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ACCURACY OPTIMIZATION OF KWH HIGH VOLTAGE CONSUMER TRANSACTIONS WITH SELECTION OF CURRENT TRANSFORMER (CT) RATIO IN ACCORDANCE WITH CONTRACTED POWER

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Abstract
The greater growth of electricity consumption, especially for high voltage consumers, it is important for PLN to know the effect of the current transformer (CT) error ratio in the accuracy of the kwh of electricity transactions, by researching the error ratio of CT 400/1 and 800/1 R, S, and T phase. When the contracted power of 120 MVA can be used CT class 0.2s ratio 400/1 and 800/1 ratio, when using CT class 0.2s ratio 400/1 then the kwh meter can be set according to the CT ratio that is the ratio 400/1 because CT ratio 400/1 has a negative error ratio at loads below 73.59%, and positive error ratio at loads over 73.59% up to 100% load, and` when using CT class 0.2s ratio 800/1 then the kwh meter can set a CT ratio of 800 / 0.98 because CT ratio 800/1 has a positive error ratio of 0.02% from 1% load to 100% load, so that it does not harm the customer as a positive CT ratio error tolerance . This needs to be done in order to create justice between PLN and high voltage consumers in the calculation of kwh transactions

1.0 INTRODUCTION

Measurement of high voltage consumer electricity consumption is an indirect measurement in which the load voltage and current are first converted into voltage and load current measurements by voltage transformers (CVT) and current transformers (CT) before entering into the transaction kwh. The accuracy of the transaction kwh is greatly influenced by the error rate on CT and CVT, in this study the author will discuss in more detail the effect of error on the CT ratio to the accuracy of the high voltage consumer kwh transaction by performing the CT test, with the CT analyzer. [1]

Therefore, the author would like to discuss about this contracted power condition, the effect of the installed CT ratio on the accuracy of the high voltage consumer transaction of PT.LSI. And simulation when the contracted power is 120 MVA with the current CT installed. This research is expected to be a input for PT. PLN management in determining the policy of whether the replacement of the installed CT ratio or the procurement of new CT with a greater CT ratio due to the addition contracted power of PT. LSI.

Current Transformer is an installation equipment that functions as a current meter in an electric power system by converting large currents into small currents accurately for measurement and protection. [2]. the function of the current transformer is as a measure of the current in the electric power system by converting large currents into small currents accurately for measurement and protection. The standard CT ratio error limits are shown in table 1 below: [3]

Table 1. CT ratio error limits according to IEC 60044-1

Test Parameters	Accuracy class	Current value of rated current				
		1%	5%	20%	100%	120%
CT ratio error (%)	0.2s	±0,75	±0,35	±0,2	±0,2	±0,2

2.0 METHODOLOGY

2.1. Determination of Thermal Relay Settings (Maximum Power Limitation)

Thermal relay is the maximum power limit that can be used by high voltage consumers according to contracted power. The settings are calculated based on the maximum current reached at a certain time. In determining the CT installed according to the contracted power based on the following equation:

$$I = \frac{S}{\sqrt{3}\, x\, V} \quad (1)$$

I = Nominal current (A); S = Contracted power (VA); V = Primary voltage (V)

The calculation of the thermal relay setting limiting high voltage consumer load current is shown in the following equation: [4]

$$I\ setting = \frac{Imax}{Ip\ CT}\ x\ In \quad (2)$$

I setting = Current setting relay thermal (A); Imax = customer's maximum load current (A)

Ip CT = Primary current CT (A); In = Nominal thermal relay current (A)

2.2. Current Transformer Ratio Error Analysis

Current transformer ratio error is an error in the amount of current due to the difference between the rated ratio of the current transformer and the actual ratio. which is stated in the equation below: [5]

$$\varepsilon(\%) = \frac{(K_n x\, I_s) - I_p}{I_p} x100 \quad (3)$$

ε = current transformer error ratio (%); Kn = identifier ratio of CT

Is = the actual secondary current of CT (A); Ip = actual primary current of CT (A)

2.3. Analysis of Energy Consumption in Transaction Meters

Calculation of energy usage at PT. PLN can be determined based on the following equation: [6]

$$E = V_s\ x\ I_s\ x\ cos\ \varphi\ x\ t\ x\ FKM \quad (4)$$

E = energy used (kwh); Vs = secondary voltage (volt)

