



# **Citipower and Powercor Distribution Loss Factor (DLF) Calculation Methodology for Large Embedded Generators**

<b>Version No</b>	<b>Date</b>	<b>Comment</b>
1.0	November 2010	Original publication for wind generation
2.0	February 2018	Methodology for solar generation included
3.0	April 2019	Methodology for solar/battery installation included

# Citipower and Powercor Distribution Loss Factor (DLF) Calculation Methodology for Large Embedded Generators

CitiPower and Powercor are responsible for calculating site specific Distribution Loss Factors (DLF's) for generators over 10 MW which are connected to the distribution system, in accordance with clause 3.6.3 of the National Electricity Code.

Citipower and Powercor have hitherto utilised Formula 2 from the "Guidance Paper: Calculation Methodology for Distribution Loss Factors for the Victorian Jurisdiction" published by the Victorian Essential Services Commission on 14th February 2007 ("ESC Formula 2") for this purpose.

The ESC Formula 2 methodology calculates the DLF for large embedded generators as:

$$\text{DLF} = 1 + \text{Losses} / (\text{Magnitude of sales} - \text{generation volume})$$

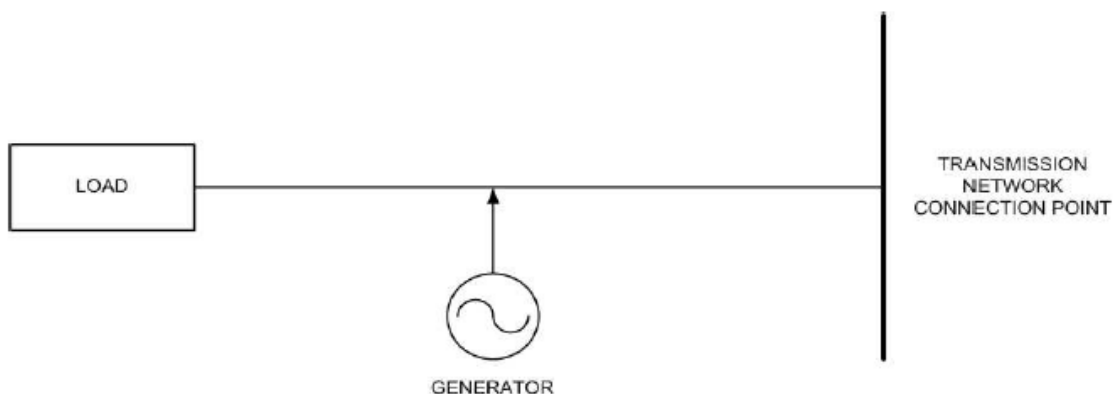
This formula exhibits a singularity at the point where sales volume equals generation volume, which clearly doesn't reflect reality. For specific generation proposals within Citipower/Powercor, this has caused very low DLF's which is impractical and does not incentivise the proponent to commit to the project.

Citipower and Powercor have revised the methodology for calculating DLF's for large embedded generators using an incremental change in losses approach as a more suitable alternative.

The revised Citipower and Powercor methodology calculates DLF for large embedded generators as:

$$\text{DLF} = 1 + (\text{Annual distribution system energy losses without generator} - \text{Annual distribution system energy losses with generator}) / \text{Annual generation volume}$$

Consider a simple generic connection of a large embedded generator as follows:



The following comments can be made with reference to the generic connection diagram above. In the (hypothetical) situation where generation was always equal to load on the distribution network, energy flow between the generator and the transmission network connection point would be zero, leading to the minimum network loss case and a maximum DLF value. The proposed algorithm above passes this test.

Additionally, in the (hypothetical) situation where generation was always exactly equal to twice the load on the distribution network, then the network losses would be equal with or without generation switched on. The proposed algorithm yields a unity DLF under these circumstances, which would also appear appropriate.

The AER has not published a methodology under the National Electricity Rules, clause 3.6.3 (g)(1), and has advised that they have no concerns with the revised methodology and that CitiPower and Powercor may therefore adopt the revised methodology as an amendment to the former ESV methodology , subject to its publication in accordance with Rule 3.6.3(g)(2).

