Philippine Electricity Market Corporation

WHOLESALE ELECTRICITY SPOT MARKET
RULES CHANGE COMMITTEE

RESOLUTION NO. 2010-07

Proposed Changes to the WESM Metering Standards and Procedures Manual, Issue 5.0

WHEREAS, on 12 August 2008, the Rules Change Committee (RCC) Metering Subcommittee submitted its proposed amendments to the WESM Metering Standards and Procedures Manual (the "Manual") to the RCC, for consideration and approval;

WHEREAS, during its 20th Meeting on 11 February 2009, the RCC approved the proposed amendments to the Manual;

WHEREAS, during its meeting on 26 April 2010, the Board Review Committee (BRC) referred back to the RCC the proposed amendments for further deliberation to incorporate recent developments in the power industry which includes enactment and implementation of new laws and other government issuances;

WHEREAS, during the 34th RCC Meeting on 02 June 2010, in compliance with the Board's directive, the RCC and the RCC Metering Subcommittee discussed the proposed amendments taking into consideration the possible implication of the DOE Circular No. DC2010-05-0006 on Disconnection Policy (the "DOE Circular");

WHEREAS, during the said 34th RCC Meeting, the RCC and the Metering Subcommittee noted that the DOE Circular does not have any relevance on the contents of the proposed changes to Section 7 on the use of Meter Register Reading in Validation, Estimation and Editing (VEE) and to Section 9 on the allocation of transformer losses in Site Specific Loss Adjustment (SSLA) calculation;

WHEREAS, during the said 34th Meeting, the RCC agreed that the proposed new Section 10 of the Manual which describes the process of De-registration of Metering Installations shall be subject for further review in order to conform with the DOE Circular;

WHEREAS, during the said 34th Meeting, the RCC agreed to re-submit to the PEM Board the proposed changes to Sections 7 and 9 of the Manual;

NOW THEREFORE, we, the undersigned and in behalf of the sector we represent, hereby resolve as follows:

RESOLVED, that the proposed amendments to Sections 7 and 9 of the WESM Metering Standards and Procedures Manual, (attached as Annex "A") are adopted and approved in full;

RESOLVED FINALLY, that the proposed amendments to Sections 7 and 9 of the WESM Metering Standards and Procedures Manual be endorsed to the PEM Board for approval.

Done this 02 June 2010, Pasig City.

Approved by: RULES CHANGE COMMITTEE **Epictetus E. Patalinghug** Acting Chairperson Independent University of the Philippines (UP)	
Members:	
Cherry Aquino-Javier Generation Sector AES Philippines (AES)	**Ralph T. Crisologo** Generation Sector SN Aboitiz Power (SNAP)
Liberty Z. Dumlao Generation Sector Power Sector Assets and Liabilities Management Corporation (PSALM)	**Alfredo L. Licudine, Jr.** Generation Sector National Power Corporation (NAPOCOR)
Raul Joseph G. Seludo Transmission Sector National Grid Corporation of the Philippines (NGCP)	**Robinson P. Descanzo** Market Operator Philippine Electricity Market Corporation (PEMC)
Vicente C. Sioson Distribution Sector (PDU) Manila Electric Company (MERALCO)	**Augusto D. Sarmiento** Distribution Sector (PDU) Dagupan Electric Corporation (DECORP)
Jose P. Santos Distribution Sector (EC) Ilocos Norte Electric Cooperative (INEC)	**Conrado D. Pecjo** Supply Sector Angeles Power, Inc.
Gloria P. Gerilla-Teknomo Independent CPI-Energy Phils., Inc.	
	Certified True and Correct: for **Elaine D. Gonzales** RCC Secretary PEMC

Proposed Changes to the WESM Metering Standards and Procedures Manual, Issue 5.0
RCC/WESM-08/05

Title	Section	Provision	Proposed Amendment	Rationale/ Recommendation
Use of Meter Register Reading in VEE	7.4.3.4	New sub-section	Meter Register Readings (Present Index & Previous Index corresponding to the start and end of the period to be settled) may be used for the VEE process under the following circumstances: a. Non availability of load profile capable meter b. Failure of both main and alternate meters c. Load profile data of the main/alternate meters is corrupted The trading participant through its MSP is required to submit the meter register readings from an installed Statistical or Revenue-class meter subject to the review and acceptance of the MO for use in the VEE process, based on the following criteria: a. The meter where the register readings are taken measures the energy at the same metering point as the main meter. If the meter is not measuring at the same metering point as the main meter, corresponding adjustments for line and transformer losses shall be applied to the register readings.	Settlement for delivery or connection point under the given circumstances. In cases of non-availability and/or failure of both registered main and alternate meters.

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Title	Section	Provision	Proposed Amendment	Rationale/ Recommendation
			b. The meter where the register readings are taken is certified by the MSP to have been tested and the error is quantified in a test report. c. The register readings are adjusted for the meter error. The meter register readings shall be treated by the MO in the following manner: a. The hourly equivalent meter data shall be computed proportionately according to the load shape obtained from available RTU data corresponding to metering point for the time covered by the register readings, or to the load shape obtained from the historical load profile data for a similar day and time. b. The hourly equivalent meter data shall undergo site – specific loss adjustment for any equipment between the market trading node and the meter. c. Register readings for succeeding settlement periods shall be submitted by the trading participant through its MSP and shall be used by the MO until a load	

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Title	Section	Provision	Proposed Amendment	Rationale/ Recommendation
			profile meter data is available.	
	7.4.3.5	New sub-section	The decision to use the substituted data in the settlement process shall be based on results of the trouble call investigation.	
General Equation	9.8.3	$Core_{Loss\text{-}Meter} = TCore_{Loss} \div N_{Meters}$	$Core_{Loss\text{-}Meter} = TCore_{Loss} * kW_{M1} \div \sum kW_{Meters}$ (Formula to be used for a Metering M1 when it registers a consumption)	Make the transformer core loss distribution dynamic in nature by allocating it proportionately to the meter readings and Avoid too high loss adjustment for metering points under a transformer with low meter readings
		$Core_{Loss\text{-}Meter} = TCore_{Loss} \div N_{Meters}$	$Core_{Loss\text{-}Meter} = TCore_{Loss} * HLS_{M1}$ (formula to be used when the meter reading of a metering point is zero)	Avoid too high loss adjustment for metering points with low meter readings
		$\mathbf{N_{Meters}}$: total number of meters for a given trading interval	(complete deletion)	The term $\mathbf{N_{Meters}}$ applies or is used only to the present equation of the transformer core loss distribution
			$\sum \mathbf{kW_{Meters}}$: summation of active power derived from the meter readings of all metering points under the same transformer.	A term introduced for the new equation of the transformer core loss distribution

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Title	Section	Provision	Proposed Amendment	Rationale/ Recommendation
			HLS : Historical Load Share; the fraction or ratio of a metering point's total energy, against the total energy of all metering points under the same transformer. The HLS for the current billing month shall be based on the energy of the last twelve (12) billing months.	A term introduced for the new equation of the transformer core loss distribution
Appendix			Please see Annex A.1	Consistency with the new terms and equations

Appendix - Site–Specific Loss Adjustment

Customer

Case 1: Single Settlement Point

A metering point is connected to only one MTN:

a. **Case 1 – A**: only one metering point is presently connected to the MTN (figure 1)

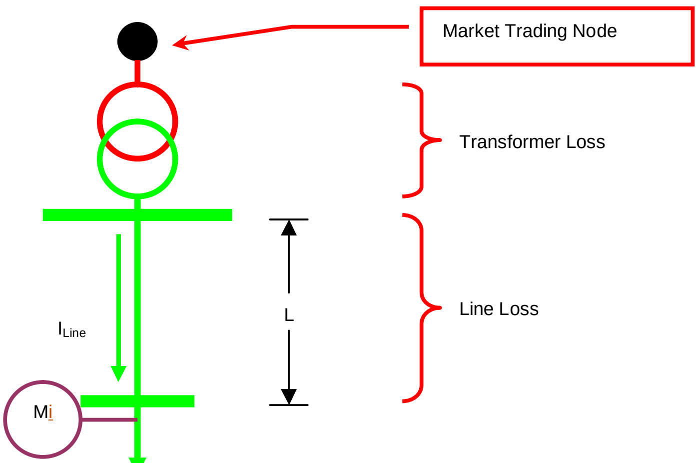

Figure 1

kW_{Mi} $= (kWh_{Mi\text{-}15min} + kWh_{Mi\text{-}30min} + kWh_{Mi\text{-}45min} + kWh_{Mi\text{-}00min}) \div 1h$

$kVar_{Mi}$ $= (kVarh_{Mi\text{-}15min} + kVarh_{Mi\text{-}30min} + kVarh_{Mi\text{-}45min} + kVarh_{Mi\text{-}00min}) \div 1h$

I_{Line} $= kW_{Mi} \div ((\sqrt{3}) * V * pf_{Mi})$

pf_{Mi} $= \cos(\tan^{-1}(kVar_{Mi} \div kW_{Mi}))$

$Line_{kW\text{-}Loss}$ $= (I_{Line})^{2} * R_{Line}$

R_{Line} $= r_a * L$

$Line_{kVar\text{-}Loss}$ $= (I_{Line})^{2} * X_{Line}$

X_{Line} $= X_l * L$

$Core_{Loss\text{-}Mi}$ $= TCore_{Loss} * (kW_{Mi} \div \sum_{i=1}^{n} kW_{Mi}) \quad = T_1Core_{Loss} \div 1$

$Copper_{Loss\text{-}Mi}$ $= ((kW_{Mi} \div pf_{Mi}) \div T_{kVA\text{-}Rating})^{2} * P_{Short\text{-}Circuit}$

$Total_{kW\text{-}Loss}$ $= Line_{kW\text{-}Loss} + Core_{Loss\text{-}Mi} + Copper_{Loss\text{-}Mi}$

$SSLF$ $= 1 + (Total_{kW\text{-}Loss} + kW_{Mi})$

$Adjusted_{kW}$ $= Total_{kWLoss} + kW_{Mi} \quad = SSLF * kW_{Mi}$

b. **Case 1 – B**: numerous metering points connected to, or are sharing the same MTN (figure 2)

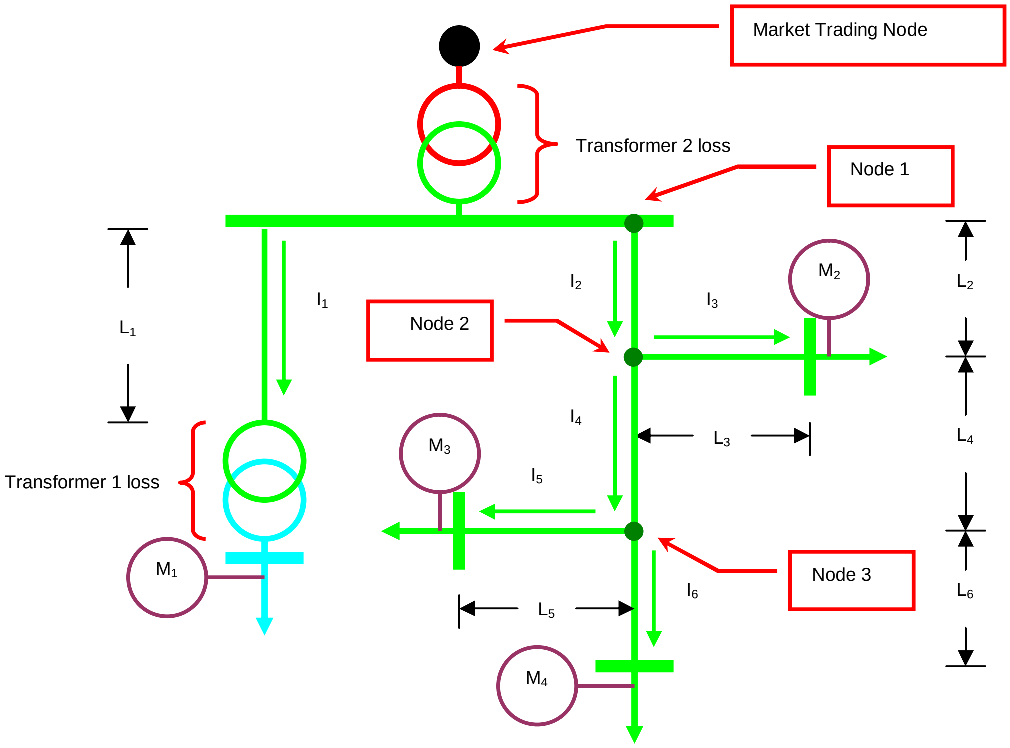

Figure 2

Active and Reactive Power:

$kW_{M1} = (kWh_{M1\text{-}15min} + kWh_{M1\text{-}30min} + kWh_{M1\text{-}45min} + kWh_{M1\text{-}00min}) \div 1h$

$kVar_{M1} = (kVarh_{M1\text{-}15min} + kVarh_{M1\text{-}30min} + kVarh_{M1\text{-}45min} + kVarh_{M1\text{-}00min}) \div 1h$

$kW_{M2} = (kWh_{M2\text{-}15min} + kWh_{M2\text{-}30min} + kWh_{M2\text{-}45min} + kWh_{M2\text{-}00min}) \div 1h$

$kVar_{M2} = (kVarh_{M2\text{-}15min} + kVarh_{M2\text{-}30min} + kVarh_{M2\text{-}45min} + kVarh_{M2\text{-}00min}) \div 1h$

$kW_{M3} = (kWh_{M3\text{-}15min} + kWh_{M3\text{-}30min} + kWh_{M3\text{-}45min} + kWh_{M3\text{-}00min}) \div 1h$

$kVar_{M3} = (kVarh_{M3\text{-}15min} + kVarh_{M3\text{-}30min} + kVarh_{M3\text{-}45min} + kVarh_{M3\text{-}00min}) \div 1h$

$kW_{M4} = (kWh_{M4\text{-}15min} + kWh_{M4\text{-}30min} + kWh_{M4\text{-}45min} + kWh_{M4\text{-}00min}) \div 1h$

$kVar_{M4} = (kVarh_{M4\text{-}15min} + kVarh_{M4\text{-}30min} + kVarh_{M4\text{-}45min} + kVarh_{M4\text{-}00min}) \div 1h$

Line Currents and Line Losses:

$I_1 = kW_{M1} \div ((\sqrt{3}) * V_1 * pf_1) = kW_{M1} \div ((\sqrt{3}) * V_1 * \cos(\tan^{-1}(kVar_{M1} \div kW_{M1})))$

$I_3 = kW_{M2} \div ((\sqrt{3}) * V_2 * pf_2) = kW_{M2} \div ((\sqrt{3}) * V_2 * \cos(\tan^{-1}(kVar_{M2} \div kW_{M2})))$

$I_5 = kW_{M3} \div ((\sqrt{3}) * V_3 * pf_3) = kW_{M3} \div ((\sqrt{3}) * V_3 * \cos(\tan^{-1}(kVar_{M3} \div kW_{M3})))$

$I_6 = kW_{M4} \div ((\sqrt{3}) * V_4 * pf_4) = kW_{M4} \div ((\sqrt{3}) * V_4 * \cos(\tan^{-1}(kVar_{M4} \div kW_{M4})))$

$Line_{5\text{-kW-Loss}} = (I_5)^2 * R_5 = (I_5)^2 * (r_{a\text{-}5} * L_5)$

$Line_{5\text{-kVar-Loss}} = (I_5)^2 * X_5 = (I_5)^2 * (X_{l\text{-}5} * L_5)$

$Line_{6\text{-kW-Loss}} = (I_6)^2 * R_6 = (I_6)^2 * (r_{a\text{-}6} * L_6)$

$Line_{6\text{-kVar-Loss}} = (I_6)^2 * X_6 = (I_6)^2 * (X_{l\text{-}6} * L_6)$

Total Active Power at Node 3 ($kW_{N\text{-}3}$) $= kW_{M3} + kW_{M4} + Line_{5\text{-kW-Loss}} + Line_{6\text{-kW-Loss}}$

Total Reactive Power at Node 3 ($kVar_{N\text{-}3}$) $= kVar_{M3} + kVar_{M4} + Line_{5\text{-kVar-Loss}} + Line_{6\text{-kVar-Loss}}$

$I_4 = kW_{N\text{-}3} \div ((\sqrt{3}) * V_{N\text{-}3} * pf_{N\text{-}3}) = kW_{N\text{-}3} \div ((\sqrt{3}) * V_{N\text{-}3} * \cos(\tan^{-1}(kVar_{N\text{-}3} \div kW_{N\text{-}3})))$

$Line_{4\text{-kW-Loss}} = (I_4)^2 * R_4 = (I_4)^2 * (r_{a\text{-}4} * L_4)$

$Line_{4\text{-kVar-Loss}} = (I_4)^2 * X_4 = (I_4)^2 * (X_{l\text{-}4} * L_4)$

$Line_{3\text{-kW-Loss}} = (I_3)^2 * R_3 = (I_3)^2 * (r_{a\text{-}3} * L_3)$

$Line_{3\text{-kVar-Loss}} = (I_3)^2 * X_3 = (I_3)^2 * (X_{l\text{-}3} * L_3)$

Total Active Power at Node 2 ($kW_{N\text{-}2}$) $= kW_{M2} + kW_{M3} + kW_{M4} + Line_{3\text{-kW-Loss}} + Line_{4\text{-kW-Loss}} + Line_{5\text{-kW-Loss}} + Line_{6\text{-kW-Loss}}$

Total Reactive Power at Node 2 ($kVar_{N\text{-}2}$) $= kVar_{M2} + kVar_{M3} + kVar_{M4} + Line_{3\text{-kVar-Loss}} + Line_{4\text{-kVar-Loss}} + Line_{5\text{-kVar-Loss}} + Line_{6\text{-kVar-Loss}}$

$I_2 = kW_{N\text{-}2} \div ((\sqrt{3}) * V_{N\text{-}2} * pf_{N\text{-}2}) = kW_{N\text{-}2} \div ((\sqrt{3}) * V_{N\text{-}2} * \cos(\tan^{-1}(kVar_{N\text{-}2} \div kW_{N\text{-}2})))$

$Line_{2\text{-kW-Loss}} = (I_2)^2 * R_2 = (I_2)^2 * (r_{a\text{-}2} * L_2)$

$Line_{2\text{-kVar-Loss}} = (I_2)^2 * X_2 = (I_2)^2 * (X_{l\text{-}2} * L_2)$

$Line_{1\text{-kW-Loss}} = (I_1)^2 * R_1 = (I_1)^2 * (r_{a\text{-}1} * L_1)$

$Line_{1\text{-kVar-Loss}} = (I_1)^2 * X_1 = (I_1)^2 * (X_{l\text{-}1} * L_1)$

Distributing $Line_{4\text{-kW-Loss}}$

For M_3, $Line_{4\text{-kW-Loss-M3}} = (Line_{4\text{-kW-Loss}} * (kW_{M3} + Line_{5\text{-kW-Loss}})) \div kW_{N\text{-}3}$

