations, the △ model of transmission line transforms to the Y model. As shown in Fig. 3.
- Step 3. The short current capacity is through from the MVA of No. 3 bus divide by the second voltage of the T3 transformer, where is calculated that procedures by the calculation rules. As shown in Fig. 4.
- In order to prevent clerical errors, this paper develops a computer calculation program, the steps are as follows.

Then the short circuit current of 1218 MVAs is calculated out according to formula (2), and shown as Fig. 5, as a result Isc = 1218MVA/ $\sqrt{3}$ *13.8kV = 55.02 KA. If a fault occurred on the bus3 that the voltage will suddenly drops 10% from 13.8kV to 12.42kV, the short circuit current value is 61.13KA,and shown as Fig. 6.

Table 1. Two kinds of fault current analysis short circuit calculation

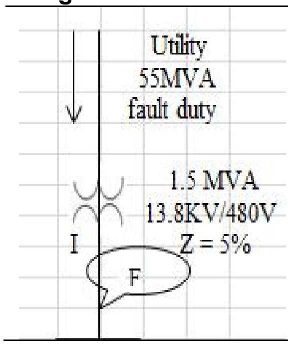
Diagram	p.u. method	MVA method
	S_{base} = 55 MVA X_{trans} duty = (1.5/0.05) x (1/55) = 0.545 p.u. Utility duty = 1 p.u. S = 0.5454 p.u. // 1 p.u. S = 19.41 MVAs $Isc = 19.41MVAs/\sqrt{3} * 480V$ Isc =19.41 MVAs/ (1.73 * 480V) = 22.35 kA	Utility duty = 55 MVA X_{trans}duty = (1.5/0.05) = 30 MVA S = 55MVA // 30MVA = 19.41 MVA $Isc = 19.41MVAs/\sqrt{3} * 480V$ Isc = 19.41 MVAs/ (1.73 * 480V) = 22.35 kA

Table 2. Symbol description

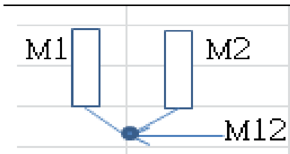
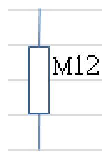
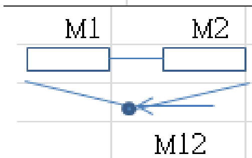
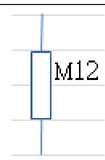
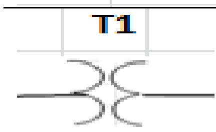
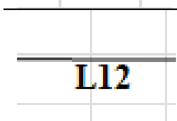
		M12=M1+M2
		M12=M1//M2 M12=(M1*M2)/(M1+M2)
	Equipment capacity 50 MVA	Short circuit equipment capability 50MVA/Z(0.05)=1000 MVA
	Equipment capacity 55 MVA	Short circuit equipment capability 55MVA/Z(0.045)=982 MVA
	13.8KV Z:0.15	1269MVA=(13.8kV*13.8kV /0.15

Table 3. Data of specification

Item	Specification	The capacity of short current
G1	55 MVA. 480V. Z=5.6 %	982 MVA
G2	50 MVA. 480V. Z=5.4 %	952 MVA
T1	50 MVA. 480V/13.8kV. Z=5 %	1000 MVA
T2	50 MVA. 480V/13.8kV. Z=5 %	1000 MVA
T3	50 MVA. 13.8kV/ 220kV. Z=5 %	1000 MVA
L12	13.8kV. Z=15 %	423 MVA(Y)/1269MVA(△)
L13	13.8kV. Z=15 %	423 MVA(Y)/1269MVA(△)
L23	13.8kV. Z=15 %	423 MVA(Y)/ 1269MVA(△)

