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| SMOGRR Number | [028](https://www.ercot.com/mktrules/issues/SMOGRR028) | SMOGRR Title | Add Series Reactor Compensation Factors |
| Date Posted | | September 25, 2023 | |
|  | |  | |
| Requested Resolution | | Normal | |
| Settlement Metering Operating Guide Sections Requiring Revision | | Section 8, Transformer and Line Loss Compensation Factors  8.1, Introduction  8.5, Calculating Series Reactor Loss Constants (new)  8.5, Reference Materials  8.6.1, Transformer and Line Loss Compensation Sheet | |
| Related Documents Requiring Revision/Related Revision Requests | | None | |
| Revision Description | | This Settlement Metering Operating Guide Revision Request (SMOGRR) gives guidance for allowing loss compensation for current limiting reactors. | |
| Reason for Revision | | Addresses current operational issues.  Meets Strategic goals (tied to the [ERCOT Strategic Plan](https://www.ercot.com/files/docs/2018/12/13/ERCOT_Strategic_Plan_2019-2023.pdf) or directed by the ERCOT Board).  Market efficiencies or enhancements  Administrative  Regulatory requirements  Other: (explain)  *(please select all that apply)* | |
| Business Case | | This SMOGRR is needed to extend the guidelines for loss compensation (previously limited to transmission lines and transformers) to include current limiting reactors which have seen increased use in renewable generation. The need for current limiting reactors (a protection device to reduce fault current) may be identified later in the design process and permitting loss compensation for current limiting reactors would allow for greater flexibility in meter installation location without requiring additional metering structures to be constructed. | |

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| Proposed Guide Language Revision |

# 8 Transformer, Line Loss, and Series Reactor Compensation Factors

## 8.1 Introduction

(1) Transformer, line loss, and series reactor compensation refers to the practice of metering electrical energy delivered at a high-voltage billing point using metering equipment connected on the low-voltage side of the delivery point. The metering equipment is provided with a means of correction that adds to, or subtracts from, the actual active and reactive metered values in proportion to losses that are occurring in the transformer, lines, and series reactors.

(2) ERCOT approval is required for loss compensation performed in the Data Aggregation System (DAS). For a specific site, where a Transmission and/or Distribution Service Provider (TDSP) is requesting ERCOT to perform loss compensation in DAS, the TDSP shall submit to ERCOT, for approval, a single percent loss correction value and supporting documentation verifying such value. Such loss compensation percentage values and supporting documentation shall be resubmitted to ERCOT on an annual basis or upon circuit parameter changes.

(3) Transformer losses are divided into two parts:

(a) The core or iron loss (referred to as the no-load loss); and

(b) The copper loss (referred to as the load loss).

(i) Both the no-load loss and the load loss are further divided into Watt and VAr components.

(ii) The no-load (iron) loss is composed mostly of eddy current and hysteresis losses in the core. No-load loss varies in proportion to applied voltage and is present with or without load applied. Dielectric losses and copper loss due to exciting current are also present, but are generally small enough to be neglected.

(iii) The load (copper) watt loss (I2 + stray loss) is primarily due to the resistance of conductors and essentially varies as the square of the load current. The VAr component of transformer load loss is caused by the leakage reactance between windings and varies as the square of the load current.

(iv) Line losses are considered to be resistive and have I2R losses. The lengths, spacings and configurations of lines are usually such that inductive and capacitive effects can be ignored. If line losses are to be compensated, they are included as part of the load losses (Watts copper).

## 8.5 Calculating Series Reactor Loss Constants

(1) Current limiting reactor loss compensation calculations with electronic meters are accomplished internally with firmware. Various information and test data about the current limiting reactor is required to program the meter. The following information is required regarding meter installations:

(a) Current limiting reactor Rated Current

(b) Current limiting reactor Rated Voltage

(2) The following data is required from the Current limiting reactor test report:

(a) Current limiting reactor Test Inductance (mH)

(b) Current limiting reactor DC Resistance at Reference Temperature (Ohms)

(3) The test data required may be obtained from the following sources:

(a) The manufacturer’s test report (preferred); or

(b) A test completed by a utility or independent electrical testing company.