For M_4, $Line_{4\text{-kW-Loss-M4}} = (Line_{4\text{-kW-Loss}} * (kW_{M4} + Line_{6\text{-kW-Loss}})) \div kW_{N\text{-}3}$

Distributing $Line_{2\text{-kW-Loss}}$

For M_2, $Line_{2\text{-kW-Loss-M2}} = (Line_{2\text{-kW-Loss}} * (kW_{M2} + Line_{3\text{-kW-Loss}})) \div kW_{N\text{-}2}$

For M_3, $Line_{2\text{-kW-Loss-M3}} = (Line_{2\text{-kW-Loss}} * (kW_{M3} + Line_{5\text{-kW-Loss}} + Line_{4\text{-kW-Loss-M3}})) \div kW_{N\text{-}2}$

For M_4, $Line_{2\text{-kW-Loss-M4}} = (Line_{2\text{-kW-Loss}} * (kW_{M4} + Line_{6\text{-kW-Loss}} + Line_{4\text{-kW-Loss-M4}})) \div kW_{N\text{-}2}$

Transformer Losses:

$T_1Core_{Loss\text{-}M1} = T_1Core_{Loss} * (kW_{M1} \div \sum_{i=1}^{n} kW_{Mi}) = T_1Core_{Loss} \div 1$

$T_1Copper_{Loss-M1} = ((kW_{M1} \div pf_1) \div T_{1kVA-Rating})^2 * P_{Short-Circuit-T1}$

$T_2Core_{Loss-M1} = T_2Core_{Loss} * (kW_{M1} \div \sum_{i=1}^{n} kW_{Mi})$

$T_2Core_{Loss-M2} = T_2Core_{Loss} * (kW_{M2} \div \sum_{i=1}^{n} kW_{Mi})$

$T_2Core_{Loss-M3} = T_2Core_{Loss} * (kW_{M3} \div \sum_{i=1}^{n} kW_{Mi})$

$T_2Core_{Loss-M4} = T_2Core_{Loss} * (kW_{M4} \div \sum_{i=1}^{n} kW_{Mi})$

$T_2Copper_{Loss} = ((kW_{N-1} \div pf_{N-1}) \div T_{2kVA-Rating})^2 * P_{Short-Circuit-T2}$

$T_2Copper_{Loss-M1} = T_2Copper_{Loss} * (kW_{M1} + Line_{1-kW-Loss}) \div kW_{N-1}$

$T_2Copper_{Loss-M2} = T_2Copper_{Loss} * (kW_{M2} + Line_{3-kW-Loss} + Line_{2-kW-Loss-M2}) \div kW_{N-1}$

$T_2Copper_{Loss-M3} = T_2Copper_{Loss} * (kW_{M3} + Line_{5-kW-Loss} + Line_{4-kW-Loss-M3} + Line_{2-kW-Loss-M3}) \div kW_{N-1}$

$T_2Copper_{Loss-M4} = T_2Copper_{Loss} * (kW_{M4} + Line_{6-kW-Loss} + Line_{4-kW-Loss-M4} + Line_{2-kW-Loss-M4}) \div kW_{N-1}$

Total Active Loss for each Meter:

$Total_{kW-Loss-M1} = Line_{1-kW-Loss} + T_1Core_{Loss} + T_1Copper_{Loss-M1} + T_2Core_{Loss-M1} + T_2Copper_{Loss-M1}$

$Total_{kW-Loss-M2} = Line_{3-kW-Loss} + Line_{2-kW-Loss-M2} + T_2Core_{Loss-M2} + T_2Copper_{Loss-M2}$

$Total_{kW-Loss-M3} = Line_{5-kW-Loss} + Line_{4-kW-Loss-M3} + Line_{2-kW-Loss-M3} + T_2Core_{Loss-M3} + T_2Copper_{Loss-M3}$

$Total_{kW-Loss-M4} = Line_{6-kW-Loss} + Line_{4-kW-Loss-M4} + Line_{2-kW-Loss-M4} + T_2Core_{Loss-M4} + T_2Copper_{Loss-M4}$

SSLF:

$SSLF_{M1} = 1 + (Total_{kW-Loss-M1} \div kW_{M1})$

$SSLF_{M2} = 1 + (Total_{kW-Loss-M2} \div kW_{M2})$

$SSLF_{M3} = 1 + (Total_{kW-Loss-M3} \div kW_{M3})$

$SSLF_{M4} = 1 + (Total_{kW-Loss-M4} \div kW_{M4})$

Adjusted Active Power:

$Adjusted_{kW-M1} = Total_{kW-Loss-M1} + kW_{M1}$

$Adjusted_{kW-M2} = Total_{kW-Loss-M2} + kW_{M2}$

$Adjusted_{kW-M3} = Total_{kW-Loss-M3} + kW_{M3}$

$Adjusted_{kW-M4} = Total_{kW-Loss-M4} + kW_{M4}$

In the event that Meter 4 reading becomes zero (0), see figure 3:

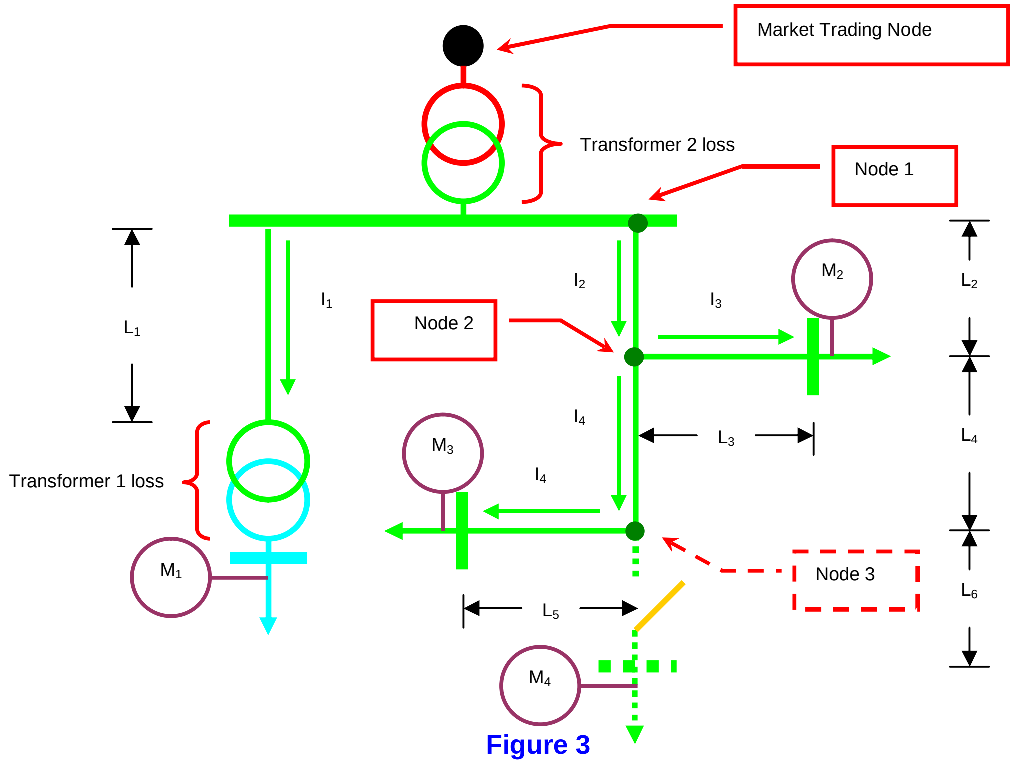

Figure 3

Active and Reactive Power:

$kW_{M1} = (kWh_{M1\text{-}15min} + kWh_{M1\text{-}30min} + kWh_{M1\text{-}45min} + kWh_{M1\text{-}00min}) \div 1h$

$kVar_{M1} = (kVarh_{M1\text{-}15min} + kVarh_{M1\text{-}30min} + kVarh_{M1\text{-}45min} + kVarh_{M1\text{-}00min}) \div 1h$

$kW_{M2} = (kWh_{M2\text{-}15min} + kWh_{M2\text{-}30min} + kWh_{M2\text{-}45min} + kWh_{M2\text{-}00min}) \div 1h$

$kVar_{M2} = (kVarh_{M2\text{-}15min} + kVarh_{M2\text{-}30min} + kVarh_{M2\text{-}45min} + kVarh_{M2\text{-}00min}) \div 1h$

$kW_{M3} = (kWh_{M3\text{-}15min} + kWh_{M3\text{-}30min} + kWh_{M3\text{-}45min} + kWh_{M3\text{-}00min}) \div 1h$

$kVar_{M3} = (kVarh_{M3\text{-}15min} + kVarh_{M3\text{-}30min} + kVarh_{M3\text{-}45min} + kVarh_{M3\text{-}00min}) \div 1h$

Line Currents and Line Losses:

$I_1 = kW_{M1} \div ((\sqrt{3}) * V_1 * pf_1) = kW_{M1} \div ((\sqrt{3}) * V_1 * \cos(\tan^{-1}(kVar_{M1} \div kW_{M1})))$

$I_3 = kW_{M2} \div ((\sqrt{3}) * V_2 * pf_2) = kW_{M2} \div ((\sqrt{3}) * V_2 * \cos(\tan^{-1}(kVar_{M2} \div kW_{M2})))$

$I_4 = kW_{M3} \div ((\sqrt{3}) * V_3 * pf_3) = kW_{M3} \div ((\sqrt{3}) * V_3 * \cos(\tan^{-1}(kVar_{M3} \div kW_{M3})))$

$Line_{5\text{-}kW\text{-}Loss} = (I_4)^2 * R_5 = (I_4)^2 * (r_{a\text{-}5} * L_5)$

$Line_{5\text{-}kVar\text{-}Loss} = (I_4)^2 * X_5 = (I_4)^2 * (X_{l\text{-}5} * L_5)$

$Line_{4\text{-}kW\text{-}Loss} = (I_4)^2 * R_4 = (I_4)^2 * (r_{a\text{-}4} * L_4)$

$Line_{4\text{-}kVar\text{-}Loss} = (I_4)^2 * X_4 = (I_4)^2 * (X_{l\text{-}4} * L_4)$

$Line_{3\text{-}kW\text{-}Loss} = (I_3)^2 * R_3 = (I_3)^2 * (r_{a\text{-}3} * L_3)$

$Line_{3\text{-kVar-Loss}} = (I_3)^2 * X_3 = (I_3)^2 * (X_{l\text{-}3} * L_3)$

Total Active Power at Node 2 ($kW_{N\text{-}2}$) $= kW_{M2} + kW_{M3} + Line_{3\text{-kW-Loss}} + Line_{4\text{-kW-Loss}} + Line_{5\text{-kW-Loss}}$

Total Reactive Power at Node 2 ($kVar_{N\text{-}2}$) $= kVar_{M2} + kVar_{M3} + Line_{3\text{-kVar-Loss}} + Line_{4\text{-kVar-Loss}} + Line_{5\text{-kVar-Loss}}$

$I_2 = kW_{N\text{-}2} \div ((\sqrt{3}) * V_{N\text{-}2} * pf_{N\text{-}2}) = kW_{N\text{-}2} \div ((\sqrt{3}) * V_{N\text{-}2} * \cos(\tan^{-1}(kVar_{N\text{-}2} \div kW_{N\text{-}2})))$

$Line_{2\text{-kW-Loss}} = (I_2)^2 * R_2 = (I_2)^2 * (r_{a\text{-}2} * L_2)$

$Line_{2\text{-kVar-Loss}} = (I_2)^2 * X_2 = (I_2)^2 * (X_{l\text{-}2} * L_2)$

$Line_{1\text{-kW-Loss}} = (I_1)^2 * R_1 = (I_1)^2 * (r_{a\text{-}1} * L_1)$

$Line_{1\text{-kVar-Loss}} = (I_1)^2 * X_1 = (I_1)^2 * (X_{l\text{-}1} * L_1)$

Distributing $Line_{2\text{-kW-Loss}}$

For M_2, $Line_{2\text{-kW-Loss-M2}} = (Line_{2\text{-kW-Loss}} * (kW_{M2} + Line_{3\text{-kW-Loss}})) \div kW_{N\text{-}2}$

For M_3, $Line_{2\text{-kW-Loss-M3}} = (Line_{2\text{-kW-Loss}} * (kW_{M3} + Line_{5\text{-kW-Loss}} + Line_{4\text{-kW-Loss}})) \div kW_{N\text{-}2}$

Transformer Losses:

$T_1Core_{Loss\text{-}M1} = T_1Core_{Loss} * (kW_{M1} \div \sum_{i=1}^{n} kW_{Mi}) = T_1Core_{Loss} \div 1$

$T_1Copper_{Loss\text{-}M1} = ((kW_{M1} \div pf_1) \div T_{1kVA\text{-}Rating})^2 * P_{Short\text{-}Circuit\text{-}T1}$

$T_2Core_{Loss\text{-}M4} = T_2Core_{Loss} * HLS_{M4}$

$T_2Core_{Loss\text{-}M1} = kW_{M1} * (T_2Core_{Loss} - (T_2Core_{Loss} * HLS_{M4})) \div \sum_{i=1}^{n} kW_{Mi}$

$T_2Core_{Loss\text{-}M2} = kW_{M2} * (T_2Core_{Loss} - (T_2Core_{Loss} * HLS_{M4})) \div \sum_{i=1}^{n} kW_{Mi}$

$T_2Core_{Loss\text{-}M3} = kW_{M3} * (T_2Core_{Loss} - (T_2Core_{Loss} * HLS_{M4})) \div \sum_{i=1}^{n} kW_{Mi}$

$T_2Copper_{Loss} = ((kW_{N\text{-}1} \div pf_{N\text{-}1}) \div T_{2kVA\text{-}Rating})^2 * P_{Short\text{-}Circuit\text{-}T2}$

$T_2Copper_{Loss\text{-}M1} = T_2Copper_{Loss} * (kW_{M1} + Line_{1\text{-kW-Loss}}) \div kW_{N\text{-}1}$

$T_2Copper_{Loss\text{-}M2} = T_2Copper_{Loss} * (kW_{M2} + Line_{3\text{-kW-Loss}} + Line_{2\text{-kW-Loss-M2}}) \div kW_{N\text{-}1}$

$T_2Copper_{Loss\text{-}M3} = T_2Copper_{Loss} * (kW_{M3} + Line_{5\text{-kW-Loss}} + Line_{4\text{-kW-Loss}} + Line_{2\text{-kW-Loss-M3}}) \div kW_{N\text{-}1}$

Total Active Loss for each Meter:

$Total_{kW\text{-}Loss\text{-}M1} = Line_{1\text{-kW-Loss}} + T_1Core_{Loss} + T_1Copper_{Loss\text{-}M1} + T_2Core_{Loss\text{-}M1} + T_2Copper_{Loss\text{-}M1}$

$Total_{kW\text{-}Loss\text{-}M2} = Line_{3\text{-kW-Loss}} + Line_{2\text{-kW-Loss-M2}} + T_2Core_{Loss\text{-}M2} + T_2Copper_{Loss\text{-}M2}$

$Total_{kW\text{-}Loss\text{-}M3} = Line_{5\text{-kW-Loss}} + Line_{4\text{-kW-Loss}} + Line_{2\text{-kW-Loss-M3}} + T_2Core_{Loss\text{-}M3} + T_2Copper_{Loss\text{-}M3}$

$Total_{kW\text{-}Loss\text{-}M4} = T_2Core_{Loss\text{-}M4}$

Adjusted Active Power:

$Adjusted_{kW\text{-}M1} = Total_{kW\text{-}Loss\text{-}M1} + kW_{M1}$

$Adjusted_{kW\text{-}M2} = Total_{kW\text{-}Loss\text{-}M2} + kW_{M2}$

$Adjusted_{kW\text{-}M3} = Total_{kW\text{-}Loss\text{-}M3} + kW_{M3}$

$Adjusted_{kW\text{-}M4} = Total_{kW\text{-}Loss\text{-}M4} + kW_{M4}$ (kW_M4 → 0)

SSLF:

$SSLF_{M1} = 1 + (Total_{kW\text{-}Loss\text{-}M1} \div kW_{M1})$

$SSLF_{M2} = 1 + (Total_{kW\text{-}Loss\text{-}M2} \div kW_{M2})$

$SSLF_{M3} = 1 + (Total_{kW\text{-}Loss\text{-}M3} \div kW_{M3})$

$SSLF_{M4} = 1 + (Total_{kW\text{-}Loss\text{-}M4} \div kW_{M4}) = \infty$ (kW_M4 → 0)

Case 2: Multiple Settlement Points

A metering point is connected to two or more MTNs during normal condition (figure 4)

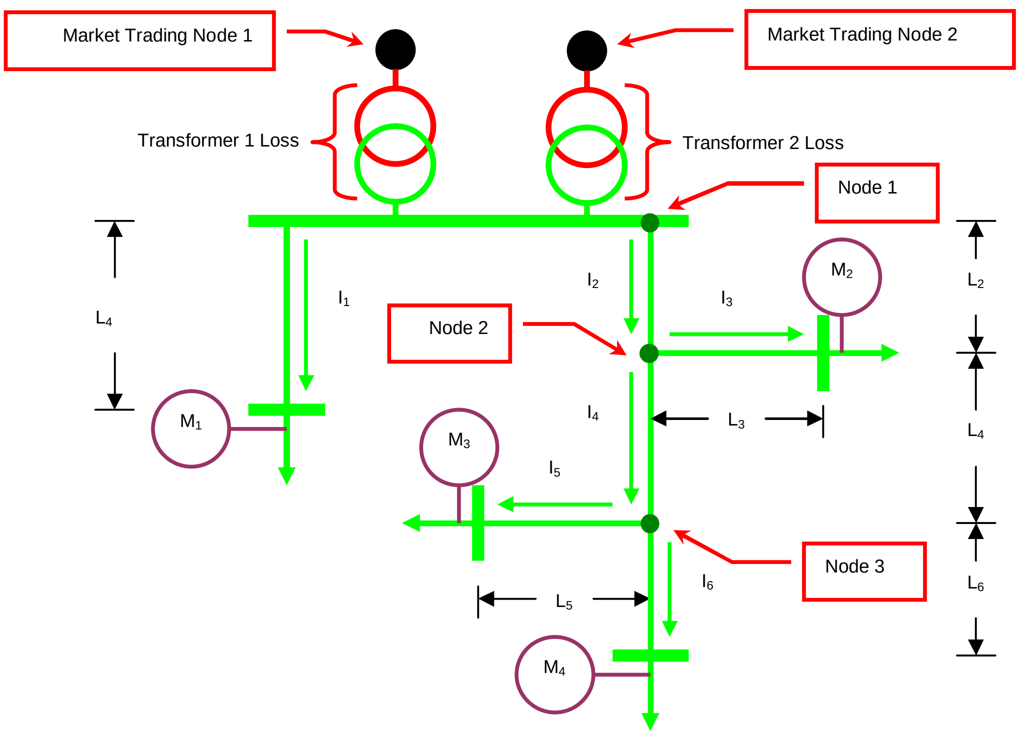

Figure 4

Active and Reactive Power:

$kW_{M1} = (kWh_{M1\text{-}15min} + kWh_{M1\text{-}30min} + kWh_{M1\text{-}45min} + kWh_{M1\text{-}00min}) \div 1h$

$kVar_{M1} = (kVarh_{M1\text{-}15min} + kVarh_{M1\text{-}30min} + kVarh_{M1\text{-}45min} + kVarh_{M1\text{-}00min}) \div 1h$

$kW_{M2} = (kWh_{M2\text{-}15min} + kWh_{M2\text{-}30min} + kWh_{M2\text{-}45min} + kWh_{M2\text{-}00min}) \div 1h$

$kVar_{M2} = (kVarh_{M2\text{-}15min} + kVarh_{M2\text{-}30min} + kVarh_{M2\text{-}45min} + kVarh_{M2\text{-}00min}) \div 1h$

$kW_{M3} = (kWh_{M3\text{-}15min} + kWh_{M3\text{-}30min} + kWh_{M3\text{-}45min} + kWh_{M3\text{-}00min}) \div 1h$

$kVar_{M3} = (kVarh_{M3\text{-}15min} + kVarh_{M3\text{-}30min} + kVarh_{M3\text{-}45min} + kVarh_{M3\text{-}00min}) \div 1h$

$kW_{M4} = (kWh_{M4\text{-}15min} + kWh_{M4\text{-}30min} + kWh_{M4\text{-}45min} + kWh_{M4\text{-}00min}) \div 1h$

$kVar_{M4} = (kVarh_{M4\text{-}15min} + kVarh_{M4\text{-}30min} + kVarh_{M4\text{-}45min} + kVarh_{M4\text{-}00min}) \div 1h$

Line Currents and Line Losses:

$I_1 = kW_{M1} \div ((\sqrt{3}) * V_1 * pf_1) = kW_{M1} \div ((\sqrt{3}) * V_1 * \cos(\tan^{-1}(kVar_{M1} \div kW_{M1})))$

$I_3 = kW_{M2} \div ((\sqrt{3}) * V_2 * pf_2) = kW_{M2} \div ((\sqrt{3}) * V_2 * \cos(\tan^{-1}(kVar_{M2} \div kW_{M2})))$

$I_5 = kW_{M3} \div ((\sqrt{3}) * V_3 * pf_3) = kW_{M3} \div ((\sqrt{3}) * V_3 * \cos(\tan^{-1}(kVar_{M3} \div kW_{M3})))$

$I_6 = kW_{M4} \div ((\sqrt{3}) * V_4 * pf_4) = kW_{M4} \div ((\sqrt{3}) * V_4 * \cos(\tan^{-1}(kVar_{M4} \div kW_{M4})))$

$Line_{5\text{-}kW\text{-}Loss} = (I_5)^2 * R_5 = (I_5)^2 * (r_{a\text{-}5} * L_5)$

$Line_{5\text{-}kVar\text{-}Loss} = (I_5)^2 * X_5 = (I_5)^2 * (X_{l\text{-}5} * L_5)$

$Line_{6\text{-}kW\text{-}Loss} = (I_6)^2 * R_6 = (I_6)^2 * (r_{a\text{-}6} * L_6)$

$Line_{6\text{-}kVar\text{-}Loss} = (I_6)^2 * X_6 = (I_6)^2 * (X_{l\text{-}6} * L_6)$

Total Active Power at Node 3 ($kW_{N\text{-}3}$) $= kW_{M3} + kW_{M4} + Line_{5\text{-}kW\text{-}Loss} + Line_{6\text{-}kW\text{-}Loss}$

Total Reactive Power at Node 3 ($kVar_{N\text{-}3}$) $= kVar_{M3} + kVar_{M4} + Line_{5\text{-}kVar\text{-}Loss} + Line_{6\text{-}kVar\text{-}Loss}$

$I_4 = kW_{N\text{-}3} \div ((\sqrt{3}) * V_{N\text{-}3} * pf_{N\text{-}3}) = kW_{N\text{-}3} \div ((\sqrt{3}) * V_{N\text{-}3} * \cos(\tan^{-1}(kVar_{N\text{-}3} \div kW_{N\text{-}3})))$

$Line_{4\text{-}kW\text{-}Loss} = (I_4)^2 * R_4 = (I_4)^2 * (r_{a\text{-}4} * L_4)$

$Line_{4\text{-}kVar\text{-}Loss} = (I_4)^2 * X_4 = (I_4)^2 * (X_{l\text{-}4} * L_4)$

$Line_{3\text{-}kW\text{-}Loss} = (I_3)^2 * R_3 = (I_3)^2 * (r_{a\text{-}3} * L_3)$

$Line_{3\text{-}kVar\text{-}Loss} = (I_3)^2 * X_3 = (I_3)^2 * (X_{l\text{-}3} * L_3)$

Total Active Power at Node 2 ($kW_{N\text{-}2}$) $= kW_{M2} + kW_{M3} + kW_{M4} + Line_{3\text{-}kW\text{-}Loss} + Line_{4\text{-}kW\text{-}Loss} + Line_{5\text{-}kW\text{-}Loss} + Line_{6\text{-}kW\text{-}Loss}$

Total Reactive Power at Node 2 ($kVar_{N\text{-}2}$) $= kVar_{M2} + kVar_{M3} + kVar_{M4} + Line_{3\text{-}kVar\text{-}Loss} + Line_{4\text{-}kVar\text{-}Loss} + Line_{5\text{-}kVar\text{-}Loss} + Line_{6\text{-}kVar\text{-}Loss}$

$I_2 = kW_{N-2} \div ((\sqrt{3}) * V_{N-2} * pf_{N-2}) = kW_{N-2} \div ((\sqrt{3}) * V_{N-2} * \cos(\tan^{-1}(kVar_{N-2} \div kW_{N-2})))$

$Line_{2\text{-}kW\text{-}Loss} = (I_2)^2 * R_2 = (I_2)^2 * (r_{a-2} * L_2)$

$Line_{2\text{-}kVar\text{-}Loss} = (I_2)^2 * X_2 = (I_2)^2 * (X_{l-2} * L_2)$

$Line_{1\text{-}kW\text{-}Loss} = (I_1)^2 * R_1 = (I_1)^2 * (r_{a-1} * L_1)$

$Line_{1\text{-}kVar\text{-}Loss} = (I_1)^2 * X_1 = (I_1)^2 * (X_{l-1} * L_1)$

Distributing $Line_{4\text{-}kW\text{-}Loss}$

For M_3, $Line_{4\text{-}kW\text{-}Loss\text{-}M3} = (Line_{4\text{-}kW\text{-}Loss} * (kW_{M3} + Line_{5\text{-}kW\text{-}Loss})) \div kW_{N-3}$

For M_4, $Line_{4\text{-}kW\text{-}Loss\text{-}M4} = (Line_{4\text{-}kW\text{-}Loss} * (kW_{M4} + Line_{6\text{-}kW\text{-}Loss})) \div kW_{N-3}$

Distributing $Line_{2\text{-}kW\text{-}Loss}$

For M_2, $Line_{2\text{-}kW\text{-}Loss\text{-}M2} = (Line_{2\text{-}kW\text{-}Loss} * (kW_{M2} + Line_{3\text{-}kW\text{-}Loss})) \div kW_{N-2}$

For M_3, $Line_{2\text{-}kW\text{-}Loss\text{-}M3} = (Line_{2\text{-}kW\text{-}Loss} * (kW_{M3} + Line_{5\text{-}kW\text{-}Loss} + Line_{4\text{-}kW\text{-}Loss\text{-}M3})) \div kW_{N-2}$

For M_4, $Line_{2\text{-}kW\text{-}Loss\text{-}M4} = (Line_{2\text{-}kW\text{-}Loss} * (kW_{M4} + Line_{6\text{-}kW\text{-}Loss} + Line_{4\text{-}kW\text{-}Loss\text{-}M4})) \div kW_{N-2}$

Transformer Losses:

$T_1Core_{Loss\text{-}M1} = T_1Core_{Loss} * (kW_{M1} \div \sum_{i=1}^{n} kW_{Mi})$

$T_1Core_{Loss\text{-}M2} = T_1Core_{Loss} * (kW_{M2} \div \sum_{i=1}^{n} kW_{Mi})$

$T_1Core_{Loss\text{-}M3} = T_1Core_{Loss} * (kW_{M3} \div \sum_{i=1}^{n} kW_{Mi})$

$T_1Core_{Loss\text{-}M4} = T_1Core_{Loss} * (kW_{M4} \div \sum_{i=1}^{n} kW_{Mi})$

$T_1Copper_{Loss} = (((kW_{N-1} \div 2) \div pf_{N-1}) \div T_{1kVA\text{-}Rating}))^2 * P_{Short\text{-}Circuit\text{-}T1}$

$T_1Copper_{Loss\text{-}M1} = T_1Copper_{Loss} * (kW_{M1} + Line_{1\text{-}kW\text{-}Loss}) \div kW_{N-1}$

$T_1Copper_{Loss\text{-}M2} = T_1Copper_{Loss} * (kW_{M2} + Line_{3\text{-}kW\text{-}Loss} + Line_{2\text{-}kW\text{-}Loss\text{-}M2}) \div kW_{N-1}$

$T_1Copper_{Loss\text{-}M3} = T_1Copper_{Loss} * (kW_{M3} + Line_{5\text{-}kW\text{-}Loss} + Line_{4\text{-}kW\text{-}Loss\text{-}M3} + Line_{4\text{-}kW\text{-}Loss\text{-}M3}) \div kW_{N-1}$

$T_1Copper_{Loss\text{-}M4} = T_1Copper_{Loss} * (kW_{M4} + Line_{5\text{-}kW\text{-}Loss} + Line_{4\text{-}kW\text{-}Loss\text{-}M4} + Line_{4\text{-}kW\text{-}Loss\text{-}M4}) \div kW_{N-1}$

$T_2Core_{Loss\text{-}M1} = T_2Core_{Loss} * (kW_{M1} \div \sum_{i=1}^{n} kW_{Mi})$

$T_2Core_{Loss\text{-}M2} = T_2Core_{Loss} * (kW_{M2} \div \sum_{i=1}^{n} kW_{Mi})$

$T_2Core_{Loss\text{-}M3} = T_2Core_{Loss} * (kW_{M3} \div \sum_{i=1}^{n} kW_{Mi})$

$T_2Core_{Loss\text{-}M4} = T_2Core_{Loss} * (kW_{M4} \div \sum_{i=1}^{n} kW_{Mi})$

$T_2Copper_{Loss} = (((kW_{N-1} \div 2) \div pf_{N-1}) \div T_{2kVA\text{-}Rating}))^2 * P_{Short\text{-}Circuit\text{-}T2}$

$T_2Copper_{Loss\text{-}M1} = T_2Copper_{Loss} * (kW_{M1} + Line_{1\text{-}kW\text{-}Loss}) \div kW_{N-1}$

$T_2Copper_{Loss-M2}$ $= T_2Copper_{Loss} * (kW_{M2} + Line_{3-kW-Loss} + Line_{2-kW-Loss-M2}) \div kW_{N-1}$

$T_2Copper_{Loss-M3}$ $= T_2Copper_{Loss} * (kW_{M3} + Line_{5-kW-Loss} + Line_{4-kW-Loss-M3} + Line_{4-kW-Loss-M3}) \div kW_{N-1}$

$T_2Copper_{Loss-M4}$ $= T_2Copper_{Loss} * (kW_{M4} + Line_{5-kW-Loss} + Line_{4-kW-Loss-M4} + Line_{4-kW-Loss-M4}) \div kW_{N-1}$

Total Active Loss for each Meter:

$Total_{kW-Loss-M1}$ $= Line_{1-kW-Loss} + T_1Core_{Loss-M1} + T_1Copper_{Loss-M1} + T_2Core_{Loss-M1} + T_2Copper_{Loss-M1}$

$Total_{kW-Loss-M2}$ $= Line_{3-kW-Loss} + Line_{2-kW-Loss-M2} + T_1Core_{Loss-M2} + T_1Copper_{Loss-M2} + T_2Core_{Loss-M2} + T_2Copper_{Loss-M2}$

$Total_{kW-Loss-M3}$ $= Line_{5-kW-Loss} + Line_{4-kW-Loss-M3} + Line_{2-kW-Loss-M3} + T_1Core_{Loss-M3} + T_1Copper_{Loss-M3} + T_2Core_{Loss-M3} + T_2Copper_{Loss-M3}$

$Total_{kW-Loss-M4}$ $= Line_{6-kW-Loss} + Line_{4-kW-Loss-M4} + Line_{2-kW-Loss-M4} + T_1Core_{Loss-M4} + T_1Copper_{Loss-M4} + T_2Core_{Loss-M4} + T_2Copper_{Loss-M4}$

SSLF:

$SSLF_{M1}$ $= 1 + (Total_{kW-Loss-M1} \div kW_{M1})$

$SSLF_{M2}$ $= 1 + (Total_{kW-Loss-M2} \div kW_{M2})$

$SSLF_{M3}$ $= 1 + (Total_{kW-Loss-M3} \div kW_{M3})$

$SSLF_{M4}$ $= 1 + (Total_{kW-Loss-M4} \div kW_{M4})$

Adjusted Active Power:

$Adjusted_{kW-M1}$ $= Total_{kW-Loss-M1} + kW_{M1}$

$Adjusted_{kW-M2}$ $= Total_{kW-Loss-M2} + kW_{M2}$

$Adjusted_{KW-M3}$ $= Total_{kW-Loss-M3} + kW_{M3}$

$Adjusted_{kW-M4}$ $= Total_{kW-Loss-M4} + kW_{M4}$

Case 3: Alternate Settlement Points:

A metering point is connected to another MTN for alternate source of power during emergency condition or pre-arranged shutdown

a. **Case 3 – A:** a metering point is connected to another transformer for alternate source of power during emergency or pre-arranged shutdown. Usual setting for alternate source of power from the same substation (figure 5).

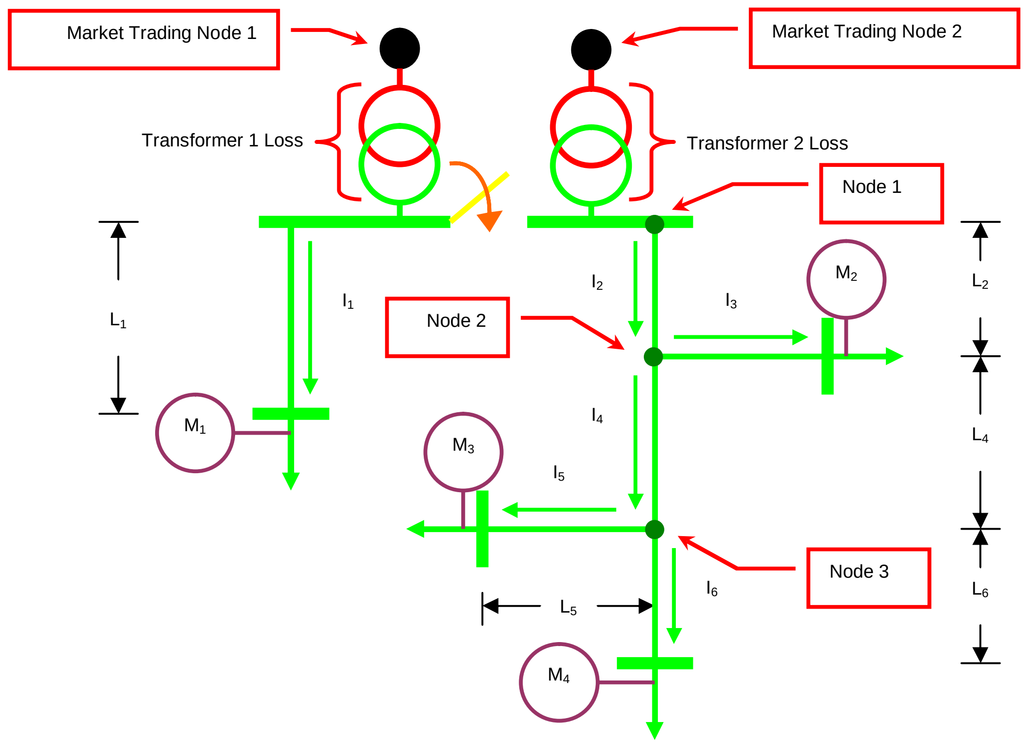

Figure 5

At normal condition (figure 5), SSLF of the meters connected to each defined point of sale can be computed separately treated the same as Case 1 – A (for T_1) and Case 1 – B (for T_2).

