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Evaluation of Circuit Breaker Specifications with Short Circuit Analysis using Etap at Isimu Substation

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Abstract:- A common problem in electrical power distribution systems is short circuit. Protection systems that work efficiently can immediately isolate the affected power grid from the short circuit before resulting in a worse impact. The protection equipment is a Circuit Breaker, with good specifications of course Circuit Breaker can work efficiently in protecting electrical power equipment in operation. This study aims to find out the specifications of Circuit Breaker in protecting 60 MVA power transformers, with a voltage of 150/20 kV at Isimu Substation. This study was conducted by calculating short circuit current using unit method per unit, performing calculation of more current rele settings and simulating from ETAP software, as well as comparing the results of manual calculations with results from ETAP software simulations. From the results of the research obtained, the large flow of short circuit disturbances that occur in each refiner operating in isimu substation, know the value of the current rele setting more, as well as know the factors that affect the specifications of the power breaker in protecting the 60 MVA power transformer at isimu substation.

Keywords:- *Sistem Proteksi, Circuit Breaker, Hubung Singkat, Rele Arus Lebi.*

Abstract:- The problem that often occurs in electric power distribution systems is a short circuit. The protection system that works efficiently can immediately isolate the affected power grid from the short circuit before causing a worse impact. The protection equipment is a Circuit Breaker, with good specifications, of course the Circuit Breaker can work efficiently in protecting electric power equipment that is in operation. This study aims to determine the specifications of the Circuit Breaker in protecting a 60 MVA power transformer with a voltage of 150/20 kV at the Isimu substation. This research was conducted by calculating the short circuit fault current using the unit per unit method, calculating the overcurrent relay settings and simulating the ETAP software, as well as comparing the results of manual calculations with the results of simulation software ETAP. From the research results obtained, the magnitude of the short circuit fault current that occurs in each feeder operating at the Isimu substation, knows the value of the overcurrent relay setting, and knows the factors that affect the specifications of the breaker in protecting the 60 MVA power transformer at Isimu Substation.

Keywords:- Protection System, Circuit Breaker, Short Circuit, Over Current Relay.

I. INTRODUCTION

One of the basic needs today is electric power. A unity consisting of various electrical components or tools such as generators, transmission lines, transformers, distribution channels and loads that are interconnected and perform their respective functions called electric power systems [1]. In order to maintain the continuity of electricity system distribution, one of the important things that must be considered is the protection system. Circuit Breaker is a protection equipment that works automatically when there is interference based on the command of the over current relay that has obtained the appropriate settings. In a state of disturbance, the Circuit Breaker should be able to localize the disturbed area to be as small as possible [2][3].

Various types of interference, among others, Over Voltage that occurs due to the greater voltage in the electrical power system than it should, usually occurs due to lightning strikes. Over Load occurs due to greater consumption or consumption of electrical energy than the amount of electrical energy generated by the plant. Reserve Power that occurs due to the change of function from generator as generator to motor as load. Short Circuit that occurs due to the connection of voltage delivery and non-voltage delivery directly not through the proper media, so as to create a very large current (abnormal) [4].

Short circuit current is divided into 3 types, namely, short circuit disturbance 1 phase to the ground, between phases and 3 phases. The largest type of short circuit is the 3-phase interference current, the magnitude of the interference current is affected by the network equivalent impedance. The equivalent impendance of a 3-phase short circuit current is a series of positive sequence equivalents. As for the equivalent impedance of the current of short circuit disruption 1 phase to the ground, among others, the series of positive sequence equivalents, negative order equivalents and zero sequence equivalents [5][6].

When installing protection equipment it is good to know the large current of short circuit interference that occurs in the refiners, which will be indispensable when determining the capacity of the Circuit Breaker as well as determining the setting value of the current rele more [7][8][9]. Large short circuit interference currents are affected by source impedance, transformer impedance and sea turtle length [10] [11].

The results of previous research, by doing calculations on nakula refiners at the substation Talang Kelapa has obtained a large current of short-circuit disruption at the point of disruption 10% of the length of the refiner is 186,962 A while the disruption that occurs at the point of 100% of the length of the refiner is 184,396 A. From the results of the study stated that the closer the point of disruption with the substation , the greater the current of interference that occurs and applies otherwise [12].

This study will aim to find out the large value of short circuit current that occurs in the refiners operating in Isimu Substation, knowing the large comparison of the value of short-circuit interference current between the results of manual calculations and the results of ETAP software simulations that occur in refiners operating at Isimu Substation, knowing the specifications of Circuit Breakers in protecting the 60 MVA power transformers at Isimu Substation , and know the factors that affect the specifications of the Circuit Breaker in protecting the 60 MVA power transformer at Isimu Substation.

II. RESEARCH METHODS

This study uses manual calculation using unit method per unit and will be validated using simulation method.

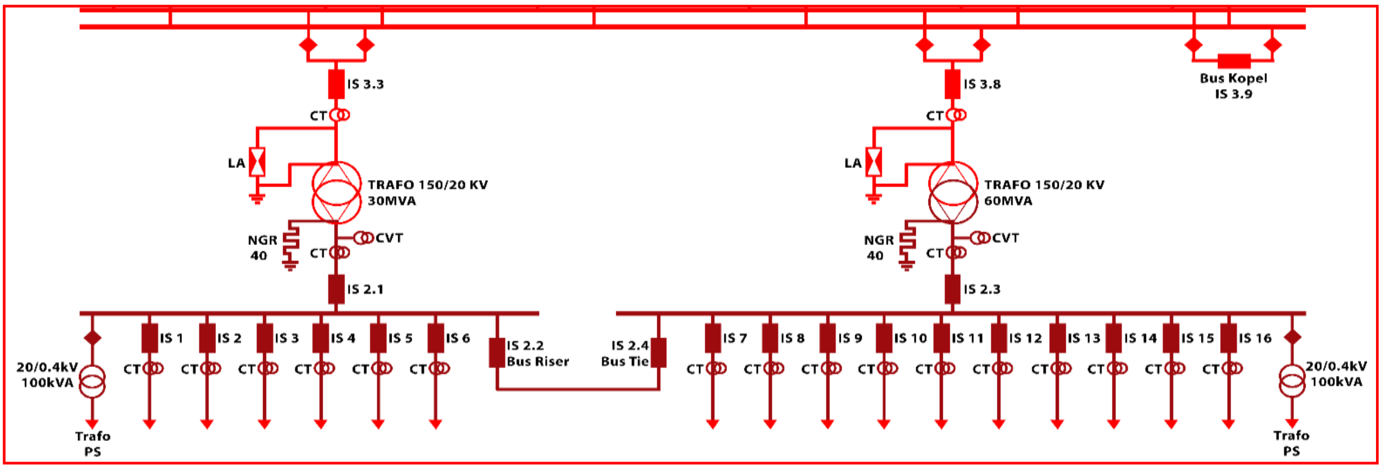
Terget 3 ways in the calculation of short circuit current. First with the Ohm method, which uses the actual values of ampere, ohm, and volt. Secondly with the MVA method which is a modification of the Ohm method, the way is by separating a series into components and counting each component. Third with unit method Per Unit, namely by converting each magnitude into units Per Unit, making it easier in the mathematical calculation process.

