Modelling and Optimisation Report
(Public Release Version)

RATCH-Australia

Collinsville Solar Thermal Power Station

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Contents

INTRODUCTION

RATCH-Australia Corporation Limited (RAC), in partnership Transfield Infrastructure Pty Limited, and The University of Queensland (UQ), is undertaking all the preparatory development work to assess the viability of converting an existing 180MW coal fired power station to a 30MW hybrid solar thermal / gas power station at the existing Collinsville Power Station (CPS) in Queensland (the Project).

As a part of the Measure, RAC will also examine the feasibility of using Novatec's Supernova Linear Fresnel Solar Thermal technology to generate superheated steam to be supplied to steam turbine/s to provide grid connected electricity. The dual-fuel boiler will also be designed to use natural gas to enhance grid reliability from the Project.

The Australian Government, through an Australian Renewable Energy Agency's (ARENA) Emerging Renewables Program Funding Agreement, is providing $2.5 million in funding for the completion of the feasibility study.

One of the key deliverables for this **Modelling and Optimisation report for public release,** which contains a summary of the non-commercially sensitive information from the following sections:

- **Preliminary Financial Model:** RAC has developed a Preliminary Financial Model comparing four different options for this project.
    - ➢ Existing Power Block with Gas
    - ➢ New Power block without Gas
    - ➢ Existing Power Block with Gas boiler
    - ➢ New Power block with Gas boiler
- **Technical-Modelling and Optimisation Report**: RAC's technical advisors, Parsons Brinckerhoff, have completed a modelling and potential plant optimisation which includes:
    - ➢ Overall plant technical model
    - ➢ Calculations of fuel consumptions, water balance, plant emissions, and field losses
    - ➢ Preliminary generation profile
- **Marginal Loss Factor Analysis Report:** RAC engaged ROAM Consulting (ROAM) to conduct a Marginal Loss Factor (MLF) assessment for the proposed Collinsville Solar project

PRELIMINARY FINANCIAL MODEL

The preliminary financial model developed by RAC to compare the potential options for the Project indicates the New Power Block with Gas Boiler has the lowest projected levelised cost of electricity.

The preliminary financial model does indicates:

- that the facility will have a levelised cost of energy (LCOE) amongst the lowest in the world to date for a solar hybrid power station.
- A new Power Block with Gas Boiler has the lowest projected levelised cost of electricity.

[Details excluded as commercially sensitive]

TECHNICAL – MODELLING AND OPTIMISATION REPORT

OVERVIEW

RAC engaged Parsons Brinckerhoff to provide a modeling and optimization report. As part of this investigation, a commercial and technical comparison has been made between 1) utilising the existing power block or 2) the installation of new plant to establish the power block. This report considers the modelling and potential plant optimisation of these two options to establish projected generation yields.

The outcomes of this modelling and optimisation report have been used as part of a full life cycle financial evaluation described in the following section.

KEY FINDINGS

The results from the modeling and optimization study clearly indicate that adopting a 'new' power block approach located in near vicinity to the existing CPS provides substantial performance benefits compared to the refurbishment option.

The advanced design incorporated in a modern steam turbine generator and integrated equipment provides various benefits, including:

- significantly improved levels of overall cycle efficiency can be obtained by use of a two cylinder reheat turbine with a moisture separator reheater (MSR) specifically designed and engineered for solar applications
- fast start-up capability and improved loading cycling performance which again improves the generation yield; and
- the solar to electrical conversion efficiency is very high with limited use of the fossil fuel.

The energy yield modelling based on the configuration for both the existing refurbished power block and the new power block has predicted the electricity

production and fuel consumption figures given in Table 1. Both these configurations include the fossil fuelled boiler and are based on same overall sized solar field.

The major difference between the two plants relates to the cycle efficiency and corresponding generation yields. The new plant would represent nearly a 20% improvement in efficiency compared to the refurbished plant, which, for the same sized solar field and boiler, would mean 21% less fossil fuel consumption, 30% less water use and a 14% increase in solar generation.