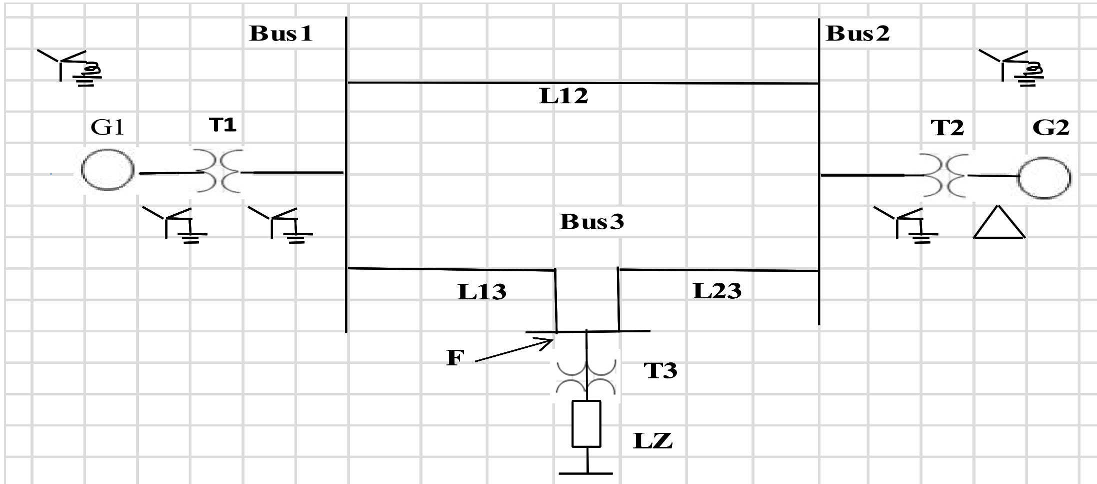


Fig. 1. Single line diagram of a simple power system

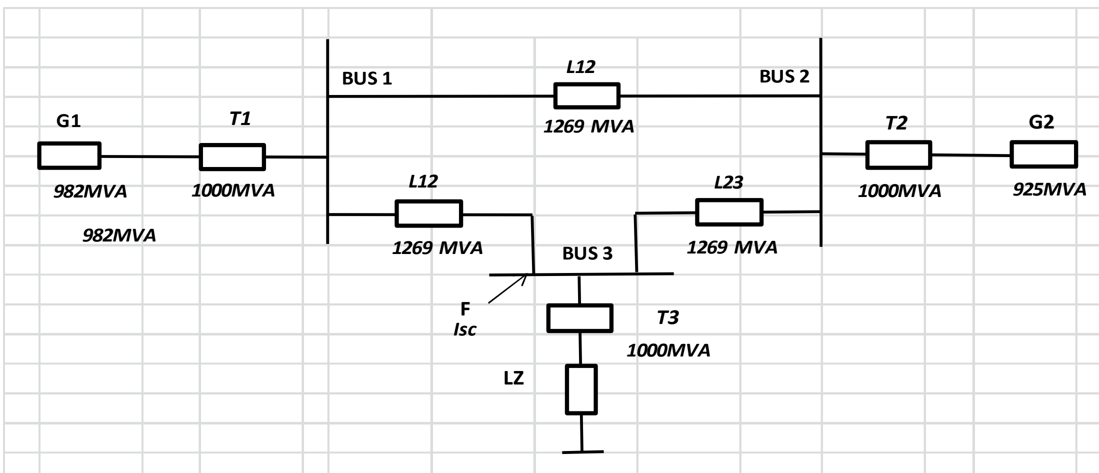


Fig. 2. The capacity of short current for each device

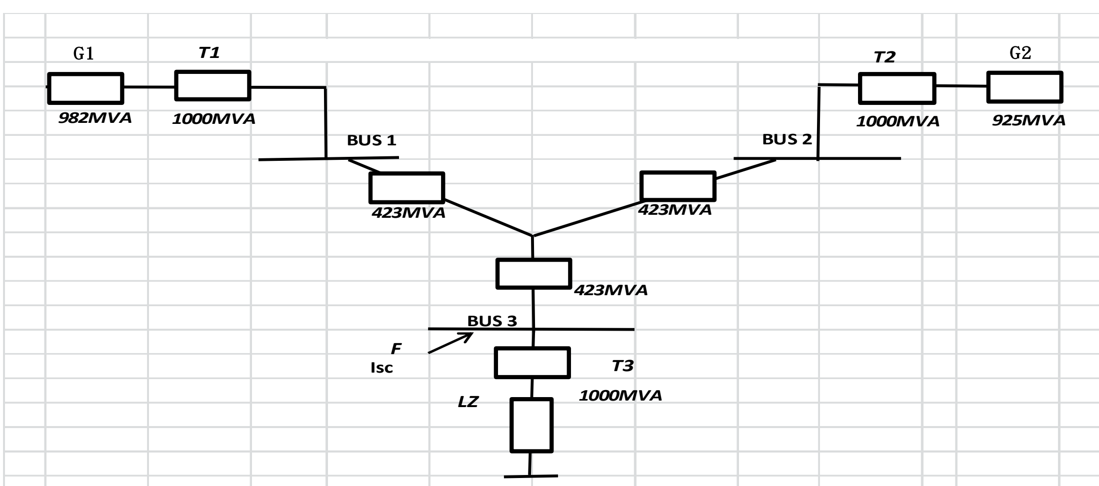


Fig. 3. The model of △transforms to the Y on transmission line

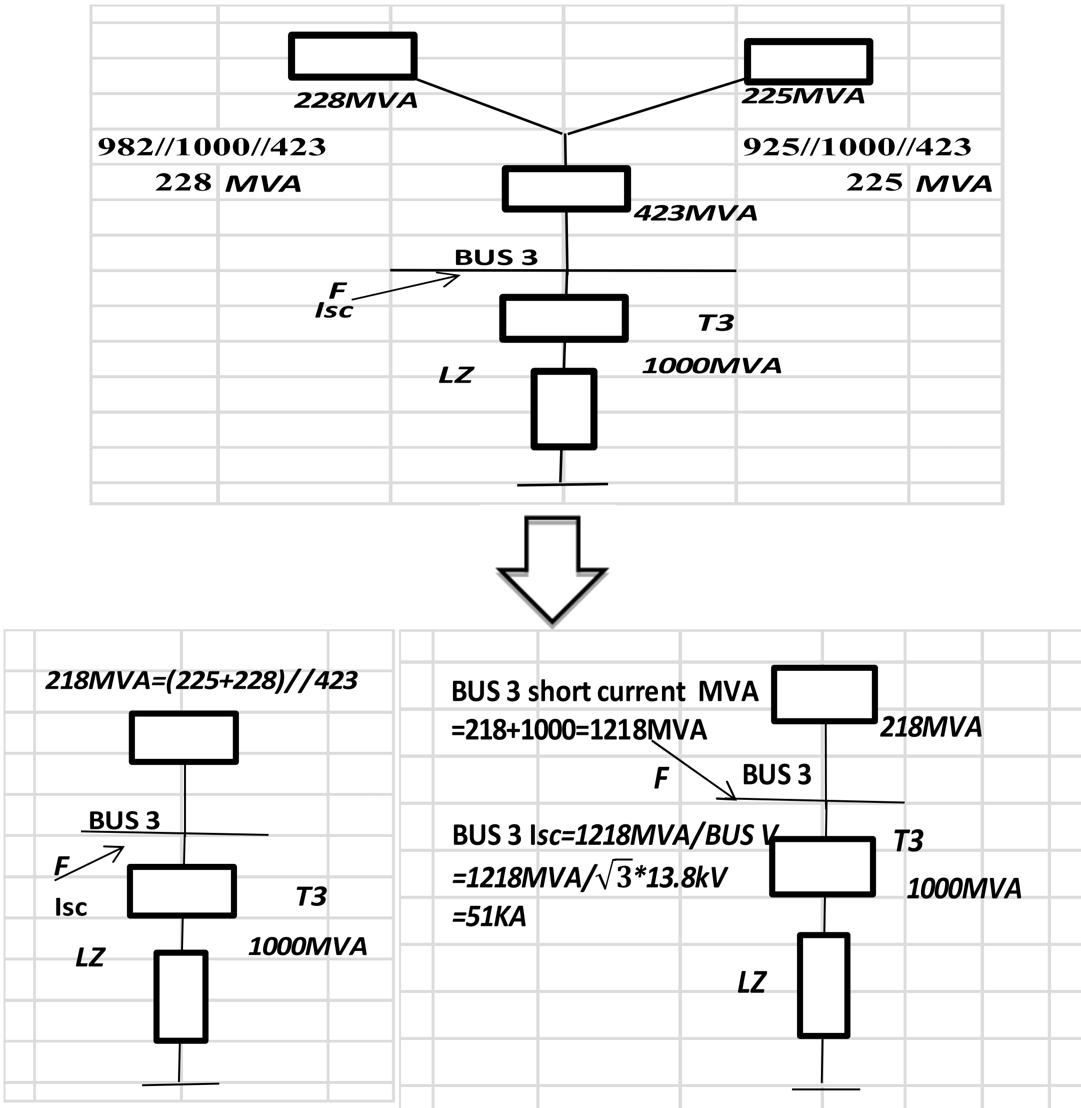


Fig. 4. Streamline processes

In short, first the system single-line diagram (Fig. 1) is established, then to simplify the transmission line to Y-type, and then the MVA value of the fault points are calculated out from Figs (2) to (4) in sequence.

As for the calculation method, it is the basic algorithm of electrical theory (including simplification and converting Fig. 2 to Fig. 3).

Case 2, A single transmission line provides users with a transformer; a motor is supplied to the secondary side of the transformer, to Find the short-circuit fault current value on the secondary side. The relevant parameters are shown in Fig. 7.