Simulation method is a form of research with the aim to find an image through a simple system on a small scale, in the simple system is done manipulation, change or control to see the effect that will be caused [13].

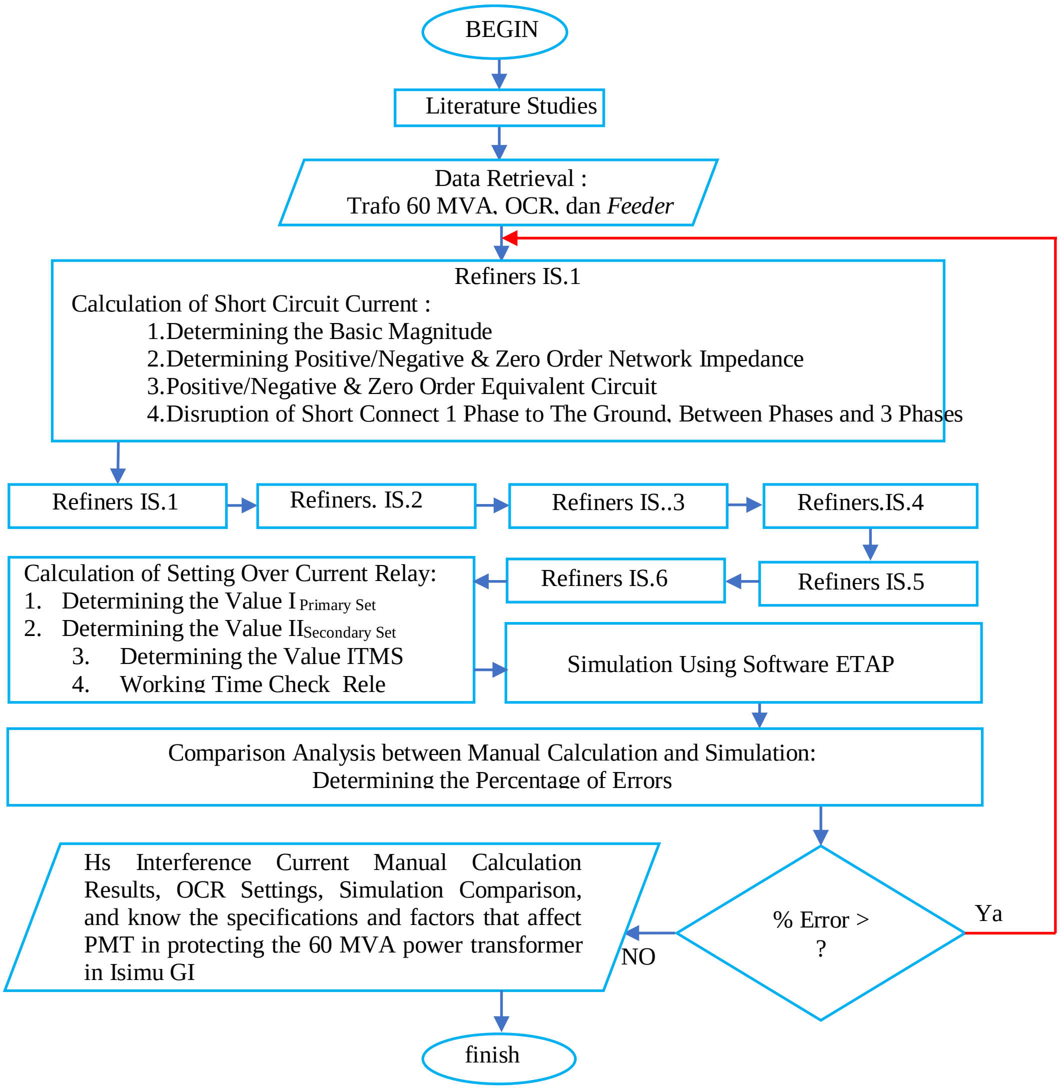
The simulation application used in this study is ETAP. The ETAP (Electric Transient and Analysis Program) is a comprehensive analytics platform for the design, simulation, operation, and automation of industrial power generation, distribution and systems. ETAP is designed to meet the requirements set and used worldwide as highly efficient software. The software becomes a fully integrated solution for energy companies, ETAP enables to manage the electric power system effectively even in real time with the ability to monitor, simulate, automate, and optimize the operation of the electric power system [14].

The following is a single line diagram from Isimu Substation, there are 2 transformers 150 kV / 20 kV with a capacity of 30 MVA and 60 MVA. Transformer 30 MVA has been disabled and replaced with 60 MVA.

The number of medium voltage refiners (20 kV) in the substation Isimu as many as 16 pieces, among others IS.1 to IS.16, but operated as many as 6 distillers namely: IS.1 serving GI Isimu - GH Isimu - In The City of Isimu - LBS Buhu, IS.2 serving GI Isimu - GH Limboto - LBS Tuladenggi, IS.3 serving GI Isimu - GH Isimu - LBS Parungi, IS.4 serving GI Isimu - LBS Batudaa , IS.5 serves GI Isimu - Recloser Yosonegoro - LBS Bolihuangga - Recloser Kayumerah - GH Limboto, IS.6 serves GI Isimu - GH Airport. Has 2 self-use transformers (PS transformers) with a capacity of 100 kVA.



Piicture 1. *Single line diagram* Of Isimu Substation (Source : PLN GI Isimu)



Gambar 2. Research flow chart

1. Literature studies

Researchers conducted literature studies by collecting books and journals related to the problems studied. Furthermore, researchers conducted field studies by retrieving data in the form of single line, transformer capacity, more current rele and refiners in PLN GI Isimu.

1. Data retrieval

The data needed to achieve the research objectives, researchers took data in the form of:

a. Transformers, researchers conducted a survey at PLN GI Isimu to see the specifications of the installed transformers.
b. Rele more current, rele more current taken data is a rele attached to the incoming side turtle. The rele serves to secure electrical equipment from more current caused by short circuit interference.
c. Suppliers, suppliers or feeders who are taken data in the form of long data of the supplier, cross-section type, cross-section size and service section.