Table 0: Key performance parameters

	Existing Power Block	**New Power Block**
Steam conditions	4.24 MPa & 454°C	12 MPa & 500°C
Maximum solar cycle efficiency	32%	38.5%
Maximum fossil fuel cycle efficiency	30.4% (LHV basis)	36.6% (LHV basis)
Total mirror area	202,230 m^2	202,230 m^2
Full load thermal input (approx.)	93.8 MW	77.9 MW
Maximum solar output	30 MWe	33 MWe
Maximum hybrid output	30 MWe	30 MWe
Annual solar electricity production	61.62 GWh	70.49 GWh
Annual fossil fuel electricity production	70.52 GWh	66.66 GWh
Total annual electricity production	132.14 GWh	137.15 GWh
Annual Water Consumption	371 Ml	253 Ml

MARGINAL LOSS FACTOR ANALYSIS REPORT

OVERVIEW

RAC engaged ROAM Consulting (ROAM) to conduct a Marginal Loss Factor (MLF) assessment for the proposed Collinsville Solar Thermal project.

The project MLFs have been assessed for eleven (11) years being 2015-16 to 2025-26 inclusive. The years 2015-16, 2017-18, 2020-21 and 2025-26 were investigated in detail with the intervening years estimated through interpolation. For the final year (2025-26) ROAM performed upside and downside sensitivity studies.

MODELLING ASSUMPTIONS & OUTCOMES

The proposed solar thermal project is to be situated at the current Collinsville power station site. The Collinsville 132 kV substation will be the likely connection point to the transmission system for both the Collinsville solar thermal and proposed Collinsville solar PV projects. As the proposed solar PV project has the capacity to affect the projected MLF for the solar thermal project, a project specific and a combined MLF have been modeled.

For completeness ROAM has included the individual volume weighted MLFs for the solar PV and thermal units. However, it is highly likely that as both units connect to the same bus for MLF calculations, AEMO will provide a single volume weighted MLF based on the total station output. The single combined MLF has been used in the financial assessment of the Collinsville solar thermal project.

The volume-weighted MLFs calculated by ROAM for the Collinsville solar thermal project in the Base, Upside and Downside cases are listed in Table 2 and shown graphically in Figures 1 and 2.

Table 2 – Collinsville Solar MLF Outcomes							
Site	Connection Arrangement	2015-16	2017-18	2020-21	2025-26		
					Downside	Base	Upside
Collinsville Solar PV and Thermal	Combined	1.0307	1.0236	1.0242	1.0271	1.0457	1.0481

Table 2 above shows that for the years 2015-16, 2017-18 and 2020-21 the MLF for the site is relatively stable. This can mainly be attributed to the growth in North Queensland demand being met by additional new entrant generators, such as the Crediton and High Road wind farms and in some cases additional generation from existing stations.

A forecast MLF of 1.03 for 2015-16 aligns well with expectations with the retirement of the Collinsville Power Station. The decrease in MLF from 2015-16 to 2017-18 is a result of the introduction of the solar thermal component of the project and the Crediton wind farm near Nebo depressing the MLF down to 1.0236.

The slight increase in MLF from 2017-18 to 2020-21 is a result of demand growth in the NQ area. This is partially offset by the increased generation from Mt Stuart, which generated approximately 70 GWh/yr. in the earlier years increasing to 200 GWh/yr. in 2020-21.

The significant increase in MLF for the base case from 2020-21 to 2025-26 is a result of local demand growth with no corresponding increase in local generation or new entrant power stations. Also note that no significant transmission augmentations along the 275 kV transmission backbone have been included for this forecast period.

If a significant network augmentation were to eventuate is would likely depress the MLF, by reducing losses in the transfers from Central Queensland to North Queensland.

The Upside case shows the resulting MLF for the project with a reduction of 210 GWh of local generation in the NQ area. The reduction in generation is mostly attributed to a reduction in the output of the bagasse fired power stations. Achieving a MLF above 1.05 for this project would be challenging with the existing network arrangement and generation profiles of both the Collinsville Solar project and surrounding generators.