At Normal Condition for T_1:

Active and Reactive Power:

$kW_{M1} = (kWh_{M1\text{-}15min} + kWh_{M1\text{-}30min} + kWh_{M1\text{-}45min} + kWh_{M1\text{-}00min}) \div 1h$

$kVar_{M1} = (kVarh_{M1\text{-}15min} + kVarh_{M1\text{-}30min} + kVarh_{M1\text{-}45min} + kVarh_{M1\text{-}00min}) \div 1h$

Line Current and Line Loss

$I_1 = kW_{M1} \div ((\sqrt{3}) * V_1 * pf_1)$

$Line_{1\text{-}kW\text{-}Loss} = (I_1)^2 * R_1 = (I_1)^2 * (r_{a\text{-}1} * L_1)$

Transformer Losses

$T_1Core_{Loss\text{-}M1} = T_1Core_{Loss} \div 1$

$T_1Copper_{Loss\text{-}M1} = ((kW_{M1} \div pf_1) \div T_{1kVA\text{-}Rating})^2 * P_{Short\text{-}Circuit\text{-}T1}$

Total Active Loss

$Total_{kW\text{-}Loss\text{-}M1} = Line_{1\text{-}kW\text{-}Loss} + T_1Core_{Loss\text{-}M1} + T_1Copper_{Loss\text{-}M1}$

SSLF

$SSLF_{M1} = 1 + (Total_{kW\text{-}Loss\text{-}M1} \div kW_{M1})$

Adjusted Active Power:

$Adjusted_{kW-M1} = Total_{kW-Loss-M1} + kW_{M1}$

At Normal Condition for T_2:

Active and Reactive Power:

$kW_{M2} = (kWh_{M2-15min} + kWh_{M2-30min} + kWh_{M2-45min} + kWh_{M2-00min}) \div 1h$

$kVar_{M2} = (kVarh_{M2-15min} + kVarh_{M2-30min} + kVarh_{M2-45min} + kVarh_{M2-00min}) \div 1h$

$kW_{M3} = (kWh_{M3-15min} + kWh_{M3-30min} + kWh_{M3-45min} + kWh_{M3-00min}) \div 1h$

$kVar_{M3} = (kVarh_{M3-15min} + kVarh_{M3-30min} + kVarh_{M3-45min} + kVarh_{M3-00min}) \div 1h$

$kW_{M4} = (kWh_{M4-15min} + kWh_{M4-30min} + kWh_{M4-45min} + kWh_{M4-00min}) \div 1h$

$kVar_{M4} = (kVarh_{M4-15min} + kVarh_{M4-30min} + kVarh_{M4-45min} + kVarh_{M4-00min}) \div 1h$

Line Currents and Line Losses:

$I_3 = kW_{M2} \div ((\sqrt{3}) * V_2 * pf_2) = kW_{M2} \div ((\sqrt{3}) * V_2 * \cos(\tan^{-1}(kVar_{M2} \div kW_{M2})))$

$I_5 = kW_{M3} \div ((\sqrt{3}) * V_3 * pf_3) = kW_{M3} \div ((\sqrt{3}) * V_3 * \cos(\tan^{-1}(kVar_{M3} \div kW_{M3})))$

$I_6 = kW_{M4} \div ((\sqrt{3}) * V_4 * pf_4) = kW_{M4} \div ((\sqrt{3}) * V_4 * \cos(\tan^{-1}(kVar_{M4} \div kW_{M4})))$

$Line_{5-kW-Loss} = (I_5)^2 * R_5 = (I_5)^2 * (r_{a-5} * L_5)$

$Line_{5-kVar-Loss} = (I_5)^2 * X_5 = (I_5)^2 * (X_{l-5} * L_5)$

$Line_{6-kW-Loss} = (I_6)^2 * R_6 = (I_6)^2 * (r_{a-6} * L_6)$

$Line_{6-kVar-Loss} = (I_6)^2 * X_6 = (I_6)^2 * (X_{l-6} * L_6)$

Total Active Power at Node 3 (kW_{N-3}) = $kW_{M3} + kW_{M4} + Line_{5-kW-Loss} + Line_{6-kW-Loss}$

Total Reactive Power at Node 3 ($kVar_{N-3}$) = $kVar_{M3} + kVar_{M4} + Line_{5-kVar-Loss} + Line_{6-kVar-Loss}$

$I_4 = kW_{N-3} \div ((\sqrt{3}) * V_{N-3} * pf_{N-3}) = kW_{N-3} \div ((\sqrt{3}) * V_{N-3} * \cos(\tan^{-1}(kVar_{N-3} \div kW_{N-3})))$

$Line_{4-kW-Loss} = (I_4)^2 * R_4 = (I_4)^2 * (r_{a-4} * L_4)$

$Line_{4-kVar-Loss} = (I_4)^2 * X_4 = (I_4)^2 * (X_{l-4} * L_4)$

$Line_{3-kW-Loss} = (I_3)^2 * R_3 = (I_3)^2 * (r_{a-3} * L_3)$

$Line_{3-kVar-Loss} = (I_3)^2 * X_3 = (I_3)^2 * (X_{l-3} * L_3)$

Total Active Power at Node 2 (kW_{N-2}) = $kW_{M2} + kW_{M3} + kW_{M4} + Line_{3-kWLoss} + Line_{4-kW-Loss} + Line_{5-kW-Loss} + Line_{6-kW-Loss}$

Total Reactive Power at Node 2 ($kVar_{N-2}$) = $kVar_{M2} + kVar_{M3} + kVar_{M4} + Line_{3-kVar-Loss} + Line_{4-kVar-Loss} + Line_{5-kVar-Loss} + Line_{6-kVar-Loss}$

$I_2 = kW_{N-2} \div ((\sqrt{3}) * V_{N-2} * pf_{N-2}) \quad = kW_{N-2} \div ((\sqrt{3}) * V_{N-2} * \cos(\tan^{-1}(kVar_{N-2} \div kW_{N-2})))$

$Line_{2\text{-}kW\text{-}Loss} = (I_2)^2 * R_2 = (I_2)^2 * (r_{a-2} * L_2)$

$Line_{2\text{-}kVar\text{-}Loss} = (I_2)^2 * X_2 = (I_2)^2 * (x_{l-2} * L_2)$

Distributing $Line_{4\text{-}kWLoss}$

For M_3, $Line_{4\text{-}kW\text{-}Loss\text{-}M3} = (Line_{4\text{-}kW\text{-}Loss} * (kW_{M3} + Line_{5\text{-}kW\text{-}Loss})) \div kW_{N-3}$

For M_4, $Line_{4\text{-}kW\text{-}Loss\text{-}M4} = (Line_{4\text{-}kW\text{-}Loss} * (kW_{M4} + Line_{6\text{-}kW\text{-}Loss})) \div kW_{N-3}$

Distributing $Line_{2\text{-}kW\text{-}Loss}$

For M_2, $Line_{2\text{-}kW\text{-}Loss\text{-}M2} = (Line_{2\text{-}kW\text{-}Loss} * (kW_{M2} + Line_{3\text{-}kW\text{-}Loss})) \div kW_{N-2}$

For M_3, $Line_{2\text{-}kW\text{-}Loss\text{-}M3} = (Line_{2\text{-}kW\text{-}Loss} * (kW_{M3} + Line_{5\text{-}kW\text{-}Loss} + Line_{4\text{-}kW\text{-}Loss\text{-}M3})) \div kW_{N-2}$

For M_4, $Line_{2\text{-}kW\text{-}Loss\text{-}M4} = (Line_{2\text{-}kW\text{-}Loss} * (kW_{M4} + Line_{6\text{-}kW\text{-}Loss} + Line_{4\text{-}kW\text{-}Loss\text{-}M4})) \div kW_{N-2}$

Transformer Losses:

$T_2Core_{Loss\text{-}M2} = T_2Core_{Loss} * (kW_{M2} \div \sum_{i=1}^{n} kW_{Mi})$

$T_2Core_{Loss\text{-}M3} = T_2Core_{Loss} * (kW_{M3} \div \sum_{i=1}^{n} kW_{Mi})$

$T_2Core_{Loss\text{-}M4} = T_2Core_{Loss} * (kW_{M4} \div \sum_{i=1}^{n} kW_{Mi})$

$T_2Copper_{Loss} = ((kW_{N-1}) \div pf_{N-1}) \div T_{2kVA\text{-}Rating})^2 * P_{Short\text{-}Circuit\text{-}T2}$

$T_2Copper_{Loss\text{-}M2} = T_2Copper_{Loss} * (kW_{M2} + Line_{3\text{-}kW\text{-}Loss} + Line_{2\text{-}kW\text{-}Loss\text{-}M2}) \div kW_{N-1}$

$T_2Copper_{Loss\text{-}M3} = T_2Copper_{Loss} * (kW_{M3} + Line_{5\text{-}kW\text{-}Loss} + Line_{4\text{-}kW\text{-}Loss\text{-}M3} + Line_{4\text{-}kW\text{-}Loss\text{-}M3}) \div kW_{N-1}$

$T_2Copper_{Loss\text{-}M4} = T_2Copper_{Loss} * (kW_{M4} + Line_{5\text{-}kW\text{-}Loss} + Line_{4\text{-}kW\text{-}Loss\text{-}M4} + Line_{4\text{-}kW\text{-}Loss\text{-}M4}) \div kW_{N-1}$

Total Active Loss for each Meter:

$Total_{kW\text{-}Loss\text{-}M2} = Line_{3\text{-}kW\text{-}Loss} + Line_{2\text{-}kW\text{-}Loss\text{-}M2} + T_2Core_{Loss\text{-}M2} + T_2Copper_{Loss\text{-}M2}$

$Total_{kW\text{-}Loss\text{-}M3} = Line_{5\text{-}kW\text{-}Loss} + Line_{4\text{-}kW\text{-}Loss\text{-}M3} + Line_{2\text{-}kW\text{-}Loss\text{-}M3} + T_2Core_{Loss\text{-}M3} + T_2Copper_{Loss\text{-}M3}$

$Total_{kWLoss\text{-}M4} = Line_{6\text{-}kW\text{-}Loss} + Line_{4\text{-}kW\text{-}Loss\text{-}M4} + Line_{2\text{-}kW\text{-}Loss\text{-}M4} + T_2Core_{Loss\text{-}M4} + T_2Copper_{Loss\text{-}M4}$

SSLF:

$SSLF_{M2} = 1 + (Total_{kW\text{-}Loss\text{-}M2} \div kW_{M2})$

$SSLF_{M3} = 1 + (Total_{kW\text{-}Loss\text{-}M3} \div kW_{M3})$

$SSLF_{M4} = 1 + (Total_{kW\text{-}Loss\text{-}M4} \div kW_{M4})$

Adjusted Active Power:

$Adjusted_{kW-M2} = Total_{kW-Loss-M2} + kW_{M2}$

$Adjusted_{kW-M3} = Total_{kW-Loss-M3} + kW_{M3}$

$Adjusted_{kW-M4} = Total_{kW-Loss-M4} + kW_{M4}$

Maintenance or emergency on one of the transformers would close the Normally Open switch to deliver continuous power supply to the load of the transformer that went off. If Transformer 1 remains on-line while Transformer 2 is shutdown (figure 6):

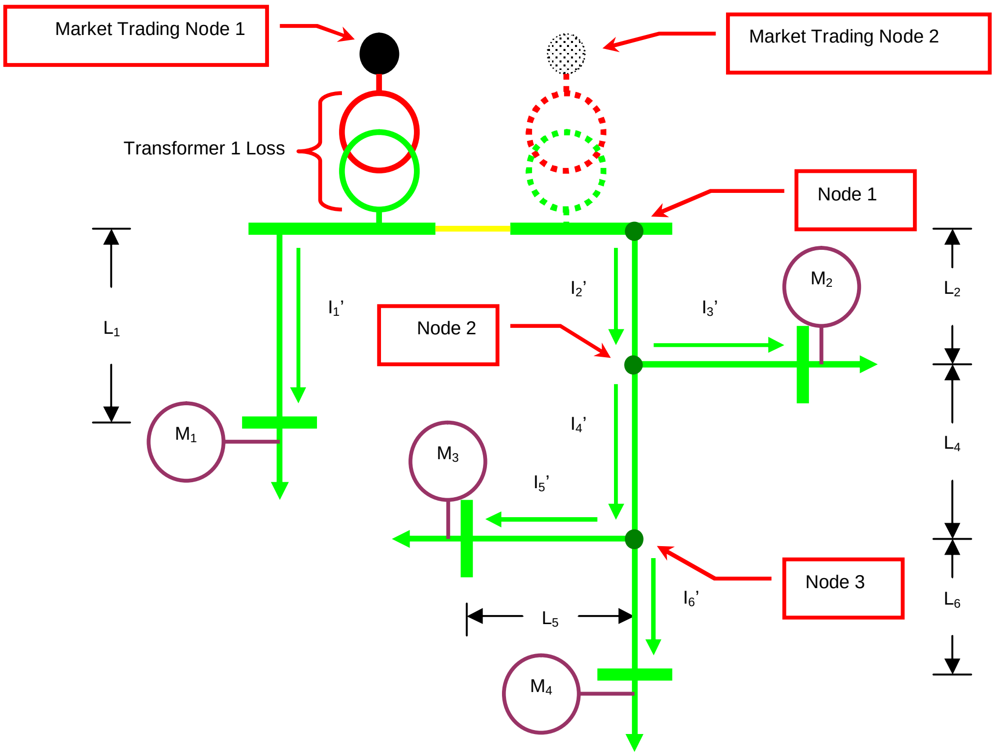

Figure 6

Active and Reactive Power:

$kW_{M1} = (kWh_{M1-15min} + kWh_{M1-30min} + kWh_{M1-45min} + kWh_{M1-00min}) \div 1h$

$kVar_{M1} = (kVarh_{M1-15min} + kVarh_{M1-30min} + kVarh_{M1-45min} + kVarh_{M1-00min}) \div 1h$

$kW_{M2} = (kWh_{M2-15min} + kWh_{M2-30min} + kWh_{M2-45min} + kWh_{M2-00min}) \div 1h$

$kVar_{M2} = (kVarh_{M2-15min} + kVarh_{M2-30min} + kVarh_{M2-45min} + kVarh_{M2-00min}) \div 1h$

$kW_{M3} = (kWh_{M3-15min} + kWh_{M3-30min} + kWh_{M3-45min} + kWh_{M3-00min}) \div 1h$

$kVar_{M3} = (kVarh_{M3-15min} + kVarh_{M3-30min} + kVarh_{M3-45min} + kVarh_{M3-00min}) \div 1h$

$kW_{M4} = (kWh_{M4-15min} + kWh_{M4-30min} + kWh_{M4-45min} + kWh_{M4-00min}) \div 1h$

$kVar_{M4} = (kVarh_{M4-15min} + kVarh_{M4-30min} + kVarh_{M4-45min} + kVarh_{M4-00min}) \div 1h$

Line Currents and Line Losses:

$I_1 = kW_{M1} \div ((\sqrt{3}) * V_1 * pf_1) = kW_{M1} \div ((\sqrt{3}) * V_1 * \cos(\tan^{-1}(kVar_{M1} \div kW_{M1})))$

$I_3 = kW_{M2} \div ((\sqrt{3}) * V_2 * pf_2) = kW_{M2} \div ((\sqrt{3}) * V_2 * \cos(\tan^{-1}(kVar_{M2} \div kW_{M2})))$

$I_5 = kW_{M3} \div ((\sqrt{3}) * V_3 * pf_3) = kW_{M3} \div ((\sqrt{3}) * V_3 * \cos(\tan^{-1}(kVar_{M3} \div kW_{M3})))$

$I_6 = kW_{M4} \div ((\sqrt{3}) * V_4 * pf_4) = kW_{M4} \div ((\sqrt{3}) * V_4 * \cos(\tan^{-1}(kVar_{M4} \div kW_{M4})))$

$Line_{5\text{-}kW\text{-}Loss} = (I_5)^2 * R_5 = (I_5)^2 * (r_{a\text{-}5} * L_5)$

$Line_{5\text{-}kVa\text{-}rLoss} = (I_5)^2 * X_5 = (I_5)^2 * (X_{l\text{-}5} * L_5)$

$Line_{6\text{-}kW\text{-}Loss} = (I_6)^2 * R_6 = (I_6)^2 * (r_{a\text{-}6} * L_6)$

$Line_{6\text{-}kVar\text{-}Loss} = (I_6)^2 * X_6 = (I_6)^2 * (X_{l\text{-}6} * L_6)$

Total Active Power at Node 3 ($kW_{N\text{-}3}$) $= kW_{M3} + kW_{M4} + Line_{5\text{-}kW\text{-}Loss} + Line_{6\text{-}kW\text{-}Loss}$

Total Reactive Power at Node 3 ($kVar_{N\text{-}3}$) $= kVar_{M3} + kVar_{M4} + Line_{5\text{-}kVar\text{-}Loss} + Line_{6\text{-}kVar\text{-}Loss}$

$I_4 = kW_{N\text{-}3} \div ((\sqrt{3}) * V_{N\text{-}3} * pf_{N\text{-}3}) = kW_{N\text{-}3} \div ((\sqrt{3}) * V_{N\text{-}3} * \cos(\tan^{-1}(kVar_{N\text{-}3} \div kW_{N\text{-}3})))$

$Line_{4\text{-}kW\text{-}Loss} = (I_4)^2 * R_4 = (I_4)^2 * (r_{a\text{-}4} * L_4)$

$Line_{4\text{-}kVar\text{-}Loss} = (I_4)^2 * X_4 = (I_4)^2 * (X_{l\text{-}4} * L_4)$

$Line_{3\text{-}kW\text{-}Loss} = (I_3)^2 * R_3 = (I_3)^2 * (r_{a\text{-}3} * L_3)$

$Line_{3\text{-}kVar\text{-}Loss} = (I_3)^2 * X_3 = (I_3)^2 * (X_{l\text{-}3} * L_3)$

Total Active Power at Node 2 ($kW_{N\text{-}2}$) $= kW_{M2} + kW_{M3} + kW_{M4} + Line_{3\text{-}kW\text{-}Loss} + Line_{4\text{-}kW\text{-}Loss} + Line_{5\text{-}kW\text{-}Loss} + Line_{6\text{-}kW\text{-}Loss}$

Total Reactive Power at Node 2 ($kVar_{N\text{-}2}$) $= kVar_{M2} + kVar_{M3} + kVar_{M4} + Line_{3\text{-}kVar\text{-}Loss} + Line_{4\text{-}kVar\text{-}Loss} + Line_{5\text{-}kVar\text{-}Loss} + Line_{6\text{-}kVar\text{-}Loss}$

$I_2 = kW_{N\text{-}2} \div ((\sqrt{3}) * V_{N\text{-}2} * pf_{N\text{-}2}) = kW_{N\text{-}2} \div ((\sqrt{3}) * V_{N\text{-}2} * \cos(\tan^{-1}(kVar_{N\text{-}2} \div kW_{N\text{-}2})))$

$Line_{2\text{-}kW\text{-}Loss} = (I_2)^2 * R_2 = (I_2)^2 * (r_{a\text{-}2} * L_2)$

$Line_{2\text{-}kVar\text{-}Loss} = (I_2)^2 * X_2 = (I_2)^2 * (X_{l\text{-}2} * L_2)$

$Line_{1\text{-}kW\text{-}Loss} = (I_1)^2 * R_2 = (I_1)^2 * (r_{a\text{-}2} * L_2)$

$Line_{1\text{-}kVar\text{-}Loss} = (I_1)^2 * X_2 = (I_1)^2 * (X_{l\text{-}2} * L_2)$

Distributing $Line_{4\text{-}kW\text{-}Loss}$

For M_3, $Line_{4\text{-}kW\text{-}Loss\text{-}M3} = (Line_{4\text{-}kW\text{-}Loss} * (kW_{M3} + Line_{5\text{-}kW\text{-}Loss})) \div kW_{N\text{-}3}$

For M_4, $Line_{4\text{-}kW\text{-}Loss\text{-}M4} = (Line_{4\text{-}kW\text{-}Loss} * (kW_{M4} + Line_{6\text{-}kW\text{-}Loss})) \div kW_{N\text{-}3}$

Distributing $Line_{2\text{-}kW\text{-}Loss}$

For M_2, $Line_{2\text{-kW-Loss-M2}}$ = $(Line_{2\text{-kW-Loss}} * (kW_{M2} + Line_{3\text{-kW-Loss}})) \div kW_{N-2}$

For M_3, $Line_{2\text{-kW-Loss-M3}}$ = $(Line_{2\text{-kW-Loss}} * (kW_{M3} + Line_{5\text{-kW-Loss}} + Line_{4\text{-kW-LossM3}})) \div kW_{N-2}$