2. Calculation of short circuit current

a. Menentukan besaran dasar

In this case the researchers assumed the base magnitude for the MVA_{base} 100 MVA, KVbase of 20 KV. Assumptions based on journals that study similar studies using the same basic magnitude.

$$Z_{base} = \frac{(KV_b)^2}{MVA_b} \qquad (1)$$

b. Specifies positive/negative & zero sequence network impedance

Formulas used:

a) Z_{source} :

$$\left[\frac{KV_{base(old)}}{KV_{base(new)}}\right]^2 \left[\frac{MVA_{base(new)}}{MVA_{base(old)}}\right] \text{(PU)} \qquad (2)$$

b) X_{Trafo} :

$$Zpu_{old} \left[\frac{KV_{base(old)}}{KV_{base(new)}}\right]^2 \times \left[\frac{MVA_{base(new)}}{MVA_{base(old)}}\right] \text{(PU)} \qquad (3)$$

c) X_{L12} :

$$\left[\frac{Impedance\ sequence}{Z_{base}}\right] \text{(PU)} \quad (4)$$

b. Positice/negative & zero sequence equivalent circuit
1. Draw an equivalent
2. Look for the total impedance of the positive/negative sequence :

$$Z_{Total1,2} = Z_S + X_T + X_{L12} \quad (5)$$

Mencari impedansi total urutan nol :

$$Z_{Total0} = Z_S + X_T + X_{L0} \quad (6)$$

c. Short circuit disturbance 1 phase to the ground,between phases and 3 phases
1. Base current :

$$I_{base} = \frac{MVA_{base}}{\sqrt{3}\ x\ KV_{base}}\ (kA) \quad (7)$$

2. 3 phase short circuit disorder :

$$I_1 = \frac{V_F}{Z_f + Z_1}\ \text{(PU)} \quad (8)$$

3. Large short circuit current interference 3 phase :

$$I = I_1 \times I_{base}\ \text{(A)} \quad (9)$$

4. Short circuit interference between phases :

$$I_1 = \frac{V_F}{Z_f + Z_1 + Z_2}\ \text{(PU)} \quad (10)$$

5. Large short circuit current between phases interference :

$$= I_1 \times I_{base}\ \text{(A)} \quad (11)$$

6. Short circuit 1 phase to the ground :

$$I_1 = \frac{V_F}{3Z_f + Z_1 + Z_2 + Z_0}\ \text{(PU)} \quad (12)$$

7. Large short circuit current interference 1 phase to the ground :

$$I = I_1 \times I_{base}\ \text{(A)} \quad (13)$$

3. Calculation of *setting over current relay*

a) Specify a value $I_{Primaryset}$ & $I_{secondaryset}$:

$$I_{Primaryset} = 1{,}05 \times I_{Burden}\ \text{(A)} \quad (14)$$

$$\text{Isecondary set} = I_{primaryset} \times \frac{1}{Ratio\ CT}\ \text{(A)} \quad (15)$$

b) Determine the value TMS:

$$TMS = \frac{\left(\frac{I_{fault}}{I_{primaryset}}\right)^{0{,}02} - 1}{0{,}14} \times t\ \text{(s)} \quad (16)$$

c) Rele uptime check:

$$t = \frac{0{,}14 \times TMS}{\left(\frac{I_{fault}}{I_{primaryset}}\right)^{0{,}02} - 1}\ \text{(s)} \quad (17)$$

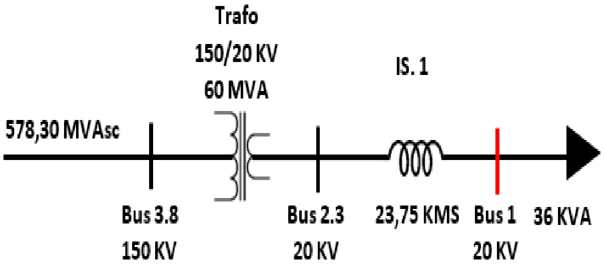
4. Conducting Software Simulation

III. RESULTS AND DISCUSSION

Short Circuit Current Calculation

The types of short circuit currents that will be calculated there are 3 types, namely short circuit current 1 phase to the ground, short circuit current between phases, and short circuit current 3 phases. The occurrence of this short circuit current will be assumed at a distance of 25%, 50%, 75% and 100% of the length of the refiner operating in ISIMU GI. The size of the 150 kV side short circuit at Isimu Substation is 578.30 MVA.

IS. 1



Gambar 3. *Single line* IS.1

a. Base Size *(base)* :
1. MVA_{base} : 100 MVA
2. KV_{base} : $Zone\ 1 = 20\ KV$

: $Zone\ 2 = 20 \times \frac{150}{20} = 150\ KV$

3. Using Equations (1)

Z_{base} : $\frac{(KV_b)^2}{MVA_b} = \frac{(20)^2}{100} = 4\ \Omega$

b. Sequence Network Impedance :

The magnitude of the source impedance can be known by using equations (2)

$$Z_{source} = \left[\frac{150}{150}\right]^2 \left[\frac{100}{578{,}30}\right] = 0{,}172\ PU$$

The size of the transformer reactance can be known by using equations (3)

$$X_{Trafo} = 0{,}122 \left[\frac{20}{20}\right]^2 \left[\frac{100}{60}\right] = 0{,}203\ PU$$

The magnitude of positive/negative and zero sequence impedance can be known using equations (4), with variations in interference points of 25%, 50%, 75% and 100% of the total length of the refiner.

$X_{L12} = \left[\frac{0{,}2162 + 0{,}3305}{4}\right] = 0{,}054 + j0{,}082\ PU$

$100\% \Rightarrow 1\ x\ 23{,}75\ x\ (0{,}054 + j0{,}082)$

$= (1{,}282 + j\ 1{,}947)\ PU$

$75\% \Rightarrow 0{,}75\ x\ 23{,}75\ x\ (0{,}054 + j0{,}082)$

$= (0{,}961 + j\ 1{,}460)\ PU$

$50\% \Rightarrow 0{,}5\ x\ 23{,}75\ x\ (0{,}054 + j0{,}082)$

$= (0{,}641 + j\ 0{,}973)\ PU$

$25\% \Rightarrow 0{,}25\ x\ 23{,}75\ x\ (0{,}054 + j0{,}082)$

$= (0{,}320 + j\ 0{,}486)\ PU$

$X_{L0} = \left[\frac{0{,}3631 + j1{,}6180}{4}\right] = 0{,}090 + j0{,}404\ PU$

$100\% \rightarrow 1\ x\ 23{,}75\ x\ (0{,}090 + j0{,}404)$

$= (2{,}137 + j\ 9.595)\ PU$

$75\% \rightarrow 0{,}75\ x\ 23{,}75\ x\ (0{,}090 + j0{,}404)$

$= (1.603 + j\ 7.196)\ PU$

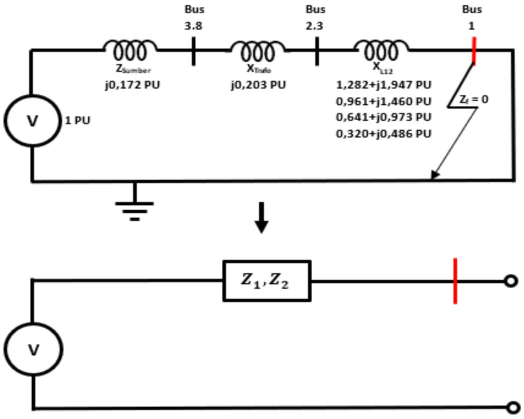
$50\% \rightarrow 0{,}5\ x\ 23{,}75\ x\ (0{,}090 + j0{,}404)$