Henceforth, the algorithm Ctipower and Powercor will use to calculate site-specific DLF's for large embedded generators will be:-

$$\text{DLF} = 1 + (\text{Annual distribution system energy losses without generator} - \text{Annual distribution system energy losses with generator}) / \text{Annual generation volume}$$

Appendix A shows a worked example of the methodology for wind generation and Appendix B shows the methodology adopted for solar generation.

CitiPower and Powercor will continue to use the methodology set out in the "Guidance Paper: Calculation Methodology for Distribution Loss Factors for the Victorian Jurisdiction" published by the Victorian Essential Services Commission on 14th February 2007 for calculating site specific DLF's for large customers and Network Average DLF's for general customers and small embedded generators.

# Appendix A – Methodology for Wind Generation

## Introduction

The application of site specific DLF's for embedded generators is an important part of the electricity market in terms of how these generators should be rewarded for their outputs. Citipower and Powercor have revised the methodology previously adopted in Victoria<sup>1</sup> and will use an incremental approach when calculating the site specific DLF for embedded generators. This approach ensures that the DLF will better reflect the **actual** impact of wind farm in terms of distribution losses.

Consider a 63 MW wind farm connection to a 66kV loop supplied from a 220/66 kV terminal station and, in turn, supplying one 66/22 kV zone substation as shown below in Figure 1

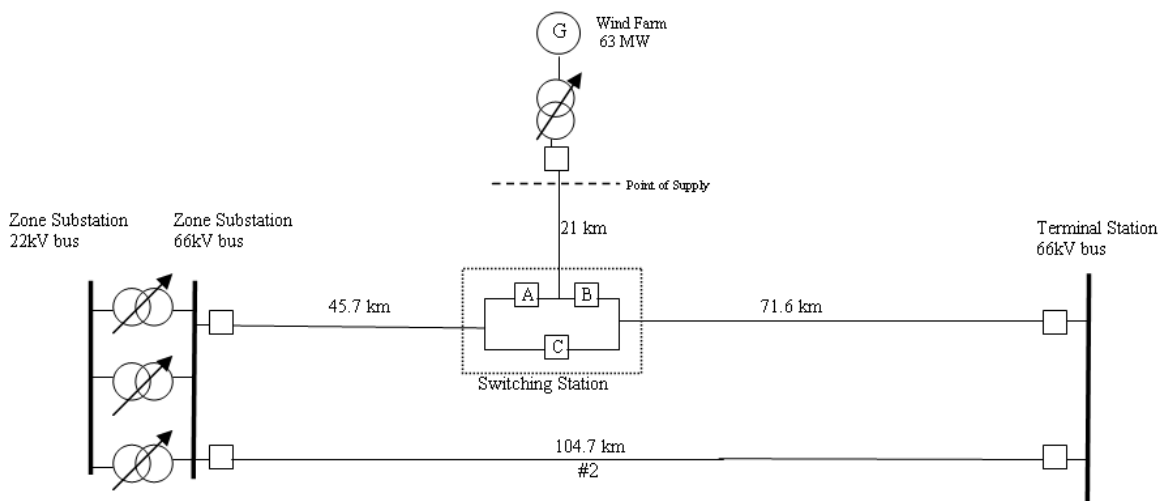


Figure 1: Connection arrangement for a 63 MW wind farm.

## Method

### Step 1 - Establish Loss Characteristics of the Distribution Network

- The zone substation annual load duration curve is shown below in order to extract useful information

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<sup>1</sup> Refer to section 2.1 of the Essential Services Commission's "Guidance Paper: Calculation Methodology for Distribution Loss Factors (DLFs) for the Victorian Jurisdiction" dated 14 February 2007.

