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Grid Connection Report - Final

Normanton Solar Farm

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1 Background

The Normanton Solar Farm (NSF) is located 5 km south of Normanton in Queensland's Carpentaria Gulf region. The project started construction in May 2016 with commissioning completed in 2017.

The NSF project has been sized to meet the local electrical demand of the Carpentaria Shire.

The solar farm has a capacity of $5MW_{DCp}$ / $4.5MW_{ac}$ which includes 16,000 x 310W solar panels. The solar panels are mounted on fixed-tilt arrays, optimised for Normanton's latitude.

1.1 Goals for the Project

The project will aim to demonstrate the benefits of providing localised solar power generation to reduce network losses in "Fringe of Grid" locations.

2 Purpose

Review the Normanton Solar Farm Grid Connection Analysis Report issued in May 2013 and make comment on the content of the report considering the solar farm is in operation.

Review and comment on the performance of the solar farm.

Review the impact the solar farm is having on the sub transmission and local distribution networks with a focus on demonstrating the benefits of localised solar power generation reducing network losses.

3 Connection Characteristics

The Normanton regional distribution network is supplied at 22kV from the Normanton Substation. Normanton Substation is supplied by 132kV and 66kV overhead power lines from Ross Substation. There is 386 km of 132kV powerline between Ross Substation Georgetown Substation and 290km of 66kV powerline between Georgetown Substation and Normanton Substation.