$= (1.068 + j\ 4.797)\ PU$

$25\% \rightarrow 0{,}25\ x\ 23{,}75\ x\ (0{,}090 + j0{,}404)$

$= (0.534 + j\ 2.398)\ PU$

c. Positive/Negative Sequence Equivalent Circuit



Picture 4. The equivalent sequence of positive/negative sequences of the refiner is.1

The total impedance of the positive/negative sequence can be known by using the equation (5)

$$Z_{Total1,2} = Z_S + X_T + X_{L12}$$

$$= j0{,}172 + j0{,}203 + X_{L12}$$

$$= j0{,}375 + X_{L12}$$

$100\% \rightarrow j0{,}375 + (1{,}282 + j\,1{,}947)$

$= (1{,}282 + j2{,}322)$ PU

$75\% \rightarrow j0{,}375 + (0{,}961 + j\,1{,}460)$

$= (0{,}961 + j1{,}835)$ PU

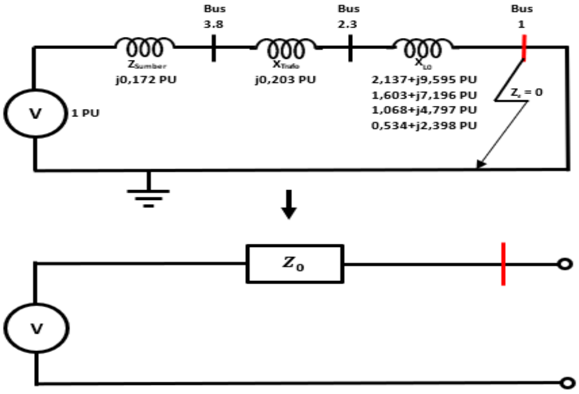
$50\% \rightarrow j0{,}375 + (0{,}641 + j\,0{,}973)$

$= (0{,}641 + j1{,}348)$ PU

$25\% \rightarrow j0{,}375 + (0{,}320 + j\,0{,}486)$

$= (0{,}320 + j0{,}861)$ PU

d. Zero Order Equivalent Circuit



Picture 5. The equivalent circuit of the zero-order of the refiner is.1

The total impedance of the positive/negative sequence can be known by using the equation (6)

$$Z_{Total0} = Z_S + X_T + X_{L0}$$

$$= j0{,}172 + j0{,}203 + X_{L0}$$

$$= j0{,}375 + X_{L0}$$

$100\% \rightarrow j0{,}375 + (2{,}137 + j\,9.595) = (2{,}137 + j9{,}97)$ PU
$75\% \rightarrow j0{,}375 + (1.603 + j\,7.196) = (1{,}603 + j7{,}571)$ PU
$50\% \rightarrow j0{,}375 + (1.068 + j\,4.797) = (1{,}068 + j5{,}172)$ PU
$25\% \rightarrow j0{,}375 + (0.534 + j\,2.398) = (0{,}534 + j2{,}773)$ PU

e. Short Circuit Disorder 3 Phase :

The size of the base current can be known using equations (7)

$$I_{base} = \frac{MVA_{base}}{\sqrt{3} \times KV_{base}} = \frac{100}{\sqrt{3} \times 20} = 2{,}886\ kA$$

The magnitude of the short circuit current of 3 phases in units per Unit can be known using equations (8) :

$$I_{1(100\%)} = \frac{V_F}{Z_f + Z_1} = \frac{1}{(1{,}282 + j2{,}322)}$$
$$= 0{,}377\angle -61^\circ\ PU$$

The magnitude of the short circuit current 3 phases after conversion into ampere units can be known using equations (9) :

$$I_{1(100\%)} = 0{,}377\angle -61^\circ\ PU\ x\ 2886\ A$$
$$= 1088{,}022\ \angle -61^\circ\ A$$

Next, use equations (8) and (9) to look for the magnitude of the 3 phase short circuit current at the variation of interference points of 75%, 50% and 25% of the total length of the refiner, as follows :

$$I_{1(75\%)} = \frac{V_F}{Z_f + Z_1} = \frac{1}{(0{,}961 + j1{,}835)}$$
$$= 0{,}482\ \angle -62{,}3^\circ\ PU$$
$$I_{1(75\%)} = 0{,}482\angle -62{,}3^\circ\ PU\ x\ 2886\ A$$
$$= 1391{,}052\ \angle -62{,}3^\circ\ A$$
$$I_{1(50\%)} = \frac{V_F}{Z_f + Z_1} = \frac{1}{(0{,}641 + j1{,}348)}$$
$$= 0{,}669\ \angle -64{,}5^\circ\ PU$$
$$I_{1(50\%)} = 0{,}669\ \angle -64{,}5^\circ\ PU\ x\ 2886\ A$$
$$= 1930{,}734\ \angle -64{,}5^\circ\ A$$
$$I_{1(25\%)} = \frac{V_F}{Z_f + Z_1} = \frac{1}{(0{,}320 + j0{,}861)}$$
$$= 1{,}088\ \angle -69{,}6^\circ\ PU$$
$$I_{1(25\%)} = 1{,}088\ \angle -69{,}6^\circ\ PU\ x\ 2886\ A$$
$$= 3139{,}968\ \angle -69{,}6^\circ\ A$$

f. Disruption of Brief Contact of Phases:

The magnitude of the short circuit current between phases in units per unit can be known using equations (9) :

$$I_{1(100\%)} = \frac{V_F}{Z_f + Z_1 + Z_2}$$
$$= \frac{1}{(1{,}282 + j2{,}322) + (1{,}282 + j2{,}322)}$$
$$= 0{,}188\ \angle -61^\circ\ PU$$