For M_4, $Line_{2\text{-kW-Loss-M4}}$ = $(Line_{2\text{-kW-Loss}} * (kW_{M4} + Line_{6\text{-kW-Loss}} + Line_{4\text{-kW-LossM4}})) \div kW_{N-2}$

Transformer Losses:

$T_1Core_{Loss\text{-}M1} = T_1Core_{Loss} * (kW_{M1} \div \sum_{i=1}^{n} kW_{Mi})$

$T_1Core_{Loss\text{-}M2} = T_1Core_{Loss} * (kW_{M2} \div \sum_{i=1}^{n} kW_{Mi})$

$T_1Core_{Loss\text{-}M3} = T_1Core_{Loss} * (kW_{M3} \div \sum_{i=1}^{n} kW_{Mi})$

$T_1Core_{Loss\text{-}M4} = T_1Core_{Loss} * (kW_{M4} \div \sum_{i=1}^{n} kW_{Mi})$

$T_1Copper_{Loss} = ((kW_{N-1}) \div pf_{N-1}) \div T_{1kVA\text{-}Rating})^2 * P_{Short\text{-}Circuit\text{-}T1}$

$T_1Copper_{Loss\text{-}M1} = T_1Copper_{Loss} * (kW_{M1} + Line_{1\text{-kW-Loss}}) \div kW_{N-1}$

$T_1Copper_{Loss\text{-}M2} = T_1Copper_{Loss} * (kW_{M2} + Line_{3\text{-kW-Loss}} + Line_{2\text{-kW-Loss-M2}}) \div kW_{N-1}$

$T_1Copper_{Loss\text{-}M3} = T_1Copper_{Loss} * (kW_{M3} + Line_{5\text{-kW-Loss}} + Line_{4\text{-kW-Loss-M3}} + Line_{2\text{-kW-Loss-M3}}) \div kW_{N-1}$

$T_1Copper_{Loss\text{-}M4} = T_1Copper_{Loss} * (kW_{M4} + Line_{6\text{-kW-Loss}} + Line_{4\text{-kW-Loss-M4}} + Line_{2\text{-kW-Loss-M4}}) \div kW_{N-1}$

Total Active Loss for each Meter:

$Total_{kW\text{-}Loss\text{-}M1} = Line_{1\text{-kW-Loss}} + T_1Core_{Loss\text{-}M1} + T_1Copper_{Loss\text{-}M1}$

$Total_{kW\text{-}Loss\text{-}M2} = Line_{3\text{-kW-Loss}} + Line_{2\text{-kWLoss-M2}} + T_1Core_{Loss\text{-}M2} + T_1Copper_{Loss\text{-}M2}$

$Total_{kW\text{-}Loss\text{-}M3} = Line_{5\text{-kW-Loss}} + Line_{4\text{-kW-Loss-M3}} + Line_{2\text{-kW-Loss-M3}} + T_1Core_{Loss\text{-}M3} + T_1Copper_{Loss\text{-}M3}$

$Total_{kW\text{-}Loss\text{-}M4} = Line_{6\text{-kW-Loss}} + Line_{4\text{-kW-Loss-M4}} + Line_{2\text{-kW-Loss-M4}} + T_1Core_{Loss\text{-}M4} + T_1Copper_{Loss\text{-}M4}$

SSLF:

$SSLF_{M1} = 1 + (Total_{kW\text{-}Loss\text{-}M1} \div kW_{M1})$

$SSLF_{M2} = 1 + (Total_{kW\text{-}Loss\text{-}M2} \div kW_{M2})$

$SSLF_{M3} = 1 + (Total_{kW\text{-}Loss\text{-}M3} \div kW_{M3})$

$SSLF_{M4} = 1 + (Total_{kW\text{-}Loss\text{-}M4} \div kW_{M4})$

Adjusted Active Power:

$Adjusted_{kW\text{-}M1} = Total_{kW\text{-}Loss\text{-}M1} + kW_{M1}$

$Adjusted_{kW\text{-}M2} = Total_{kW\text{-}Loss\text{-}M2} + kW_{M2}$

$$Adjusted_{KW-M3} = Total_{kW-Loss-M3} + kW_{M3}$$

$$Adjusted_{kW-M4} = Total_{kW-Loss-M4} + kW_{M4}$$

If Transformer 1 is shutdown while Transformer 2 remains on-line (figure 7), the manner of computation is the same, only, it is the core loss and full-load copper loss of Transformer 2 that would be distributed.

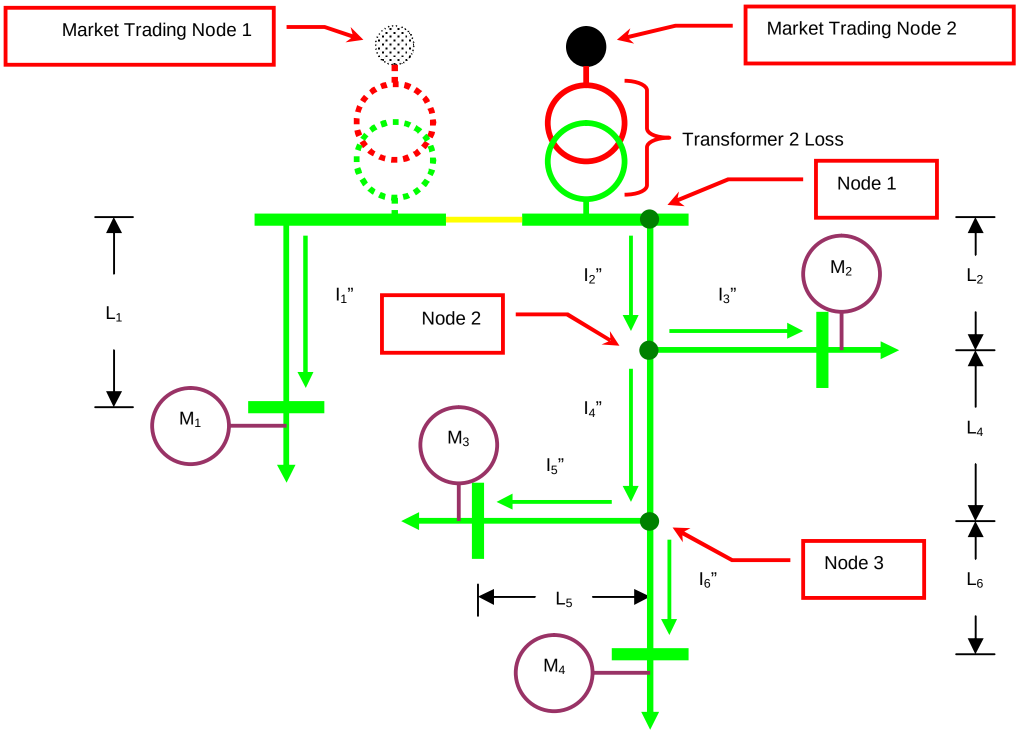

Figure 7

b. Case 3 – B: a metering point is connected to another line for alternate source of power during emergency or pre-arranged shutdown. This is the usual setting for alternate source of power from another substation (figure 8).

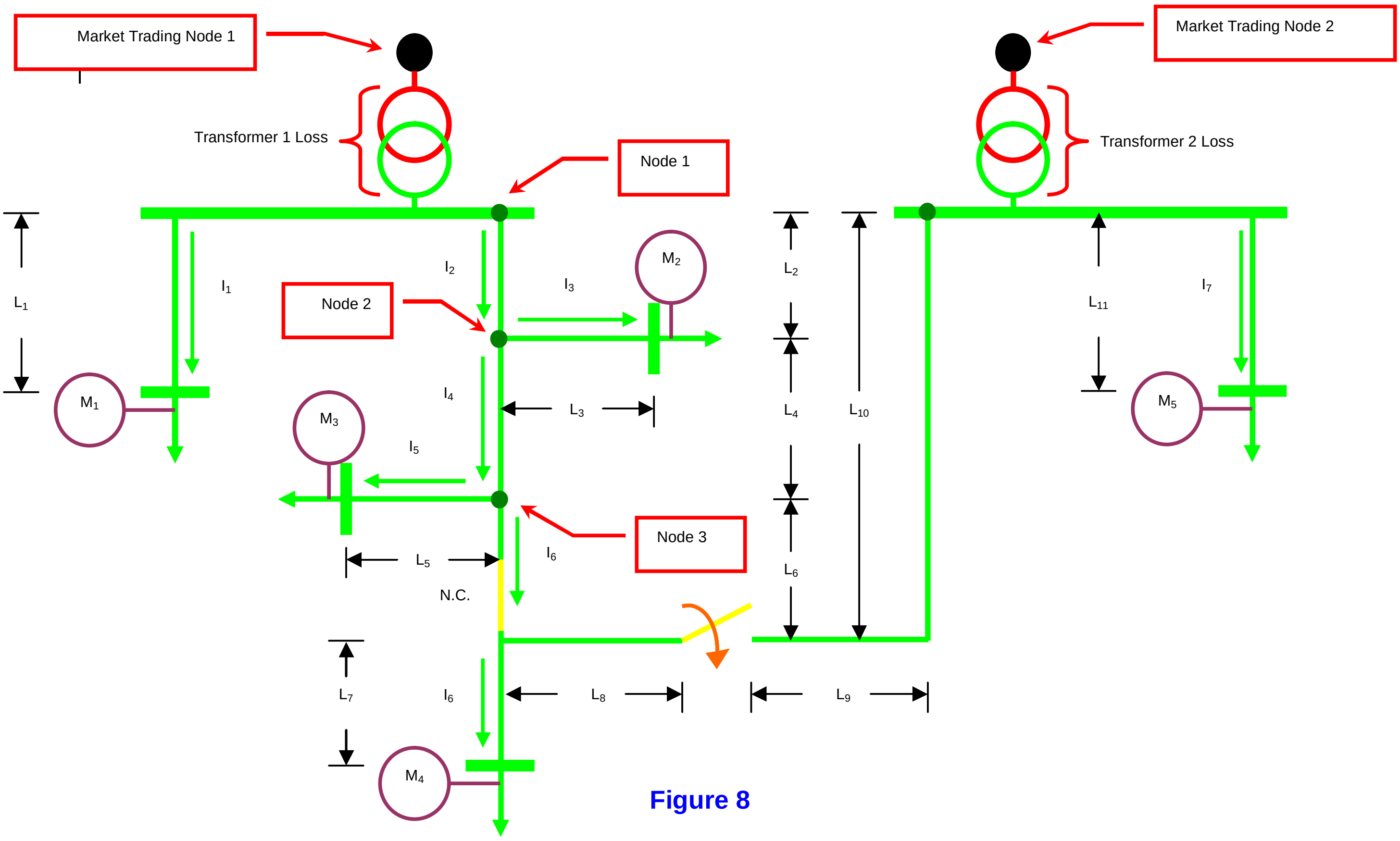

Figure 8

At normal condition (figure 8), SSLF of the meters connected to each MTN can be computed separately treated the same as in Case 1 – A (for T_2) and Case 1 – B (for T_1).

At Normal Condition for T_1:

Active and Reactive Power:

$kW_{M1} = (kWh_{M1\text{-}15min} + kWh_{M1\text{-}30min} + kWh_{M1\text{-}45min} + kWh_{M1\text{-}00min}) \div 1h$

$kVar_{M1} = (kVarh_{M1\text{-}15min} + kVarh_{M1\text{-}30min} + kVarh_{M1\text{-}45min} + kVarh_{M1\text{-}00min}) \div 1h$

$kW_{M2} = (kWh_{M2\text{-}15min} + kWh_{M2\text{-}30min} + kWh_{M2\text{-}45min} + kWh_{M2\text{-}00min}) \div 1h$

$kVar_{M2} = (kVarh_{M2\text{-}15min} + kVarh_{M2\text{-}30min} + kVarh_{M2\text{-}45min} + kVarh_{M2\text{-}00min}) \div 1h$

$kW_{M3} = (kWh_{M3\text{-}15min} + kWh_{M3\text{-}30min} + kWh_{M3\text{-}45min} + kWh_{M3\text{-}00min}) \div 1h$

$kVar_{M3} = (kVarh_{M3\text{-}15min} + kVarh_{M3\text{-}30min} + kVarh_{M3\text{-}45min} + kVarh_{M3\text{-}00min}) \div 1h$

$kW_{M4} = (kWh_{M4\text{-}15min} + kWh_{M4\text{-}30min} + kWh_{M4\text{-}45min} + kWh_{M4\text{-}00min}) \div 1h$

$kVar_{M4} = (kVarh_{M4\text{-}15min} + kVarh_{M4\text{-}30min} + kVarh_{M4\text{-}45min} + kVarh_{M4\text{-}00min}) \div 1h$

Line Currents and Line Losses:

$I_1 = kW_{M1} \div ((\sqrt{3}) * V_1 * pf_1) = kW_{M1} \div ((\sqrt{3}) * V_1 * \cos(\tan^{-1}(kVar_{M1} \div kW_{M1})))$

$I_3 = kW_{M2} \div ((\sqrt{3}) * V_2 * pf_2) = kW_{M2} \div ((\sqrt{3}) * V_2 * \cos(\tan^{-1}(kVar_{M2} \div kW_{M2})))$

$I_5 = kW_{M3} \div ((\sqrt{3}) * V_3 * pf_3) = kW_{M3} \div ((\sqrt{3}) * V_3 * \cos(\tan^{-1}(kVar_{M3} \div kW_{M3})))$

$I_6 = kW_{M4} \div ((\sqrt{3}) * V_4 * pf_4) = kW_{M4} \div ((\sqrt{3}) * V_4 * \cos(\tan^{-1}(kVar_{M4} \div kW_{M4})))$

$Line_{5\text{-kW-Loss}} = (I_5)^2 * R_5 = (I_5)^2 * (r_{a\text{-}5} * L_5)$

$Line_{5\text{-kVar-Loss}} = (I_5)^2 * X_5 = (I_5)^2 * (X_{l\text{-}5} * L_5)$

$Line_{6\text{-kW-Loss}} = (I_6)^2 * R_6 = (I_6)^2 * (r_{a\text{-}6} * L_6)$

$Line_{6\text{-kVar-Loss}} = (I_6)^2 * X_6 = (I_6)^2 * (X_{l\text{-}6} * L_6)$

$Line_{7\text{-kW-Loss}} = (I_6)^2 * R_7 = (I_6)^2 * (r_{a\text{-}7} * L_7)$

$Line_{7\text{-kVar-Loss}} = (I_6)^2 * X_7 = (I_6)^2 * (X_{l\text{-}7} * L_7)$

Total Active Power at Node 3 ($kW_{N\text{-}3}$) $= kW_{M3} + kW_{M4} + Line_{5\text{-kW-Loss}} + Line_{6\text{-kW-Loss}} + Line_{7\text{-kW-Loss}}$

Total Reactive Power at Node 3 ($kVar_{N\text{-}3}$) $= kVar_{M3} + kVar_{M4} + Line_{5\text{-kVar-Loss}} + Line_{6\text{-kVar-Loss}} + Line_{7\text{-kVar-Loss}}$

$I_4 = kW_{N\text{-}3} \div ((\sqrt{3}) * V_{N\text{-}3} * pf_{N\text{-}3}) = kW_{N\text{-}3} \div ((\sqrt{3}) * V_{N\text{-}3} * \cos(\tan^{-1}(kVar_{N\text{-}3} \div kW_{N\text{-}3})))$

$Line_{4\text{-kW-Loss}} = (I_4)^2 * R_4 = (I_4)^2 * (r_{a\text{-}4} * L_4)$

$Line_{4\text{-kVar-Loss}} = (I_4)^2 * X_4 = (I_4)^2 * (X_{l\text{-}4} * L_4)$

$Line_{3\text{-kW-Loss}} = (I_3)^2 * R_3 = (I_3)^2 * (r_{a\text{-}3} * L_3)$

$Line_{3\text{-kVar-Loss}} = (I_3)^2 * X_3 = (I_3)^2 * (X_{l\text{-}3} * L_3)$

Total Active Power at Node 2 ($kW_{N\text{-}2}$) $= kW_{M2} + kW_{M3} + kW_{M4} + Line_{3\text{-kW-Loss}} + Line_{4\text{-kW-Loss}} + Line_{5\text{-kW-Loss}} + Line_{6\text{-kW-Loss}} + Line_{7\text{-kW-Loss}}$

Total Reactive Power at Node 2 ($kVar_{N\text{-}2}$) $= kVar_{M2} + kVar_{M3} + kVar_{M4} + Line_{3\text{-kVar-Loss}} + Line_{4\text{-kVar-Loss}} + Line_{5\text{-kVar-Loss}} + Line_{6\text{-kVar-Loss}} + Line_{7\text{-kVar-Loss}}$

$I_2 = kW_{N\text{-}2} \div ((\sqrt{3}) * V_{N\text{-}2} * pf_{N\text{-}2}) = kW_{N\text{-}2} \div ((\sqrt{3}) * V_{N\text{-}2} * \cos(\tan^{-1}(kVar_{N\text{-}2} \div kW_{N\text{-}2})))$

$Line_{2\text{-kW-Loss}} = (I_2)^2 * R_2 = (I_2)^2 * (r_{a\text{-}2} * L_2)$

$Line_{2\text{-kVar-Loss}} = (I_2)^2 * X_2 = (I_2)^2 * (X_{l\text{-}2} * L_2)$

$Line_{1\text{-kW-Loss}} = (I_1)^2 * R_2 = (I_1)^2 * (r_{a\text{-}2} * L_2)$

$Line_{1\text{-kVar-Loss}} = (I_1)^2 * X_2 = (I_1)^2 * (X_{l\text{-}2} * L_2)$

Distributing $Line_{4\text{-kW-Loss}}$

For M_3, $Line_{4\text{-kW-Loss-M3}} = (Line_{4\text{-kW-Loss}} * (kW_{M3} + Line_{5\text{-kW-Loss}})) \div kW_{N\text{-}3}$

For M_4, $Line_{4\text{-kW-Loss-M4}} = (Line_{4\text{-kW-Loss}} * (kW_{M4} + Line_{6\text{-kW-Loss}} + Line_{7\text{-kW-Loss}})) \div kW_{N\text{-}3}$

Distributing $Line_{2\text{-kW-Loss}}$

For M_2, $Line_{2\text{-kW-Loss-M2}} = (Line_{2\text{-kW-Loss}} * (kW_{M2} + Line_{3\text{-kW-Loss}})) \div kW_{N-2}$

For M_3, $Line_{2\text{-kW-Loss-M3}} = (Line_{2\text{-kW-Loss}} * (kW_{M3} + Line_{5\text{-kW-Loss}} + Line_{4\text{-kW-Loss-M3}})) \div kW_{N-2}$