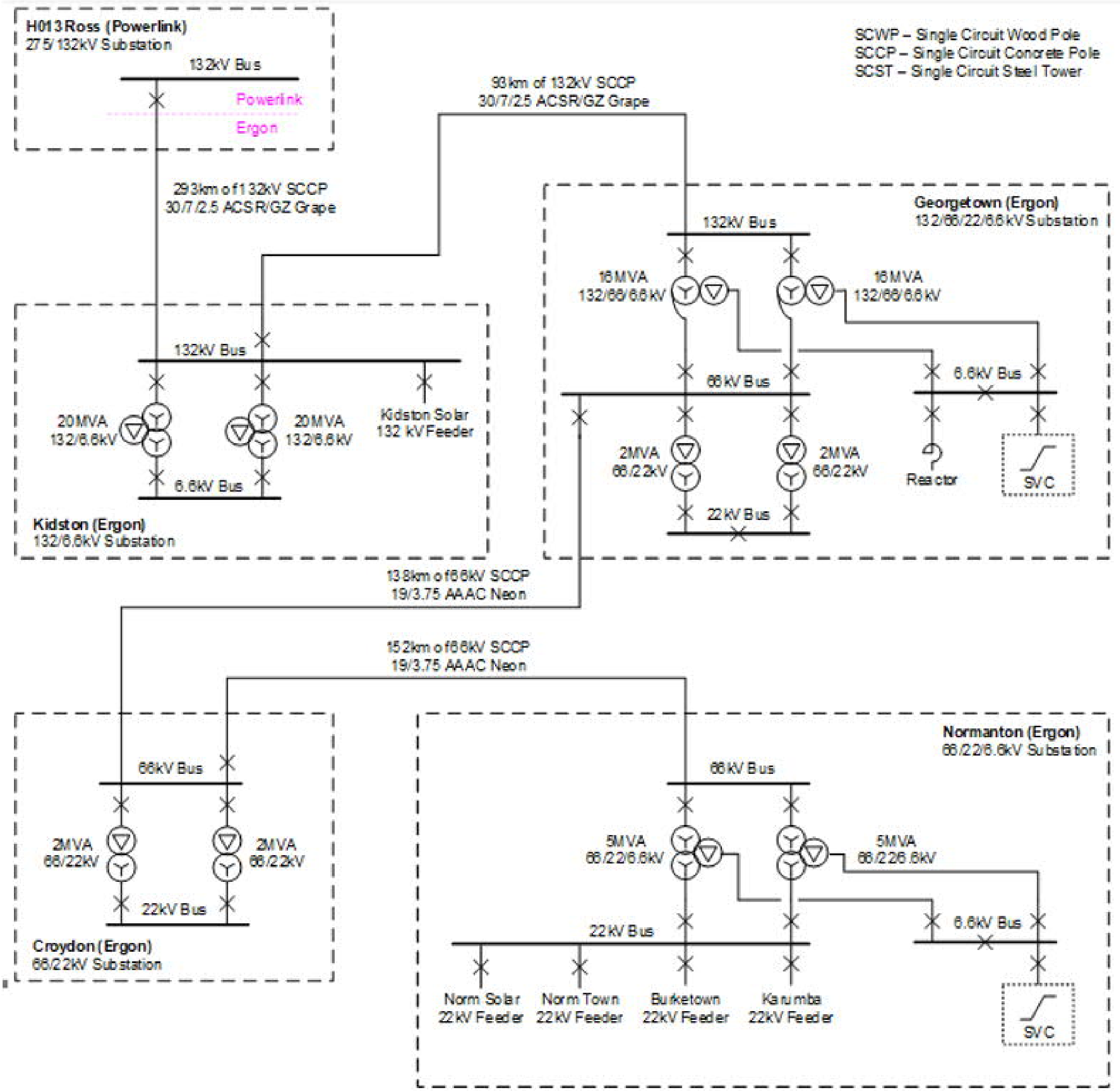

Figure 3-1: Distribution Network Single Line Diagram

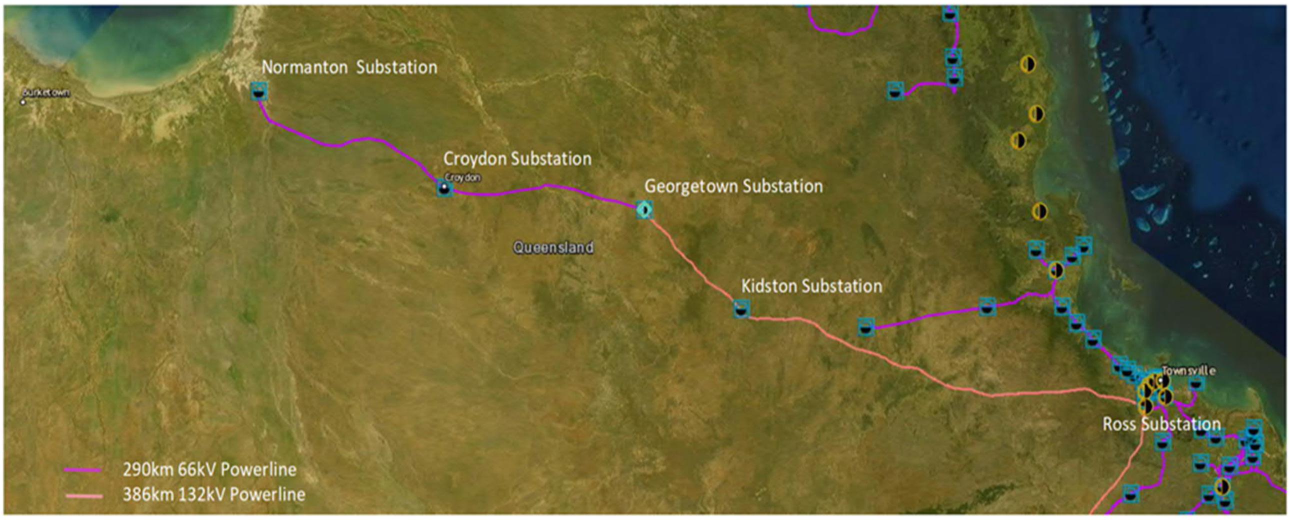

Figure 3-2: Distribution Network Geographic Arrangement

Normanton Solar Farm (NSF) is connected to the local distribution network at the Normanton Substation 22kV bus via a 5km length of dedicated 22kV overhead powerline.