The magnitude of the short circuit current between phases after conversion into Ampere units can be known using equations (11) :

$$I_{1(100\%)} = 0{,}188\ \angle -61^\circ\ PU\ x\ 2886\ A$$

$= 542{,}568 \angle -61^\circ\ A$

Next, use equations (10) and (11) to look for the magnitude of the short circuit current between phases at variations of interference points of 75%, 50% and 25% of the total length of the refiner, as follows :

$$I_{1(75\%)} = \frac{V_F}{Z_f + Z_1 + Z_2}$$

$$= \frac{1}{(0{,}961 + j1{,}835) + (0{,}961 + j1{,}835)}$$

$= 0{,}241 \angle -62{,}3^\circ\ PU$

$I_{1(75\%)} = 0{,}241 \angle -62{,}3^\circ\ PU\ x\ 2886\ A$

$= 695{,}526 \angle -62{,}3^\circ\ A$

$$I_{1(50\%)} = \frac{V_F}{Z_f + Z_1 + Z_2}$$

$$= \frac{1}{(0{,}641 + j1{,}348) + (0{,}641 + j1{,}348)}$$

$= 0{,}334 \angle -64{,}5^\circ\ PU$

$I_{1(50\%)} = 0{,}334 \angle -64{,}5^\circ\ PU\ x\ 2886\ A$

$= 963{,}924 \angle -64{,}5^\circ\ A$

$$I_{1(25\%)} = \frac{V_F}{Z_f + Z_1 + Z_2}$$

$$= \frac{1}{(0{,}320 + j0{,}861) + (0{,}320 + j0{,}861)}$$

$= 0{,}544 \angle -69{,}6^\circ\ PU$

$I_{1(25\%)} = 0{,}544 \angle -69{,}6^\circ\ PU\ x\ 2886\ A$

$= 1569{,}984 \angle -69{,}6^\circ\ A$

g. Disruption of Brief Contact 1 Phase to the Ground :

The magnitude of the short circuit current 1 phase to the ground in units per Unit can be known using equations (12) :

$$I_{1(100\%)} = \frac{V_F}{3Z_f + Z_1 + Z_2 + Z_0}$$

$$= \frac{1}{(1{,}282 + j2{,}322) + (1{,}282 + j2{,}322) + (2{,}137 + j9{,}97)}$$

$= 0{,}065 \angle -72{,}1^\circ\ PU$

The magnitude of the short circuit current 1 phase to the ground after conversion into ampere units can be known using equations (13) :

$I_{1(100\%)} = 0{,}065 \angle -72{,}1^\circ\ PU\ x\ 2886\ A$

$= 187{,}59 \angle -72{,}1^\circ\ A$

Furthermore, use equations (12) and (13) to look for large currents of short circuit interference 1 phase to the ground at variations of interference points of 75%, 50% and 25% of the total length of the refiner, as follows :

$$I_{1(75\%)} = \frac{V_F}{3Z_f + Z_1 + Z_2 + Z_0}$$

$$= \frac{1}{(0{,}961 + j1{,}835) + (0{,}961 + j1{,}835) + (1{,}603 + j7{,}571)}$$

$= 0{,}084 \angle -72{,}5^\circ\ PU$

$I_{1(75\%)} = 0{,}084 \angle -72{,}5^\circ\ PU\ x\ 2886\ A$

$= 242{,}424 \angle -72{,}5^\circ\ A$

$$I_{1(50\%)} = \frac{V_F}{3Z_f + Z_1 + Z_2 + Z_0}$$

$$= \frac{1}{(0{,}641 + j1{,}348) + (0{,}641 + j1{,}348) + (1{,}068 + j5{,}172)}$$

$= 0{,}121 \angle -73{,}3^\circ\ PU$

$I_{1(50\%)} = 0{,}121 \angle -73{,}3^\circ\ PU\ x\ 2886\ A$

$= 349{,}206 \angle -73{,}3^\circ\ A$

$$I_{1(25\%)} = \frac{V_F}{3Z_f + Z_1 + Z_2 + Z_0}$$

$$= \frac{1}{(0{,}320 + j0{,}861) + (0{,}320 + j0{,}861) + (0{,}534 + j2{,}773)}$$

$= 0{,}215 \angle -75{,}3^\circ\ PU$

$I_{1(25\%)} = 0{,}215 \angle -75{,}3^\circ\ PU\ x\ 2886\ A$

$= 620{,}49 \angle -75{,}3^\circ\ A$

Table 1. Short-circuit current of the refiner is.1

Long (%)	1 Phase to the Ground (A)	Inter-Phase (A)	3 Phase (A)
25	620,49	1569,984	3139,968
50	349,206	963,924	1930,734
75	242,424	695,526	1391,052
100	187,59	542,568	1088,022

Table 2. Short-circuit current of refiners IS.2

Long (%)	1 Phase to the Ground (A	Inter-Phase (A)	3 Phase ((A)
25	291,486	822,51	1645,02
50	152,958	453,102	906,204
75	103,896	311,688	626,262
100	77,922	236,652	476,19

Table3. Short circuit interference current the refiner IS.3

Long (%)	1 Phase to the Ground (A	Inter-Phase (A)	3 Phase ((A)
25	230,88	660,894	1324,674

50	121,212	357,864	715,728
75	80,808	245,31	490,62
100	60,606	184,704	372,294

Tablel 4. Short circuit interference current the refiner IS.4

Long (%)	1 Phase to the Ground (A	Inter-Phase (A)	3 Phase ((A)
25	199,134	473,304	949,494
50	101,01	248,196	496,392
75	69,264	167,388	334,776
100	51,948	124,088	251,082

Table 5. Short circuit interference current the refiner IS.5

Long (%)	1 Phase to the Ground (A	Inter-Phase (A)	3 Phase ((A)
25	380,952	891,774	1786,434
50	204,906	484,848	972,582
75	138,528	386,724	666,666
100	103,896	253,968	507,936

Table 6. Short circuit interference current the refiner IS.6

Long (%)	1 Phase to the Ground (A	Inter-Phase (A)	3 Phase ((A)
25	1191,918	2412,696	4828,278
50	759,018	1673,88	3347,76
75	556,998	1266,954	2533,908
100	438,672	1012,986	2028,858

The table above is a table of manual calculation results of short circuit current type 1 phase to the ground, between phases and 3 phases are assumed to occur at 25%, 50%, 75% and 100% of the total length of refiners operating in isimu substation. Total Length of IS.1 Refiners is 23.75 KMS, IS.2 refiners are 58.24 KMS, IS.3 refiners are 75.49 KMS, IS.4 refiners are 76.67 KMS, IS.5 refiners are 37.36 KMS, and IS.6 refiners are 7.98 KMS.

OCR Setting Calculation *(Over Curreng Relay)*

Before searching for a TMS value, first look for the value from the $I_{Primaryset}$ dan $I_{secondaryset}$ First. I_{burden} d517 A, the known time (t) is 0.3s (not smaller than 0.3s). This is useful to keep the rele from trip due to the inrush current of the current transformers that have been connected to other networks.