For M_4, $Line_{2\text{-kW-Loss-M4}} = (Line_{2\text{-kW-Loss}} * (kW_{M4} + Line_{6\text{-kW-Loss}} + Line_{7\text{-kW-Loss}} + Line_{4\text{-kW-Loss-M4}})) \div kW_{N-2}$

Transformer Losses:

$$T_1Core_{Loss\text{-}M1} = T_1Core_{Loss} * (kW_{M1} \div \sum_{i=1}^{n} kW_{Mi})$$

$$T_1Core_{Loss\text{-}M2} = T_1Core_{Loss} * (kW_{M2} \div \sum_{i=1}^{n} kW_{Mi})$$

$$T_1Core_{Loss\text{-}M3} = T_1Core_{Loss} * (kW_{M3} \div \sum_{i=1}^{n} kW_{Mi})$$

$$T_1Core_{Loss\text{-}M4} = T_1Core_{Loss} * (kW_{M4} \div \sum_{i=1}^{n} kW_{Mi})$$

$$T_1Copper_{Loss} = (((kW_{N-1} \div 2) \div pf_{N-1}) \div T_{1kVA\text{-}Rating})^2 * P_{Short\text{-}Circuit\text{-}T1}$$

$$T_1Copper_{Loss\text{-}M1} = T_1Copper_{Loss} * (kW_{M1} + Line_{1\text{-kW-Loss}}) \div kW_{N-1}$$

$$T_1Copper_{Loss\text{-}M2} = T_1Copper_{Loss} * (kW_{M2} + Line_{3\text{-kW-Loss}} + Line_{2\text{-kW-Loss-M2}}) \div kW_{N-1}$$

$$T_1Copper_{Loss\text{-}M3} = T_1Copper_{Loss} * (kW_{M3} + Line_{5\text{-kW-Loss}} + Line_{4\text{-kW-Loss-M3}} + Line_{2\text{-kW-Loss-M3}}) \div kW_{N-1}$$

$$T_1Copper_{Loss\text{-}M4} = T_1Copper_{Loss} * (kW_{M4} + Line_{6\text{-kW-Loss}} + Line_{7\text{-kW-Loss}} + Line_{4\text{-kW-Loss-M4}} + Line_{2\text{-kW-Loss-M4}}) \div kW_{N-1}$$

Total Loss for each Meter:

$$Total_{kW\text{-}Loss\text{-}M1} = Line_{1\text{-kW-Loss}} + T_1Core_{Loss\text{-}M1} + T_1Copper_{Loss\text{-}M1}$$

$$Total_{kW\text{-}Loss\text{-}M2} = Line_{3\text{-kW-Loss}} + Line_{2\text{-kWLoss-M2}} + T_1Core_{Loss\text{-}M2} + T_1Copper_{Loss\text{-}M2}$$

$$Total_{kW\text{-}Loss\text{-}M3} = Line_{5\text{-kW-Loss}} + Line_{4\text{-kW-Loss-M3}} + Line_{2\text{-kW-Loss-M3}} + T_1Core_{Loss\text{-}M3} + T_1Copper_{Loss\text{-}M3}$$

$$Total_{kW\text{-}Loss\text{-}M4} = Line_{6\text{-kW-Loss}} + Line_{7\text{-kW-Loss}} + Line_{4\text{-kW-Loss-M4}} + Line_{2\text{-kW-Loss-M4}} + T_1Core_{Loss\text{-}M4} + T_1Copper_{Loss\text{-}M4}$$

SSLF

$$SSLF_{M1} = 1 + (Total_{kW\text{-}Loss\text{-}M1} \div kW_{M1})$$

$$SSLF_{M2} = 1 + (Total_{kW\text{-}Loss\text{-}M2} \div kW_{M2})$$

$$SSLF_{M3} = 1 + (Total_{kW\text{-}Loss\text{-}M3} \div kW_{M3})$$

$$SSLF_{M4} = 1 + (Total_{kW\text{-}Loss\text{-}M4} \div kW_{M4})$$

Adjusted Active Power:

$$Adjusted_{kW\text{-}M1} = Total_{kW\text{-}Loss\text{-}M1} + kW_{M1}$$

$Adjusted_{kW-M2}$ $= Total_{kW-Loss-M2} + kW_{M2}$

$Adjusted_{kW-M3}$ $= Total_{kW-Loss-M3} + kW_{M3}$

$Adjusted_{kW-M4}$ $= Total_{kW-Loss-M4} + kW_{M4}$

At Normal Condition for T_2:

Active and Reactive Power:

kW_{M5} $= (kWh_{M5-15min} + kWh_{M5-30min} + kWh_{M5-45min} + kWh_{M5-00min}) \div 1h$

$kVar_{M5}$ $= (kVarh_{M5-15min} + kVarh_{M5-30min} + kVarh_{M5-45min} + kVarh_{M5-00min}) \div 1h$

Line Current and Line Loss

I_7 $= kW_{M5} \div ((\sqrt{3}) * V_5 * pf_5)$

$Line_{11-kW-Loss}$ $= (I_7)^2 * R_{11}$ $= (I_7)^2 * (r_{a-11} * L_{11})$

Transformer Losses

$T_2Core_{Loss-M5}$ $= T_2Core_{Loss} \div 1$

$T_2Copper_{Loss-M5}$ $= ((kW_{M5} \div pf_5) \div T_{2kVA-Rating})^2 * P_{Short-Circuit-T2}$

Total Active Loss for the Meter

$Total_{kW-Loss-M5}$ $= Line_{11-kW-Loss} + T_2Core_{Loss} + T_2Copper_{Loss-M5}$

SSLF

$SSLF_{M5}$ $= 1 + (Total_{kW-Loss-M5} \div kW_{M5})$

Adjusted Active Power:

$Adjusted_{kW-M5}$ $= Total_{kW-Loss-M5} + kW_{M5}$

Maintenance or emergency on the line would close the Normally Open switch to deliver continuous power supply to the load of the line that went off. If Transformer 1 remains on-line while Transformer 2 is shutdown (figure 9):

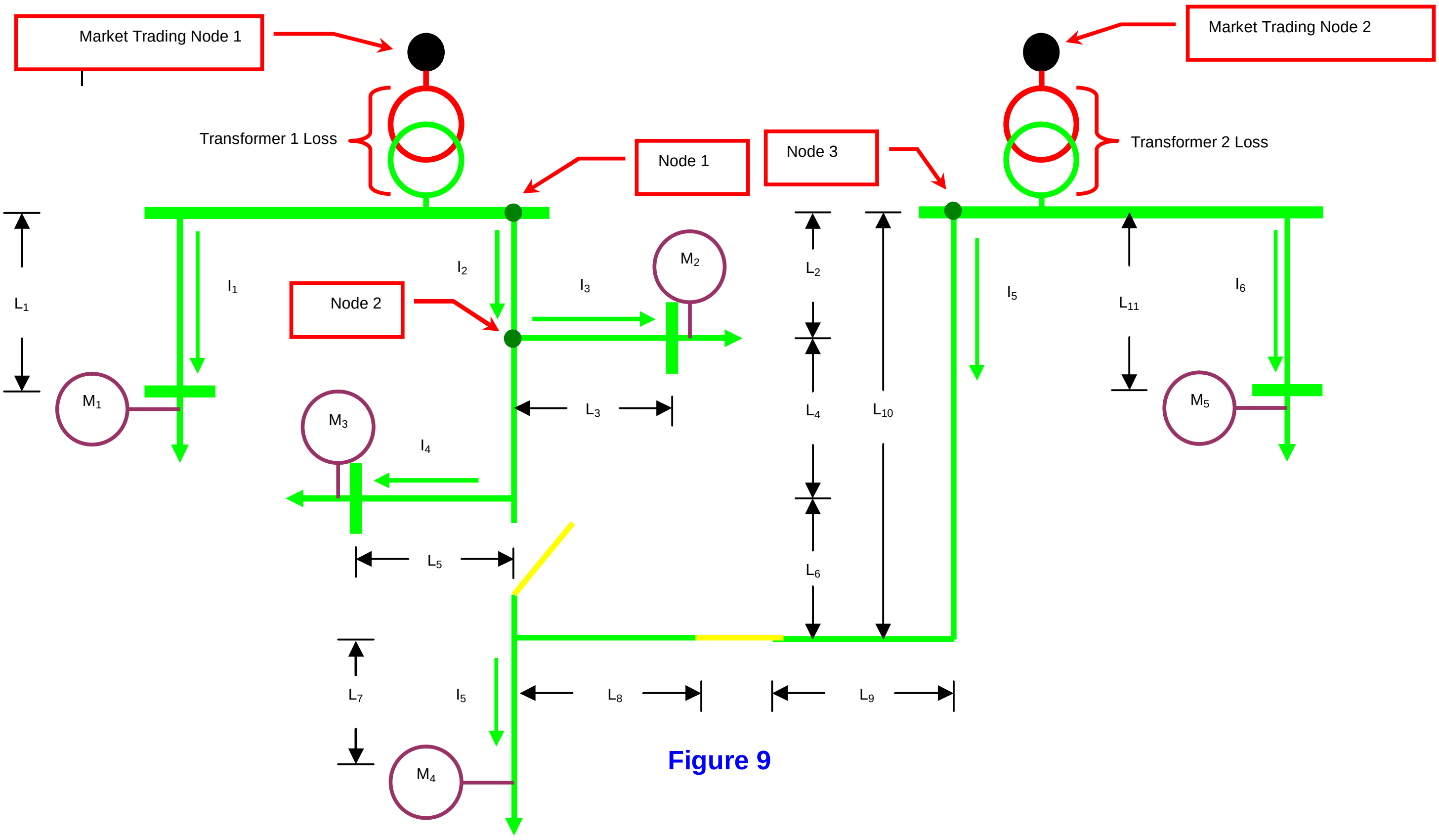

Figure 9

Active and Reactive Power:

$kW_{M1} = (kWh_{M1\text{-}15min} + kWh_{M1\text{-}30min} + kWh_{M1\text{-}45min} + kWh_{M1\text{-}00min}) \div 1h$

$kVar_{M1} = (kVarh_{M1\text{-}15min} + kVarh_{M1\text{-}30min} + kVarh_{M1\text{-}45min} + kVarh_{M1\text{-}00min}) \div 1h$

$kW_{M2} = (kWh_{M2\text{-}15min} + kWh_{M2\text{-}30min} + kWh_{M2\text{-}45min} + kWh_{M2\text{-}00min}) \div 1h$

$kVar_{M2} = (kVarh_{M2\text{-}15min} + kVarh_{M2\text{-}30min} + kVarh_{M2\text{-}45min} + kVarh_{M2\text{-}00min}) \div 1h$

$kW_{M3} = (kWh_{M3\text{-}15min} + kWh_{M3\text{-}30min} + kWh_{M3\text{-}45min} + kWh_{M3\text{-}00min}) \div 1h$

$kVar_{M3} = (kVarh_{M3\text{-}15min} + kVarh_{M3\text{-}30min} + kVarh_{M3\text{-}45min} + kVarh_{M3\text{-}00min}) \div 1h$

$kW_{M4} = (kWh_{M4\text{-}15min} + kWh_{M4\text{-}30min} + kWh_{M4\text{-}45min} + kWh_{M4\text{-}00min}) \div 1h$

$kVar_{M4} = (kVarh_{M4\text{-}15min} + kVarh_{M4\text{-}30min} + kVarh_{M4\text{-}45min} + kVarh_{M4\text{-}00min}) \div 1h$

$kW_{M5} = (kWh_{M5\text{-}15min} + kWh_{M5\text{-}30min} + kWh_{M5\text{-}45min} + kWh_{M5\text{-}00min}) \div 1h$

$kVar_{M5} = (kVarh_{M5\text{-}15min} + kVarh_{M5\text{-}30min} + kVarh_{M5\text{-}45min} + kVarh_{M5\text{-}00min}) \div 1h$

Line Currents and Line Losses:

$I_1 = kW_{M1} \div ((\sqrt{3}) * V_1 * pf_1) = kW_{M1} \div ((\sqrt{3}) * V_1 * \cos(\tan^{-1}(kVar_{M1} \div kW_{M1})))$

$I_3 = kW_{M2} \div ((\sqrt{3}) * V_2 * pf_2) = kW_{M2} \div ((\sqrt{3}) * V_2 * \cos(\tan^{-1}(kVar_{M2} \div kW_{M2})))$

$I_4 = kW_{M3} \div ((\sqrt{3}) * V_5 * pf_3) = kW_{M3} \div ((\sqrt{3}) * V_5 * \cos(\tan^{-1}(kVar_{M3} \div kW_{M3})))$

$Line_{5\text{-}kW\text{-}Loss} = (I_4)^2 * R_5 = (I_4)^2 * (r_{a\text{-}5} * L_5)$

$Line_{5\text{-}kVar\text{-}Loss} = (I_4)^2 * X_5 = (I_4)^2 * (X_{l\text{-}5} * L_5)$

$Line_{4\text{-}kW\text{-}Loss} = (I_4)^2 * R_4 = (I_4)^2 * (r_{a\text{-}4} * L_4)$

$Line_{4\text{-}kVar\text{-}Loss} = (I_4)^2 * X_4 = (I_4)^2 * (X_{l\text{-}4} * L_4)$

$Line_{3\text{-}kW\text{-}Loss} = (I_3)^2 * R_3 = (I_3)^2 * (r_{a\text{-}3} * L_3)$

$Line_{3\text{-}kVar\text{-}Loss} = (I_3)^2 * X_3 = (I_3)^2 * (X_{l\text{-}3} * L_3)$

Total Active Power at Node 2 ($kW_{N\text{-}2}$) $= kW_{M2} + kW_{M3} + Line_{3\text{-}kW\text{-}Loss} + Line_{4\text{-}kW\text{-}Loss} + Line_{5\text{-}kW\text{-}Loss}$

Total Reactive Power at Node 2 ($kVar_{N\text{-}2}$) $= kVar_{M2} + kVar_{M3} + Line_{3\text{-}kVar\text{-}Loss} + Line_{4\text{-}kVar\text{-}Loss} + Line_{5\text{-}kVar\text{-}Loss}$

$I_2 = kW_{N\text{-}2} \div ((\sqrt{3}) * V_{N\text{-}2} * pf_{N\text{-}2}) = kW_{N\text{-}2} \div ((\sqrt{3}) * V_{N\text{-}2} * \cos(\tan^{-1}(kVar_{N\text{-}2} \div kW_{N\text{-}2})))$

$Line_{2\text{-}kW\text{-}Loss} = (I_2)^2 * R_2 = (I_2)^2 * (r_{a\text{-}2} * L_2)$

$Line_{2\text{-}kVar\text{-}Loss} = (I_2)^2 * X_2 = (I_2)^2 * (X_{l\text{-}2} * L_2)$

$Line_{1\text{-}kW\text{-}Loss} = (I_1)^2 * R_1 = (I_1)^2 * (r_{a\text{-}1} * L_1)$

$Line_{1\text{-}kVar\text{-}Loss} = (I_1)^2 * X_1 = (I_1)^2 * (X_{l\text{-}1} * L_1)$

$I_5 = kW_{M4} \div ((\sqrt{3}) * V_7 * pf_4) = kW_{M4} \div ((\sqrt{3}) * V_7 * \cos(\tan^{-1}(kVar_{M4} \div kW_{M4})))$

$Line_{7\text{-}kW\text{-}Loss} = (I_5)^2 * R_7 = (I_5)^2 * (r_{a\text{-}7} * L_7)$

$Line_{7\text{-}kVar\text{-}Loss} = (I_5)^2 * X_7 = (I_5)^2 * (X_{l\text{-}7} * L_7)$

$Line_{8\text{-}kW\text{-}Loss} = (I_5)^2 * R_8 = (I_5)^2 * (r_{a\text{-}8} * L_8)$

$Line_{8\text{-}kVar\text{-}Loss} = (I_5)^2 * X_8 = (I_5)^2 * (X_{l\text{-}8} * L_8)$

$Line_{9\text{-}kW\text{-}Loss} = (I_5)^2 * R_9 = (I_5)^2 * (r_{a\text{-}9} * L_9)$

$Line_{9\text{-}kVar\text{-}Loss} = (I_5)^2 * X_9 = (I_5)^2 * (X_{l\text{-}9} * L_9)$

$Line_{10\text{-}kW\text{-}Loss} = (I_5)^2 * R_{10} = (I_5)^2 * (r_{a\text{-}10} * L_{10})$

$Line_{10\text{-}kVar\text{-}Loss} = (I_5)^2 * X_{10} = (I_5)^2 * (X_{l\text{-}10} * L_{10})$

$I_6 = kW_{M5} \div ((\sqrt{3}) * V_{11} * pf_5) = kW_{M5} \div ((\sqrt{3}) * V_{11} * \cos(\tan^{-1}(kVar_{M5} \div kW_{M5})))$

$Line_{11\text{-}kW\text{-}Loss} = (I_6)^2 * R_{11} = (I_6)^2 * (r_{a\text{-}11} * L_{11})$

$Line_{11\text{-}kVar\text{-}Loss} = (I_6)^2 * X_{11} = (I_6)^2 * (x_{l\text{-}11} * L_{11})$

Distributing $Line_{2\text{-}kW\text{-}Loss}$

For M_3, $Line_{2\text{-}kW\text{-}Loss\text{-}M3} = (Line_{2\text{-}kW\text{-}Loss} * (kW_{M3} + Line_{4\text{-}kW\text{-}Loss} + Line_{5\text{-}kW\text{-}Loss})) \div kW_{N\text{-}4}$

For M_2, $Line_{2\text{-}kW\text{-}Loss\text{-}M2} = (Line_{2\text{-}kW\text{-}Loss} * (kW_{M2} + Line_{3\text{-}kWLoss})) \div kW_{N\text{-}4}$

Transformer Losses:

$T_1Core_{Loss-M1} = T_1Core_{Loss} * (kW_{M1} \div) \sum_{i=1}^{n} kW_{Mi}$

$T_1Core_{Loss-M2} = T_1Core_{Loss} * (kW_{M2} \div) \sum_{i=1}^{n} kW_{Mi}$

$T_1Core_{Loss-M3} = T_1Core_{Loss} * (kW_{M3} \div) \sum_{i=1}^{n} kW_{Mi}$

$T_1Copper_{Loss} = ((kW_{N-1} \div pf_{N-1}) \div T_{1kVA-Rating})^2 * P_{Short-Circuit-T1}$

$T_1Copper_{Loss-M1} = T_1Copper_{Loss} * (kW_{M1} + Line_{1-kW-Loss}) \div kW_{N-1}$

$T_1Copper_{Loss-M2} = T_1Copper_{Loss} * (kW_{M2} + Line_{3-kW-Loss} + Line_{2-kW-Loss-M2}) \div kW_{N-1}$