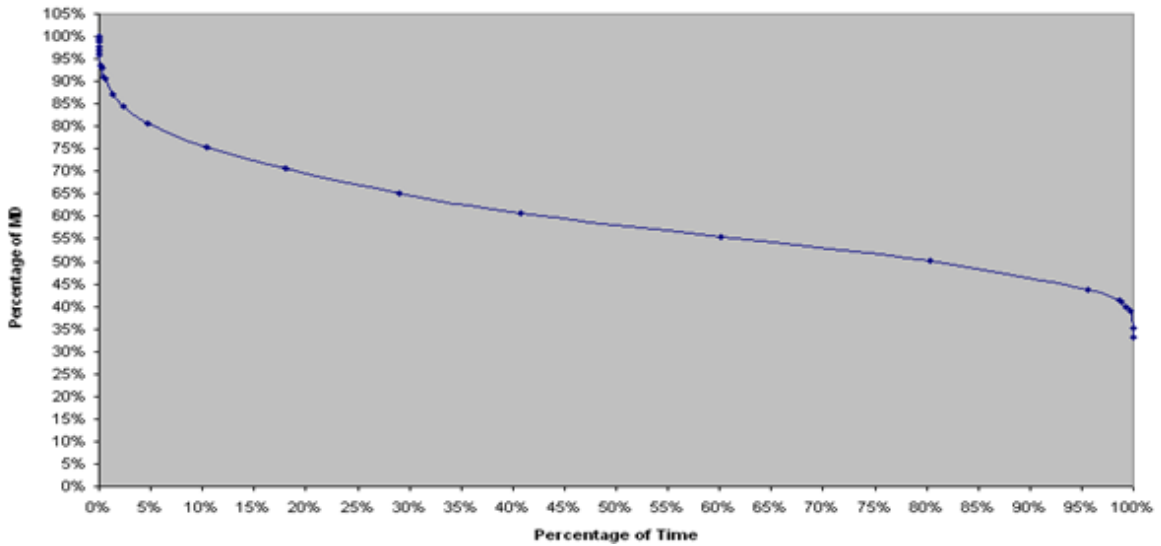


Figure 2: Zone Substation Load Duration Curve

- The equal area criterion was used to estimate the total loss energy across the whole year.
- Using this method the following Demand/Duration weighting factors were extracted:

Demand	Duration
87%	3%
78%	6%
72%	9.5%
62%	48%
49%	33.5%

Table 1: Proposed weighting to be used for load flow analysis

- These values can be used to adequately represent losses on 66kV system for the whole year.
- Hence, the demand/duration weighting values from table 1 can be plotted on the load duration curve as show in figure 3 to emulate a representation of losses at any given load.

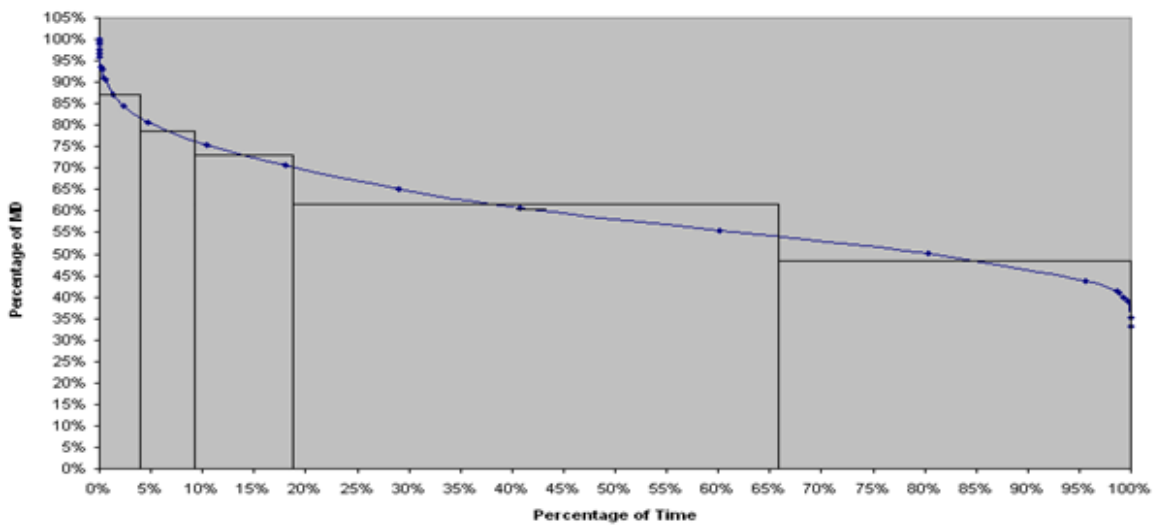


Figure 3: Correct loss equivalence representation

- A generation duration curve, as shown in figure 4, represents the percentage of time that generation level is exceeded.