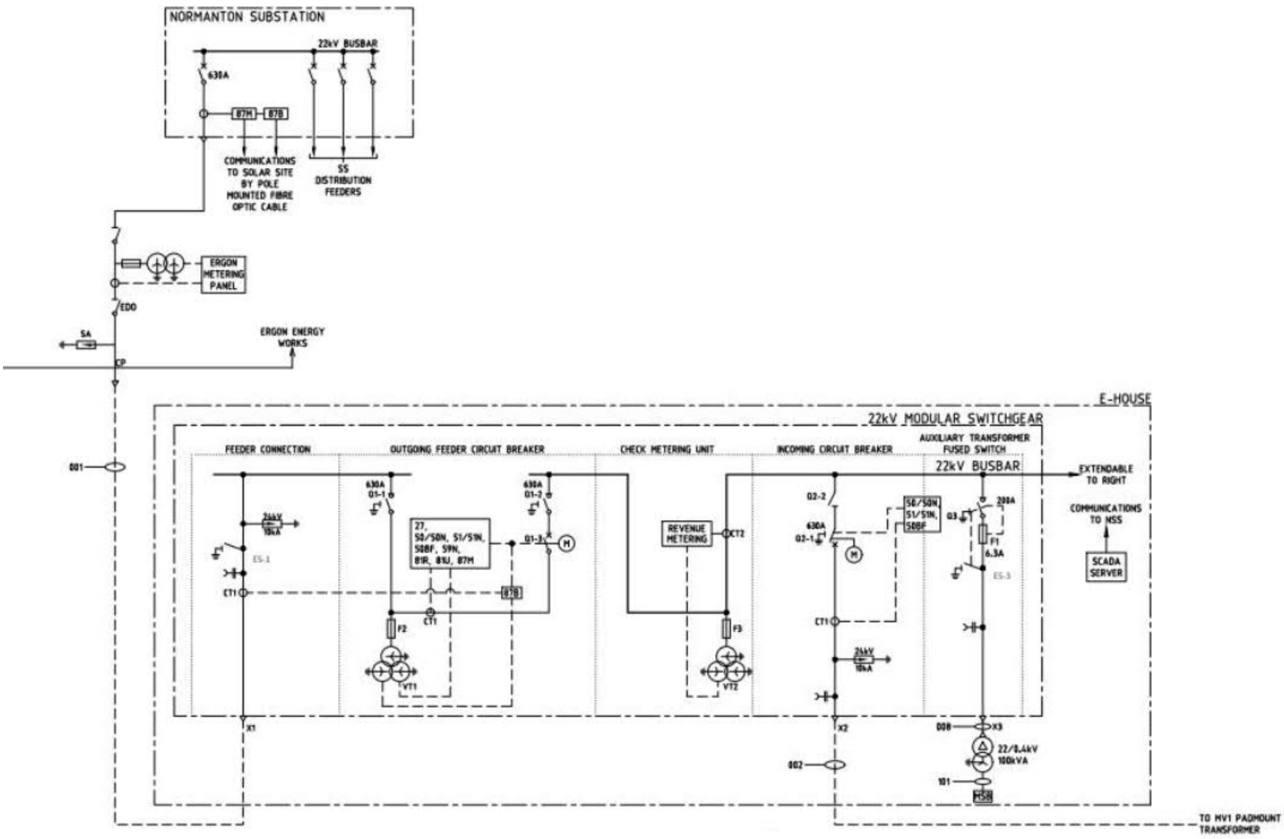

Figure 3-3: NSF Connection Single Line Diagram

4 Loss Factor Determination

In an electricity system, as electricity flows through transmission and distribution networks towards end customers, a portion of that electricity is 'lost' due to physical factors such as electrical resistance. These losses increase as more generation connects in locations that are distant from load centres. Marginal Loss Factors (MLFs) reflect the impact of electricity losses along the network and are applied to market settlements in the National Electricity Market (NEM), and so affect generator revenues. They represent electricity losses along the transmission and distribution network between a connection point and the regional reference node, which is used to represent the regional centre of the transmission network. In the NEM, MLFs guide the location of new generation asset connections to the network. A generator with a relatively high loss factor (say 1.10) will receive a greater market revenue than a similar generator with a lower loss factor (say 0.85), all other factors being equal. This mechanism provides a price signal for generators to locate nearer a load centre, and for a load to locate near a centre of generation.

The calculation of MLFs is complex and based on load flow modelling of the transmission network, connection point demand forecasts and estimated dispatch of committed generating units. The Australian Energy Market Operator (AEMO) uses a forward-looking loss factor methodology (1) for calculating MLFs. MLF calculations are reviewed and approved by the Australian Energy Regulator (AER). AEMO publishes a Regions and Marginal Loss Factors Report annually for each major terminal station. MLFs typically apply to the transmission level of the electricity network.

Distribution Loss Factors (DLFs) are calculated annually by Distribution Network Service Providers (DNSPs) to determine the amount of energy dispatched to or by customers. DLFs are reviewed and approved by the AER and published by AEMO for each year of reference.

DLFs can be calculated for major customers as an Individually Calculated Customer (ICC) if the customer is a generator of greater than 10MW. For individually calculated customers, the DLF is calculated to determine the losses directly attributable to the customers connection.

For customers not subscribing to an ICC DLF, average DLFs are calculated for each significant supply level in the network and applied to non- ICC customers. Average DLFs are calculated for sub-transmission busses and lines, distribution busses and lines and low voltage buses and lines at actual and virtual nodes. The method used to calculate average DLFs is to carry out load flow studies to determine losses at coincident network peak with the application of a calculated Load Loss Factor (LLF) to obtain actual losses. LLFs are calculated based on load duration curves, which are computed from half hour average demands over a full year. Sub-transmission systems are modelled using load flow analysis software package (PowerFactory). Losses on the distribution network are calculated using forecast feeder peak demand data and iron losses which are obtained from the Ergon Energy corporate database. Ergon Energy publishes DLFs for three zones covering the network, east region, west region and Mt Isa region. Further information including a comprehensive description of the calculation methodology used by Ergon Energy to calculate DLFs can be found in the Ergon Energy Distribution Loss Factors Methodology – 2021 publication.

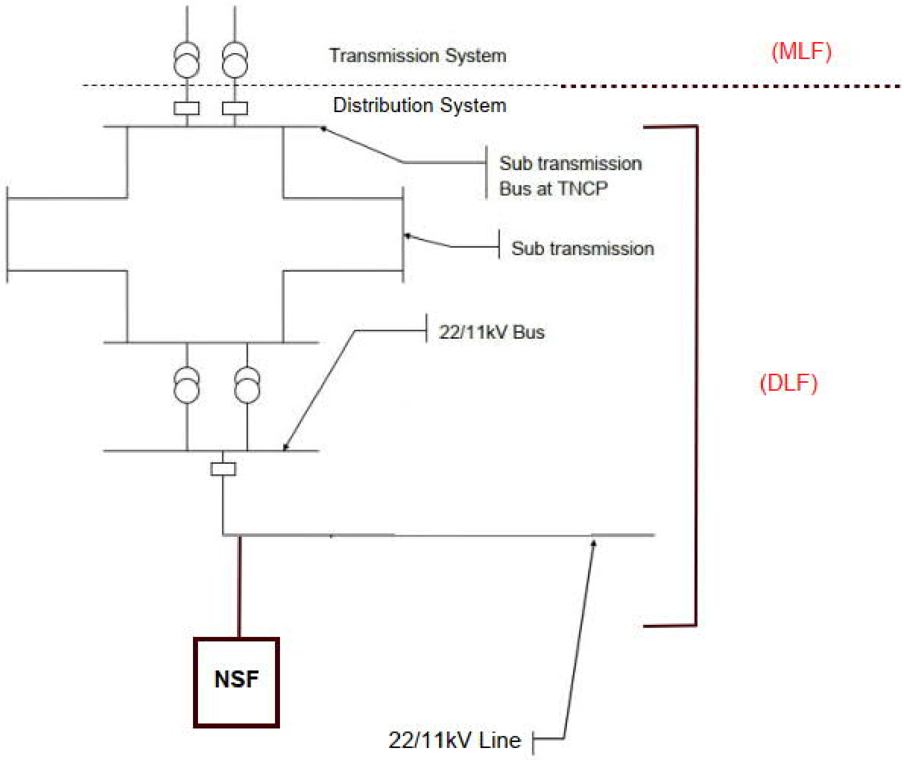

Figure 4-1: MLF and DLF Zones

MLF is calculated at Ross Substation which is the transmission level substation connecting NSF to the Queensland transmission network.