$T_1Copper_{Loss-M3} = T_1Copper_{Loss} * (kW_{M3} + Line_{5-kW-Loss} + Line_{4-kW-Loss} + Line_{2-kW-Loss-M3}) \div kW_{N-1}$

$T_2Core_{Loss-M4} = T_2Core_{Loss} * (kW_{M4} \div) \sum_{i=1}^{n} kW_{Mi}$

$T_2Core_{Loss-M5} = T_2Core_{Loss} * (kW_{M5} \div) \sum_{i=1}^{n} kW_{Mi}$

$T_2Copper_{Loss} = ((kW_{N-3} \div pf_{N-3}) \div T_{2kVA-Rating}))^2 * P_{Short-Circuit-T2}$

$T_2Copper_{Loss-M5} = T_2Copper_{Loss} * (kW_{M5} + Line_{11-kW-Loss}) \div kW_{N-3}$

$T_2Copper_{Loss-M4} = T_2Copper_{Loss} * (kW_{M4} + Line_{7-kW-Loss} + Line_{8-kW-Loss} + Line_{9-kW-Loss} + Line_{10-kW-Loss}) \div kW_{N-3}$

Total Active Loss for each Meter:

$Total_{Loss-M1} = Line_{1-Loss} + T_1Core_{Loss-M1} + T_1Copper_{Loss-M1}$

$Total_{Loss-M2} = Line_{3-Loss} + Line_{2-Loss-M2} + T_1Core_{Loss-M2} + T_1Copper_{Loss-M2}$

$Total_{Loss-M3} = Line_{4-Loss} + Line_{5-Loss} + Line_{2-Loss-M3} + T_1Core_{Loss-M3} + T_1Copper_{Loss-M3}$

$Total_{Loss-M4} = Line_{7-Loss} + Line_{8-Loss} + Line_{9-Loss} + Line_{10-Loss} + T_2Core_{Loss-M4} + T_2Copper_{Loss-M4}$

$Total_{Loss-M5} = Line_{11-Loss} + T_2Core_{Loss-M5} + T_2Copper_{Loss-M5}$

SSLF

$SSLF_{M1} = 1 + (Total_{kW-Loss-M1} \div kW_{M1})$

$SSLF_{M2} = 1 + (Total_{kW-Loss-M2} \div kW_{M2})$

$SSLF_{M3} = 1 + (Total_{kW-Loss-M3} \div kW_{M3})$

$SSLF_{M4} = 1 + (Total_{kW-Loss-M4} \div kW_{M4})$

$SSLF_{M5} = 1 + (Total_{kWLoss-M5} \div kW_{M5})$

Adjusted Active Power:

$Adjusted_{kW-M1} = Total_{kW-Loss-M1} + kW_{M1}$

$Adjusted_{kW-M2} = Total_{kW-Loss-M2} + kW_{M2}$

$Adjusted_{kW-M3} = Total_{kW-Loss-M3} + kW_{M3}$

$Adjusted_{kW-M4} = Total_{kW-Loss-M4} + kW_{M4}$

$Adjusted_{kW-M5} = Total_{kW-Loss-M5} + kW_{M5}$

Case 4: Lagging MTN: A metering point is located before the MTN. The meter is installed at a voltage level higher or equal to the voltage level of the MTN (figure 10).

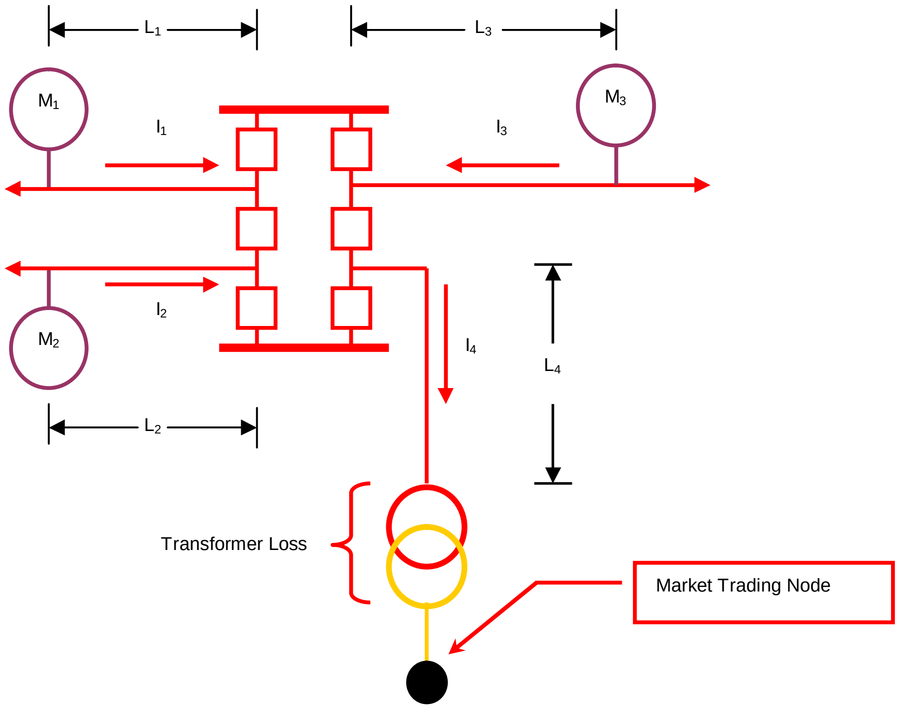

Figure 10

Simplifying Figure 10:

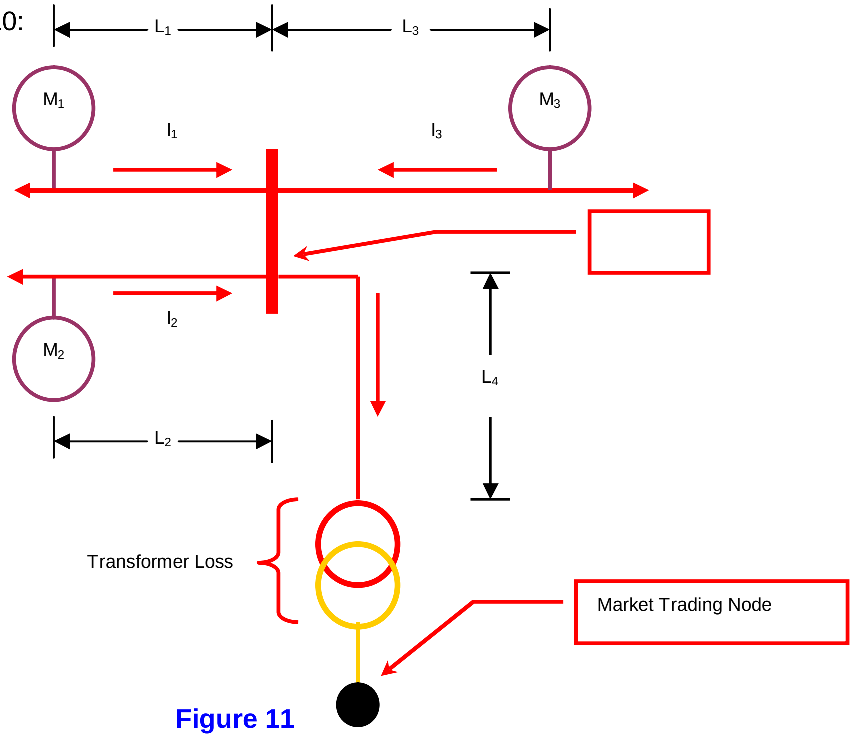

Figure 11

Active and Reactive Power:

$kW_{M1} = (kWh_{M1\text{-}15min} + kWh_{M1\text{-}30min} + kWh_{M1\text{-}45min} + kWh_{M1\text{-}00min}) \div 1h$

$kVar_{M1} = (kVarh_{M1\text{-}15min} + kVarh_{M1\text{-}30min} + kVarh_{M1\text{-}45min} + kVarh_{M1\text{-}00min}) \div 1h$

$kW_{M2} = (kWh_{M2\text{-}15min} + kWh_{M2\text{-}30min} + kWh_{M2\text{-}45min} + kWh_{M2\text{-}00min}) \div 1h$

$kVar_{M2} = (kVarh_{M2\text{-}15min} + kVarh_{M2\text{-}30min} + kVarh_{M2\text{-}45min} + kVarh_{M2\text{-}00min}) \div 1h$

$kW_{M3} = (kWh_{M3\text{-}15min} + kWh_{M3\text{-}30min} + kWh_{M3\text{-}45min} + kWh_{M3\text{-}00min}) \div 1h$

$kVar_{M3} = (kVarh_{M3\text{-}15min} + kVarh_{M3\text{-}30min} + kVarh_{M3\text{-}45min} + kVarh_{M3\text{-}00min}) \div 1h$

Line Currents and Line Losses:

$I_1 = kW_{M1} \div ((\sqrt{3}) * V_1 * pf_1) = kW_{M1} \div ((\sqrt{3}) * V_1 * \cos(\tan^{-1}(kVar_{M1} \div kW_{M1})))$

$I_2 = kW_{M2} \div ((\sqrt{3}) * V_2 * pf_2) = kW_{M2} \div ((\sqrt{3}) * V_2 * \cos(\tan^{-1}(kVar_{M2} \div kW_{M2})))$

$I_3 = kW_{M3} \div ((\sqrt{3}) * V_3 * pf_3) = kW_{M3} \div ((\sqrt{3}) * V_3 * \cos(\tan^{-1}(kVar_{M3} \div kW_{M3})))$

$Line_{1\text{-}kW\text{-}Loss} = (I_1)^2 * R_1 = (I_1)^2 * (r_{a\text{-}1} * L_1)$

$Line_{1\text{-}kVar\text{-}Loss} = (I_1)^2 * X_1 = (I_1)^2 * (X_{l\text{-}1} * L_1)$

$Line_{2\text{-}kW\text{-}Loss} = (I_2)^2 * R_2 = (I_2)^2 * (r_{a\text{-}2} * L_2)$

$Line_{2\text{-}kVar\text{-}Loss} = (I_2)^2 * X_2 = (I_2)^2 * (X_{l\text{-}2} * L_2)$

$Line_{3\text{-kW-Loss}} = (I_3)^2 * R_3 = (I_3)^2 * (r_{a\text{-}3} * L_3)$

$Line_{3\text{-kVar-Loss}} = (I_3)^2 * X_3 = (I_3)^2 * (X_{l\text{-}3} * L_3)$

Total Active Power at Node 1 ($kW_{N\text{-}1}$) $= kW_{M1} + kW_{M2} + kW_{M3} + Line_{1\text{-kW-Loss}} + Line_{2\text{-kW-Loss}} + Line_{3\text{-kW-Loss}}$

Total Reactive Power at Node 1 ($kVar_{N\text{-}1}$) $= kVar_{M1} + kVar_{M2} + kVar_{M3} + Line_{1\text{-kVar-Loss}} + Line_{2\text{-kVar-Loss}} + Line_{3\text{-kVar-Loss}}$

$I_4 = kW_{N\text{-}1} \div ((\sqrt{3}) * V_{N\text{-}1} * pf_{N\text{-}1}) = kW_{N\text{-}1} \div ((\sqrt{3}) * V_{N\text{-}1} * \cos(\tan^{-1}(kVar_{N\text{-}1} \div kW_{N\text{-}1})))$

$Line_{4\text{-kW-Loss}} = (I_4)^2 * R_4 = (I_4)^2 * (r_{a\text{-}4} * L_4)$

$Line_{4\text{-kVar-Loss}} = (I_4)^2 * X_4 = (I_4)^2 * (x_{l\text{-}4} * L_4)$

Distributing $Line_{4\text{-kW-Loss}}$

For M_1, $Line_{4\text{-kW-Loss-M1}} = (Line_{4\text{-kW-Loss}} * (kW_{M1} + Line_{1\text{-kW-Loss}})) \div kW_{N\text{-}1}$

For M_2, $Line_{4\text{-kW-Loss-M2}} = (Line_{4\text{-kW-Loss}} * (kW_{M2} + Line_{2\text{-kW-Loss}})) \div kW_{N\text{-}1}$

For M_3, $Line_{4\text{-kW-Loss-M3}} = (Line_{4\text{-kW-Loss}} * (kW_{M3} + Line_{3\text{-kW-Loss}})) \div kW_{N\text{-}1}$

Transformer Losses:

$T_1Core_{Loss\text{-}M1} = T_1Core_{Loss} * (kW_{M1} \div \sum_{i=1}^{n} kW_{Mi})$

$T_1Core_{Loss\text{-}M2} = T_1Core_{Loss} * (kW_{M2} \div \sum_{i=1}^{n} kW_{Mi})$

$T_1Core_{Loss\text{-}M3} = T_1Core_{Loss} * (kW_{M3} \div \sum_{i=1}^{n} kW_{Mi})$

$T_1Copper_{Loss} = ((kW_{N\text{-}1} \div pf_{N\text{-}1}) \div T_{1kVA\text{-}Rating})^2 * P_{Short\text{-}Circuit\text{-}T1}$

$T_1Copper_{Loss\text{-}M1} = T_1Copper_{Loss} * (kW_{M1} + Line_{1\text{-kW-Loss}} + Line_{4\text{-kW-Loss-M1}}) \div kW_{N\text{-}1}$

$T_1Copper_{Loss\text{-}M2} = T_1Copper_{Loss} * (kW_{M2} + Line_{2\text{-kW-Loss}} + Line_{4\text{-kW-Loss-M2}}) \div kW_{N\text{-}1}$

$T_1Copper_{Loss\text{-}M3} = T_1Copper_{Loss} * (kW_{M3} + Line_{3\text{-kW-Loss}} + Line_{4\text{-kW-Loss-M3}}') \div kW_{N\text{-}1}$

Total Loss for each Meter:

$Total_{kW\text{-Loss-M1}} = Line_{1\text{-kW-Loss}} + Line_{4\text{-kWLoss-M1}} + T_1Core_{Loss\text{-}M1} + T_1Copper_{Loss\text{-}M1}$

$Total_{kW\text{-Loss-M2}} = Line_{2\text{-kW-Loss}} + Line_{4\text{-kWLoss-M2}} + T_1Core_{Loss\text{-}M2} + T_1Copper_{Loss\text{-}M2}$

$Total_{kW\text{-Loss-M3}} = Line_{3\text{-kW-Loss}} + Line_{4\text{-kW-Loss-M3}} + T_1Core_{Loss\text{-}M3} + T_1Copper_{Loss\text{-}M3}$

SSLF

$SSLF_{M1} = 1 - (Total_{kW\text{-Loss-M1}} \div kW_{M1})$

$SSLF_{M2} = 1 - (Total_{kW\text{-Loss-M2}} \div kW_{M2})$

$SSLF_{M3} = 1 - (Total_{kW\text{-Loss-M3}} \div kW_{M3})$

Adjusted Meter Data:

$Adjusted_{kW\text{-}M1} = kW_{M1} - Total_{kW\text{-}Loss\text{-}M1}$

$Adjusted_{kW\text{-}M2} = kW_{M2} - Total_{kW\text{-}Loss\text{-}M2}$

$Adjusted_{kW\text{-}M3} = kW_{M3} - Total_{kW\text{-}Loss\text{-}M3}$

Generators

Case 1: One Metering Point – One Market Trading Node: A metering point measures the dispatch of only one generating unit (figure 12).

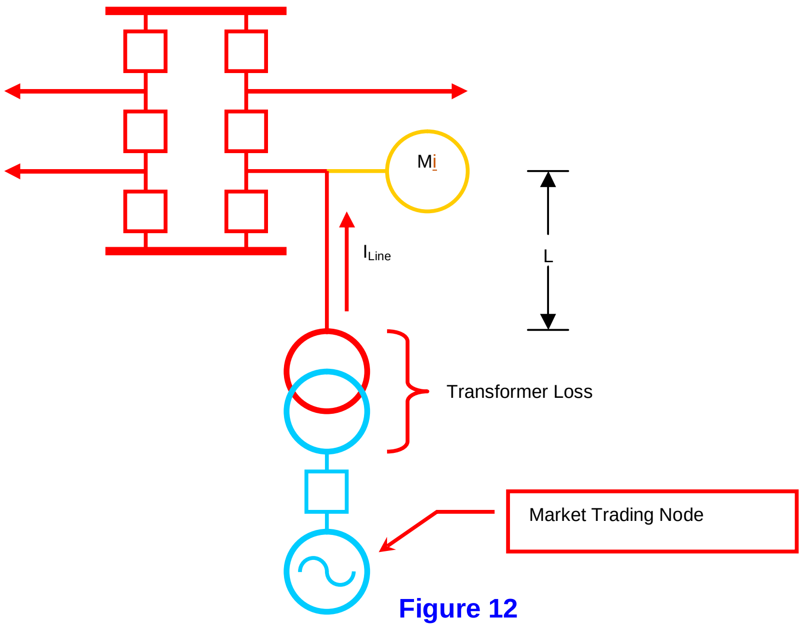

Figure 12

$kW_{Mi} = (kWh_{Mi\text{-}15min} + kWh_{Mi\text{-}30min} + kWh_{Mi\text{-}45min} + kWh_{Mi\text{-}00min}) \div 1h$

$kVar_{Mi} = (kVarh_{Mi\text{-}15min} + kVarh_{Mi\text{-}30min} + kVarh_{Mi\text{-}45min} + kVarh_{Mi\text{-}00min}) \div 1h$

$I_{Line} = kW_{Mi} \div ((\sqrt{3}) * V * pf_{Mi})$, $pf_{Mi} = \cos(\tan^{-1}(kVar_{Mi} \div kW_{Mi}))$

$Line_{kW\text{-}Loss} = (I_{Line})^2 * R_{Line}$, $R_{Line} = r_a * L$

$Line_{kVar\text{-}Loss} = (I_{Line})^2 * X_{Line}$, $X_{Line} = x_l * L$

$Core_{Loss\text{-}Mi} = T_1Core_{Loss} \div 1$

$Copper_{Loss\text{-}Mi} = ((kW_{Mi} \div pf_{Mi}) \div T_{kVA\text{-}Rating})^2 * P_{Short\text{-}Circuit}$

$Total_{kW\text{-}Loss} = Line_{kW\text{-}Loss} + Core_{Loss\text{-}Mi} + Copper_{Loss\text{-}Mi}$

$SSLF = 1 + (Total_{kW\text{-}Loss} \div kW_{Mi})$

$Adjusted_{kW} = SSLF * kW_{Mi} = Total_{kW\text{-}Loss} + kW_{Mi}$

Case 2: One Metering Point – Multiple Market Trading Nodes: A metering point measures the aggregate dispatch of a group or block of generating units (figure 13)