$I_{primaryset}$ and $I_{secondaryset}$ can be calculated using equations (14) and (15) :

$$I_{primaryset} = 1{,}05\ x\ I_{burden} = 1{,}05\ A\ x\ 517 = 542{,}85\ A$$

$$I_{secondaryset} = I_{primaryset}\ x\ \frac{1}{Ratio\ CT} = 542{,}85\ x\ \frac{1}{2000/1} = 0{,}271\ A$$

Time Multiple Setting can be calculated using equations (17) :

$$t = \frac{0{,}14\ x\ TMS}{\left(\frac{I_{fault}}{I_{Primaryset}}\right)^{0{,}02} - 1}$$

Ket: t = Rele working time (s)

TMS = *Time Multiplier Setting* (0,05 – 1)

I_{Fault} = Short circuit interference current biggest (A)

$I_{primaryset}$ = Current Setting (A)

Look for large TMS values, using equations (16):

$$0{,}3 = \frac{0{,}14\ x\ TMS}{\left(\frac{4828{,}278}{542{,}85}\right)^{0{,}02} - 1}$$

$$TMS = \frac{\left(\frac{4828{,}728}{542{,}85}\right)^{0{,}02} - 1}{0{,}14}\ x\ 0{,}3$$

$$TMS = 0{,}095\ s = 0{,}1\ s$$

Rele Uptime Check uses equations (17) for distance variations of 25%, 50%, 75% and 100% as follows :

1. Distance 25% (IS.6)

$$t = \frac{0{,}14\ x\ 0{,}1}{\left(\frac{4828{,}278}{542{,}85}\right)^{0{,}02} - 1} = 0{,}313\ s$$

2. Distance 50% (IS.6)

$$t = \frac{0{,}14\ x\ 0{,}1}{\left(\frac{3347{,}76}{542{,}85}\right)^{0{,}02} - 1} = 0{,}377\ s$$

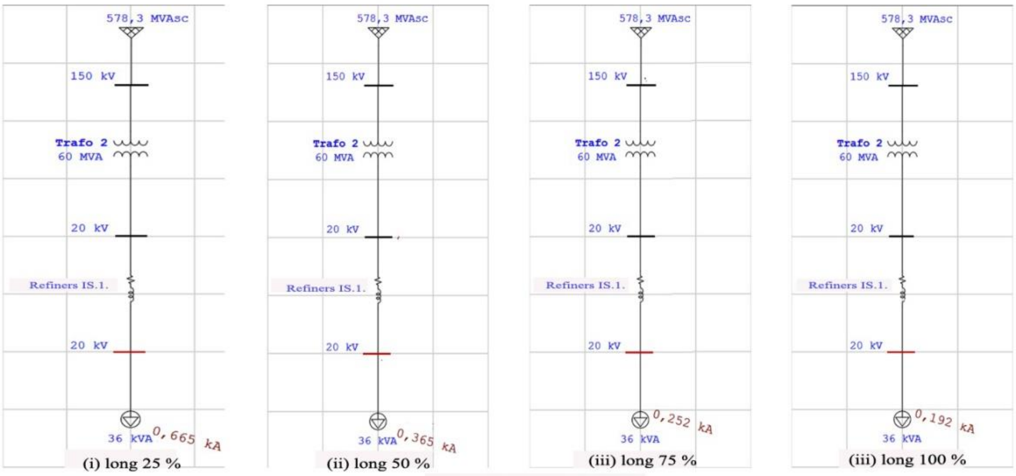
3. Distance 75% (IS.6)

$$t = \frac{0{,}14\ x\ 0{,}1}{\left(\frac{2533{,}908}{542{,}85}\right)^{0{,}02} - 1} = 0{,}447\ s$$

4. distance 100% (IS.6)

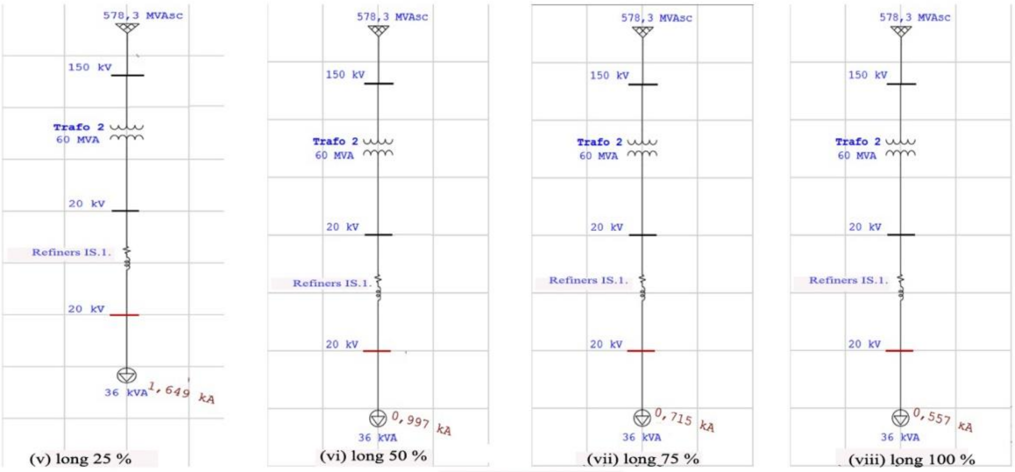
$$t = \frac{0{,}14\ x\ 0{,}1}{\left(\frac{2028{,}858}{542{,}85}\right)^{0{,}02} - 1} = 0{,}523\ s$$

From the calculation of the current rele setting above, get a result that is not smaller than 0.3 s. If interference occurs at a distance of 25%, then the time it takes rele to order the Circuit Breaker (CB) to disconnect is 0.313 seconds. If interference occurs at a distance of 50%, then the rele working time is 0.377 seconds, and at a distance of 75% the length of rele working time is 0.447 seconds, if it occurs at a distance of 100%, then the rele uptime is 0.523 seconds. Based on effective rele working time, it can be known that the specification of PMT (power breaker) in protecting the 60 MVA power transformer at Isimu substation is good.