Is = secondary current (ampere); Cos φ = Power factor

t = Time (hour); FKM (meter times factor) = CT ratio x PT ratio

2.4. Research Framework

This research framework is a brief description of the research steps carried out from beginning to end shown in Figure 1 below:

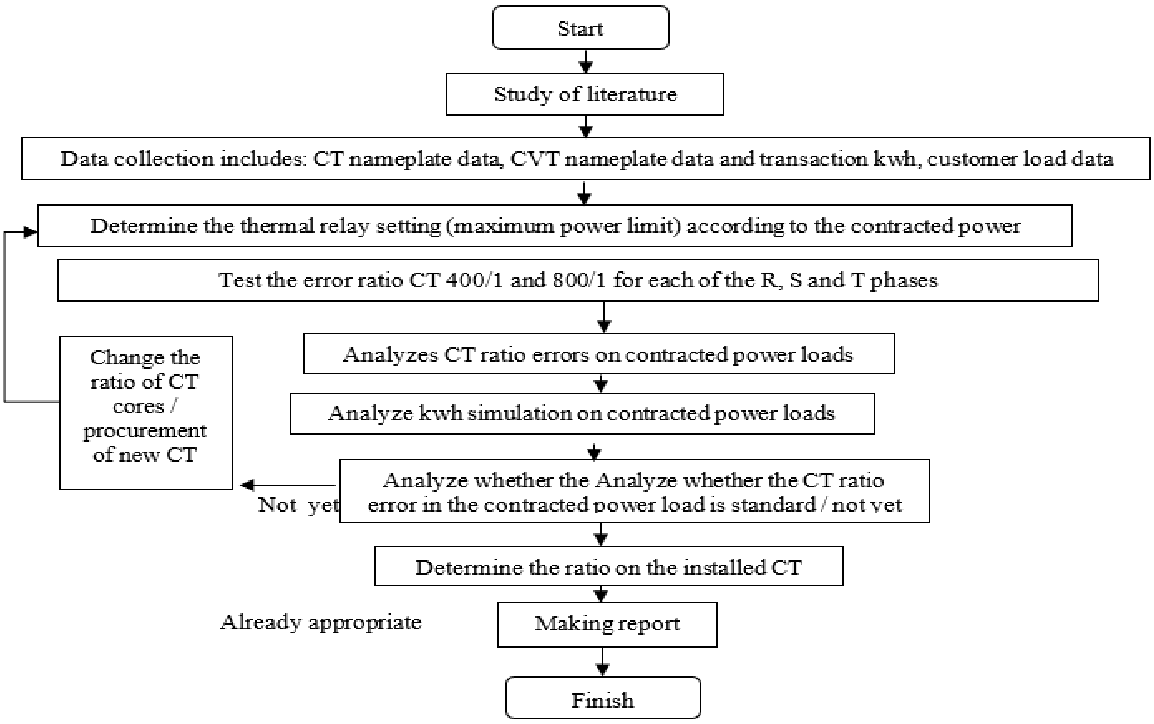

Figure 1. Research Flow Diagram

3.0 RESULANTS AND DISCUSSION

3.1. General Description

In this research, to compare the error ratio of CT, data collection is done on the high voltage consumers of PT. LSI according to the data in table 2 below:

Table 2. Customer Data

PLN	**UID BANTEN**
Consumer ID	546900470659
Consumer	PT. LAUTAN STEEL INDONESIA
Tarif	I4
Power (VA)	1200000000

3.2. Determination of Thermal Rele Settings (Maximum Power Limiting)

In terms of determining the CT installed on the 120 MVA contracted power based on equation (1) follows: For a 120 MVA contracted power then S = 120 x 10^6 VA and high voltage 150 kV then V = 150 x 10^3 volt, so the nominal current can be determined as follows

$I = \frac{S}{\sqrt{3}\,x\,V} = \frac{120 \text{ x } 10^6 \text{ VA}}{\sqrt{3}\,x \text{ 150 x } 10^3}$ = 462 ampere

Based on equation (1) when the contracted power is 120 MVA, the maximum load current is 462 ampere. So if it is included in equation (2) then the setting current in the thermal relay can be determined as follows:

- ❖ When the CT ratio used is 400/1, the current setting in the thermal relay:

  $I\ setting = \frac{462\ ampere}{400}\,x\ In = 1.155\ x\ In$

- ❖ When the CT ratio used is 800/1, the current setting in the thermal relay :

  $I\ setting = \frac{462\ ampere}{800}\,x\ In = 0.5775\ x\ In = 0.58\ x\ In$

3.3. Comparison of CT Class 0.2s Error Ratio Analysis simulation Ratio 400/1 and Ratio 800/1 for 120 MVA Contracted Power Customers

1. **Analysis of the error ratio of CT class 0.2s 400/1 in the simulation of 120 MVA contracted power customers**

   The results of the secondary current in the simulation of the customer's contracted power 120 MVA ratio CT 400/1 at 100% nominal burden are shown in table 3 below:

Table 3. Test Results Data with CT Class 0.2s Ratio 400/1

Test Results Data with CT Class 0.2s Ratio 400/1							
% of rated current CT	% Contracted power	Rated current CT (A)	Contracted primary current power (A)	Secondary Current phase R (A)	Secondary Current phase S (A)	Secondary Current phase T (A)	Average current (A)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)=[(5)+(6)+(7)]/3
115.50%	100%	462	462	1.1631	1.1827	1.1446	1.1635
100%	86.58%	400	400	1.0030	1.0200	0.9860	1.0030
95%	82.25%	380	380	0.9519	0.9681	0.9348	0.9516
85%	73.59%	340	340	0.8500	0.8636	0.8364	0.8500
75%	64.94%	300	300	0.7485	0.7605	0.7335	0.7475
65%	56.28%	260	260	0.6474	0.6572	0.6338	0.6461
57.75%	50%	231	231	0.5735	0.5815	0.5608	0.5719
23.1%	20%	92.4	92.4	0.2280	0.2310	0.2222	0.2271
20%	17.32%	80	80	0.1974	0.2000	0.1924	0.1966
11.55%	10%	46.2	46.2	0.1135	0.1153	0.1106	0.1132
5.78%	5%	23.1	23.1	0.0567	0.0575	0.0552	0.0564
5%	4.33%	20	20	0.0491	0.0498	0.0478	0.0489
2.89%	2.50%	11.56	11.56	0.0284	0.0288	0.0276	0.0282
1.16%	1%	4.62	4.62	0.0113	0.0115	0.0110	0.0112
1%	0.87%	4	4	0.0098	0.0099	0.0095	0.0097

2. **Analysis of the error ratio of CT class 0.2s 800/1 in the simulation of 120 MVA contracted power customers.**

   The results of the secondary current in the simulation of the customer's contracted power 120 MVA ratio CT 800/1 at 100% nominal burden are shown in table 4 below:

Table 4. Test Results Data with CT Class 0.2s Ratio 800/1

Test Results Data with CT Class 0.2s Ratio 800/1							
% of rated current CT	% Contracted power	Rated current CT (A)	Contracted primary current power (A)	Secondary Current phase R (A)	Secondary Current phase S (A)	Secondary Current phase T (A)	Average current (A)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)=[(5)+(6)+(7)]/3
115.50%	200%	924	924	1.1920	1.1943	1.1839	1.1900
100%	173.16%	800	800	1.0310	1.0340	1.0240	1.0297
95%	164.50%	760	760	0.9795	0.9823	0.9728	0.9782
85%	147.19%	680	680	0.8764	0.8789	0.8704	0.8752
75%	129.87%	600	600	0.7733	0.7755	0.7680	0.7723
65%	112.55%	520	520	0.6702	0.6715	0.6650	0.6689
57.75%	100%	462	462	0.5954	0.5966	0.5908	0.5943
23.1%	40%	184.8	184.8	0.2379	0.2384	0.2361	0.2375
20%	34.63%	160	160	0.2060	0.2064	0.2044	0.2056

11.55%	20%	92.4	92.4	0.1188	0.1191	0.1179	0.1186
5.78%	10.01%	46.24	46.24	0.0595	0.0596	0.0590	0.0594
5%	8.66%	40	40	0.0515	0.0516	0.0510	0.0514
2.89%	5%	23.1	23.1	0.0297	0.0298	0.0295	0.0297
1.16%	2.01%	9.28	9.28	0.0119	0.0120	0.0118	0.0119
1%	1.73%	8	8	0.0103	0.0103	0.0102	0.0103