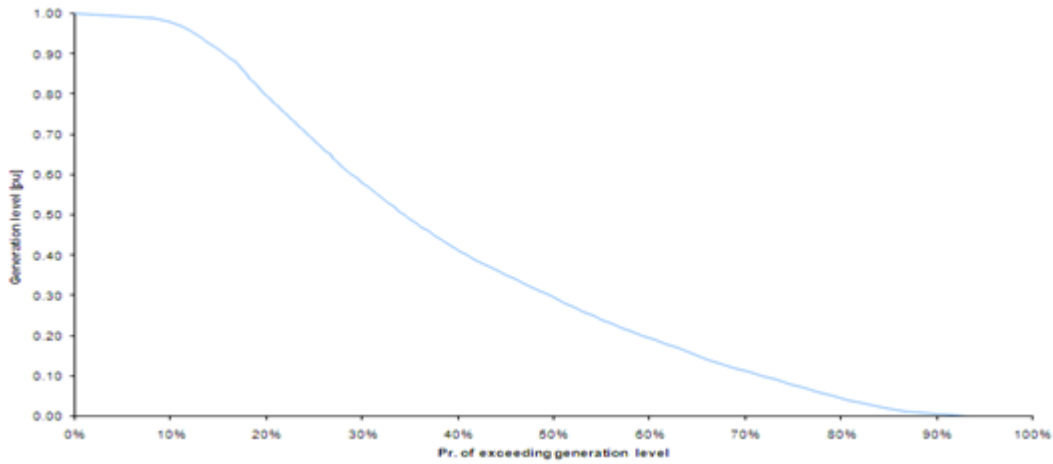


Figure 4: Generation duration curve

The annual generation volume equals the area underneath the generation duration curve shown in Figure 4 above and for this example = 212.474 MWh

- Equal area criterion was once again used in order to determine various combinations of the wind farm output.

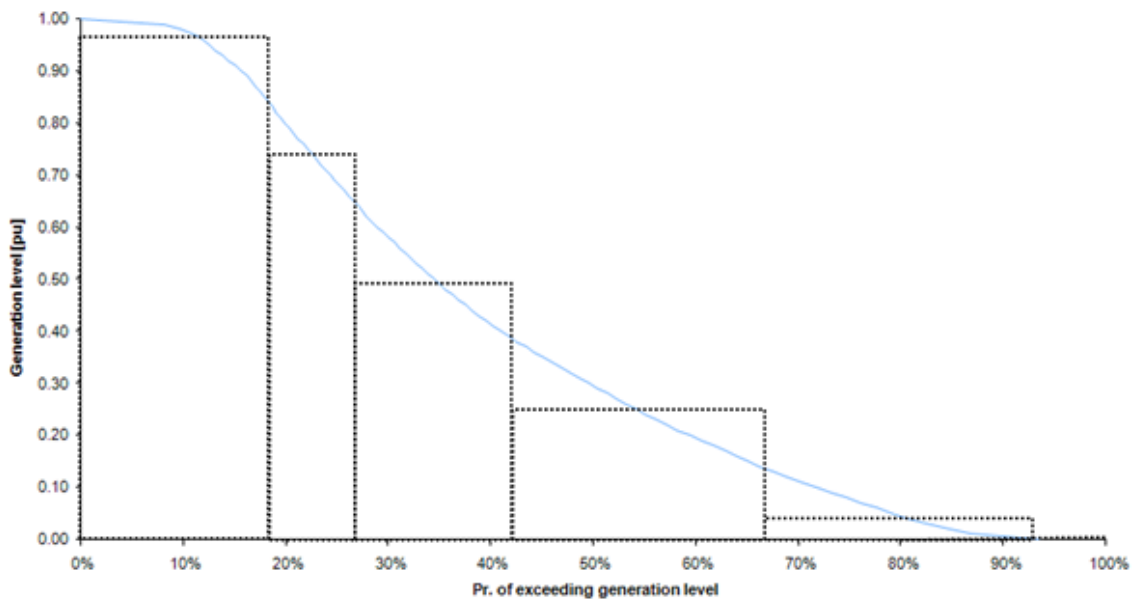


Figure 5: Generation duration curve weighting factors using the equal area criterion

- Hence, the generation duration weighting can be extracted as follows:

Generation	Duration
0%	7%
5%	26%
25%	25%
50%	15%
75%	9%
96.5%	18%

Table 2: Generation duration weighting

- So using the values from table 1 and 2 it can be seen that a total of thirty different studies must be conducted in order to determine the losses on the 66kV system.