Normanton is in the Carpentaria Shire which falls into Ergon Energy's west region network for DLFs classification.

Normanton Solar Farm (NSF) is connected to the Ergon Energy distribution network at the Normanton Substation 22kV bus via a 22kV overhead power line making the connection a 22kV line connection for the application of the DLF.

NSF has a maximum output capacity of 4.5MW. As NSF is less than 10MW, an ICC DLF was not applicable and the average tariff class DLF is applied to the connection. While the investigation into an ICC DLF was pursued by the NSF proponents in 2013, no definitive resolution was put forward by Ergon Energy.

DLF is calculated for a tariff class 22kV line – west region connection.

To calculate the overall network loss factor applying to a generator connection, the MLF is multiplied by the DLF.

Table 4-1: Total Loss Factor Calculation

Loss Factor	2012/2013	2020/2021 (*)
MLF (Ross Sub Stn)	1.1006	0.9650
DLF (22kV Line – West)	1.133	1.078
Total Loss Factor Applied	**1.247**	**1.04027**

***Regions and Marginal Loss Factors: FY20-21 (AEMO) and Distribution Loss Factors for the 2020/21 Financial Year (AEMO)**

Applying the 2020/2021 loss factor to a sample NSF revenue meter generated energy data.

Load at Revenue Meter (MW.h) x Total Loss Factor 20/21 (1.04027) = Loss Adjusted Revenue (MW.h)

856.16 MW.h x 1.04027 = 890.64 MW.h

Considering the NSF produced the same sample revenue generated energy data recorded in 2020/2021 and applying the 2012/2013 loss factor.

Load at Revenue Meter (MW.h) x Total Loss Factor 12/13 (1.247) = Loss Adjusted Revenue (MW.h)

856.16 MW.h x 1.247 = 1,067.63 MW.h

Assuming the price per MW.h of energy has not changed, and the same generated energy is delivered, in the nine years since NSF was commissioned revenue has reduced by 16.5% due to the reduction in total loss factor.

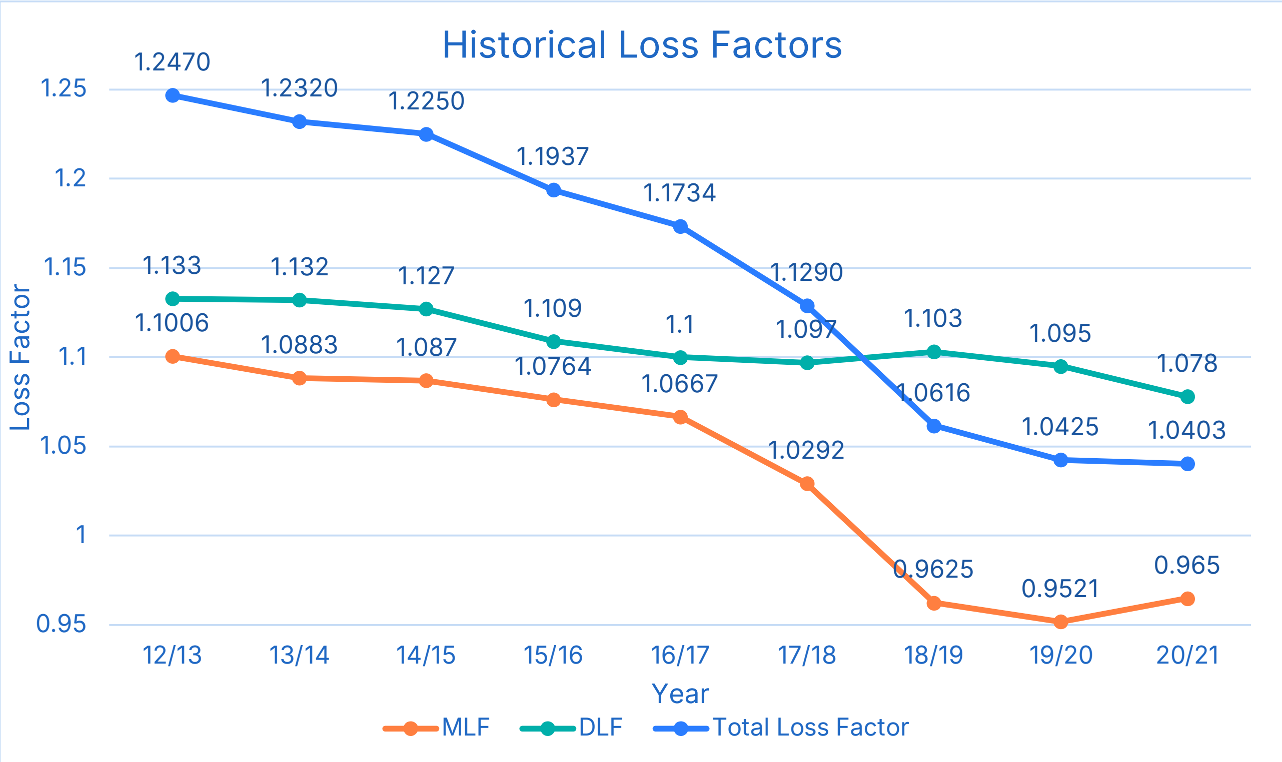

Figure 4-2: Historical Loss Factors 2012/13 to 2020/21

Figure 4-2 shows that the progressive reduction in total loss factor is driven by the reduction in MLF at Ross Substation. DLF for the west region has trended down but at a slower rate.