The results of the analysis of the error ratio of CT class 0.2s 400/1 and 800/1 in the simulation of 120 MVA contracted power customers by entering the average CT secondary currents phase R, S, T in table 3 and table 4 into equation (3) so that the results can be displayed in table 5 below:

Table 5. Comparison Data for CT Class 0.2s Ratio 400/1 and Ratio 800/1

CT accuracy class 0.2S		**Percentage of rated CT current**						
		1%	**1.16%**	**2.89%**	**5%**	**5.78%**	**11.55%**	**20%**
Percentage error CT ratio (%)	Ratio 400/1	-0.0260	-0.0260	-0.0227	-0.0227	-0.0227	-0.0203	-0.0170
	Ratio 800/1	0.02667	0.02586	0.02742	0.02733	0.02710	0.02684	0.02800
Gap Error Current		0.05267	0.05186	0.05008	0.05000	0.04977	0.04717	0.04500

CT accuracy class 0.2S		**Percentage of rated CT current**							
		23.10%	**57.75%**	**65%**	**75%**	**85%**	**95%**	**100%**	**115.50%**
Prosentase error rasio CT (%)	Rasio 400/1	-0.0170	-0.0139	-0.0060	-0.0033	0.00000	0.00167	0.00300	0.00733
	Rasio 800/1	0.02799	0.02903	0.02900	0.02967	0.02967	0.02967	0.02967	0.03033
Gap Error Current		0.04499	0.04297	0.03500	0.03300	0.02967	0.02800	0.02667	0.02300

From table 5 above, it can be shown in Figure 2 below :

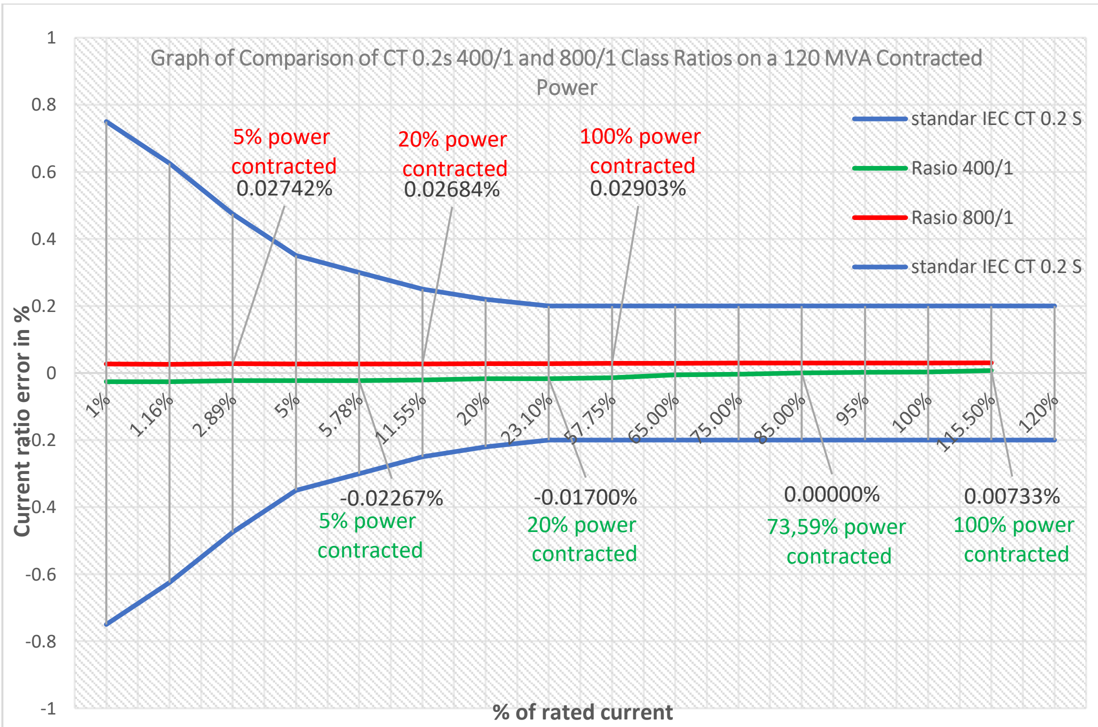

Figure 2. Graph of Comparison CT Class 0.2s Ratio 400/1 and Ratio 800/1 on a 120 MVA Contracted Power