## Results

- Load flow analyses were conducted for each scenario and the absolute 66kV power loss results (in MW) were obtained and tabulated as shown below in table 3.

		WIND FARM OUTPUT					
		0%	5%	25%	50%	75%	96.5%
	<b>Weighting</b>	<b>7%</b>	<b>26%</b>	<b>25%</b>	<b>15%</b>	<b>9%</b>	<b>18%</b>
ZONE SUB LOAD 87%	3.0%	3.26	3.26	1.86	2.47	5.13	9.31
ZONE SUB LOAD 78%	6.0%	2.43	2.53	1.37	2.38	5.49	9.51
ZONE SUB LOAD 72%	9.5%	2.06	2.07	1.18	2.26	5.42	9.68
ZONE SUB LOAD 62%	48.0%	1.45	1.49	0.89	2.32	5.76	10.03
ZONE SUB LOAD 49%	33.5%	0.90	1.00	0.65	2.33	5.99	10.59

Table 3: Absolute power losses for the wind farm

- The following three steps have been used in order to determine the Distribution Loss Factor (DLF) using the incremental approach.

### Step 2 - Calculate Distribution Losses without Generation

- From table 3 the average energy loss **without** generation can be calculated by multiplying each weighting factor by its corresponding 0% generation power loss as shown in Table 4:

Weighting	0% Generation	Demand Loss (MW)
<del>3.0%</del>	<del>3.26</del>	<del>0.0978</del>
<del>6.0%</del>	<del>2.43</del>	<del>0.1458</del>
<del>9.5%</del>	<del>2.06</del>	<del>0.1957</del>
<del>48.0%</del>	<del>1.45</del>	<del>0.6960</del>
<del>33.5%</del>	<del>0.90</del>	<del>0.3015</del>
		<b>1.4368</b>

Table 4: Calculation of the annual average demand loss without generation

Therefore, average demand loss without generation is 1.4368 MW. Annual energy loss **without** generation is given by multiplying this value by the number of hours in a year (8760 hrs):

$$\text{Annual Energy Loss without generation} = 1.4368 * 8760 = 12,586 \text{ MWh}$$

### Step 3 - Calculate Distribution Losses with Generation

- The weighting factors for each combination of wind farm output and zone substation load were calculated and are shown below. These weighting factors represent the percent of time a given combination of wind farm output and zone substation load might occur.

		WIND FARM OUTPUT					
		0%	5%	25%	50%	75%	96.5%
ZONE SUB LOAD	Weighting	7%	26%	25%	15%	9%	18%
		0.0021	0.0078	0.0075	0.0045	0.0027	0.0054
87%	3.0%	0.0042	0.0156	0.0150	0.0090	0.0054	0.0108
78%	6.0%	0.0067	0.0247	0.0238	0.0143	0.0086	0.0171
72%	9.5%	0.0336	0.1248	0.1200	0.0720	0.0432	0.0864
62%	48.0%	0.0235	0.0871	0.0838	0.0503	0.0302	0.0603
49%	33.5%						

Table 5: Assumed weighting factors

- These weighting factors were then multiplied by the power loss values from table 3. As a result, table 6 shows the demand loss for each combination of zone substation load and wind farm generation.

		WIND FARM OUTPUT					
		0%	5%	25%	50%	75%	96.5%
ZONE SUB LOAD	Weighting	7%	26%	25%	15%	9%	18%
		0.0068	0.0254	0.0140	0.0111	0.0139	0.0503
87%	3.0%	0.0102	0.0395	0.0206	0.0214	0.0296	0.1027
78%	6.0%	0.0137	0.0511	0.0280	0.0322	0.0463	0.1655
72%	9.5%	0.0487	0.1860	0.1068	0.1670	0.2488	0.8666
62%	48.0%	0.0211	0.0871	0.0544	0.1171	0.1806	0.6386
49%	33.5%						

↓

SUM = 3.4052 MW

Table 6: Normalised demand loss for the wind farm

- As shown, the average demand loss is 3.4052 MW. Therefore, the annual energy loss with generation is given by multiplying this value by the number of hours in a year (8760 hrs):

$$\text{Annual Energy Loss with generation} = 3.4052 * 8760 = 29,830 \text{ MWh}$$