MLFs are implemented to inform the location of new generation asset connections by acting to control the revenue a proponent receives and encourage generation assets to be built close to loads. In 2017 and 2018 a number of large-scale solar farms including Ross River Solar Farm (140MW), Clare Solar Farm (150MW) and Haughton Solar Farm Stage 1 (100MW) connected to the North Queensland transmission network. Around the same period Kidston Solar Farm Stage 1 (50MW) connected to the Ergon Energy sub-transmission network on the 132kV Ross – Kidston feeder. MLFs reduced markedly during 2018 because of the penetration of renewables onto the North Queensland grid, in particular large-scale solar farms.

NSF is connected at the end of a long distribution powerline. NSF is one of the more remote generation connection on the Ergon Energy network. The output from NSF may result in neutral or small reverse power flow through the sub transmission network, however under an averaged DLF calculation methodology, this will not materially change the DLF value for the west region. The relatively small value of NSF generation in comparison to the load flow levels through Ross Substation will not materially change the MLF either.

4.1 Analysis

Figure 4-2 indicates the MLF and DLF trend is flattening with the DLF contributing to a total loss factor >1.0 With the Ross Substation MLF below 1.0, the expectation is no more large scale solar farms will connect to the North Queensland transmission network until the North Queensland region load increases.

A total loss factor, considering the west region DLF, of >1 indicates there is still some scope for fringe of grid generators; however, positive revenue margins are small (~4%).

1. Further information on Loss Factor calculation methodology can be found in "AEMO Marginal Loss Factors for the 2020-21 Financial Year" publication.

5 Solar Farm Performance

NSF performance analysis has been undertaken based on kilowatt hour (kW.h) data recorded at 30-minute intervals at the revenue metering station.

During the course of a year each generation day will be different in terms of output. Generation output is reliant upon the angle of the sun, dawn and dusk times, the level and density of cloud and weather events like monsoonal storms. The graphs presented reflect the typical output profile for a fixed panel array solar farm. The graphs represent sample days under various seasonal conditions on clear (cloudless) days where the highest output is achieved.