(4) The standard calculation should result in a compensation that will lower the measured load values and increase generation values (if measured). The TDSP shall ensure correct calculation and meter programming is utilized to correctly adjust the recorded values as required for the specific meter point configuration.

## 8.6 Reference Materials

(1) The following additional references may be referred to for assistance when calculating the compensation factors referred to in this Section 8, Transformer and Line Loss Compensation Factors.

(a) Handbook For Electricity Metering, Edison Electric Institute, Ninth Edition, 1992.

(b) Institute of Electrical and Electronics Engineers (IEEE) Std. C57.12.00-2000, IEEE Standard General Requirements for Liquid Immersed Distribution, Power and Regulating Transformer.

(c) IEEE Std. C57.16-2011, IEEE Standard for Requirements, Terminology, and Test Code for Dry-Type Air-Core Series Connected Reactors.

### 8.7.1 Transformer and Line Loss Compensation Sheet

Name:

Delivery:

Location:

Rev. Date:

|  |  |  |  |
| --- | --- | --- | --- |
| HV Rated Voltage: | V | VT Ratio: | :1 |
| HV Tap: | V | CT Ratio: | :5 |
| LV Tap: | V | Joint Use (Y/N): |  |
| Trf. Conn. (Y/D): |  | Metering Trf. Use: | 100 % |
| Trf. Phase (1 or 3) |  | Contract kW: | kW |
| # Meter Elem.: |  | Power Factor: | % |

Comments:

**TRANSFORMER DATA**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Serial Number | KVa Rating | No Load  (Fe)  Loss | Load  (Cu) Loss | (Z)  Impedance | (IE)  Exciting  Current |

|  |  |
| --- | --- |
| Total kVa rating: | Max Available kVa: |

**LINE DATA**

|  |  |  |
| --- | --- | --- |
|  | Resistance | Length |
| #1 Line Type: | Ohms/mile | Miles |
| #2 Line Type: | Ohms/mile | Miles |
| #3 Line Type: | Ohms/mile | Miles |
| #4 Line Type: | Ohms/mile | Miles |
| #5 Line Type: | Ohms/mile | Miles |
| #6 Line Type: | Ohms/mile | Miles |

**SERIES REACTOR DATA**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Serial Number | Rated Current | Rated Voltage | Resistance (Ohms) | Inductance (mH) |

**\*\*TRANSFORMER LOSS COMPENSATION TEST POINTS FOR WATTHOURS\*\***

**SERIES TEST**

|  |  |
| --- | --- |
| Test Load | % Total |
| Full |  |
| 0.5 P.F. |  |
| Light |  |