#### Step 4 - Calculate DLF using the revised approach:

$$DLF = 1 + \frac{(\text{Annual Energy Losses without Generation} - \text{Annual Energy Losses with Generation})}{(\text{Annual Generation Volume})}$$

- Calculated annual energy loss **without** generation = 12,586 MWh from step 2
- Calculated annual energy loss with generation = **29,830 MWh from step 3**
- Annual estimated generation volume for wind farm = **212,474 MWh**

Therefore,  $DLF = 1 + (12,586 - 29,830)/212,474$

$$DLF = 0.9188$$

#### Methodology – After 12 months' worth of network load data with generation connected is available.

The above methodology for the initial calculation of the DLF is used where 12 months' worth of actual generation is not available and the proponent provides an expected annual generation duration curve. Once the generator has been operating for at least 12 months, a more accurate way of determining losses with the generator connected can be calculated as described below.

1. Once 12 months' worth of SCADA data is available with the generator in service, 66kV line current (amps) can be obtained from Trendscada for the 66kV network the generator is connected to. 15 min, 30 min or 1 hr average currents can be obtained.
2. Obtaining the resistance of the line from circuit data sheets,  $3 \times I^2 R$  losses can be calculated for each 15 min, 30 min or 1 hr average line current over a whole year for the 66kV network and summated in a spreadsheet to get the annual energy losses with the generator connected. Losses during system abnormalities are not normally adjusted as these normally occur for a very small percentage of the time over a year and hence would have minimal impact on annual losses.
3. Annual energy losses without generator connected can be obtained as previously described by using an annual load duration curve subdivided into the several constant load blocks throughout the year and doing as many load flows as deemed appropriate to obtain what the annual energy losses would have been without the effect of the generator.
4. Once annual energy losses with and without generator is obtained, the DLF can be calculated using the formula described in step 4 above.

## Appendix B – Methodology for Solar Generation

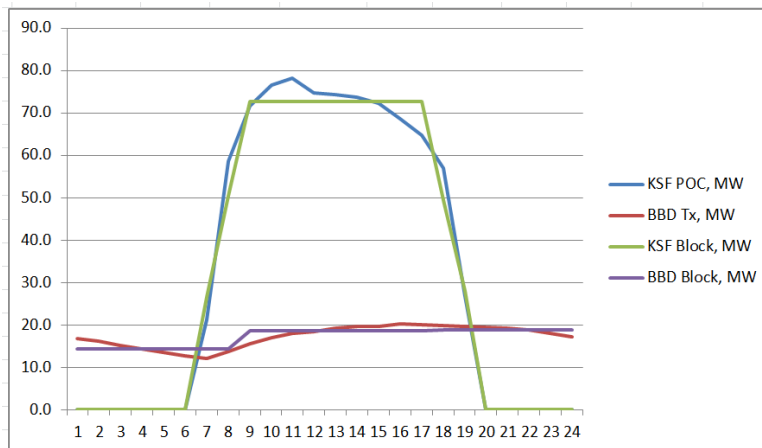
The methodology in Appendix A is written for wind generation where there is no direct correlation between wind speed and the cyclic nature of electrical load on the network. That is, varying wind speed and hence varying generation levels could occur at any time of the day or night.

With generation due to solar, generation output occurs during daylight hours only so only load during the daylight hours should be considered when determining annual network energy losses with generation connected.

### **(A) Methodology – Prior to having 12 months worth of network load data with generation connected.**

This methodology to be used to determine the initial site-specific DLF for a solar farm prior to commissioning is described below. Once 12 months' worth of data is available, use methodology described in section (B).

1. Obtain 12 months' worth of load data (MW & MVar) for the network the generator is going to connect to. One hour average data would be sufficient although you could use half hour or 15 minute data if you prefer.
2. Determine the average daily load profile (MW & MVar) for every month of the year by determining the average load (MW & MVar) for each of the 24 hours in a day for the month in question.
3. The load data is segregated into three seasons, summer (Dec, Jan & Feb), winter (Jun, Jul Aug) and autumn/spring (Mar, Apr, May, Sep, Oct & Nov). The average hourly load data is determined for these three seasons to derive an average daily load profile per season.
4. Obtain 12 months' worth of expected hourly generation data (MW) from the proponent.
5. Determine the average daily generation profile (MW & MVar) for every month of the year using the connection point powerfactor by determining the average generation (MW & MVar) for each of the 24 hours in a day for the month in question.
6. The generation data is segregated into three seasons, summer (Dec, Jan & Feb), winter (Jun, Jul Aug) and autumn/spring (Mar, Apr, May, Sep, Oct & Nov). The average hourly load data is determined for these three seasons to derive an average daily generation profile per season.
7. Superimpose the average daily load profile with the average daily generation load for each of the three seasons as shown on next page. In this example KSF represents a Solar Farm's average generation daily profile and BBD is a zone substation load:



8. For simplification and to reduce the number of load flows required, draw a line that best fits through the load and generation data, essentially creating block loads and generation values.
9. Perform load flow studies for each hour to determine demand losses (MW) on the connecting network with and without the generation for each of the three seasons.
10. The demand losses are then converted to annual energy losses (MWh) with and without the effect of the generator. This is performed by adding the demand losses for each hour of the day for each season and then multiplying by the number of days in the season. This gives the energy losses for each of the three seasons. The energy losses for each of the three seasons are then added to obtain the annual energy losses in MWh.
11. Site specific DLF is then calculated using the formula:-  

$$DLF = 1 + (\text{Annual Energy Losses without Gen} - \text{Annual Energy Losses with Gen}) / \text{Annual Gen Volume}.$$

**(B) Methodology – After 12 months’ worth of network load data with generation connected is available.**

5. Once 12 months’ worth of SCADA data is available with the generator in service, 66kV line current (amps) can be obtained from Trendscada for the 66kV network the generator is connected to. 15 min, 30 min or 1 hr average currents can be obtained.
6. Obtaining the resistance of the line from circuit data sheets,  $3I^2R$  losses can be calculated for each 15 min, 30 min or 1 hr average line current over a whole year for the 66kV network and summated in a spreadsheet to get the annual energy losses with the generator connected. Losses during system abnormalities are not normally adjusted as these normally occur for a very small percentage of the time over a year and hence would have minimal impact on annual losses.
7. Annual energy losses without generator connected can be obtained as previously described in (A) or using an annual load duration curve subdivided into the several constant load blocks throughout the year and doing as many load flows as deemed appropriate to obtain what the annual energy losses would have been without the effect of the generator.
8. Once annual energy losses with and without generator is obtained, the DLF can be calculated using the formula described in (A)11 above.

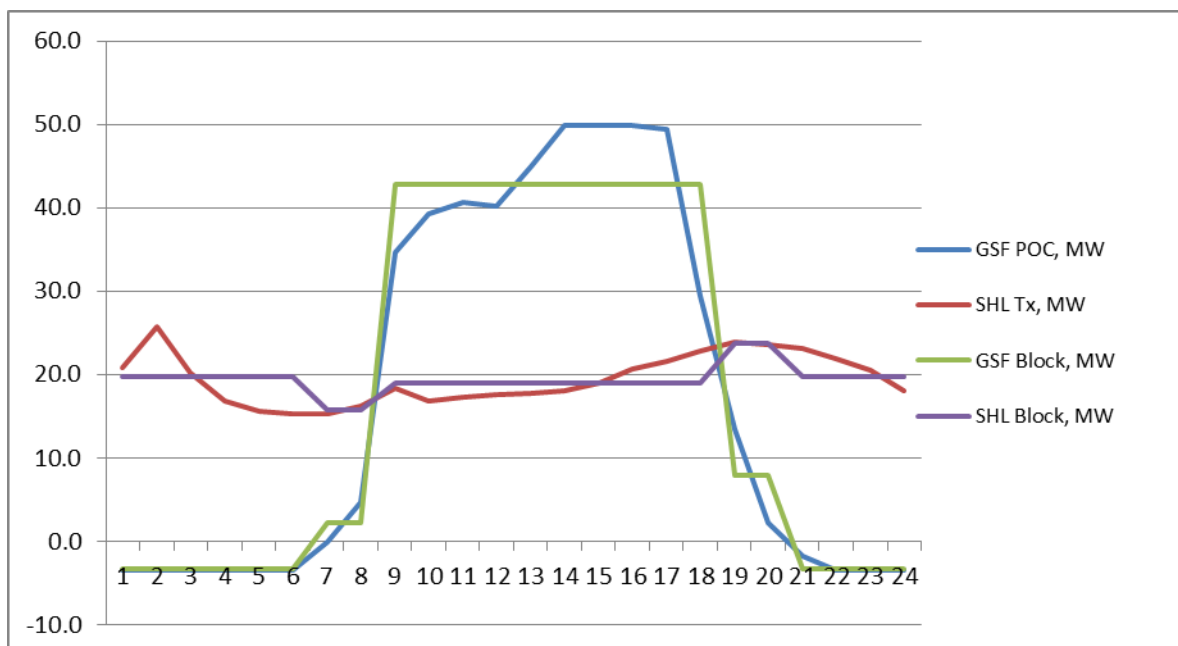
## Appendix C – Methodology for Solar Generation/Battery