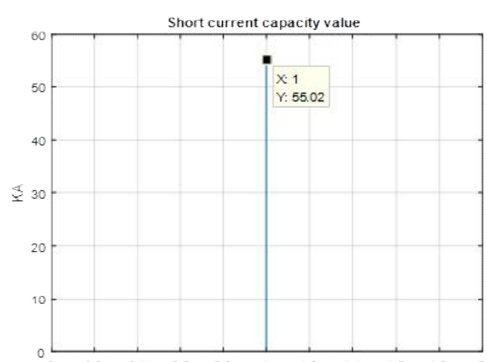


Fig. 5. Short current value for case 1

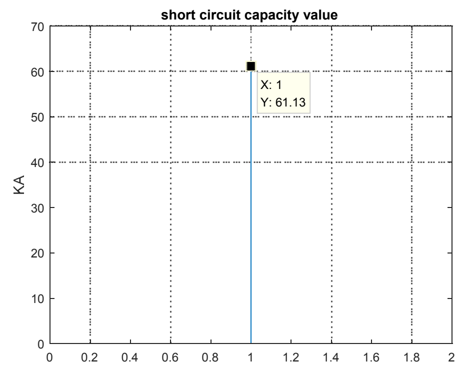


Fig. 6. Short current value for case 1

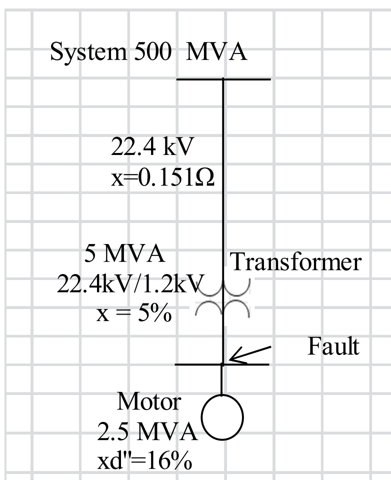


Fig. 7. Case 2 simple line diagram

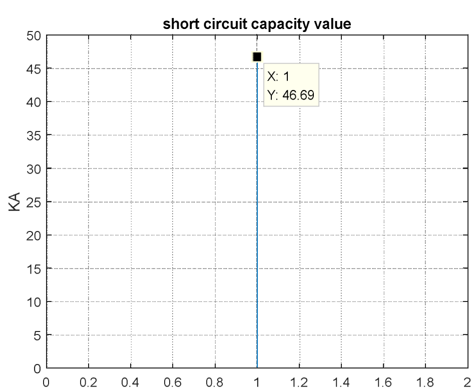


Fig. 8. Short current value for case 2

Then the short circuit current of 96.9 MVAs is calculated out according to formula (2), and shown as Fig. 8, as a result Isc = $96.9MVA/\sqrt{3}*1.2kV = 46.68$ KA.

4. CONCLUSIONS

This article adopted the MVA method because it is easier and simpler than the p.u. method. Because of the major advantage of it, during procedure not need unified for p.u. While you want to find the short circuit fault current at a certain point, firstly you must to find what source is provided, and it is before the fault point. Another technique is to transform the structure of transmission line from △ to Y so that it easy to simplify for calculation. The interruption capacity of transmission line is calculated from the square of the transmission voltage divided by the impedance value of transmission line. As a result, Isc is larger than the Ic, because when the power system has any fault, the value of rated voltage will suddenly fall below the normal one. The method can provide accurate and effective calculation of system short circuit capacity and current at each equipment point, so that designer can make appropriate specifications in design and procurement to avoid wasteful investment.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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APPENDIX

Executive Program

Case 1

```
>>clear all

Xeq=input ('Please input the impedance value of each device: Xeq=[G1|G2|T1|T2|T3|L12|L13|L23|V];= ');
fprintf ('to solve the # 3 BUS short current capacity \n')
X1= Xeq(1)*Xeq(3)/Xeq(1)+Xeq(3);
X2= Xeq(2)*Xeq(4)/Xeq(2)+Xeq(4);
X3= (Xeq(6)* Xeq(7))/(Xeq(6)+ Xeq(7)+Xeq(8));
X4= (Xeq(6)* Xeq(8))/(Xeq(6)+ Xeq(7)+Xeq(8));
X5= (Xeq(7)* Xeq(8))/(Xeq(6)+ Xeq(7)+Xeq(8));
X6= X1+X3;
X7= X2+X4;
X8= (X6*X7)/(X6+X7);
X9=(X8*X5)/(X8+X5);
X10=X9+Xeq(5);
Isc=X10/(1.73*Xeq(9));
r=Isc;
stem(r)
grid on
```

Case 2

```
>>clear all

Xeq=input ('Please input the impedance value of each device: Xeq=[S|LV|Lx|T|Tx|M|Mx|V];= ');
fprintf ('to solve the Tr second side short current capacity \n')
X1= (Xeq(2)*Xeq(2))/Xeq(3);
X2= Xeq(4) /Xeq(5);
X3=Xeq(6) /Xeq(7);
X4=(Xeq(1)*X1)/(Xeq(1)+X1);
X5= (X4*X2)/(X4+X2);
X6= (X5+X3);
Isc=X6/(1.73*Xeq(8));
r=Isc;
stem(r)
grid on
```


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