**\*\*TRANSFORMER LOSS COMPENSATION TEST POINTS FOR VARHOURS\*\***

**SERIES TEST**

|  |  |
| --- | --- |
| Test Load | % Total |
| Full |  |
| Light |  |

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Example: Transformer, Series Reactor and Line Loss Compensation Calculation Sheet** | | | | | | | | | | | | | | | | | |
|  | | | | | | | | | | | | | | | | | |
|  | | | | | | | Date: 12/14/2000 | | | | | | | | | | |
|  | | | | | | | | | | | | | | | | | |
|  | | | | | | | | | | | | | | | | | |
| **Transformer Information** | | | | |  | **Transmission Line Information** | | | | |  | **Series Reactor Information** | | |  | **Meter Information** | |
|  | | | | |  |  | | | | |  |  | | |  |  | |
| Xfmr Manufacturer | | ABB | | |  | Line Type | | 4/0 ACSR | | |  | Reactor Manufacturer | GE | |  | PTR (xxx/1) | 60 |
| Xfmr Serial Number | | 1000001 | | |  | Line Length (miles) | | 7.360 | | |  | Reactors Serial Numbers | 3543130010, 3543130011, 354313012 | |  | CTR (xxx/1) | 120 |
| Xfmr size (KVA) | | 12000 | | |  | Line Res. @ 50 C | | 0.592 | | |  | Reactor Rated Current | 1200 | |  | Meter Rated volt (V) | 120 |
| Xfmr Pri. test volt (p-p-v) | | 110000 | | |  | \*Total Line Res. | | 4.357 | | |  | Average Series Reactor Reactance (mH) | 2.477 | |  | Meter class (amp) | 20 |
| Xfmr. sec. test volt (p-p-v) | | 13090 | | |  | \*Line Loss (VA) | | 266549 | | |  | Average Series Reactor Resistance (Ohms) | .00731323 | |  | Number of elements | 3 |
| Xfmr. No-Load loss (Watts) | | 22200 | | |  |  | |  | | |  |  |  | |  | \*Meter Nominal Watts (Watts) | 3600 |
| Xfmr. Excitation Current (%) | | 0.45 | | |  |  | |  | | |  |  |  | |  | \*Nominal CT Primary amp (A) | 1200 |
| Xfmr. Load loss (Watts) | | 51360 | | |  |  | |  | | |  |  |  | |  | \* Meter secondary test volt (V) | 125.9586 |
| Xfmr Impedance (%) | | 8.84 | | |  |  | |  | | |  |  |  | |  | \*Nominal Primary VA (VA) | 25920000 |
| \*Xfmr sec. Test amp (A) | | 529.27 | | |  |  | |  | | |  |  |  | |  |  |  |
| \*Xfmr Pri Amps @ 1/2 Mtr Cl (A) | | 142.80 | | |  |  | |  | | |  |  |  | |  |  |  |
|  | | | | | | | | | | | | | | | | | |
| **XFMR Loss Constants** | | | | | | | | | | | | | | | | | |
|  | | | | | | | | | | | | | | | | | |
| \*No Load VA loss (VA) | | | | | | | | | | 54000 | | | | | | | |
| \*No Load loss phase angle (alpha) | | | | | | | | | | 65.73 | | | | | | | |
| \*No Load VAr loss (VAr) | | | | | | | | | | 49226 | | | | | | | |
| \*Load VA loss (VA) | | | | | | | | | | 1060800 | | | | | | | |
| \*Load loss phase angle (beta) | | | | | | | | | | 87.22 | | | | | | | |
| \*Load VAr loss (VAr) | | | | | | | | | | 1059556 | | | | | | | |
|  | | | | | | | | | | | | | | | | | |
| **Series Reactor Losses** | | | | | | | | | | | | | | | | | |
|  | | | | | | | | | | | | | | | | | |
| \* SR Loss Watts | | | | | | | | | | 10531.0512 | | | | | | | |
| \* SR Loss Vars | | | | | | | | | | 3566880.00 | | | | | | | |
| \* SR % Watt Cu Losses | | | | | | | | | | -0.040629 | | | | | | | |
| \* SR % Vars Cu Losses | | | | | | | | | | -13.761111 | | | | | | | |
|  | | | | | | | | | | | | | | | | | |
| **% Transformer Losses** | | |  | **% Transmission Line Losses** | | | | | | | **% Series Reactor Losses** | | | | | **% Total Losses** | |
|  |  | |  |  | | | | |  | |  | | | | |  |  |
| % Xfmr Watt Fe Loss | 0.07774 | |  |  | | | | |  | |  | | |  | | %Tot. Watt Fe Loss | 0.07774 |
| % Xfmr Watt Cu Loss | 1.01857 | |  | % Line Watt Cu Loss | | | | | 1.02835 | | SR % Watt Cu Losses | | | -0.040629 | | %Tot. Watt Cu Loss | 2.00063 |
| % Xfmr VAr Fe Loss | 0.15645 | |  |  | | | | |  | |  | | |  | | %Tot. VAr Fe Loss | 0.15645 |
| % Xfmr VAr Cu Loss | 21.01307 | |  |  | | | | |  | | SR % Var Cu Losses | | | -13.761111 | | %Tot. VAr Cu Loss | 7.251959 |