In table 5 and figure 2 above it can be seen that when the contracted power is 120 MVA, CT class 0.2s ratio 400/1 has a negative error value at 1% up to 73.59% of load the contracted power, and a positive error ratio value at >73.59% up to 100% of load contracted power. While CT class 0.2s ratio 800/1 has a positive error value at 1% up to 100% of load contracted power, but has a value of error ratio that is greater than the CT class 0.2s ratio of 400/1 but still according to the IEC standard 60044-1.

3.4. Energy Consumption Simulation Analysis on 120 MVA Contracted Power Customers

1. The simulation of customer load usage on CT class 0.2s ratio 400/1 is shown in table 6 below :

Table 6. Duration and Secondary Current CT Class 0.2s Ratio 400/1 for Load Usage Simulation

No	Time	Duration (hour)	Load usage simulation	Secondary current (A)
1	00.00-05.00	5	1%	0,0112
2	05.00-08.00	3	20%	0,2271
3	08.00-12.00	4	100%	1,1585
4	12.00-13.00	1	20%	0,2271
5	13.00-18.00	5	100%	1,1585
6	18.00-22.00	4	5%	0,0564
7	22.00-00.00	2	1%	0,0112

The parameters in the kwh transaction analysis using CT class 0.2s ratio 400/1 as follows :

- Primary CT current = 462 A
- CT ratio = 400/1
- Primary voltage (Vp) = 150,000 Volt
- Power connected (contracted) = 120,000,000 VA
- Meter times factor (FKM) = $\left(\frac{400}{1}\right) x \left(\frac{150.000/\sqrt{3}}{100/\sqrt{3}}\right)$ = 600.000
- Secondary voltage (Vs) = 57.7 volt
- Power factor = 0.9
- Time = 24 hours
- Rates per KWH for WBP = Rp. 996,774
- Rates per KWH for LWBP = Rp. 996,774

By entering the above parameters into equation (4) the energy used in the customer load usage simulation on CT class 0.2s ratio 400/1 can be shown in table 7 below :

Table 7. Energy Usage in the Simulation of Customer Load Usage on CT Class 0.2s Ratio 400/1

No	Secondary current (A)	Secondary voltage (V)	Power factor	Duration (hour)	FKM	Energy usage (kwh)
(1)	(2)	(3)	(4)	(5)	(6)	(7)= [(2)x(3)x(4)x(5)x(6)]/1000
1	0.01125	57.7	0.9	5	600000	1752.59
2	0.227073	57.7	0.9	3	600000	21225.42
3	1.158465	57.7	0.9	4	600000	144381.81
4	0.227073	57.7	0.9	1	600000	7075.14
5	1.158465	57.7	0.9	5	600000	180477.26
6	0.056441	57.7	0.9	4	600000	7034.35
7	0.01125	57.7	0.9	2	600000	701.04
		Total KWh				362647.62

(Energy No. 6 is a WBP group)

From the results of the analysis, it is known that the energy usage in the customer load simulation on CT class 0.2s ratio 400/1 for 24 hours is 362.647,62 kWh.

Energy cost calculation is as follows:
LWBP energy costs = 355.613,26 kWh x Rp 996,774 = Rp 354.466.053
WBP energy costs = 7034,35 kWh x Rp 996,774 = Rp 7.011.662
The total cost of Energy = Rp 354.466.053 + Rp 7.011.662 = Rp 361.477.715

2. The simulation of customer load usage on CT class 0.2s ratio 800/1 is shown in table 8 below :

Table 8. Duration and Secondary Current CT Class 0.2s Ratio 800/1 for Load Usage Simulation

No	Time	Duration (hour)	Load usage simulation	Secondary current (A)
1	00.00-05.00	5	1%	0,0059
2	05.00-08.00	3	20%	0,1187
3	08.00-12.00	4	100%	0,5946
4	12.00-13.00	1	20%	0,1187
5	13.00-18.00	5	100%	0,5946
6	18.00-22.00	4	5%	0,0296
7	22.00-00.00	2	1%	0,0059