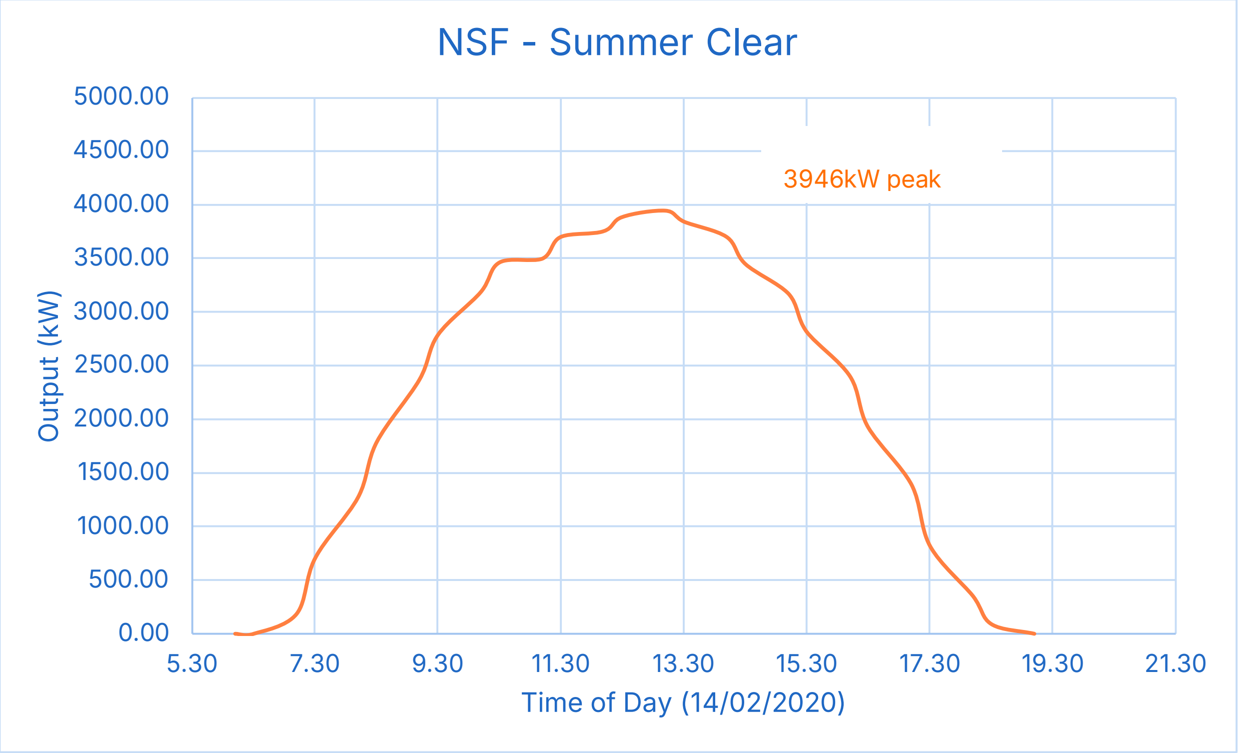

Figure 5-1: Solar Farm Output Summer

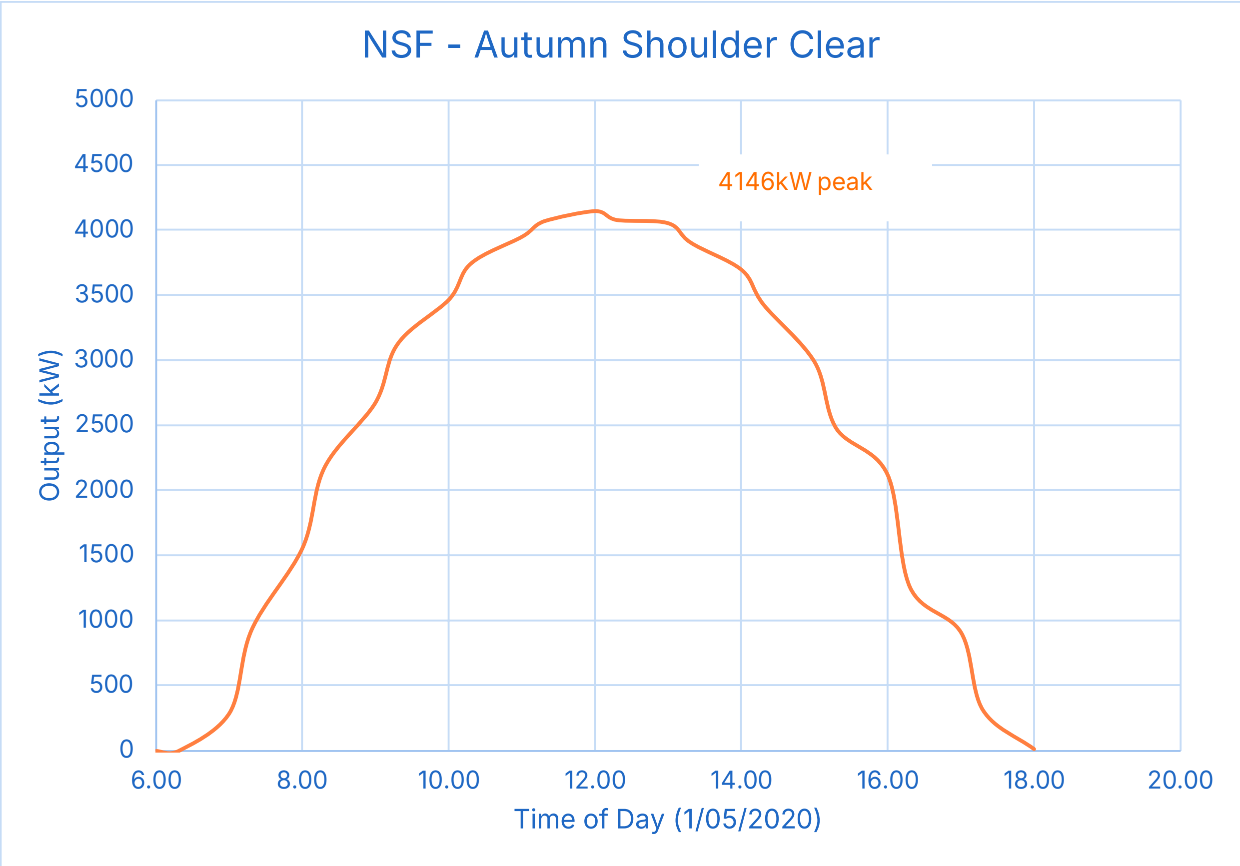

Figure 5-2: Solar Farm Output Autumn

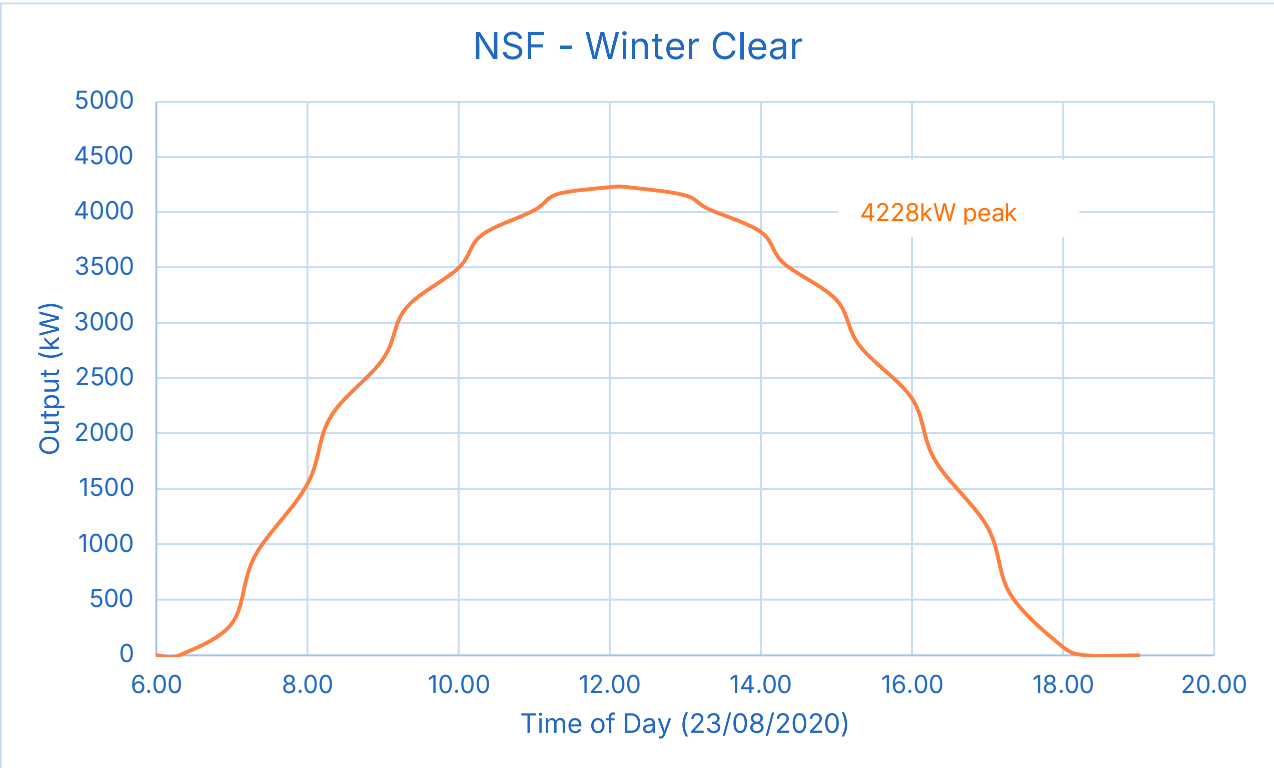

Figure 5-3: Solar Farm Output Winter

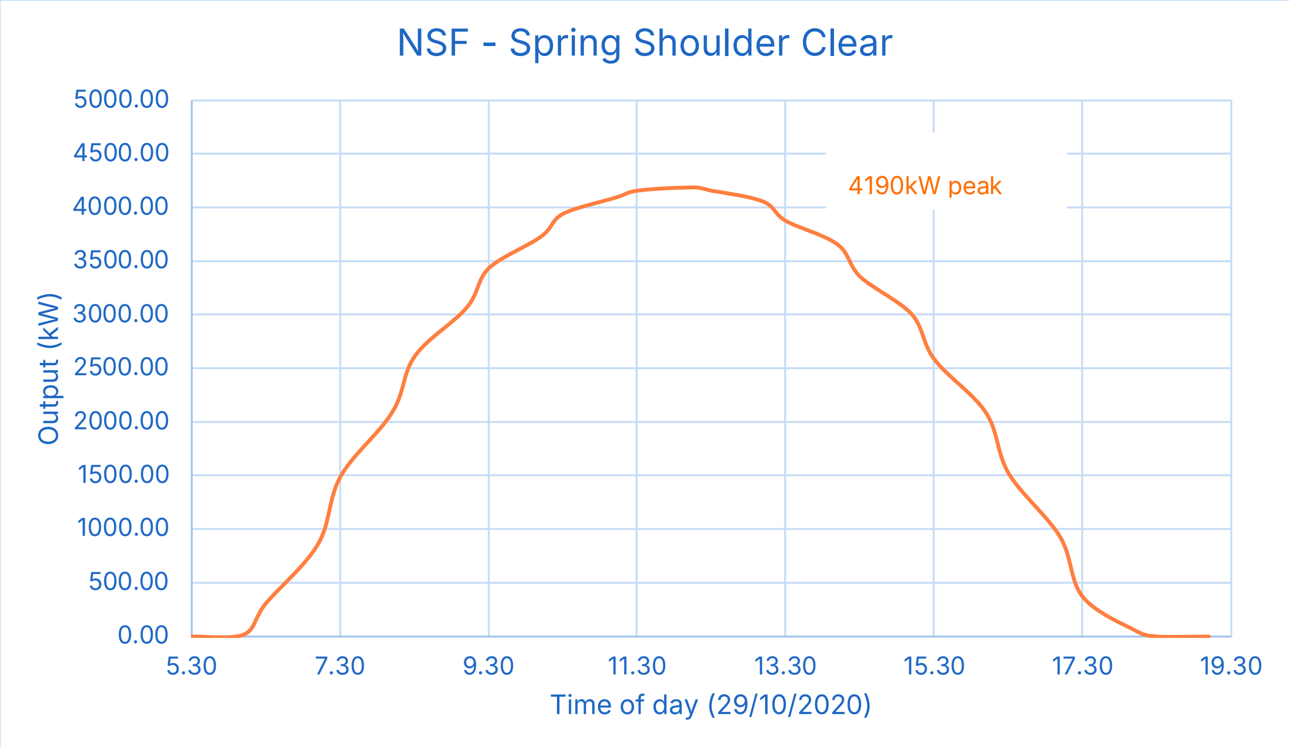

Figure 5-4: Solar Farm Output Spring

The graphs demonstrate the well understood ramp-up and ramp-down characteristics of solar PV as the sun rises and exposes more solar energy onto the fixed panels with less reflectivity as the sun's position is higher in the sky.

The data reflects the maximum output of the site does not vary significantly between seasons – for a clear day the differential noted between Summer, Winter and Spring/Autumn is the length of the day.

NSF is a 4.5MWac system, with output limited to 4.5MW based on inverter ratings at 25^{0}C. The daily kilowatt outputs recorded for the clear days nominated is between 6% and 12% below the rated solar farm output. This reduction can be attributed to ambient temperature de-rating of both the solar panels and inverters (particularly in summer), losses within the internal DC and AC reticulation system, transformer losses, periodic preventative maintenance activities, reactive power demand on the 22kV network, panel environmental contamination and solar panel degradation over time. The first 1 -2 years of solar panel life cycle return the highest degradation profile.

The highest output performance occurs during the winter months when ambient temperatures are low, minimising panel de-rating, and there is a high proportion of clear days.

The worst output performance occurs during the summer months where high ambient temperatures cause elevated levels of panel and inverter de-rating and there is a high proportion of cloudy days.