|  |  |
| --- | --- |
| **\*Calculated Values for the Transformer, Series Reactor and Line Loss Compensation Calculation Sheet** | |
|  | |
| Where: | Xfmr Sec. test amps=(Xfmr rating in VA)/(Xfmr secondary test p-p volt x Sqrt 3) |
|  | Xfmr Pri. Amp @ 1/2Mtr CL=(Xfmr Secondary test p-p volt/Xfmr Primary test p-p volt) x Nominal CT Primary Amp |
|  | Total Line Res.=Line Length x Line Res. (per mile) |
|  | Line Loss=3 x Total Line Res. x (Xfmr Primary Amp @ 1/2 Meter Class amp)^2 |
|  | Average Series Reactor (SR) Resistance (3 Element)=(Phase A Reactor Resistance + Phase B Reactor Resistance + Phase C Reactor Resistance)/3 |
|  | Average Series Reactor (SR) Resistance (2 Element)=(Phase A Reactor Resistance + Phase C Reactor Resistance)/2 |
|  | Average Series Reactor (SR) Reactance (3 Element)=(Phase A Reactor Reactance + Phase B Reactor Reactance + Phase C Reactor Reactance)/3 |
|  | Average Series Reactor (SR) Reactance (2 Element)=(Phase A Reactor Reactance + Phase C Reactor Reactance)/2 |
|  | SR Loss Watts=((Nominal CT Primary Amps)^2)\*Average SR Resistance |
|  | SR Loss Vars=((Nominal CT Primary Amps)^2)\*Average SR Reactance |
|  | Meter Test Current=(Number of Elements \* 1/2 Class Amps of Meter) |
|  | SR % Watt Cu Losses= -(SR Loss Watts \* 100)/(CTR\*PTR\*Meter Test Current\*Meter Rated Volt) |
|  | SR % Var Cu Losses= -(SR Loss Vars \* 100)/(CTR\*PTR\*Meter Test Current\*Meter Rated Volt) |
|  | Meter Nominal Watts=(Meter Class amp/2) x Meter Rated voltage x Number of elements |
|  | Nominal CT Primary Amps=(Meter Class amp/2) x CTR |
|  | Meter secondary test Volt=(Xfmr sec test volt)/(PTR x Sqrt 3) for 3 elm; (Xfmr sec test volt)/(PTR) for 2 elm |
|  | Nominal Primary VA=CTR x PTR x Meter Nominal Watts |
|  | No Load VA loss=(Xfmr Excitation current x Xfmr rating in VA) / 100 |
|  | No Load loss phase angle=acos(Xfmr No Load watts loss/No Load VA loss) |
|  | No Load VAr Loss=No Load VA loss x sin(No Load loss phase angle (alpha)) |
|  | Load VA loss=(Xfmr Impedance x Xfmr rating in VA ) / 100 |
|  | Load loss ph angle (beta)=acos(Xfmr load loss/Load VA loss) |
|  | Load VAr loss=Load VA loss x sin(Load loss phase angle (beta) |
|  | % Watt Fe Loss=((Xfmr No-load loss x (Meter rated volt/Meter sec. test volt)^2) / Nominal Primary VA) x 100 |
|  | % Watt Cu Loss=((Xfmr Load loss x ((Meter Class amp/2) x (CTR/Xfmr sec. test amp))^2) / Nominal Primary VA) x 100 |
|  | % VAr Fe Loss=((No Load VAr loss x (Meter Rated volt/Meter Sec. test volt)^4) / Nominal Primary VA) x 100 |
|  | % VAr Cu Loss=((Load VAr loss x ((Meter Class amp/2) x (CTR/Xfmr sec. test amp))^2) / Nominal Primary VA) x 100 |
|  | % Line Cu Loss=(Line Loss VA/ Nominal Primary VA) x 100 |
|  | % Total Losses= %Xfmr(Fe or Cu) losses + %Line(Fe or Cu) losses |

|  |  |  |
| --- | --- | --- |
| **Percent Error Calculations for Meters** | | |
| **With Transformer/Line Loss Compensation** | | |
|  | | |
| FL = 120 VOLTS @ 5 AMPS @ UNITY | **FL=** | **1.179** |
|  | | |
| LL = 120 VOLTS @ .5 AMPS @ UNITY | **LL=** | **1.657** |
|  | | |
| PF = 120 VOLTS @ 5 AMPS @ 50% | **PF=** | **2.358** |
|  | | |
| **Calculations for Watt Loss Compensation** | | |
|  | | |
| FL = 1/2 Watt CU losses + 2 \* Watt FE losses | | |
|  | | |
| LL = 1/20th Watt CU losses + 20 \* Watt FE losses | | |
|  | | |
| PF = UNITY \* 2 | | |