Increasing the MLF for the project will mostly be outside the direct control of the Collinsville Solar project operators. Increases in MLF will mostly be attributed to local demand growth and deferral of new entrant power stations.

Conversely a decrease in MLF, as shown by the downside case in 2025-26, can result from the introduction of a new entrant generator. In the downside case for this study ROAM has modelled a generic 300 MW wind farm connected to Ross producing 850 GWh/yr.

The new entrant generator does not necessarily have to be a wind farm, a moderately sized new entrant gas turbine at Townsville would produce a similar effect in depressing the MLF at Collinsville. The actual effect of a new peaking generator would depend on the degree to which the operation of the power station overlapped with the Collinsville solar plant. If there was little or no overlap, there would be little or no change to the volume weighted MLF of the solar power station. ROAM does not necessarily consider that any specific new entrant project fits these generation parameters perfectly. However, this result has been included to give RAC a guide as to the possible change in MLF at Collinsville, for a new entrant generator producing 850 GWh/yr.

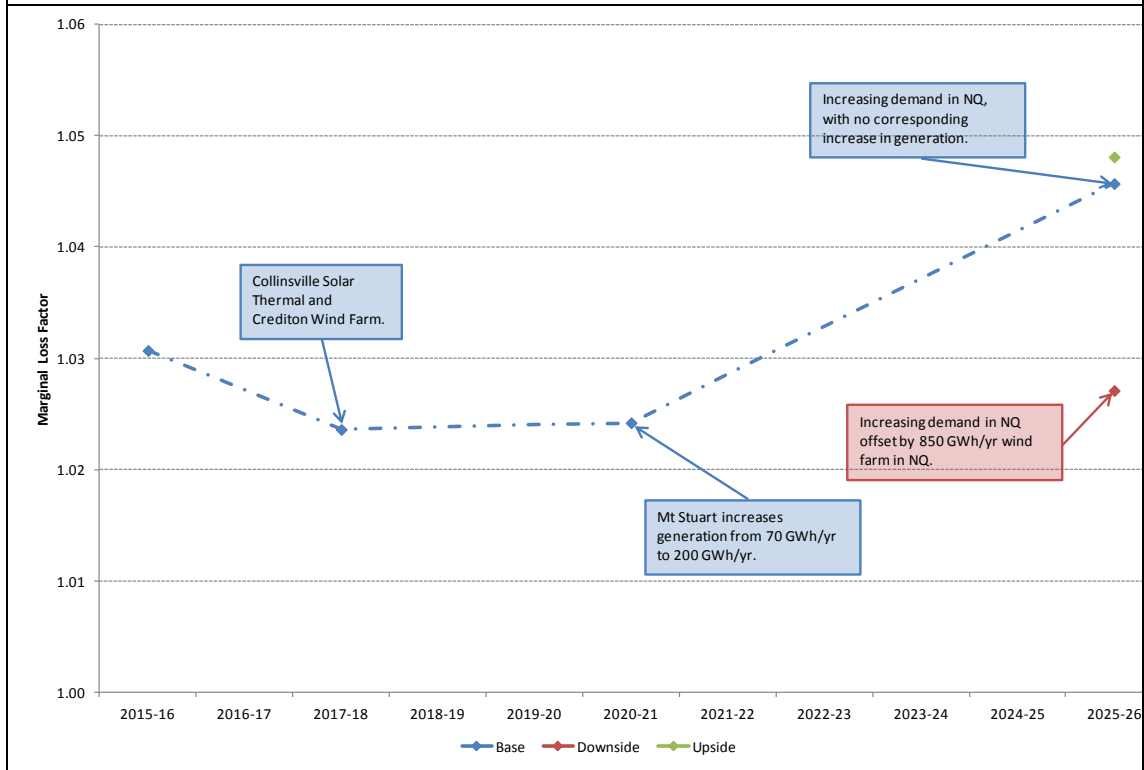**Figure 1 – Collinsville Solar Station MLF Results**

Figure 2 shows the MLF measured at the Collinsville substation for a given generation output of the Collinsville Solar project, for the base case in 2025-26. This provides the simulated MLF for every half hour of operation of the station, before conversion to a single annual volume weighted value. In general terms as generation from a power station increases the MLF decreases, and vice versa. However, there are many other influencing factors, including demand and other generator output levels, which influence the value of MLF in a given half hour.