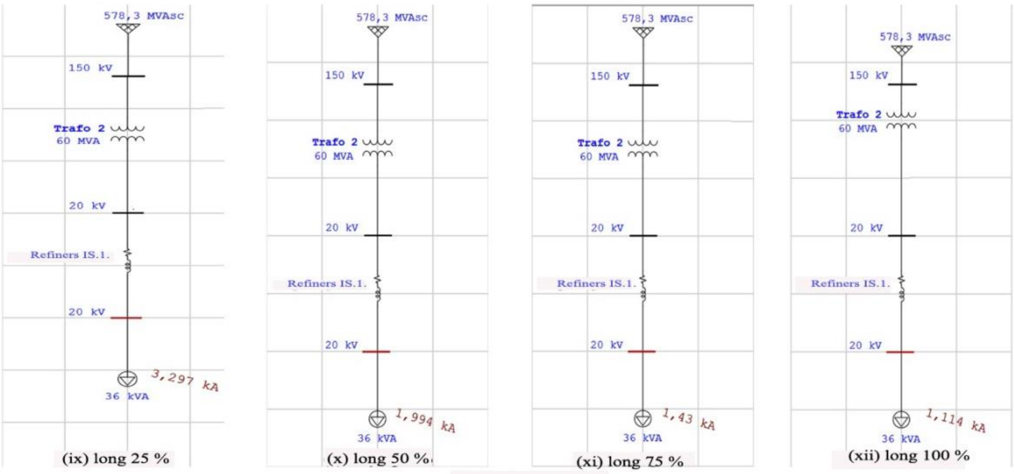
(i) long 25 % (ii) long 50 % (iii) long 75 % (iii) long 100 %

short contact 1 Phase to Ground



(v) long 25 % (vi) long 50 % (vii) long 75 % (viii) long 100 %

short-circuit between phases



(ix) long 25 % (x) long 50 % (xi) long 75 % (xii) long 100 %

short 3 phase relationship

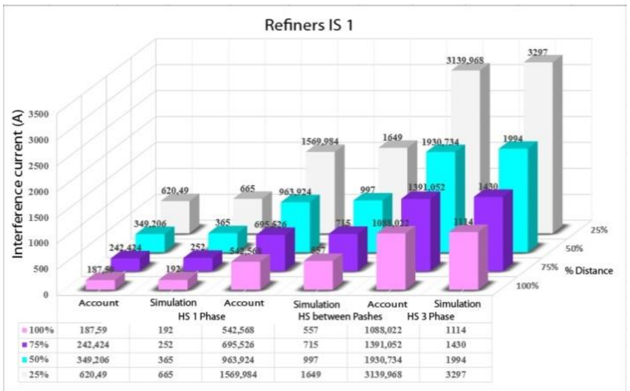
Picture 6. Simulation results of short circuit interference in IS.1

Simulation Using ETAP Software

The picture above is the result of simulation on ETAP software, which simulates the occurrence of short circuit type 1 phase to the ground, between phases and 3 phases in the is.1 refiners assuming interference occurs at the point of 25%, 50%, 75% and 100% of the total length of the refiner.

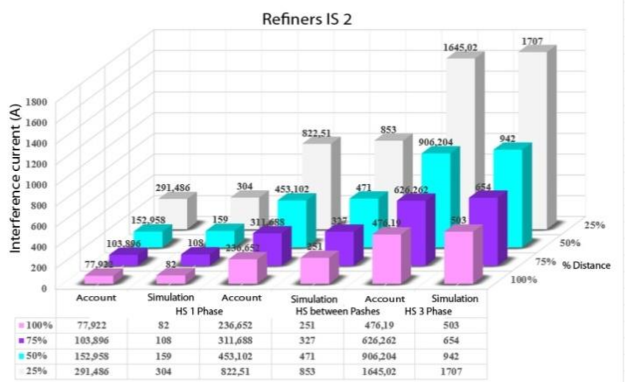
Comparison of Manual Calculation and Simulation of ETAP Software

Picture 7. The results of the calculation comparison and simulation of IS.1



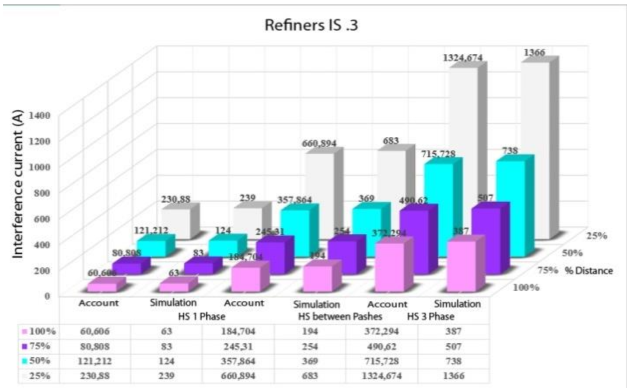
	Account	Simulation	Account	Simulation	Account	Simulation
	HS 1 Phase		HS between Pashes		HS 3 Phase	
100%	187,59	192	542,568	557	1088,022	1114
75%	242,424	252	695,526	715	1391,052	1430
50%	349,206	365	963,924	997	1930,734	1994
25%	620,49	665	1569,984	1649	3139,968	3297

Picture 8. The results of the calculation comparison and simulation of IS.2



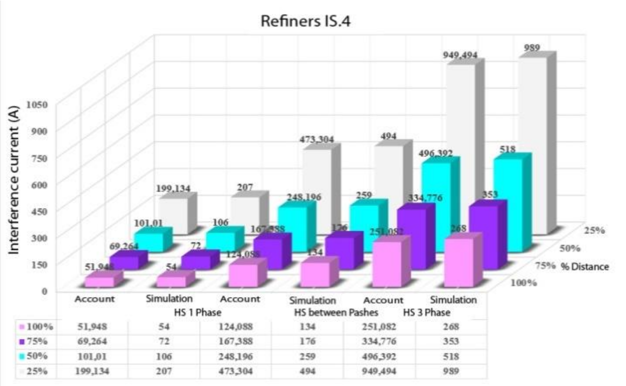
	Account	Simulation	Account	Simulation	Account	Simulation
	HS 1 Phase		HS between Pashes		HS 3 Phase	
100%	77,922	82	236,652	251	476,19	503
75%	103,896	108	311,688	327	626,262	654
50%	152,958	159	453,102	471	906,204	942
25%	291,486	304	822,51	853	1645,02	1707

Picture 9. The results of the calculation comparison and simulation of IS IS.3



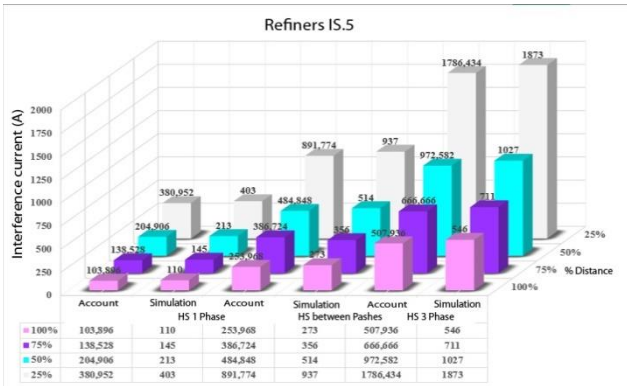
	Account	Simulation	Account	Simulation	Account	Simulation
	HS 1 Phase		HS between Pashes		HS 3 Phase	
100%	60,606	63	184,704	194	372,294	387
75%	80,808	83	245,31	254	490,62	507
50%	121,212	124	357,864	369	715,728	738
25%	230,88	239	660,894	683	1324,674	1366