With generation due to solar and battery, solar generation output occurs during daylight hours only and battery charge occurs during system off-peak hours and discharge occurs during system peak hours. Therefore, load during the 24 hours should be considered when determining annual network energy losses with generation and battery connected.

### (A) Methodology – Prior to having 12 months worth of network load data with generation/battery connected.

This methodology to be used to determine the initial site-specific DLF for a solar/battery farm prior to commissioning is described below. Once 12 months' worth of data is available, use methodology described in section (B).

1. Obtain 12 months' worth of load data (MW & MVAR) for the network the generator/battery is going to connect to. One hour average data would be sufficient although you could use half hour or 15 minute data if you prefer.
2. Determine the average daily load profile (MW & MVAR) for every month of the year by determining the average load (MW & MVAR) for each of the 24 hours in a day for the month in question.
3. The load data is segregated into four quarters, Q1 to Q4. The average hourly load data is determined for these four quarters to derive an average daily load profile per quarter.
4. Obtain 12 months' worth of expected hourly solar farm and battery output/input data (MW) from the proponent.
5. Determine the average daily input and output profile (MW & MVAR) for every quarter of the year using the connection point powerfactor by determining the average output/input (MW & MVAR) for each of the 24 hours in a day for the month in question.
6. The input/output data is segregated into four quarters, Q1 to Q4. The average hourly load data is determined for these four quarters to derive an average daily output/input profile per quarter.
7. Superimpose the average daily load profile with the average daily generation/battery load for each of the four quarters as shown on next page. In this example GSF represents a Solar Farm/battery's average output/input daily profile and SHL is a zone substation load:



8. For simplification and to reduce the number of load flows required, draw a line that best fits through the load and generation/battery data, essentially creating block loads and generation/battery values.
9. Perform load flow studies for each hour to determine demand losses (MW) on the connecting network with and without the generation/battery for each of the four quarters.
10. The demand losses are then converted to annual energy losses (MWh) with and without the effect of the generator/battery. This is performed by adding the demand losses for each hour of the day for each quarter and then multiplying by the number of days in the quarter. This gives the energy losses for each of the four quarters. The energy losses for each of the four quarters are then added to obtain the annual energy losses in MWh.

11. Site specific DLF is then calculated using the formula:-

$$\text{DLF} = 1 + \frac{(\text{Annual Energy Losses without Generation/Battery} - \text{Annual Energy Losses with Generation/Battery})}{(\text{Annual Generation Volume} + \text{Annual Battery Consumption Volume})}$$

**(B) Methodology – After 12 months’ worth of network load data with generation/battery connected is available.**

1. Once 12 months’ worth of SCADA data is available with the generator/battery in service, 66kV line current (amps) can be obtained from Trendscada for the 66kV network the generator/battery is connected to. 15 min, 30 min or 1 hr average currents can be obtained.
2. Obtaining the resistance of the line from circuit data sheets,  $3xI^2R$  losses can be calculated for each 15 min, 30 min or 1 hr average line current over a whole year for the 66kV network and summated in a spreadsheet to get the annual energy losses with the generator/battery connected. Losses during system abnormalities are not normally adjusted as these normally occur for a very small percentage of the time over a year and hence would have minimal impact on annual losses.
3. Annual energy losses without generator/battery connected can be obtained as previously described in (A) or using an annual load duration curve subdivided into the several constant load blocks throughout the year and doing as many load flows as deemed appropriate to obtain what the annual energy losses would have been without the effect of the generator/battery.
4. Once annual energy losses with and without generator/battery is obtained, the DLF can be calculated using the formula described in (A)11 above.