From the trend line in Figure 2 it can be seen that the gradient of this line is quite shallow. This implies that the MLF at this substation is not overly susceptible to change for any given generation output from the Collinsville Solar project. This means any changes in the MLF for the project from year to year are more likely a result of external factors rather than the operation of the Collinsville solar project.

Figure 2 – Collinsville Solar Station MLF with respect to Generation, 2025-26 Base
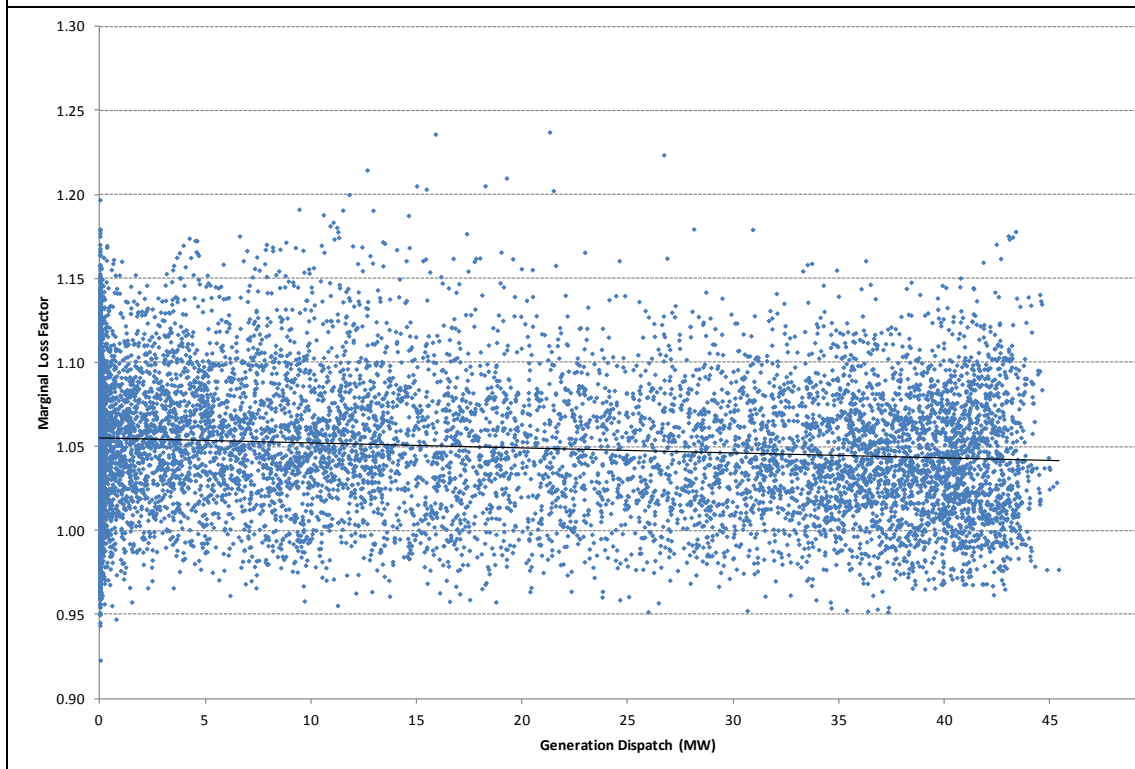
CONSTRAINT ANALYSIS

Due to the network arrangement around the Collinsville substation consisting of six (6) 132 KV transmission lines and the close proximity of the 275 kV network via the Strathmore substation, curtailment due to security requirements is unlikely for the Collinsville Solar project.

The Collinsville Solar project was not observed to be curtailed in any of the simulation years used for the MLF assessment.