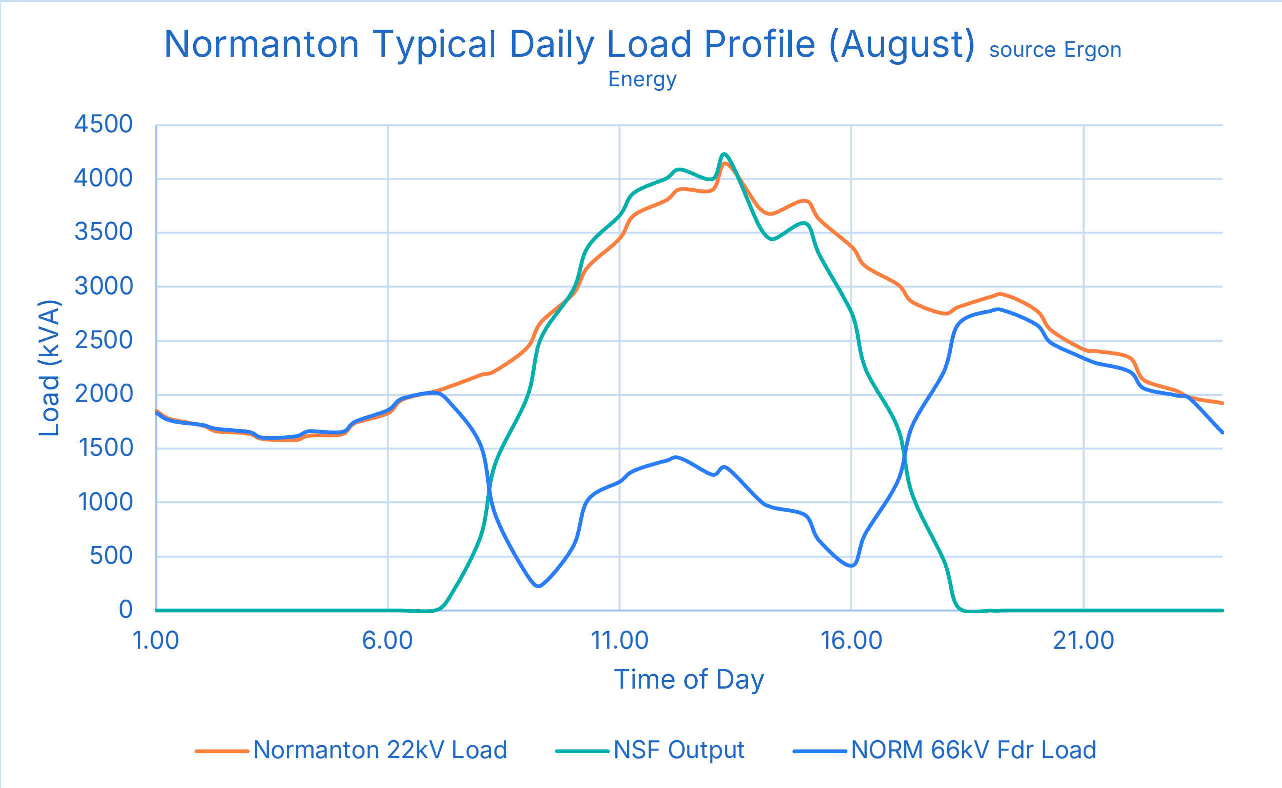

Figure 5-5: Distribution Network Load Profile

Data provided by Ergon Energy for sections of the sub-transmission and distribution network has been used to evaluate the effect the NSF has on Normanton sub-transmission and distribution network. Data was only available for 10 days in July – August 2019. August is one of the best generation output months and the data represented in Figure 5-5 is considered typical for the purpose of this report.

Figure 5-5 shows a large decrease in energy demand from the 66kV sub transmission network during the middle of the day with similar morning and evening demands being maintained. The decrease during the middle of the day is attributed to the ramp-up of the NSF output to supply local 22kV distribution network loads. Local generation acts to significantly decrease ohmic losses on the sub transmission network and reduce the reactive power transmitted on the network. Ohmic losses, referred to as I^2R or copper losses, increase with the square of the current transmitted in the power line conductors. The square function of current means a small reduction in current delivers a bigger reduction in power line losses. Figure 5-5 demonstrates the positive effect local generation has a distribution network through delivering current (power) close to the loads thereby reducing the current carried on the network powerlines and reducing powerline losses.

The electrical size of the NSF appears to be matched to the load demand on the Normanton 22kV distribution network.

6 Summary and Next Steps

The penetration of renewables onto the North Queensland grid in 2018 resulted in a marked reduction in MLFs causing the total loss factor, and in turn revenues, to reduce by 16.5%. Until the North Queensland region sees further load growth, it may not be attractive for new generation assets to connect in the region.

The connection of the NSF is having a positive impact on the sub transmission network through reducing transmission line losses. The NSF is reducing network losses by providing localised solar power generation through the middle of the day peak demand period.

The electrical size of the NSF appears to be matched to the load demand on the Normanton 22kV distribution network.

Using the average tariff class DLF to assess the commercial viability for a <10MW solar farm may not return the best commercial benefit. Given the complexity and legislative requirements for approving loss factors, where generation assets <10MW are proposed for connection in remote sections of the distribution network, consider pathways to having the DLF assessed under the ICC process. Engage the DNSP early in the project development phase and understand the restrictions and limitation of progressing down the ICC pathway for a connection <10MW. In the case of <10MW generators, the cost/commercial benefit associated with the ICC process may mean the better commercial option is to take the average DLF.

For fringe of grid generators, consideration should be given to selecting the location such that the generator is greater than 10MW allowing the DLF to be assessed under an ICC connection.

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