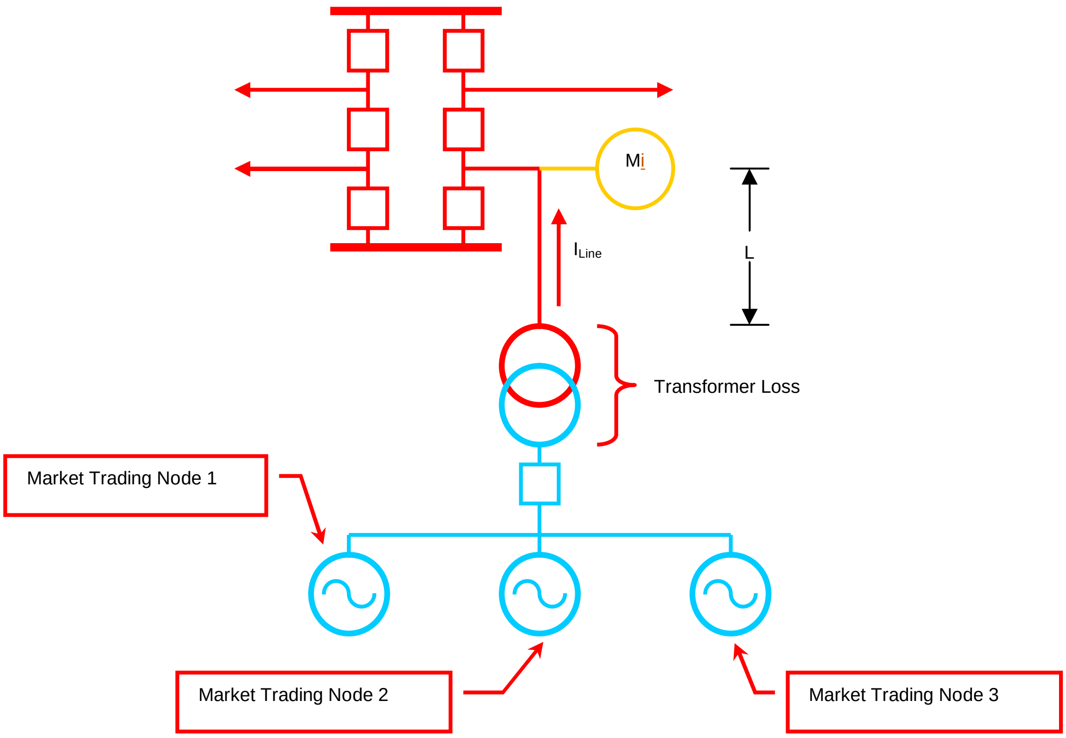

Figure 13

kW_{Mi} $= (kWh_{Mi\text{-}15min} + kWh_{Mi\text{-}30min} + kWh_{Mi\text{-}45min} + kWh_{Mi\text{-}00min}) \div 1h$

$kVar_{Mi}$ $= (kVarh_{Mi\text{-}15min} + kVarh_{Mi\text{-}30min} + kVarh_{Mi\text{-}45min} + kVarh_{Mi\text{-}00min}) \div 1h$

I_{Line} $= kW_{Mi} \div ((\sqrt{3}) * V * pf_{Mi})$

pf_{Mi} $= \cos(\tan^{-1}(kVar_{Mi} \div kW_{Mi}))$

$Line_{kW\text{-}Loss}$ $= (I_{Line})^{2} * R_{Line},\ R_{Line} = r_a * L$

$Line_{kVar\text{-}Loss}$ $= (I_{Line})^{2} * X_{Line},\ X_{Line} = x_l * L$

$Core_{Loss\text{-}Mi}$ $= T_1Core_{Loss} * kW_{M1} \div kW_{M1} = T_1Core_{Loss} * 1$

$Copper_{Loss\text{-}Mi}$ $= ((kW_{Mi} \div pf) \div T_{kVA\text{-}Rating})^{2} * P_{Short\text{-}Circuit}$

$Total_{kW\text{-}Loss}$ $= Line_{kW\text{-}Loss} + Core_{Loss\text{-}Mi} + Copper_{Loss\text{-}Mi}$

$SSLF$ $= 1 + (Total_{kWLoss} \div kW_{Mi})$

$Adjusted_{kW}$ $= Total_{kWLoss} + kW_{Mi} = SSLF * kW_{Mi}$

Disaggregation of Adjusted Active Power:

$MTN_{1\text{-Meter-Equivalent}} = Adjusted_{kW} * (EPQ_{MTN1} \div \sum_{i=1}^{n} EPQ_{MTNi})$

$MTN_{2\text{-Meter-Equivalent}} = Adjusted_{kW} * (EPQ_{MTN2} \div \sum_{i=1}^{n} EPQ_{MTNi})$

$MTN_{3\text{-Meter-Equivalent}} = Adjusted_{kW} * (EPQ_{MTN3} \div \sum_{i=1}^{n} EPQ_{MTNi})$

Where:

EPQ_{MTN} = Real Time Ex-Post Quantity of the generator

Case 3: Multiple Metering Points – Multiple Market Trading Nodes: A group of metering points measures the aggregate dispatch of a group or block of generating units (figure 14).

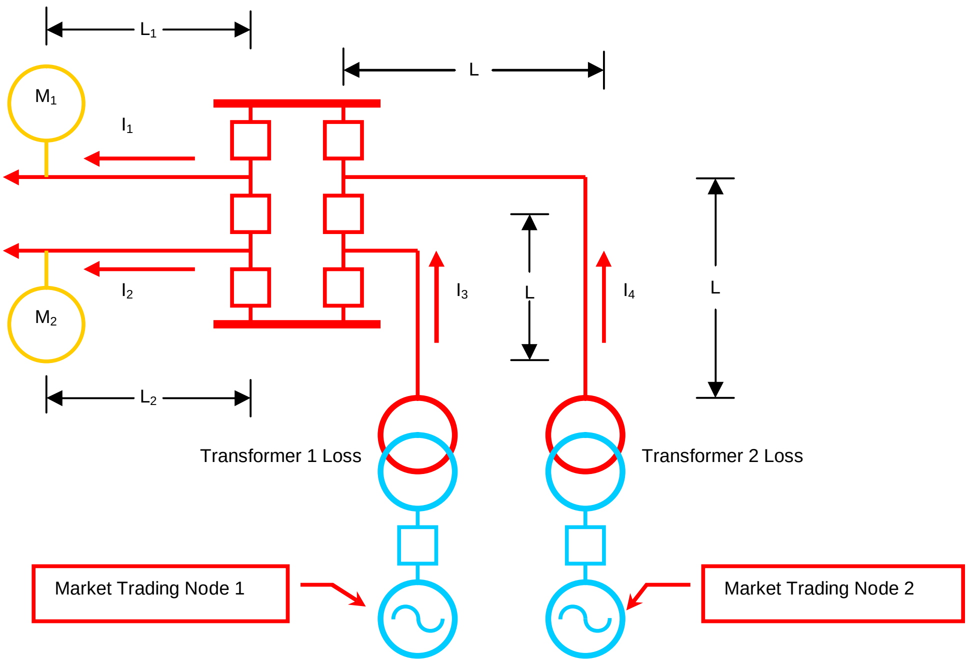

Figure 14

Simplifying Figure 14:

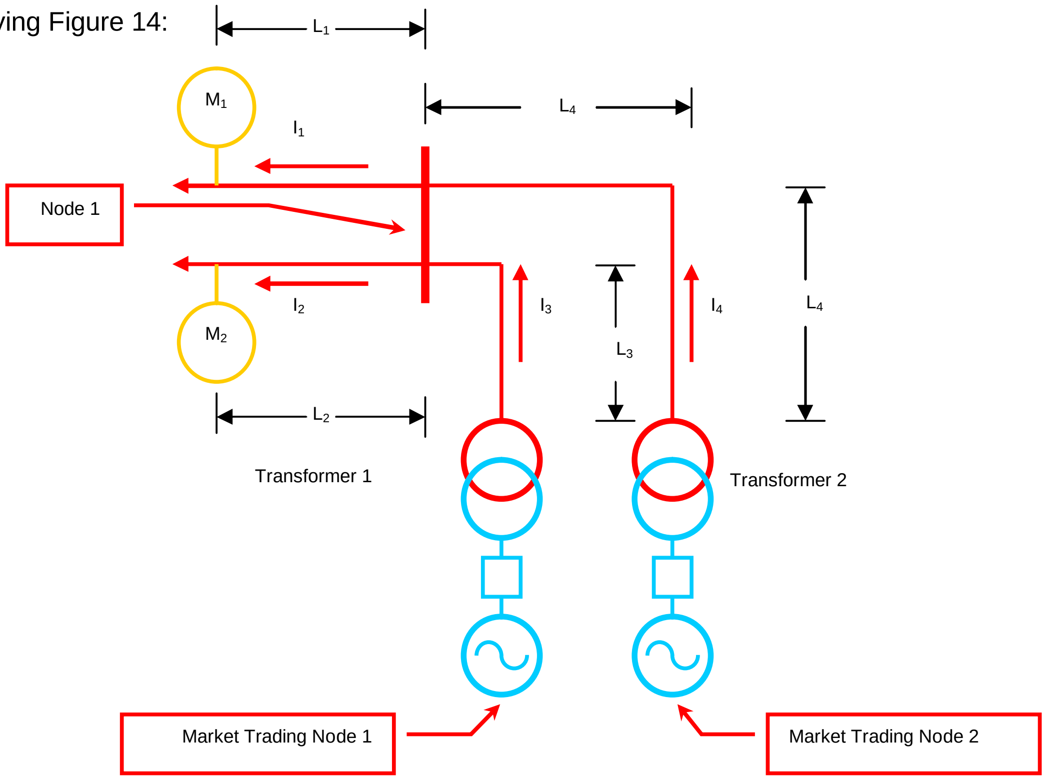

Figure 15

Active and Reactive Power:

$kW_{M1} = (kWh_{M1\text{-}15min} + kWh_{M1\text{-}30min} + kWh_{M1\text{-}45min} + kWh_{M1\text{-}00min}) \div 1h$

$kVar_{M1} = (kVarh_{M1\text{-}15min} + kVarh_{M1\text{-}30min} + kVarh_{M1\text{-}45min} + kVarh_{M1\text{-}00min}) \div 1h$

$kW_{M2} = (kWh_{M2\text{-}15min} + kWh_{M2\text{-}30min} + kWh_{M2\text{-}45min} + kWh_{M2\text{-}00min}) \div 1h$

$kVar_{M2} = (kVarh_{M2\text{-}15min} + kVarh_{M2\text{-}30min} + kVarh_{M2\text{-}45min} + kVarh_{M2\text{-}00min}) \div 1h$

Line Currents and Line Losses:

$I_1 = kW_{M1} \div ((\sqrt{3}) * V_1 * pf_1) = kW_{M1} \div ((\sqrt{3}) * V_1 * \cos(\tan^{-1}(kVar_{M1} \div kW_{M1})))$

$I_2 = kW_{M2} \div ((\sqrt{3}) * V_2 * pf_2) = kW_{M2} \div ((\sqrt{3}) * V_2 * \cos(\tan^{-1}(kVar_{M2} \div kW_{M2})))$

$Line_{1\text{-}kWLoss} = (I_1)^2 * R_1 = (I_1)^2 * (r_{a\text{-}1} * L_1)$

$Line_{1\text{-}kVarLoss} = (I_1)^2 * X_1 = (I_1)^2 * (X_{l\text{-}1} * L_1)$

$Line_{2\text{-}kWLoss} = (I_2)^2 * R_2 = (I_2)^2 * (r_{a\text{-}2} * L_2)$

$Line_{2\text{-}kVarLoss} = (I_2)^2 * X_2 = (I_2)^2 * (X_{l\text{-}2} * L_2)$

Total Active Power at Node 1 ($kW_{N\text{-}1}$) = $kW_{M1} + kW_{M2} + Line_{1\text{-}kW\text{-}Loss} + Line_{2\text{-}kW\text{-}Loss}$

Total Reactive Power at Node 1 ($kVar_{N\text{-}1}$) = $kVar_{M1} + kVar_{M2} + Line_{1\text{-}kVar\text{-}Loss} + Line_{2\text{-}kVar\text{-}Loss}$

$I_1 + I_2 = I_3 + I_4$

Since current (I) is inversely proportional to resistance (R), I = 1 ÷ R

$I_3 = (I_1 + I_2) * R_4 \div (R_3 + R_4)$, $I_4 = (I_1 + I_2) * R_3 \div (R_3 + R_4)$

$Line_{3\text{-kW-Loss}} = (I_3)^2 * R_3 = (I_3)^2 * (r_{a\text{-}3} * L_3)$

$Line_{3\text{-kVar-Loss}} = (I_3)^2 * X_3 = (I_3)^2 * (X_{l\text{-}3} * L_3)$

$Line_{4\text{-kW-Loss}} = (I_4)^2 * R_4 = (I_4)^2 * (r_{a\text{-}4} * L_4)$

$Line_{4\text{-kVar-Loss}} = (I_4)^2 * X_4 = (I_4)^2 * (X_{l\text{-}4} * L_4)$

Distributing $Line_{3\text{-kW-Loss}}$

For M_1, $Line_{3\text{-kW-Loss-M1}} = (Line_{3\text{-kW-Loss}} * (kW_{M1} + Line_{1\text{-kW-Loss}})) \div kW_{N\text{-}1}$

For M_2, $Line_{3\text{-kW-Loss-M2}} = (Line_{3\text{-kW-Loss}} * (kW_{M2} + Line_{2\text{-kW-Loss}})) \div kW_{N\text{-}1}$

Distributing $Line_{4\text{-kW-Loss}}$

For M_1, $Line_{4\text{-kW-Loss-M1}} = (Line_{4\text{-kW-Loss}} * (kW_{M1} + Line_{1\text{-kW-Loss}})) \div kW_{N\text{-}1}$

For M_2, $Line_{4\text{-kW-Loss-M2}} = (Line_{4\text{-kW-Loss}} * (kW_{M2} + Line_{2\text{-kW-Loss}})) \div kW_{N\text{-}1}$

Transformer Losses:

$T_1Core_{Loss\text{-}M1} = T_1Core_{Loss} * (kW_{M1} \div \sum_{i=1}^{n} kW_{Mi})$

$T_1Core_{Loss\text{-}M2} = T_1Core_{Loss} * (kW_{M2} \div \sum_{i=1}^{n} kW_{Mi})$

$T_2Core_{Loss\text{-}M1} = T_2Core_{Loss} * (kW_{M1} \div \sum_{i=1}^{n} kW_{Mi})$

$T_2Core_{Loss\text{-}M2} = T_2Core_{Loss} * (kW_{M2} \div \sum_{i=1}^{n} kW_{Mi})$

$T_1Copper_{Loss} = (((kW_{N\text{-}1} \div 2) \div pf_{N\text{-}1}) \div T_{1kVA\text{-}Rating}))^2 * P_{Short\text{-}Circuit\text{-}T1}$

$T_1Copper_{Loss\text{-}M1} = T_1Copper_{Loss} * (kW_{M1} + Line_{1\text{-kW-Loss}}) \div kW_{N\text{-}1}$

$T_1Copper_{Loss\text{-}M2} = T_1Copper_{Loss} * (kW_{M2} + Line_{2\text{-kW-Loss}}) \div kW_{N\text{-}1}$

$T_2Copper_{Loss} = (((kW_{N\text{-}1} \div 2) \div pf_{N\text{-}1}) \div T_{2kVA\text{-}Rating}))^2 * P_{Short\text{-}Circuit\text{-}T2}$

$T_2Copper_{Loss\text{-}M1} = T_2Copper_{Loss} * (kW_{M1} + Line_{1\text{-kW-Loss}}) \div kW_{N\text{-}1}$

$T_2Copper_{Loss\text{-}M2} = T_2Copper_{Loss} * (kW_{M2} + Line_{2\text{-kW-Loss}}) \div kW_{N\text{-}1}$

$T_1Copper_{Loss\text{-}M1} = ((kW_{M1} \div pf_1) \div T_{1kVA\text{-}Rating})^2 * P_{Short\text{-}Circuit\text{-}T1}$

Total Loss for each Meter:

$Total_{kW\text{-}Loss\text{-}M1} = Line_{1\text{-kW-Loss}} + Line_{3\text{-kW-Loss-M1}} + Line_{4\text{-kW-Loss-M1}} + T_1Core_{Loss\text{-}M1} + T_2Core_{Loss\text{-}M1} + T_1Copper_{Loss\text{-}M1} + T_2Copper_{Loss\text{-}M1}$

$Total_{kW\text{-}Loss\text{-}M2}$ = $Line_{2\text{-}kW\text{-}Loss}$ + $Line_{3\text{-}kW\text{-}Loss\text{-}M2}$ + $Line_{4\text{-}kW\text{-}Loss\text{-}M2}$ + $T_1Core_{Loss\text{-}M2}$ + $T_2Core_{Loss\text{-}M2}$ + $T_1Copper_{Loss\text{-}M2}$ + $T_2Copper_{Loss\text{-}M2}$

SSLF

$SSLF_{M1} = 1 + (Total_{kW\text{-}Loss\text{-}M1} \div kW_{M1})$

$SSLF_{M2} = 1 + (Total_{kW\text{-}Loss\text{-}M2} \div kW_{M2})$

$SSLF_{M3} = 1 + (Total_{kW\text{-}Loss\text{-}M3} \div kW_{M3})$

$SSLF_{M4} = 1 + (Total_{kW\text{-}Loss\text{-}M4} \div kW_{M4})$

Adjusted Active Power:

$Adjusted_{kW\text{-}M1} = Total_{kW\text{-}Loss\text{-}M1} + kW_{M1}$

$Adjusted_{kW\text{-}M2} = Total_{kW\text{-}Loss\text{-}M2} + kW_{M2}$

Disaggregation of Adjusted Meter Data:

$MTN_{1\text{-}Meter\text{-}Equivalent}$ $= Adjusted_{kW\text{-}M1} * EPQ_{MTN1} \div \sum_{i=1}^{n} EPQ_{MTNi}$

$+ Adjusted_{kW\text{-}M2} * EPQ_{MTN1} \div \sum_{i=1}^{n} EPQ_{MTNi}$

$= Adjusted_{kW\text{-}M1} + Adjusted_{kW\text{-}M2} * (EPQ_{MTN1} \div \sum_{i=1}^{n} EPQ_{MTNi})$

$MTN_{2\text{-}Meter\text{-}Equivalent}$ $= Adjusted_{kW\text{-}M1} * EPQ_{MTN2} \div \sum_{i=1}^{n} EPQ_{MTNi}$

$+ Adjusted_{kW\text{-}M2} * EPQ_{MTN2} \div \sum_{i=1}^{n} EPQ_{MTNi}$

$= Adjusted_{kW\text{-}M1} + Adjusted_{kW\text{-}M2} * (EPQ_{MTN2} \div \sum_{i=1}^{n} EPQ_{MTNi})$