Picture 10. The results of the calculation comparison and simulation of IS.4



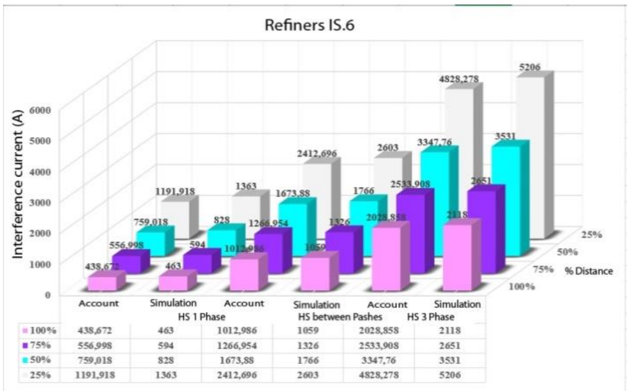
	Account	Simulation	Account	Simulation	Account	Simulation
	HS 1 Phase		HS between Pashes		HS 3 Phase	
100%	51,948	54	124,088	134	251,082	268
75%	69,264	72	167,388	176	334,776	353
50%	101,01	106	248,196	259	496,392	518
25%	199,134	207	473,304	494	949,494	989

Picture 11. The results of the calculation comparison and simulation of IS.5



	Account	Simulation	Account	Simulation	Account	Simulation
	HS 1 Phase		HS between Pashes		HS 3 Phase	
100%	103,896	110	253,968	273	507,936	546
75%	138,528	145	386,724	356	666,666	711
50%	204,906	213	484,848	514	972,582	1027
25%	380,952	403	891,774	937	1786,434	1873

Picture 12. The results of the calculation comparison and simulation of IS.6



	Account	Simulation	Account	Simulation	Account	Simulation
	HS 1 Phase		HS between Pashes		HS 3 Phase	
100%	438,672	463	1012,986	1059	2028,858	2118
75%	556,998	594	1266,954	1326	2533,908	2651
50%	759,018	828	1673,88	1766	3347,76	3531
25%	1191,918	1363	2412,696	2603	4828,278	5206

The graph and table above show the comparison results between manual calculation and ETAP software simulation. It appears that there is no large difference between the results of manual calculations and the results of ETAP simulations.

Percentage error from Comparison between Simulation and Manual Calculation

Table 7. Percentage of HS comparison errors of IS refiners.1

distance	*% Error*		
	HS 1 Phase	HS Inter-Phase	HS 3 Phase
25%	7%	5%	5%
50%	5%	3%	3%
75%	4%	3%	3%
100%	2%	3%	2%

Tabel 8. Persentase *error* perbandingan HS penyulang IS.2

distance	*% Error*		
	HS 1 Phase	HS Inter-Phase	HS 3 Phase
25%	4%	4%	4%
50%	4%	4%	4%
75%	4%	5%	4%
100%	5%	6%	6%

Tabel 9. Persentase *error* perbandingan HS penyulang IS.3

distance	*% Error*		
	HS 1 Phase	HS Inter-Phase	HS 3 Phase
25%	4%	3%	3%
50%	2%	3%	3%
75%	3%	4%	3%
100%	4%	5%	4%

Tabel 10. Persentase *error* perbandingan HS penyulang IS.4

distance	*% Error*		
	HS 1 Phase	HS Inter-Phase	HS 3 Phase
25%	4%	4%	4%
50%	5%	4%	4%
75%	4%	5%	5%
100%	4%	8%	7%

Tabel 11. Persentase *error* perbandingan HS penyulang IS.5

distance	*% Error*		
	HS 1 Phase	HS Inter-Phase	HS 3 Phase
25%	6%	5%	5%
50%	4%	6%	6%
75%	5%	8%	7%
100%	6%	7%	7%

Tabel 12. Persentase *error* perbandingan HS penyulang IS.6

distance	*% Error*		
	HS 1 Phase	HS Inter-Phase	HS 3 Phase
25%	14%	8%	8%
50%	9%	6%	5%
75%	7%	5%	5%
100%	6%	5%	4%

Based on the table above, it appears that the percentage of errors contained in each refiner operating in the isimu substation ranges from 2% to 14%. This is natural, given that the variables used in ETAP software when running simulated short circuit current are very diverse, while the variables used when performing manual calculations are limited.

IV. CLOSING

From the results of manual calculations and simulations conducted on ETAP software in this study can be concluded several things as follows:

1. The largest short circuit current occurs in is.6, a type of short circuit 3 phases, at a distance of 25% of the length of the refiner 7.98 KMS of 4828,278 A (calculation result) and 5206 A (simulation result). Meanwhile, the smallest short circuit current occurs in the IS.4 refiner, a type of short circuit 1 phase to the ground, at a distance of 100% of the length of the refiner 76.67 KMS of 51,948 A (calculation result) and 54 A (simulation result).
2. Comparison between the results of manual calculations with the results of ETAP software simulations against various types of short circuit current (1 phase to the ground, between phases, and 3 phases) that occur in 6 refiners operating in Isimu Substation, as well as in a variety of disruption points (25%, 50%, 75% and 100% of the total length of the refiners), obtained the largest percentage of average errors occurred in IS.6 refiners which is 7% and the smallest percentage of errors occurred in IS refiners.3 that is 3%. There is a difference between manual calculation and simulation or so-called percentage error is a natural thing to happen, caused by ETAP software using various variables behind the scenes when running a short circuit interference flow analysis program (1 phase to the ground, between phases, and 3 phases), while manual calculation is limited.
3. Based on the results of manual calculations as well as comparisons with simulation results on ETAP software the power breaker specification (PMT) in protecting the 60 MVA power transformer at isimu substation is good. This is based on setting the working time of incoming rele by taking a large short circuit current of 3 phases in the is.6 refiner (is the supplier with the largest short circuit current among other refiners) which occurs at 25%, 50%, 75% and 100% turtle length respectively of 0.313 seconds, 0.377 seconds, 0.447 seconds and 0.523 seconds. From the calculation result obtained the result of rele working time that is not smaller than 0.3 seconds. This is useful to keep the rele from trip due to the inrush current of the current transformers that have been connected to other networks.
4. Based on the results of the analysis, there are several factors that affect the specification of power breakers (PMT) in protecting the transformer 60 MVA in GI Isimu, among others, the magnitude of the short circuit current that occurs. The magnitude or smallness of the short circuit interference current is influenced by the type of short circuit interference itself, as well as the variation in the location of the interference of short circuit, the farther the point of disruption, the smaller the short circuit current and the closer the point of disruption, the greater the current of short circuit interference. Another factor is, setting the current rele more. The faster the time of the current rele work the deeper ordered pmt to immediately disconnect the network when a short circuit occurs then the better the specifications of the PMT.

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