The parameters in the kwh transaction analysis using CT class 0.2s ratio 800/1 as follows :

- Primary CT current = 462 A
- CT ratio = 800/1
- Primary voltage (Vp) = 150,000 Volt
- Power connected (contracted) = 120,000,000 VA
- Meter times factor (FKM) = $\left(\frac{800}{1}\right) x \left(\frac{150.000/\sqrt{3}}{100/\sqrt{3}}\right)$ = 1.200.000
- Secondary voltage (Vs) = 57.7 volt
- Power factor = 0.9
- Time = 24 hours
- Rates per KWH for WBP = Rp. 996,774
- Rates per KWH for LWBP = Rp. 996,774

By entering the above parameters into equation (4) the energy used in the customer load usage simulation on CT class 0.2s ratio 800/1 can be shown in table 9 below :

Table 9. Energy Usage in the Simulation of Customer Load Usage on CT Class 0.2s Ratio 800/1

No	Secondary current (A)	Secondary voltage (V)	Power factor	Duration (hour)	FKM	Energy usage (kwh)
(1)	(2)	(3)	(4)	(5)	(6)	(7)= [(2)x(3)x(4)x(5)x(6)]/1000
1	0.0059	57.7	0.9	5	1200000	1848.56
2	0.1187	57.7	0.9	3	1200000	22197.08
3	0.5946	57.7	0.9	4	1200000	148220.48
4	0.1187	57.7	0.9	1	1200000	7399.03
5	0.5946	57.7	0.9	5	1200000	185275.59
6	0.0296	57.7	0.9	4	1200000	7389.43
7	0.0059	57.7	0.9	2	1200000	739.42
		Total KWh				373069.59

(Energy No. 6 is a WBP group)

From the results of the analysis, it is known that the energy usage in the customer load simulation on CT class 0.2s ratio 800/1 for 24 hours is 373.069,62 kWh.

Energy cost calculation is as follows:
LWBP energy costs = 365,680.16 kWh x Rp 996,774 = Rp 364.500.478
WBP energy costs = 7389,43 kWh x Rp 996,774 = Rp 7.365.593

The total cost of Energy = Rp 364.500.478 + Rp 7.365.593 = Rp 371.866.071

3. Comparison of energy comsumption simulation analysis for 120 MVA contracted power customers with the usage of CT class 0.2s ratio 400/1 and CT class 0.2s ratio 800/1.

Energy comsumption simulation analysis for 120 MVA contracted power customers with the usage of CT class 0.2s ratio 400/1 and CT class 0.2s ratio 800/1 can be shown in table 10 below :

Table 10. Energy comsumption simulation analysis for 120 MVA contracted power customers with the usage of CT class 0.2s ratio 400/1 and CT class 0.2s ratio 800/1

No	Load usage simulation	Energy comsumption (kWh)		energy consumption difference (kWh)
		CT class 0.2s ratio 800/1	CT class 0.2s ratio 400/1	
1	1%	1848.56	1752.59	95.967
2	20%	22197.08	21225.42	971.662
3	100%	148220.48	144381.81	3838.666
4	20%	7399.03	7075.14	323.887
5	100%	185275.59	180477.26	4798.332
6	5%	7389.43	7034.35	355.077
7	1%	739.42	701.04	38.387
	Total kWh	373069.59	362647.62	10421.977

Based on table 10 above, that CT class 0.2s ratio 800/1 has a greater current error ratio than CT class 0.2s ratio 400/1. However, if the possibility current ratio is positive on CT class 0.2s ratio 800/1 then the positive boundary range is greater so that the current measurement becomes greater, which results in a larger measurement in kwh.

4.0 CONCLUSION

When the high voltage consumer contracted power of PT. LSI 120 MVA, the CT core ratio 400/1 and CT ratio 800/1 can be used because it is still according to IEC 60044-1 standard, and when the CT 400/1 core is used then the CT ratio setting at kwh the transaction meter is 400/1, but when the core is changed to the CT ratio of 800/1, it is necessary to change the CT ratio setting on the kwh meter transaction which is 800 / 0.98, because the CT ratio of 800/1 has a positive CT ratio error of 0, 02%, so it does not harm the customer.

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